



Chase
Research
Cryogenics

World leaders in
sub-Kelvin cryogenics

**SINGLE-STAGE SUB-KELVIN ^4He CRYOCOOLER
TYPE GL4 (Helium 4)**



GENERIC INSTALLATION AND OPERATING INSTRUCTIONS

Photo shows a typical CRC GL4 cryocooler

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THIS GENERIC OPERATING MANUAL describes how to install and operate a CRC GL4 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.

Both this manual and the Excel data file are important parts of the technical documentation for this product. You are advised to make a note below of the location of the Excel file specific to your cryocooler unit. CRC can, on request, provide a copy of the Excel file for your unit – just let us know the serial number engraved around the mainplate.

This revision of the manual was created in September 2020.

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 the cold heads.

Do not tamper with the copper capillary fill tubes.

Avoid the use of acid fluxes when soldering near the cryocooler. Chloride based fluxes will corrode stainless steel and could damage your cryocooler.

After unpacking the cryocooler according to the instructions supplied, the cryocooler should be immediately transferred into the host cryostat. The shipping brace doubles as a stand for the cryocooler, though when used as a stand, the screws through the aluminium plate into the cold heads should NOT be in place. When picking the cryocooler up, it should be held by the main plate.

2. SAFETY OF CHASE RESEARCH CRYOGENICS PRODUCTS

2.1. Pressure Equipment Directive 2014/68/EU.

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, nor CE marking applied.

The cryocooler is covered by Article 4 Paragraph 3 of the Pressure Equipment Directive, which states:

“Pressure equipment and assemblies below or equal to the limits set out in points (a), (b) and (c) of paragraph 1 and in paragraph 2 respectively shall be designed and manufactured in accordance with the sound engineering practice of a Member State in order to ensure safe use. Pressure equipment and assemblies shall be accompanied by adequate instructions for use. Without prejudice to other applicable Union harmonisation legislation providing for its affixing, such equipment or assemblies shall not bear the CE marking referred to in Article 18.”

2.2. UK Pressure Equipment (Safety) Regulations 2016.

The pressurized modules making up this cryocooler unit have internal volumes much lower than 1 litre, and pressure x volume much lower than 200 bar-litres, hence the cryocooler is exempt from the Essential Safety Requirements set out in Schedule 2 of the PESR Regulations 2016. This means that the cryocooler does not require a written scheme of examination. The cryocooler complies in all respects with the requirements of Regulation 8 of PESR 2016. The *owner* has duties under the PESR 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.

2.3. Safe Operation

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

2.4. 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 several 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.
- A shipping brace for safe storage of the unit when not in use.

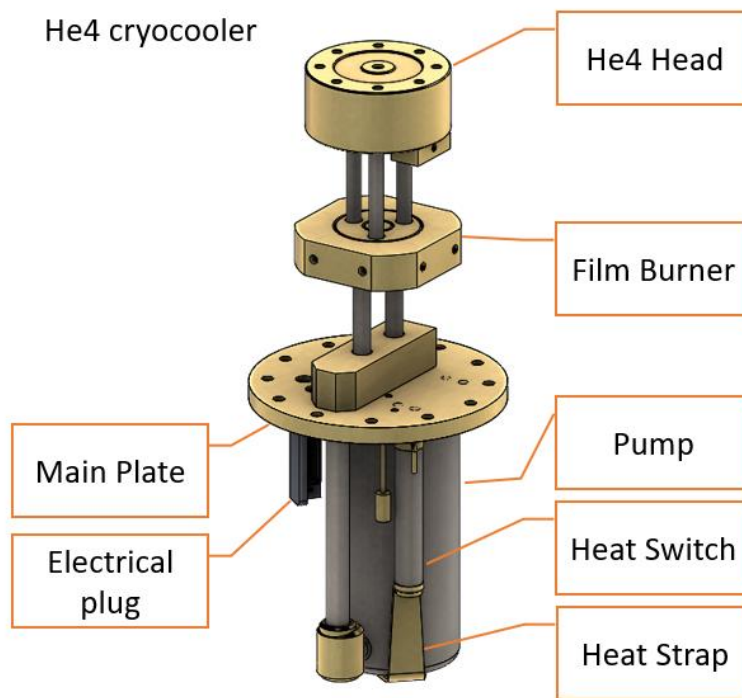
The applications for which cryocooler units are intended make it impossible to place warning labels on the unit itself. However if the cryocooler is incorporated into another instrument, that instrument should carry a warning label to alert the user that the cryocooler contains no user-serviceable parts 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

