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HALL D PROCEDURE NO.:
D00000-04-02-P002 Rev B

TITLE: Hall D Solenoid Commissioning

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B	Extensive revision to include Power Supply Qualification at 15 A, the interlock verification necessary, verification of Ground Fault Detector placement, test for turn-to-turn shorts, calibration of the Quench Detector and leaving final cool-down to LHe temp.	GB		GB		5/23/13
A	Incorporated changes recommended by reviews. Updated to reflect actual installation	JTB	TW for GB	TW for GB	TW	2/22/13
REV.	DESCRIPTION	BY	CHK.	APP.	APP.	DATE

Re - Commissioning Goals – Very Low Current (15 A)

1. Re-verify correct operation of selected mechanical, cryo, safety and control/monitoring/archiving systems.
2. Qualify the Magnet Power Supply (MPS) at up to 15 A (normal or superconducting state allowed) under the Solenoid's inductive load such that improvements such as "tuning" or staged ramp profile ramp-up may be measured for their ability to minimize transients, and thus not trip the Quench Detector (QD).
3. Verify that the Ground Fault Detector (GFD) is installed to mask the existing ground fault in Coil 3 while being sensitive to ground faults in other portions of the magnet.
4. Balance Channel 3 of the Quench Detector (with channel 1 and 2 not used)
5. Perform proper cooldown from ~ 70 K to LHe temperature and filling of the LHe vessel.
6. Demonstrate stable cryogenic operation with full LHe vessel.
7. Demonstrate that selected features of the Solenoid remain viable, such as no turn-to-turn shorts, after the quench experienced during initial commissioning.
8. Demonstrate staged ramp profile ramp-down to 0A while not tripping the Quench Detector.

Administrative Requirements

Perform all Solenoid Operations per the Operational Safety Procedure (OSP)

Prior to cooldown, complete the appropriate items in Pre-Cooldown Checklist (D00000-04-02-P003). Upload a copy of the completed checklist to HDList for the cooldown activity and to the solenoid ELOG. The following tasks must be accomplished and logged into HDList for the cooldown activity and to the solenoid ELOG (https://logbooks.jlab.org/book/hdsolenoid).

Note that a partial list of the System fast and slow interlocks are verified during this sequence. The remainder will be verified at the next stage of Re-Commissioning, the 140 A Tests.

Partial Interlock Qualification and Qualifying the Magnet Power Supply Improvements

1. Using a small (< 10A DC) power supply, supply 2-7 A across the leads of the solenoid with power supply cables disconnected, power supply's negative lead attached to the negative lead and verify the following:
    a. Voltage tap cascade integrity with the volt meter negative lead attached to the magnets negative lead, for each primary and redundant signal (1) at the pins in the feed-throughs on top of the standpipes, (2) pins on top of the resistor boxes and (3) redundant tap

readings at the voltage tap switch box as well as primary tap voltages at the quench detector. Publish the values in the spreadsheet: Solenoid Coils Resistances & Voltage Tap Readings.xlsx located in: M/halld_engineering/Solenoid/Commissioning and in the Log. Study the readings vs. past readings for anomalies.

b. Voltage tap cascade to establish the location of the ground fault with the voltmeter negative lead attached to ground. Measure each primary and redundant signal (1) at the pins in the feed-throughs on top of the standpipes, (2) pins on top of the resistor boxes and (3) redundant tap readings at the voltage tap switch box as well as primary tap voltages at the quench detector. Publish the values in the spreadsheet: Solenoid Coils Resistances & Voltage Tap Readings.xlsx located in: M/halld_engineering/Solenoid/Commissioning and in the Log. Study the readings vs. past readings for anomalies.

