June 19, 1994

Revision 3.

Probe C Contamination Control Plan

The gyroscopes which will be flown in the Science Mission experiment are particularly sensitive to contamination. Nonmetallic particles may interact with the electric fields used to support the gyroscope and cause frictional drag on the gyroscope. Metallic particles may exchange charge at the electrode and rotor surfaces, bouncing back and fourth, and exchange angular momentum between the rotor and the housing. At a larger size scale, particles may prevent free rotation, and it has long been suspected that particles may play a role in the infrequent arcing that occurs between the electrodes and the rotor. The GP-B gyroscopes are also particularly vulnerable to contamination from regions outside the housing. Not only is it impossible to completely seal the gyroscope because of the gas spin-up system, but vibration during launch and the weightless environment allow the potential for the generation and redistribution of particles.

Another important aspect of Gravity Probe B is the light which reaches the telescope. Contamination either from particles or condensable nonvolatile residues or particles reduce that amount of light which reaches the telescope. In addition, particles may scatter stray light which would increase the background light level and decrease the sensitivity of the telescope pointing system. The most crucial parts of the telescope are the roof prisms which are used to divide the light from the reference star and determine the center of the star image. A 25 micron diameter particle could render the roof prism useless, while other contamination could change the apparent direction of the star. Although a small but constant bias in the apparent direction would not affect the outcome of the experiment, a bias which varied at the roll frequency could seriously affect the outcome of the experiment.

Another important consideration in the cleanliness of the probe is the possibility of magnetic particles on the interior or exterior of the probe. When the probe is inserted into the liquid helium dewar which contains the lead bag, any magnetic particles on the exterior of the probe will increase the magnetic field in the interior of the lead bag, and thereby increase the trapped magnetic field in the gyroscopes. Magnetic particles within

the probe may have a even larger effect on the trapped magnetic field in the gyroscopes because they may be closer to the gyroscope. The Gravity Probe B Magnetic Control Plan provides requirements on the maximum permissible magnetic contamination.

The contamination control plan which is presented here is based on experience with the cleanliness requirements and procedures and the expected environment of future probes. Future probes will be subjected to much more severe conditions when they are vibrated and then placed in a weightless environment. The requirements and procedures given here are intended to be used in addition to good standard cleanliness procedures and design. Without an awareness of the importance of cleanliness on the part of all the individuals working on the probe, these guidelines will be ineffective.

The probe has been divided into seven zones, numbered according to how critical the cleanliness is to each zone. Each zone is described below, along with the reason for the cleanliness requirements within that zone, the cleanliness levels required within that zone, special procedures that should be used, and design considerations.

DEFINITIONS

Level: Level refers to the cleanliness level of a surface as specified in MIL-STD-1246. This document specifies the maximum number of particles of a given size per square foot of surface area which can remain on a surface after cleaning. In this contamination control plan, the cleanliness level of the surface is typically specified as better than level 100. For this level the maximum allowable number of particles per square foot greater than a given size is

Size	Number
100 microns	1
50	11
25	78
15	265

Class: Class refers to the number of particles greater than a given size per cubic foot in a clean room as specified by FED-STD-209. In a class 100 clean room the maximum number of particles per cubic foot greater than a given size is

Size	Number
0.5 microns	100
0.3	300
0.2	750

There is not necessarily any relationship between level 100 and class 100.

Verification: Verification refers to the process utilized to determine if a hardware surface or a cleanroom environment meets the required specification. The procedures for measuring the cleanliness of surfaces are given in MIL-STD-1246 and follow ASTM guidelines. Methods of verifying room air cleanliness are given in FED-STD-209.

Verification of a surface cleanliness level involves counting the number of particles greater than a given size range to determine whether the surface meets the required cleanliness level. However, in many instances it would be valuable to know not only whether the surface or clean room meets the required specification, but also to know by how much the surface exceeds the required specification. In these instances, it would be valuable to count the particles to the smallest size range technically possible. In these cases, verification of the cleanliness levels should be made to the highest level technically possible.