The cryocooler shown in the figure below is a standard model. In use, the cryocooler is inverted, i.e. the head will be at the bottom. The main plate needs to be thermally sunk to the cold head of a precooler 4K or below, see section 4.1 for more information. The ^4He cold head and the film burner can both be used to extract heat from the experiment, see section 5 for more information. The pump and heat switch can reach up to 50K during operation, these need to be radiation shielded from the head, for more information see section 5.1. All electrical connections are mounted on the main plate on an MDM connector. Pin-outs are listed at the end of this manual.



The following short names for the various parts of the cryocooler are used throughout this user manual:

Short name used in this manual	Refers to the cryocooler part
4-head	^4He cold head
FB	Film burner
4-Pump	^4He pump
4-Switch	Heat Switch for the ^4He pump

4. INSTALLATION

4.1. Mechanical

Before installing the unit in your cryostat, be sure to remove all the pieces of packing material 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 cryocooler. The heat switch can be easily damaged, and if bent or twisted is likely to fail.

This cryocooler is designed to work equally well in either a ‘wet’ cryostat using liquid ^4He to cool the mainplate, or in a ‘dry’ cryostat with the mainplate thermally sunk to a mechanical pre-cooler at 4K or below, such as a GM or pulse tube cryocooler. The thermal link to the pre-cooler should be made from gold plated copper to ensure excellent thermal contact between the cryocooler and the pre-cooler. To attach the cryocooler to the 4K stage of the pre-cooler there are twelve 4.1mm diameter (M4 clearance) holes symmetrically distributed upon a 76 mm pitch circle on the main plate. (Note: UNC #6 clearance holes are substituted if requested by the customer). A CAD file of your cryocooler can be provided on request.

Because the cooling down of the heads depends upon gas convection, and on liquid helium collecting in the heads fed by gravity, the cryocooler *must* be kept close to vertical with the heads downwards.



Ensure spring washers are 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 on a 21-pin MDM-SSP connector mounted onto the main plate. Pin-outs are listed at the end of this instruction manual.

The table below summarises the temperature sensors installed on the unit.

ITEM	Calibration	Options
4-head RuO₂	Generic lakeshore cryotronics.	Individually calibrated sensors available on request
Film burner diode	Specific calibration supplied in individual data file	No diode supplied
Main plate diode	Generic – supplied by CRC Ltd	No diode supplied
Pump diode	Generic – supplied by CRC Ltd	
Switch diode	Generic – supplied by CRC Ltd	

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	300Ω approx.	20 to 25 V
Heat switch heater	1 off	10kΩ	5 V
Diode thermometers	3 or 4 off	0.5 to 1.8V	10μA DC
4-head RuO ₂ thermometer	1 off	1kΩ to 3kΩ	1μA max.

Generic (i.e. standard calibration) RuO₂ sensors from Lakeshore Cryotronics are the default option on the head of all CRC cryocoolers. Individually calibrated 'CERNOX' or RuO₂ sensors are only fitted (at additional cost) at the customer's request. The thermometer on the 4-head is operated as a 4-wire device and should ideally be driven by an AC current no greater than 1μA.

Calibration tables for all thermometer sensors are in the Excel data file that accompanies each unit. Generic diode calibration curves for the pump diode and heat switch diode, and a calibration curve specific to the film burner diode, are supplied as standard. The diode thermometers require excitation with currents of 10μA DC.

The heat switch heater typically requires about 5 V to keep the switch in the 'ON' state with the absorber pod at greater than ~20K, and it will cool to the off state (T < 10 K) in ten to fifteen minutes.

The pump heater impedance is typically 300Ω. During the cooling cycle it is necessary to warm the 4-pump to between 45 and 50k. A heater current of up to 100 to 130mA will heat the 4-pump rapidly; lower heater currents will result in slower heating. Stabilisation of the 4-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 a user's experiment mounted on a separate cold table. They are the 4-head and the film burner.