2. Solenoid Checklist D000000402-P003 (less requirements based on being at Liquid Helium temperatures) shall be complete and scanned into ELOG.
3. The lead from the Ground Fault Detector shall be landed between high value resistors, each connected to the positive or to the negative leads, internal to the Power Supply. The values of the resistors shall mirror the inductance values of all turns on either side of the Ground Fault position. That ground fault is associated with Coil 3. Alter the electrical schematic to reflect the new installation.
4. Voltage tap circuits, quench protection circuits, pick-up coils, PXi system and archiving system shall be operational.
5. Re-attach the Vapor Cooled Leads' Jumpers to the bus bars, and remove the shorting jumpers from the bus bars in the Solenoid Vapor Cooled Leads' Junction Boxes, so that the magnet is back in the Power Supply's circuit.
1. If the Solenoid is not full of liquid helium with the cryo plant fully operational, the following interlocks need to be by-passed or commented out "Buggered" and noted in the elog.
   1.1. Hard wire Vacuum controller
   1.2. PLC Helium Level (Differential Pressure)
   1.3. Hard Wire Lower VCL Temperature
   1.4. Hard Wire VCL Flow Controller
   1.5. PLC Vacuum Failure
   1.6. PLC VCL Flow
6. Transfer the jumper on the MPS Regulation Board Jumper 1 from its left-most, resistive position to its right-most or inductive position.
7. Set two Current Limits (1) Newport Controller, (2) PLC Software to 20 A. Set the Power Supply Limit to 25 A (higher because of low resolution of read-out)
8. Zero-Out the Strain gauge readings.

9. Remove all “Buggers” in the system other than those detailed in 5 above or be aware of necessary buggers and log that the operator accepts them.
10. Turn on the PXi System, initiating a recording session named by the date and time.
11. Zero the PXi data logging system.
12. If local mode is available, switch the MPS to local mode, turn on the MPS with the current set to 0A and set the slew rate to the lowest *viable* unit.
13. Observe if the transients still trip the QD upon turn-on.
14. If the QD trips, dis-engage the QD using the momentary switch and turn on the MPS again. Re-engage the QD by letting go of the switch.
15. Demonstrate local control by manually raising the current (If local control not available, use remote control for item 11 through 14) from 0A to 2A
16. Verify that both the scrolling LED Current Indicator Sign and the Fan are operational.
17. Activate Emergency Stop button on front panel of MPS. Verify initiation of Fast Dump (contactor opening noise).
18. Verify Voltage spike (0.06 V from Dump Resistor + ~ 0.6 V from the diodes) as read by the PXi system, indicating Dump Resistor is connected. Reset Emergency Stop Button.
19. Put MPS in Remote Mode.
20. Command the Dump Contactor to close (reset button) and turn MPS **on** at a requested current of zero. Verify supply is turned on.
21. Observe if the transients still trip the QD upon Power Supply’s turn-on.
22. If the QD trips, dis-engage the QD using the momentary switch and turn on the MPS again. Re-engage the QD by letting go of the switch. Use this method to turn on the Power Supply if required for all future actions of this procedure.

Partial Hard Wire Fast Dump Interlock Tests (There are no partial PLC Fast Dump Tests)

23. Simulate Upstream (US) VCL overvoltage using Voltage Tap Test Box. Verify SOE “VCL Overvoltage” if it is operational. Verify initiation of fast dump by the US VCL Newport Controller.
24. Simulate Downstream (DS) VCL overvoltage using Voltage Tap Test Box. Verify SOE “VCL Overvoltage” if it is operational, Verify initiation of fast dump by the DS VCL Newport Controller.

Partial Hard Wire Slow Dump Interlock Tests

- The HMI MPS and Interlock screens should indicate which interlock tripped in tests below. At currents below approximately 160 A, the only hardware indication that the Power Supply is in Slow Dump Mode is that the current starts declining at the fast dump rate but the dump contactor does not open (Only the sound of the inlet power contactors is heard and there is no indication on the power supply display). Actual Slow dump functionality will be tested during higher current ramps.

- For each test below, verify that the SOE (If the SOE is operational) indicates the proper "first-fault". If the SOE indication is wrong, troubleshoot and correct the SOE system. Successful indication of Slow Dump is verified by decreasing magnet current and NO audible report from the Fast Dump Contactor.
- This test segment continues under the low current above. Actual Slow Dump requires 160A or more to trigger current going through the Thyristor. Below that current the Pass Bank still turns off, the dump switch remains closed but the Dump Resistor and diode absorb the energy.
- Verify that solenoid has zero current, but MPS is on. Disconnect Coil 1 Voltage Tap Cable from its current limiting resistor box. DO NOT ATTEMPT TO RAMP WITH VT CABLE DISCONNECTED. Verify SOE "VT Cable Interlock" and Interlock HMI Screen indicates Slow Dump. Reconnect Voltage Tap Cable.

