Op. Order No. _____

GRAVITY PROBE B
PROCEDURE FOR
SCIENCE MISSION DEWAR

PREPARE FOR CRYO OPS FOLLOWING TRANSPORT TO B1610

To be performed at Vandenberg Air Force Base building 1610

THIS DOCUMENT DOES NOT CONTAIN HAZARDOUS OPERATIONS

P1000 Rev. A

ECO No.1422

June 23, 2003

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Op. Order No. _____

Payload Technical Manager

REVISION RECORD

REVISION	***ECO***	***CHANGES***	***DATE***
A	1422	Procedure is revised for arrival on the Medium Payload Transporter (SV horizontal) instead of the Super Guppy (SV vertical). Option of pumping out probe with the UTS is deleted. Added use of GSE valves on the flight well pumping line. Specifies that a leak check of the dewar vacuum shell be performed as a part of P1015, *Connection of High Vacuum Pumping Module*. Corrects sequencing errors in original	

Table of Contents

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
ARP	Attitude Reference Platform	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	PCI	PDU Circuit Instrumentation (Console)
EFM	Exhaust gas Flow Meter	PDU	Power Distribution Unit
EG-x	Gauge x of Gas Module exhaust section	PFCG	Fill Cap assembly pressure Gauge
EM	Electrical Module	PFM	Pump equipment Flow Meter
ERV-x	Relief valve of Gas Module exhaust section	PG-x	Gauge x of Pump equipment
EV-x	Valve number x of Gas Module exhaust section	PM	Pump Module
FCV	Fill Cap Valve	psi	pounds per square inch
FEE	Forward Equipment Enclosure	psig	pounds per square inch gauge
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	Space Vehicle
GTVC-RV	Guard Tank Vent Cap relief valve	SV-x	SMD Valve number x
GTVC-V	Guard Tank Vent Cap valve	TD	Test Director
GTV-G	Guard Tank vent pressure gauge	TG-x	Gauge x of Utility Turbo System
GTV-RV	Guard Tank vent relief valve	TV-x	Valve x of Utility Turbo System
GTV-V	Guard Tank vent valve	UTS	Utility Turbo System
HCU	(External) Heater Control Unit	VAFB	Vandenberg Air Force Base
HX-x	Vent line heat exchanger in Gas Module	Vac	Vacuum
KFxx	Quick connect o-ring vacuum flange (xx mm diameter)	VCP-x	Vent cap pressure gauge
LD	(Helium) Leak Detector	VCRV-x	Vent cap relief valve
LHe	Liquid Helium	VCV-x	Vent cap valve
LHSD	Liquid Helium Supply Dewar	VDC	Volts Direct Current

Liq	Liquid
LL	Liquid level
LLS	Liquid level sensor
LMMS	Lockheed Martin Missiles and Space
LMSC	Lockheed Missiles and Space Co.
MPT	Medium Payload Transporter
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 Well

LIST OF SPECIFIC HEADING DEFINITIONS

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

Note:
Used to indicate an operating procedure of such importance that it must be emphasized.

CAUTION:
Used to identify hazards to equipment.

WARNING:
Used to identify hazards to personnel.

A Scope

This procedure is a master procedure that effects the preparation for cryogenic operations following transport to VAFB B1610. The steps include:

Uncrate, position, and secure GSE
Certify Electrical Module, Gas Module and DAS*
Certify Vacuum Module*
Certify UTS*
Verify Helium Cylinder Content / Connect Helium Supply Line*
Set up portable oxygen monitor
Verify configuration
Connect burst disk vent lines
Disconnect TM&A from SMD*
Connect Electrical GSE to SMD*
SMD Functional Test (consistency check of available temperatures and pressures)*
Verify Vacuum Shell Pressure
Perform Connection of High Vacuum Pumping Module and pump on vacuum shell*
Leak check of vacuum shell
Stop Pumping on SMD Vacuum Shell / Disconnect Vacuum Module*
Certify Pump Module
Connect Main Tank Vent Line to Gas Module – Main Tank at NBP*
Connect Guard Tank Vent Line to Gas Module*
Guard Tank Vent Line Impedance*

*These steps are covered by called procedures.