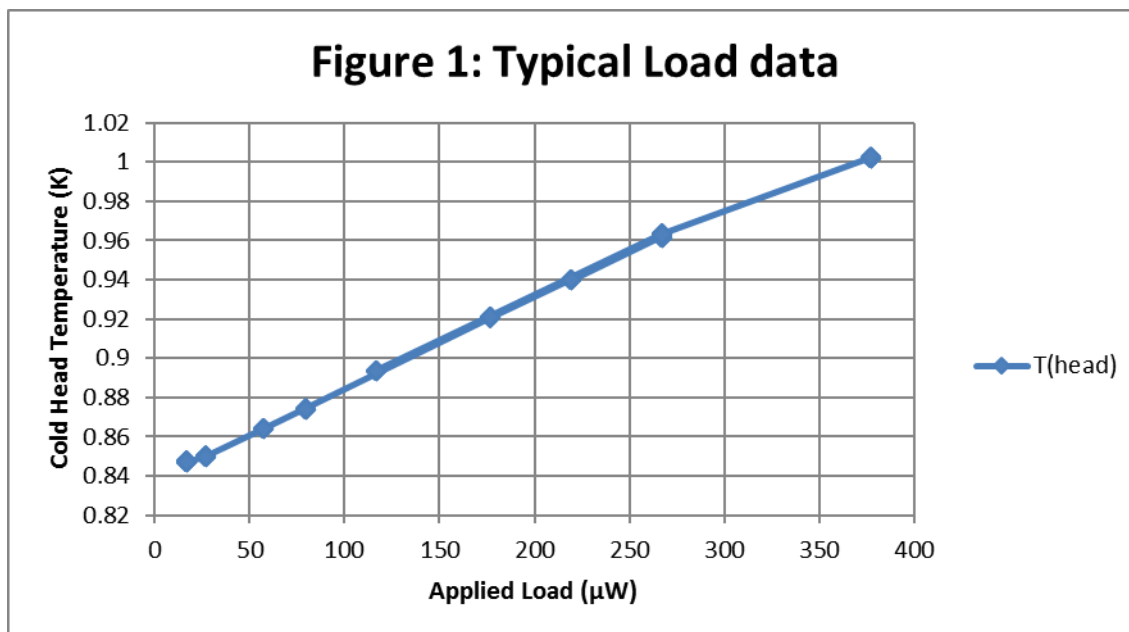
The top surface of the 4-head has 8 holes tapped M3 on a 40mm pitch circle and a further axial hole tapped M4. The film burner has 8 M3 tapped holes on the main body, in pairs 20mm apart on each side. (Note: UNC #4 threads are substituted if requested by the customer). A CAD file can be provided on request.

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

GL4 cryocoolers are made in different sizes. The size of a GL4-type cryocooler determines its run time and temperature at a given heat loading. The cryocooler you have purchased will have been

built to your requirements and tested to verify that it meets its specification. Details of the specification and of the test results are in the Excel file accompanying your unit.

Under no load, and with the main plate at $\sim 4\text{K}$, the 4-head will typically run at about 800mK , and the film burner at about 1K . If the main plate can be kept colder than 4K , then the cryocooler will also run colder. When the 4-head is loaded the head temperature increases, which may be seen from the typical data in Figure 1 below. Load data for your specific cryocooler will be supplied in the Excel data file that accompanies your unit. Optimum temperatures and run times should be obtained with the loads on the 4-head and film burner distributed, so that the film burner runs at about 1.5 to 2K .



5.1. Radiation shielding

The 4-head, and any cold table/experimental equipment/detector assembly you attach, must be properly radiation shielded at $\sim 4\text{K}$ to achieve a sub-Kelvin operation. Any ancillary support structure (cold table) and experimental wiring looms may be thermally sunk to the film burner 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 cryocooler unit are necessary for satisfactory operation. If your cryocooler performance is not meeting the specification, this is likely to be due to a radiation load. Check your radiation shielding and consider adding extra multi-layered insulation around your radiation shields, or around the pump.

