Inbeam Cryostat Operations

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1 Overview

The JLab inbeam cryostat is an integral component of the HDice target system. The goal of the system is the production and use of frozen-spin polarized deuterium hydride (HD) ice targets for nuclear physics experiments. The inbeam cryostat holds the HD ice target in the CLAS detetector and allows manipulation and measurement of the target polarization.

2 Inbeam Cryostat

In order for the inbeam cryostat to perform its job it must hold the target at temperatures from 1.5 K downto 0.2 K and in a magnetic field of 0.9 Tesla. Further, it must allow the target to be inserted and withdrawn. The design and construction of the inbeam cryostat has been examined in detail in a published description,

M.M.Lowry. *et al.*, NIM A 815 (2016) 31.

The safety aspects of the cryostat are covered in the documents submitted for the Experimental Readiness Review and accessible on-line at

https://jlabdoc.jlab.org/docushare/dsweb/View/Collection-9218

Prior to beginning maintenance or repair work on the cryostat or any of its ancillary components, knowledgeable HDice staff must be consulted to ensure the system is an appropriate state for testing and repair.

3 Procedures

Before attempting any of the procedures detailed in the following sections, all personnel should acquaint themselves with standard laboratory safety procedures, including vacuum pumping, liquid cryogen handling, magnetic field safety and proper hoist operation. All personnel must have read this manual fully. This equipment is for experimental use only and requires handling by trained personnel only.

3.1 Preparing

This procedure details preparing the cryostat for operation.

1. Confirm power is being supplied to the pumping skid from Big Betha, that water is flowing to the turbo pumps, and that air is supplied to the pendulum valves. Check the LabView programs are running and the RealTime controller is functioning.

2. If not already there, rotate the cryostat to vertical.

3. Rotate the baffle control to near the out position but not fully out. Evacuate the cryostat vacuum space to better than 5e-5 mb as read on the cold cathode gauge.

4. Prepare the helium-4 spaces by using the purge connections to cross connect the 1K-pot, the 4 K plate, the 4 K vent, the 80 K coil and the two MagLead cooling lines. Force all 5 flow controllers to open. Set 1K NV to 2 turns open. Pump with the 1K scroll pumps to better than 0.03 mb as read on P2. Back fill with clean helium4. Close all 5 flow controllers.

5. Use the 1K scroll pumps to clean the two LN2 cold traps to better than 0.03 mb as read on P2.

6. Use the 1K scroll pumps to back the helium-3 turbos and pump the helium-3 circuit to better then 0.001 mb as read on P1.

3.2 Cooling with Helium-4

This procedure describes the cooling of the cryostat from room temperature to that of liquid helium, 4.2 Kelvin. This procedure requires that Procedure 3.1 has been completed before beginning this procedure.

1. Place the double-access insert, with level meter and re-fill lance, into the liquid helium buffer dewar.

2. With the delivery end sealed so as to cross-couple the liquid and vapor tubes, insert the 4-layer transfer line into the access port of the insert in the buffer dewar, purging the line as you go.

3. Connect the vacuum-jacketed line, warm-up can, flow controller, and pump to the vapor exit on the 4-layer transfer line.

4. Remove the cross-coupling end seal from the 4-layer line and insert into the delivery port on the cryostat.

5. Close the purge valves except for the ones to the 1K pot and MagLead B. Close the MagLead B cryostat connection valve. Turn on the Bellows pumps. Set all flow controllers to auto with settings of

Controller	4-LTL	4K vent	4K plate	80 K coil	Mag A	Mag B
Flow [ltr/min]	10.0	0.0	2.0	8.0	0.5	1.5

6. Confirm the heaters for the warm-up can, the 80K coil and the 4K plate are working.

7. After roughly a day, the 4K nose should begin accumulating liquid. Up the flow in the 4LTL to 30 ltr/min and fill the bath to between 30% and 60%. Adjust 4-LTL flow as needed to maintain level.

