TC-MSS-20B

# MATRA MARCONI SPACE

ANCHORAGE ROAD, PORTSMOUTH,
PO3 5PU, ENGLAND

HIRDLS PROGRAM
FILE COPY

| HIRDLS Distribution | | | |
|---|---|---|---|
| 2 | OX(JCW) | 1 | EOS PO |
| 1 | GD | 1 | PFG |
| 1 | PMcP | 1 | Gmc |
| 1 | OX(JB) | | |
| RAL Ref. | | | |
| HIR/10/02 | | | |
| 12/12/91 | | | |

Note: This is Issue B. supercedes A.

# HIRDLS

TECHNICAL NOTE - CLEANLINESS

AND CONTAMINATION CONTROL.

DATE: 12/12/91
INITIALS: GD/PMcP/PFG/Gmc/OXF
FILE NO: EOS-HIR-MMS-TN-0006

PREPARED BY: FPR.NORTHAM. OND, HND, CMet, BSc(Hons)

| | | | | | | |
|---|---|---|---|---|---|---|
| RESPONSIBLE ENGINEER | FPR Northam | FPR Northam | | | | |
| PRODUCT ASSURANCE | [illegible] | [illegible] | | | | |
| PROJECT MANAGER | A Hanley | A Hanley | | | | |
| CUSTOMER | RAL | RAL | | | | |
| ISSUE | A | B | | | | |
| SRB/CCB DATE | 6.11.91 | 28.11.91 | | | | |
| PROJECT HIRDLS | | SHEET 1 OF 21 SHEETS | | NUMBER HIR-MMS-TN-0006 | | |

© THE MATRA MARCONI SPACE UK, 1991

THE COPYRIGHT IN THIS DOCUMENT IS THE PROPERTY OF THE MATRA MARCONI SPACE UK LIMITED. This document is supplied by the Matra Marconi Space UK Limited on the express terms that it is to be treated as confidential and that it may not be copied, used or disclosed to others for any purpose except as authorised in writing by this Company.

Any person, other than the authorised holder, who finds or otherwise obtains possession of the document, should post it, together with his name and address, to the Registrar, Matra Marconi Space UK Limited, Anchorage Road, Portsmouth, England. P03 5PU.

Postage will be refunded.

DISTRIBUTION LIST

| INTERNAL | EXTERNAL |
|---|---|
| A.THORNBURY | Dr GM.COURTIER (RAL) 2 Copies |
| FPR.NORTHAM | |
| A.PAFFETT | |
| M.ALGAR | |
| PROJ. LIB. | |

## CHANGE RECORD.

| CHANGE NUMBER | CHANGE DETAILS | ISSUE |
|---|---|---|
| 001 | 1.2 Correct FED 209 requirement | B |
| 002 | APPENDIX 3 Pg 18 Correct units | B |
| 003 | Correct document number | B |
| 004 | Integral sign added to sheet 17 | B |

Contents

1.0 **SCOPE.**

1.1 Introduction.
1.2 Requirements.

2.0 **APPLICABLE DOCUMENTS.**

3.0 **CONTAMINATION CONTROL METHODS.**

3.1 Design.
3.2 Material Selection
3.3 Customer furnished items.
3.4 Thermal Vacuum Bake Out.
3.5 Education.
3.6 Packaging and Storage.
3.7 Processing Operations.
3.8 Facilities and Personnel.
3.9 Tooling.
3.10 Documentation.

4.0 **CLEANLINESS VERIFICATION.**

4.1 Airborne Particulate Contamination.
4.2 Liquid Particulate Contamination.
4.3 Particulate Fallout.
4.4 Organic Contamination.
4.5 Records and Documentation.

APPENDIX. 1 Typical Materials used by MMS UK.
APPENDIX. 2 Clean Room Facilities.
APPENDIX. 3 Particle Fallout Calculations.

Figure 1 IR organic contamination control witness sample.
Figure 2 TGA organic contamination control witness sample.
Figure 3 Graph of PFO for class 100
Figure 4 Graph of PFO for class 200

## 1.0 SCOPE.

This document reviews the cleanliness control requirements for HIRDLS and details the cleanliness and contamination control philosophy to be used during the design and build of the HIRDLS configuration, structure and thermal system.

