CHASE RESEARCH CRYOGENICS LTD.
WORLD LEADERS IN SUB-KELVIN CRYOGENICS

TWO-STAGE SUB-KELVIN ^{4}He COOLER

TYPE “HELIUM 4”

GENERIC INSTALLATION AND OPERATING INSTRUCTIONS

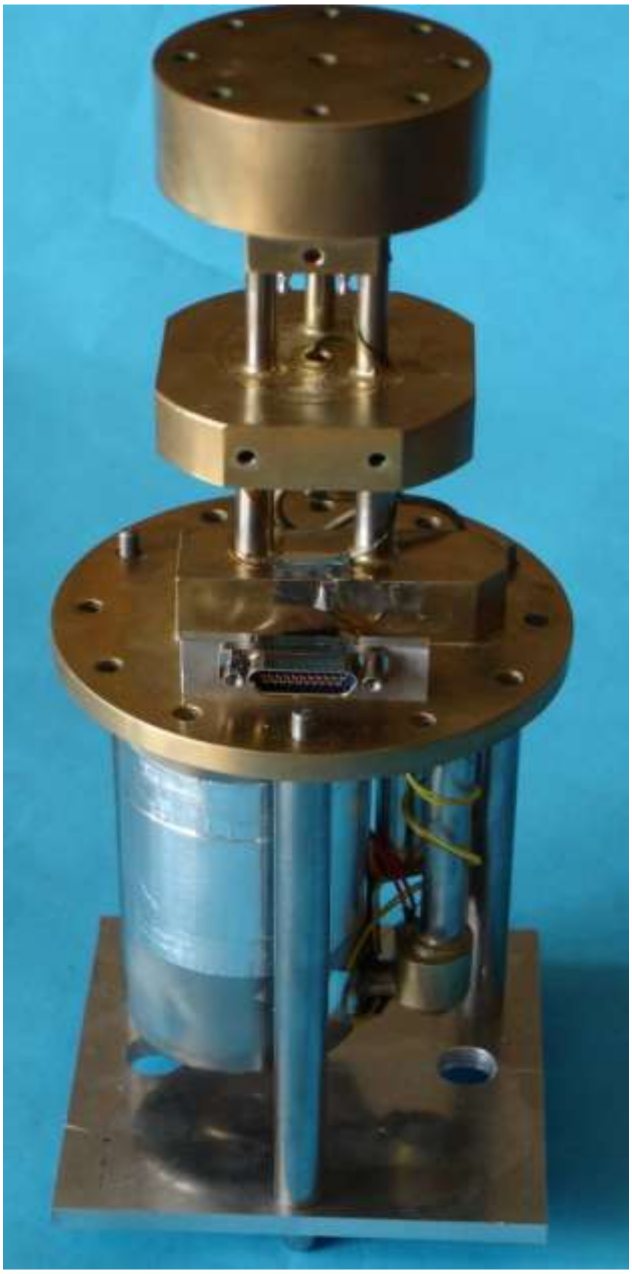

Photo shows a typical CRC ‘Helium 4’ cooler

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Contents

THIS GENERIC OPERATING MANUAL describes how to install and operate a CRC ‘Helium 4’ cryocooler. It is accompanied by an Excel file that contains the validation test data and the calibration files that are **specific** to the cryocooler unit that you have purchased.

You are advised to make a note below of the location of the Excel file specific to your cryocooler unit.

1. GENERAL HANDLING

WARNING!

CRC CRYOCOOLERS CONTAIN HELIUM GAS AT HIGH PRESSURE.

Do not crush, twist or bend the unit. Avoid applying mechanical stresses. Do not heat the unit above room temperature. Keep in a sealed cryostat, or in the shipping box and brace in which it came.

Do not hold or lift the unit by means of the cold heads.

Do not tamper with the copper capillary fill tubes.

Avoid the use of acid fluxes when soldering in the vicinity of the cooler. Chloride based fluxes will corrode stainless steel and could damage your cooler.

After unpacking the cooler according to the instructions supplied, the cooler should be immediately transferred into the host cryostat. The shipping brace doubles as a stand for the cooler, though when used as a stand, the three screws through the aluminium plate into the cold heads should NOT be in place. When picking the cooler up, it should be firmly grasped by the cryopump radiation shield or the main plate/angle bracket.

1. SAFETY OF CHASE RESEARCH CRYOGENICS PRODUCTS

1.1. Pressure Equipment Directive 97/23/EC (Pressure Equipment Regulations 1999)

This CRC cryocooler unit is manufactured in accordance with Sound Engineering Practice. The volume and gas pressure within the cryocooler are such that the equipment falls below the lower classification limit in Annex II of the Pressure Equipment Directive. Hence the requirements for Conformity Assessment do not apply and no Declaration of Conformity can be made, or CE marking applied.