Particulate Fallout: Particulate fallout in a clean room will cause surface cleanliness levels to degrade with time. The particulate fallout rate depends on many factors

including the activity in the room, location of the part in the room, and how parts are handled within the clean room. However, a rough guide to the particulate fallout rate is given in Figure 1. Note that in a class 100 environment, a level 100 surface will degrade to a level 150 in approximately 10 days. In a class 10 environment, a level 100 surface will degrade to a level 150 in approximately 100 days. In Figure 1, it is assumed that the reference environment is maintained regardless of the level of activity. A more accurate measure of the particulate fallout rate may be made by placing witness samples close to a part in a clean room.

ESTIMATED PARTICULATE FALLOUT VS TIME FOR FED-STD-209 B CLASS ENVIRONMENTS

5-4740-8-60
MSFC/EH12

Figure 1 - This chart gives the particulate fallout rate vs. time for various class clean rooms. The dashed lines for class 10 and class 1 are estimated rates extrapolated from the other curves (J. Sakols, LMSC). Since the particulate fallout rate depends on many factors, including the activity in the room and the location in the room, these curves should be taken as estimates.

Zone: I - Interior of Gyroscope

Reason for Cleanliness Requirement: Frictional Drag, Precession Torques, Electrical Breakdown

Required Cleanliness Levels: Consideration of the torques acting on the gyroscopes due to dielectric and metallic particles has led to the following goals for the cleanliness levels within the gyroscope housing:

Size Range	Maximum Number
>3 micron	0
1-3 micron	0
0.3-1micron	1
0.1-0.3 micron	10
0.03-0.1 micron	100

Although it will be very difficult to verify these cleanliness levels by direct inspection, these goals should be used to determine procedures for cleaning and handling the gyroscope, cleanliness requirements for other areas of the probe, and procedures for handling the probe once the gyroscopes have been installed.

Verification: Verification of the cleanliness levels within the gyroscope will be done by measuring the spin-down rate of the gyroscope. The gyroscope spin-down rate is a sensitive indicator of any contamination within the gyroscope. A spin-down rate of less than 0.1 milliHertz/hour at spin speeds less than 5 Hz indicates a adequate level of cleanliness.

Special Procedures: Standard housing cleaning and installation procedures should be followed.

Design Considerations:

Environment: After cleaning and assembly the gyroscopes shall be protected from particulate fallout. They shall be installed and removed from test probes in Class 10 or better environment. Where possible, witness samples shall be placed near the gyroscopes during assembly and testing.

Zone: II - Spin-up Gas Inlet Line after Filter and Spin-up Exhaust Line

Reason for Cleanliness Requirement: Communicates directly with Zone I and Spin-up Gas Flows through the Gyroscope.
Required Cleanliness Levels: All parts shall be cleaned to level 100 or better per MIL-STD-1246 using the reference procedure listed below.

Reference Cleaning Procedure: The reference cleaning procedures for the spin-up inlet and exhaust lines and the final spin-up inlet filter are listed below:

Spin-up Inlet

1. Vapor Degrease
2. Ultrasonic
3. Flush with Freon
4. Interior of tubes flushed with Quadrex
5. Certified to highest level technically possible
6. Bag and seal entire tube in bags certified to level 100 or better. Bags remain sealed until assembly.
7. Install in Probe
8. Recertify
9. Bag exposed ends in bagging certified to level 100 or better

Spin-up exhaust line and heat exchanger

1. Vapor degrease
2. Acid clean
3. Ultrasonic
4. Freon Flush
5. Flush with quadrex

(Heat exchangers braze weld. Repeat steps 3-5)

6. Follow steps 4-8 of inlet line procdeure

Inlet Filter

1. Follow steps 1-5 for filter element.
2. Repeat steps 1-5 for sub-assembly.
3. Follow steps 6-8 of inlet line as applicable.

Verification: Verification of the cleanliness levels shall be done to the highest level technically possible, using the ASTM procedures, before and after assembly into the probe. Results of these verification tests shall be delivered with the probe as provided by LMSC**.**

Special Procedures: During evacuation and venting of the probe, procedures shall be used to ensure that any particles are pumped away from gyroscope side of the inlet filter. If a gyroscope is installed, evacuation and venting of the probe shall be done in such a way that a minimum amount of gas (and particulates) is pumped through the gyroscope. In addition, any evacuation or venting of the probe shall be done in at a

sufficiently slow rate that the flow of gas remains in the laminar flow regime.
Guidelines for evacuation are that (1) Evacuation and Venting of the probe shall be done at a rate of less than 10 Torr/minute and (2) that the flow be limited at a point as close as possible to the vacuum pump.