## 1.1 INTRODUCTION.

Contamination can arise from a number of sources and via a number of processes such as outgassing, cure offgassing, venting, handling, manufacturing, particle generation from motors and mechanisms, incorrect purging or cleaning.

A project responsible cleanliness engineer will be appointed who will report directly to the project PA manager. The engineer shall be responsible for assessing all cleanliness and contamination control aspects of the design, manufacturing processes, process equipment and cleanroom facilities.

## 1.2 REQUIREMENTS.

The project defined requirements for this instrument design are detailed below:

* FED STD 209D Class 1000 during assembly integration and test where the optics are exposed. (airborne particulate contamination limits of 1000 particles >= 0.5 μm and 7 particles > 5μm per cubic foot)

* FED STD 209D Class 10000 during assembly and integration of structures and components where the optics are protected or not fitted. (airborne particulate contamination limits of 10000 particles >= 0.5 μm and 70 particles > 5μm per cubic foot)

* MIL STD 1246C Class 100 particulate contamination on optical surfaces per square foot, (0 to 15μm count = 265, 15 to 25μm = 78, 25 to 50μm = 11, 50 to 100μm = 1. this is equal to 123.32 ppm (mm2/m2))

* MIL STD 1246C Class 200 particulate contamination on other surfaces per square foot, Class 200 (0 to 15μm count = 4190, 15 to 25μm = 1240, 25 to 50μm = 170, 50 to 100μm = 16)

* MIL STD 1246C Class A, organic contamination on optical surfaces 0.1 mg per square foot. (107 $\mu g/cm^2$)

* MIL STD 1246C Class A, organic contamination on other surfaces 0.1 mg per square foot. (107 $\mu g/cm^2$)

* GSFC-240-05-01, Thermal vacuum outgassing rate of less than 1.0 $\times 10^{-7}$ $g/cm^2$/hour during the last 5 hours of bake out.

## 2.0 APPLICABLE DOCUMENTS.

The following documents are relevant to this technical note.

| | |
|---|---|
| PA-HIR-6 | HIRDLS Contamination control plan. |
| FED STD 209D | Clean room and work station requirements controlled environment. |
| MIL STD 1246C | Cleanliness levels and contamination control program. |
| ESA PSS 01-201 | Contamination and cleanliness control. |
| ESA PSS 01-204 | Particle contamination control in cleanrooms by particulate fallout measurements. |
| ESA PSS 01-705 | Detection of organic contamination by infrared spectroscopy techniques. |
| ESA PSS 01-702 | A screening test method employing a thermal vacuum for the selection of materials to be used in space. |
| S3-07-006 | Requirements for work environment control. |
| BS 5295 | Environmental cleanliness in enclosed spaces. |
| HIR-SP-MMS-015 | MMS UK PA Plan (3164-11001-PLP). |
| GSFC-420-05-01 | EOS Performance Assurance Requirements for general instruments. |

## 3.0 CONTAMINATION CONTROL METHODS.

### 3.1 DESIGN.

Materials shall be selected where practical to limit outgassing and particulate shedding. Some typical materials are detailed in Appendix 1.

During the design phase and as an activity of drawing review the project responsible cleanliness engineer shall assess the impact on the item cleanliness due to the processes being performed at that manufacturing stage.

All drawings shall state the cleanliness level that the process shall be conducted under and the cleanliness level to be achieved after cleaning.

Design considerations that will be taken into account are the inherent contamination resulting from the process and the methods to remove or reduce such contamination.

Other design factors that will be implemented are materials and design features which can impact on the cleanliness level of the part. eg no blind threaded holes or silicone adhesives near or within outgassing contamination range of the optics, thermal blanket materials and design shall be evaluated for shedding. The scrunched and net design of thermal blanket layup shall be tested for contamination levels and applicability to the HIRDLS project.

Any reworks or repair actions carried out under MRB or NCR control shall be assessed by the cleanliness control engineer for their impact on the cleanliness quality of the assembly.

### 3.2 MATERIAL SELECTION

All materials shall be selected for their clean processing and stable properties in the space environment. Material properties of interest here are the mixing and filling of adhesives, the thermal vacuum stability of materials, the outgassing properties of polymers, the corrosion data and oxide types of metals and the history of materials in similar applications eg Long Duration Exposure Facility, (LDEF) results and Atomic oxygen resistance.

### 3.3 CUSTOMER FURNISHED ITEMS.

MMS UK integrate several customer furnished items including gyro, telescope mirrors, and the IFC black body, these items may be a source of external contamination during MMS manufacturing and assembly operations.

