MOOG - GMA

Document No: 50569

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# DOCUMENT REVISION RECORD

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MOOG - GMA

# Detailed Specification

# Gas Management Assembly

# for the

# Gravity Probe-B Space Vehicle

Teamwork & Innovation
RELATIVITY MISSION
SPACE VEHICLE

**August 20, 2001**

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# 1. SCOPE

## 1.1 General

This specification establishes the performance and test requirements for the Gravity Probe-B Gas Management Assembly, hereinafter referred to as the GMA.

## 1.2 Function

The GMA provides helium gas at specified flow rates for use in spinning-up gyroscopes, and as exchange gas in the Probe.

# 2. APPLICABLE DOCUMENTS

## 2.1 Government Documents

The following government documents are applicable to the extent specified in this document. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification supersede.

| | |
|---|---|
| MIL-STD-454 | Standard General Requirements for Electronic Equipment (tailored) |
| MIL-STD-975 | NASA Standard Electrical, Electronic and Electromechanical (EEE) Parts List |
| MIL-STD-1522A | Standard General Requirements for Safe Design and Operation of Pressurized Missile and Space Systems |
| MIL-HDBK-5 | Metallic Materials and Elements for Aerospace Structures |
| NHB 5300.4 (3A-1) | Workmanship Standard for Soldering |
| NHB 5300.4 (3H) | Workmanship Standard for Crimping |
| NHB 5300.4 (3G) | Workmanship Standard for Interconnecting Cables, Harnesses and Wiring |

## 2.2 Non-Government Documents

The following documents are applicable to the extent specified in this document. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification supersede.

| | |
|---|---|
| 8A02681 | GMA Interface Control Drawing |

## 3.0 REQUIREMENTS

### 3.1 Interfaces

3.1.1 Functional Interface

The input/output functions are shown in Figure 1.

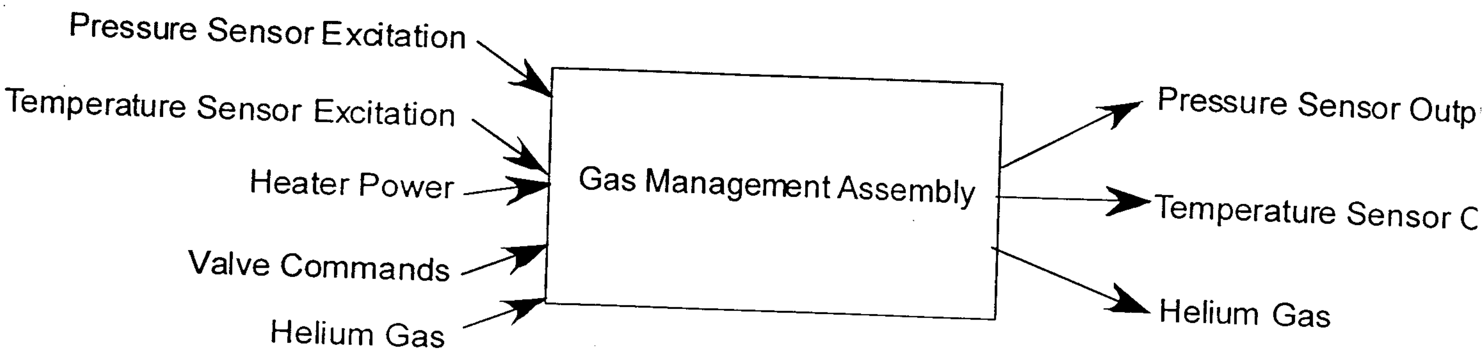


Fig. 1 Functional Interfaces

3.1.2 Mechanical Attachments

The interfacing mounting surface, attach points, electrical connectors, keep-out zones, and gas inlets and outlets will be compatible with the configurations and locations shown in LM drawing 8A02681.

3.1.3 Electrical Interface

The interfacing electrical circuits will be wired as shown in LMMS drawing 8A02681.

3.1.3.1 Valves
The valves shall be supplied a 30 V input, which is provided to the Latch Valve through a circuit which has a 4 ohm resistor in series. The pulse duration is 450 msec plus/minus 10 %. The resistance of each valve coil will be 58 ± 1 ohms at 70 ± 5 °F.

3.1.3.2 Temperature Sensors
Silicon Diode Temperature sensors will be supplied to the vendor as GFE.

3.1.3.3 Pressure Transducers
The pressure transducers shall be supplied with an excitation voltage of 10 ± .5 Volts. The input resistance shall be 5000 ohms minimum. The full-scale output voltage for each channel shall be no greater than the value shown in Table 1.

| ID # | ECU Side | Max Output Voltage (mV) |
|---|---|---|
| P2 | A | 30.30 |
| P10 | A | 7.69 |
| P1 | A | 33.33 |
| P7 | A | 10 |
| P11 | A | 10 |
| P13 | A | 20 |
| P4 | A | 20 |
| | | |
| P8 | B | 7.69 |
| P14 | B | 7.69 |
| P9 | B | 10 |
| P12 | B | 10 |
| P6 | B | 10 |
| P3 | B | 20 |
| P5 | B | 20 |

Table 1. Allowable Pressure Transducer Output Voltage

## 3.2 Characteristics

3.2.1 Performance

The GMA shall have the following performance upon command at the operating conditions specified in 3.2.8 and environments specified in 3.2.5 throughout the life specified in 3.2.7.