Design Requirements: The ground support equipment shall be designed so that the above special procedures may be implemented.
The final filter must be a 0.5 micron or smaller absolute filter.
Materials used in this zone of the probe must have a level of condensable nonvolatile residues such that the obscuation of light entering the telescope shall not exceed 5%.
Environment: After cleaning, the spin-up inlet and exhaust lines, as provided by LMSC, shall be bagged in a Class 100 or better area. These bags shall only be removed in a Class 100 or better clean room, and the inlet and exhaust lines shall be protected from particulate fallout.

Zone: III - Bore of the Quartz Block

Reason for Cleanliness Requirement: Communicates directly with Zone I

Required Cleanliness Levels: All parts shall be cleaned with methods consistent with level 100 or better. A reference cleaning procedure is listed below. Departures from the reference cleaning procedure may be made depending on the part, but any change in the cleaning procedure shall produce better cleanliness levels than the reference cleaning procedure.

Verification: Verification of the cleanliness levels within zone III shall be done by verifying that the reference procedure listed below cleans surfaces adequately. It is important that this verification be repeated (particularly before a crucial integration of the gyroscopes into the probe) to insure that the procedure still produces adequate cleanliness levels.

Special Procedures: Record cleaning procedures and verification test results in hardware file folders

Design Requirements : Materials used in this zone of the probe must have a level of condensable nonvolatile residues such that the obscuation of light entering the telescope shall not exceed 5%.

Reference Procedure: The following reference procedure shall be used for cleaning parts in this zone:

1. Spray with deionized water to loosen dirt particles
2. Place parts in beaker with hot water and 1% solution, by volume, of Microdetergent and use ultrasonic cleaner for about 10 minutes.
3. Rinse in dump rinser for about 2 cycles.
4. Wash in tray with hot water and 1% Microdetergent and use Z-foam cloths for rubbing the parts.
5. Rinse parts with DI water (> 2 Mohm-cm resistivity) hand sprayer.
6. Use Water-pick for parts with hard to reach places.
7. Rinse again with DI water hand sprayer.
8. Rinse again in dump rinser for at least two cycles.
9. Place part in beaker with methanol and place beaker in water inside ultrasonic cleaner.
10. Blow dry with dry, filtered nitrogen
11. Place in clean container (similarly cleaned) and seal container.
12. Take to Quadrex and place inside still in its container.

13. Once door is closed to Quadrex, open container and clean both container and part with Shearstress flow of filtered Freon.
14. Run drying cycle. While still in closed Quadrex machine, place part back in container and seal.
15. Remove container and bag or double bag (as appropriate) immediately for transport to final destination.

Environment: After cleaning, the parts to be used in Zone III shall be protected from particulate fallout. Installation of these parts shall be done in a Class 10 or better environment. Unless the parts are recleaned, they shall not be removed from the clean room unless they are bagged or encapsulated in a sealed vessel like the probe.

Zone: IV - Birdcage Area - Interior of Probe Below the Quartz Block Mounting Flange.

Reason for Cleanliness Requirement: Communicates Directly with Zone III

Required Cleanliness Levels: All parts shall be cleaned to level 100. Verification of the cleanliness level will be done to the highest level technically possible. After cleaning, parts shall be bagged in level 100 or better.

Verification: Verification of the Cleanliness Levels within this zone may be done either by measuring the cleanliness levels on each of the parts or by qualifying the procedure used to clean the parts.

Special Procedures: Evacuation of the probe shall be done at a maximum rate of 10 Torr/minute to avoid redistribution of particles due to gas flow. The flow of gas during the initial evacuation shall be throttled as close to the vacuum pump as possible.

Venting of the probe shall be done with dry, filtered (0.5 micron or better) nitrogen at a maximum rate of 10 Torr/minute.