These items should arrive for integration at MMS in a verified and fully documented clean state from the supplier. Witness samples should be included during transport and storage to verify the organic cleanliness level of the item. These can be tested by RAL prior to integration to the instrument.

The particulate fallout on such items may be verified by analysis using image analysis of the item surfaces.

## 3.4 THERMAL VACUUM BAKE OUT.

Before integration of the optics, the structure either as a whole or in its piece parts will need to be subjected to a vacuum bake out to remove condensable and moisture vapour that could contaminate the optical elements. The thermal blankets also require a thermal vacuum bake out.

A procedure will be prepared that details the controls for the facility and the instrument to ensure that no cross contamination is introduced to the optical system and that the cleanliness control level is maintained at all stages of the operation.

The vacuum facility should include a residual gas analyzer (mass spectrometer) to determine the species being driven off and a cold finger to collect and contain possible contaminants from the vacuum pump system. The facility shall be flushed with dry research grade nitrogen after bake out to reduce the tendency for re-condensing of vapours during removal of the instrument from the chamber.

It should be noted that this operation can only be continuously monitored by using a quartz crystal micro balance (QCM) and that during the last 5 hours of bake out the offgassing should not exceed $1.0 \times 10^{-7}$ g/cm$^2$/hour as defined by EOS PAR GFSC420-05-01.

The current baseline is that MMS UK will provide necessary labour support for thermal bake out, but do not currently possess a QCM to enable the thermal vacuum bake out to be carried out on site. MMS UK have a facility to monitor organic contamination by Infra Red spectroscopy in accordance with ESA PSS-01-705 but this requires that the vacuum cycle be interrupted to remove the monitor sample for analysis. MMS also have a residual gas analyzer (mass spectrometer) fitted to our thermal vacuum chambers that could monitor the offgassing species but this equipment is not able to measure the concentration of the organic contamination.

## 3.5 EDUCATION.

Probably the most important aspect of cleanliness and contamination control, is educating the work force to think clean.

MMS have a number of video tapes which specifically cover the subject of operator conduct and working practices in a clean environment. All assembly technicians and engineers who will come into contact with the equipment in a clean state shall be briefed on the impact of their actions whilst working on the assembly and shall watch the video presentations on the subject before being allowed to work in the environment or on the equipment.

## 3.6 PACKAGING AND STORAGE.

All packaging methods shall be tested to determine their cleanliness before use, also all packaging materials shall be tested before release to the project manufacturing group.

Certain packaging materials shall not be allowed in the clean room environment or be used in contact with any piece part. eg PVC, polyethylene sheet which contains plasticizers or low molecular weight fillers, bubble wrap and foam rubber.

Double bagging shall be employed to ensure that the packaging can be cleaned to the cleanliness level into which it shall be introduced, also if a clean item is to be moved from one clean environment to another then it shall be bagged at each stage on the exit route and debagged at each stage in the entry route to seal out contamination and leave contamination behind at each entry stage.

A purpose built equipment storage and flight case shall be designed and produced which shall include suitable environmental monitoring and if required an on board gas purging and moisture removal system shall be incorporated.

## 3.7 PROCESSING OPERATIONS.

Any soldering operations required shall be limited to reflow operations. Thus the dirty operations of tinning and flux application would be performed in a lower grade environment before cleaning to the flight level. All soldering irons used should have local tip vacuum extraction to remove flux and solder vapours. Where possible crimping shall be used in preference to soldering for harness wiring connectors.

Adhesive mixing and preparation shall be conducted in a separate area to the application area.

Operations such as abrasion before bonding shall be carried out wherever possible in a separate area or if required on the payload then local vacuum cleaning shall be used during and after the operation to limit contamination.

Paperwork shall be kept in a glove box such that it is isolated from the immediate work environment.

The optical surfaces may be kept clean during bonding operations by covering them with a protective shield or by flushing of the surface with dry research grade nitrogen, this may be complimented by air extraction during curing to remove the offgassing cure products from some resins and adhesive systems.

Consideration shall be given for some assemblies (eg the optical mount bonding) and some materials (eg thermal optical paints) to receive a vacuum post cure before integration into the main payload assembly.

## 3.8 FACILITIES AND PERSONNEL.

As previously stated all personnel involved shall be informed of their responsibilities to cleanliness control.