3.2.1.1 Gas Supply
The GMA shall be capable of providing a minimum of 1100 liters of Helium gas [Standard Temperature and Pressure (0 deg C, 760 torr)] at the outlets of the GMA, while maintaining a minimum tank pressure of 689,500 Pa (100 psia).

3.2.1.2 Mass Flow Rate – Gyro Spin Up
The GMA shall be capable of providing helium gas at a flow rate of 725 sccm ± 20 %, calculated using Root Sum Squared (RSS), to each of the Science Gyroscopes. This flow rate is only required for one gyro at a time and assumes the downstream inlet pressure for each gyroscope inlet at the Probe is 40 Torr.

3.2.1.3 Mass Flow Rate – Gyro Slow Spin
The GMA shall be capable of providing helium gas at a flow rate of 2 sccm ± 20 %, calculated using Root Sum Squared (RSS), to each of the Science Gyroscopes. This flow rate is only required for one gyro at a time and assumes the downstream inlet pressure for each gyroscope inlet at the Probe is 40 Torr.

3.2.1.4 Mass Flow Rate – Exchange Gas
The GMA shall be capable of providing helium gas at a flow rate of 2 sccm ± 20 %, calculated using Root Sum Squared (RSS), at the inlet to the probe. This flow rate assumes the downstream inlet pressure at the probe is $< 1 \times 10^{-8}$ torr. The design shall incorporate features in the event of failure to incorporate a maximum flow of 10 sccm into the probe.

3.2.1.5 Mass Flow Rate – System Purge
The GMA shall be capable of flowing gas overboard through a non-propulsive vent at a rate not greater than 800 sccm.

3.2.1.6 Pressure Transducer Accuracy

The output produced by the pressure transducers shall be within 1.5% of full-scale value of the value predicted by the calibration curve for a given unit. This accuracy is required over the range of survival temperatures specified in, and during and after exposure to a total radiation dose of 50Krads.

3.2.1.7 Evacuation

The GMA system shall be capable of an internal vacuum less than 1 X $10^{-6}$ torr.

3.2.2 Physical Characteristics

The GMA shall have the following physical characteristics before, during (where applicable) and after exposure to the environments specified in 3.2.5.

3.2.2.1 Mass
The assembled GMA mass shall be less than 64 kg.

3.2.2.2 Space Envelope
The GMA external dimensions shall meet the space envelope requirements shown in LM drawing 8A02681.

3.2.2.3 Structural Integrity
The GMA shall be capable of withstanding the following loads:

3.2.2.3.1 Proof Pressure
The system proof pressure shall be 1.5 times Maximum Expected Operating Pressure (MEOP).

3.2.2.3.2 Burst Pressure
The system design burst pressure shall be 2 times Maximum Expected Operating Pressure (MEOP) for tanks, 4.0 times for tubing and fittings, and 2.5 times MEOP for other components. Successful operation of system components is not required after exposure to burst pressure.

3.2.2.3.3 Collapse Pressure
The GMA shall withstand a collapse pressure of 101,325 Pa-differential (14.7 psid).

3.2.2.3.4 Pressure Vessel Safety
The GMA tanks and components shall meet the requirements of MIL-STD-1522A. The tanks shall be designated "Fracture Critical" and handled appropriately. Vendor shall supply "Fracture Control" plan.

3.2.2.3.5 Limit Inlet Load
The limit inlet load shall be TBD-LM N axial, TBD-LM N side load, and TBD-LM N-m moment, applied simultaneously at the inlet flanges (ref LM drawing 8A02681).

3.2.2.3.6 Strength
The GMA shall withstand the stress resulting from the loads specified in 3.2.2.3.5 with positive margins of safety using factors of safety of 1.25 for yield and 2.0 for ultimate.

3.2.2.3.7 First Structure Mode
Natural frequency of assembled GMA shall be greater than 50 Hz.

3.2.2.4 Redundancy
Redundancy shall be provided to ensure that, to the greatest extent practicable, there are no single point failures.

3.2.2.5 Electrical Characteristics
The electrical components of the GMA shall have the following characteristics:

3.2.2.5.1 Electrical Circuits
To the maximum extent practicable, primary failure conditions of input/output functions shall present electrically open circuits or very high impedance to interfacing equipment.

3.2.2.5.2 Wire Harnessing
All conductor sizes shall be adequate for the expected current and voltage levels.

3.2.2.5.3 Conductors
All conductors shall be twisted shielded pair type.

3.2.2.5.4 Insulation Resistance
The insulation resistance between all electrically isolated circuits, including unused pins, and the GMA ground plane shall not be less than 100 megaohms at 250 VDC.

3.2.2.5.5 Wire Damage
Insulated hook-up and harness wire shall be protected from insulation damage due to abrasion, extrusion or other thermal or mechanical stress, which might expose conductors unintentionally.

3.2.2.7 External Leakage
External gas leakage into the GMA shall be less than $1 \times 10^{-6}$ (TBR-SU) scc/sec of Gaseous Helium with the interior evacuated.

3.2.2.8 Internal Leakage
Internal leakage of each of the valves shall be less than $1 \times 10^{-4}$ scc/sec of Gaseous Helium per seat at MEOP and at 20 psia inlet pressure.

3.2.2.9 Contamination

3.2.2.9.1 Internal Contamination
Internal GMA components shall be cleaned to MIL-STD-1246 level 100A. Assembly of the GMA shall occur in a clean room environment compatible with maintaining the specified level of cleanliness.

3.2.2.9.2 External Contamination
GMA external surfaces shall be free of contamination when examined by an individual with 20/20 (or corrected to 20/20) vision under white light (min. 100-ft. candles), at an oblique angle, at a distance of 40 centimeters (16 inches).