The cryocooler is covered by Article 3 Paragraph 3 of the Pressure Equipment Directive, which states: “Pressure equipment and/or assemblies below or equal to the limits in sections 1.1, 1.2 and 1.3 and section 2 respectively must be designed and manufactured in accordance with the sound engineering practice of a Member State in order to ensure safe use. Pressure equipment and/or assemblies must be accompanied by adequate instructions for use and must bear markings to permit identification of the manufacturer or of his authorized representative established within the Community. Such equipment and/or assemblies must not bear the CE marking referred to in Article 15.”

1.2. Pressure Systems Safety Regulations 2000

This cryocooler unit does not contain a pressure x volume product exceeding 250 bar-litres hence PSSR regulations 5(4), 8-10 and 14 do not apply. This means that the system does not require a written scheme of examination. The cryocooler is not ‘mobile’ in the sense intended in the PSSR hence *the owner* has duties under these regulations to ensure that a) the safe operating limits are not exceeded; b) the unit is operated in accordance with these instructions; c) the unit is returned to Chase Research Cryogenics Ltd in the event that any maintenance is required. The cryocooler contains no user-serviceable parts.

1.3. Safe Operation

The safe operating temperature range of this cryocooler is 0 to 320 K.

1.4. Risk Assessment

CRC cryocoolers contain Helium gas under pressure. The stored energy of the system is less than 50 bar litres. All system components are integrity tested during manufacture; the slightest leak will make the cryocooler lose its stored gas and cease to function. A unit that has leaked presents no risks whatever to the user; the following risk assessment applies therefore only to functional units.

Hazards and consequences

Accidental damage to the cryocooler unit could result in the sudden release of pressurised gases, causing mechanical failure of the unit and potential injury (or damage to surrounding instruments) from ejected debris.

Possible events leading to failure are: overheating of the unit, for example in a fire; dropping or crushing of the unit; twisting or bending of the gas tubes. Mechanical damage to the unit is most likely to occur during assembly of the instrument of which the cryocooler forms part.

Risks without controls in place

It is extremely unlikely that the above events will lead to danger. Chase Research Cryogenics Ltd has produced more than one hundred cryocooler units of various designs, which are in use for a range of applications worldwide. To date there has never been a sudden failure of a cryocooler unit – indicating that with normal use (including inevitable handling mishaps) the units have an excellent safety record. User experience to date shows that accidental mechanical damage to cryocooler units is likely to result in slow leaks, not sudden failures.

Controls in place

The controls that are in place to eliminate (as far as reasonably practicable) the risks arising from mechanical damage to a cryocooler unit are:

- This written instruction manual, containing warnings about the potential risks arising from damage to the unit and alerting the user to more risky operations;
- Instructions that the unit should not be used if it has been subjected to overheating, dropping, crushing, bending or twisting;
- A warning label on the transit box that the instructions should be read prior to handling the unit.

The applications for which cryocooler units are intended make it impossible to place warning labels on the unit itself. However if the cryocooler is incorporated into another instrument, that instrument should carry a warning label to alert the user that the cryocooler contains no user-serviceable parts and should not be disassembled.

Risks with controls in place

Providing users read and follow this instruction manual the risks are negligible.

3. A BRIEF DESCRIPTION OF THE CRYOCOOLER UNIT

This cryocooler unit has a single cold head on one side of the circular main plate, as can be clearly seen in the illustration on the title page. Between the ^{4}He cold head and the main plate there is a film burning stage (^{4}He film burner). In operation the unit will be inverted with respect to this picture, with the cold head lowermost.

This model of cryocooler provides two points at which heat may be extracted from an experiment mounted on a separate cold table. They are the ^{4}He cold head and the ^{4}He film burner (the copper platform that sits between the ^{4}He cold head and the main plate). There are holes tapped on each of these surfaces for thermal connections between your experiment and the cryocooler.

The cold head is provided with a calibrated RuO_2 (or in some cases, Cernox) thermometer sensor to monitor the temperature. The sensor is inserted into sockets machined directly into the head. Wiring for the thermometer sensor is carried from an isolated standoff.

A cryopump and gas-gap heat switch are on the other side of the main plate. The cryopump has a heater element that controls the cooling cycle. It is provided with standard active gas-gap heat switch that is activated by a 10 kΩ heater resistor, and it also carries a diode thermometer. A heat strap is fitted between the heat switch and the cryopump.

All electrical connections are brought out to a connector mounted onto the main plate. Pin-outs are listed at the end of this manual.

4. INSTALLATION

4.1. Mechanical

Before installing the unit in your cryostat, be sure to remove all of the pieces of foam board packing from around the pump, as mentioned in the unpacking instructions.

There should be no need to touch the heat switch or heat strap during installation or normal operation of the fridge. The heat switch can be easily damaged, and if bent or twisted is likely to fail.

This unit is designed to work equally well in either 'wet' cryostat using liquid ^{4}He, or in a 'dry' cryostat, i.e. from a mechanical cooler head such as a pulse tube.

Mounting holes are provided on the fridge main plate, for attaching the fridge to your cryostat cold plate. There are twelve 4.1mm diameter (M4 clearance) holes symmetrically distributed upon a 115 mm pitch circle around the periphery of the circular main plate. In addition to these, there is also a row of 4 x M4 clearance holes at ½" (12.7mm) centres, close to one edge of the main plate.

Always use spring washers, or suitable low expansion washers (e.g. Invar or Tungsten), under every bolt head. These will take out differential thermal contraction that might otherwise cause loosening of the bolts, and thus compromise thermal contact.

4.2. Electrical

All electrical connections are brought out to a connector mounted onto the main plate. This will normally be a 21-pin connector for coolers with 4 diode thermometers (mounted on the cryopump, heat switch, film burner and main plate), or, on customer request, a 15-pin connector for coolers with no diode thermometer on the main plate. Pin-outs are listed at the end of this instruction manual. Voltage / current requirements for driving the heater and thermometers are summarised in the table below.

ITEM	NUMBER	IMPEDANCE/ JUNCTION VOLTAGE	VOLTAGE/ CURRENT
4-pump heater	1 off	200Ω approx.	70 to 100 mA
Heat switch heater	1 off	10kΩ	3 to 4V
Diode thermometers	3 or 4 off	0.5 to 1.8V	10µA DC
^{4}He-head RuO_2 thermometer	1 off	1kΩ to 3kΩ	1µA max.

Generic (i.e. standard calibration) RuO_2 sensors from Lakeshore Cryotronics are the default option on all CRC cryocoolers. Individually calibrated 'CERNOX' or RuO_2 sensors are only fitted (at additional cost) at the customer's express requirement. Generic diode calibration curves for the cryopump and heat switch diodes are supplied as standard by CRC Ltd. A calibration curve specific to the film burner diode is also supplied.

Wiring for the temperature sensor on the ^{4}He cold head is carried to an insulated stand-off mounted on the cold head, and from there directly to the connector. This thermometer is operated as a 2-wire device and should ideally be driven by an AC current no greater than 1µA. The diode thermometers require excitation with currents of 10µA DC. Calibration data for all thermometer sensors are in the Excel data file that accompanies this unit.

As supplied, the heat switch heater requires about 3 or 4 V to keep the switch in the 'ON' state with the absorber pod at around 20 to 25 K, and it will cool to the off state ($T < 8$ or 10 K) in ten to fifteen minutes.

The ^{4}He cryopump heater impedance is about 200Ω. To begin the cooling cycle, once the main plate and cold head is at around 4.2K, it is necessary to warm the ^{4}He cryopump to around 50K. A heater current of up to 100 to 130mA or so will heat the pump rapidly; lower heater currents will result in slower heating. Stabilisation of the pump temperature at around 50K will typically require a heater current of around 12 to 15mA. Try to ensure that the lead-in wiring to the heater is not unduly dissipative.

5. ATTACHING YOUR EXPERIMENT TO THE CRYOCOOLER.

This model of cryocooler provides two points at which heat may be extracted from an experiment mounted on a separate cold table. They are the ^{4}He cold head and the ^{4}He film burner (the copper platform that sits between the heads and the main plate).

The top surface of the ^{4}He cold head has 8 holes tapped M3 on a 40mm P.C.D. and a further axial hole tapped M4. The film burner has 6 M3 tapped holes on the main body, in pairs on each of the three free sides.

While fixing experimental equipment to the cold head, extreme care should be taken, not to torque or bend the gas pipes. Always support the cold head against the applied torque.

Under no load, and with the main plate at 4.2K, the cold head will run at about 800mK, and the film burner at about 1K. If the main plate can be kept colder than 4.2K then the fridge will also run correspondingly colder. When the head is loaded, the film burner temperature alters, as may be seen from a glance at figure 6. Optimum temperatures and run times should be obtained with the loads distributed so that the exchanger runs at about 1.5 to 2.0 K.

5.1. Radiation shielding

The cold head, and any cold table/experimental equipment/detector assembly you attach, must be properly radiation shielded at around 4K in order to achieve sub-Kelvin operation. Any ancillary support structure (cold table) and experimental wiring looms may be thermally sunk to the ^{4}He film burner at some point between the ^{4}He cold head and the 4K plate, to improve the operating temperature. The film burner is designed to buffer the parasitic loads due to wiring and mechanical support structures. No other mechanical attachments to the fridge unit are necessary, in order to achieve satisfactory operation.