All personnel shall be advised on their clothing and conduct whilst dressing for the work environment. eg people with beards and moustaches shall wear beard masks, the wearing of outside shoes, makeup and hair spray shall not be allowed inside the entry areas or the clean rooms.

All personnel shall wear the required clothing for the clean environment:

| | |
|---|---|
| Class 100000: | Mop hats, gowns, disposable over shoes, gloves or finger cots. Entry via airlock. |
| Class 10000 : | Mop hats, overalls, launderable boots and gloves. Entry via airlock with air shower. |
| Class 1000 : | Hoods, overalls, launderable boots and gloves. Entry via airlock with air shower and tacky mats. |
| Class 100 : | Hoods, masks, overalls, launderable knee length boots and long gloves. Entry via airlock with air shower to class 10000 and tacky mats into class 100 area from class 10000. |

Personnel shall take extra precautions when conducting certain operations. For example at all times in class 10000, 1000 and 100 cleanroom environments approved gloves shall be worn which seal the cuffs of the clean room coat; during operations on the optics face masks shall be worn which have a clear acrylic visor to prevent eye lash and brow particulate contamination; microscopes should be angled such that the operators face is not directly over the work item.

The number of personnel who have access to the work area shall be controlled and the number of people in the area at any one time shall be restricted.

3.9 TOOLING.

All tools shall be made from glass, non magnetic stainless steel or stable polymer and shall be cleaned before entry to the clean area, this also applies to tool boxes and trays. Tooling should be removed from the area and periodically cleaned, adhesive application tools should be throw away and used only once. The use of wooden cocktail sticks and applicators shall be prohibited.

3.10 DOCUMENTATION.

Significant particulate contamination can emanate from documentation and paperwork and organic contamination from chemically loaded items such as felt pens. A consideration of the contaminating source and methods to reduce this is given below.

Pencils are prohibited in any of the cleanroom environments and felt tip pens are not to be used where there is an organic contamination limit.

Engineering dye line print drawings shall not be allowed in Class 1 or 2 clean areas as they have a powdery emulsion surface which is developed using Ammonia or Sulphur during the printing process.

Drawings can be printed onto acetate sheets that can be cleaned or the drawings can be coated with a fablon polymer coating to seal in the contamination.

Photocopies must not be exposed to the Class 1 or 2 clean room environment as they can have large residual electrostatic charges which act like a large electrostatic magnet which holds dust on its surface. This charge dissipates with time and any dust from the copier toner or other sources is released.

In practice paper work can be maintained and processed inside a reader box which segregates the paper from the cleanroom environment.

## 4.0 CLEANLINESS VERIFICATION.

### 4.1 AIRBORNE PARTICULATE CONTAMINATION.

Airborne particulate material can be measured using a CLIMET CI7300 airborne particle analyzer to the MMS standard S3-07-006 Standard Work Environment Control.

This equipment shall be used to test the airborne particulate contamination level in the clean room environment, daily for class 100, weekly for class 1000 and every fortnight for class 10000. The equipment can also be used to test the particulate products from clean room clothing and consumables eg wipes and swabs.

### 4.2 LIQUID PARTICULATE CONTAMINATION.

MMS are presently investigating the purchase of a liquid particulate contamination analyzer which can analyse particulate material in liquids or by dipping material into standard test liquids to test the particle size distribution in the range 2 to 150 $\mu$m.

Such equipment would be used to test the particulate contamination from process consumables such as swabs, wipes, cleanroom detergents, cleaning solvents before and after cleaning processes and surface wipes from the payload or its components.

### 4.3 PARTICULATE FALLOUT.

MMS are currently procuring a digital image analysis system which with our existing microscopes and video cameras will enable us to measure directly the particulate contamination on a witness plate surface or in many cases directly from the instrument surface.

The range of particle sizes that can be measured is dependant only on the magnification used but with increasing magnifications the number of sample areas must be increased to give a representative test area. The system can produce colour photographs of the field of view and data on the particulate material eg particle numbers and the size of each particle, aspect ratio analysis will give the proportion of fibrous contamination to spherical or flake material. Various light types can be used for analysis of the different particle types eg UV light for organic contamination, polarized light for metallic particulates and white light for general measurements

Witness plates can be placed in and around the payload to measure the particulate fallout during assembly and test. These will be measured and recorded on a periodic basis to give an analysis of contamination with time and the type of work being carried out.