3.2.2.9.3 Self-Generated Contaminants
The GMA shall incorporate design features to minimize self-generated contaminants.

3.2.2.9.4 Purging Capability
The GMA design shall maximize the ability to purge the GMA during ground and on orbit operations.

3.2.2.10 Cycle Life Margin
After GMA protoqualification testing, all components shall have at least a 2 to 1 cycle life margin over the requirements specified in 3.2.7.2.2.

3.2.3 Failure Propagation

The GMA shall be designed so that a failure of a component will not induce any other failure external to the failed component.

3.2.4 Maintainability

The GMA design shall be such that scheduled maintenance and repair, or adjustments, are not required.

3.2.5 Environmental Conditions

The GMA shall perform as specified in 3.2.1 during exposure, if appropriate, and after exposure to all natural and induced environments experienced during the following: manufacture, test, transportation, handling, storage, launch-pad, ascent, and orbit operations.

3.2.5.1 Non-Operating Environments
The GMA shall be designed to withstand, without degradation of the physical characteristics specified in 3.2.2, an atmospheric pressure from 95 to $108 \times 10^3$ Pa, a temperature of 16° to 35° C, and a relative humidity of not more than 90%. and the following non-operating requirements.

3.2.5.1.1 Transportation, Handling and Storage Environment
The GMA, when packaged and packed in accordance with Section 5, shall not experience environmental conditions more severe than those specified for flight when the unit is exposed to the pre-flight transportation, storage and handling environments.

3.2.5.1.2 Launch and Ascent Environment
The GMA shall be capable of withstanding the random vibration environment. The protoqual random vibration environment shall be that shown in Figure 2. The acceptance random vibration level is 3 dB lower than the protoqual level.

The Gas Management Assembly shall be capable of performance as specified herein after exposure to the random vibration environment as specified in Figure 1. The unit shall be subjected to an overall level of 11 Grms in each of 3 axes, 1 minute /axis. Test tolerance shall be as listed in Table 1.

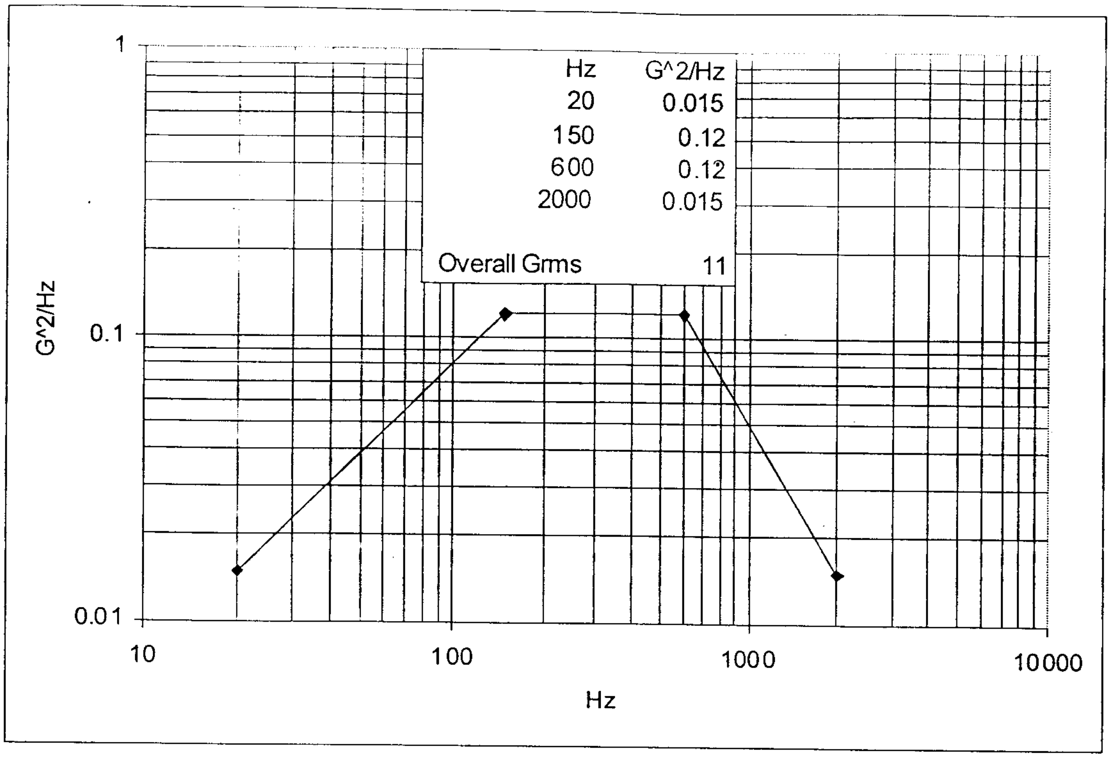


Figure 1. GMA Protoqual Random Vibration Environment

| | | |
|---|---|---|
| PSD: | 20 to 1000 Hz: | +/-1.5dB |
| | 1000 to 2000 Hz: | +/-3dB |
| RMS: | | ±10% overall |

Table 1 Random Vibration Test Tolerance

The GMA shall be capable of performing after exposure to the protoqual pyroshock environment shown in Figure 2. Figure 2 is a Shock Response Spectrum with Q= 10.