25. Verify that solenoid has zero current but MPS is on. Disconnect a Cable from the Non Voltage tap cable string. Verify Cable Interlock Trip on Interlock HMI Screen indicate Slow Dump. Verify SOE "Cable Interlock". Reconnect Cable.
26. Reset the CEBAF (MPS Panel) Current Setting on the Power Supply to 10A. Ramp to 15A. Verify initiation of slow dump as current passes 10 A. Verify SOE "CEBAF Overcurrent" Reset MPS front panel overcurrent limit to 25 A.
27. Reset the Newport Overcurrent detector current Setting to 10 A. Initiate ramp to 20 A. Verify trip of MPS as current passes 10 A. Reset Newport overcurrent detector set point to 20 A.
28. Verify that the GFD is working (0.5 V limit). Verify SOE "Ground Fault" is indicated
29. Disengage the connector from the PLC to the Watchdog Relay. Verify that Slow Dump is initiated. Verify SOE "PLC Watchdog"". Re-engage the connector.

15 A QD Tuning and T2T Short Measurement

30. With the MPS on, check that the offset of the Quench Detector is zero.
31. Disengage the Quench Detector with the momentary switch.
32. Start a ramp to 15 A at about 0.012 A/sec.
33. Observe the signal from the QD on a Fluke Meter, turning the Balance Pot for Channel 3 to reduce the absolute value of the error signal.
34. Engage the QD (release the momentary switch) as soon as balance is achieved (<0.1 V on the error signal) during steady ramping.
35. If necessary, disengage the Quench Detector with the momentary switch when near to 15 A so as not to trip the QD.
36. Start a ramp to zero at a similar ramp rate.
37. Engage the QD (release the momentary switch) as soon as balance is achieved (<0.1 V on the error signal) during steady ramping down.

38. Analyze the PXi Data to verify the Inductances remain the same as during initial commissioning.
39. Analyze the PXi Data for lag in magnetic field vs. current to establish that turn-to-turn shorts are not indicated.

Staged Ramp and Tuned Power Supply Tests
Note that "staged ramp" means the soft start to a ramp process where the start and end of a ramp is accomplished in several stages where each stage consists of a slew rate for a time period followed by the next stage with a changed slew rate for a time period etc.

40. Initiate staged ramp to 15 A at stages to be worked out during these tests. The object is to assess if voltage tap transients are reduced such that the QD error signal doesn't exceed 5 V.
41. Leveling off the current may need additional programming or manual intervention by the operator to achieve the goal of not tripping the quench detector as the power supply stabilizes at a set current.
42. Observe if the QD's 5 V trip limit was exceeded (at the sensitivity settings ~150 mV now set), leading to a fast dump upon start of ramp. If so, try other combinations of stages to not exceed the limit. Also try decreasing the sensitivity setting to at least get a ramp started, backing off to original settings as experimentation with the stages allows. Operator may also try the biasing the balance the opposite side of the limit and try a ramp again. (The latter solution may not work for the staged ramp down.)
43. PLC's Coil and Tap-Coil Quench Detectors may be qualified for use during the above tests. Observe if thresholds are exceeded.
44. Observe if the inductive Tap-coil Voltages recorded in the PXi are consistent with former readings.
45. Observe that the GFD didn't trip.
46. Ramp down to zero current using a staged ramp, by the operator (or programmed) as soon as possible to avoid heating the Solenoid Coils.
47. Staged Ramping may, or may not, be successful in not exceeding the QD error signal limit of 5 V.
48. If further testing is delayed, turn off the PXi Data logging.

The remaining portion of this test may be accomplished several days later.

