GRAVITY PROBE B
PROCEDURE FOR
SCIENCE MISSION DEWAR

DISCONNECT MAIN TANK VENT LINE FROM GAS MODULE – MAIN TANK SUBATMOSPHERIC

May 8, 2000

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

A. SCOPE

This procedure provides the necessary steps to disconnect the Main Tank vent line from the Gas Module and install a Vent Cap, while the Main Tank liquid is subatmospheric. The steps include:

Close Main Tank vent valve (SV-9)

Perform leak-back test on Main Tank vent valve

Disconnect vent line and install vent cap

Leak test vent cap and backfill with helium gas.

The Guard Tank may contain liquid or be evacuated. In either case it may be connected to or disconnected from the Gas Module. The Well is evacuated. The Main Tank Vent Cap installed in this procedure is not the flight unit that is installed after the final conditioning of the Main Tank for launch.

B. SAFETY

B.1. Description of 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 Potential 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%. 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.3. 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 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 Hardware 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.

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, 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 refers to or calls for the use of hardware located in the Gas Module (Figure 1), Pump Module (Figure 2), and Electrical Module (Table 1).

E.3.3. 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.3.4. Additional Test Equipment

Description
Helium leak detector
Helium leak detector calibrated leak; cal. due date:
Endevco pressure transducer readout, model 136

E.3.5. Additional Hardware

Description
Main Tank Vent Cap – Figure 4

E.3.6. Tools

Description
Torque Wrench, 1-1/4-in socket, 60 in-lb

E.3.7. Expendables

Description	***Quantity***	***Mfr./Part No.***
Alcohol	AR	N/A
99.99% pure gaseous helium	AR	N/A
Vacuum Grease	AR	Braycote Micronic 601

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 Veeder-Root	PFM-1	576013-716	No	-
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,	VG-1, VG-2	96021521	No	-

No.	*Location*	*Description*	*User Name*	*Serial No.*	*Cal Required*	*Status Cal due date*
		Granville-Phillips 360	VG-5			

E.5. Configuration Requirements

E.5.1. Main Tank

Liquid in the Main Tank is subatmospheric.

The Main Tank vent line consists of two parts: a short line attached to the dewar, and a long line that connects the short line to the Gas Module. The vent line can be disconnected at the dewar or at the bayonet joining the long and short lines. For tilting purposes, it is usually disconnected at the end of the short line.

E.5.2. Guard Tank

The Guard-Tank may contain liquid, or be depleted. There is no required liquid level. When the Guard Tank is depleted, its pressure must be independently regulated from a source of 99.99% pure helium gas.

Whenever independently regulated, the Guard Tank pressure must be continuously monitored and maintained at a positive value relative to the atmosphere. 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 or supplying a source of He gas for independent regulation.

E.5.3. Well

The Well is evacuated.

E.5.4. Vacuum Shell

There is no requirement for the vacuum shell pressure.

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

1. 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).
2. The thruster vent manifold is installed at the thruster vent port and valved off.

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 internal fill-line burst disk.
3. A foreign object and debris shield covers the upper cone of the SMD.
4. The ion-pump magnet is installed.
5. The Guard Tank Vent Line may be connected to the Gas Module, or it may be disconnected, with a vent cap installed.
6. The Vacuum shell pump out port at SV-6 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 with the Vacuum Module actively pumping the vacuum shell.
7. The Well Vent Manifold may be installed and valved off.
8. The Fill Cap Assembly is 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
SU/GP-B P0141	FIST Emergency Procedures
LMSC-P088357	Science Mission Dewar Critical Design Review
P0108	Quality Plan

F.3. Additional Procedures

No additional procedures are indicated.

Operation Number:_____

Date Initiated:_____

Time Initiated:_____

G. OPERATIONS

G.1. Verify Appropriate QA Notification

- Verify SU QA notified.

  Record: Individual notified _____,

  Date/time _____/_____.

- Verify ONR representative notified.

  Record: Individual notified _____,

  Date/time _____/_____.

G.2. Leak Check Main Tank Vent Cap.

Note: Leak checking is performed by "bagging" the assembly and leak checking for a minimum of three minutes. Open inlet ports are to be plugged. Background should be less than $1x10^{-7}$ scc/s and no rise should be noticed during the test.