6. OPERATION: QUICK-START GUIDE

6.1. Summary of the operating steps

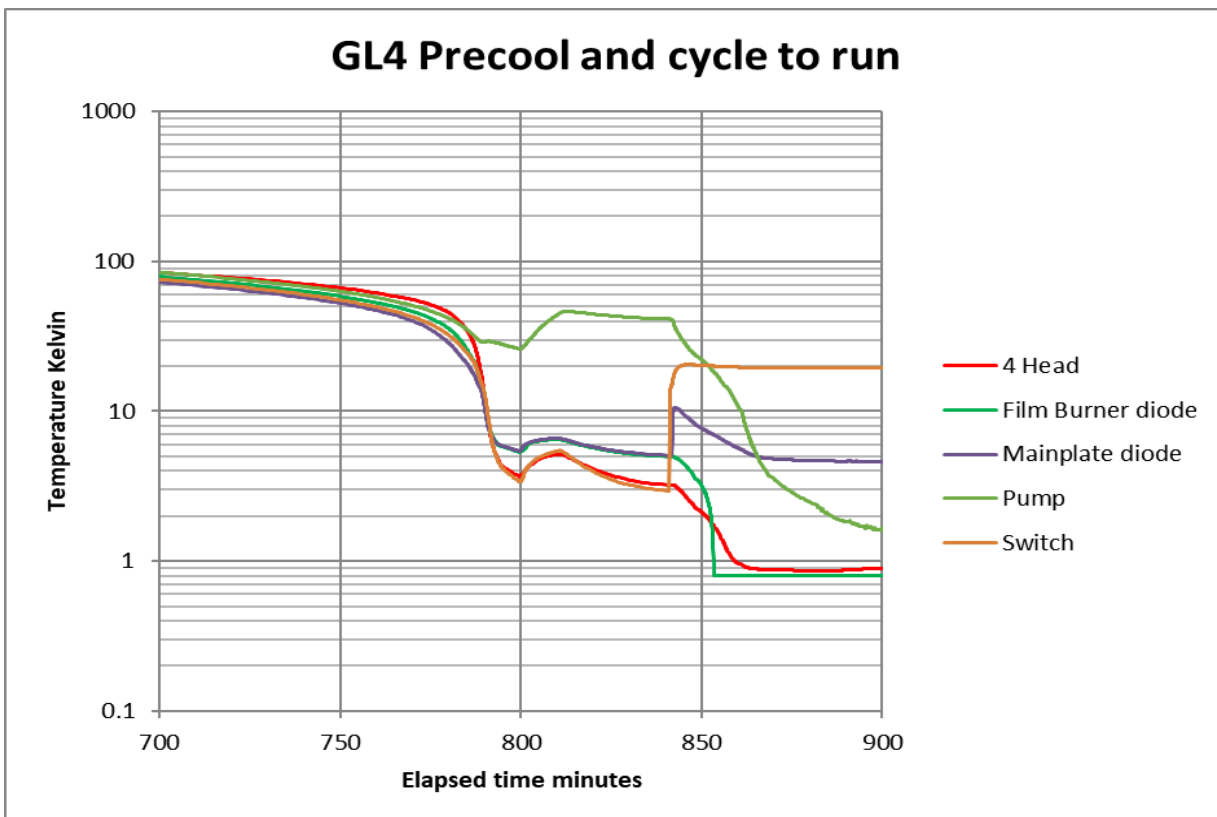
The basic operational sequence is as follows.

- Pre-cool from room temperature to $\sim 4\text{K}$.
- During pre-cooling, when the heat switch turns OFF (it is at less than 10K), heat the pump to $45\text{-}55\text{K}$ and keep it in that temperature range while the head cools to below 4K and its temperature stabilises.
- Turn OFF the 4-pump heat and turn ON the 4-switch.

A detailed flow diagram showing all the steps for running the cryocooler can be seen at the end of this manual. The temperatures suggested are only approximate and may need to be adjusted to achieve the best performance for your specific cryocooler and experiment. If you are using a mechanical pre-cooler with a low cooling power (e.g. 100mW) try the lower end of the suggested pump temperature range. If you are using a more powerful mechanical precooler, or precooling with liquid helium, you will get the best performance at the top end of the suggested temperature range. An operational sequence for a typical GL4 cryocooler is illustrated below.

6.2. Pre-cool and cycle to run

An illustration of a typical pre-cool and first cycle with a low-power GM precooler is shown below. Cooling times will be shorter with a higher-power GM.

