SPIRE Cryostat Operating Procedures

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Host system	Windows 2000 SP2
Word Processor	Microsoft Word 2000 SR1
File	Cryostat Operations Procedures Issue 0.1.Doc

Document Change Record

Date	Index	Affected Pages	Changes
11-Mar-2003	0.1	All	First Draft
24-Mar-2003	0.2	All	Comments from AS Scientific, Eric Clark and Alan Pearce Incorporated. Mainly minor typos and corrections.
03-April-2003	0.3	17-19	Comments from Mike Trower and Richard Down (ISIS cryostat division) after pre-test checkout

Contents

1 Scope of Document

This document describes the procedures for the safe operation of the SPIRE calibration cryostat. The procedures for filling the cryostat are based on those defined in the cryostat-operating manual (AD 1).

2 Applicable Documents

	Title	Author	Reference	Date
AD 1	SPIRE Cryostat Operating Manual	AS Scientific	SPIRE-RAL-DOC-001472 Issue 1.0	08-Jan-2002
AD 2	RAL Safety Codes	CCLRC	http://www-internal.clrc.ac.uk/staff/notices/ral_safety_codes.	

3 Cryostat Description

3.1 General

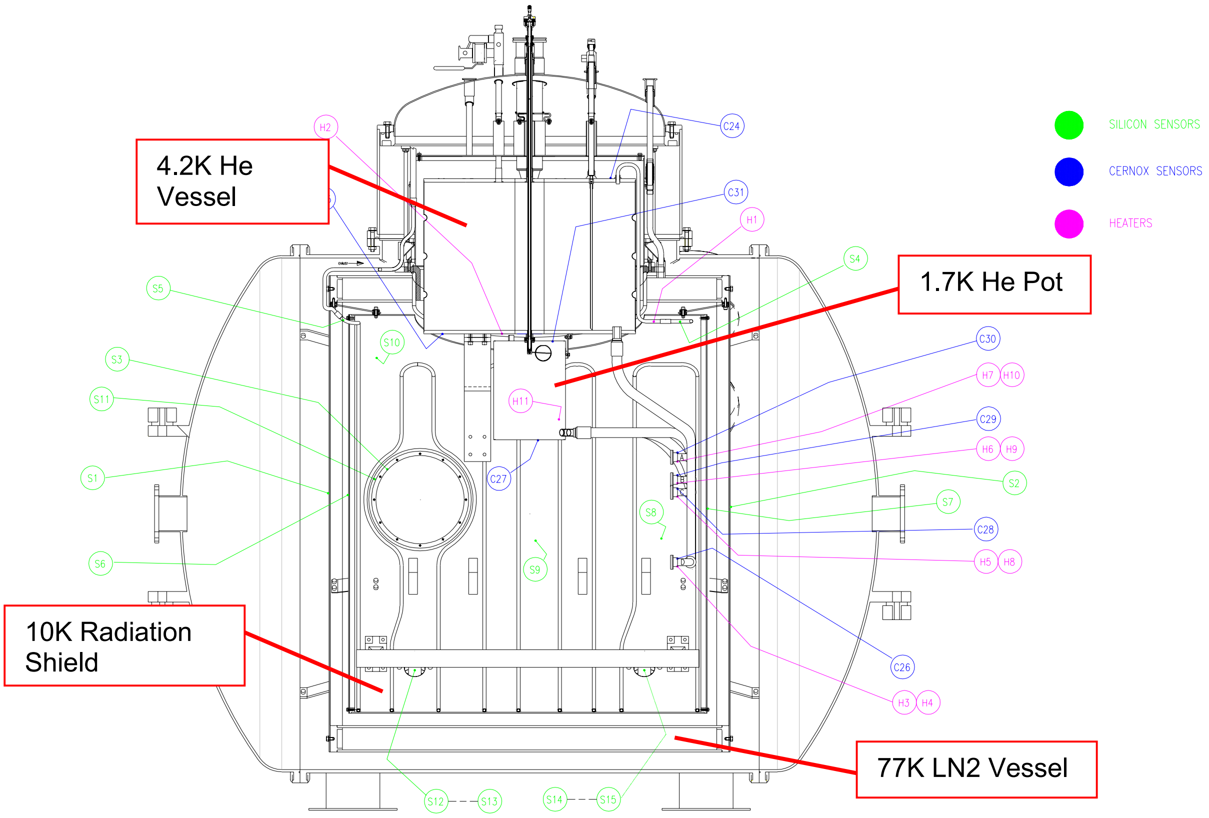

Figure 1: Cross section of SPIRE test cryostat showing the different temperature stages and thermometer locations (Drawing ref AD1).

