GRAVITY PROBE B
PROCEDURE FOR
SCIENCE MISSION DEWAR

Reduce Liquid Level in Main Tank
(Liquid Subatmospheric)

P0719 Rev-

June 20, 2001

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

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 Well is evacuated. 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. Examples include: positioning Dewar in tilt stand; integrating probe with airlock; positioning airlock on Dewar; removing airlock from Dewar; removing probe from Dewar; and positioning support equipment such as pressurized gas cylinders and supply dewars.

A number of undesired events may be associated with these operations. For example, personnel or equipment can be struck when hardware is being moved (e.g. by forklift or crane load). Personnel are subject to entrapment while positioning hardware, such as hands or feet caught between objects as hardware is moved into place. Suspended hardware may be dropped. Personnel can be caught between objects such as forklifts and walls or loads and building support columns.

In addition, 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 discusses 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

The FIST OPS laboratory has an oxygen deficiency monitor that alarms when the oxygen level is reduced to 19.5%. Prior to beginning this procedure in any facility other than the FIST OPS Lab, the presence of a similar oxygen monitor must be verified by safety and operations personnel. Additional temperature and pressure alarms, provided by the DAS, warn of potential over-pressure conditions. Emergency vent line deflectors are installed over the four burst disks on the SMD vacuum shell, and oxygen collection pans are on the floor beneath them.

The following requirements apply to personnel involved 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 and full-face shields are to be worn whenever the possibility of splashing cryogens exists.

The FIST Emergency Procedures document, SU/GP-B P0141, discusses emergency procedures. These documents should be reviewed for applicability at any facility where the hardware is operated.

B.2.3. Other Hazards

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

B.2.4. Injuries

In case of any injury obtain medical treatment as follows
LMMS **Call 117;** Stanford University **Call 9-911**

C. **QUALITY ASSURANCE**

C.1. **QA Notification**

The ONR 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 PTD 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 PTD 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 Test Director is the designated signer for the “witnessed by” sign-off located at the end of each procedure. The person in charge of the operation (Test Director or Test Engineer) is to sign the “completed by” sign-off.

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

Test Director	***Test Engineer***
Mike Taber	Tom Welsh
Dave Murray	Chris Gray
Jim Maddocks	Bruce Clarke
Dave Frank	

E. REQUIREMENTS

E.1. Electrostatic Discharge Requirements

This procedure does not include any equipment sensitive to electrostatic discharge.

E.2. Lifting Operation Requirements

There are no lifting operations in this procedure

E.3. Hardware/Software Requirements

E.3.1. Commercial Test Equipment

No commercial test equipment is required for this operation.

E.3.2. Ground Support Equipment

The Ground Support Equipment includes the Gas Module, the Pump Module, the Electrical Module, and the Vacuum 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 (see the *Electrical Module Manual* for details), and provides remote control of valves in the Gas Module, Pump Module, and SMD. The Vacuum Module contains a turbo pump, backed by a vane pump, and provides the capability to pump out the SMD vacuum shell.

This procedure uses hardware located in the Gas Module (Figure 1), the Pump Module (Figure 2) and the Electrical Module (Table 1).

E.3.3. Computers and Software:

The Data Acquisition System (DAS) and data acquisition software are 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.3.4. Additional Test Equipment

No additional test equipment is required.

E.3.5. Additional Hardware

No additional hardware is required

E.3.6. Tools

No tools are required.

E.3.7. Expendables

No expendables are required.

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***	***User 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	User 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 1 x 10^{-4} torr. Document No. P0213, 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. Station 200 temperature (CN 01) set at $T \leq 6.5$ K.
   b. Top of lead bag temperature set (CN 28) at $T \leq 6.0$ K.
   c. Relative Guard Tank Pressure (CN 46) set at $\Delta P \geq 0.3$ torr.

2. The Facility Main Alarm System must be armed.

E.5.6. GSE and Non-flight Hardware

1. The ion-pump magnet is installed.
2. GSE cabling must be connected between the SMD and the Electrical Module (P/N 5833812) and between the SMD and the Data Acquisition System (P/N 5833811).
3. The Main Tank vent line must be connected to the Gas Module with a vacuum insulated line (P/N 5833806). Document No. P0672, *Connect Main Tank Vent Line to Gas Module – Main Tank Subatmospheric*, contains the procedures for connecting vent lines.
4. 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 P0676, *Connect Guard Tank Vent Line to Gas Module*, contains the steps for connecting the GT vent line.
5. The thruster vent port is flanged to a shut-off valve.
6. 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. A relief valve is installed in place of the SMD fill-line burst disk.
3. A foreign object and debris shield may cover the upper cone of the SMD and is required whenever work is being performed above the SMD such that hard objects could be dropped and impact the SMD or Probe.
4. 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.
5. The Fill Cap Assembly may be installed at SV-13

E.7. **Verification/Success Criteria**

N/A

E.8. **Payload Constraints and Restrictions**

N/A

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*
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*

F.3. Additional Procedures

Document No.	Title
SU/GP-B-P0672	*Connect Main Tank Vent Line to Gas Module – Main Tank Subatmospheric*
SU/GP-B P0676	*Connect Guard Tank Vent Line to Gas Module*
SU/GP-B P0213	*Connect Vacuum Module / Pump on SMD Vacuum Shell*

Operation Number:____________

Date Initiated:____________

Time Initiated:____________

G. OPERATIONS

G.1. Verify Appropriate QA Notification

o Verify SU QA notified.

Record: Individual notified __________________,

Date/time ________/________.

o Verify ONR representative notified.

Record: Individual notified __________________,

Date/time ________/________.

G.2. Verify Configuration Requirements

G.2.1. Ensure Facility Main Alarm System enabled.

G.2.2. Verify Dewar Top Plate heaters are operational.

G.2.3. Verify Actuator Control for EV-9 is in “Subatm He” position.

G.2.4. Verify liquid in Main Tank is subatmospheric (< 4K) and record temperature at bottom of tank CN [09] ________K.

G.2.5. Verify ion-pump magnet installed.

G.2.6. Verify Vacuum Shell Pressure < 1×10^{-4} 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 1×10^{-4} torr, turn off Vac-ion pump and perform procedure P0213 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.2.7. Ensure GSE cabling connected between SMD and Electrical Module and between SMD and Data Acquisition System.

G.2.8. Verify Main Tank vent line connected to Gas Module. If not perform procedure P0672, *Connect Main Tank Vent Line to Gas Module – Main Tank Subatmospheric*, to connect Main Tank vent.

G.2.9. If liquid in Guard Tank, verify Guard Tank vent line connected to Gas Module. If not, perform procedure P0676, Connect Guard Tank Vent Line to Gas Module, to connect Guard Tank vent.

G.2.10. Ensure DAS watchdog timer and alarm enabled.

G.2.11. Verify DAS alarm system enabled and record set points.

1. ***Station 200 temperature*** – verify CN [01] on DAS alarm list and set to alarm at T ≤ 6.5 K. Record set point. __________K
2. ***Top of lead bag temperature*** – verify CN [28] on DAS alarm list and set to alarm at T ≤ 6.0 K. Record set point. __________K
3. ***Relative Guard Tank Pressure*** – verify CN [46] on DAS alarm list and set to alarm at ΔP ≥ 0.3 torr. Record set point. _________torr

G.2.12. 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.2.13. 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 99.99% pure helium gas available at appropriate regulator (APR-2 or APR-3).

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**

Note: Refer to Operating Instructions for DAS keyboard/mouse operations.

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.

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 $< \Delta P <$ 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
3. Station 200 temperature CN [01] ______ 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 and STA 200 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.

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.

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 99.99% pure helium gas available at appropriate regulator (APR-2 or APR-3).

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.

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. Ensure Facility Main Alarm System enabled.

G.10.13. Continue to monitor Guard Tank pressure until HEX-1 temperature CN [05] reaches steady state. Be prepared to add heat to GT as necessary.

G.10.14. Once HEX-1 temperature reaches steady value, turn off Guard Tank heater power supply.

G.10.15. 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

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	SMD External Temp. Control M.T. Vent Bayonet /O-ring (^oC/ ^oC)	SMD External Temp. Control SV-9 Valve /Top Plate (^oC/ ^oC)	SMD External Temp. Control SV-9 Knob/ Top Plate Cylinder (^oC/ ^oC)

										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 (°C/ °C)	SV-9 Valve /Top Plate (°C/ °C)	SV-9 Knob/ Top Plate Cylinder (°C/ °C)

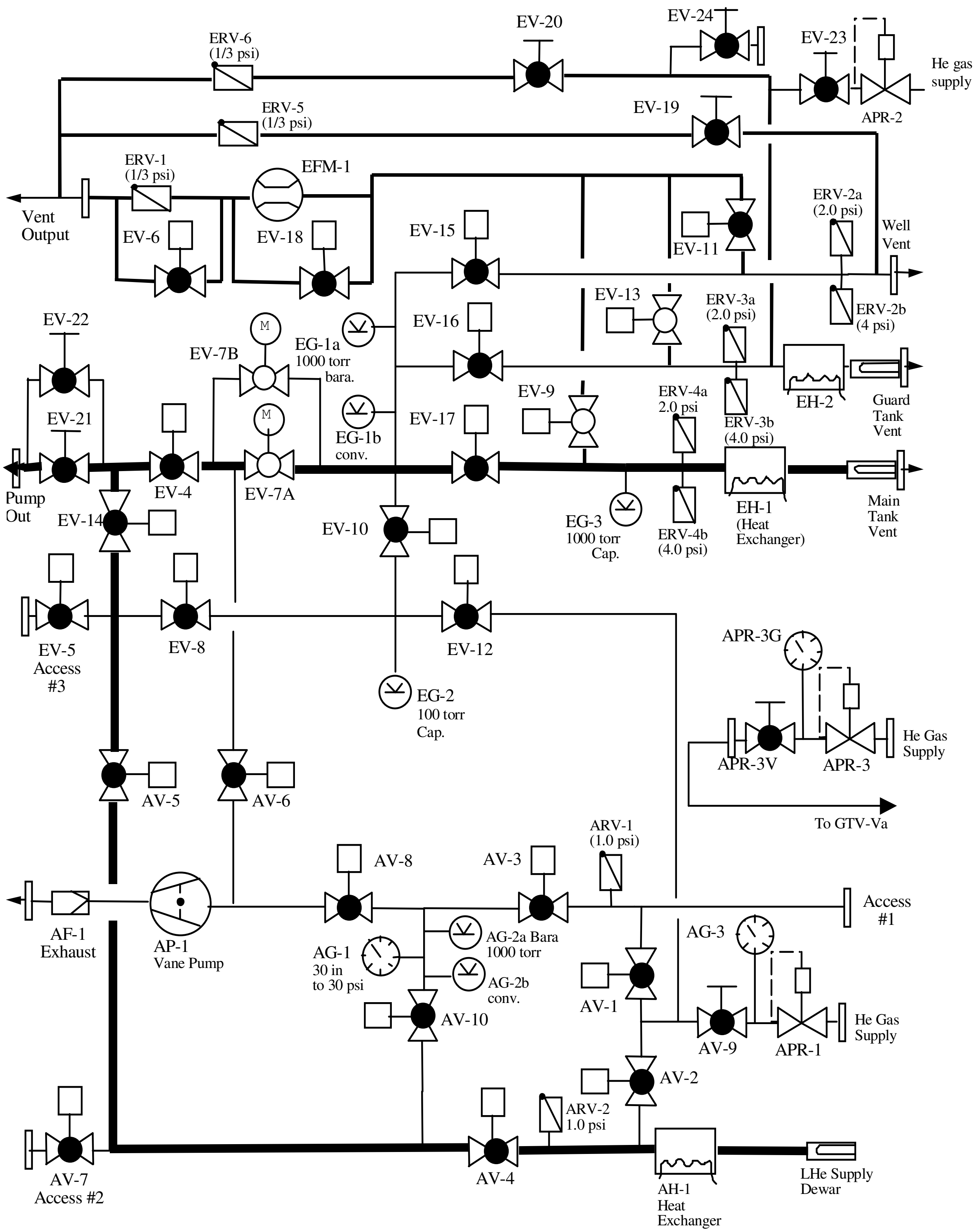

Figure 1. Schematic of Gas Module Plumbing.

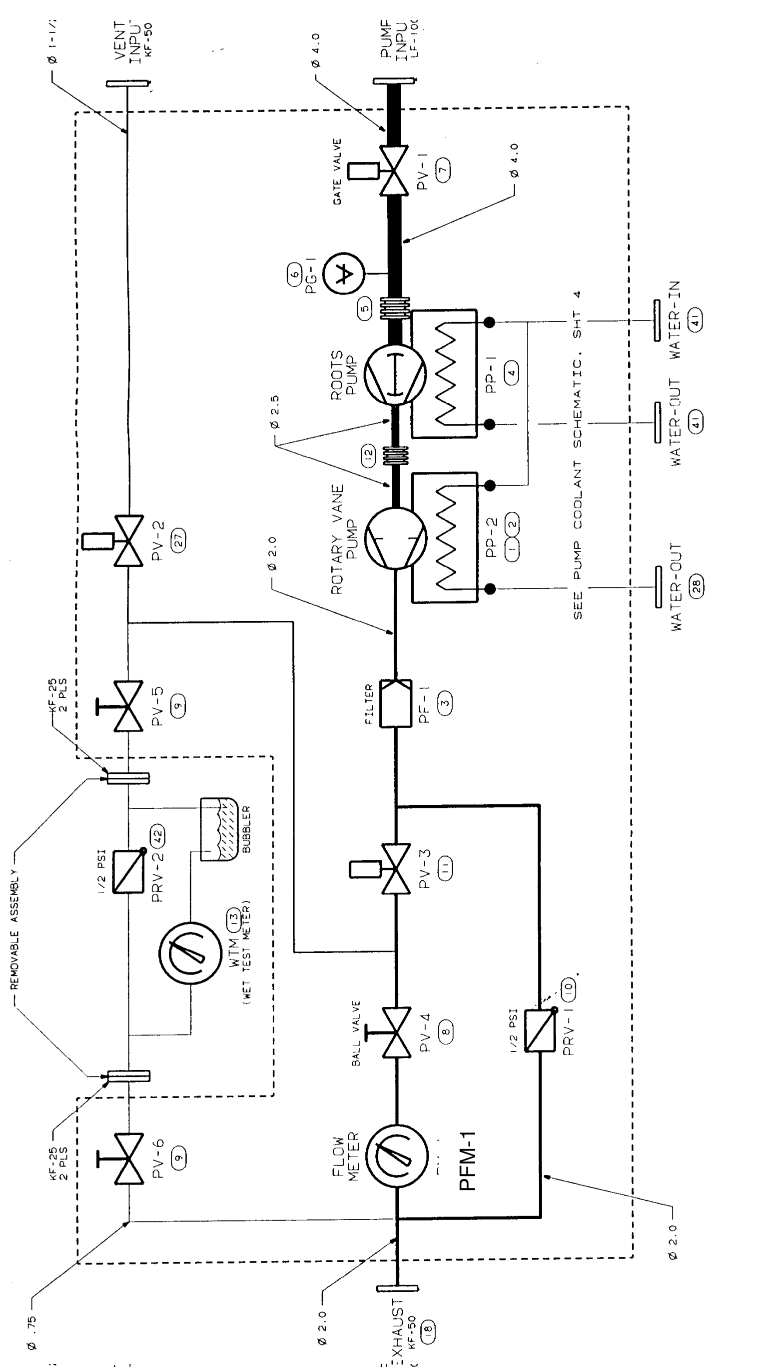

Figure 2. Schematic of Pump Module plumbing.

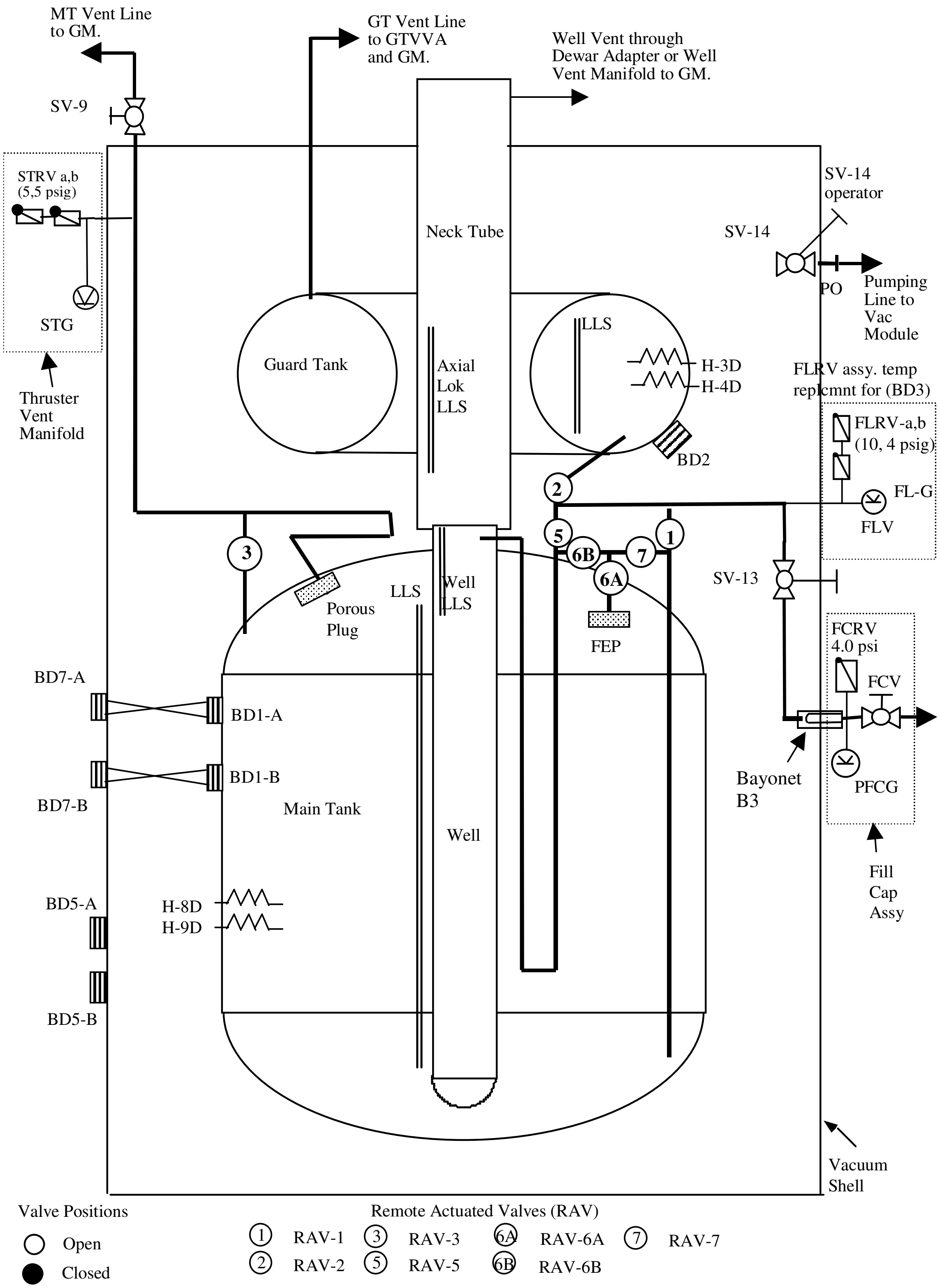

Figure 3. Schematic of Science Mission Dewar plumbing.

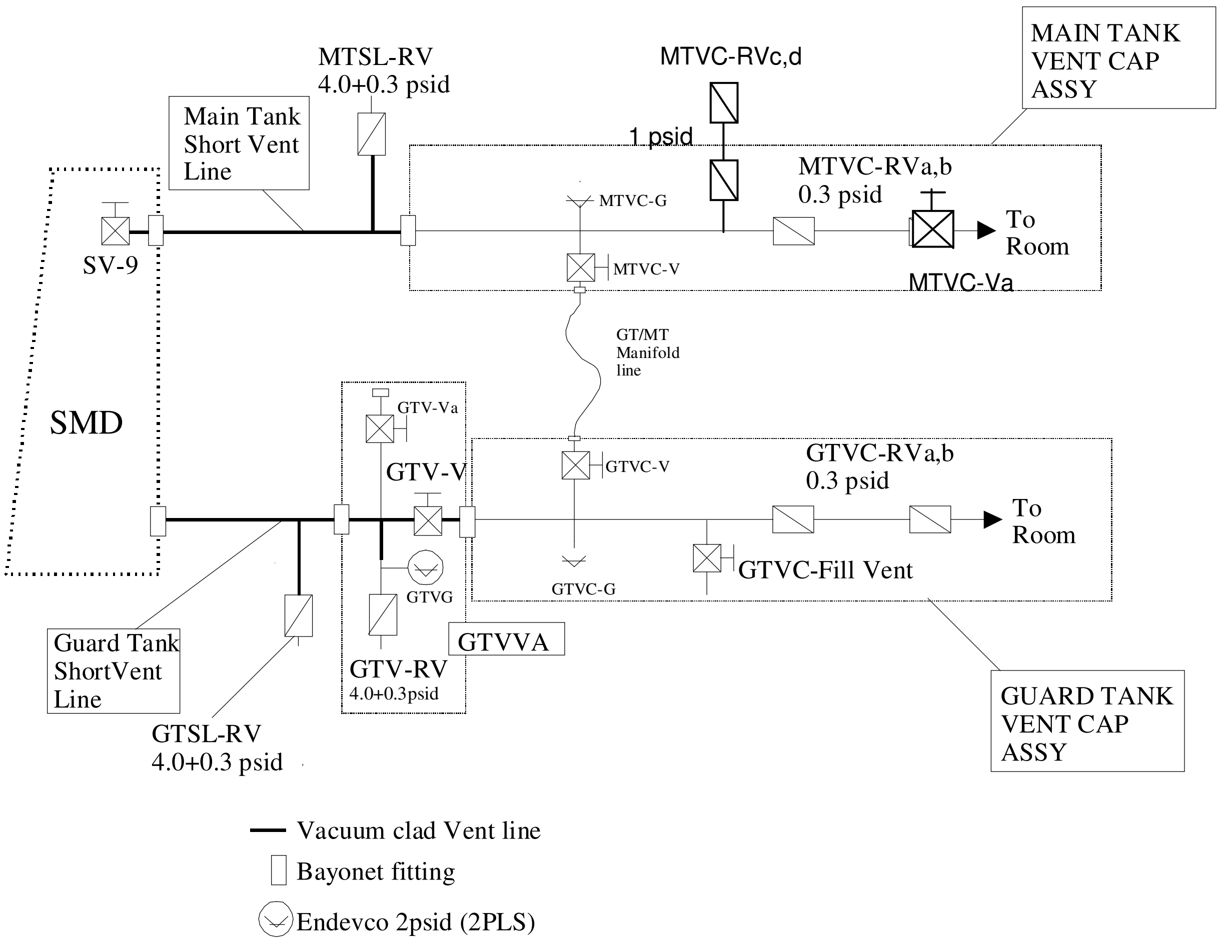

Figure 4. Schematic representation of Guard Tank Vent Valve Assembly (GTVVA) and Main Tank and Guard Tank vent cap assemblies. Common manifold capability is provided by the GT/MT manifold line.