**The environment in Figure 2 applies to a test in the normal to mounting plane axis only. The test tolerance is ±6 dB. With natural frequencies spaced at 1/6-octave intervals, at least 50 percent of the test spectrum values are greater than the nominal test specification. The Off-axis (axes in-mounting-plane) test level (SRS) will be plotted with an overlay of the specified environment shown in Figure 2.**

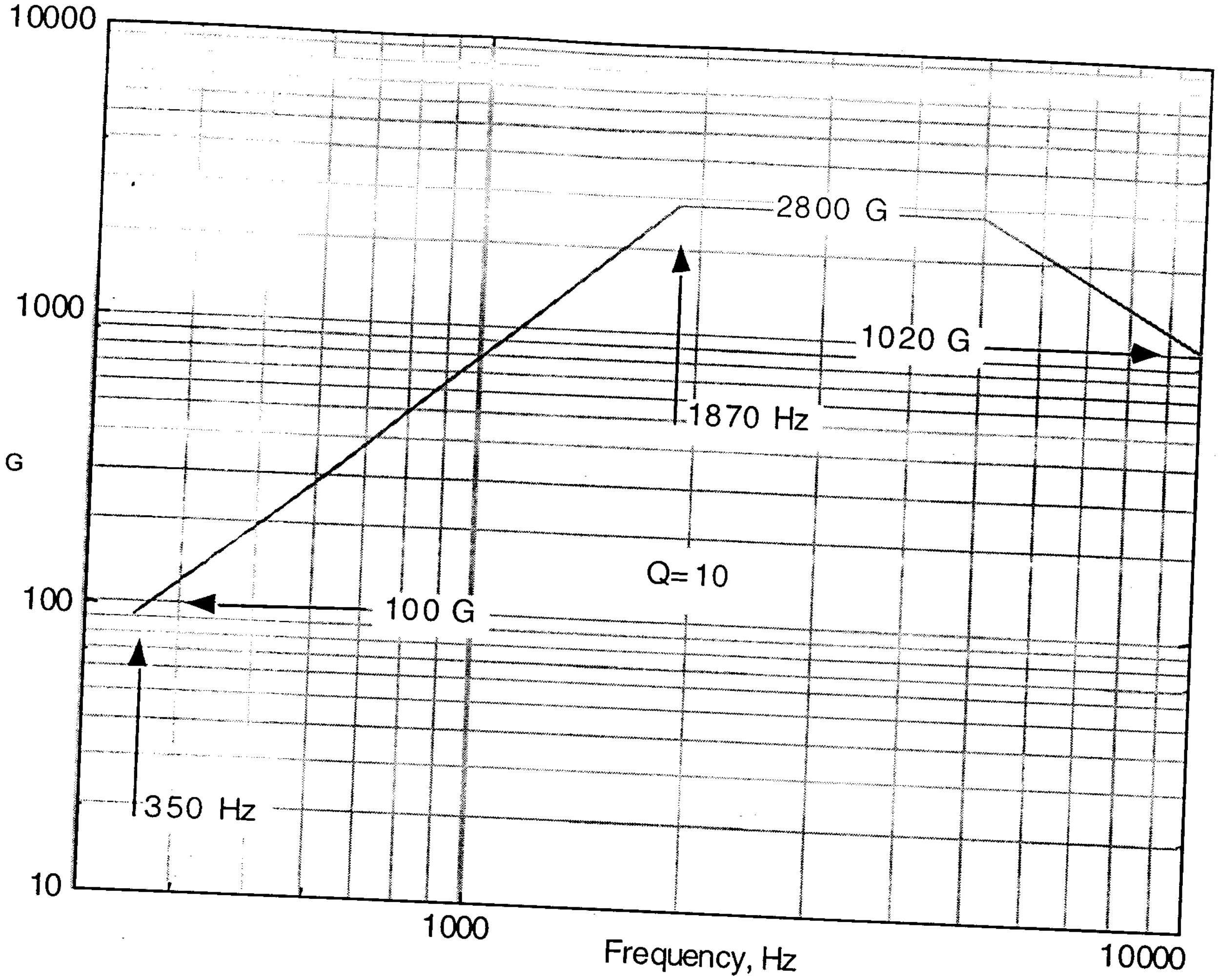


Figure 2. GMA Interface Protoqual Pyroshock Environment

3.2.5.2 Operating Environments
The GMA shall be designed to meet the performance requirements of 3.2.1 and the physical characteristic requirements of 3.2.2 in the following orbital environments.

3.2.5.2.1 Temperature

| | Operate | | Survival | |
|---|---|---|---|---|
| | Max | Min | Max | Min |
| Acceptance | 35C | 5C | 35C | -44C |
| Proto-qual | 40C | 0C | 40C | -49C |

3.2.5.2.2 Acceleration and Sustained Load
The GMA design load is 15g to be applied in any direction.

3.2.5.2.3 Solar Radiation
Not applicable, except for the solar radiation contribution to the thermal environment as defined in 3.2.5.2.

3.2.6 Transportability

The GMA, when packaged and packed in accordance with Section 5, shall be capable of being transported by air and road.

3.2.7 Useful Life

3.2.7.1 Shelf Life
The GMA shall be designed to have a shelf/storage life of five years after protoqualification testing. The internal volume of the GMA shall be pressurized to a pressure not greater than 50 psig.

3.2.7.2 Operating Life

3.2.7.2.1 Orbital Life
The GMA will be capable of satisfactory operation in the orbital environment for a period of not less than 24 months.

3.2.7.2.2 Cycle Life
Each latching valve shall be capable of 5,000 cycles after protoqualification test, at the maximum operating temperature specified in 3.2.5.2.1. Each Fill/Drain valve shall be capable of 50 cycles after protoqualification, at ambient conditions.