8. The 1K pot should also fill during this process. Up the flow in MagLead B to 4 ltr/min if necessary.

9. Once the pot has filled, switch to pumping with the 1K pot scroll pumps. Close the purge valves cross connecting to MagLead B, open the MagLead B cryostat valve and set flow to 0.5 ltr/min. Adjust the 1K NV to maintain level.

10. After 1K pot is below 2 K or 30 mb on P2, start 1K Roots pump. Continue to adjust the 1K NV as needed to maintain level.

After levels and temperatures have stabilized, the helium-4 systems of the cryostat are operating and the cryostat is ready for helium-3 circulation.

3.3 Refilling the LHe Buffer Dewar

This procedure details re-filling the liquid helium buffer dewar. This procedure requires that the cryostat be in normal operating condition following Procedure 3.2.

1. Place the withdrawl lance and flex hose in the supply dewar. Purge and pre-cool them by allowing exhaust vapor to flow. Close valve when flame appears.
2. Purge and pre-cool buffer dewar fill lance by allowing exhaust vapor to flow. Close valve when flame appears.
3. Connect the flex line to the fill lance and open to the buffer dewar.
4. Activate the pressure maintance on the supply dewar and begin transfer.
5. When supply dewar empties, close valves and disconnect.
6. Note the date, time, and level reading in the log book.
7. Repeat as necessary.

3.4 Maintaining the LN2 Trap Dewar

This procedure details maintaining the liquid nitrogen trap dewar next to the pumping skid.

1. If a depleted LN2 cylinder is connected, close the cylinder valve, disconnect the line, and replace the cylinder.
2. Confirm that the LN2 transfer hose is connected to the LN2 supply cylinder, that it empties into the trap dewar, and that the remote control cold valve is plugged into the LN2 controller.
3. Confirm the LN2 level meter readout and level controller are turned on.
4. Open the valve on the LN2 supply cylinder and the transfer should begin automatically.
5. Note the date, time, supply cylinder reading in the log book.
6. Repeat as necessary.

3.5 Cooling with Helium-3

This procedure describes the cooling of the cryostat from the temperature of liquid helium, 4.2 K, to base temperature by circulating the helium-3/4 mixture. This procedure requires that Procedures 3.2 and 3.4 have been completed before beginning this procedure.

1. Place the radiation baffle control in the closed position.

2. Place cold trap A in the LN2 trap dewar.

3. Open the dump valve and valve 9 from the dump to the back of the helium-3 scrolls. Open valve13A to allow helium-3/4 mixture into trap A.

4. Turn on the helium-3 scroll pumps. Open all the valves between the pumps and the turbo(s). Open the Pendulum valve(s).

5. Open all the valves between the manual valve on trap A and the helium-3 return on the cryostat. Confirm the He3/4 NV is set to the 9 o'clock position.

6. With valve 12A closed, open the manual valve on trap A. Slowly open valve 12A until helium-3/4 flow is 2.0 ltr/min.

7. As unit cools, adjust V12A to maintain flow.

8. When V12A fully open, and unable to maintain flow, close V6 and V9 and open V14. Slowly reopen V6 to maintain flow.

9. When V6 fully open and unable to maintain flow, turn on turbo(s).

10. When unable to maintain flow, turn on Still heater, slowly upping heat to 8mW.

11. Allow to cool to base.

The cryostat is now in running mode.

3.6 Cleaning the LN2 Trap

This procedure details cleaning either one of the two liquid nitrogen cooled traps next to the pumping skid. This procedure requires that the cryostat be in normal operating condition following Procedure 3.5.

1. Make sure the new trap has its cleanout valve (V11A or V11B) closed and that the trap is inserted in the LN2 reservoir.

2. Open the new trap entrance (V13A or V13B) to admit mixture.

3. Switch the circulation from the old trap to the new by opening exit valve V12A/ manual and closing V12B or vise versa.