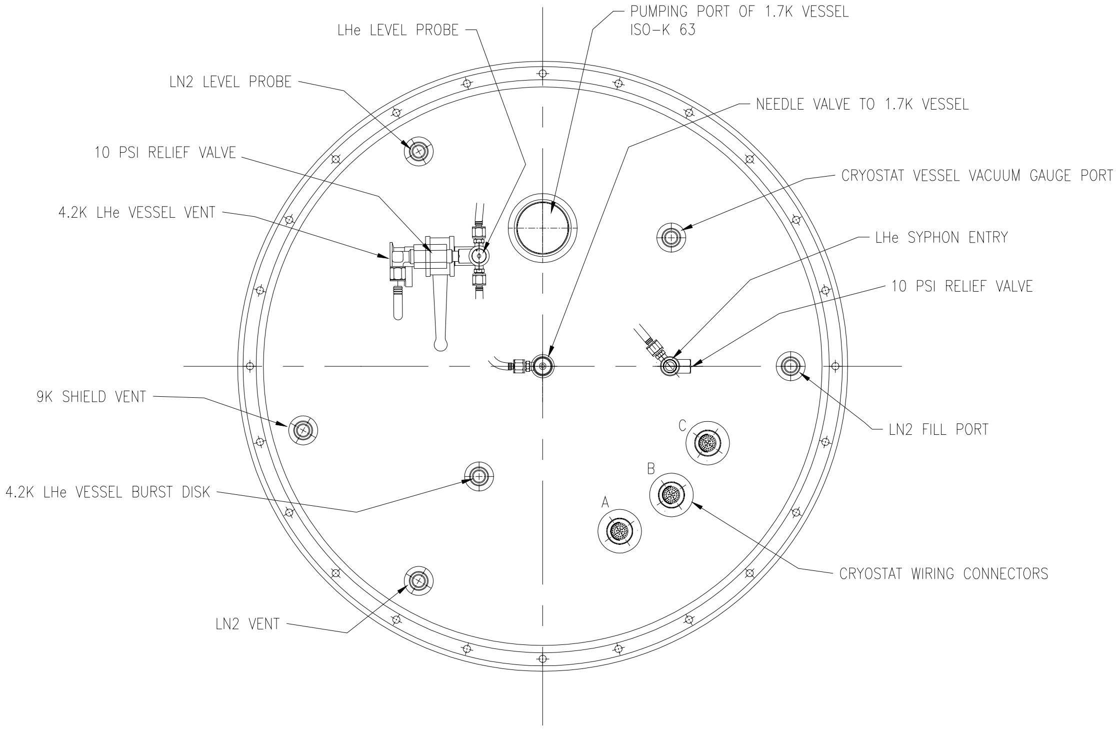

Figure 2: Position of services on the top spinning of the Cryostat

The SPIRE Calibration Cryostat has four stages of cooling, an outer liquid nitrogen cooled vessel at 77K, a 9K radiation shield, a 4.2K liquid He vessel and a 1.7K pumped liquid He pot, Figure 1. These stages are described below with reference to Figure 2, which shows the positions of the ports and services on the top flange of the cryostat.

3.1.1 Nitrogen vessel

This acts as a radiation shield and a means of pre-cooling for the inner vessels. It can contain a volume of over 240 litres of liquid nitrogen. The vessel has three ports. It is filled via the LN2 fill port, which gives access to an internal tube that extends to the base of the can. The LN2 vent port should be open at all times, and the exhaust gas vented outside the room.

The level of nitrogen in the vessel is monitored by the level probe situated in the third port. The level probe consists of four PT100 temperature sensors at different heights in the vessel. The lowest sensor is level with the base of the filter flange. The level probe may be powered by a 12 V supply (with a pull-up series resistance of 120 ohms).

3.1.2 4.2 K helium vessel

The main helium vessel has a capacity of approximately 110 litres. The vessel is filled by a syphon through the LHe syphon entry. The vessel is protected by a burst disk, and by two 10 psi relief valves. It has one flexible cold strap connected to the base of the vessel which connects to the SPIRE level-1 interface. The exhaust gas from the vessel may vent through either the LHe vessel vent ball valve or through the ‘9 K’ shield. The helium level probe is positioned in the vessel vent. The end of the probe is 15 mm above the base of the helium can. It requires a calibrated 100mA supply. The operator shall ensure that the 100mA source is within calibration and recorded in the logbook.

3.1.3 '9 K' shield

This is cooled by the exhaust gas from the main helium vessel. The temperature of the shield is dependent on the rate of evaporation of helium. If the boil off is too low, it can be increased by applying heat to H2 on the base of the helium can. This will increase the flow of cold gas through the shield and lower the temperature. Conversely if the temperature of the shield is too low, heater H1 can be used to apply heat to the gas inlet tube. Twelve gold-plated braids thermally link the instrument to copper blocks brazed to the inside of the shield.