3.2.8 Operating Conditions

3.2.8.1 Pressurant Fluids
The GMA will be exposed to gaseous helium of 99.9995 % purity. The gas supplied from the GMA shall be gaseous helium of 99.9990 % purity.

3.2.8.2 Test and Cleaning
For testing purposes, gaseous Helium of 99.9995 % purity shall be used. All cleaning fluids shall be compatible with the material of the GMA, and the specified cleanliness level.

## 3.3 Design and Construction

3.3.1 Parts, Materials and Processes

Parts, materials and processes shall be selected to meet the reliability requirements and environmental requirements specified herein. The following materials are prohibited:

1) Cadmium, Zinc, or Selenium
2) Pure, unalloyed tin (greater than 99.1% tin)
3) Corrosive Solder Fluxes
4) Mercury and compounds of Mercury
5) Silicones which evolve a corrosive acid

3.3.1.1 Outgassing
All materials exposed to vacuum shall not lose more than one (1) percent of total weight after exposure for 24 hours at 125° C and $1.333 \times 10^{-4}$ Pa and no more than 0.1 percent of the material shall be in the form of vaporizable condensable materials.

3.3.1.2 Dissimilar Metals
Where it is impractical to avoid dissimilar metals in direct contact with each other or their exposure to the same electrolyte, suitable protection shall be provided as required to meet the environmental requirements specified under paragraphs 3.2.5 herein.

3.3.1.3 Corrosion Resistance
Metals shall either be of a corrosion resistant type or suitably treated or protected to resist corrosion. Protective methods and materials for cleaning, surface treatment, and application of finishes and protective coatings shall be accomplished per contractor's best practices. Cadmium, zinc, or electro-deposited tin shall not be used as a finish.

3.3.1.4 Fungus Resistance
Materials that are nutrients for fungi shall not be used.

3.3.1.5 Electronic Equipment
Electronic equipment shall be designed and manufactured in accordance with MIL-STD-454, Standard General Requirements for Electronic Equipment (tailored). Reliability of parts shall meet the intent of class B (ICs), JANTXV (discrete semiconductors) and ERMIL (passive parts).

3.3.1.6 Bonding and Grounding
The mounting surfaces for the GMA to the spacecraft and electrical connectors to the GMA shall be bare metal.

3.3.1.7 Contamination Control
Procedures and processes shall be utilized to insure that contamination control limits are maintained on the unit during manufacture, assembly, test and transportation. Whenever the internal flow passages of the GMA are exposed, the GMA shall be within a clean room level compatible with maintaining the specified level of cleanliness and gas purity.

3.3.1.8 Lubricants
The GMA shall not use any lubricants in the wetted gas path.

3.3.1.9 Fasteners
Fasteners shall be NAS type with appropriate strength specifications.

3.3.2 Workmanship

The workmanship will be of quality to assure safety, proper operation, high reliability, and service life requirements. Particular attention will be given to neatness, cleanliness, and thoroughness of all processes involving assembly and finishing of all hardware items. Workmanship standards will be employed throughout all phases of hardware manufacture to control the quality of operation. Electrical workmanship shall comply with NASA NHB 5300.4 (3A-1), 5300.4 (3G), and 5300.4 (3H). Items not covered by the NHB series for electrical and electronic workmanship shall be in accordance with MIL-STD-454, Requirement 9.

3.3.3 Product Marking

The end-item GMA pallet shall be marked by engraving or other suitable method.

# 4. QUALITY ASSURANCE PROVISIONS

## 4.1 General

This section outlines quality assurance provisions necessary to verify the Section 3 performance/design characteristics and operability of the GMA. The test program shall be in accordance with the specification herein.

### 4.1.1. Responsibility for Tests

Tests shall be performed by the GMA Vendor.

## 4.2 Quality Conformance Inspections

Formal qualification inspections, analyses and tests shall be conducted to validate that the GMA satisfies the requirements of Section 3 herein. The GMA shall undergo acceptance testing and protoqualification testing. This activity also shall verify the effectiveness of the manufacturing process. When environmental conditions cannot be properly or conservatively simulated in test, allowances for material properties, combined loading and other missing effects shall be provided in test procedures and applied loads. Where prior loading histories affect the structural adequacy of a test article, these shall be included in all test requirements. Adequate instrumentation shall be provided in order to evaluate test results. All protoqualification testing shall be completed prior to the first flight. Environmental acceptance testing shall be completed on the GMA prior to its installation on a flight or qualification model spacecraft.

### 4.2.1 General Test Conditions

#### 4.2.1.1 Ambient Conditions

Unless otherwise specified, the following tests shall be performed at an atmospheric pressure from 95 to $108 \times 10^3$ Pa, a temperature of 16° to 35° C, and a relative humidity of not more than 90%. When tests are performed with atmospheric conditions substantially different from these values, proper allowance for changes in instrument readings shall be made to compensate for deviations from the specified conditions.

#### 4.2.1.2 Calibration

The accuracy of instruments and test equipment shall be periodically verified by the calibration procedures that ensure tracebility to NIST standards.

#### 4.2.1.3 Test Sequence

Operative and non-operative requirements may be verified during a single test sequence.

#### 4.2.1.4 Performance Checks

Prior to the conduct of each test, the test article shall be instrumented and checked for satisfactory performance under ambient room conditions. Performance checks shall be made in accordance with the test procedures. A record shall be made of all data necessary to determine complete operational and performance characteristics.

4.2.2 Acceptance Tests

4.2.2.1 Test Sequence
The sequence of acceptance tests shall be as shown below:

| Test Sequence | Test | Method |
|---|---|---|
| 1 | Dimensional Inspection | 4.2.2.2.1 |
| 2 | Insulation Resistance | 4.2.2.2.2 |
| 3 | Proof Pressure | 4.2.2.2.3 |
| 4 | External Leakage | 4.2.2.2.4 |
| 5 | Ambient Functional | 4.2.2.2.5 |
| 6 | Cleanliness Verification | 4.2.2.2.6 |
| 7 | Mass Properties | 4.2.2.2.7 |

4.2.2.2 Test Methods
The methods of conducting tests shall be as follows:

4.2.2.2.1 Dimensional Inspection
Verify as-built dimensions and interface locations.

4.2.2.2.2 Insulation Resistance
Insulation resistance shall be verified using the method described in NHB 5300.4 (3G).

4.2.2.2.3 Proof Pressure
Pressurize to 1.5 times MEOP.

4.2.2.2.4 External Leakage
The GMA shall be evacuated using a helium leak detector. All mechanical joints and 100 percent of the surface shall be checked using helium.

4.2.2.2.5 Ambient Functional
The resistance of each valve coil shall be measured at ambient temperature. The response of each latching valve shall be verified. The internal leakage rate of each latching valve shall be verified. The regulation band of the pressure regulators shall be verified. The calibration of each pressure transducer shall be verified. The leakage rate of the fill/drain valves shall be verified.

With the GMA outlets exhausting into a pressure of 40 torr at the probe inlet, the helium mass flow output of each GMA flow path shall be verified at ambient temperature. The flow output shall be verified at the Maximum and Minimum Expected Operating Pressures of the He supply tank system.

4.2.2.2.6 Cleanliness and Gas Purity Verification
The outside surface of the GMA shall be visually examined to the criteria established in 3.2.2.9.2. Cleanliness and gas purity shall be demonstrated by collecting samples at each of the flow path outlets.

4.2.2.2.7 Mass Properties
The mass of the GMA shall be measured and recorded.

4.2.3 Protoqualification Tests

4.2.3.1 Test Sequence
The sequence of protoqualification tests shall be as shown below:

| Test Sequence | Test | Method |
|---|---|---|
| 1 | Acceptance Test | 4.2.2.1 |
| 2 | Random Vibration | 4.2.3.2.1 |
| 3 | Abbreviated Ambient Functional | 4.2.3.2.2 |
| 4 | External Leakage | 4.2.2.2.4 |
| 5 | Cleanliness Verification | 4.2.2.2.6 |
| 6 | Thermal Cycling | 4.2.3.2.3 |
| *7 | Hot/Cold Leakage | 4.2.3.2.4 |
| *8 | Hot/Cold Functional | 4.2.3.2.5 |
| 9 | Insulation Resistance | 4.2.2.2.2 |
| 10 | Ambient Functional | 4.2.2.2.5 |
| 11 | Cleanliness Verification | 4.2.2.2.6 |

* The Hot/Cold Leakage and Functional Tests may be performed concurrently with the Thermal Cycling Test.

The pressure transducers shall be radiation tested separately.

4.2.3.2 Test Methods
The methods of conducting tests shall be as follows:

4.2.3.2.1 Random Vibration
The GMA shall be exposed to the protoqualification test random vibration environment as defined in paragraph 3.2.5.1.2. The level shall be as shown in Figure 2. The level shall be applied on each axis, one axis at a time. The test tolerance shall be ±3 dB over the whole frequency range. At the conclusion of testing, the GMA shall be visually examined for evidence of damage or adverse effects.

4.2.3.2.2 Abbreviated Ambient Functional
The resistance of each valve coil shall be measured at ambient temperature. The response of each latching valve shall be verified. The internal leakage rate of each plumbing branch shall be verified. The regulation band of the pressure regulators shall be verified. The calibration of each pressure transducer shall be verified. The leakage rate of the fill/drain valves shall be verified.

4.2.3.2.3 Thermal Cycling
The GMA shall be subjected to 6 thermal cycles between the minimum survival temperature specified in 3.2.5.2.1 and the maximum survival temperature in 3.2.5.2.1, while the GMA is in a vacuum of 1.33 Pa ($10^{-2}$ torr) or lower. Each temperature cycle shall begin at ambient temperature. The dwell time at the high and low temperature shall be 6 hours or greater during the first and last cycle. Intermediate cycles shall have at least 1-hour soaks at the hot and cold temperatures with power turned on. The temperature profile is shown in Figure 4. The Hot/Cold Leakage (4.2.3.2.4) and Hot/Cold Functional Tests (4.2.3.2.5) shall be performed during the last thermal cycle.