Appendix 3 details the analysis of particulate fallout with reference to the requirements and includes some recommendations on the determination of required particulate cleanliness levels based on obscuration factors, which the customer should consider.

## 4.4 ORGANIC CONTAMINATION.

RAL have not defined their proposed test method for monitoring surface organic contamination and Mil Std 1246C does not detail specific or recommended test methods for this requirement.

RAL should define if the organic contamination levels defined in Mil Std 1246C are at any test point during assembly or if they apply at delivery of the completed instrument.

Although the current base line is that RAL will provide MMS with some form of organic contamination witness samples and an off site test facility, RAL should consider the effect of where such testing is conducted as there are strategic difficulties off site test facilities.

For example: Cross contamination during packaging, transit and testing, also schedule impacts whilst waiting for test results and samples to return in order to confirm if an assembly can be fitted to the instrument or go on to the next stage in manufacture.

The effect on organic contamination levels by critical processes and materials could be tested by IR spectroscopy and by Thermo-Gravimetric Analysis (TGA). This should be applied to the following typical processes: Solvent cleaning, Adhesive bonding, Thermal vacuum proof testing, Thermal cycling and Packaging materials.

IR spectroscopy can give the mass of contaminating species by differential analysis of the spectra peaks as well as identifying the contaminant chemical species, this should be carried out in accordance with ESA PSS 01-705. TGA can give an accurate value of the total contamination mass per unit area to within 1 $\mu g$, which is less that 1% of the Mil Std 1246 requirement of 107 $\mu g/cm^2$.

The TGA decomposition temperatures of the contamination can identify some of the contamination species as well as their thermal stability when assessing the contamination or assembly for future thermal operations.

These analysis methods should be an ongoing test method to determine the level of organic contamination on the space craft at any point during assembly.

The IR spectroscopy method would require Calcium Fluoride $CaF_2$ witness samples that can be strategically fixed on the structure to measure the organic contamination with time. These samples can be processed after cure cycles and thermal or thermal vacuum cycling to indicate the contaminating effect of each process. The data is cumulative and will give an organic contamination level at each test stage and at the end of assembly prior to delivery to RAL.

The TGA test method would require metal coils of platinum which can be burnt off to give a baseline measurement and re tested at intervals or after critical processes. This method would give discrete point or process data which if accumulated can give a total organic contamination figure.

Figures 1 and 2 show typical sample configurations.

In the event of extreme local organic contamination the contaminating species and the cause of contamination can be determined by analysis using a scanning electron microscope fitted with an X ray energy analyzer (EDAX)

## 4.5 RECORDS AND DOCUMENTATION.

A cleanliness record log book shall be used to record the cleaning procedures used and the level of cleanliness achieved for each part of the assembly and the instrument itself. This shall be conducted as part of the manufacturing history records and traceability shall be maintained.

All cleaning procedures shall be approved and configured documents of the company or project specific documents issued to process a particular item within the project. All cleanliness verification procedures shall be configured documents of the company and shall be used only by approved operators.

APPENDIX. 1 TYPICAL MATERIALS USED BY MMS UK.

| Sub Assembly | Typical Materials. |
|---|---|
| Thermal | MLI, Chemglaze Z306 or Electrodag 501 black painted, Dacron net, Vapour deposited Aluminium and Indium Tin oxide, edge sealed with Kapton tape. |
| Optical Bench | Aluminium alloy 6082 or 6061 T651. Machined black painted or anodized. Isostatic mounts stainless steel or Titanium. Mirror mounts Invar or Telcoseal 1 bonded with Araldite or Epotek 301-2 optical adhesives. |
| Baseplate | Al alloy honeycomb bonded with Redux 319L, CFRP skirt edge sealed with Kapton tape. |
| Outer structure | Al alloy machined frame black painted or black anodised. Al alloy honeycomb to support sun shield. |
| Sunshield | Al alloy machined black painted or black anodised. Hybrid stepper motor, potentiometer position sensor, linear solenoid release mechanism. These items may require qualification. |

## APPENDIX 2 CLEAN ROOM FACILITIES.

MMS UK have an extensive range of clean room facilities which includes, PCB assembly areas, waveguide assembly rooms, material and process testing facilities, AIT and structure assembly areas. These areas are controlled by an internal specification S3-07-006 'Work Environment Control'.