3.1.4 '1.7 K' Vessel

The '1.7 K' vessel is used to cool the SPIRE level-0 interfaces via three fluid straps. The vessel is fed with liquid helium from the main can via a needle valve and capillary tube. A sufficient head of helium in the main can is essential for liquid to flow through into the '1.7 K' vessel.

When the '1.7 K' vessel is full, the temperature of the liquid helium in the vessel is reduced by pumping through the ISO-K 63 pumping port. The needle valve may be closed and the '1.7 K' vessel operated as a 'single shot' system, or the valve may be opened slightly and liquid fed continuously into the vessel during pumping. As it passes through the capillary the incoming liquid is pre-cooled as it flows through a coil inside the top flange of the '1.7 K' vessel. The base temperature attainable depends on the capacity of the pump used and on the rate of flow of helium through the needle valve.

3.2 Vacuum System

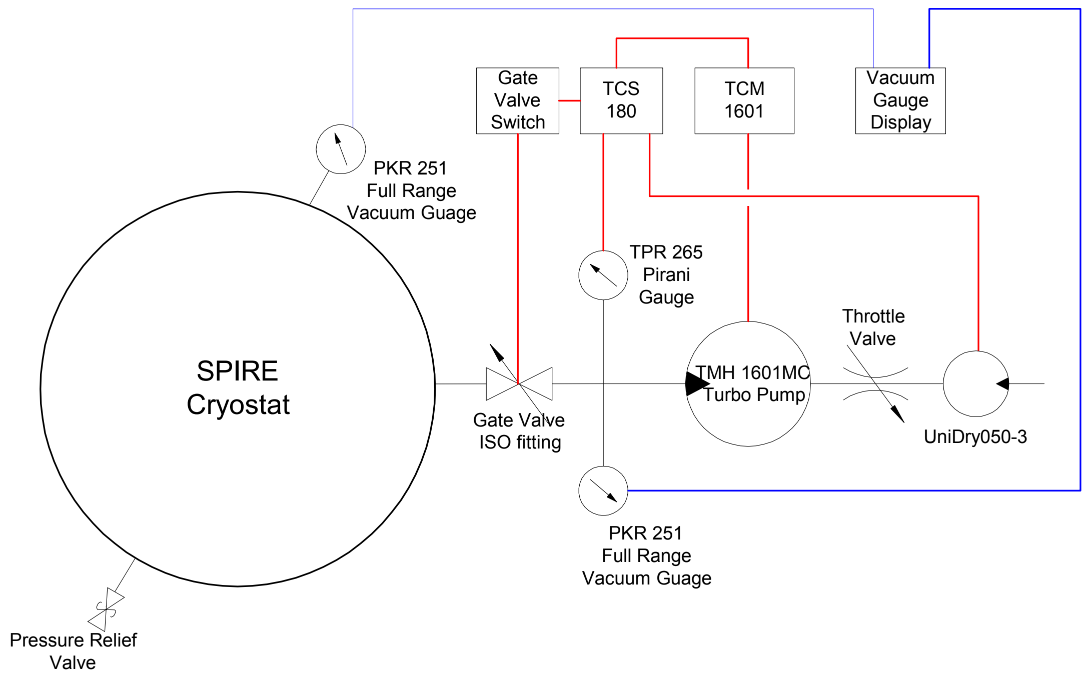

Figure 3: Schematic of cryostat main vacuum system

4 Constraints

4.1 Safety

Great care should be taken when handling liquid nitrogen and helium. The main hazards associated with liquid Nitrogen and Helium are:

- Cold "burns" to the person.
- Explosions due to the vaporization of the liquified gas into an enclosed space.
- Asphyxiation due to exclusion of oxygen.
- Spillage onto structural materials, which can cause thermal contraction of the metal, say steelwork, with resultant cracking.

All people working with the cryostat should have instruction on the safe handling of cryogenic liquids and familiarise themselves with the laboratory safety code RALSC10 which can be found on http://www-internal.clrc.ac.uk/staff/notices/ral_safety_codes. The safety code must be followed at all times when handling cryogenic liquids. A risk assessment shall be performed before operating the cryostat.

The personal oxygen monitors provided must be used when entering the lab when the cryostat is cold. These are calibrated every 6 months by the manufacturers (crowcon in Abingdon).

When the oxygen monitor alarm sounds leave the room immediately and call ????. DO NOT attempt to enter the room afterwards until the all clear has been given.

The gloves provided shall be worn when transferring liquid helium and nitrogen into the tank.

Any dewars with worn or damaged castors or which are difficult to wheel safely should be taken out of service and returned to stores immediately for repair or maintenance.

