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GRAVITY PROBE B, RELATIVITY GYROSCOPE EXPERIMENT
STANFORD, CALIFORNIA 94305-4085

INTERNAL LEAKAGE CHECK OF THE FLIGHT GMA AT VAFB

GP-B ENGINEERING PROCEDURE

To be performed at Vandenberg Air Force Base Building 1610

THIS DOCUMENT CONTAINS HAZARDOUS OPERATIONS

P0961 Rev -

27, February, 2003

PREPARED _____ _____
S Buchholz, Technical Writer Date

APPROVED _____ _____
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APPROVED _____ _____
Harv Moskowitz, LMSSC Safety Engineer Date

APPROVED _____ _____
NASA/KSC Safety Date

APPROVED _____ _____
D. Ross, Quality Assurance Date

APPROVED _____ _____

R. Brumley, Hardware Manager Date

REVISION RECORD

Rev	Date	Comments
-	2/27/03	

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List of Abbreviations and Acronyms

CSTOL	Colorado State Test and Operations Language	He	Helium
D-Log	Discrepency Log	LM	Lockheed Martin
DR	Discrepency Report	NASA	National Aeronautics and Space Administration
ECU	Electronic Control Unit	psi	pounds per square inch
ESD	Electro Static Discharge	psia	pounds per square inch absolute (=psig +14.7)
FEU	Flight Equivalent Unit	psig	pounds per square inch gauge
GDS	Gas Delivery System	QA	Quality Assurance
GMA	Gas Management Assembly	SU	Stanford University
GP-B	Gravity Probe B	S/V	Space Vehicle
		VAFB	Vandenberg Air Force base

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 measures the internal through leak rate of the solenoid valves on the flight Gas Management Assembly. A leak detector is connected downstream, and the solenoids are pressurized to a 20 psi differential and a near steady state leak rate measured. This mimics exactly the leak test performed by Moog. This procedure is a revision of P0931, which was used at LM and SU. The revision incorporates requirements for VAFB.

B SAFETY

B.1 General

The GMA is a gas pressure vessel. Under normal operations, the GMA requires no safety measures or equipment beyond those required for the use of a supply gas cylinder. Use caution when any of the systems are pressurized and connected to a vacuum system. Do not vent pressure > 100 psi through the pumping portions of the system. Only allow pressure > 100 psi to vent through approved ports and make sure that they are open at time of venting. Personnel Protective Equipment (PPE) will be worn during hazardous operations as required by location. Note that the GMA is an extremely high value piece of space flight equipment. The GMA tanks are also fracture critical items, so care must be taken not to damage them in any way.

B.2 Mishap Notification

B.2.1 Injury

In case of any injury or illness requiring medical treatment - Dial 911

B.2.2 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.2.3 Contingency Response

Responses to contingencies/emergency (e.g., power failure) are listed in Section G.10.

C QUALITY ASSURANCE

C.1 QA Notification

This test will be conducted on a formal basis to approved and released procedures. **The QA program office and NASA program and NASA Safety representative shall be notified 24 hours prior to the start of this procedure**. A Quality Assurance Representative, designated by D. Ross shall be present during the procedure and shall review any discrepancies noted and approve their disposition. Upon completion of this procedure, the QA Program Engineer, D. Ross or her designate, 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 redline (make minor changes during execution) this procedure is given solely to the Test Director 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 Test Director or QA Representative, experiment functionality may be affected. Within hazardous portions of this procedure, all steps shall be worked in sequence and out-of-sequence work or redlines shall be approved by NASA Safety prior to their performance.

C.3 Discrepancies

Discrepancies will be recorded in a D-log or as a DR per Quality Plan P0108.

D TEST PERSONNEL

D.1 Personnel Responsibilities

The Test Director shall be Chris Gray or an alternate he shall designate. The person performing the operations (Test Director or Test Engineer) has overall responsibility for the implementation of this procedure and shall sign off the completed procedure and relevant sections within it.

D.2 Personnel Qualifications

The Test Director must have a detailed understanding of all procedures and experience in all of the GMA operations.

D.3 Required 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
NASA Safety Rep	1	SFAO or ANALEX

E REQUIREMENTS

E.1 Electrostatic Discharge Requirements

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

E.2 Lifting Operation Requirements

N/A

E.3 Hardware/Software Requirements

- Flight ECU
- Appropriate software for controlling GMA on the spacecraft, this includes a null script which enables command-line control of the GMA.
- Flight Gas Management Assembly (GMA) installed on the S/V
- Gas Delivery System (GDS)
- GMA Fill Manifold
- GMA Spin up Outlet Manifold.
- Vacuum leak detector
- Alcatel pump cart (or equivalent dry pumping system)
- Clean manual valve
- Plumbing lines, cleaned consistently with Class 100 practices
- Plumbing gender changers, elbows, etc. as required, cleaned consistently with Class 100 practices
- Class 100 down flow hood, if required
- Hand held particle counter, if required (sensitive to 0.5 microns or better)

Calibration Date: _____ S/N: _____ Model #: _____

E.4 Instrument Pretest Requirements

All GMA instrumentation used in taking data shall be “in calibration” at time of test.

E.5 Configuration Requirements

GMA work will be performed under Class 100 flow hood or in clean room. (Class 1,000 or better)

E.6 Optional Non-flight Configurations

N/A

E.7 Verification/ Success Criteria

Procedure must measure a leak rate for every measurable GMA solenoid valve (ie. Table 2 is completely filled out).

E.8 Constraints and Restrictions

Normal clean room practices apply under down flow hood and in clean room.

F REFERENCE DOCUMENTS

F.1 Drawings

Drawing No.	Title
26273	GMA Schematic, GP-B Dwg

F.2 Supporting documentation

Document No.	Title
S0699	GMA Leakage Test CSTOL
S0681	CSTOL Scripts for GMA Testing
SU/GP-B P0108	Quality Plan
SU/GP-B P059	GP-B Contamination Control Plan
LM/P479945	Missile System Prelaunch Safety Package
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 P0875	GP-B Maintenance and Testing at all Facilities
Various	ECU operations as applicable
P0960	GDS Operations
P0923	Connecting and Disconnecting the GMA and the GAF
P0968	Bleed Down of the GMA High Pressure

G OPERATIONS

G.1 Verify Appropriate QA Notification

QA Notified:

NASA Program and Safety Representative Notified:

_____ (Date & Time)

_____ (Date & Time)

G.2 Verify Configuration Requirements

Verify GMA is situated in a Class 1000 or better clean room or under a Class 100 or better flow hood. If GMA is under flow hood, verify the environment with a hand held particle counter. Counts under the hood shall average better than 10 per 0.1 cubic foot measured of size 0.5 micron or greater

Quality _____

G.3 Setting Up the GMA

Started on: _____

Note: Mark off each step of this section as it is completed.

Warning:
This procedure is considered a hazardous operation. These operations involve working with medium-pressure helium. Use standard practices for handling of medium-pressure gas (500 to 3000 psi per EWR 127-1).

- Complete Pre-Test Checklist (Section **G.8**)
- Verify connection of the Flight ECU to the GMA and start up the ECU and appropriate software. Record script used here: _____ **Do not cycle any GMA solenoid valves at this time**.
- Use the ECU to read GMA pressure sensors GP1, GP2, GP3, GP4, GP5, and GP6.
- Record their values here:

Table 1, GMA pressures, PSIA:

	GP1	GP2	GP3	GP4	GP5	GP6
Required	>200	<30	<30	<30	<30	<30
Pressure						

If GP, GP 5 and GP6 are above 30 psia, bleed the pressure out using procedure P0968. Bleed until pressure is at about 20 psia and record final pressures here:

Table 1A, GMA pressures, PSIA:

	GP1	GP2	GP3	GP4	GP5	GP6
Required	>200	~20	~20	~20	~20	~20
Pressure						

- If GP1 reads below 200 psia, fill the tanks to above 250 psia using P0960.
- Verify that GSE is connected per diagram 2 (Note: the GDS may not be necessary).
- Verify that GMA valve configuration (solenoid valves V1 through V6 closed, and V7 through V30 open, outlet manifold valves OMG1, OMG2, OMG3, OMG4, and OMP1A open and under vacuum).
- Now ready for leakage test.

Quality _____

G.4 GMA Internal Leakage Test.

Started on: _____

Note: Mark off each step of procedure as it is completed. All GMA solenoid valves will be opened with the ECU. Automatic vent on the leak detector should be disabled for this entire section

Warning:
Hazardous operations are about to begin, these operations involve working with medium-pressure helium. Use standard practices for handling of medium-pressure gas.

