Operation of the Hall D Cryotarget

Chris Keith, May 5 2014

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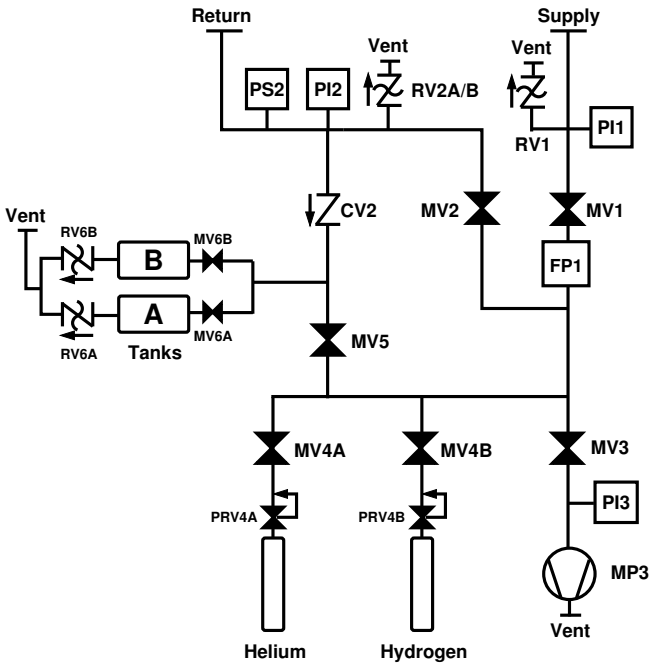
1. Pre-cool down checklist

1. Approximately 24 hours before the cool down, the vacuum chamber should be evacuated. Open the scattering chamber gate valve (use the button to override the vacuum switch); turn on the vacuum pumps. When chamber vacuum is less than 10 torr, close the override switch.
2. Check that the supply and return lines are properly connected between the target and the gas panel;
3. Check all plumbing connections between the gas panel and vent header and from the vent header to the vent line leading outside the hall;
4. Check that the vent header is being purged with an inert gas (nitrogen);
5. Check that the Aeroquip coolant lines are connected to the pulse tube refrigerator (PTR) and its compressor;
6. Check that the heater and thermometer cables are properly connected between the target and the Lake Shore 335 and 218 electronics;
7. Check that all readbacks and controls are functioning with the PLC;
8. Check that the water cooling lines are connected to the compressor;
9. Check that the compressor pressure gauges read 200 ± 5 psig;
10. If necessary perform a pump and purge procedure on the gas panel and target system (see Appendix);
11. Confirm that the storage tanks are loaded with sufficient hydrogen or deuterium. These values can be found in Section 5 of this document. If necessary, add gas to the system using the procedure attached.
12. Confirm the following valve line-up on the gas panel:

    OPEN: MV1, MV5
    LOCKED OPEN: MV6A, MV6B
    CLOSED: MV2, MV3, MV4A, MV4B



2. Cooling the target

2.1 Manual cool down

1. Confirm that the vacuum chamber pressure is 5 x 10^{-5} or lower.
2. Confirm that the LS218 and LS336 are reading appropriately for all sensors (e.g. around 290 K at room temperature).
3. Load the appropriate set point for the condenser into the Heater 1 controls of the LS336, and confirm that the other settings for this heater are correct. These values can be found in Section 5.
4. Start the alarm handler and strip tools.
5. Turn on the water cooling for the compressor.
6. Turn on the compressor power and press the "Compressor ON" button. Check the compressor display for any error messages. Refer to Section 7.6.4 of the compressor manual.
7. The Target is now cooling.
    a. After about 2 hours, the condenser should reach the boiling point of hydrogen (about 23 K for H2 and 26 K for D2) and a small amount of gas will condense there. This will be evidenced by a very slight drop in the target pressures PI1 and PI2. The condenser temperature will remain steady at this temperature.
    b. Shortly thereafter the cell temperatures should begin cooling. When they get close to the hydrogen boiling point, gas will start condensing inside the target cell and PI1 and PI2 will drop steadily. The condenser and cell temperatures will also drop as the system cools along the hydrogen vapor pressure curves. See section 5.
    c. Hydrogen will continue to condense until the entire system is filled (cell, condenser, fill and return lines). The PTR will continue to cool the system until the condenser set point is reached and the LS336 begins to take control. The condenser and cell thermometers will level out at this set point. The target is now full and subcooled by about 2 degrees kelvin.
8. The target is now ready for beam.

2.2 PLC controlled cool down

1. Confirm that the vacuum chamber pressure is 5 x 10^{-6} or lower.
2. Confirm that the LS218 and LS336 are reading appropriately for all sensors (e.g. around 290 K at room temperature).
3. Start the alarm handler and strip tools.
4. Turn on the water cooling for the compressor.
5. Turn on the compressor power and press the "Fill Target with Liquid" button on the target computer. Confirm that there is no error message from the compressor. If there is, refer to Section 7.6.4 of the compressor manual.

6. The Target is now cooling. The control computer should have the message: "**Target is Cooling: NOT Ready for Beam**".
    a. After about 2 hours, the condenser should reach the boiling point of hydrogen (about 23 K for H2 and 26 K for D2) and a small amount of gas will condense there. This will be evidenced by a very slight drop in the target pressures PI1 and PI2. The condenser temperature will remain steady at this temperature.
    b. Shortly thereafter the cell temperatures should begin cooling. When they get close to the hydrogen boiling point, gas will start condensing inside the target cell and PI1 and PI2 will drop steadily. The condenser and cell temperatures will also drop as the system cools along the hydrogen vapor pressure curves. See section 5.
    c. Hydrogen will continue to condense until the entire system is filled (cell, condenser, fill and return lines). The PTR will continue to cool the system until the condenser set point is reached and the LS336 begins to take control. The condenser and cell thermometers will level out at this set point. The target is now full and subcooled by about 2 degrees kelvin
7. The control computer should display the message: "**Target is FULL: Ready for Beam**".

3. Warming target for empty target runs

The goal of this procedure is to remove the liquid from the target cell so that measurements can be made with a cell filled with cold hydrogen gas. It is assumed that the cell is filled with liquid at the beginning of the procedure.

3.1 Manual procedure

1. Enter a setpoint temperature of 30 K into the Heater 2 controls of the LS336 and confirm that the PID settings for this heater are correct (see Section 5).
2. As liquid boils from the target, the pressures PI1 and PI2 will increase. The condenser should stay cold enough to continue condensing hydrogen, but the cell will be too warm to allow the liquid to accumulate there.
3. When PI1 and PI2 reach a pressure of about 35 psia, the cell is empty and ready for beam.

3.2 PLC controlled procedure

1. Press the "**Empty the Target**" button on the control computer. The target status should change to "**Target is Emptying: NOT Ready for Beam**"
2. As liquid boils from the target, the pressures PI1 and PI2 will increase. The condenser should stay cold enough to continue condensing hydrogen, but the cell will be too warm to allow the liquid to accumulate there.
3. When PI1 and PI2 reach a pressure of about 35 psia, the status will change to "**Target is EMPTY: Ready for Beam**".

4. Warming the target, end of run

This procedure is the same whether the target is filled with liquid or cold gas.

4.1 Manual Warm up

1. Turn OFF both heaters on the LS336
2. Press the OFF button on the compressor. Wait a few moments and turn OFF the compressor power. Turn off water cooling for the compressor.
3. The pressure of the hydrogen in the gas panel should rise almost immediately after steps 1 and 2.
4. If necessary the system can be forced to warm to room temperature more rapidly by spoiling the vacuum. THIS MAY ONLY BE DONE AFTER ALL THERMOMETERS INDICATE A TEMPERATURE OF 100 K OR GREATER.
    a. Close the gate valve on the vacuum chamber.
    b. Turn off the turbo pump and it's backing pump.
    c. Bleed in a dry, inert gas (nitrogen or argon) until the vacuum pressure reads about 50 torr. Do NOT use helium; it will complicate future leak checks of the vacuum chamber.
5. When the condenser and cell thermometers reach room temperature, confirm that the gas pressures PI1 and PI2 are the same as their initial, pre-cooldown values.
6. CLOSE and LOCK the tank valves MV6A and MV6B.

4.1 PLC Controlled Warm up

1. Press the "**Turn Target OFF**" button on the control computer.
2. Turn OFF the compressor power. Turn off water cooling for the compressor.
3. The pressure of the hydrogen in the gas panel should rise almost immediately after steps 1 and 2.
4. If necessary the system can be forced to warm to room temperature more rapidly by spoiling the vacuum. THIS MAY ONLY BE DONE AFTER ALL THERMOMETERS INDICATE A TEMPERATURE OF 100 K OR GREATER.
    a. Close the gate valve on the vacuum chamber.
    b. Turn off the turbo pump and it's backing pump.
    c. Bleed in a dry, inert gas (nitrogen or argon) until the vacuum pressure reads about 50 torr. Do NOT use helium; it will complicate future leak checks of the vacuum chamber.
5. When the condenser and cell thermometers reach room temperature, confirm that the gas pressures PI1 and PI2 are the same as their initial, pre-cooldown values.
6. CLOSE and LOCK the tank valves MV6A and MV6B.

5. Typical Settings

5.1 Room Temperature Storage Pressures

Hydrogen: 33 psia Deuterium: 35 psia

5.2 Liquid Hydrogen Target

LS336 Settings

L1 A: Condenser 1	P	60	L2: C: Cell 1	P	30
Setp: 18 K	I	20	Setp: 30 K	I	10
Heat: 15% of High	D	0	Heat: 0 % of OFF	D	0

Condenser Temperatures: LS336_T1, _T2 = 18 K
Target Cell Temperatures LS336_T3, _T4 = 18 K
Target Pressures: PI1 = PI2 = 18 psia

5.3 Liquid Deuterium Target

LS336 Settings

L1 A: Condenser 1	P	60	L2 C: Cell 1	P	30
Setp: 22 K	I	20	Setp: 30 K	I	10
Heat: 20% of High	D	0	Heat: 0 % of OFF	D	0

Condenser Temperatures: LS336_T1, _T2 = 22 K
Target Cell Temperatures LS336_T3, _T4 =22 K
Target Pressures: PI1 = PI2 = 18 psia

5.4 Hydrogen Gas Target ("empty target")

LS336 Settings

L1 A: Condenser 1	P	60	L2 C: Cell 1	P	30
Setp: 18 K	I	20	Setp: 30 K	I	10
Heat: 0% of High	D	0	Heat: 30 % of High	D	0

Condenser Temperatures: LS336_T1, _T2 = 18 K
Target Cell Temperatures LS336_T3, _T4 =30 K
Target Pressures: PI1 = PI2 = 33 psia

5.5 Deuterium Gas Target ("empty target")

LS336 Settings

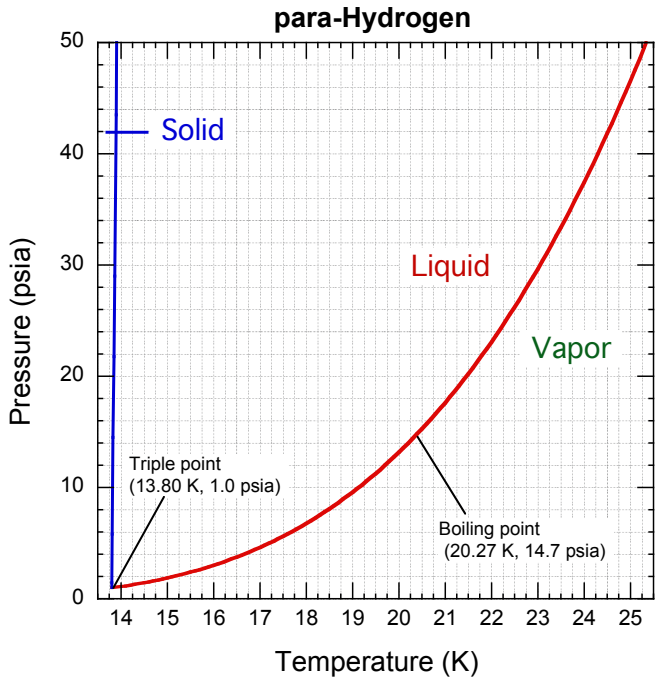
L1 A: Condenser 1	P	60	L2 C: Cell 1	P	30
Setp: 22 K	I	20	Setp: 30 K	I	10
Heat: 0% of High	D	0	Heat: 30 % of OFF	D	0

Condenser Temperatures: LS336_T1, _T2 = 22 K
Target Cell Temperatures LS336_T3, _T4 =30 K
Target Pressures: PI1 = PI2 = 35 psia