G.2.1. Record Leak detector background:_____ scc/s

G.2.2. Record Leak Detector after three minutes:_____ scc/s

G.2.3. Briefly pull open outer relief valve to ensure that inner valve is tight.

G.3. Verify Configuration Requirements

G.3.1. Ensure Facility Main Alarm System enabled.

G.3.2. Verify proper sealing of Well. Record closure (cover plate, Hole cutter, Probe etc.)._____

G.3.3. Verify liquid in Main Tank is subatmospheric and record pressure.

Main Tank pressure (EG-2) _____ torr.

G.3.4. Ensure Thruster Vent Manifold installed and vent valve STV closed.

G.3.5. Ensure DAS alarm system enabled and record set points.

1. ***Station 200 temperature*** – ensure 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*** – ensure CN [28] on DAS alarm list and set to alarm at T ≤ 6.0 K. Record set point. _____K
3. ***Relative Guard Tank pressure*** – ensure CN [46] on DAS alarm list and set to alarm at ΔP ≥ 0.3 torr. Record set point. _____torr

G.3.6. Ensure 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 ≥ 10%. Record set point. _____ %

G.3.7. Verify GSE cabling connected between SMD and Electrical Module and between SMD and Data Acquisition System.

G.4. **Record Initial Configuration and Conditions**

G.4.1. Record Main Tank pumping configuration.

- o Main Tank actively pumped by AP-1 (Gas Module).
- o Main Tank actively pumped by PP-1/PP-2 (Pump Module).
- o Main Tank in non-vented mode.

G.4.2. Record Guard Tank Configuration.

- o Guard Tank contains liquid and is connected to Gas Module.
  - o Venting through EV-20 (EV-20 open, EV-16 and EV-13 closed).
  - o Venting through EV-13 (EV-13 open, EV-16 and EV-20 closed).
- o Guard Tank contains liquid and is disconnected from Gas Module.
- o Guard Tank is depleted and is connected to Gas Module.
- o Guard Tank is depleted and is disconnected from Gas Module.

G.4.3. Record initial liquid helium levels as appropriate.

1. Main Tank (LL-1D or LL-2D) _____%
2. Guard Tank (LL-5D or LL-6D) _____%

G.4.4. Record relative Guard Tank pressure (GTV-G):_____ torr.

G.5. **Set up Main Tank in Non-vented Mode.**

CAUTION
During the period of Main Tank vent closure the temperatures at station 200 and the top of the lead bag are to be continuously monitored.

G.5.1. Record date/time : _____/_____.

G.5.2. Record Main Tank Pressure (EG-2):_____ torr

G.5.3. Close SV-9 and torque to 60 in-lbs.

G.5.4. Enter comment into the DAS "Close Main Tank vent valve SV-9."

G.6. **Perform Leak-back Test of SV-9 Closure**

G.6.1. Valve off pumps from Main Tank

1. Close/verify closed EV-4, EV-21/22,EV-14, EV-5, EV-8 and EV-12.
2. Close/verify closed AV-5 and AV-6.

G.6.2. Ensure EV-9, EV-15, and EV-16 closed.

G.6.3. Open/verify open EV-10 and EV-17.

G.6.4. Ensure EV-7a/b open.

G.6.5. Turn on/verify on AP-1

G.6.6. Ensure Blank-off installed on Auxiliary Gas Section access port no. 1.

G.6.7. Open AV-8, AV-3 and AV-1.

G.6.8. Open EV-12 and evacuate to <25 mtorr as measured at AG-2b.

G.6.9. Close AV-8.

G.6.10. Wait for 10 minutes and then verify that pressure AG-2b does not increase by more than 10 mtorr in 20 minutes while recording every 4 minutes:

Time (min)	0	4	8	12	16	20
P (AG-2b) torr	_____	_____	_____	_____	_____	_____

Pass/Fail: _____ torr/ 20 min: _____.

G.6.11. If leak-back test fails, repeat steps G.6.6 through G.6.9.

G.6.12. Open AV-9 until pressure reaches 0 psig as read on gauge AG-1, then close AV-9.

G.6.13. Close EV-10, EV-12, and EV-17.

G.6.14. Close all open AV valves.

G.7. **Disconnect Main Tank Vent Line and Install Vent Cap**

G.7.1. Remove vent line from Main Tank exhaust at one of the following locations:

- θ Bayonet at SV-9,**or**
- θ Bayonet at end of short vent line opposite from SV-9.

G.7.2. Inspect o-rings on Main Tank vent cap assembly (Figure 4) and lightly lubricate radial seal o-ring with Braycote.

G.7.3. Install Vent Cap.

G.7.4. Install calibrated Leak Detector to VCV-2 on Vent Cap.

G.7.5. Open VCV-2 and evacuate with leak detector the volume between the two o-rings.

G.7.6. Record Leak Detector background, _____ scc/s.

G.7.7. Bag the outer seal of the Vent Cap, purge bag with GHe and record:

1. Initial reading:_____ scc/s
2. One minute reading:_____ scc/s
3. Pass/Fail: _____ (Pass = **no** increase from initial background)

G.7.8. Close VCV-2 and remove Leak Detector.

G.8. **Condition Main Tank Vent Cap**

G.8.1. Volume protecting O-ring

1. Connect a pumping line between the Vent Cap at valve VCV-2 and Gas Module access port no. 1.
2. Close/verify closed AV-1 and AV-9.
3. Open AV-8 and AV-3.
4. Open VCV-2 and evacuate Vent Cap to <25 mtorr measured at AG-2b.
5. Close AV-8.
6. Open AV-1.
7. Open AV-9 until pressure reaches 1.5 psig as read on gauge AG-1 and then close AV-9.
8. Close AV-1 and AV-3.
9. Close VCV-2.
10. Remove the pumping line from the Vent Cap.
11. Install a blank-off cap on valve VCV-2 and, using Endevco 136 readout, record:
    a. Date and Time:_____/_____.

b. Pressure VCP-2:_____ torr differential

G.8.2. Condition volume downstream of SV-9

1. Connect a pumping line between the Vent Cap at valve VCV -1 and Gas Module access port no. 1.
2. Close/verify closed AV-1 and AV-9.
3. Open VCV-1.
4. Open AV-8 and AV-3 and evacuate to <25 mtorr measured at AG-2B.
5. Close AV-8.
6. Close VCV-1.
7. Remove the pumping line from the Vent Cap.
8. Install a blank-off cap on valve VCV-1.

G.9. **Establish Final Configuration**

G.9.1. Open SV-9 and record:

1. Date and Time: _____/_____.
2. Pressure VCP-1:_____ torr
3. Pressure VCP-2:_____ torr differential

G.9.2. **(Option)** Remove Main Tank Vent line from Gas Module and install blankoff at inlet to Main Tank heat exchanger.

G.9.3. Cover open ends of vent line.

G.9.4. Ensure EV-4, EV-21/22, EV-14, EV-5, EV-8, and EV-12 closed.

G.9.5. Close/verify closed EV-9, EV-10, and EV-17.

G.9.6. Open EV-16.

G.9.7. Ensure all AV valves closed.

G.9.8. Turn off pump AP-1

G.9.9. 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 1] _____ K (≤ 6.5 K)

  b. Top of Lead Bag set point [CN 28] _____ K (≤ 6.0 K)

G.9.10. Ensure liquid level sensor alarms enabled, as appropriate, and record set points if changed.

1. Main Tank Level Set Point _____%
2. Guard Tank Set Point _____%

G.9.11. Ensure Guard Tank pressure on DAS alarm list and set to alarm at 0.3 torr differential.

G.9.12. Ensure Facility Main Alarm System enabled..

Completed by:_____

Witnessed by:_____

Date: _____

Time:_____

Quality Manager_____**Date**_____

Payload Test Director_____**Date**_____

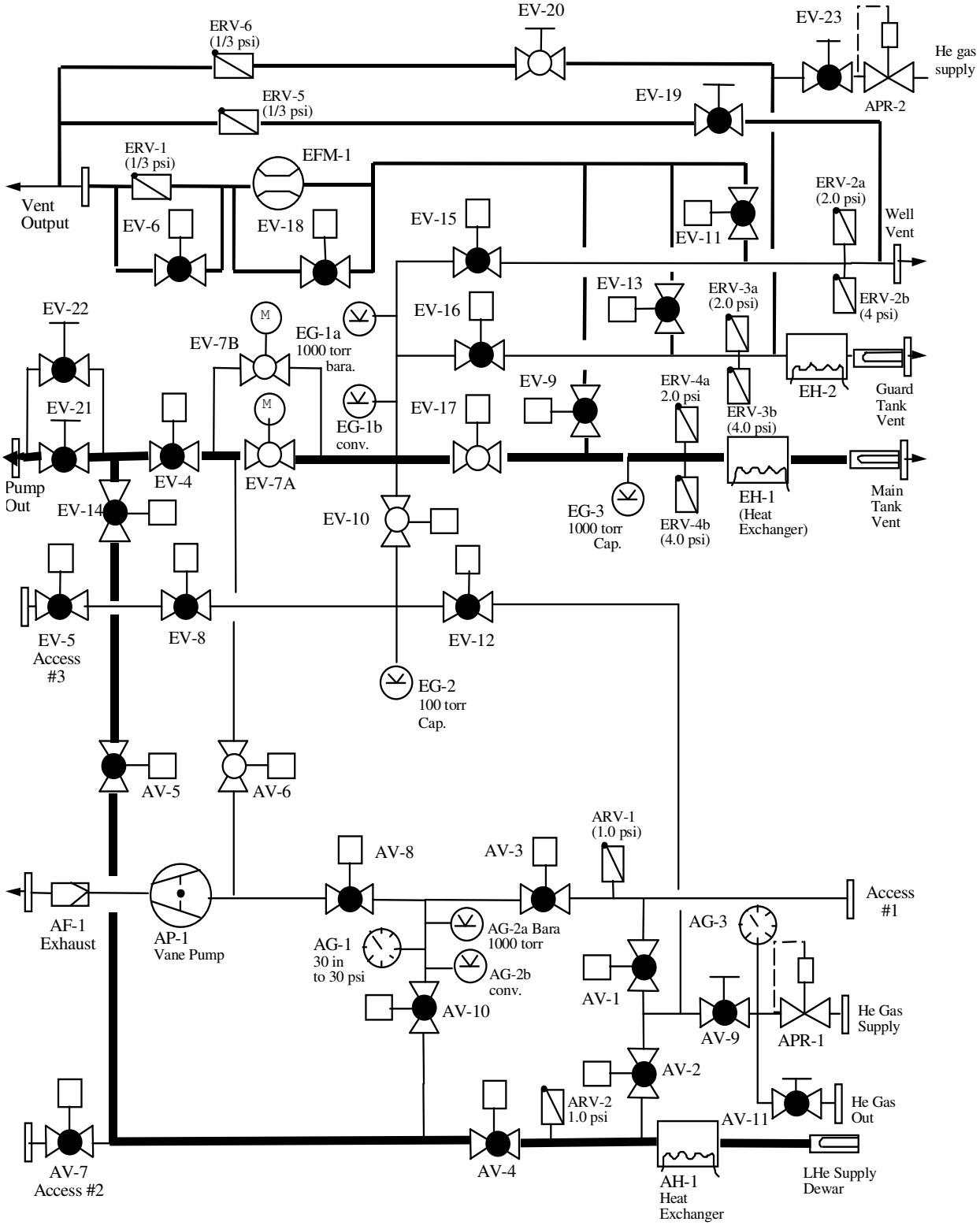

Figure 1. Schematic of Gas Module plumbing. Valve configuration corresponds to likely initial configuration – Main Tank bath being pumped by AP-1 and the Guard Tank, with liquid, venting through EV-20.

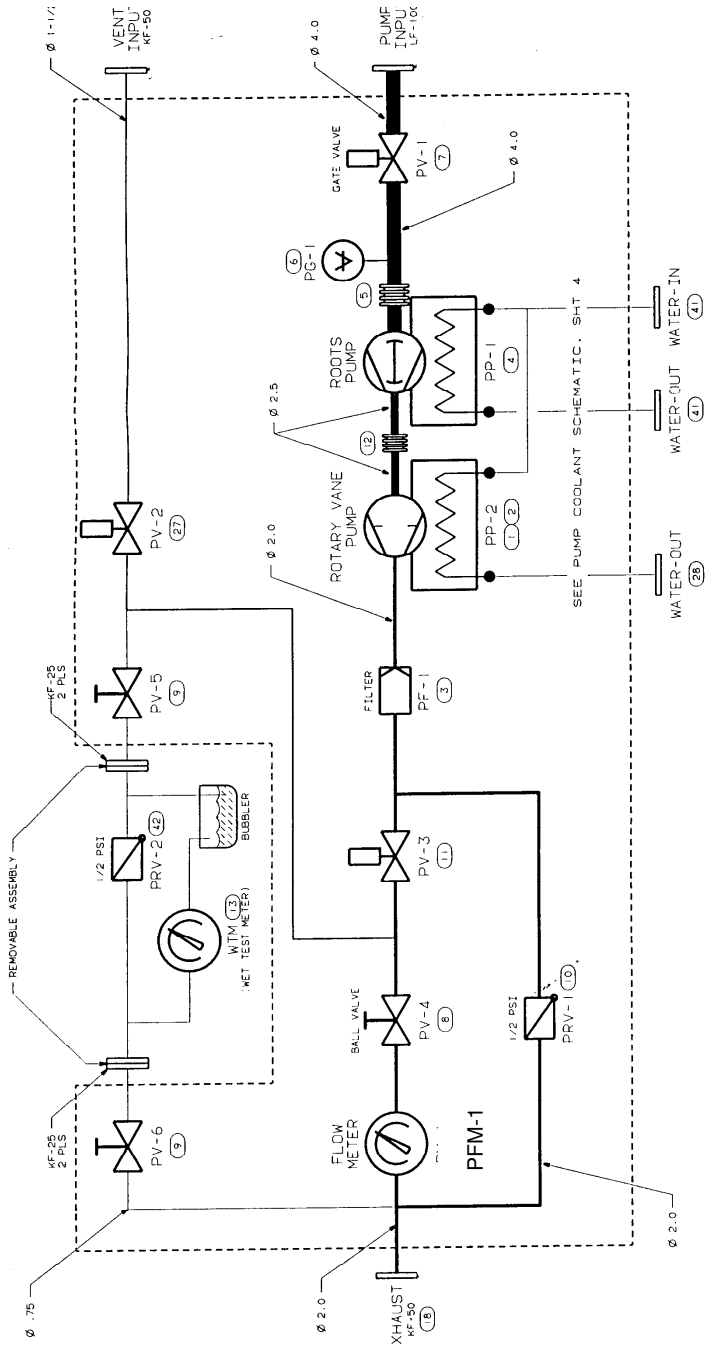

Figure 2. Schematic of Pump Module plumbing.

