GRAVITY PROBE B
PROCEDURE FOR
SCIENCE MISSION DEWAR

Reduce Liquid Level in Main Tank
(Liquid Subatmospheric)

To be performed at Vandenberg Air Force Base building 1610

This document contains non-hazardous operations

P1035
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REVISION RECORD

REVISION	ECO	PAGES	DATE

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List of Abbreviations and Acronyms

AG-x	Gauge x of Gas Module auxiliary section	MTVC	Main Tank Vent Cap
AMI	American Magnetics Inc.	MTVC-G	Main Tank Vent Cap pressure gauge
ATC	Advanced Technology Center	MTVC-RV	Main Tank Vent Cap relief valve
APR-x	Pressure regulator x of Gas Module	MTVC-V	Main Tank Vent Cap valve
AV-x	Valve x of Gas Module auxiliary section	NBP	Normal boiling point
CG-x	Gauge x of portable helium pressurization source	ONR	Office of Naval Research
CPR-x	Pressure regulator x of portable helium pressurization source	PFCG	Fill Cap assembly pressure Gauge
CV-x	Valve x of portable helium pressurization source	PFM	Pump equipment Flow Meter
CN [xx]	Data acquisition channel number	PG-x	Gauge x of Pump equipment
DAS	Data Acquisition System	PM	Pump Module
EFM	Exhaust gas Flow Meter	psi	pounds per square inch
EG-x	Gauge x of Gas Module exhaust section	psig	pounds per square inch gauge
EM	Electrical Module	PTD	Payload Test Director
ERV-x	Relief valve of Gas Module exhaust section	PV-x	Valve x of the Pump equipment
EV-x	Valve number x of Gas Module exhaust section	QA	Quality Assurance
FCV	Fill Cap Valve	RAV-x	Remote Actuated Valve-x
FIST	Full Integrated System Test	RGA	Residual Gas Analyzer
GHe	Gaseous Helium	SMD	Science Mission Dewar
GM	Gas Module	STV	SMD Thruster vent Valve
GP-B	Gravity Probe-B	SU	Stanford University
GSE	Ground Support Equipment	SV-x	SMD Valve number x
GT	Guard Tank	TG-x	Gauge x of Utility Turbo System
GTVC	Guard Tank Vent Cap	TV-x	Valve x of Utility Turbo System
GTVC-G	Guard Tank Vent Cap pressure gauge	UTS	Utility Turbo System
GTVC-RV	Guard Tank Vent Cap relief valve	Vac	Vacuum
GTVC-V	Guard Tank Vent Cap valve	VCP-x	Vent cap pressure gauge
GTV-G	Guard Tank vent pressure gauge	VCRV-x	Vent cap relief valve
GTV-RV	Guard Tank vent relief valve	VCV-x	Vent cap valve
GTV-V	Guard Tank vent valve	VDC	Volts Direct Current
HX-x	Vent line heat exchanger in Gas Module	VF-x	Liquid helium Fill line valve
KFxx	Quick connect o-ring vacuum flange (xx mm diameter)	VG-x	Gauge x of Vacuum Module
LHe	Liquid Helium	VM	Vacuum Module
LHSD	Liquid Helium Supply Dewar	VV-x	Valve x of Vacuum Module

LLS	Liquid level sensor
LM	Lockheed Martin Co.
MT	Main Tank
VW-x	Valve x of Dewar Adapter

LIST OF SPECIFIC HEADING DEFINITIONS

Each type of alert message will precede the procedural step to which it applies

1. NOTE: Used to indicate an operating procedure of such importance that it must be emphasized
2. CAUTION: Used to identify hazards to equipment
3. WARNING: Used to identify hazards to personnel

A. SCOPE

This procedure describes the steps necessary to reduce the liquid helium level in the Main Tank of the Science Mission Dewar when the liquid is subatmospheric. Two methods are provided:

1. An isothermal method in which only enough heat is added to maintain a constant liquid temperature of 1.7 K (this method is intended for small adjustments)
2. A second method in which the liquid is warmed to approximately 3.4 K (to take advantage of better pumping speed), boiled away isothermally, then repumped to 1.7 K.

The steps include:

Switch Pumping of Main Tank to Pump Module (if necessary)

Turn on Main Tank heater

Reduce liquid level

Turn off Main Tank heater

Return pumping to Gas Module.

The Guard Tank may contain liquid or be depleted.

B. SAFETY

B.1. Potential Hazards

Personal injury and hardware damage can result during normal positioning, assembly and disassembly of hardware.

Liquid helium used in the SMD represents a hazardous material for the personnel involved in the operations. Cryogenic burns can be caused by contact with the cold liquid or gas, high pressures can result if boiling liquid or cold gas is confined without a vent path, and asphyxiation can result if the vent gas is allowed to accumulate.

The SMD Safety Compliance Assessment, document GPB-100153C and the Missile System Prelaunch Safety Package LM/P479945, discuss the safety design, operating requirements and the hazard analysis of the SMD..

B.2. Mitigation of Hazards

B.2.1. Lifting hazards

There are no lifting operations in this procedure

B.2.2. Cryogenic Hazards

In VAFB building 1610, the GP-B cryogenic team provides an oxygen deficiency monitor that alarms when the oxygen level is reduced to 19.5%. Additional temperature and pressure alarms, provided by the DAS, warn of potential over-pressure conditions. Emergency vent lines are installed over the four burst disks to direct any flow to an outside area.

Only authorized and trained personnel are allowed in VAFB facilities without escort. All personnel working on platforms at a height 30 inches or more off the floor are required to have an approved air tank (emergency breathing apparatus) within easy reach. Note that tank need not be kept available when working from ladder. In the unlikely event of a large LHe spill all employees have been instructed to evacuate the room and contact NASA safety.

The following additional requirements apply to all personnel involved directly in cryogenic operations. Gloves that are impervious to liquid helium and liquid nitrogen are to be worn whenever the possibility of splashing or impingement of high-velocity cryogens exists or when handling equipment that has been cooled to cryogenic temperatures. Protective clothing, non-absorbent shoes and full-face shields with goggles/glasses are to be worn whenever the possibility of splashing cryogens exists..

B.2.3. Other Hazards

All tools or other items used with the potential to damage the SMD or Probe shall be tethered.