Design Requirements : Particular attention shall be paid to the use of fasteners, adhesives, and the smoothness of the surfaces. Fasteners must be compatible with cleanliness level 100 and the expected vibration levels. Adhesives are a potential source of particles, and the rough surfaces can generate particles during the assembly process.

The design of the probe must allow for the recleaning and reverification of this zone after assembly of the probe to the best extent possible. Areas that cannot be recleaned and reverified must be brought to the attention of the cleanliness committee

Materials used in this zone of the probe must have a level of condensible nonvolatile residues such that the obscuation of light entering the telescope shall not exceed 5%.

Environment: After cleaning, the parts to be used in this zone shall protected from particulate fallout. They shall be bagged and only opened in class 100 or better clean rooms.

Zone: V - Interior of Probe Above Quartz Block Mounting Flange.

Reason for Cleanliness Requirement: Communicates Directly with Zone IV

Required Cleanliness Levels: All parts shall be cleaned and verified to level 100 or better. Since this region of the probe is relatively inaccessible after assembly and many regions would be difficult to reclean, special care must be taken to insure that this region does not become contaminated

Verification: Verification of the cleanliness levels of the parts used in this area before assembly may be done either by measuring the cleanliness levels of each part or by qualifying the procedure used to clean the parts.

Special Procedures: See special procedures of Zone IV.

Design Requirements: Particular attention shall be paid to the use of fasteners, adhesives, and the smoothness of the surfaces. Fasteners must be compatible with cleanliness level 100 and the expected vibration levels. Adhesives are a potential source of particles, and the rough surfaces can generate particles during the assembly process.

Environment: After cleaning, parts to be used in this area shall be protected from particle fallout. They shall be stored in bags verified to level 100 or better.

After assembly of the probe, it is unlikely that this region of the probe can easily be recleaned. Therefore, it is important that this area of the probe be protected from particulate fallout. In order to achieve better than class 100 air flow over the hardware, activity interrupting the laminar flow will be limited only to those procedures for which there is no alternative.

Zone: VI - Ground Support Equipment Vacuum System

Reason for Cleanliness Requirement: Communicates Directly with Zones II and V

Required Cleanliness Levels: All parts of the ground support vacuum equipment shall be cleaned using standard cleaning methods for vacuum equipment.

Special Procedures: Venting and evacuation procedures shall be designed to prevent particles from flowing into the probe, prevent motion of particles due to turbulent gas flow, and to ensure that condensation of water does not occur on critical parts.

Design Considerations: Special design consideration shall be given the prevention of oil backstreaming in the vacuum system.

Environment:

Zone: VII - Exterior of Probe

Reason for Cleanliness Requirement: Communicates Directly with other zones when probe is open. In addition any magnetic particles on the exterior of the probe may increase the magnetic field within the lead bag when the probe is inserted into the dewar

Required Cleanliness Levels: Exterior of the probe shall initially be cleaned and certified for level 200. The entire probe shall be bagged before it is removed from the clean room.

The design of the probe must allow recleaning and recertification of the exterior of the probe to level 200

Special Procedures:

Design Considerations:

Environment:

Zone: VI - Ground Support Equipment Vacuum System

Reason for Cleanliness Requirement: Communicates Directly with Zones II and V

Required Cleanliness Levels: All parts of the ground support vacuum equipment shall be cleaned using standard cleaning methods for vacuum equipment.

Special Procedures: Venting and evacuation procedures shall be designed to prevent particles from flowing into the probe, prevent motion of particles due to turbulent gas flow, and to ensure that condensation of water does not occur on critical parts.

Design Considerations: Special design consideration shall be given the prevention of oil backstreaming in the vacuum system.

Environment:

Zone: VII - Exterior of Probe

Reason for Cleanliness Requirement: Communicates Directly with other zones when probe is open. In addition any magnetic particles on the exterior of the probe may increase the magnetic field within the lead bag when the probe is inserted into the dewar

Required Cleanliness Levels: Exterior of the probe shall initially be cleaned and certified for level 200. The entire probe shall be bagged before it is removed from the clean room.

The design of the probe must allow recleaning and recertification of the exterior of the probe to level 200

Special Procedures:

Design Considerations:

Environment: