**Commissioning of LCLS II Cryoplant Systems**

It is important that the commissioning staff is completely familiar with the operating and maintenance manuals and the operating procedures provided for the system to be commissioned before the start of the commissioning. Any differences in the presented procedures should be discussed with a Jlab engineer and resolved before the start of the commissioning of any equipment.

**The following are required before the start of commissioning:**

1. ODH classification, activated and operating ODH detection and alarms for the areas
2. Activated and operating fire protection detection and alarms for the areas
3. Emergency evacuation procedures for the areas
4. LN2 contract/requisition (specifications)
5. GHe contract/requisition (specifications)
6. Gas purity analyzers, like calibrated Arc cells and Parametric H2O analyzer, activated and calibrated
7. Cold traps with vacuum pumps for pump and backfills
8. Calibration equipment
9. Sensors operationally checked and calibration verified
10. Leak detectors

**Pre Commissioning Checks:**

1. **General Equipment and Piping Installation Verification (PCK1):**

It is required to verify the proper installation of the systems by checking the following certifications **before** the beginning of the commissioning process.

1. Cleanliness Certification verification
2. Pressure Test Certification verification
3. Leak Check Certification verification
4. Safety Check verification
5. QA Dept. Check verification
6. Safety Dept. Check verification

NOTE: These six (6) certifications are required for each system to be commissioned. Therefore commission of any system should not proceed without these six (6) pre commissioning certifications.

1. **Equipment Specific Installation Verification (PCK2):**

For each system to be commissioned, the following equipment specific checks should be conducted **before** the start of the commissioning process.

System/ Equipment Manufacturers Checks:

Make sure all the manufacturers installation and pre startup requirements are verified and checked as specified in the system/ equipment manuals.

System Installation Check, by verifying:

1. Job Hazard Analysis is performed including lock and tag requirements.
2. Proper Power and safety trips and disconnects are in place (Verify voltages, fuse sizes, breaker set points etc.)
3. All the piping is connected properly
4. The vent and drain lines are connected
5. All the instrumentation and controls are connected and verified
6. All the Instruments are calibration checked
7. All automatic valves (pneumatic and electric) are checked for functionality, seating and valve travel (stroke)
8. The system is pumped, purged and if required cold trapped for cleanliness
9. If required, oil levels are checked in the system
10. **Equipment Specific Controls Checks (PCK3):**

For each system to be commissioned, the following applicable equipment specific controls checks should be conducted before and during the commissioning process.

1. System safety shutdowns check
2. System emergency shutdown check
3. System interlocks
4. System local operation
5. System remote operation
6. Restart after a power outage/upset conditions shutdown
7. Control loop tuning as required

**Commissioning:**

The commissioning of the systems will be described in phases, consistent with the planned commissioning order of the equipment. The phases I through VI represent the commissioning of the refrigeration equipment.

## System Readiness Reviews

One month before the starting of each commissioning phase the pre commissioning requirements documents, detailed step by step commissioning plans and when applicable test plans will be submitted to an internal Readiness Review committee for assessment.

**Phase I - Basic Utilities:**

1. **Power:**
2. Check the Power is connected to all the required equipment and all the devices to be commissioned
3. Make sure the breakers have proper rated fuses and trip set points
4. **Water:**
5. Make sure the cooling tower and the water lines have been verified for all the pre commissioning requirements (as given above). They are:
	* + 1. General Equipment and Piping Installation Verification (PCK1)
			2. Equipment Specific Installation Verification (PCK2)
			3. Equipment Specific controls Checks (PCK3)
6. Verify the water lines are connected to all the required equipment to be commissioned and keep the supply and return valves closed on the all equipment.
7. Make sure the water is treated and has the proper additives (check the chemistry). Make sure the piping and water are clean.
8. Circulate water through the by pass valves provided at different locations on the water line system, before opening to the loads.
9. Start opening one load at a time and check each system for cleanliness, leaks and proper circulation.
10. Make sure the required flow rate and the supply pressure are available from the cooling tower system.
11. **Instrument Air:**
12. Make sure the Instrument Air compressor system installation has been verified for all the pre commissioning requirements (as given above). They are:
* General Equipment and Piping Installation Verification (PCK1)
* Equipment Specific Installation Verification (PCK2)
1. Operate the instrument air compressor and perform the
* Equipment Specific controls Checks (PCK3)
1. Verify the dryer operation
2. Check the filters
3. Set the controls on the Air compressor system to maintain the air pressure in the air receiver tank at 90 psig.
4. Verify the operation of the instrument air supply by adjusting the pressure levels of the primary compressor and the backup utility air supply system.

**Phase II - System Utilities:**

* + 1. **Nitrogen System** (JLab. Dwg. NO.79720-2001)

# LN2 Dewar:

**Commissioning Preparation:**

Make sure the LN2 Dewar including the connecting piping installation has been verified for all the pre commissioning requirements (as given above). They are:

* General Equipment and Piping Installation Verification (PCK1)
* Equipment Specific Installation Verification (PCK2)

**Initial Commissioning:**

1. Leave Dewar and all the sections of piping under dry nitrogen gas purge for a day. Make sure there is GN2 flow through all the branches by balancing the valves.
2. Use the vacuum pump cart and cold trap and evacuate and purify the process side of the Dewar and piping. This may take a few cold trap changes and GN2 back fills to reach the final purity and the ultimate pressure below a micron range. Record the vacuum level attained in the dewar.
3. Use the vacuum pump cart and cold trap and evacuate and purify the vacuum jacket of the Vessel. The insulation space should be re-evacuated any time the pressure gets “too high”. (In general, 150 microns / 2 X 10-1 mbar in a cold vessel is enough to suggest re-evacuating). Evacuation of Perlite tank insulation is normally done with a mechanical vacuum pump. The pump should be equipped to prevent backflow of pump in case of power failure and with a cold trap to remove water vapor. (For re-evacuating a cold tank, a compound pump of 20 to 30 cfm capacity is required). For a warm tank, where pressures are likely to be higher and gas volumes are likely to be larger, a compound pump (up to100 cfm) is more suitable. Connect the pump to the tank evacuation valve, start the pump and evacuate the line; then slowly open the tank-evacuating valve. It is desirable to have a vacuum gauge at the pump, and to check that the pump and line blank-off is as low as they should be, (usually below 10 microns) before opening tank valve. The vacuum gauge can be used while pumping to get an idea of progress. Sometimes there is an appreciable gradient within a tank insulation space while pumping: when the pumping is stopped, pressures equalize and pressure at the tube may increase. Therefore, when evacuation appears complete, close the evacuating valve, wait 10 minutes, and reread the gauge. If there is no change, evacuation is complete. The tank should be evacuated to 50 microns / 6.6 X 10-2 mbar or less. Record the vacuum level attained in the dewar insulating vacuum.

# LN2 Transfer Line:

**Commissioning Preparation:**

Make sure the LN2 piping installation has been verified for all the pre- commissioning requirements (as given above). They are:

* General Equipment and Piping Installation Verification (PCK1)
* Equipment Specific Installation Verification (PCK2)

**Initial Commissioning:**

1. Leave all the sections of piping under dry nitrogen gas purge for a day. Make sure there is GN2 flow through all the branches by balancing the valves and the bayonets.
2. Use the vacuum pump cart and cold trap and evacuate and purify the process side piping. This may take a few cold trap changes and GN2 back fills to reach the final purity and the ultimate pressure below a micron / 1.3 X 10-3 mbar range. Record the vacuum level attained in the process side of the piping.
3. Use the vacuum pump cart and cold trap and evacuate and purify the vacuum jacket side piping. This may take a few cold trap changes and GN2 back fills to reach the final purity and the ultimate pressure below a micron/ 1.3 X 10-3 mbar range.
4. Record the vacuum level attained in the vacuum-jacket insulating vacuum.

**LN2 Dewar Cool down:**

After all the LN2 / GN2 piping is connected and all the commissioning checks as stated above are performed, the LN2 Dewar is ready for cool down.

Follow the Dewar manufacturer’s manual for cool down. The heat to be removed for cool down is ~500MJ from the 6000 kg of the inner vessel. It may take up to 600 gal of LN2 for cool down, before LN2 starts accumulating in the dewar. Connect an LN2 dewar to the supply line and slowly open (may be 20%) the bottom fill valve. Vent the GN2 from the top of the tank by maintaining a positive pressure of more than 5 PSIG in the Dewar. Record the vacuum level in the dewar insulating vacuum before and after cool down.

**Initial Fill:**

1. Connect hose to transport and remove cap from tank Fill Connection
2. See that transport has some pressure and open appropriate transport valves for a few seconds to blow some product gas through the hose to remove any foreign matter that might be in it.
3. Connect hose to Fill Connection
4. Again, open transport valves to pressurize the hose and check for leaks.
5. Disconnect gauge lines from contents gauge (LI88X02) and open line shut-off valves.
6. Open Bottom Fill valve (MV88X01) and Vent valve (MV88X10), maintaining a positive pressure of more than 5 PSIG in the Dewar
7. As vapor flows freely from both gauge lines, close valves and reconnect contents gauge (LI88X02).
8. Start transferring liquid at a low rate by pressure difference only. The cool down should be done very slowly and it may take ~24hrs to reach 80K, before the LN2 starts accumulating in the dewar. The LN2 supply should be adjusted to the order of 20 g/s or 2000 SCFH.
9. Be sure contents gauge by-pass valve (MV88X02C) and Pressure Build manual valve (MV88X05) are closed.
10. Watch tank gauges. If contents gauge oscillates violently, partially close liquid valve and gas valve. If necessary, close liquid valve and open by-pass valve to shut off gauge.
11. If contents gauge has been shut off, periodically try it to see if it can sensibly be left in operation and to get an idea of the liquid level.
12. When the tank is approximately 1/4 full, try closing Vent valve.
13. When tank pressure gets high enough – say about 10 psi above desired operating pressure **TBD** – open Top Fill valve and close Bottom Fill valve.
14. If pressure rises too high with only the Top Fill open and Bottom Fill closed, open Vent enough to hold desired pressure.
15. When tank is approximately 3/4 full, open Full Tri-cock (MV88X04).
16. When liquid flows out of Full Tri-cock, stop pump and close Top and Bottom Fill, Vent and Full Tri-cock valves.
17. Close transport valves and drain hose. (Even though hose pressure has been released, be careful when hose is disconnected – sometimes liquid stays in the hose for an amazingly long time.)
18. Watch tank pressure – it will tend to rise quite rapidly in a vessel, which has just been filled for the first time.
19. Be sure the gauge shut-off valves are open and the contents gauge by-pass is closed.

#### Setting Regulators

Regulator – “Pressure Build”– set the operating pressure of 50 Psig

With the regulators set, the vessel is ready to go into service.