G.4.1 Request the area operation light be changed to Amber.
G.4.2 Establish a 10 foot controlled area.
G.4.3 Request a PA announcement that a hazardous task is about to begin.
G.4.4 Ensure all nonessential personnel are clear of area.
G.4.5 Use the ECU to open GMA solenoid valves V3 and V5.
G.4.6 Verify manual valves OM Purge is closed and open OM Leak valve. Start leak detector.
G.4.7 Wait ten minutes or until a stable leak rate is reached.
G.4.8 Record leak rate from V1 in Table 2.
G.4.9 Open solenoid valves V4 and V6.
G.4.10 Close solenoid valves V3 and V5.
G.4.11 Wait ten minutes or until a stable leak rate is reached.
G.4.12 Record leak rate from V2 in Table 2.
G.4.13 Close solenoid valves V4 and V6.
G.4.14 Open solenoid valve V1.
G.4.15 Wait ten minutes or until a stable leak rate is reached.
G.4.16 Record leak rate from V3 and V5 in Table 2.
G.4.17 Close GMA solenoid valve V1.
G.4.18 Close OM leak to isolate leak detector, open OM purge.
G.4.19 Open solenoid valves V3 and V5 and start OM purge vacuum source to evacuate.
G.4.20 When vacuum source is up to speed (i.e. current draw <0.33 amps) close OM Purge and open OM Leak then wait one minute.
G.4.21 Close solenoid valves V3 and V5.
G.4.22 Wait for a sufficiently low background leak rate. Record background here _____.
G.4.23 Open solenoid valve V2.
G.4.24 Wait ten minutes or until a stable leak rate is reached.
G.4.25 Record leak rate from V4 and V6 in Table 2.
G.4.26 Close solenoid valves V7, V8, and V10-V30 (leave V9 open).
G.4.27 Close Outlet manifold manual valves OMG2, OMG3, OMG4, and OMP1A.
G.4.28 Open solenoid valves V1, V2, V3, V4, V5, and V6.
G.4.29 Wait ten minutes or until a stable leak rate is reached.
G.4.30 Record leak rate from V7 in Table 2.
G.4.31 Close solenoid valve V9 and open solenoid valve V10.
G.4.32 Wait ten minutes or until a stable leak rate is reached.

G.4.33 Record leak rate from V8 in Table 2.
G.4.34 Close solenoid valve V10 and open solenoid valve V7.
G.4.35 Wait ten minutes or until a stable leak rate is reached.
G.4.36 Record leak rate from V9 in Table 2.
G.4.37 Close solenoid valve V7
G.4.38 Close OM leak to isolate leak detector, open OM purge.
G.4.39 Open V9.
G.4.40 Start OM Purge vacuum source to evacuate.
G.4.41 When vacuum source is up to speed (i.e. current draw <0.33 amps) close OM Purge and open OM Leak then close V9.
G.4.42 Wait for a sufficiently low background leak rate. Record background here _____.
G.4.43 Open solenoid valve V8.
G.4.44 Wait ten minutes or until a stable leak rate is reached.
G.4.45 Record leak rate from V10 in Table 2.
G.4.46 Close solenoid valve V8.
G.4.47 Close Outlet Manifold Manual Valve OMG1.
G.4.48 Open Outlet Manifold Manual Valve OMG2.
G.4.49 Open V13.
G.4.50 Wait ten minutes or until a stable leak rate is reached.
G.4.51 Record leak rate from V11 in Table 2.
G.4.52 Close V13 and open V14.
G.4.53 Wait ten minutes or until a stable leak rate is reached.
G.4.54 Record leak rate from V12 in Table 2.
G.4.55 Close V14 open V11.
G.4.56 Wait ten minutes or until a stable leak rate is reached.
G.4.57 Record leak rate from V13 in Table 2
G.4.58 Close solenoid valve V11
G.4.59 Close OM leak to isolate leak detector, open OM purge.
G.4.60 Open V13.
G.4.61 Start OM Purge vacuum source to evacuate.
G.4.62 When vacuum source is up to speed (i.e. current draw <0.33 amps) close OM Purge and open OM Leak then close V13.
G.4.63 Wait for a sufficiently low background leak rate. Record background here _____.
G.4.64 Open solenoid valve V12.
G.4.65 Wait ten minutes or until a stable leak rate is reached.
G.4.66 Record leak rate from V14 in Table 2.
G.4.67 Close V12.
G.4.68 Close OMG2 and open OMG3.
G.4.69 Open V17.
G.4.70 Wait ten minutes or until a stable leak rate is reached.
G.4.71 Record leak rate from V15 in Table 2.
G.4.72 Close V17 and open V18.
G.4.73 Wait ten minutes or until a stable leak rate is reached.
G.4.74 Record leak rate from V16 in Table 2.
G.4.75 Close V18 and open V15.