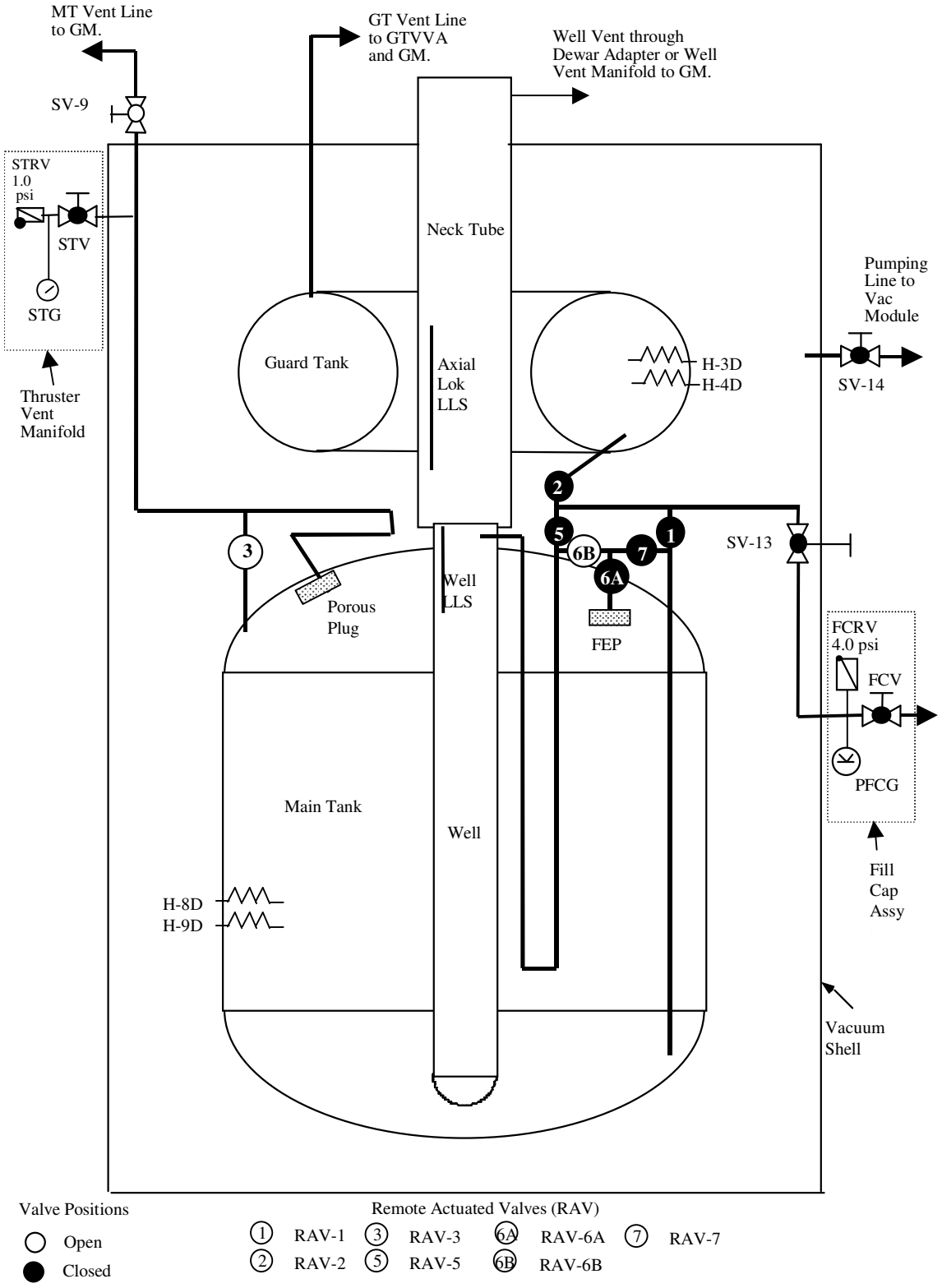

Figure 3. Schematic of Science Mission Dewar plumbing.

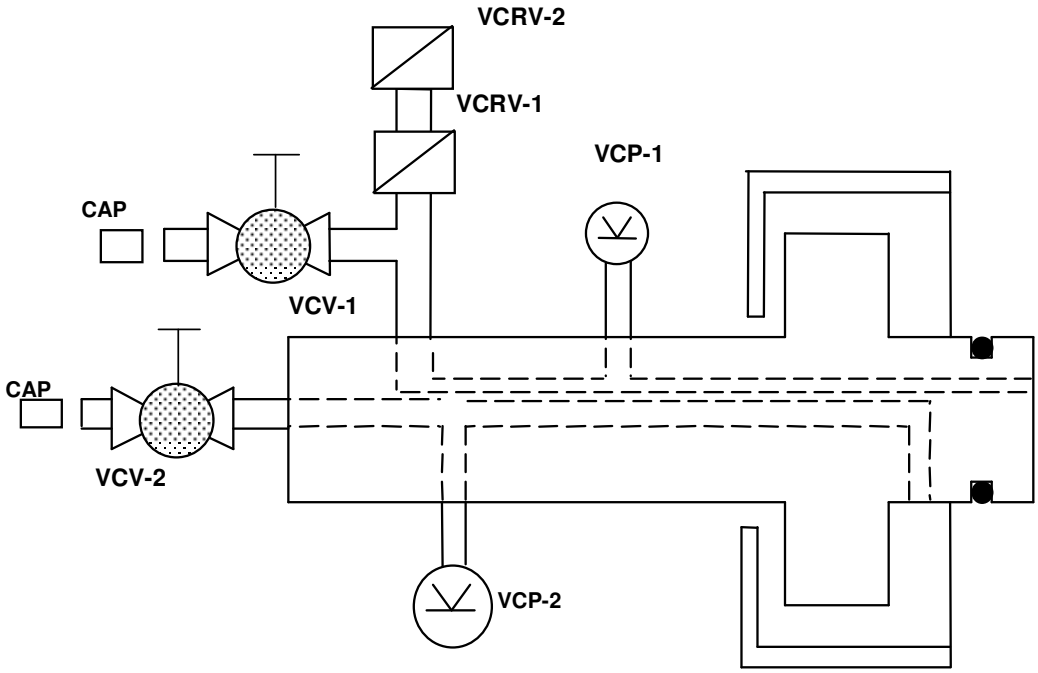

Figure 4. Main Tank Vent Cap Assembly for subatmospheric applications.