49. Tune the MPS to the 25 H, actual Inductance of the Solenoid using the methods given by Danfysik.
50. Turn on the PXi Data Logging, if it was turned off.
51. Test the efficacy of the "Tuning" using the staged ramp to 15 A as above to assess if voltage tap transients are reduced such that the QD error signal doesn't exceed 5 V.
52. After completion of the tests. Ramp down the MPS, using a staged ramp, by the operator (or programmed) as soon as possible to avoid heating the coils. Turn the MPS off at the breaker and administratively lock it out until cool down is complete or detach the cables to the solenoid at the Vapor Cooled Leads' Junction Boxes.
53. End the session and turn off the PXi System

54. Remove the Buggers installed as part of Item 5 and elog that the individual buggers removed.
55. If QD sensitivity was changed during the test, re-adjust the sensitivity to the original values of ~150 mV using voltage sources and the Test Box.

Cool Down Heat Exchanger Use

1. Verify connection of Nitrogen vent line to heat exchanger
2. Plug in and turn ON the Nitrogen heater. Set thermostat to 80° F
3. Verify integrity of Nitrogen vent line from heater outlet to wall
4. Verify installation of flat plate check valve on heat exchanger Nitrogen vent (outside of hall). Ensure plate moves freely on the mounting rods.

Cryogenic Instrumentation and Control

1. Connect all instrumentation cabling between Controls Rack, Solenoid, Heat Exchanger and PXI system. Verify connections and proper operation.
2. Use the manual key switch on the controls rack to actuate each JT valve from full close > full open > full close – fill in and sign the valve checkout checklist.
3. From HMI, actuate each JT Valve from full close > full open > full close. Record the actuation time each way and update the valve actuation rate in the PLC code, if necessary. Calibrate LVDT read backs as required.
4. Identify all temperature and pressure sensors on P&ID (D00000-09-01-0001) – verify that sensors indicate appropriate values at HMI (~room temperature, ~1 atm pressure (or 0" H_2O for DP)).
5. The LHe level gauge is inoperative for this test and the back-up, differential pressure gauge set is used instead.

Cool Down

Cooldown steps listed below are accomplished under the direction of the Cryo group on an as required basis.

Pre-Final Cooldown Steps and checks

1. Demonstrate that there are no leaks in the Nitrogen Circuits by vacuum leak check.
2. Demonstrate that there are no leaks in the Helium circuits by vacuum leak check.
3. Perform pump and purge of Helium system in accordance with MSCRYO standard practices
   a. During pump and purge demonstrate capability of adjusting zero-current VCL flow
   b. H_2O contamination shall satisfy MSCRYO

    c. N_2 contamination shall satisfy MSCRYO
4. After successful pump and purge, leave system in 100% warm bypass:
    a. Close manual valve on side of cooldown heat exchanger
    b. Open JTV9, EV6 and JTVs 1 through 4
    c. Set VCL flow controllers to the baseline flow (I=0A) (29 SLPM)
5. Close all Nitrogen JT Valves
6. Make LN2 U-Tube connection between cryogenic transfer line end can and cooldown heat exchanger
7. Make LN2 U-Tube connection between cooldown heat exchanger and distribution box

The solenoid is now in Helium bypass mode and is ready for cooldown.

Cooldown to 4.5 K and introduction of LHe

Cooldown brings the temperature of the cold mass to approximately 4 K and fills the LHe reservoir.

1. Transfer the U-Tube from the Helium supply feed in the Helium cooldown heat exchanger to the bayonet socket in the transfer line end can
2. Stab the cold Helium return U-Tube
3. Close the valve from the relief stack to warm helium return line
4. Open the Vapor Cooled Lead piping valves and activate the controllers to minimum lead flow
5. Adjust cold Helium flow to continue cooldown of four coils to 4 K. The maximum Helium pressure in the tank shall not exceed 1.4 atm.
6. Monitor the operation and regulation of the LN2 circuit and tune as necessary
7. Monitor the icing of the distribution box top sensors and instrumentation and take corrective action as necessary. Pay particular attention to the VCL insulators and 535 MCM bus conductor terminations.
8. Tune the PID loop to maintain 80% liquid level in the LHe reservoir.
9. Once "full" of LHe (80%), evaluate all cryogenic LHe temperature sensors for accuracy. Identify non-functioning primary temperature sensors and switch to secondary sensors as needed.
10. Make an estimate of the cooldown rate based on an analysis of the cooldown data and compare to cooldown models.
11. Evaluate the VCL mass flow meters
    a. Without powering the magnet, simulate a current ramp and observe a change in flow.