G.4.76 Wait ten minutes or until a stable leak rate is reached.
G.4.77 Record leak rate from V17 in Table 2.
G.4.78 Close solenoid valve V15.
G.4.79 Close OM leak to isolate leak detector, open OM purge.
G.4.80 Open V17.
G.4.81 Start OM Purge vacuum source to evacuate.
G.4.82 When vacuum source is up to speed (i.e. current draw <0.33 amps) close OM Purge and open OM Leak then close V17.
G.4.83 Wait for a sufficiently low background leak rate. Record background here _____.
G.4.84 Open solenoid valve V16.
G.4.85 Wait ten minutes or until a stable leak rate is reached.
G.4.86 Record leak rate from V18 in Table 2.
G.4.87 Close V16.
G.4.88 Close OMG3 and open OMG4.
G.4.89 Open V21
G.4.90 Wait ten minutes or until a stable leak rate is reached.
G.4.91 Record leak rate from V19 in Table 2.
G.4.92 Close V21 and open V22.
G.4.93 Wait ten minutes or until a stable leak rate is reached.
G.4.94 Record leak rate from V20 in Table 2.
G.4.95 Close V22 and open V19.
G.4.96 Wait ten minutes or until a stable leak rate is reached.
G.4.97 Record leak rate from V21 in Table 2.
G.4.98 Close solenoid valve V19.
G.4.99 Close OM leak to isolate leak detector, open OM purge.
G.4.100 Open V21.
G.4.101 Start OM Purge vacuum source to evacuate.
G.4.102 When vacuum source is up to speed (i.e. current draw <0.33 amps) close OM Purge and open OM Leak then close V21.
G.4.103 Wait for a sufficiently low background leak rate. Record background here _____.
G.4.104 Open solenoid valve V20.
G.4.105 Wait ten minutes or until a stable leak rate is reached.
G.4.106 Record leak rate from V22 in Table 2.
G.4.107 Close V20.
G.4.108 Close OMG4 and open OMP1A.
G.4.109 Open V25
G.4.110 Wait ten minutes or until a stable leak rate is reached.
G.4.111 Record leak rate from V23 in Table 2.
G.4.112 Close V25 and open V26.
G.4.113 Wait ten minutes or until a stable leak rate is reached.
G.4.114 Record leak rate from V24 in Table 2.
G.4.115 Close V26 and open V23.
G.4.116 Wait ten minutes or until a stable leak rate is reached.
G.4.117 Record leak rate from V25 in Table 2.
G.4.118 Close solenoid valve V23.

G.4.119 Close OM leak to isolate leak detector, open OM purge.

G.4.120 Open V25.

G.4.121 Start OM Purge vacuum source to evacuate.

G.4.122 When vacuum source is up to speed (i.e. current draw <0.33 amps) close OM Purge and open OM Leak then close V25.

G.4.123 Wait for a sufficiently low background leak rate. Record background here _____.

G.4.124 Open solenoid valve V24.

G.4.125 Wait ten minutes or until a stable leak rate is reached.

G.4.126 Record leak rate from V26 in Table 2.

G.4.127 Close V24.

G.4.128 Close OMP1A and OM Leak valve and disconnect leak detector.

G.4.129 Connect leak detector to **OM Vent 2**.

G.4.130 Start leak detector to evacuate plumbing and open OM Vent 2.

G.4.131 After leak detector goes into test mode, verify automatic vent is disabled and stop leak detector.

G.4.132 Open OM Vent 3 and start leak detector.

G.4.133 Open V29.

G.4.134 Wait ten minutes or until a stable leak rate is reached.

G.4.135 Record leak rate from V27 in Table 2.

G.4.136 Close V29 and open V30.

G.4.137 Wait ten minutes or until a stable leak rate is reached.

G.4.138 Record leak rate from V28 in Table 2.

G.4.139 Close V30 and open V27.

G.4.140 Wait ten minutes or until a stable leak rate is reached.

G.4.141 Record leak rate from V29 in Table 2.

G.4.142 Close solenoid valve V27.

G.4.143 Close OM Vent 2 to isolate leak detector and open OM Vent 1.

G.4.144 Open V29.

G.4.145 Start OM Vent 1 vacuum source to evacuate.

G.4.146 When vacuum source is up to speed (i.e. current draw <0.33 amps) close OM Vent 1 and open OM Vent 2 then close V29.

G.4.147 Wait for a sufficiently low background leak rate. Record background dominated by leakage through V27 and V29 _____.

G.4.148 Open solenoid valve V28.

G.4.149 Wait ten minutes or until a stable leak rate is reached.

G.4.150 Record leak rate from V30 in Table 2.

G.4.151 Open solenoid valve V27 and record aggregate leakage through V29 and V30_____.

G.4.152 Close V27, CV28, OM Vent valves1, 2 and 3.

G.4.153 Stop the leak detector without venting.

Quality _____

G.5 GMA Final Configuration

Started on: _____

Note:
Mark off each step of this section as it is completed.

G.5.1 Verify Table 2 is completely filled out.
G.5.2 Read GP1 using the ECU and record final pressure here: _____
G.5.3 If desired, the tank pressure may be bled out using P0968.
G.5.4 Verify all outlet manifold manual valves are closed.
G.5.5 Use the ECU to close all solenoid valves or run GMA Sleep Procedure.
G.5.6 The GMA is now safely filled to about 20 psia downstream of the regulators.
G.5.7 Shut down the leak detector and remove any unneeded GSE as desired by test director.

NOTE
HAZARDOUS OPERATIONS ARE NOW COMPLETE.

G.5.8 Request PA announcement that hazardous operations are now complete.
G.5.9 Ensure area warning light is returned to green
G.5.10 Disband controlled area
G.5.11 Complete Post Test Checklist (Section G.9).

Quality _____

G.6 Tables

Table 2, Solenoid valve leak rates

Solenoid Valve	Leak rate SCCS	Test Engineer initial	Quality Stamp	Solenoid Valve	Leak rate SCCS	Test Engineer initial	Quality Stamp
V1*				V17			
V2*				V18			
V3 + V5				V19			
V4 +V6				V20			
V7				V21			
V8				V22			
V9				V23			
V10				V24			
V11				V25			
V12				V26			
V13				V27			
V14				V28			
V15				V29			
V16				V30			
*200+ psi differential							