4.2 Pumping and purging

The helium vessels must not be pumped without a vacuum in the outer vessel.

The 1.7 K vessel should not be pressured to more than 0.3 bar gauge (5 psi).

The main helium vessel has been designed to take a maximum pressure of 1 bar (15 psi) gauge.

It is essential that neither the needle valve nor capillary be allowed to become blocked at any stage during the cooldown. For this reason they should be pumped and purged with He at each stage of cooling.

4.3 Warming Up

Any remaining liquid helium and nitrogen in the vessels should be siphoned out into Dewars.

Heaters may be used to increase the rate of warming, but care should be taken to monitor the temperatures reached. Temperatures should not exceed room temperature, as this is the upper limit of the majority of the sensor calibrations.

The vacuum in the outer vessel should be let up using clean nitrogen gas. Ensure that the vessel does not become over pressured.

The vessel doors should not be opened until all the temperature sensors are steady and at room temperature, to prevent condensation.

5 Operations Procedures

5.1 Vacuum System

5.1.1 Cryostat Pumpdown – CRY_PUMP

Objective:	To pump down cryostat from atmospheric pressure to high vacuum.
Initial Conditions:	Chamber at Atmospheric Pressure (~1000mbar) Tank doors open Vacuum system control electronics OFF Turbo Pump fan unit power OFF N2 supply closed 3 Phase supply OFF TFCS Logging OFF
Final Conditions:	Chamber at High Vacuum (~10^{-5}mbar) Tank doors closed Vacuum system control electronics operational Turbo Pump at full speed (600Hz) Turbo Pump fan unit power ON N2 supply at 6bar 3 Phase supply ON TFCS Logging ON
Constraints:	Pumping must not start until a test readiness review has been held and authorisation to proceed has been given. Only authorised personnel can perform this procedure (see section 4).
Total Duration:	>24hours

Step.	Action
1.	Verify Initial Conditions • Chamber at Atmospheric Pressure • Tank doors open • Vacuum system control electronics OFF • Turbo Pump fan unit power OFF • N2 supply closed • 3 Phase supply OFF
2.	Inspect door seals and seal faces. Wipe as necessary
3.	Close tank doors and secure all clamps
4.	Open N2 supply to gate valve – pressure set to 6bar.
5.	Switch on power to vacuum system electronics – gate valve will open. If the gate valve does not open press the manual control switch. The indicator should change. If not investigate fault.
6.	Switch on power to turbo pump cooling unit.
7.	Switch on 3-phase supply for backing pump.

8.	Start TFCS pressure and temperature logging and monitoring.

Step.	Action
9.	Check initial configuration of TCM1601 turbo pump controller using following checklist. Change parameters as required to correct settings.

#	Display	Description	Required Value	OK
Settings Commands				
001	Heating	Pre-selection	0 = OFF	
002	Standby	Standby Selected	0 = OFF	
004	RUTime ctr	Run Up Time Monitoring		
010	Pump Stat	Pumping station status	OFF	
012	Vent Enab	Venting Enable	OFF	
013	Brake Enab	Pre Selection Brake	1 = OFF	
018	Conf OUT3	Configuration – cooling	3 = AIR Cooling	
019	Conf OUT2	Configuration K2	2 = OFF	
023	Motor TMP	Motor Turbopump ON/OFF	ON	
024	Conf. Out 1	Configuration K1	0	
025	OpMode BkP	Operations Mode Backing Pump	0 = Non Stop	
026	OpMode TMP	Operations Mode TMP	0	
027	Gas Mode	Gas Mode	0	
028	OpMode Rem	Remote Operations Mode	0 = Standard	
030	Vent Mode	Venting Mode	1 = Do Not Vent	
031	HiFlowCtrl	Hi Flow Control	0 = OFF	
Set Values				
700	TMP RUTime	Maximum Run Up Time in Mins	45	
701	Switch pnt	Rotation Speed Switchpoint	80%	
703	HVVthrshld	High Vacuum Pressure Switchpoint	1E-1	
704	TMSheatset	TMS heating temp set value	40	
707	TMProt set	Rotation speed set value	50%	
710	BKP off	Pmin for interval backing pump ops.	0	
711	BKP on	Pmax for interval backing pump ops.	0	
717	Stdbyrotset	Preset rotation speed at standby	66.7%	
720	Vent Freq.	Venting Frequency	50%	
721	Vent time	Venting time in seconds	3600	
738	Gaugetype	Vacuum pressure gauge type	TPR250	
794	Param Set	Parameter Set	1 = extended	
795	Servicelin	Contains the service line	309	
797	Address	Unit Address	1	

Step.	Action
10	Close backing line valve to 20% to restrict flow during initial pump down.
11	Set parameter to 340 to view Pirani pressure (use buttons on TCM1601 to adjust)
12	If all parameters are correct start pumping system by pressing . Record the time at start of pumpdown. If an error occurs the gate valve will shut and the pumps will stop. Press the acknowledge button If error persists investigate fault and abort the procedure.

Step.	Action
13	Wait for tank pressure to reach 100mbar – this will take several minutes. Turbo pump will spin up slowly.
14	At 100mbar open backing line valve to full. Release all door clamps, except clamps at 3 o'clock position which should remain in place but loose. Loosen bolts on pressure relief plate to allow it to drop in the event of a cryogen vessel failure. Record the time.
15	Record time when pressure reaches 1mbar.
16	Record time and pressure when turbo pump reaches full speed (=600Hz).
17	Monitor pump down and leave to pump down. Manually record chamber, pumping port and backing line pressures on checklist at hourly intervals.

5.1.2 Letup to Air – CRY_LETUP

Objective: To let-up chamber from high vacuum to atmospheric pressure.

Initial Conditions:
Chamber at High Vacuum (~10^{-5}mbar)
Instrument and tank at room temperature.
Tank doors closed
Vacuum system control electronics operational
Turbo Pump fan unit power ON
N2 supply at 6bar
3 Phase supply ON
Turbo Pump at full speed (600Hz)
TFCS Logging ON

Final Conditions:
Chamber at Atmospheric Pressure (~1000mbar)
Tank doors open
Vacuum system control electronics OFF
Turbo Pump fan unit power OFF
N2 supply closed
3 Phase supply OFF
TFCS Logging OFF

Constraints: The chamber must not be vented until a test review has been held and authorisation to proceed has been given.

Only authorised personnel can perform this procedure (see section 4).

Total Duration: <6hours

Step.	Action
1.	Verify Initial Conditions • Chamber at high vacuum (~10^{-5}mbar) • Turbo Pump at full speed (600Hz) • Gate valve OPEN • All temperatures within chamber at ambient (>296K). • Check that venting is disabled. (TCM1601 Parameters 012 = OFF, 030 = 1) • Check that pressure relief valve is free to drop and that door clamps at 3 o'clock position are in position and slightly loose.
2.	Stop pumps by pressing . This will open the 3 phase relay to switch off the backing pump and close the fore line valve.
3.	Wait for the turbo-pump to slow down to 0Hz. Record time when pump stops

Step.	Action
4.	When turbo pump has stopped start venting. Select parameter 012 and set to ON Select parameter 030 and set to 2 (Venting “ON”) Record time at start of venting.
5.	Wait for pressure to rise.
6.	When the pressure reaches atmospheric the pressure relief valve will drop and the doors will open slightly. Record time when pressure reaches atmospheric.
7.	Switch off 3-phase supply for backing pump.
8.	Stop TFCS pressure and temperature logging and monitoring.
9.	Pump electronics can now be switched off. N2 supply to gate valve can be closed.

5.2 Cryogenic Operations

5.2.1 Cryostat Cooldown – CRY_COOL

Objective:	To cool the SPIRE instrument from room temperature to cryogenic temperatures
Initial Conditions:	Chamber at High Vacuum (~10^{-5}mbar) Instrument and tank at room temperature. Turbo Pump at full speed (600Hz) Gate valve OPEN TFCS temperature and pressure logging ON All valves on top should be initially shut.
Final Conditions:	Chamber at High Vacuum (<10^{-6}mbar) SPIRE at cryogenic temperatures Turbo Pump OFF Gate valve CLOSED TFCS temperature and pressure logging ON
Constraints:	The cool down must not start until authorisation to proceed has been given. Only authorised personnel can perform this procedure (see section 4).
Total Duration:	TBC

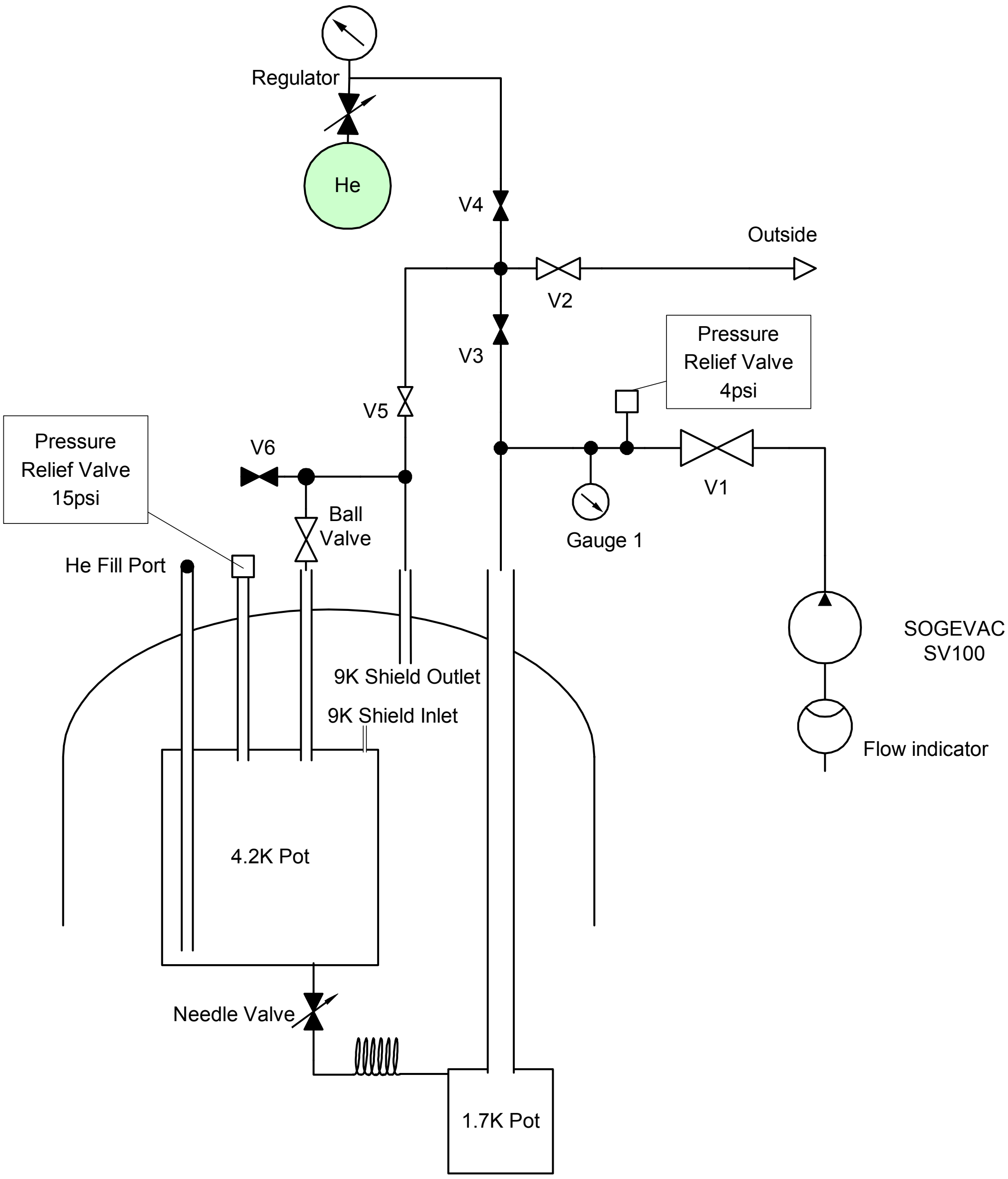

Figure 4: Schematic of He tank purge/fill system

Step.	Action
1.	**Purge the 1.7K Pot with Helium gas**
1.1.	Attach a supply of warm, dry, high purity helium gas as shown in Figure 4. Open regulator on He supply to 2psi. Use fine regulator to set to 2psi and check flow with flowgauge. Check that the 1.7 K vessel is protected by a 4-psi pressure relief valve. Close all valves. Attach blanking plate to He fill port to provide vacuum seal.
1.2.	Open V4, V5 and needle valve to allow flow of He through 4.2K pot and 1.7K pot. Purge gas line with He and close V4.
1.3.	Switch on vacuum pump and open V1, V3, needle valve and ball valve to evacuate vessels
1.4.	Close V1 and Open V4 to allow gas to enter the 1.7 K vessel until a pressure of a 2psi is shown on the gauge. The pressure must NOT exceed 4psi.
1.5.	Open V1 to evacuate vessels
1.6.	Close V1 and Open V4 to allow gas to enter the 1.7 K vessel until a pressure of a 2 psi is shown on the gauge. The pressure must NOT exceed 4 psi. Repeat steps 1.5 and 1.6 at least 3 times.
1.7.	Leave V4 open to maintain overpressure in the helium vessels until helium can blank is removed to pre-cool with liquid nitrogen. If pressure should drop during N2 fill, shut V3, open V1 for 10 minutes to evacuate tanks. Shut V1 and open V4 to refill with gas until pressure increases to 2 psi.
2.	**Fill the Nitrogen Shield**
2.1.	Ensure that the nitrogen vessel is vented.
2.2.	Fill the nitrogen vessel through the fill port until the level probe shows that the vessel is full. This will require approximately **450** litres of N2.
2.3.	After filling connect the fill port to the N2 vent line.
2.4.	When the chamber pressure begins to fall as cryopumping starts, press the gate valve switch to manually shut off the gate valve. Verify that the chamber vacuum pressure continues to fall. It is now safe to switch off the turbo pump if necessary.
3.	**Pre-cool the Helium cans with Liquid Nitrogen**
3.1.	Verify that the helium vessels still contain an overpressure of helium gas. If not, re-purge with helium gas as described in step 1.
3.2.	Close the needle valve.
3.3.	Remove vacuum seal from He fill port and attach liquid nitrogen supply to He siphon inlet.
3.4.	Slowly begin transfer of liquid nitrogen into the helium can through the syphon inlet.
3.5.	Open V2 and the ball valve to allow the cold nitrogen gas to flow through, close V4 to stop the flow of He gas, and cool, the 9 K shield as well as cooling the top fittings of the helium can. Verify that there is a flow of cold gas through the vent line.

Step.	Action
3.6.	Continue to let liquid nitrogen into the helium can. Care should be taken not to overfill as this will increase the time required to boil off the liquid nitrogen before helium filling Open the needle valve and ensure that there is a flow through into the 1.7 K vessel, indicated by gas opening the 4-psi relief valve. Open V3.
3.7.	Monitor temperature sensors S27-30 to ensure that nitrogen is cooling the 1.7 K vessel and straps. Regularly check that there is a flow through the capillary and needle valve.
3.8.	Continue to fill the 1.7 K vessel until sensors S27-30 are reading 100 K. (It should not be overfilled to reduce the time required to boil off the liquid nitrogen before helium filling.) Close the needle valve. **Note:** It may be necessary to pump on the 9 K shield vent line, and/or to apply heat to H2 on the base of the helium can, to draw sufficient nitrogen gas through the shield.
4.	**Empty Liquid Nitrogen from He Vessels**
4.1.	When the helium vessels have cooled sufficiently the liquid nitrogen should be removed. Close V2 and V3 and open V4 and V5 to pressurise the top of the main helium vessel with helium gas. Syphon out as much liquid as possible into the nitrogen vessel. Check the level of nitrogen in the helium can (for example, by dipping through the burst disk port) to ensure all the nitrogen has been syphoned off. If there is still a level of liquid nitrogen remaining, use a longer syphon through the burst disk port.
4.2.	Close V4 and open V3 and the needle valve. Evaporate the remaining liquid using the heaters. Apply appropriate power to heaters H2, 4, 8, 9, 10 and 11 (and possibly H 5-7) until the temperature of the four cold straps and both helium vessels is above 100 K indicating that all the liquid nitrogen has been evaporated.
4.3.	When sure that the liquid nitrogen has been removed purge the helium vessels with helium gas. Switch on the capillary heater.
4.4.	Close off He fill port. Open needle valve, V3, V5 and V1 to pump out gas.
4.5.	Close V1 and open V4 and pressurise He vessels. When pressurised close V3. Check the flow through the valve and capillary.
4.6.	Repeat steps 4.4 and 4.5 twice to ensure that the vessels are pressurised with He before commencing filling.
4.7.	Close V3 and the needle valve.
4.8.	The vessels may now be filled with liquid helium.
5.	**Fill 4K vessel**
5.1.	Open V5, V2 and ball vent valve on the helium can.
5.2.	Insert the helium siphon into the helium Dewar. Ensure there is a flow of gas through the siphon and then insert the other end of the siphon into the helium inlet. Ensure that the siphon is seated tightly in the siphon housing. Transfer liquid helium. When the transfer line is in close V4

Step.	Action
5.3.	Once filling is proceeding, close the ball valve to vent through the 9K shield for the remainder of the fill. Apply heat to H2 on the base of the helium can to increase the flow through the shield. (NOTE: During tests an applied heat of 1.8 W was sufficient to give a shield temperature of 14 K. This could be reduced once the operating temperature is achieved)
5.4.	When there is sufficient depth in the 4.2K vessel open V1 and the needle valve and fill the 1.7K can.
5.5.	Re-fill the main can with liquid helium until the level probe indicates the can is full. NOTE: Cooling and filling both helium vessels in the cryostat is likely to use in the region of 200 litres of liquid helium.
6.	**Cool the 1.7K vessel**
6.1.	Open V1 and close V3 and start pump. The needle valve may be cracked open to continuously fill the vessel. This is also likely to have the effect of raising the vessel temperature slightly (see step 5.4)

5.2.2 Cryostat Warmup – CRY_WARM

Objective: To heat the SPIRE instrument from cryogenic temperatures to ambient

Initial Conditions:
Chamber at High Vacuum (<10^{-6}mbar)
SPIRE at cryogenic temperatures
Vacuum system control electronics operational
Turbo Pump OFF
Gate valve CLOSED
TFCS temperature and pressure logging ON

Final Conditions:
Chamber at High Vacuum (~10^{-5}mbar)
Instrument and tank at room temperature.
Turbo Pump at full speed (600Hz)
Gate valve OPEN
TFCS temperature and pressure logging ON

Constraints: The chamber must not be vented until authorisation to proceed has been given.

Only authorised personnel can perform this procedure (see section 4).

Total Duration: TBC

Step.	Action
1.	**Check that all SPIRE subsystems are OFF**
2.	**Remove remaining liquid helium from 4K pot**
2.1.	Close needle valve
2.2.	Connect siphon to He fill port. Open V4 and pressurise 4K pot to remove liquid Helium
2.3.	When all He has been siphoned off close off regulator and remove siphon.
2.4.	Disconnect He level probe
2.5.	Close off fill port, open needle valve, V1, V5 and V4 and purge with warm He.
2.6.	Apply power to heaters H2, 4, 8, 9, 10 and 11 to raise temperature of SPIRE to above 100K. Monitor the temperatures of the interface points and the HOB plate to ensure that the temperature gradients are <TBC K.
3.	**Start turbo pump**
3.1.	If the pump is operating then proceed to step
3.2.	Switch on power to turbo pump cooling unit.
3.3.	Switch on 3-phase supply for backing pump.
3.4.	Check initial configuration of TCM1601 turbo pump controller using following checklist. Change parameters as required to correct settings.

#	Display	Description	Required Value	OK
Settings Commands				
001	Heating	Pre-selection	0 = OFF	
002	Standby	Standby Selected	0 = OFF	
004	RUTime ctr	Run Up Time Monitoring		
010	Pump Stat	Pumping station status	OFF	
012	Vent Enab	Venting Enable	OFF	
013	Brake Enab	Pre Selection Brake	1 = OFF	
018	Conf OUT3	Configuration – cooling	3 = AIR Cooling	
019	Conf OUT2	Configuration K2	2 = OFF	
023	Motor TMP	Motor Turbopump ON/OFF	ON	
024	Conf. Out 1	Configuration K1	0	
025	OpMode BkP	Operations Mode Backing Pump	0 = Non Stop	
026	OpMode TMP	Operations Mode TMP	0	
027	Gas Mode	Gas Mode	0	
028	OpMode Rem	Remote Operations Mode	0 = Standard	
030	Vent Mode	Venting Mode	1 = Do Not Vent	
031	HiFlowCtrl	Hi Flow Control	0 = OFF	
Set Values				
700	TMP RUTime	Maximum Run Up Time in Mins	45	
701	Switch pnt	Rotation Speed Switchpoint	80%	
703	HVVthrshld	High Vacuum Pressure Switchpoint	1E-1	
704	TMSheatset	TMS heating temp set value	40	
707	TMProt set	Rotation speed set value	50%	
710	BKP off	Pmin for interval backing pump ops.	0	
711	BKP on	Pmax for interval backing pump ops.	0	
717	Stdbyrotset	Preset rotation speed at standby	66.7%	
720	Vent Freq.	Venting Frequency	50%	
721	Vent time	Venting time in seconds	3600	
738	Gaugetype	Vacuum pressure gauge type	TPR250	
794	Param Set	Parameter Set	1 = extended	
795	Servicelin	Contains the service line	309	
797	Address	Unit Address	1	

3.5.	Set parameter to 340 to view Pirani pressure (use ◀ ▶ buttons on TCM1601 to adjust)
3.6.	If all parameters are correct start pumping system by pressing ⓘ. Record the time at start of pumpdown. If an error occurs the gate valve will shut and the pumps will stop. Press the acknowledge button If error persists investigate fault and abort the procedure.
3.9.	Record time when pressure reaches 1mbar.
3.10	Record time and pressure when turbo pump reaches full speed (=600Hz).
3.11	Monitor pump down and leave to pump down.

3.12	When pressure reaches 10^{-6} mbar open the gate valve.
4.	**Warm up Liquid Nitrogen Vessel**
4.1.	Connect supply of Nitrogen gas to N2 fill port and blow out N2 through vent
4.2.	Monitor the level nitrogen level sensors and vacuum pressure during warm up. Continue to heat the SPIRE interface temperatures to ensure that SPIRE temperatures remain above the temperature of the N2 shroud.
4.3.	When all liquid nitrogen has been removed allow the nitrogen vessel to warm up.
4.4.	When the instrument temperatures are at 270K switch off heaters.
4.5.	When all temperatures in the cryostat are > 290K it is safe to let up to atmospheric pressure.