B.3. Mishap Notification

B.3.1. Injury

In case of any injury or illness requiring emergency medical treatment **DIAL 911**

B.3.2. Hardware Mishap

In case of an accident, incident, or mishap, notification is to proceed per the procedures outlined in Lockheed Martin Engineering Memorandum EM SYS229 and Stanford University GP-B P0879. Additionally, VAFB NASA Safety and 30th Space Wing Safety will be notified as required.

B.3.3. Contingency Response

1. Responses to contingencies/emergency (e.g., power failure) are listed in Appendix 3.

C. QUALITY ASSURANCE

C.1. QA Notification

The NASA program and the NASA safety representative and SU QA shall be notified 24 hours prior to the start of this procedure. Upon completion of this procedure, the QE Manager will certify his/her concurrence that the effort was performed and accomplished in accordance with the prescribed instructions by signing and dating in the designated place(s) in this document.

C.2. Red-line Authority

Authority to red-line (make minor changes during execution) this procedure is given solely to the TD or his designate and shall be approved by the QA

Representative. Additionally, approval by the Payload Technical Manager shall be required, if in the judgement of the TD or QA Representative, experiment functionality may be affected

C.3. Discrepancies

A Quality Assurance Representative designated by D. Ross shall review any discrepancy noted during this procedure, and approve its disposition. Discrepancies will be recorded in a D-log or a DR per Quality Plan P0108. Any time a procedure calls for verification of a specific configuration and that configuration is not the current configuration, it represents a discrepancy of one of three types. These types are to be dealt with as described below.

1. If the discrepancy has minimal effect on procedure functionality (such as the state of a valve that is irrelevant to performance of the procedure) it shall be documented in the procedure, together with the resolution. Redlines to procedures are included in this category.
2. If the discrepancy is minor and affects procedure functionality but not flight hardware fit or function, it shall be recorded in the D-log. Resolution shall be in consultation with the PTD and approved by the QA representative.
3. All critical and major discrepancies, those that effect flight hardware fit or functions, shall be documented in a D-log and also in a Discrepancy Report, per P0108.

D. TEST PERSONNEL

D.1. Personnel Responsibilities

The performance of this procedure requires a minimum complement of personnel as determined by the Test Director. The person performing the operations (Test Director or Test Engineer) is to sign the “Completed by” sign-off. Any other qualified person or QA person who can attest to the successful performance of this procedure may sign the “Witnessed by” sign-off. The Test Director will perform Pre-Test and Post-Test Briefings in accordance with P0875 “GP-B Maintenance and Testing at all Facilities.” Checklists will be used as directed by P0875.

D.2. Personnel Qualifications

The Test Director must have a detailed understanding of all procedures and facility operations and experience in all of the SMD operations. Test Engineers must have SMD Cryogenic operations experience and an understanding of the operations and procedures used for the cryogenic servicing/maintenance of the Dewar.

D.3. Qualified Personnel

The following personnel are essential to the accomplishment of this procedure:

FUNCTIONAL TITLE	NUMBER	AFFILIATION
Test Director/Test Engineer	1	Stanford
GP-B Quality Assurance	1	Stanford

E. REQUIREMENTS

E.1. Electrostatic Discharge Requirements

When working on the space vehicle, proper ESD protection is required. Prior to use all wrist straps will be checked using a calibrated checker.

E.2. Lifting Operation Requirements

There are no lifting operations in this procedure

E.3. Hardware/Software Requirements

E.3.1. Ground Support Equipment

The Ground Support Equipment includes the Gas Module, the Electrical Module. The Gas Module provides the capability to configure vent paths, read pressures and flow rates, and pump and backfill vent lines. The Pump Module provides greater pumping capacity than the Gas Module, together with additional flow metering capabilities. The vent output of the Gas Module flows through the Pump Module. The Electrical Module contains the instruments listed in Table 1, and provides remote control of valves in the Gas Module, Pump Module, and SMD.

E.3.2. Computers and Software:

The Data Acquisition System (DAS) is required for this procedure. The DAS reads and displays pressures, temperatures, and flow rates and monitors critical parameters. No additional computers or software are required.

E.3.3. Additional Test Equipment

No additional test equipment is required.

E.3.4. Additional Hardware

No additional hardware is required

E.3.5. Tools

No tools are required.

E.3.6. Expendables

WARNING

Alcohol is a skin irritant, potentially toxic if skin absorbed, and flammable. All hazardous waste will be placed into approved waste containers.

Description	***Quantity***	***Mfr./Part No.***
Alcohol	AR	N/A
99.999% pure gaseous helium	AR	N/A

Vacuum Grease	AR	Dow Corning High Vacuum or Apiezon N

E.4. Instrument Pretest Requirements

The GSE instruments required to perform this procedure are listed in Table 1, together with their serial numbers, where available. Instruments that are required to have current calibrations are indicated in the Cal-Required column. Instruments that do not require calibration are those not used to verify performance requirements and are not connected to flight instrumentation. The status column is to be filled in with the due date of the instrument calibration sticker and verified to be in calibration by QE or QE designee. Serial numbers are to be updated as appropriate.

Table 1. Required Instrumentation and Calibration Status

No.	*Location*	*Description*	*Name*	*Serial No.*	*Cal Required*	*Status Cal due date*
1	DAS	Power Supply, H-P 6627A	-	3452A01975	Yes	
2	DAS	Power Supply, H-P 6627A	-	3452A01956	Yes	
3	DAS	Data Acquisition/Control Unit H-P 3497A	-	2936A245539	No	-
4	DAS	Digital Multimeter H-P 3458A	-	2823A15047	Yes	
5	EM	Vacuum Gauge Controller Granville-Phillips Model 316	EG-1a, -1b	2827	No	-
6	EM	Vacuum Gauge Controller Granville-Phillips Model 316	AG-2a, -2b	2826	No	-
7	EM	Vacuum Gauge Controller Granville-Phillips Model 316	EG-3	2828	No	-
8	EM	MKS PDR-C-2C	EG-2, FCG	92022108A	No	-
9	EM	Flow meter Matheson 8170	EFM-1	96186	No	-
10	EM	Flow meter totalizer Matheson 8124	EFM-1	96174	No	-
11	EM	Liquid Helium Level Controller American Magnetics, Inc. 136	LLS Main Tank	96-409-11	No	-
12	EM	Liquid Helium Level Controller American Magnetics, Inc. 136	LLS Guard Tank	96-409-10	No	-
13	EM	Liquid Helium Level Controller American Magnetics, Inc. 136	LLS Well	96-409-9	No	-
14	EM	Liquid Helium Level Controller American Magnetics, Inc. 136	LLS Axial Lock	96-409-12	No	-
15	EM	Pressure Controller, MKS 152F-92	EV-7a, -7b	96203410A	No	-
16	EM	Power Supply HP 6038A	H08D Tank Heater	96023407A	Yes	
17	EM	Power Supply HP 6038A	H09D Tank Heater	3511A-13332	Yes	
18	EM	Power Supply HP 6038A	RAV Power Supply	3329A-12486	Yes	
19	EM	Vac Ion Pump power supply Varian 929-0910, Minivac	SIP	5004N	No	-
20	EM	Flow meter totalizer	PFM-1	576013-716	No	-