6. OPERATION.

6.1. Pre-cool

Because the cooling down of the heads depends upon gas convection, the fridge should be kept close to vertical during the cooldown process.

The cold head will normally cool to 4K more rapidly than the cryopump, but if the attached experimental thermal mass is large then the cryopump may cool first. In this case the cold head will cool very slowly after the cryopump cools to below 20 K, and the gas is adsorbed into it. If left like this, the head will take two or three days to cool. The key to a rapid cooldown is to keep the ^{4}He cryopump *warmer* than about 20 K until the head is cold. After the cryopump heat switch has turned off, apply about 25 mA of heater current to the ^{4}He cryopump until it has warmed up enough. You will see that the cold head starts to cool quite rapidly once the pump is above about 20K. The optimum strategy and timings will naturally depend upon the thermal loads and masses connected to the cooler unit.

An illustration of a typical precool is shown in Figures 1 and 2. These show cooldown from LN2 to L4He in a wet dewar. When running the cooler from a mechanical pre-cooler (e.g. a PT or GM cooler) the same general considerations apply, and cooling timescales will be similar unless limited by the cooling rate of the pre-cooler. The Excel file accompanying this manual contains the test run data for your specific unit.

Figure 1: Pre-cool to LN_2.

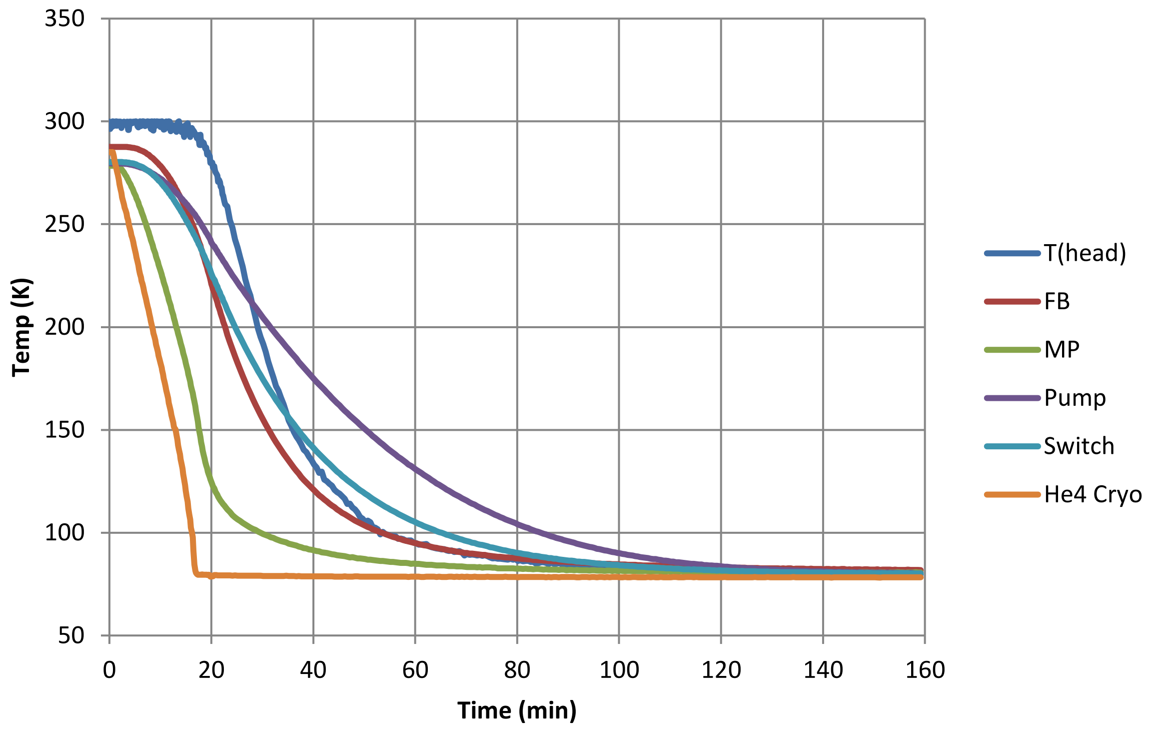
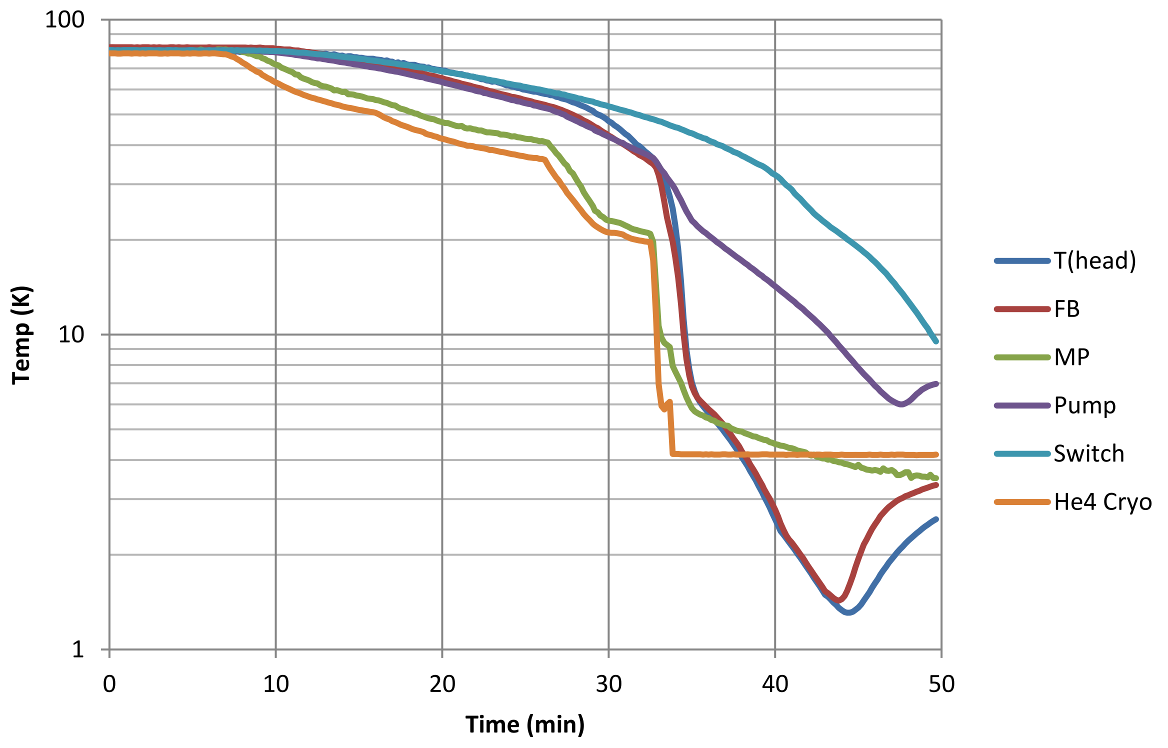