This is **not** a hazardous procedure.

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 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

A rupture of the main tank burst disk(s) will be obvious due to the plume of cold gas. Emergency vent lines are installed over the burst disks on the SMD vacuum shell during this procedure to eliminate the possibility of direct plume impingement on personnel. Orderly evacuation shall be performed in the event one or more of these burst disks rupture. An oxygen deficiency monitor that alarms when the oxygen level is reduced to 19.5% will be set up in this procedure as an added precaution. Temperature and pressure alarms, provided by the DAS, warn of potential over-pressure conditions.

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 a ladder. In the unlikely event of a large LHe spill all employees have been instructed to evacuate the room and contact NASA and VAFB safety. Additional safety mitigations are specified in some of the procedures called by this procedure.

B.2.3 Other Hazards

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

B.3 Mishap Notification

B.3.1 Injury

In case of any injury obtain medical treatment as follows
VAFB Call 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 Spacewing Safety will be notified as required.

B.3.3 Contingency Response

Responses to contingencies (e.g., power failure, burst disk failure) are listed in Appendix 3.

C **Quality Assurance**

C.1 QA Notification

The NASA program and 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 judgment of the TD or QA Representative, mission 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.

C.3.1 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.

C.3.2 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.

C.3.3 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 Required Personnel

List below those personnel involved with the procedure

Test Director	***Test Engineer***	***Safety Engineer***
1.	1. 2. 3. 4.	1.

E Requirements

E.1 Electrostatic Discharge Requirements

Any person who comes in contact with the SV must use a grounding wrist strap that has been tested that day. Appropriate attachment points are positioned around the SV.

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, and 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 Pump Module is cooled by a circulating chilled water unit. The vent output of the Gas Module flows through the Pump Module. The Electrical Module contains instrumentation and provides remote control of valves in the Gas Module, Pump Module, and SMD. The External Heater Control Unit (HCU) is a separate unit which provides power and temperature control of various external heaters associated with the Main Tank and Guard Tank vent plumbing. Other GSE and non-flight items that are part of the initial hardware configuration are noted in E.5.5.

E.3.3 Computers and Software:

The Data Acquisition System (DAS) and data acquisition software are required for some of the procedures called by 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	***Manufacturer***	***Model***
O_2 Monitor and Alarm	Alpha-Omega Instruments	1000

E.3.5 Additional Hardware:

Description	***Manufacturer***	***Model***
Flexible vent line and manifold for BD5/7 A/B (main tank and vacuum shell burst disks)	–	–
Flexible vent line for Gas Module	–	–

E.3.6 Protective Clothing: N/A

E.3.7 Tools: N/A

Description

E.3.8 Expendables N/A

Description	***Quantity***	***Mfr./Part No.***

E.4 Instrument Pretest Requirements: N/A

E.5 Configuration Requirements

The SMD is configured as required for shipment to VAFB per P1044, *Transport Payload from Lockheed Martin B156 to VAFB B1610*. It will arrive in B1610 mounted horizontally in the MPT, lifted from the MPT, and mounted horizontally in the Tilt Dolly. It is then tilted vertical and transferred to the Assembly Stand. P1044 configures the system as needed to support these operations. The portion of the FEE skin that allows access to the Main Tank vent must then be removed for this procedure.

E.5.1 Main Tank

Liquid in the Main Tank must be at its normal boiling point (NBP).

E.5.2 Guard Tank

The Guard Tank is depleted and regulated to a pressure > 30 torr above atmosphere. Care must be taken at all times to keep its pressure above atmospheric.

E.5.3 Well

The Well is evacuated. Access valves VW-1 and VW-2 are closed, and the port is capped. (Fig. 1)

E.5.4 SMD Vacuum Shell

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

E.5.5 GSE and Non-flight Hardware (see Fig. 1 for plumbing schematic)

E.5.5.1 The Main Tank vent bayonet (B1) has a vent cap assembly installed.

E.5.5.2 The fill bayonet (B3) has a cap assembly installed.