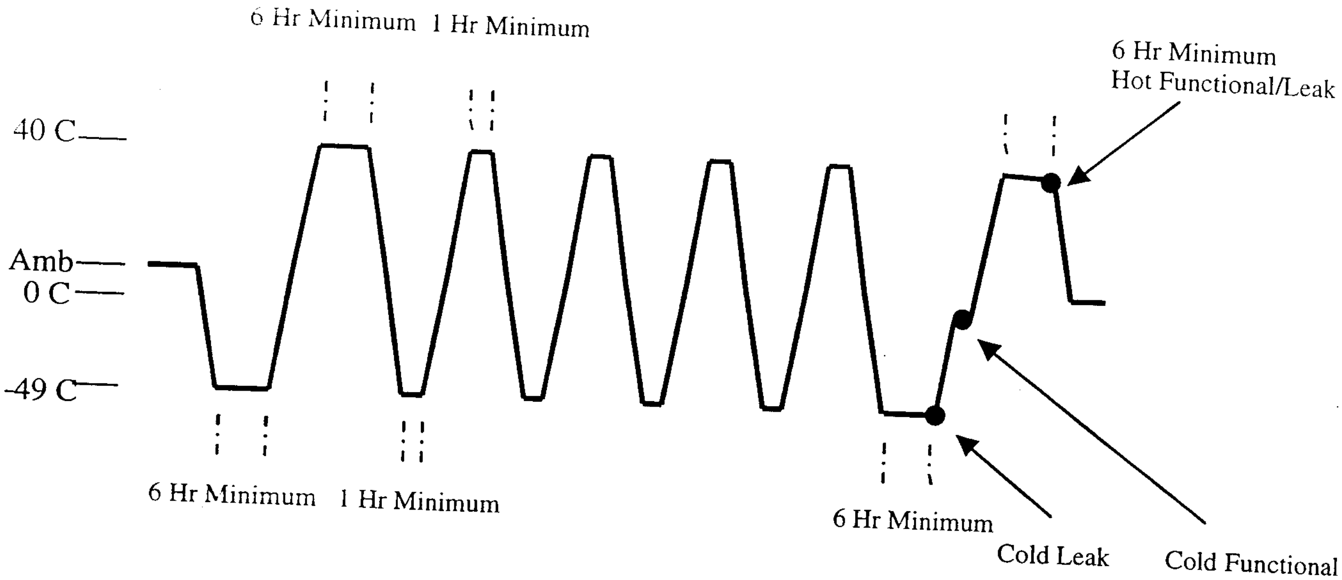


Figure 4. Thermal Cycling Profile

4.2.3.2.4 Hot/Cold Leakage
All mechanical joints and 100 percent of the GMA surface shall be checked using a helium leak detector at the minimum and maximum survival temperatures specified in 3.2.5.2.1.

4.2.3.2.5 Hot/Cold Functional
The following tests shall be performed at the minimum and maximum operating temperatures. The resistance of each valve coil shall be measured. The response of each latching valve shall be verified. The internal leakage rate of each latching valve shall be verified. The regulation band of the pressure regulators shall be verified. The calibration of each pressure transducer shall be verified. The leakage rate of the fill/drain valves shall be verified. Performance of the thermal control components shall be verified.

With the GMA outlets exhausting into a pressure of 40 torr at the probe inlet, the helium mass flow output of each GMA flow path shall be verified the minimum and maximum operating temperatures. The flow output shall be verified at the Maximum and Minimum Expected Operating Pressures of the He supply tank system.

## 4.3 Verification

4.3.1 General

The verification program shall ensure that the GMA conforms to the requirements specified in Sec 3. Each requirement will be verified as specified herein.

4.3.2 Responsibility for Verification

Verification that the GMA meets the design and performance requirements specified in Sec 3 is the responsibility of the Vendor.

4.3.3 Verification Methods

Qualification and acceptance shall be accomplished by any one or more of the following methods:

- Similarity
- Analysis
- Inspection
- Demonstration
- Test

4.3.3.1 Similarity
Verification by similarity is the process of assessing by review of prior test data or hardware configuration and application that the article is similar or identical in design and manufacturing process to another article that has previously been qualified to equivalent or more stringent specifications.

4.3.3.2 Analysis
Verification by analysis is a process used in lieu of or in addition to testing to verify compliance to specification requirements. The selected techniques may include systems engineering analysis, statistics and qualitative analysis, computer and hardware simulations, and analog modeling. Analysis may be used when it can be determined that:

- Accurate analysis is possible
- Test is not cost-effective or physically possible
- Similarity is not applicable
- Verification by inspection is not adequate.

4.3.3.3 Inspection
Verification by inspection (that is, physical verification of compliance with drawings, wire coding, material compliance) may be used in lieu of or in conjunction with testing to verify design features.

4.3.3.4 Demonstration
Validation by demonstration is the process where demonstration techniques (for example, service access, transportability, crew-hardware interfaces, and replacement provisions) are used in lieu of or in conjunction with test to verify compliance with the requirements.

4.3.3.5 Tests
Verification tests may be functional or environmental. Functional testing is conducted on flight or flight-configured hardware at conditions equal to or less than design specifications. Its purpose is to establish that the hardware performs satisfactorily in accordance with design specifications. Environmental testing is conducted on flight or flight-configured hardware to ensure the flight hardware will perform satisfactorily in its flight environment. Examples are vibration, acoustic, and thermal-vacuum. Environmental testing may or may not be combined with functional testing, depending on the objectives of the test.

4.3.4 Verification Selection
The methods selected for verification of the design and performance requirements of Sec 3 are presented in the verification matrix, Table 4.3-1.