Figure 2: Pre-cool to L4He.



6.2. Running the cooler

It is easy to get this cooler to run, but it takes practice and some experimentation to achieve the best possible performance. Your particular experimental configuration will affect the thermal loadings on, and conductances between, the various parts of the cooler, and may consequently alter the optimum mode of operation. The generic method of operation is described below and full test data for your specific cooler are given in the Excel file that accompanies this operating manual. You are recommended to experiment with variations on the method of operation, once some familiarity with the successful operation of the unit has been gained, in order to optimise performance for your application.

The generic method for this type of cooler is to first heat the pump up to around 50 K, and to maintain it at this temperature while ensuring that the ^{4}He liquefaction point (in this model, the main plate) cools to below the critical point of ^{4}He (5.2K). The colder the liquefaction point gets while the pump is warm, the higher will be the liquefaction efficiency, and hence the longer the fridge will run before needing to be recycled.

You should try variations on the cryopump temperature to find a regime giving the best performance for your particular experimental set-up. You may not need to heat the cryopump as high as 50K if you can keep the main plate significantly below 4K while the pump is hot. In fact, if the main plate is kept below about 3.5K, the ^{4}He cryopump may not need to get hotter than about 40K. This is because, with a lower main plate temperature the ^{4}He condensation will be more efficient, and also less ^{4}He will be used in cooling the cold head to the working temperature.

6.1. Typical first cycle after cool-down to 4K.

Once the ^{4}He charge is liquefied, the ^{4}He cryopump is allowed to cool by turning off the heater power and turning on the heat switch. This can be done more or less abruptly, depending upon the voltage applied to the switch heater. The heat switch will start to turn on when only about 1 to 1.5V is applied, and will be fully on when about 4V is applied. The switch begins to turn on at around 14 to 17K, and is fully on at around 20 to 25K. At this stage the cold head temperature and film burner temperature will start to fall rapidly.

The sequence of events is illustrated in Figure 3. The graph begins at t=0 with the heat switch turned off and the cryopump temperature at around 20K.

t = 3: Apply 20V (50.4mA, 1.01W) to the pump heater.