No.	*Location*	*Description*	*Name*	*Serial No.*	*Cal Required*	*Status Cal due date*
		Veeder-Root				
21	GM	Pressure Gauge, Heise	AG-1	CC-122077	No	-
22	GM	Pressure Gauge, Marshall Town	AG-3	N/A	No	-
23	GM	Main Tank Heat Exchanger: a) Thermocouple, b) Current meter, c) Temperature set point controller	-	C-19950	No	-
24	GM	Guard Tank Heat Exchanger: a) Thermocouple, b) Current meter, c) Temperature set point controller	-	C-09920	No	-
25	VM	Vacuum Gauge readout, Granville-Phillips 316	VG-3 VG-4	2878	No	-
26	VM	Vacuum Gauge readout, Granville-Phillips 360	VG-1 VG-2 VG-5	96021521	No	-

E.5. Configuration Requirements

E.5.1. Main Tank

Liquid in the Main Tank must be subatmospheric. The Actuator Control valve for EV-9 must be in the “Subatm He” position. This valve ensures that EV-9 fails closed in the event of a power failure.

E.5.2. Guard Tank

The Guard-Tank may contain liquid, or be depleted. Whenever it is depleted its pressure must be independently regulated to maintain it at a positive value relative to the atmosphere and continuously monitored. Monitoring is accomplished by placing the relative pressure, as read at the Guard Tank Vent Valve Assembly (GTV-G), on the DAS alarm list. The pressure is kept positive by maintaining liquid in the tank and applying heat to the Guard Tank as necessary or supplying a source of He gas for independent regulation.

E.5.3. Well

The Well is evacuated whenever the Main Tank is subatmospheric.

E.5.4. SMD Vacuum Shell

The Vacuum Shell pressure must be less than 5×10^{-5} torr. Document No. P1015, contains the procedure for connecting to and pumping on the SMD vacuum shell.

E.5.5. Alarm System

1. The DAS alarm system must be enabled and contain the following alarm set-points:
    a. Top of lead bag temperature set (CN 175 and CN 178) at $T \leq 6.0$ K.
    b. Relative Guard Tank Pressure (CN 46) set at $\Delta P \geq 0.3$ torr.

E.5.6. GSE and Non-flight Hardware

1. The ion-pump magnet is installed.
2. The Main Tank vent line must be connected to the Gas Module with a vacuum insulated line (P/N 5833806). Document No. P1004, *Connect Main Tank Vent Line to Gas Module – Main Tank Subatmospheric*, contains the procedures for connecting vent lines.
3. If the Guard Tank contains liquid, the Guard Tank vent line must be connected to the Gas Module with a vacuum insulated line (P/N 5833813). Procedure P1008, *Connect Guard Tank Vent Line to Gas Module*, contains the steps for connecting the GT vent line.
4. The dewar Top Plate and Main Tank Vent Bayonet heaters must be operational.

E.6. **Optional Non-flight Configurations**

The following modifications or non-flight arrangement of the basic SMD configuration may also be in place. They are incidental to the performance of this procedure and not required.

1. The SMD is installed in its transportation and test fixture.
2. The Vacuum shell pump out port at SV-14 may be connected to the Vacuum Module (P/N 5833816) via a 2-in valve and pumping line, with the valve in either the closed position or in the open position. The Vacuum Module pump may be off, actively pumping the pumping line up to a closed SV-14, or actively pumping the vacuum shell.
3. The Fill Cap Assembly may be installed at SV-13

F. REFERENCE DOCUMENTS

F.1. Drawings

Drawing No.	*Title*
LMMS-5833394	Instrumentation Installation

F.2. Supporting Documentation

Document No.	*Title*
LMMC-5835031	GP-B Magnetic Control Plan
GPB-100153C	SMD Safety Compliance Assessment
LM/P479945	Missile System Prelaunch Safety Package
SU/GP-B P0141	FIST Emergency Procedures
LMSC-P088357	Science Mission Dewar Critical Design Review
SU/GP-B P0108	Quality Plan
LMMS GPB-100333	Science Mission Dewar Failure Effects and Causes Analysis
SU/GP-B P059	GP-B Contamination Control Plan
EM SYS229	Accident/Mishap/Incident Notification Process
EWR 127-1	Eastern and Western Range Safety Requirements
KHB 1710.2 rev E	Kennedy Space Center Safety Practices Handbook

F.3. Additional Procedures

Document No.	*Title*
SU/GP-B P0879	Accident/Incident/Mishap Notification Process
SU/GP-B P1015	Connect Vacuum Module to SMD
SU/GP-B P0875	GP-B Maintenance and Testing at all Facilities

Operation Number:_____

Date Initiated:_____

Time Initiated:_____

G. OPERATIONS

G.1. Verify Appropriate QA Notification

- Verify SU QA notified.

  Record: Individual notified _____,

  Date/time _____/_____.

- Verify NASA program representative notified.

  Record: Individual notified _____,

  Date/time _____/_____.

- Record calibration due dates in Table 1 (Sections. E.3.4, E.4)
- Persons actually performing this procedure should list their names in Sec D.3.
- Verify completion of the pre-operations checklist (Appendix 1).
- Verify proper operation of GP-B Cryogenic Team oxygen monitor
- Verify availability and functioning of emergency shower.

G.2. Verify Configuration Requirements

G.2.1. Verify Dewar Top Plate heaters are operational.

G.2.2. Verify Actuator Control for EV-9 is in “Subatm He” position.

G.2.3. Verify liquid in Main Tank is subatmospheric (< 4K) and record temperature at bottom of tank CN [09] _____K.

G.2.4. Verify ion-pump magnet installed.

G.2.5. Verify Vacuum Shell Pressure < 5 x 10^{-5} torr.

1. Turn on Vac-ion pump and record time of day _____
2. Use DAS [Monitor Data] for CN 99.
3. When value is steady, record pressure (IP) _____ torr. If pressure is above 5x10^{-5} torr, turn off Vac-ion pump and perform procedure P1015 to connect Vacuum Module and pump out SMD vacuum shell.
4. Exit [Monitor Data] and collect data with [Set Data Interval] to 5 min.
5. When data cycle is complete, turn off Vac-ion pump.

G.2.6. Ensure DAS watchdog timer and alarm enabled.

G.2.7. Verify DAS alarm system enabled and record set points.

1. ***Top of lead bag temperatures*** – verify CN [175 and 178] on DAS alarm list and set to alarm at $T \leq 6.0$ K. Record set point. _____K
2. ***Relative Guard Tank Pressure*** – verify CN [46] on DAS alarm list and set to alarm at $\Delta P \geq 0.3$ torr. Record set point. _____torr

G.2.8. Verify liquid-level alarms enabled and record set points.

1. ***Main Tank*** – ensure liquid-level alarm set ≥ 20%. Record set point. _____%
2. ***Guard Tank*** – ensure liquid-level alarm set ≥ 20%, if there is liquid in the Guard Tank. Record set point. _____%

G.2.9. Record liquid helium levels:

1. ***Main Tank*** _____%
2. ***Guard Tank*** – _____%

G.3. **Establish Initial Condition of SMD**

G.3.1. Using the RAV log book verify that the dewar's internal valves are in the following positions. If not, investigate to verify previous RAV operations properly recorded. If necessary, note resolution in D-log.

1. ***Open***: RAV-3, and RAV-6B.
2. ***Closed***: RAV-1, RAV-2, RAV-5, RAV-6A, and RAV-7.

G.3.2. Verify that SMD external valves are in the following positions.

1. ***Open***: SV-9.
2. ***Closed***: SV-13 and FCV.

G.4. **Establish GSE Valve Configuration and Record Pressures**

G.4.1. Set GSE valves as indicated in following Table. Record configuration in left-hand column, then place or ensure corresponding valve states as indicated.

Configure Initial Valve States		
	Verify Open	***Verify Closed***
Main Tank vent		
o Pumping w/ AP-1	EV-7a/b (varies), EV-10, EV-17, AV-6 PV-2, PV-4	EV-4, EV-5, EV-6, EV-8, EV-9, EV-11, EV-12, EV-14, EV-15, EV-16, EV-18, EV-19, EV-21/22 All AV valves except AV-6 PV-1, PV-3, PV-5, PV-6
o Pumping w/ PP-1/PP-2	EV-4, EV-7a/b (varies), EV-10, EV-17, EV-21/22, PV-1, PV-2, PV-3, PV-4	EV-5, EV-6, EV-8, EV-9, EV-11, EV-12, EV-14, EV-15, EV-16, EV-18 EV-19 All AV valves PV-5, PV-6
Guard Tank vent		
o Connected to GM with liquid	EV-13, GTV-V	EV-20, EV-23, EV-24, GTV-Va
o Connected to GM, depleted and pressure regulated at EV-23	EV-23, GTV-V APR-2 (set to 1 psig)	EV-13, EV-20, EV-24 GTV-Va
o Not connected to GM, depleted and pressure regulated at GTV-Va	GTV-Va, APR-3V, APR-3 (set to 1 psig)	EV-13, EV-20, EV-23, EV-24 GTV-V, GTVC-V GTVC-Fill Vent

G.4.2. If Guard Tank depleted:

Verify source of 99.999% pure helium gas available at appropriate regulator .

G.4.3. Record Guard Tank pressure (GTV-G) _____ torr (relative to atm).

G.4.4. Record Main Tank pressure (EG-3) _____ torr.

G.5. **Set Up Data Acquisition**

G.5.1. Set the Main Tank liquid level sampling interval to 1 minute.

G.5.2. Input comment to DAS “start reduction of Main Tank liquid level”.

G.6. **Transfer Pumping to Pump Module.**

- o Already pumping with Pump Module, skip this section.
- o Currently pumping with AP-1, perform this section.

G.6.1. Verify that PV-2 is open.

G.6.2. If PP-1, and PP-2 are off, perform the following:

1. Close/verify closed PV-3.
2. Verify on/turn on cooling water to pump module and verify that the flow rate is 0.5 gal./min. for each pump.
3. Turn on rotary vane pump PP-2
4. Open PV-1.
5. Turn on PP-1.
6. Verify operation of pumps. Record pressure at PG-1: _____.
7. Open PV-3 when PG-1 reads <1 torr.

G.6.3. Record positions of EV-7a _____ % open and EV-7b _____ % open.

G.6.4. Open EV-7a 100%.

G.6.5. Open EV-21 and EV-4.

G.6.6. Close AV-6

G.6.7. Open/verify open PV-4

G.6.8. Close/verify closed PV-5 and PV-6.

G.7. **Reduce Main Tank Liquid Level (Maintain Current Temperature)**

- o Only making minor adjustments to level, perform this section.
- o Desire to make major level corrections, skip this section.

G.7.1. Specify desired final helium level in Main Tank: _____%

Note:

Heaters H09D and H08D are designed for 1.25 A and 52 VDC (40 ohms) per the SMD CDR [Ref. 4]. Heater power supplies should be operated in the voltage-limited mode.

It is desirable to maintain the Main Tank temperature constant throughout level reduction. To accomplish this the boiloff rate must match the pumping throughput. The Pump Module pumps (PP-1 and PP-2) provide a nominal maximum pumping speed of 20 standard liters per minute (see data file 9905140.PCD) when pumping on the 1.8 K bath. (This will remove liquid at the rate of 1.5 liter/hour or 1.5%/day.) Using this as the maximum allowable constant-temperature boiloff rate implies a heat input requirement of 1.4 W to the Main Tank. The steady-state heat leak into the Main Tank is on the order of 0.4 W. In

the following steps, then, the initial voltage set point for the Main Tank heater provides a heat input of 1 W.

G.7.2. Turn on Main and Guard Tank vent-line heat exchangers (EH-1, EH-2).

G.7.3. Record data in attached Data Sheet and continue recording every 15 minutes.

G.7.4. Turn on Main Tank Heater (H08D or H09D):

1. Set power supply current limit to 1.25 amp.
2. Set voltage of heater H09D to 6.3 Vdc and record:
   a. Time of Day: _____
   b. Voltage _____ Vdc Current _____ A

G.7.5. Throughout the MT level reduction, adjust heater voltage as appropriate to maintain constant Main Tank temperature at CN [09].

CAUTION
Monitor and maintain positive Guard Tank pressure. If the Guard Tank pressure (GTV-G) drops below atmospheric pressure (0.0 torr) perform the following option to turn on heater H03D and add heat to the Guard Tank. Failure to comply may result in hardware damage

G.7.6. **(Option)** Turn on Guard Tank Heater H03D to maintain positive Guard Tank pressure:

1. Turn on power supply for Guard-Tank heater (H-3D or H-4D)
2. Set power supply current limit to 0.07 amps.
3. Set voltage limit to 50 VDC and record:

   V _____Vdc and I _____A.

4. Adjust heater voltage as necessary to maintain Guard Tank pressure (GTV-G). in the range 15 torr < ΔP < 30 torr.
5. Monitor and maintain positive Guard Tank pressure throughout the pump-down. Record data on attached data sheets.

G.7.7. When Main Tank liquid level sensor reads desired level record:

1. Time of day:_____
2. Main Tank bottom temperature CN [09] _____ K

G.7.8. Turn off power supply (H-8D and H-9D) to Main Tank heater(s).

G.7.9. Turn off Main and Guard Tank vent-line heat exchangers (EH-1, EH-2).

G.8. **Reduce Main Tank Liquid Level (Raise Temperature, Boil Off, Repump)**

- o Desire to make substantial level corrections, perform this section.
- o Only making minor adjustments to level, skip this section.

G.8.1. Specify desired final helium level in Main Tank: _____%

Note:

The Main Tank heaters H09D and H08D are designed for 1.3 A and 52 VDC (40 ohms) per the SMD CDR [Ref. 4]. Set points of 50 VDC and 1.25 A result in approximately 60 W of heat being deposited in the Main Tank.

The Main-Tank vent-line heat exchanger in the Gas Module has a maximum throughput of approximately 2.6 g/s, above which it begins to ice up. This maximum flow rate occurs at pressures above about 315 torr, corresponding to a temperature of 3.4 K.

G.8.2. Stop pumping on Main Tank.

1. Record position of
    a. EV-7a _____ % open
    b. EV-7b _____ % open.
2. Close SV-9
3. Close EV-4 and EV-21
4. Verify closed EV-22

G.8.3. Add heat to raise Main Tank temperature to 3.4 K.

Note:

The heat required to raise the temperature of liquid helium from 1.7K to 3.4 K is 845 J/L. Assuming 2300 liters in the Main Tank, it will require 1.94 MJ to raise the temperature to 3.4 K from 1.7K. Using both Main Tank heaters at near full capacity (60 W each for a total of 120 W) will raise the temperature in approximately 5 hours, provided the Main Tank is valved off from the Pump Module during this time.

CAUTION

Lead bag temperatures must be carefully monitored while heating the Main Tank. This is especially true if the GT is empty, as there is then no vent cooling. Failure to comply may result in equipment damage.

1. Turn on Main Tank Heaters (H08D and H09D):
    a. Set power-supply current limits to 1.25 amp.
    b. Set voltages to 60 Vdc:
    c. Record time of Day: _____

d. Record for heater H08D

Voltage _____ Vdc Current _____ A

e. Record for heater H09D

Voltage _____ Vdc Current _____ A

G.8.4. When the temperature reaches 3.4 K, resume pumping on Main Tank with Pump Module.

Note:

This provides a boiloff rate of 2.6 g/s (latent heat at 3.4 K = 23.2 kJ/kg, max pump speed to stay within capacity of GM vent line heat exchanger.

1. Turn on Main and Guard Tank vent-line heat exchangers (EH-1 and EH-2).
2. Adjust throttling valves EV-21 and EV-7a/b to full open positions.
3. Open EV-4 and SV-9.
4. Adjust Main Tank heaters to 60 W total

Note:

60 W provides a boiloff rate of 2.6 g/s (latent heat at 3.4 K = 23.2 kJ/Kg, max pump throughput is 2.6 g/s to stay within capacity of GM vent line heat exchanger).

a. Set power supply voltages for heaters H08D and H09D to 60 Vdc:

b. Record time of Day: _____

c. Record heater settings

H08D: Voltage _____ Vdc Current _____ A

H09D: Voltage _____ Vdc Current _____ A

5. Record data in Data Sheet and continue recording every 15 min.
6. Continue to heat and pump to reduce liquid to appropriate intermediate level.

Note:

The appropriate intermediate level is determined by the final temperature and final liquid level desired. The following table gives the appropriate intermediate level as a function of the desired final temperature when the starting pumpdown temperature is 3.4 K and a final level of 48% is desired.

Desired Final Temperature	***Appropriate intermediate level for final level of 48%***
1.9	63.2
1.8	64.0

1.7	64.7
1.6	65.2

7. Throughout the MT level reduction, adjust heater voltage as appropriate to maintain constant Main Tank temperature of 3.4 K at CN [09].

CAUTION
Monitor and maintain positive Guard Tank pressure. If the Guard Tank pressure (GTV-G) drops below atmospheric pressure (0.0 torr) perform the following option to turn on heater H03D and add heat to the Guard Tank. Failure to comply may result in equipment damage

8. (Option) Turn on Guard Tank Heater H03D to maintain positive Guard Tank pressure:
    a. Turn on power supply for Guard-Tank heater (H-3D or H-4D)
    b. Set power supply current limit to 0.07 amps.
    c. Set voltage limit to 50 VDC and record:
    d. V _____Vdc and I _____A.
    e. Adjust heater voltage as necessary to maintain Guard Tank pressure (GTV-G). in the range 15 torr < ΔP < 30 torr.
    f. Monitor and maintain positive Guard Tank pressure throughout the pump-down. Record data on attached data sheets.

G.8.5. When Main Tank level reaches appropriate intermediate level
    1. Record Main Tank level _____ %
    2. Turn off heaters and continue pumping to desired temperature.

G.8.6. When desired temperature is reached, reset EV-7a/b to previous settings, as recorded in G.8.2.