E.5.5.3 The TM&A is connected by cables to the SMD to monitor key pressures and temperatures per the latest revision of P0789, *Connect TM&A to SMD*.

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*
EM SYS229	*Accident/Mishap/Incident Notification Process*
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*
EWR 127-1 , 31 March 1995, Eastern and Western Range Safety Requirements	*Hazardous and Safety Critical Procedures*
KHB 1710, rev D	*Kennedy Space Center Safety Practices Handbook*

F.3 Additional Procedures

Document No.	***Title***
SU/GP-B P1020	*Certification of Electrical Module, Gas Module, and DASI*
SU/GP-B P1025	*Certify Pump Module*
SU/GP-B P1022	*Certify Vacuum Module*
SU/GP-B P1023	*Certify UTS*
SU/GP-B P1014	*Verify helium cylinder content / connect helium supply line*
SU/GP-B P1012	*Disconnect TM&A from SMD*
SU/GP-B P1013	*Connect Electrical GSE to SMD*
SU/GP-B P1038	*Guard Tank Vent Line Impedance*
SU/GP-B P1039	*Check GT Vent Line Impedance and Eliminate Blockage [optional]*
SU/GP-B P1019	*Discontinue Pump-Out of Probe-C with UTS [optional]*
SU/GP-B P1006	*Connect Main Tank Vent Lines to Gas Module – Main Tank at NBP*
SU/GP-B P1008	*Connect Guard Tank Vent Line to Gas Module*
SU/GP-B P1044	*Transport Payload from Lockheed Martin B156 to VAFB B1610*

Op. Order No._____
Date Initiated_____
Time Initiated_____

G Operations

G.1 Verify preparations

- o Verify SU QA program office notified.

  Record: Individual notified _____,

  Date/time _____/_____.

- o Verify NASA Program representative notified.

  Record: Individual notified _____,

  Date/time _____/_____.

- o Verify NASA Safety representative has been notified and has given concurrence to proceed.

  Record: Individual notified _____,

  Date/time _____/_____.

- o Verify that the persons performing this procedure, the test director, and safety engineer are identified in Sec. D.3.

- o Verify performance of pre-operations checklist (Appendix 1).

- o Verify availability of equipment, hardware, tools, and expendables listed in sections E.3.2 through E.3.8.

G.2 Position GSE in B1610

G.2.1 Uncrate the GSE items noted in E.3.2 and position them so as to not interfere with SV operations.

G.2.2 Power all units, except the chiller and the Pump Module, through the PDU. (The blower unit in the PM is powered separately through the PDU.)

G.3 Certify GSE

G.3.1 Perform P1020, *Certify Electrical Module, Gas Module and DAS*, and record Date: _____; Op. No.: _____

G.3.2

G.3.3 Perform P1022, *Certify Vacuum Module* and record Date: _____; Op. No.: _____

G.3.4 Perform P1023, *Certify UTS*, and record Date: _____; Op. No.: _____

G.3.5 Verify that the UTS compressor is disabled and that the pneumatic

valves are connected to nitrogen supply regulated to ~80psi

G.3.6 If six-pack of helium gas is not already certified, perform P1014, *Verify Helium Cylinder Content / Connect Helium Supply Line*
Date: _____; Op. No.: _____
Comment: Perform the connection portion of this procedure after the SV has been set up in B1610.

G.3.7 Set up portable Alpha Omega oxygen monitor and perform calibration per manufacturer's instructions.

G.4 Verify Configuration

G.4.1 SV mounted on Assembly Stand, (vertical orientation).

G.4.2 Guard Tank vent pressure regulated through GTV-Va (2.5 to 3 psig).

G.4.3 Main Tank vent capped with 1.5 psid relief per Figure 1.

G.4.4 Fill cap assembly installed at SV-13.

G.4.5

G.5 Perform Initial Assessments and Set Up

G.5.1 Connect a vent manifold and vent line(s) from the dewar main burst disks (BD5/7 A/B) to an external vent.

G.5.2 Position the GSE as depicted in Fig. 2 and seismically secure.