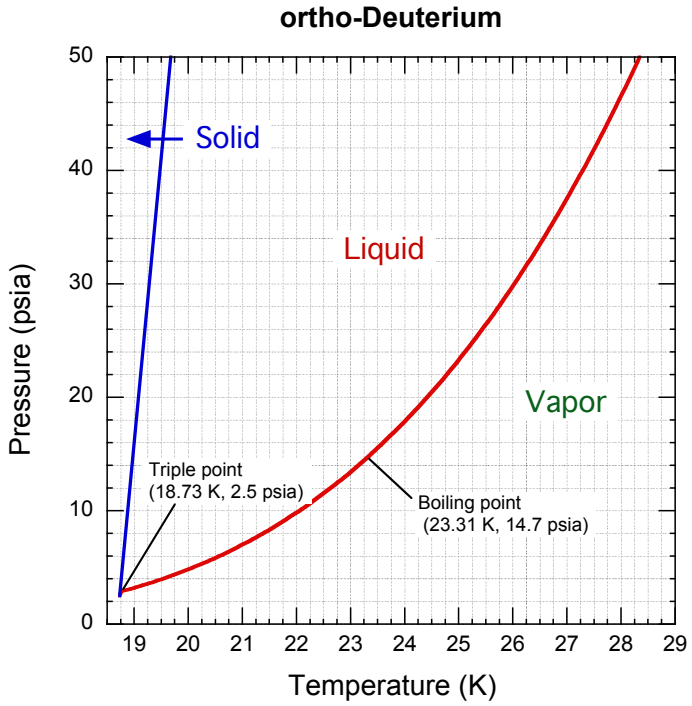
6. Hydrogen and Deuterium Vapor Pressure Curves

Source: National Institute of Standards, Thermophysical Properties of Fluid Systems
http://webbook.nist.gov/chemistry/fluid/

6.1 para-hydrogen



6.2 ortho-deuterium



Appendices: Gas Handling procedures for the Hall D Cryotarget

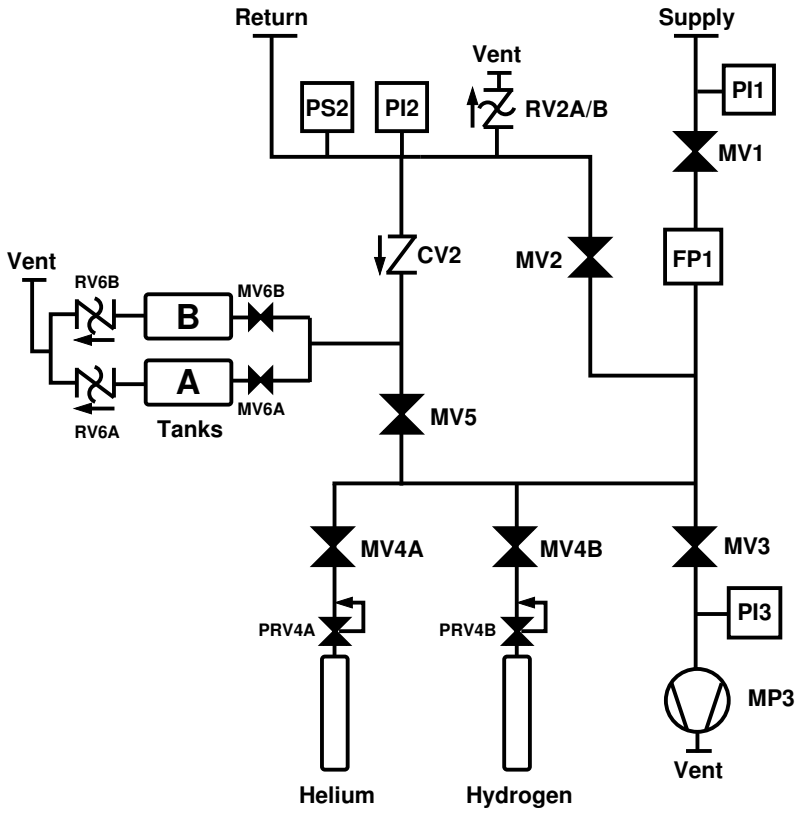


Figure 1: P&I diagram for the Hall D cryotarget gas panel.