G.7 Diagrams

Diagram 1, GMA Schematic

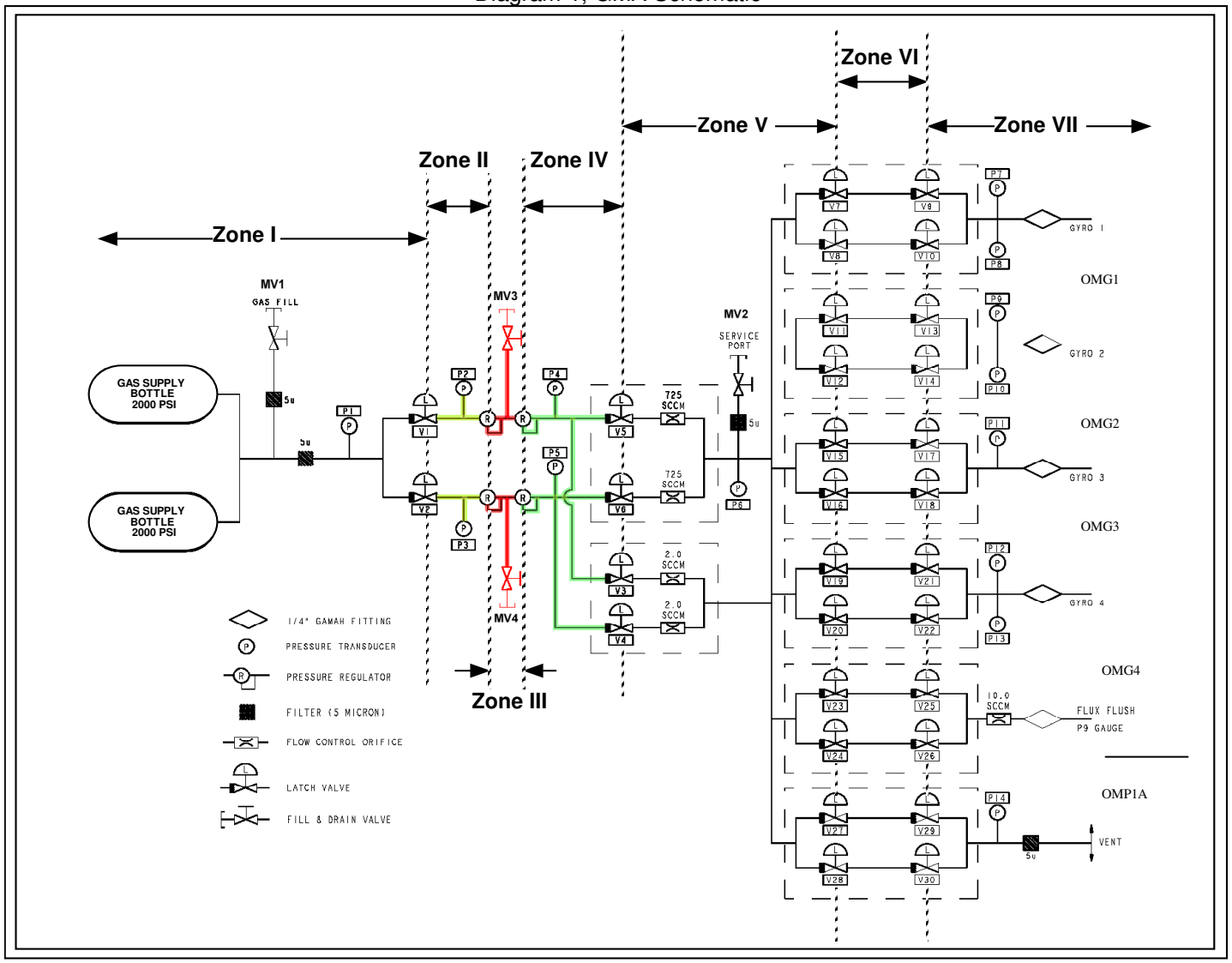
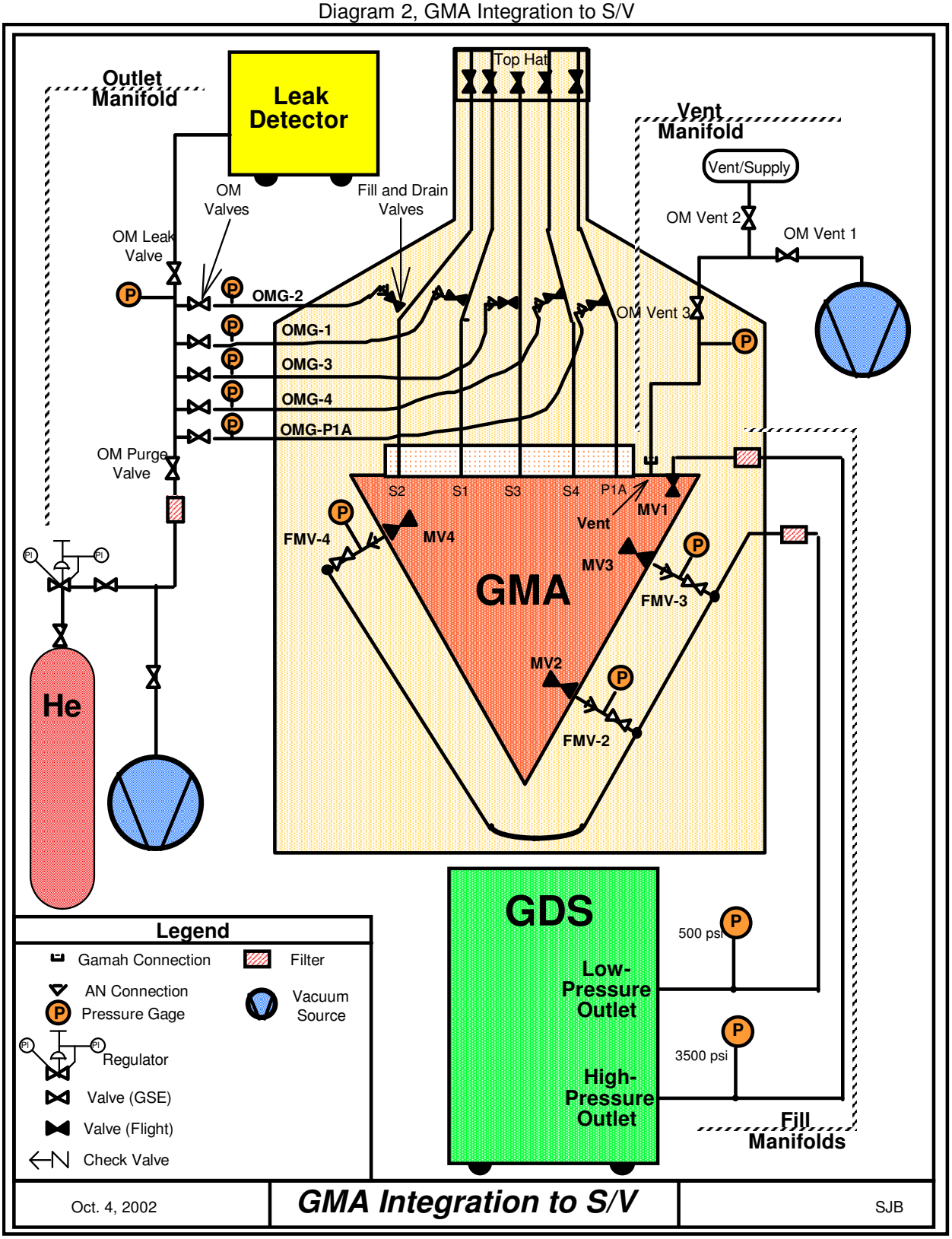