4. Close old trap entrance (V13A or V13B). Record the trap change in the log book. Note current P1 value.

5. Scavenge mixture from the trap by opening the pumpout (V11A or V11B) and V8.

6. When P1 has returned to previously noted value, close V8 and connect trap to 1K scrolls by opening V7, V2A and V5A.

7. Lift the trap from the LN2 reservoir, place it in the nearby holder and turn on the heater tape.

8. Allow the trap to slowly warm while being pumped.

9. When warm, close the cleanout connections (V11A or V11B, V7, V2A and V5A). Turn off the heater tape.

At this point the trap is ready to return to service whenever desired.

3.7 Warming up the Cryostat

This procedure stops the circulation of helium-3/4 mxture, recovers the mixture and warms the cryostat to room temperature. It is required that the cryostat not contain a target (see Transfer Cryostat Operations Manual) and that all magnets be de-energized (see Procedures 3.11, 3.12, and 3.13). It assumes the system is in the running mode following completion of Procedure 3.5.

1. Open V9, close V14, and close off the trap entrances (V13A and V13B).

2. Set the still heater to 15 mW and set the mixing chamber heater to 2 mW.

3. Open V5 to scavenge from return and traps.

4. Once P1 is low, the LN2 traps are not needed and the cleanout, Procedure 3.6, should be performed on them without returning either to the trap dewar. Stop the LN2 level controller and close the supply cylinder valve.

5. The 1K pot no longer needed so stop the 1K Roots pump. Close V4A. Stop 1K scrolls. Allow pressure to build up on G3 to near the bath pressure. Open V1A.

6. Once all the mixture has been recovered, liquid helium is not required. Open the 4K vent bypass. Vent the liquid helium buffer dewar. Set the 4-LTL, 4K plate, 80K coil, MagLead A and MagLead B flow controllers to closed. Turn off the 4 K plate, 80 K coil and 4-LTL heaters. Stop the 4-LTL diaphragm pump and recovery bellows pumps.

7. Disconnect the vacuum-jacketed vapor line from the 4-LTL. Lift the withdrawl end from the buffer dewar. Remove the delivery end from the cryostat. Return the 4-LTL to its storage position.

8. When the system has reached room temperature, close the dump tank valve. Turn off all heaters, stop the turbo(s), close all IGH valves. stop the helium-3 scrolls.

9. Note date, time, dump pressure, etc. in the log book.

3.8 Energizing the Main Magnet

This procedure describes ramping the main superconducting magnet located around the target at the end of the snout. It requires that the cryostat be operating in liquid helium-4 mode (see Procedure 3.2). It assumes the cryostat is vertical with a minimum bath level of 40% or horizontal with a minimum bath level of 60%.

1. Set MagLead A flow controller to 3.0 ltr/min and monitor the three voltage taps for the main magnet during ramping. Increase flow if needed.
2. Turn on the Oxford Magnet Power Supply and confirm that the uninterruptible power supply that powers it is working properly.
3. Set the ramp rate to 2.0 amps/min or less. Set the desired current or field. Push the sweep-to-field button.
4. When the supply reaches the desired current and stops ramping, push the hold button.

The last two steps may be repeated as often as desired to energize the magnet at any desired field between 0.0 and 0.9 Tesla.

3.9 Energizing the Transfer Magnet

This procedure describes ramping up the transfer superconducting magnet located between the main magnet and the shutter opener. It requires that the cryostat be operating in liquid helium-4 mode. (see Procedure 3.2). It assumes the cryostat is vertical with a minimum bath level of 60%.

1. Set MagLead A flow controller to 3.0 ltr/min. and monitor the three voltage taps for transfer magnet during ramping. Increase flow if needed.
2. Turn on the Cryomagnetics Power Supply and confirm that the uninterruptible power supply that powers it is working properly.
3. Ramp the supply up to 17 amps at 1.5 Amps/min.

3.10 Energizing the Transverse Saddle-Coil Magnet

This procedure describes ramping up the transverse saddle-coil magnet located around the target at the end of the snout. It requires that the cryostat be operating in liquid helium-4 mode. (see Procedure 3.2 It assumes the cryostat is vertical with a minimum bath level of 40% or horizontal with a minimum bath level of 60%.