G.5.3 Disconnect TM&A – perform procedure P1012, *Disconnect TM&A from SMD*. Record date and operation number _____ / _____.

G.5.4 Connect Electrical GSE – perform procedure P1013, *Connect Electrical GSE to SMD*. Record date and operation number _____ / _____.

G.5.5 Verify that the DAS alarm system is enabled and contains the following alarm set-points:

Top of lead bag temperature set (CN 175) at $T \leq 6.0$ K.

Top of lead bag temperature set (CN 178) at $T \leq 6.0$ K.

Relative Guard Tank Pressure (CN 46) set at $\Delta P \geq 30$ torr.

G.5.6 Verify that the audible alarm is armed.

G.5.7 Verify Vacuum Shell Pressure < 5 x 10^{-5} torr.

G.5.7.1 Install the ion pump magnet.

G.5.7.2 Connect the ion pump cable to its readout.

G.5.7.3 Turn on Vac-ion pump and record time of day _____

G.5.7.4 Use DAS [Monitor Data] for CN 99.

G.5.7.5 When value is steady, record pressure (IP) _____ torr.

G.5.7.6 Exit [Monitor Data] and collect data with [Set Data Interval] to 5 min.

G.5.7.7 When data cycle is complete, turn off Vac-ion pump.

G.5.8 Perform procedure P1015, *Connection of High Vacuum Pumping Module*, (Op. No._____) with the following options:

G.5.8.1 Select Initial Configuration 1 (pumping line disconnected), and Final Configuration 3 (actively pumping on SMD vacuum)

G.5.8.2 Perform the leak check portion of the procedure.

G.5.9 When it is desired to discontinue pumping on the SMD vacuum shell, perform P1016, *Stop Pumping on SMD Vacuum Shell / Disconnect Vacuum Module*, (Op. No._____) with the following modifications and options:

G.5.9.1 Use Initial Configuration 1 (actively pumping on SMD vacuum) and Final Configuration 3 (pumping line disconnected)

G.5.9.2 Use options G.6.19, G.6.20, and G.6.27 to perform complete disconnection and shut down.

G.6 Set up Pump Module

G.6.1 Perform P1025, *Certify Pump Module*, and record
Date: _____; Op. No.: _____

Comment: Certification of the Pump Module accomplishes the connection and leak check of a pumping line from the Pump Module to the Gas Module.

G.6.2 Connect / verify connected a vent line from the Gas Module to the Pump Module and from the Pump Module to an external vent.

G.7 Final Operations

G.7.1 Perform procedure P1006, *Connect Main Tank Vent Lines to Gas Module – Main Tank at NBP.*
Record date and operation number _____ / _____.

G.7.2 Connect Guard Tank vent line to Gas Module per procedure P1008, *Connect Guard Tank Vent Line to Gas Module*.
Record date and operation number _____ / _____.

G.7.3 Perform P1038, *Guard Tank Vent Line Impedance.*
Record date and operation number _____ / _____.