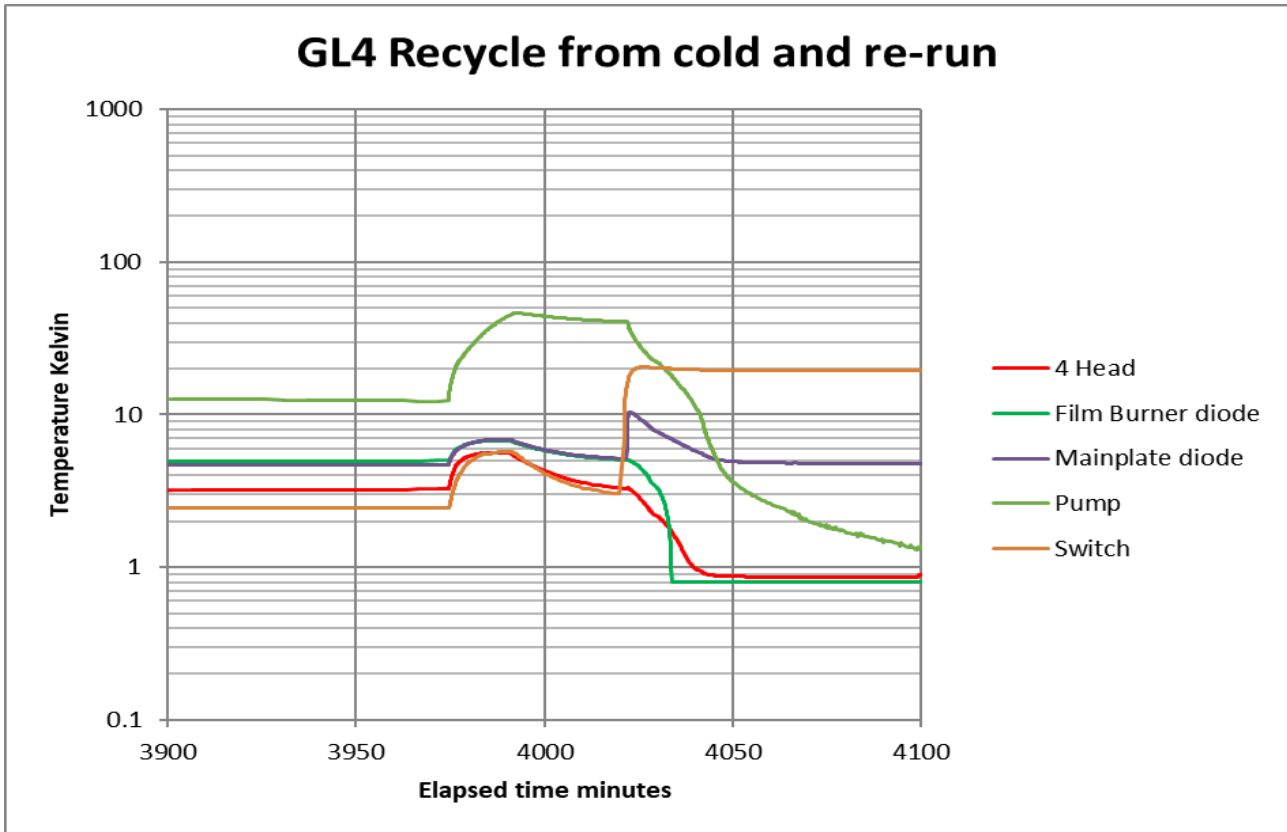


Here you can see that after ~800 minutes the head temperature is less than 4K, the heat switch is off (<10K) and the pump is at more than 25K. To get the GL4 running the pump is warmed to nearly 50K by applying a voltage of 20V. The pump heater is turned down or off while the head temperature drops to less than 3K. As the head temperature stabilises, the heat switch is turned on with a voltage of 5V and the GL4 starts to run.

Note in this figure that the film burner diode readings bottom out during the run because the generic diode calibration has been used. Diode readings at these temperatures are only indicative. In some cases we are able to provide a specific calibration for the film burner diode fitted to your cryocooler, which will improve the accuracy of the FB diode readings below 4K.

6.3. Recycle from cold and run

The run time of a GL4 cryocooler will depend on the size of the unit (i.e. how much gas it contains), on parasitic loads, and on loads applied by your cryostat and experiment. When the unit expires, it can be recycled from cold and run again. A typical sequence with a low-power GM pre-cooler is illustrated below.



At the beginning of this sequence the 4-head has expired and the heat switch has been turned off. As before the pump is warmed to nearly 50K and kept warm until the head re-cools and stabilises. The switch is turned on and the GL4 once again begins to run. The entire recycling sequence takes around 100 minutes. A faster recycle (warming the pump rapidly with a higher voltage) can be carried out if a higher-power GM is used, as it has more capacity to quickly remove the heat input to cycle the pump.