1. Set MagLead B flow controller to 3.0 ltr/min and monitor the three voltage taps for saddle coil magnet during ramping. Increase flow if needed.

2. Turn on the Oxford Magnet Power Supply and confirm that the uninterruptible power supply that powers it is working properly.

3. Set the ramp rate to 9.0 amps/min or less. Set the current as desired upto 60 Amps. Push the sweep-to-field button.

4. When the supply reaches the desired current and stops ramping, push the hold button.

The last two steps may be repeated as often as desired to energize the magnet at any desired current between 0.0 and 60.0 Amps.

3.11 De-Energizing the Main Magnet

This procedure describes ramping down the superconducting magnet located around the target at the end of the snout. It assumes the magnet has been energized with Procedure 3.8.

1. Set the ramp rate on the Oxford Magnet Power Supply to 2.0 amps/min or less. Push the sweep-to-zero button.

2. When the supply reaches zero current and stops ramping, push the hold button.

3. Turn off the supply. If the transfer magnet is off, set the MagLead A flow controller to 0.5 ltr/min.

3.12 De-Energizing the Transfer Magnet

This procedure describes ramping down the transfer superconducting magnet located between the end of the snout and the shutter opener. It assumes the magnet has been energized with Procedure 3.9.

1. Ramp the Cryomagnetics Power Supply down to zero current at 1.5 Amps/min.

2. Turn off the supply. Set the MagLead B flow controller to 0.5 ltr/min.

3.13 De-Energizing the Transverse Saddle-Coil Magnet

This procedure describes ramping down the transverse saddle-coil magnet located around the target at the end of the snout. It assumes the magnet has been energized with Procedure 3.10.

1. Set the ramp rate on the Oxford Magnet Power Supply to 9.0 amps/min or less. Push the sweep-to-zero button.

2. When the supply reaches zero current and stops ramping, push the hold button.

3. Turn off the supply. If the main magnet is off, set the MagLead A flow controller to 0.5 ltr/min.

3.14 Rotating the Cryostat

This procedure describes rotating the cryostat from vertical to horizontal or vice versa. It assumes that the cryostat is operating in running mode (see Procedure 3.5).

1. Confirm the 1K-pot level is no more than 95% and the bath level is at least 60%.
2. Check interferences to confirm the cryostat will not strike any obstacles and no lines will be pinched or over-stretched.
3. If going vertical, remove the locking bolt.
4. Slowly pump the ratchet wrench to swing the cryostat in the correct direction. Manuveur the 4-LTL as necessary. Continue to check interferences during procedure.
5. If going horizontal, pay particular attention to the bath level as liquid reaches the upstream wall as excessive bath boiloff can occur at that point.
6. If going horizontal, pay particular attention as the 1K pump line reaches horizontal as liquid from the pot can run up and cause rapid pressurization.
7. If going horizontal, insert the locking bolt when the horizontal stop is reached.

3.15 Transferring a Target

This procedure describes the steps required to transfer a target into or out of the inbeam cryostat. It requires that the cryostat be operating in running mode and vertical (see Procedures 3.5 and 3.14). This procedure requires that the transfer cryostat be cold and positioned on top of the inbeam cryostat and coupled to it with a fully evacuated vacuum lock (see Transfer Cryostat Procedure 3.11).

1. Energize the transfer magnet with Procedure 3.9.
2. Follow the procedure for inserting a target, Transfer Cryostat Procedure 3.16, or withdrawing a target, Transfer Cryostat Procedure 3.15 upto the point of having docked the LN2 section in the shutter opener.
3. Open the Radiation Baffle.
4. Continue to follow the procedure for inserting a target, Transfer Cryostat Procedure 3.16, or withdrawing a target, Transfer Cryostat Procedure 3.15 upto the point of being ready to un-docked the LN2 section from the shutter opener.
5. Close the Radiation Baffle.
6. Finish the procedure for inserting a target, Transfer Cryostat Procedure 3.16, or withdrawing a target, Transfer Cryostat Procedure 3.15.
7. De-Energize the transfer magnet with Procedure 3.12.