H **Operation completed.**

Completed by:_____

Witnessed by:_____

Date: _____

Time:_____

Quality Manager_____**Date**_____

Payload Test Director_____**Date**_____

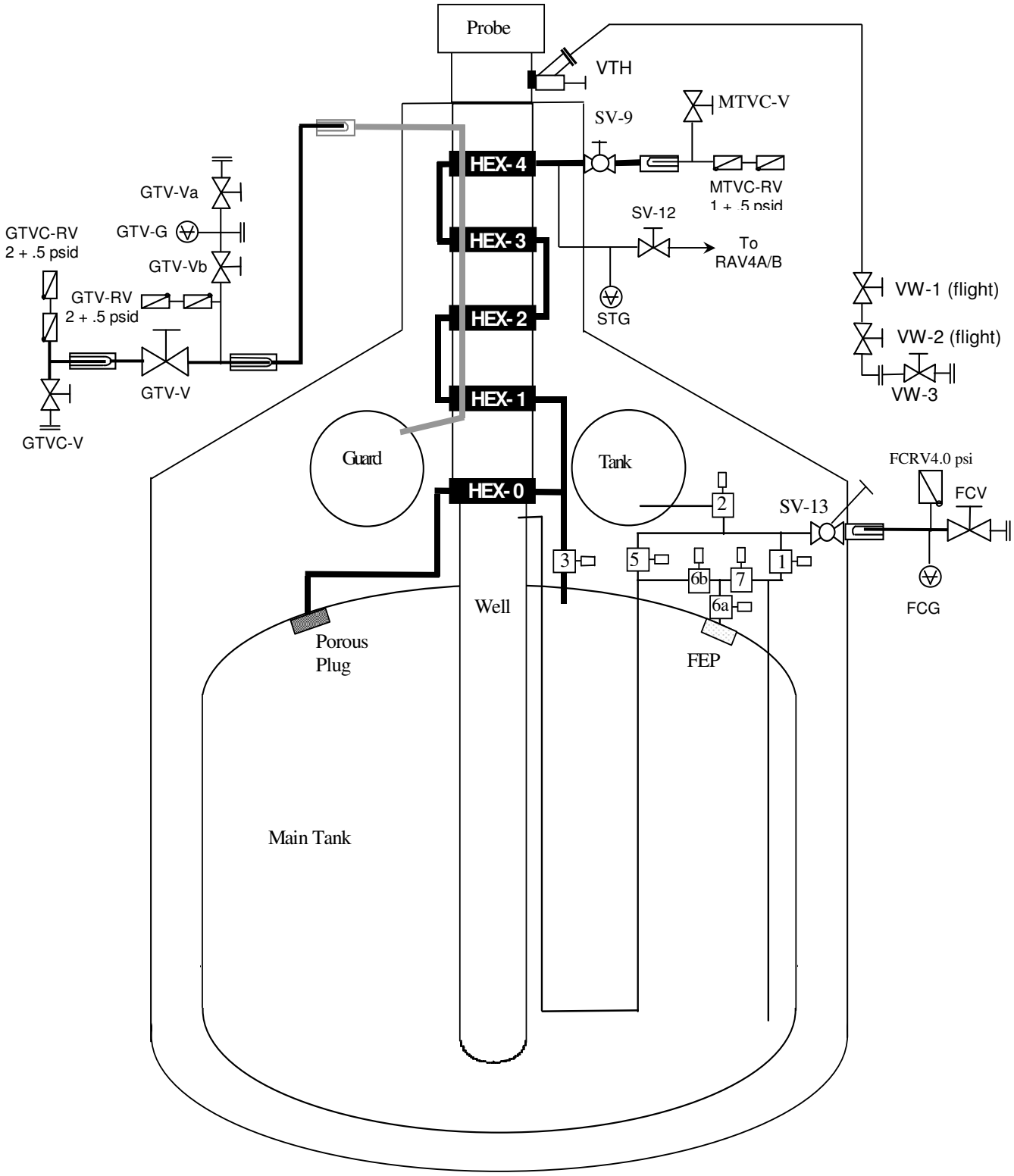

Figure 1. Schematic representation of SMD Plumbing with cryo GSE used for shipment to VAFB.

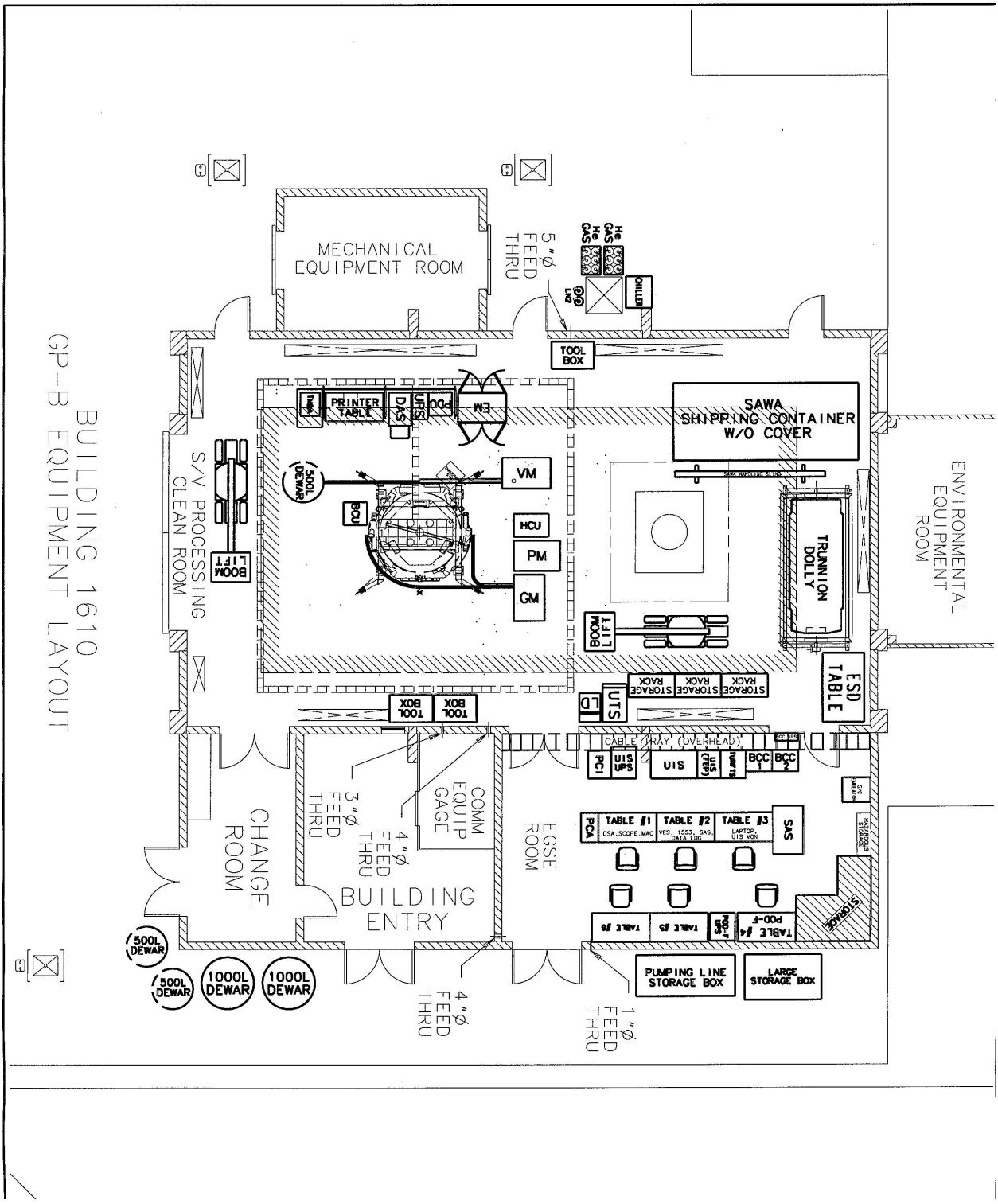

Figure 2. Equipment layout in B1610. See “Acronyms and Abbreviations” for nomenclature.

l Appendix 1 – Pre-Procedure 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 knows their individual 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. Confirm that each test team member understands that there will be a post-test team meeting.		
	Team Lead Signature: _____		

J Appendix 2 – Post-Procedure 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 Responses**

	Condition	Circumstance	Response
1	Power Failure	During called procedure	Follow contingency response specified in the called procedure
		Otherwise	**Wait for power restoration:** Re-establish valve configuration (if appropriate), and resume procedure
2	Temperature limits at top of lead bag (CN 175, 178) exceeded	Before connection of the Main Tank vent line (G.7.1)	**ALLOW MAIN TANK TO VENT** 1. Verify that SV-9 is open 2. Crack open MTVC-V to increase vent rate until temperature stabilizes.
3	Temperature limits at top of lead bag (CN 75, 178) exceeded	After connection of the Main Tank vent line (G.7.1)	Increase Main Tank vent flow 1. Verify SV-9, EV-9 are open 2. Open EV-6 and EV-18 to increase flow rate.
4	Burst disk rupture (MT/GT)	ANY TIME	Evacuate room