Prior to beginning these procedures the responsible party must:

- Confirm that the fill and return lines are properly connected to the Hall D cryotarget
- Confirm that the vacuum chamber surrounding the target cell is at a vacuum pressure no higher than 10 torr.
- Confirm that Tank A and Tank B are connected to the vent header at relief valves RV6A and RV6B.
- Confirm that the target relief valves RV2A and RV2B are connected to the vent header
- Confirm that the exhaust of mechanical pump MP3 is connected to the vent header.
- Confirm that the vent header is being purged by an inert gas.

A1. Pump & Purge

- Connect a cylinder of high purity HELIUM to regulator PRV4A. The valve on the cylinder should be CLOSED and the regulator set to ZERO pressure.
- Connect a cylinder of high purity HYDROGEN (or DEUTERIUM) to regulator PRV4B. The valve on the cylinder should be CLOSED and the regulator set to ZERO pressure.

A1.1 PUMP

1. CLOSE MV3. OPEN MV1, MV2, MV4A, MV4B, MV5, MV6A, MV6B.

Turn ON mechanical pump MP3.

2. OPEN MV3 and pump on the system until PI3 indicates a pressure less than 100 mtorr. Both PI1 and PI2 should read zero psia. Confirm that pressure switch PS2 is ENERGIZED.
3. CLOSE MV2 and MV3.
4. CYCLE all ball valves on the gas panel and tanks. (CLOSE/OPEN or OPEN/CLOSE).

A1.2. PURGE with HELIUM

5. CLOSE MV4A. OPEN the valve on the HELIUM cylinder and set the regulator PRV4A to 20 psig. OPEN the valve on the regulator.
6. OPEN MV4A and bleed helium into the system until PI2 reads 20 psiA.
7. CLOSE MV4A and OPEN MV2.
8. Repeat steps 2 through 7 (omit step 5) for a total of FOUR times.
9. CLOSE the valve on the helium cylinder, set PRV4A to ZERO pressure, and CLOSE the regulator valve.

A1.3. PURGE with HYDROGEN/DEUTERIUM

10. OPEN MV3 and pump on the system until PI3 indicates a pressure less than 100 mtorr. Both PI1 and PI2 should read zero psia.
11. CLOSE MV2 and MV3.
12. CLOSE MV4B. OPEN the valve on the HYDROGEN cylinder and set the regulator PRV4B to 20 psig. OPEN the valve on the regulator.
13. OPEN MV4B and bleed hydrogen into the system until PI12 reads 20 psiA.
14. CLOSE MV4B and OPEN MV2.
15. Repeat steps 10 through 14 (omit step 12) for a total of FOUR times. On the fourth time, fill the system with hydrogen to a pressure of 35 psia. This is the correct charge of H2 gas necessary to operate the system as a liquid hydrogen or deuterium target

A1.4. FINAL STEPS

16. CLOSE MV4B, and OPEN MV2. Turn MP3 OFF.

17. CLOSE the valve on the hydrogen cylinder, set regulator PRV4B to ZERO pressure, and , CLOSE the regulator valve.

The target is now ready for cooling.

Confirm the following valve line-up on the gas panel:

OPEN: MV1, MV5
LOCKED OPEN: MV6A, MV6B
CLOSED: MV2, MV3, MV4A, MV4B

A2. Add gas to a WARM system

If a PUMP/PURGE has been performed on the system, but it becomes necessary to add additional hydrogen to it, the following steps should be undertaken.

1. Connect a hydrogen cylinder to regulator PRV4B. Make sure the valve on the cylinder is CLOSED and PRV4B is set to ZERO pressure.
2. CLOSE MV1, MV2 and MV5.
3. Turn ON pump MP3 and wait until vacuum gauge PI3 reaches 100 mtorr or less.
4. OPEN MV3 and MV4B and pump until PI3 reaches 100 mtorr or less.
5. CLOSE MV3 and MV4B.
6. OPEN the valve on the hydrogen cylinder and set regulator PRV4B to 20 psig.
7. OPEN MV4B to purge the line with hydrogen.
8. CLOSE MV4B.
9. Repeat steps 4 through 8 (omit step 6) for a total of FOUR times.
10. OPEN MV1 and MV5.
11. OPEN MV4B and fill the system with hydrogen gas to the desired pressure, as indicated by PI1. This pressure should be 35 psia for a liquid hydrogen target.
12. CLOSE MV4B. CLOSE the cylinder valve, set the regulator to ZERO pressure, and CLOSE the regulator valve.
13. CLOSE MV1 and MV5.
14. OPEN MV3 and MV4B. Pump until PI3 reached 100 mtorr or less.
15. CLOSE MV3 and MV4B. Turn off vacuum pump MP3.
16. Disconnect the hydrogen cylinder from PRV4B.
17. OPEN MV1 and MV5.
18. Confirm the following valve line-up on the gas panel:

    OPEN: MV1, MV5
    LOCKED OPEN: MV6A, MV6B
    CLOSED: MV2, MV3, MV4A, MV4B

A3. Add gas to a COLD system

This procedure should NOT be performed without specific authorization from a Target Group scientist (Chris Keith, Dave Meekins or Josh Pierce).

1. Connect a hydrogen cylinder to regulator PRV4B. Make sure the valve on the cylinder is CLOSED and PRV4B is set to ZERO pressure.
2. CLOSE MV1, MV2 and MV5. Note that the target is still open to storage tanks A and B via check valve CV2.
3. Turn ON pump MP3 and wait until vacuum gauge PI3 reaches 100 mtorr or less.
4. OPEN MV3 and MV4B and pump until PI3 reaches 100 mtorr or less.
5. CLOSE MV3 and MV4B.
6. OPEN the valve on the hydrogen cylinder and set regulator PRV4B to 20 psig.
7. OPEN MV4B to purge the line with hydrogen.
8. CLOSE MV4B.
9. Repeat steps 4 through 8 (omit step 6) for a total of FOUR times.
10. OPEN MV1 and MV5.
11. OPEN MV4B and fill the system with hydrogen gas to the desired pressure, as indicated by PI1. This pressure should be about 18 psia for a subcooled liquid hydrogen target.
12. CLOSE MV4B. CLOSE the cylinder valve, set the regulator to ZERO pressure and CLOSE the regulator valve.
13. CLOSE MV1 and MV5.
14. OPEN MV3 and MV4B. Pump until PI3 reached 100 mtorr or less.
15. CLOSE MV3 and MV4B. Turn off vacuum pump MP3.
16. OPEN MV1 and MV5.
17. Disconnect the hydrogen cylinder from PRV4B.
18. Confirm the following valve line-up on the gas panel:

    OPEN: MV1, MV5
    LOCKED OPEN: MV6A, MV6B
    CLOSED: MV2, MV3, MV4A, MV4B

NOTE: The hydrogen pressure should be closely monitored when the target is warmed. The system is protected against over pressurization by relief valves RV2A and RV2B, as well as RV6A and RV6B.

A4. Hydrogen removal and inert gas fill.

Use this procedure when it is desired to remove hydrogen from the system at the end of the run. This must be performed on a WARM target (>100 K). Pumping on a cold system can potentially freeze hydrogen inside the condenser, and inert gases like argon and nitrogen freeze at temperatures below 90 K. It is preferred NOT to use HELIUM as the inert gas, since diffusion through the kapton target cell will interfere with future leak checks on the vacuum chamber.

1. Connect a cylinder of dry, inert gas (nitrogen or argon) to regulator PRV4A. Do NOT use HELIUM. CLOSE the cylinder valve and set PRV4A to ZERO pressure.
2. OPEN MV1, MV2, MV4A, and MV5.
3. If you wish to remove hydrogen from the tanks, OPEN MV6A and MV6B. If you wish to keep the hydrogen in the tanks, CLOSE MV6A and MV6B, and LOCK them CLOSED.
4. Turn ON vacuum pump MP3 and OPEN MV3. Pump until the vacuum gauge PI3 reads 100 mtorr or less. Both gauges PI1 and PI2 should read ZERO.
5. CLOSE MV2, MV3 and MV4A. Turn OFF MP3.
6. OPEN the cylinder valve and set regulator PRV4A to 20 psig.
7. OPEN MV4A until the system pressure (PI1 and PI2) reads about 18 psia.
8. CLOSE MV4A.
9. Set PRV4A to ZERO pressure, CLOSE the cylinder valve and CLOSE the regulator valve.

The system is now filled with inert gas.

A5. List of Qualified Personnel

Additional personnel can be added to this list by: Chris Keith.

James Brock
Chris Keith
Dave Meekins
Josh Pierce