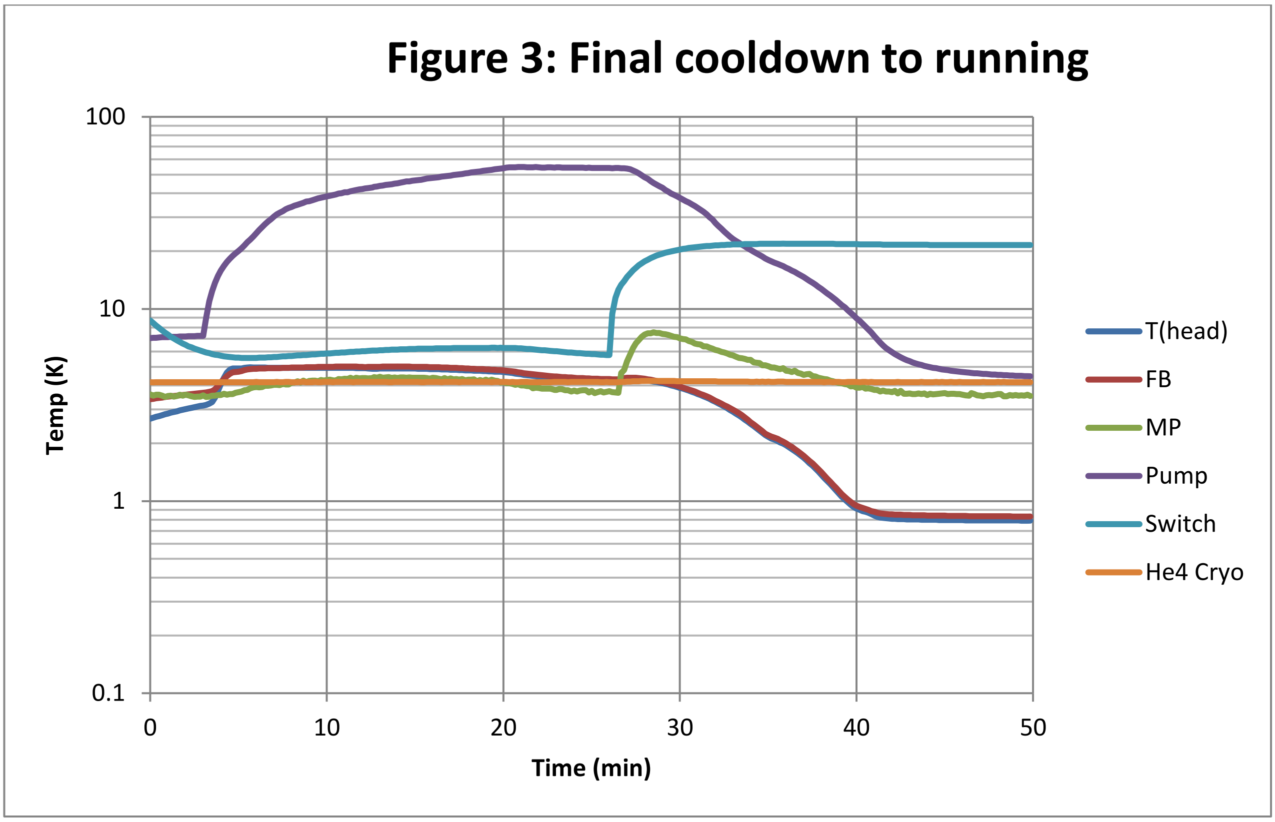
t = 5: Increase pump heater to 25V (63mA, 1.57W).

t = 20: Turn pump heater power OFF.