17 July 2001

| | | Verification Method | | | | | |
|---|---|---|---|---|---|---|---|
| | | S | A | I | D | T | Remarks |
| 3.1 | *Interfaces* | | | | | | N/A |
| 3.1.1 | Functional Interface | | | | | X | |
| 3.1.2 | Mechanical Attachments | | | X | | | |
| 3.1.3 | Electrical Interface | | | | | X | |
| 3.1.3.1 | Valves | | | | | X | |
| 3.1.3.2 | Temperature Sensors | | | | | | ..................N/A |
| 3.1.3.3 | Pressure Transducers | | | | | X | |
| 3.2 | *Characteristics* | | | | | | ..................N/A |
| 3.2.1 | ***Performance*** | | | | | | ..................N/A |
| 3.2.1.1 | Gas Supply | | | | | X | |
| 3.2.1.2 | Mass Flow Rate – Gyro Spin Up | | | | | X | |
| 3.2.1.3 | Mass Flow Rate – Gyro Slow Spin | | | | | X | |
| 3.2.1.4 | Mass Flow Rate – Exchange Gas | | | | | X | |
| 3.2.1.5 | Mass Flow Rate – System Purge | | | | | X | |
| 3.2.1.6 | Pressure Transducer Accuracy | | | | | X | |
| 3.2.2 | *Physical Characteristics* | | | | | | ..................N/A |
| 3.2.2.1 | Mass | | | | | X | |
| 3.2.2.2 | Space Envelope | | | X | | | |
| 3.2.2.3 | *Structural Integrity* | | | | | | ..................N/A |
| 3.2.2.3.1 | Proof Pressure | | | | | X | |
| 3.2.2.3.2 | Burst Pressure | | | | | X | |
| 3.2.2.3.3 | Collapse Pressure | | | | | X | |
| 3.2.2.3.4 | Pressure Vessel Safety | | X | | | X | |
| 3.2.2.3.5 | Limit Inlet Load | | X | | | | |
| 3.2.2.3.6 | Strength | | X | | | | |
| 3.2.2.4 | Redundancy | | X | | | | |
| 3.2.2.5 | *Electrical Characteristics* | | | | | | ..................N/A |
| 3.2.2.5.1 | Electrical Circuits | | X | | | | |
| 3.2.2.5.2 | Wire Harnessing | | X | X | | | |
| 3.2.2.5.3 | Conductors | | | X | | | |
| 3.2.2.5.4 | Insulation Resistance | | | | | X | |
| 3.2.2.5.5 | Wire Damage | | | X | | | |
| 3.2.2.7 | External Leakage | | | | | X | |
| 3.2.2.8 | Internal Leakage | | | | | X | |
| 3.2.2.9 | *Contamination* | | | | | | ..................N/A |

| | | Verification Method S | A | I | D | T | Remarks |
|---|---|---|---|---|---|---|---|
| 3.2.2.9.1 | Internal Contamination | | | X | | | |
| 3.2.2.9.2 | External Contamination | | | X | | | |
| 3.2.2.9.3 | Self-Generated Contaminants | | X | | | X | |
| 3.2.2.9.4 | Purging Capability | | X | | | | |
| 3.2.2.10 | Cycle Life Margin | X | | | | | |
| 3.2.3 | Reliability | | X | | | | |
| 3.2.4 | Maintainability | | X | | | | |
| 3.2.5 | *Environmental Conditions* | | | | | | ..................N/A |
| 3.2.5.1 | *Non-Operating Environments* | | | | | | ..................N/A |
| 3.2.5.1.1 | Transportation, Handling and Storage Environment | | X | | | | |
| 3.2.5.1.2 | Launch and Ascent Environment | | X | | | X | |
| 3.2.5.1.3 | Pyroshock | | | | | X | |
| 3.2.5.2 | *Operating Environments* | | | | | | ..................N/A |
| 3.2.5.2.1 | Temperature | | | | | X | |
| 3.2.5.2.2 | Acceleration and Sustained Load | | X | | | | |
| 3.2.5.2.3 | Solar Radiation | | | | | | ..................N/A |
| 3.2.6 | Transportability | | X | | | | |
| 3.2.7 | *Useful Life* | | | | | | |
| 3.2.7.1 | Shelf Life | | X | | | | |
| 3.2.7.2 | *Operating Life* | | | | | | ..................N/A |
| 3.2.7.2.1 | Orbital Life | X | | | | | |
| 3.2.7.2.2 | Cycle Life | X | | | | | |
| 3.2.8 | *Operating Conditions* | | | | | | ..................N/A |
| 3.2.8.1 | Pressurant Fluids | | | X | | | |
| 3.2.8.2 | Test & Cleaning | | | X | | | |
| 3.3 | *Design and Construction* | | | | | | ..................N/A |
| 3.3.1 | Parts, Materials and Processes | | | X | | | |
| 3.3.1.1 | Outgassing | | X | | | | |
| 3.3.1.2 | Dissimilar Metals | | | X | | | |
| 3.3.1.3 | Corrosion Resistance | | | X | | | |
| 3.3.1.4 | Fungus Resistance | | | X | | | |
| 3.3.1.5 | Electronic Equipment | | | X | | | |
| 3.3.1.6 | Bonding and Grounding | | | X | | | |
| 3.3.1.7 | Contamination Control | | | X | | | |
| 3.3.1.8 | Lubricants | | | X | | | |

| | | Verification Method | | | | | Remarks |
|---|---|---|---|---|---|---|---|
| | | S | A | I | D | T | |
| 3.3.2 | Workmanship | | | X | | | |
| 3.3.3 | Nameplates and Product Marking | | | X | | | |

# 5. PREPARATION FOR DELIVERY

## 5.1 Packing

The GMA shall be packaged to maintain the contamination level specified in 3.2.2.9. The GMA shall be packed separately in a container that includes a shock and vibration mitigation system capable of protecting each item as required by 3.2.5.1.1. The vibration and shock mitigation system shall secure each item to prevent movement during transportation and handling. Individual containers shall be so constructed as to allow removal of parts for inspection without damage to the container or labels.