G.9. **(Option) Return Pumping of SMD to Gas Module Pump**

G.9.1. Verify closed all AV valves.

G.9.2. Verify on/turn on AP-1.

G.9.3. Open AV-8.

G.9.4. When AG-2b < 50 mtorr proceed.

G.9.5. Open AV-6.

G.9.6. Close EV-4.

G.9.7. Shut down pump module

1. Close EV-21/-22.
2. Close PV-1.
3. Power down PP-1 and PP-2.
4. Close PV-3.

G.10. **Establish Final Configuration**

G.10.1. Verify GSE valves set as indicated in following Table. Record configuration in left-hand column, then ensure corresponding valve states are as indicated.

Configure Final Valve States		
	Verify Open	***Verify Closed***
Main Tank vent		
o Pumping w/ AP-1	EV-7a/b, EV-10, EV-17, AV-6 PV-2, PV-4	EV-4, EV-5, EV-6, EV-8, EV-9, EV-11, EV-12, EV-14, EV-15, EV-16, EV-18, EV-19, EV-21/22 All AV valves except AV-6 PV-1, PV-3, PV-5, PV-6
o Pumping w/ PP-1/PP-2	EV-4, EV-7a/b (varies), EV-10, EV-17, EV-21/22, PV-1, PV-2, PV-3, PV-4	EV-5, EV-6, EV-8, EV-9, EV-11, EV-12, EV-14, EV-15, EV-16, EV-18 EV-19 All AV valves PV-5, PV-6
Guard Tank vent		
o Connected to GM with liquid	EV-13, GTV-V	EV-20, EV-23, EV-24, GTV-Va
o Connected to GM, depleted and pressure regulated at EV-23	EV-23, GTV-V APR-2 (set to 1 psig)	EV-13, EV-20, EV-24 GTV-Va
o Not connected to GM, depleted and pressure regulated at GTV-Va	GTV-Va, APR-3V, APR-3 (set to 1 psig)	EV-13, EV-20, EV-23, EV-24 GTV-V, GTVC-V GTVC-Fill Vent

G.10.2. If Guard Tank depleted:

Verify source of 99.999% pure helium gas available at appropriate regulator.

G.10.3. Input comment to DAS “End Main Tank liquid level reduction”.

G.10.4. Set the DAS data cycle to 15 minutes.

G.10.5. Ensure that power to Vac-Ion pump is off.

G.10.6. Ensure that vent-line heat exchangers (EH-1, EH-2) are off.

G.10.7. Ensure Main Tank heaters are powered off (H-8D and H-9D).

G.10.8. Ensure DAS alarm enabled and record set points if changed

- Thermal conditions substantially unchanged, alarm set points for Station 200 and lead bag are unchanged and set to alarm.
- Thermal conditions substantially changed, temperature alarm points reset as follows:
  a. Station 200 set point CN [01] _____ K (≤ 6.5 K)
  b. Top of Lead Bag set point CN [28] _____ K (≤ 6.0 K)

G.10.9. Ensure liquid level sensor alarms enabled on Main Tank and Guard Tank and record set points if changed.

1. Main Tank Level Set Point _____%
2. Guard Tank, if it contains liquid Set Point _____%

CAUTION

The Guard Tank may tend to continue to subcool following the completion of this procedure. Establish continuous monitoring of the Guard Tank pressure by placing it on the DAS alarm list. Failure to comply may result in equipment damage.

G.10.10. Ensure Guard Tank pressure on DAS alarm list and set to alarm at 0.3 torr differential.

G.10.11. Ensure DAS watchdog timer and alarm enabled.

G.10.12. Continue to monitor and record data on data sheet for 30 minutes to ensure that system stabilizes.

H. PROCEDURE COMPLETION

Completed by:_____

Witnessed by:_____

Date: _____

Time:_____

Quality Manager_____**Date**_____

Payload Test Director_____**Date**_____

Data Sheet 1

										SMD External Temp. Control		
Date Time	M.T. bottom T-9D [9] (K)	Sta. 200 T-1D [1] (K)	Lead bag top T-20D [28] (K)	HX-1 T-03D [5] (K)	G.T. bottom T-15D [24] (K)	M.T. Pressure EG-3 [114] (torr)	G.T. Pressure EG-1 [112] (torr)	Main Tank Liquid level LL-1D [101] (%)	Main Tank Flow rate PFM-1 [110] LL/hr	M.T. Vent Bayonet /O-ring (^{o}C/ ^{o}C)	SV-9 Valve /Top Plate (^{o}C/ ^{o}C)	SV-9 Knob/ Top Plate Cylinder (^{o}C/ ^{o}C)

										SMD External Temp. Control		
Date Time	M.T. bottom T-9D [9] (K)	Sta. 200 T-1D [1] (K)	Lead bag top T-20D [28] (K)	HX-1 T-03D [5] (K)	G.T. bottom T-15D [24] (K)	M.T. Pressure EG-3 [114] (torr)	G.T. Pressure EG-1 [112] (torr)	Main Tank Liquid level LL-1D [101] (%)	Main Tank Flow rate PFM-1 [110] LL/hr	M.T. Vent Bayonet /O-ring (^{o}C/ ^{o}C)	SV-9 Valve /Top Plate (^{o}C/ ^{o}C)	SV-9 Knob/ Top Plate Cylinder (^{o}C/ ^{o}C)

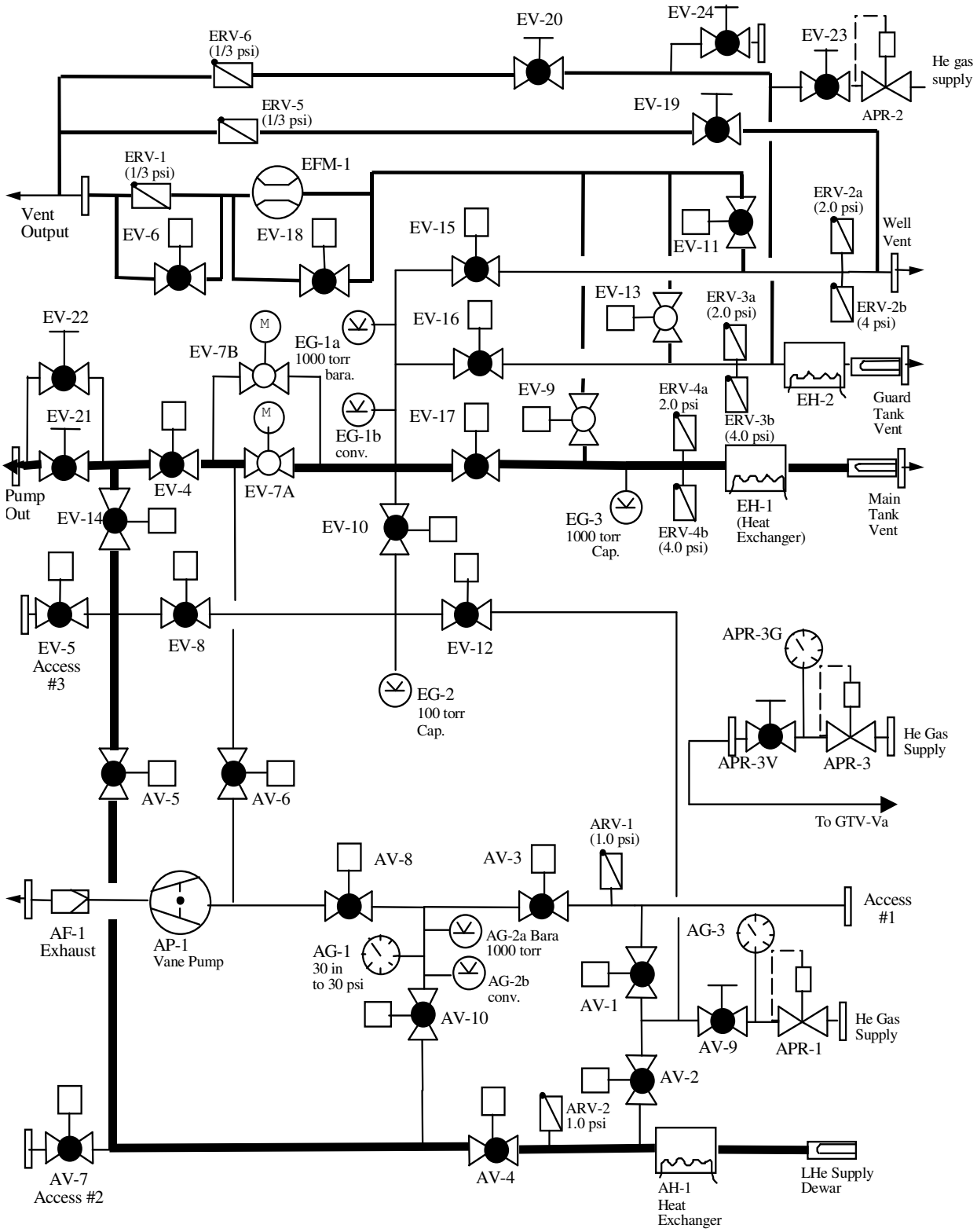

Figure 1. Schematic of Gas Module Plumbing.

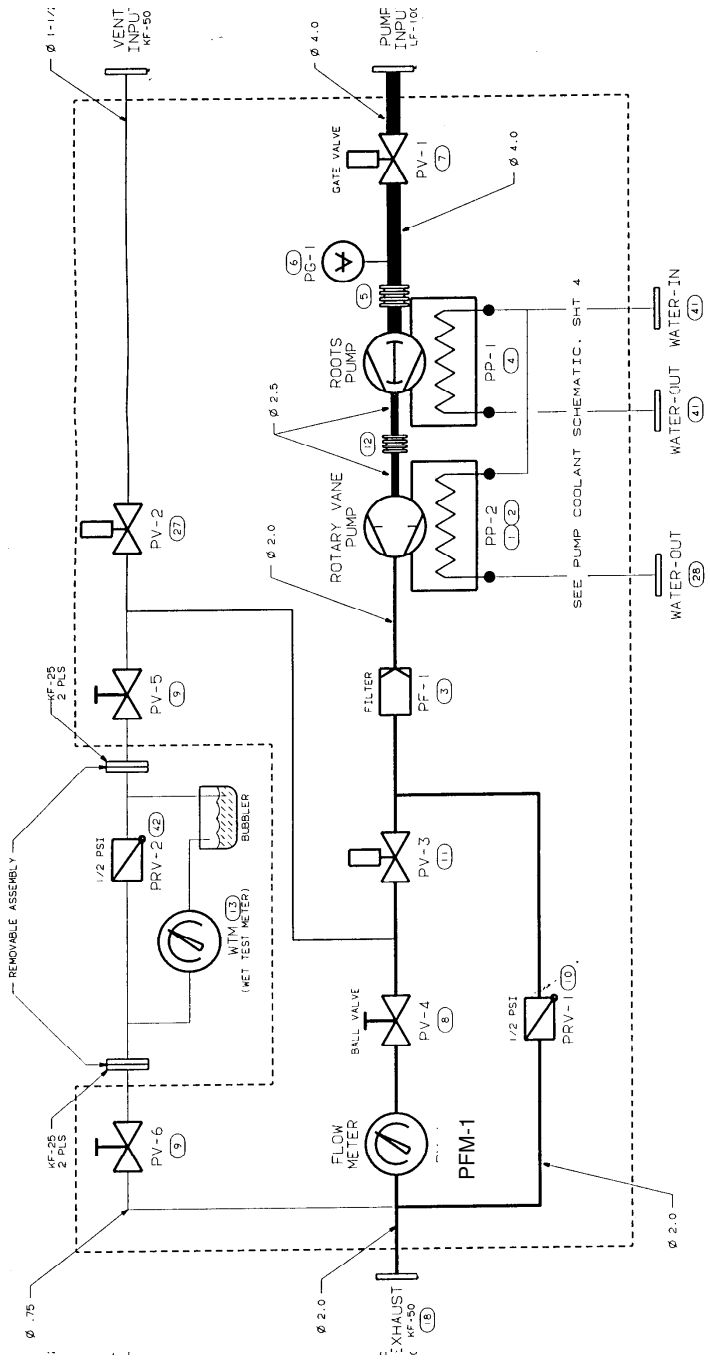

Figure 2. Schematic of Pump Module plumbing.

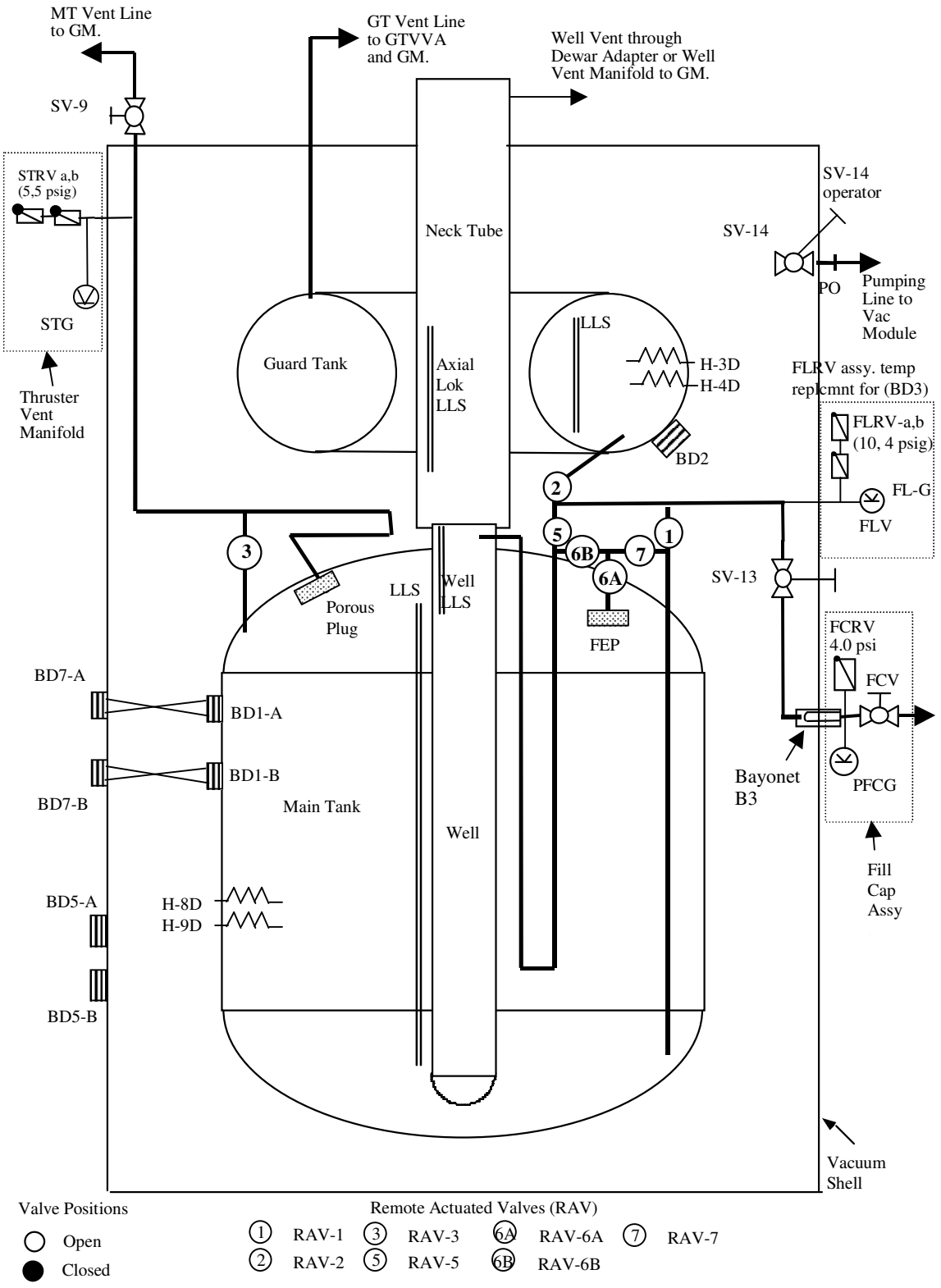

Figure 3. Schematic of Science Mission Dewar plumbing.

APPENDIX 1 PRE OPERATIONS CHECKLIST

DATE	CHECKLIST ITEM	COMPLETED	REMARKS
	1. Verify the test procedure being used is the latest revision.		
	2. Verify all critical items in the test are identified and discussed with the test team.		
	3. Verify all required materials and tools are available in the test area.		
	4. Verify all hazardous materials involved in the test are identified to the test team.		
	5. Verify all hazardous steps to be performed are identified to the test team.		
	6. Verify each team member is certified for the task being performed and knows their responsibilities.		
	7. Confirm that each test team member clearly understands that he/she has the authority to stop the test if an item in the procedure is not clear.		
	8. Confirm that each test team member clearly understands that he/she must stop the test if there is any anomaly or suspected anomaly.		
	9. Notify management of all discrepancy reports or d-log items identified during procedure performance. In the event an incident or major discrepancy occurs during procedure performance management will be notified immediately.		
	10. Verify/Perform engineering and safety high bay walk down. Ensure all discrepancies are corrected prior to procedure performance.		
	11. Confirm that each test team member understands that there will be a post-test team meeting.		
	Team Lead Signature: _____		

J. APPENDIX 2 POST OPERATIONS CHECKLIST

DATE	CHECKLIST ITEM	COMPLETED	REMARKS
	1. Verify all steps in the procedure were successfully completed.		
	2. Verify all anomalies discovered during testing are properly documented.		
	3. Ensure management has been notified of all major or minor discrepancies.		
	4. Ensure that all steps that were not required to be performed are properly identified.		
	5. If applicable sign-off test completion.		
	6. Verify all RAV valve operations have been entered in log book		
	7. Verify the as-run copy of procedure has been filed in the appropriate binder		
	Team Lead Signature: _____		

K. APPENDIX 3– CONTINGENCY/EMERGENCY RESPONSES

Condition	Circumstance	Response
Power Failure	Before Sec. G.5.2 (closure of SV-9)	Wait for power restoration, and resume procedure
Liquid nitrogen spill	Anytime	Clear area until all spilled liquid has evaporated.
Temperature limits (CN 29 or 28) exceeded	Any time	Close EV-17 (if open) and open EV-9. Crack open SV-9 to allow MT to vent. Adjust SV-9 as necessary to restore temperature(s) below alarm limits. Open EV-6 and EV-18 if higher flow rate is needed.
Burst disk rupture (MT/GT)	Any time	Evacuate room
Pressure in Main Tank exceeds limit	Any time	Open Main Tank vent valve
Oxygen monitor alarm	Any time	Evacuate