Diagram 2, GMA Integration to S/V



G.8 Pre-Test 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. If helium is to be used verify that a blue "HELIUM" tag is around the neck of the helium cylinder.		
	6. Verify all hazardous steps to be performed are identified to the test team.		
	7. Verify each test team member is certified for the task being performed and knows their individual responsibilities.		
	8. 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.		
	9. Confirm that each test team member clearly understands that he/she must stop the test if there is any anomaly or suspected anomaly.		
	10. 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.		
	11. Verify/Perform an Engineering and Safety high-bay walk down. Ensure all discrepancies are corrected prior to start of operations.		
	12.Confirm that each test team member understands that there will be a post-test team meeting.		
	TEAM LEAD SIGNATURE: _____		

G.9 Post-Test 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 not required to be performed are properly identified.		
	5- If applicable sign-off test completion.		
	TEAM LEAD SIGNATURE _____		

G.10 Contingency/Emergency Responses

In the event of an emergency requiring shutdown and/or evacuation which does allow time for steps to be taken without endangering personnel, the following general steps should be taken, in order of priority (operator to determine sequence):

- Isolate the flight hardware wetted surfaces (fluid flow paths) from the exterior environment by closing GSE valves (GDS V-24, GDS V-25, OMVent, OMPurge, and OMVent, or similar, as applicable to the state of assembly.)
- Use ECU to close all GMA solenoid valves.
- Record state of GMA and related flight volumes as known (valves open/closed, current pressures, ECU status, etc.).
- Shut down GSE as desired (leak detectors, vacuum sources, ECU control systems, GDS, etc.).

In the event of a power failure, the Test Director shall implement similar steps as (see above emergency shutdown steps).

In the event that these steps have been taken (in part or whole), when it safe for personnel to return to the equipment:

- The Test Director shall perform an evaluation of the current state of the hardware.
- With concurrence of the GMA, Responsible Engineer and QA, the Test Director shall issue a d-log detailing the steps required to return the flight equipment to its prior state and to establish which step the procedure shall continue from. The test director may issue partial instructions (i.e. start up GSE) for the purpose of better evaluation of the flight hardware status.
- If the Test Director, Responsible Engineer, or QA believe it necessary, a discrepancy report may be issued for MRB review.

H PROCEDURE SIGN OFF

The results obtained in the performance of this procedure are acceptable:

_____ date: _____
Test Director

Discrepancies if any:

Approved: _____ date: _____
C. Gray, GMA Responsible Engineer

Approved: _____ date: _____
QA Representative

Approved: _____ date: _____
D. Ross, QA