Be sure manual valves are as listed below:

* + Vacuum valve (MV88X09) ................................. Closed tight and sealed
	+ Vacuum Gauge shut off (MV88X08) ..................... Closed
	+ Full Tri-cock (MV88X04) ................................. Closed
	+ Liquid Withdrawal valve (MV88X15) .......……….. Open
	+ Bottom Fill (MV88X01) ............................................. Closed
	+ Top Fill (MV88X02) ............................................. Closed
	+ Contents Gage Liquid and Vapor (MV88X02A & B).. Open, at least partially
	+ Contents Gage By-Pass (MV88X02c) ..................... Closed
	+ Vent valve (MV88X10)...................................……….. Closed
	+ Vapor shut-off valve (MV88X07) ..................... Open
	+ Pressure Build manual valve (MV88X05)...............…. Open
	+ Hose Drain valve (MV88X03) ................................…. Closed

#### Re-filling procedure

* + 1. Connect hose, purge hose, and check for leaks as under "Initial Fill."
		2. Start filling through Bottom Fill valve, using transfer pump on transport.
		3. Watch tank pressure. When it starts to rise, start opening Top Fill and closing Bottom Fill valves until pressure is steady at desired tank operating pressure.
		4. Increase pumping speed if so desired.
		5. Open both Top Fill and Bottom Fill valves gradually until one is wide open and pressure is steady.
		6. Watch contents gauge – when it shows about 90% full, open Full Tri-cock valve.
		7. When liquid comes out of the Full Tri-cock, stop pumping. Close Bottom Fill, Top Fill, and Full Tri-cock valves. Close appropriate valves on transport and bleed pressure from hose.
		8. Disconnect hose and cap connections.

**Dewar Boil-off Test:**

After cool down and fill of the dewar, allow for thermal stabilization (a week) and measure the boil off. Compare the boil off to the specified maximum allowable heat leak equivalent provided by manufacturer.

**Commissioning Preparation:**

1. Make sure the Vacuum Skid installation has been verified for all the pre commissioning requirements (as given above). They are:
* General Equipment and Piping Installation Verification (PCK1)
* Equipment Specific Installation Verification (PCK2)
1. Operate each vacuum pump and perform the
* Equipment Specific controls Checks (PCK3)

**Helium Gas Storage:** (JLab. Dwg. NO.79720-0000)

**Commissioning Preparation:**

Make sure the Helium Gas storage System installation has been verified for all the pre commissioning requirements (as given above). They are:

* General Equipment and Piping Installation Verification (PCK1)
* Equipment Specific Installation Verification (PCK2)

**Initial Commissioning:**

Use the vacuum pump cart and cold trap and evacuate and purify the process side of the helium gas storage tanks and piping. This may take several cold trap changes and helium back fills to reach the final purity including moisture removal and the ultimate pressure below ten-micron range. Record the vacuum level attained in the tanks.

As a minimum the dirty line, purifier discharge line and one gas storage tank (of the eight) should be commissioned at this stage.

**Phase III - Helium Recovery System:** (JLab. Dwg. NO. 79520-0000):

# Recovery Compressor: (JLab. Dwg. NO.79520-0002):

**Commissioning Preparation:**

1. Make sure the Recovery Compressor skid installation has been verified for all the pre commissioning requirements (as given above). They are:
* General Equipment and Piping Installation Verification (PCK1)
* Equipment Specific Installation Verification (PCK2)
1. Make sure the Recovery Compressor gas management skid installation has been verified for all the pre commissioning requirements as well.
2. Make sure the Recovery Compressor, its gas management are connected to the helium gas storage and the installation has been verified for all the pre commissioning requirements as well.

**Initial Commissioning:**

**A temporary Recovery Compressor system will be used in the initial phase of commissioning and testing of the Cryogenic Systems.**

 R.S. Helium Compressor Module is 1215SE1668KOEMBJ0C

The unit consists of a Dunham-Bush 279 CFM displacement 150 hp screw compressor, an oil cooler, helium after cooler, mist separator, adsorber, various safety and alarm devices and instrumentation. All of these components are skid mounted and enclosed in a cabinet, which has a control panel containing controls, and instrumentation required for unattended operation and for monitoring system performance.

Refer to the Technical Manual for Installation, Operation and Maintenance

What follows is an extract from the Manual.

Utility requirements:

Compressor motor: 460V, 3phase, 60Hz power. 112 KW nominal consumption

Instrument Console: 115V, 60Hz for operation of controls and indicators

Cooling Water: 20 gal/min at 75F or less and 30psig DP.

Skid (approx.3200 lbs) must be installed level and properly supported to prevent excessive vibrations.

Evacuating and purging the Unit and the associated piping, in case of exposure to air or moisture

Piping must be leak tight and evacuated to 100 microns or better.

Compressor must be evacuated to less than 300 microns by pumping from the charging and evacuating fitting.

Maintain vacuum for a minimum of 12 hours

Valve off vacuum and pressurize system with helium

Compressor can be charged to 150psig using the evacuation and charge fitting

Start the compressor and perform “manual” operation in accordance with the procedures that will follow. Operate the slide valve “LOAD/UNLOAD” pushbutton and “throttle” the suction valve as necessary, to establish the supply pressure at **TBD** and the return pressure at **TBD**. Add or bleed gas (makeup gas) as necessary.

Check oil level and rotation

Operate the compressor for ½ -hour

Stop the compressor and blow down the gas through the vent valve in the by-pass manifold.

Repeat 4 times

## System Operation

## Status

Recovery System has being interconnected and it is at positive pressure **TBD**

The inline manual valves in the helium piping and water piping are open

The electrical power control box main switch is on the “OFF” position

Prior to first time operation, the proper motor rotation needs to be verified using a phase analyzer to prevent damage to the compressor from reverse rotation.