7. OPTIMISING THE PERFORMANCE OF YOUR CRYOCOOLER

It is easy to get your cryocooler to run but takes practice and experimentation to achieve the best possible performance. Your experimental configuration will affect the thermal loadings on, and conductances between, the various parts of your cryocooler. Try experimenting with slight variations of the generic method of operation described in this manual to optimise the performance for your own application.

7.1. Pre cool

Keep the pump above 25K once the switch has turned OFF for the initial cooldown.

It is important to understand that for the initial cool down, the cold head cools by gas convection, and the pump cools by conduction via the heat switch while the heat switch is ON. The cold head will cool rapidly while the pump is warmer than $\sim 25\text{K}$, but once the pump drops below this temperature the head could take a long while to reach its final cooldown temperature. This is because when the gas is adsorbed into the pump, the head cannot cool by gas convection. The key to a rapid cooldown is once the heat switch has turned OFF, reheat the pump above $\sim 25\text{K}$ and stabilise it at this temperature. You should then see the cold head cool rapidly to around 4K .

7.2. Running the cryocooler

Experiment with varying the pump temperature during the run to find the best performance for your set up.

Once the 4-head is $\sim 4\text{K}$, and the switch is off, the cryocooler is ready to start running. The generic method is to heat the pump to the suggested temperature in the flow diagram and maintain it there the 4-head cools to below the critical liquefaction point of ^4He (5.2K). The colder the 4-head gets while the pump is hot, the higher the liquefaction efficiency, and hence the longer the cryocooler will run before it must be recycled. You should try variations of pump temperatures to find a procedure that provides the best performance for your set up. When operating from a low-powered mechanical pre-cooler (e.g. 100mW @ 4K GM unit), you will achieve more efficient ^4He condensation by starting at the lower end of the suggested range of temperatures. This is because imposing a smaller load on the mechanical pre-cooler from the hot pump will enable a faster and more efficient recycle and run.

7.3. Operating the heat switch

Turning the switch on slowly will put less load into the pre-cooler.

Once the ^4He is liquified (when the 4-head and film burner temperatures have stopped falling) the 4-pump is allowed to cool by turning OFF the pump heater and turning ON the heat switch. The hot 4-pump will impose a large heat load onto the 4K plate which will cause the temperature to rise temporarily. However, the rate of cooling the pump can vary depending on the voltage applied to the switch. The switch will begin to turn ON at $14\text{-}17\text{K}$ and be fully on above $\sim 20\text{K}$. If the switch is turned on slowly, by applying a lower voltage at first and gradually increasing it, the heat from the pump is dissipated more slowly and so there is less temperature rise at the 4K plate. In addition, if there is a small pause between turning off the pump power and turning on the switch power, in this time the pump will cool slightly by the parasitic load down the pump tube. At this point the 4-head temperature and film burner temperature will fall rapidly.

7.4. Applied loads

Use the 4-Head and Film burner to buffer any applied loads.

In operation, the applied loading from lead-in wiring may be dissipated on the film burner to optimise the 4-head temperature or run time. The longest run times will be obtained when the loads on the 4-head are minimised.

8. STANDARD PIN-OUT ASSIGNMENTS

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

Function	Red box for twisted pair.	Designation	MDM 21-SSP.	Drive current
				or voltage
4-HEAD RuO ₂ V+	Red box	Green box	1	100nA AC Or low voltage Driver e.g. V<0.5mV
4-HEAD RuO ₂ V-			12	
4-HEAD RuO ₂ I+			2	
4-HEAD RuO ₂ I-			13	
NC			3	
DIODE FILM BURNER I+	Red box	Blue box	4	10μA
DIODE FILM BURNER I-			14	
DIODE MAINPLATE I+	Red box	Blue box	5	10μA
DIODE MAINPLATE I-			15	
DIODE 4-PUMP I+	Red box	Blue box	6	10μA
DIODE 4-PUMP I-			16	
DIODE 4-SWITCH I+	Red box	Blue box	7	10μA
DIODE 4-SWITCH I-			17	
			8	
			18	
HEATER 4-SWITCH I+	Red box	Magenta box	9	5 Volts
HEATER 4-SWITCH I-			19	
			10	
			20	
HEATER 4-PUMP I+	Red box	Magenta box	11	50 to 100 mA 20 to 30 V 300Ω
HEATER 4-PUMP I-			21	