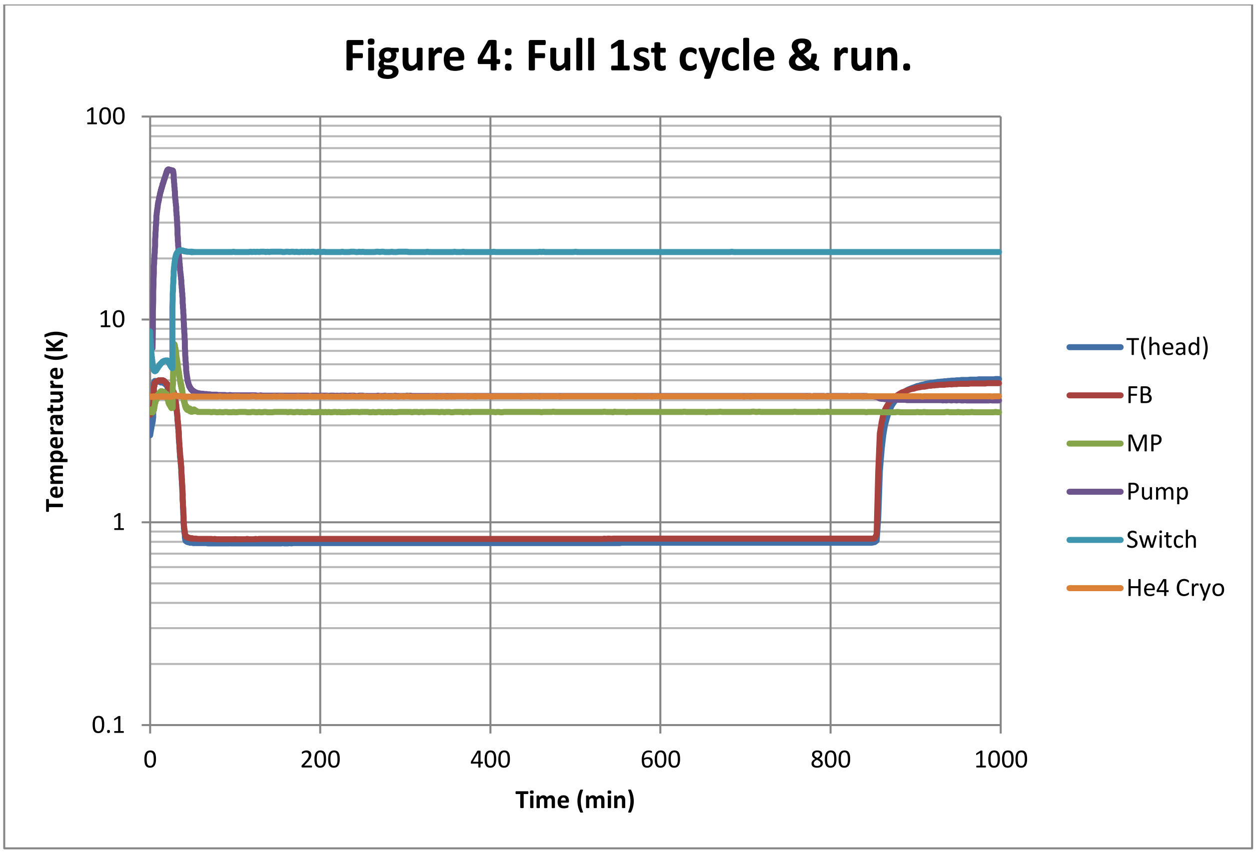
t = 26: Turn heat switch ON, 3V.

t = 50: Cooler is now running.

All timings are in minutes.



In this example the cooler continued to run for a total of around 13.5 hours, see Figure 4.



An annotated test log and run data for your specific cooler are given in the Excel file that accompanies this manual. The operation of your cooler is shown with no applied load, and with a range of applied thermal loads.

6.2. Typical re-cycle from cold

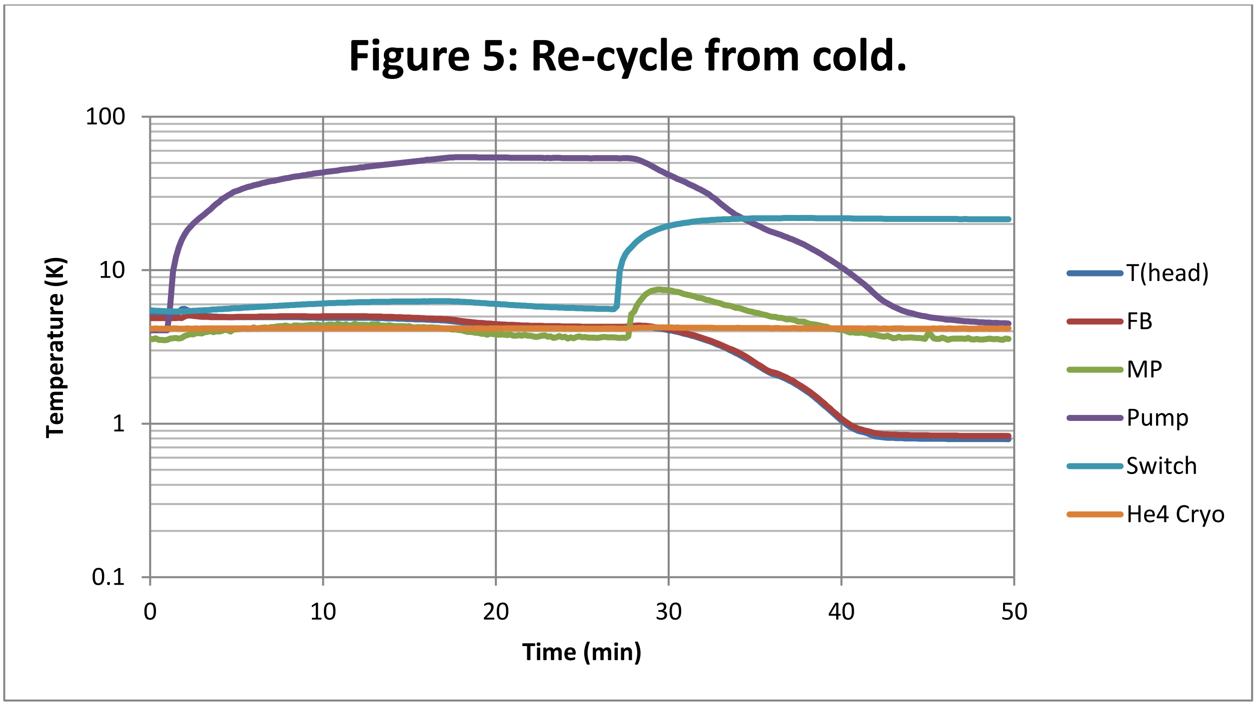
The re-cycle from cold is extremely simple to perform, and takes less than 1 hour from start to finish. See example in Figure 5.

t = 1: Apply 25V (63mA, 1.57W) the pump heater.