# Manual Operation

1. Position the electrical power control box main switch to the “ON” position. All control console indicator lights (except motor overload) will illuminate.
2. Reset the pushbuttons on control console. All indicator lights will extinguish.
3. Press the “START” push button on the compressor control console to “START” position. Unit will operate, all indicator lights should remain extinguished, if any indicator light is illuminated the unit will stop automatically. Refer to the manual for trouble shooting procedures
4. Check suction pressure and discharge pressure indicators readings. IMMEDIATELY SHUT DOWN COMPRESSOR IF RETURN PRESSURE IS GREATER THAN SUPPLY PRESSURE; CHECK FOR PROPER PHASING OF CONNECTIONS TO COMPRESSOR.
5. Observe the discharge pressure gauge on the control panel. The pressure should be 240-250 psig during automatic operation.
6. Press the “MANUAL” pushbutton on the slide valve control “MANUAL/AUTO” load switch. Compressor ready for manual operation.
7. Depending upon system requirements press either the “LOAD” or “UNLOAD” pushbutton on the slide valve load switch. In the manual position the slide valve will vary output from 30-100 % of capacity. Pushbutton must be held depressed until the desired slide valve movement is achieved. When pushbutton is released slide valve movement will stop. The corresponding light will illuminate while pressing the pushbutton.
8. Observe the suction and discharge pressure indicators for desired system requirements. Release pushbutton after obtaining desired readings.
9. Operate the recovery compressor locally with helium from gas storage tank and using the gas management bypass valve and operate at 1.1 atm suction pressure and 13 atm discharge pressure at 50% load on the slide valve (bleed the gas out of the system if the pressure raises above 14 atm) and perform the Equipment Specific controls Checks (PCK3)
10. To shut down compressor:
* Press “STOP” pushbutton on compressor console
* Position the electrical power control box main switch to the “OFF” position

## Automatic Operation

1. Perform the “Manual Operation” procedures steps 1) through 5) above.
2. Press the “AUTO” pushbutton on the slide valve control “MANUAL/AUTO” load switch.
3. Observe the discharge pressure gauge on the control panel. The pressure should be 240-250 psig during automatic operation.
4. To shut down compressor
* Press “STOP” pushbutton on compressor console
* Position the electrical power control box main switch to the “OFF” position

# Helium Purifier System: (JLab. Dwg. NO. 79520-0001, AET DWG No. 5872-1\_REV6)

**Commissioning Preparation:**

1. Make sure the Purifier skid installation has been verified for all the pre commissioning requirements (as given above). They are:
* General Equipment and Piping Installation Verification (PCK1)
* Equipment Specific Installation Verification (PCK2)
1. Make sure the Purifier skid is connected to the Recovery Compressor and the helium gas storage and the installation has been verified for all the pre commissioning requirements as well.
2. Fill the beds in the cold box with adsorbent (make sure the adsorbent is filled with a funnel and the funnel has a side connection connected to a vacuum system to extract all the fines from the adsorbent) to the top of the bed and half way in the fill pipe.
3. Fill the beds outside with mol sieve (make sure the adsorber is filled with a funnel and the funnel has a side connection connected to a vacuum system to extract all the fines from the mol sieve) to the top of the bed and half way in the fill pipe.
4. Secure the beds and check for leaks.

**Initial Commissioning:**

1. Leave all the four beds under dry nitrogen gas purge for a week.
2. Use the purifier regen procedure given in the operations section; with the following changes

**Note:** For the initial regen

* + Set Mol Seve Bed (Mols 731) temperature control to 450K
	+ Set ADS Bed (ADS 731) temperature control to 380K

First time regeneration takes many more times of cold traps change than the normal regen operation (may take more than two weeks of heating and vacuum pumping)

**Purifier regeneration procedure:**

Regeneration of Purifier-2 (**All Valve operations need to be very slow**) will be performed as per vendor provided procedures.

The valves and the Instruments for Purifier-2 have the tag numbers as **7XX2X**

1. De-pressurize the beds very slowly by opening MV73243 until the process side (helium side) reaches 3 atm (30 psig) on PT73221
2. LN2 / GN2 Circuits
	1. Shut LN2 supply PV73262
	2. Drain LN2
	3. Start the GN2 flow by opening MV73296 and MV73272
3. Isolate Mol Seve (Dryer) and the Silica (80K) beds
	1. Open MV73256 to control the Mol Seve Bed (MOLS 732) pressure at 30 Psig
	2. Open MV73258 to control the Silica Bed (SIL 732) pressure at 30 Psig
	3. Isolate Mol Seve (Dryer) and the Carbon (80K) beds by closing MV73221
4. Heating of Mol Seve (Dryer) and the Silica Bed (SIL 732)
	1. Activate the heater HTR73212 for the Mol Seve Bed (MOLS 732)
	2. Activate the heater HTR73224 with GN2 flow for the Silica Bed (SIL 732)
	3. Leave the heaters on until
		* 1. Mol Seve Bed (MOLS 732) reaches 425K
			2. Carbon Bed (SIL 732) reaches 325K
			3. Continue to maintain the temperatures for at least 8 hrs at the set temperatures
			4. This may take 2 days
5. Vacuum Pumping
	1. Mol Seve Bed (MOLS 732):
		* 1. Open MV73255 to vent the Mol Seve Bed (MOLS 732) pressure to 0 Psig on PT73211
			2. Close MV73255 and MV73256
			3. Make sure the LN2 cold trap is clean and LN2 is on for the Vac. Pump cart cold trap
			4. Open to Vacuum Pump By slowly opening MV73291
	2. Silica Bed (SIL 732)
		* 1. Open MV73257 to vent the Carbon Bed (SIL 732) pressure to 0 Psig on PT73221
			2. Close MV73258 and MV73257
			3. Make sure the LN2 cold trap is clean and LN2 is on for the Vac. Pump cart cold trap
			4. Open to Vacuum Pump By slowly opening MV73292
	3. Pump the beds for one day
		* 1. Isolate the GN2 flow by closing MV73296
			2. Isolate the pump and note the pressure of the bed at the vacuum pump cart
			3. Clean the traps
			4. Back fill both the beds with helium to 1 atm by opening MV73241 and the opening the Isolation valve MV73221 between the beds
	4. Pump the beds for the second day
		* 1. Isolate the pump and note the pressure of the bed at the vacuum pump cart
			2. Clean the traps
			3. Back fill both the beds with helium to 1 atm by opening MV73241 and the opening the Isolation valve MV73221 between the beds
	5. Repeat above step, pumping of the beds until the bed pressure at the Vac Pump carts are below 50 microns with the pumps isolated and the rate of rise of pressure is less than say **TBD** microns/hour (rate {eg: 10 microns/hour} to be established in the field)

If the bed pressure is below 50 microns and the rate of rise of pressure If is less than **TBD** microns/hour, the bed cleanup process is complete

**Note:** If the bed pressure is not below 50 microns after three pump and back fills look for valve leaks by closing the additional valves

* 1. Isolate the beds from the Vacuum pump carts.

Close MV73291 for Mol Seve Bed (MOLS 732)

Close MV73292 for Silica Bed (SIL 732)

* 1. Back fill the beds with helium by opening MV73241 and the Isolation valve MV73221 between the beds to approximately 1.5atm pressure
	2. Establish the helium circulation through the beds by opening MV73241 and through MV73242 at approximately 1g/s
1. Cooling the Beds:
	1. Establish the helium circulation of approximately 1g/s through the beds for at least one hour before turning on LN2
	2. Turn on the LN2 by switching on the controller for the PV73262
	3. Leave it on the circulation for at least 24hours

**Now the Purifier-2 is regenerated and available for use**

**The Process can be repeated for the regeneration of Purifier-1**

The valves and the Instruments for Purifier-1 have the tag numbers as **7XX1X** as compared to Purifier-2, which has the tag numbers as **7XX2X**

**Helium Gas Storage and Distribution: (**JLab. Dwg. NO. 79720-000 & 79120-0010)

After the purifier is commissioned, complete the commissioning of the helium gas storage and the associated piping.

1. Dwg. No. 79120-0010: CMV11011, CMV11015, CMV11021, CMV11025, CMV11041, CMV11042, CMV11043, CMV11045, CMV11046 AND CMV11047 are closed.
2. Use the vacuum pump cart and cold trap and evacuate and purify the process side of the helium gas storage tanks and piping. This may take a few cold trap changes and helium back fills (up to 5 back fills and evacuations) to reach the final purity of 40 to 50 ppm N2 and the ultimate pressure below ten-micron range. Record the vacuum level attained in the tanks.
3. Start circulating He gas from/to recovery purifier system through 1st tank only
4. Monitor impurity level with arc cells
5. Switch purifier and regenerate when necessary
6. <5ppm N2 and <1 ppm of moisture is the goal purity level, when reached, isolate tank and proceed to the next one until all system is clean

**Phase IV - Compressor System:** (JLab. Dwg. NO. 79120-0002)

**Final Oil Removal:** (JLab. Dwg. NO. 79120-0006)

**Commissioning Preparation:**

1. Make sure the Compressor Oil Removal system installation has been verified for all the pre commissioning requirements (as given above). They are:
* General Equipment and Piping Installation Verification (PCK1)
* Equipment Specific Installation Verification (PCK2)
1. Make sure the oil removal system is connected to the compressor system, gas management, Oil management, Helium gas storage and to the cold box piping and the installation has been verified for all the pre commissioning requirements as well.
2. Fill the bed with carbon (make sure the charcoal is filled with a funnel and the funnel has a side connection connected to a vacuum system to extract all the fines from the charcoal) to the top of the bed.
3. Install and secure the inlet filter.
4. Secure the bed and check for leaks.

**Initial Commissioning:**

1. Leave all the four vessels under dry nitrogen gas purge for a week.
2. Isolate Carbon Adsorber: MV21064, MV21066 closed. Pump and back fill with GN2 with heater set to control on T=380K. This process will take three to four weeks to remove all the moisture from the charcoal.

**CHL Main Compressor System:** (JLab. Dwg. NO. 79120-0002)

**Commissioning Preparation:**

Each Main compressor skid includes the main motor, compressor with slide valve, oil pump and motor, oil manifolds, oil separators, oil cooler, after cooler, heaters, valves, and instruments required for operation of the skid. The Main Compressor Diagrams are shown on drawings 79120-0003 (LP Stage), 79120-0004 (MP Stage) and 79120-0005 (HP Stage).

1. Make sure the compressor system installation has been verified for all the pre commissioning requirements (as given above). They are:
* General Equipment and Piping Installation Verification (PCK1)
* Equipment Specific Installation Verification (PCK2)

**Initial Commissioning:**

1. Isolated each stage by closing suction and discharge manual valves
2. Leave each stage of the compressor system under dry nitrogen gas purge for a week making sure of no hidden volumes.
3. All automatic valves (pneumatic and electric) are checked for functionality, seating and valve travel (stroke) including the compressor gas management control valves
4. Check the control valve operation
5. Check the compressor oil system
6. Pressurize system with Helium (~1Atm) and evacuate approx. 5 times (we expect ~50ppm of N2 at this point)
7. Circulate Helium gas from/to purifier with recovery system through each single stage, all the associated piping and bypass lines, one at a time.
8. Monitor impurity level with arc cells. Switch purifier and regenerate when necessary. <5ppm N and <1ppm moisture is the goal purity, when reached, isolate stage and proceed to the next one until all system is clean
9. **Charge the stage with required amount of oil**
10. Check motor rotation
11. Install the motor to compressor coupling and check motor alignment. A PHPK representative will verify proper alignment of the couplings
12. Run the compressor locally at partial load on the slide valve and using the bypass valve on the compressor gas management valve
13. Check the oil injection system
14. Start the compressor from remote control system
15. Check the compressor loading
16. Stop the compressor from remote control system
17. Operate each compressor and perform the
	* Equipment Specific controls Checks (PCK3)

## Compressor Performance Testing:

PHPK representative will overview the 168 hours (7 days) endurance/test run at the design condition followed by 24 hours performance test. For each compressor the performance will be measured and evaluated at the design point.

**Phase V - CHL 4.5K Cold Box System:**

**Vacuum System:** (JLab. Dwg. NO.)

This system has three vacuum pumps.

Vac. Pump-1: Is designated for supporting guard vac. for all systems

Vac. Pump-2: Is the stand by spare

Vac. Pump-3: Is designated for supporting 2.1K shell vacuum

# LHe Dewar: (JLab. Dwg. NO. 79720-0001)

**Commissioning Preparation:**

Make sure the Helium Dewar including the connecting piping installation has been verified for all the pre commissioning requirements (as given above). They are:

* General Equipment and Piping Installation Verification (PCK1)
* Equipment Specific Installation Verification (PCK2)

**Initial Commissioning:**

1. Leave Dewar and all the sections of piping under dry nitrogen gas purge for a day. Make sure there is GN2 flow through all the branches by balancing the valves.
2. Use the vacuum pump cart and cold trap and evacuate and purify the process side of the Dewar and piping. This may take a few cold trap changes and helium back fills to reach the final purity and the ultimate pressure below ten-micron range. Record the vacuum level attained in the dewar. Circulate Helium gas from/to purifier with recovery system through the dewar and all branches of piping and monitor impurity level with arc cells. Switch purifier and regenerate when necessary. <5ppm N and <1ppm moisture is the goal purity, when reached, isolate the dewar.
3. Use the vacuum pump cart and cold trap and evacuate and purify the vacuum jacket of the Vessel. Check the rate of raise of pressure in the vacuum space for one week. If there is no appreciable pressure raise for this period, record the vacuum level attained in the dewar insulating vacuum.

# Dewar Cool down:

After all the piping is connected and all the commissioning checks as stated above are performed, the LHe Dewar is ready for cool down. Follow the Dewar manufacturer’s manual for cool down. If it is not available, connect the LHe dewar to the 4.5K cold box 3 atm 4.5K supply line and slowly open (may be 20%) the valve. Return the GHe from the dewar shield return line of the dewar (and/or the load balance line) to the compressors by maintaining a positive pressure of more than 5 PSIG in the Dewar. The cool down should be done very slowly over more than 12 hrs, before the LHe starts accumulating in the dewar. Record the vacuum level in the dewar insulating vacuum before and after cool down. Check the functionality of all the associated valves, instruments and heaters.

# Dewar Boil-off Test:

After cool down and fill of the dewar, allow for thermal stabilization (a week) and measure the boil off. Compare the boil off to the specified maximum allowable heat leak equivalent provided by manufacturer.

**CHL MAIN COLD BOX (MCB)** (JLab. Dwg. NO. 79221-0002)

The 4.5 K cold box system includes the turbine expanders, valves, heat exchangers, instruments and control devices provided by the cold box vendor ALATUS. The vendor package for the cold box includes dedicated interlocks and trips required for safety and machine protection. The 4.5 K cold box PLC performs all the control algorithms including turbines. The details are listed in the control philosophy provided by ALATUS.

**Commissioning Preparation:**

Make sure the cold box including the connecting piping installation has been verified for all the pre commissioning requirements (as given above). They are:

* General Equipment and Piping Installation Verification (PCK1)
* Equipment Specific Installation Verification (PCK2)

**Initial Commissioning:**

1. If required, use the vacuum pump cart and cold trap and evacuate and purify the vacuum jacket of the cold box. This may take a few cold trap changes and GN2 back fills to reach the final purity and the ultimate pressure below a micron range. Start the diffusion pump and pump down the vacuum space to below 1.0 e-05 torr.
2. Purify all the process side of the nitrogen piping with a minimum of 5 pump and backfills of GN2
3. Purify all the process side of the helium piping (all the helium passes) with a minimum of 5 pump and backfills of helium. Circulate He gas from/to purifier with recovery system through the each pass of the cold box and monitor impurity level with arc cells. Make sure there are no dead sections in the circuits with contamination trapped in the system. Do not allow the turbines to rotate. The turbine loops need to be purified with slow pump and back fills with out rotating the turbines. Switch purifier and regenerate when necessary. <5ppm N2 is the goal purity, when reached, switch to the other passes.
4. Cold box manufacturer will load the turbine cartridges and complete the remaining commissioning of the cold box
5. Keep all the turbine inlet valves closed. Very slowly establish the helium pressures in LP, MP and HP circuits. Set gas management mass in valve to control the high-pressure max to about 13 atm. Follow the procedure in control philosophy provided by ALATUS about connection and pressurization. **Maintain caution** not to open these interfacing valves fully all of a sudden and drop the HP (high stage pressure) below 12 atm. If the pressure drops below 12 atm., it can result in damaging the compressor oil removal coalescers and charcoal beds at different locations in the system due to larger sudden differential pressure across the oil removal system. If dewar is also part of the system, circulate the helium through the dewar also to purify the dewar as well. Circulate the helium for at least one hour at these pressure conditions in all the three circuits. Make sure the system is operating stably at these conditions. Check the purity of helium in each circuit. If the N2 and moisture content are above 2 ppm, stop. Repeat purification of cold box and the main compressors with a combination of pump and back fills and circulation of helium using the purifier system.
6. After all the circuits in the cold box and compressor system are pure and helium circulated for at least one hour, follows the cool down procedure of cold box with or without Dewar as per control philosophy provided by ALATUS.

# 4.5K Cold box Cool down:

The cold box manufacturer will perform the initial cool down. The control loops for performing this operation are given in the cold box process flow diagram and control philosophy.

The cold box operation and controls will be checked for equipment Specific controls Checks (PCK3), before the start of any operations and testing.

# 4.5K Cold box Tests:

The initial tests given in the testing section will be performed under the supervision of the cold box manufacturer, ALATUS. ALATUS representatives will test the plant to verify the following performance design specifications as per ALATUS acceptance procedure:

|  |  |  |  |
| --- | --- | --- | --- |
|  Mode-1: Max. Capacity | Supply | Return |   |
|   | w [g/s] | P(atm] | T (K] | P(atm] | T (K] | q [kW] |
|   |   |   | Compressor |   |   |   |
| LP | 729.5 | 1.05 | 306.1 | 6.15 |   |   |
| MP | 579.4 | 2.35 | 306.3 | 6.15 |   |   |
| HP | 1318.9 | 6 | 310 | **19.0** |   |   |
|  |  |  | LN2 Supply |  |  |  |
| LN2 Supply | 104 | 4 | 91.41 |   |   |   |
|   |   |   | Load |   |   |   |
| Warm Shield | 145.5 | 3.56 | 35 | 2.56 | 55 | **15.2** |
| Cold Shield | 40.59 | 3.0 | 5.43 | 1.277 | 7.5 | 1.3 |
| 4-K Refrigeration |   |   |   |   |   |   |
| 4-K Liquefaction | 15 | 3.2 | 4.55 | 1.10 | 300 | 23.4 |
| Sub-Atmospheric | 200 | 3.2 | 4.55 | 1.236 | 30 | **31.8** |

NOTE:

Dewar heater power = 3.816 (Sub-atmo.) + 0.286 (liquefaction) = 4.102 kW

Sub-atmos. Test heater = 28.069 kW

|  |  |  |  |
| --- | --- | --- | --- |
|  Mode-2: Nominal | Supply | Return |   |
|   | w [g/s] | P(atm] | T (K] | P(atm] | T (K] | q [kW] |
|   |   |   | Compressor |   |   |   |
| LP | 768.1 | 1.05 | 306.1 | 4.74 |   |   |
| MP | 283.1 | 1.17 | 306.1 | 4.74 |   |   |
| HP | 1011.1 | 4.59 | 310 | 14.85 |   |   |
|  |  |  | LN2 Supply |  |  |  |
| LN2 Supply | 51.5 | 4 | 91.41 |   |   |   |
|   |   |   | Load |   |   |   |
| Warm Shield | 112.3 | 3.5 | 37.5 | 2.5 | 55 | 10.1 |
| Cold Shield | 28.9 | 3.0 | 5.55 | 1.234 | 7.8 | 0.9 |
| 4-K Refrigeration |   |   |   |   |   |   |
| 4-K Liquefaction |  |  |  |  |  |  |
| Sub-Atmospheric | 157 | 3.2 | 4.55 | 1.2 | 30 | 24.9 |

NOTE:

Dewar heater power = 2.996 (Sub-atmo.) + 0.286 (liquefaction) = 3.282 kW

Sub-atmos. Test heater = 22.034 kW

|  |  |  |  |
| --- | --- | --- | --- |
|  Mode-3: Max. Liquefaction | Supply | Return |   |
|   | w [g/s] | P(atm] | T (K] | P(atm] | T (K] | q [kW] |
|   |   |   | Compressor |   |   |   |
| LP | 636.3 | 1.05 | 307.5 | 5.42 |   |   |
| MP | 507.2 | 2.08 | 309.5 | 5.42 |   |   |
| HP | 1153.4 | 5.27 | 310 | **19.11** |   |   |
|  |  |  | LN2 Supply |  |  |  |
| LN2 Supply | **420.5** | 4 | 91.41 |   |   |   |
|   |   |   | Load |   |   |   |
| Warm Shield | 141.4 | 3.3 | 42.8 | 2.3 | 56.5 | 10.1 |
| Cold Shield | 19.9 | 3.2 | 5.7 | 1.23 | **10.8** | 0.9 |
| 4-K Refrigeration |   |   |   |   |   |   |
| 4-K Liquefaction\* | **140** | 3.2 | 4.55 | 1.10 | 300 | 218.6 |
| Sub-Atmospheric |  |  |  |  |  |  |

NOTE:

\* Maximum liquefaction mode should be stopped when ambient air heat exchanger HX21000 is saturated.

Dewar heater power = 0.0 (Sub-atmo.) + 2.671 (liquefaction) = 2.671 kW

Sub-atmos. Test heater = 0.0 kW

|  |  |  |  |
| --- | --- | --- | --- |
|  Mode-4: Max. Refrigeration | Supply | Return |   |
|   | w [g/s] | P(atm] | T (K] | P(atm] | T (K] | q [kW] |
|   |   |   | Compressor |   |   |   |
| LP | 584.0 | 1.05 | 305.7 | 5.08 |   |   |
| MP | 489.1 | 1.99 | 305.7 | 5.08 |   |   |
| HP | 1083.1 | 4.93 | 310 | 17.3 |   |   |
|  |  |  | LN2 Supply |  |  |  |
| LN2 Supply | 55.1 | 4 | 91.41 |   |   |   |
|   |   |   | Load |   |   |   |
| Warm Shield | 145.5 | 3.5 | 35 | 2.5 | 55 | 15.2 |
| Cold Shield | 31.2 | 3.2 | 5.4 | 1.23 | **9.0** | 1.3 |
| 4-K Refrigeration | **487.5** | 3.2 | 4.6 | 1.25 | 4.5 | **9.0\*** |
| 4-K Liquefaction\* |  |  |  |  |  |  |
| Sub-Atmospheric |  |  |  |  |  |  |

NOTE:

\*Refrigeration heater power injection will be shared by the heaters inside Dewar and sub-cooler since Dewar heater capacity is limited to 6 kW.

Dewar heater power = 6.0 kW

Sub-cooler heater power = 3.0 kW

|  |  |  |  |
| --- | --- | --- | --- |
|  Mode-5: Max. Fill | Supply | Return |   |
|   | w [g/s] | P(atm] | T (K] | P(atm] | T (K] | q [kW] |
|   |   |   | Compressor |   |   |   |
| LP | 723.5 | 1.05 | 307.1 | 6.10 |   |   |
| MP | 573.5 | 2.35 | 307.4 | 6.10 |   |   |
| HP | 1307.0 | 5.95 | 310 | **19.45** |   |   |
|  |  |  | LN2 Supply |  |  |  |
| LN2 Supply | 174.1 | 4 | 91.41 |   |   |   |
|   |   |   | Load |   |   |   |
| Warm Shield | **190.5** | 3.7 | 37.4 | 2.7 | 52.7 | 15.2 |
| Cold Shield | 39.5 | 3.2 | 5.5 | 1.27 | 7.8 | 1.3 |
| 4-K Refrigeration |  |  |  |  |  |  |
| 4-K Liquefaction\* | 45 | 3.2 | 4.6 | 1.1 | 300 |  |
| Sub-Atmospheric | 157 | 3.2 | 4.6 | 1.236 | 30 |  |

NOTE:

Dewar heater power = 2.996 (Sub-atmo.) + 0.859 (liquefaction) = 2.671 kW

Sub-atmos. Test heater = 22.034 kW

|  |  |  |  |
| --- | --- | --- | --- |
|  Mode-6: Stand-by | Supply | Return |   |
|   | w [g/s] | P(atm] | T (K] | P(atm] | T (K] | q [kW] |
|   |   |   | Compressor |   |   |   |
| LP | 221.7 | 1.05 | 306.9 | 2.5 |   |   |
| MP | 181.8 | 1.05 | 307.0 | 2.5 |   |   |
| HP | 413.5 | 2.35 | 310 | 12.45 |   |   |
|  |  |  | LN2 Supply |  |  |  |
| LN2 Supply | 16.7 | 4 | 91.41 |   |   |   |
|   |   |   | Load |   |   |   |
| Warm Shield | 85.9 | 3.7 | 32.5 | 2.7 | 55 | 10.1 |
| Cold Shield | 35.7 | 3.0 | 5.68 | 1.23 | 7.5 | 0.9 |
| 4-K Refrigeration | 27.1 | 3.2 | 4.55 | 1.25 | 4.47 | 0.5 |
| 4-K Liquefaction\* |  |  |  |  |  |  |
| Sub-Atmospheric |  |  |  |  |  |  |

Following picture shows the schematic diagram for the 4.5 K cold box testing



**Phase V I - 2.1K COLD BOX (SCB)** (JLab. Dwg. NO. 79222-0000)

The 2.1 K cold box system includes the cold compressors, magnetic bearing controls, frequency controls etc. provided by the cold compressor manufacturer Air-Liquide. The vendor package for the cold compressors includes interlocks required for safety and machine protection.

**Commissioning Preparation:**

Make sure the cold box including the connecting piping installation has been verified for all the pre commissioning requirements (as given above). They are:

* General Equipment and Piping Installation Verification (PCK1)
* Equipment Specific Installation Verification (PCK2)

**Initial Commissioning:**

The cold compressors in the 2.1 K Cold Box provide pumping required to achieve 2.1 K operation in the super-conducting cavities. Jefferson Lab is providing PLC controls for the 2.1 K Cold Box. The speed ratios (gear ratios with respect to Cold Compressor-4) among the 4 compressors will be used as provided by vendor for pump down and for the steady state operation.

1. Cold compressor manufacturer will load the compressor cartridges and complete the remaining commissioning of the cold compressors.
2. Do not supply power to the magnetic bearings, until the cooling water supply is provided for the cold box and the cold compressors.
3. If required, use the vacuum pump cart and cold trap and evacuate and purify the vacuum jacket of the cold box. This may take a few cold trap changes and GN2 back fills to reach the final purity and the ultimate pressure below a micron range. Start the diffusion pump and pump down the vacuum space to below 1.0 e-05 torr.
4. Purify all the process side of the helium piping (all the helium passes) with a minimum of 5 pump and backfills of helium. Circulate He gas from/to purifier with recovery system through the each pass of the cold box and monitor impurity level with arc cells. Make sure there are no dead sections in the circuits with contamination trapped in the system. Do not allow the cold compressors to rotate. The piping loops need to be purified with slow pump and back fills with out rotating the compressors. Follow the procedure provided by Air-Liquide for this. Switch purifier and regenerate when necessary. <5ppm N2 is the goal purity, when reached, switch to the other passes.

# 2.1K Cold box Cool down:

The initial cool down, diode calibration etc. will be performed under Jlab direct super vision. The cold box operation and controls will be checked for equipment Specific controls Checks (PCK3), before the start of any operations and testing.

# 2.1K Cold box Tests:

The initial testing and establishing the operating parameters will be performed under Jlab direct super vision. Following table shows parameters for cold compressor.

|  |  |  |  |
| --- | --- | --- | --- |
| Modes | Mass Flow | Suction | Discharge |
| Maximum Capacity | ≥ 215 g/s | 3.5 K, 27 mbar | < 30 K, 1.2 bara |
| Nominal Capacity | ≥157 | 3.6 K, 28 mbar |
| Minimum Capacity | ≤150 g/s | 3.6 K, 28 mbar |

Following test scheme will be used for the performance testing of 2 K cold box including the cold compressors without connecting to LINAC.



1. Test Dewar of 10 kL capacity along with the testing heaters will be located near the CAN A of the interface box.
2. 16 kW and 2 kW test heaters in u-tubes will be used here to provide flow paths for warm shield and cold shield respectively.
3. After cool down of the entire system is complete, test Dewar will be filled with liquid helium up to 10 % - 15 % in order to provide sufficient vapor helium pumping volume for the cold compressor.
4. Cold compressor start up process will be performed using the test Dewar, which will reach sub atmospheric condition up to the discharge side of the JT valve in line A.
5. Inlet mass flow rate will be established using the main 10 KL Dewar.
6. Suction temperature for the cold compressor will be adjusted using the 3 kW heater.