Diode thermometer

Ruthenium Oxide thermometer

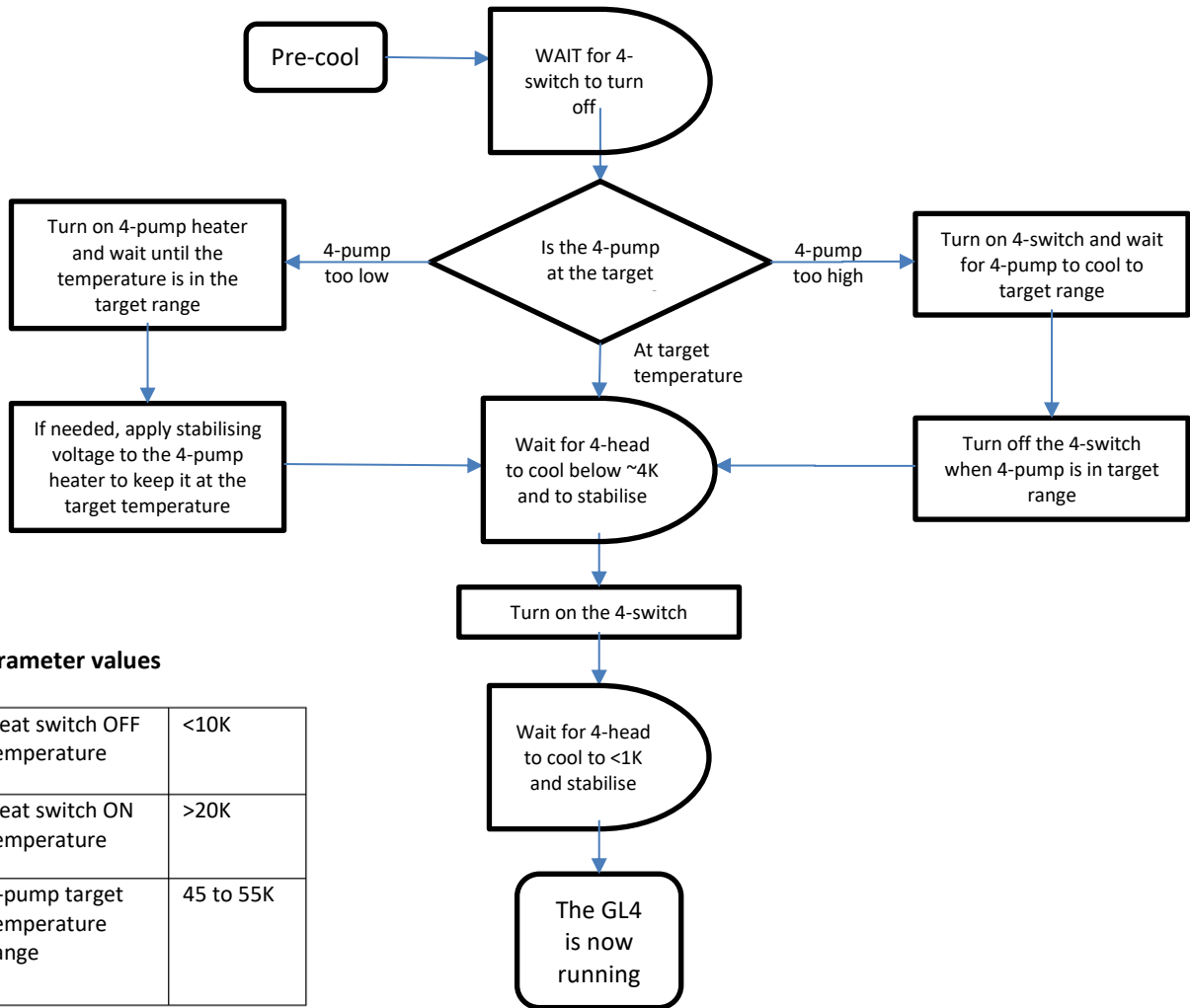
Heater wires

Twisted pair



9. FLOW CHART OF GL4 OPERATING PROCEDURE

Note that some operations occur in parallel.



Parameter values

Heat switch OFF temperature	<10K
Heat switch ON temperature	>20K
4-pump target temperature range	45 to 55K