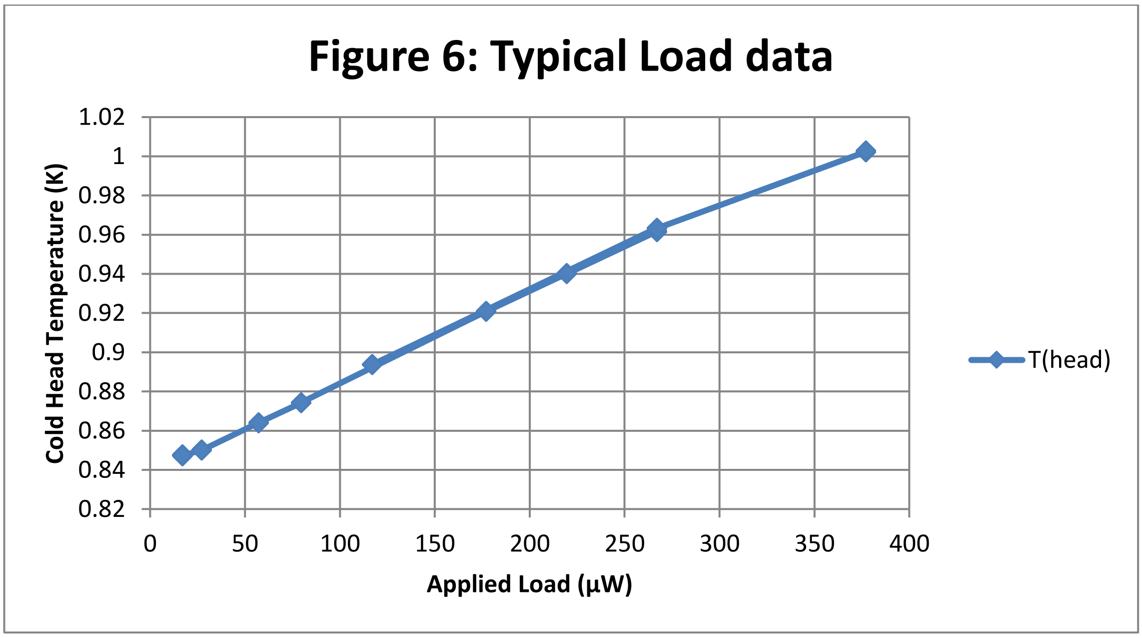
t = 17: Turn pump heater current OFF.

t = 27: ^{4}He pump switch ON, 3V.

t = 50: Fridge is running.



Finally, a typical load curve for the cold head is presented in Figure 6. The blue data points are for no load applied to the film burner, and the red are for 100µW of load applied to the Film Burner.



7. STANDARD PIN-OUT ASSIGNMENTS.

The table below shows wiring pin-outs to 21-pin micro-D SSP.

Function	Red box for twisted pair.	Designation	MDM 21-SSP.	Drive current or voltage
COLD HEAD RuO_2 V+	🟥	🟩	1	100nA AC Or low voltage Driver e.g. V<0.5mV
COLD HEAD RuO_2 V-			12	
COLD HEAD RuO_2 I+	🟥		2	
COLD HEAD RuO_2 I-			13	
NC			3	
DIODE FILM BURNER I+	🟥	🟦	4	10µA
DIODE FILM BURNER I-			14	
DIODE MAINPLATE I+	🟥	🟦	5	10µA
DIODE MAINPLATE I-			15	
DIODE 4HE PUMP I+	🟥	🟦	6	10µA
DIODE 4HE PUMP I-			16	
DIODE 4HE SWITCH I+	🟥	🟦	7	10µA
DIODE 4HE SWITCH I-			17	
			8	
			18	
			9	
			19	
HEATER 4HE SWITCH I+	🟥	🟪	10	3 to 4 Volts
HEATER 4HE SWITCH I-			20	
HEATER 4HE PUMP I+	🟥	🟪	12	50 to 100 mA 24 to 30 V
HEATER 4HE PUMP I-			21	

Diode thermometer	🟦
Ruthenium Oxide thermometer	🟩
Heater wires	🟪
Twisted pair	🟥