The correlation between MMS specification and FED STD specification is as follows:

| MMS CLASS | BS5295 CLASS | FED STD 209D CLASS | MIL STD 1246C CLASS |
|---|---|---|---|
| 1 | 1 | 100 | 85 |
| NONE | NONE | 1000 | 145 |
| 2 | 2 | 10000 | 210 |
| 3 | 3 | 100000 | 300 |
| 4 | 4 | NONE | NONE |

Class 1000 can be achieved by the use of a class 100 laminar flow hood inside a class 10000 area in practice this would be expected to be better than class 1000 for airborne particulate count and better than MIL STD 1246C class 145 for particulate fallout.

## APPENDIX 3 PARTICLE FALLOUT ANALYSIS.

MIL STD 1246C defines the particulate fallout as following the law:

$$\text{Log } N = 0.926\ (\text{Log}^2(C) - \text{Log}^2(d))$$

Where N = The number of particles greater than particle diameter 'd' and C is the Mil Std class.

Re-arrange to give N for a given Class and d particle limiting diameter.

$$N = 10\ \hat{}\ (\text{Log}^2(C) - \text{Log}^2(d))$$

Numerically integrate to find N for d = 1 to 100

Numerically differentiate to find $dN = N_2 - N_1$

This now gives the number of particles (dN) for each particle size step $d_1$ to $d_n$.

Find the integral mean diameter $d_m$ for the size range $\Sigma\ d_1,\ d_{(n+1)}$ and use this to define the mean particle obscured area $A_m$.

Vis : assumption all particles are spherical.

Obscured area of each particle $A = (\pi\ d^2)\ /\ 4$

Mean value of a function $1/(a-b) \int_b^a f(x)\ dx$

Integrate for d

$$\pi d_m^2/4 = \pi\ /(12(d_2-d_1))\ *\ (d_2^3-d_1^3)$$

Transpose in terms of $d_m$.

$$dm = \sqrt{1/(3(d_2-d_1)\ *\ (d_2^3 - d_1^3)}$$

This value of $d_m$ used for $\Sigma\ d_i,\ d_{i+j}$ is substituted into the area of circle equation and multiplied by dN the number of particles in the size range $d_i$ to $d_{i+j}$.

This gives the obscuration factor in $\mu m$ per square foot. Multiply the value by 10.76391 to convert to $m^2$ and divide by $1x10^6$ to convert to $\mu m\ /\ mm^2$ or ppm.

This calculation was performed for particle sizes between 1 and 200$\mu m$ diameter for Mild Std 1246 classes 100 and 200, the graphs figures 3 and 4 show the particle fallout in ppm for increasing particle diameters. 100$\mu m$ was taken as the limiting diameter and the corresponding PFO value is obtained.

Results show that for Mil Std class 100 where the optics are exposed the particulate fallout will be approximately 2.96 ppm absolute.

The particulate fallout (PFO) as defined by ESA PSS 01-204 can be calculated from the equation:

$$PFO = 0.069(\text{ Fed Std 209 Class})^{0.72} \text{ ppm / 24 hrs.}$$

This equation is widely used by ESA and has found to have a good correlation with actual ESTEC measured values from ESA approved clean rooms.

For class 100 the PFO = 1.9 ppm / 24 hrs.

For class 1000 the PFO = 9.97 ppm / 24 hrs.

Thus if the optics are exposed in a Fed Std 209 class 1000 environment then the particulate fallout per hour will be:

9.97 / 24 = 0.4154 ppm / hr

If this is compared to the particulate fallout requirement of Mil Std 1246C class 100 then the absolute fallout is 2.96 ppm, thus the optics can be exposed for 7.12 hrs before cleaning is required.

For the entire instrument with the optics covered the Mil Std 1246C class 200 gives a ppm of 46.81 absolute. Thus the instrument can be exposed to 112.68 hrs or 4.69 days before a clean down is required.

Even if it is assumed that Fed Std 209 class 100 is achieved by the use of a class 100 laminar flow hood in a class 10000 area, the ESA/ESTEC equation gives a particulate fallout of 1,92 ppm per day (0.08 ppm / hr) which allows an exposure 37 hrs (1.54 days) with the optics exposed or an exposure of 585 hrs (24.38 days) if the optics are covered, after which a complete clean down is required.

A PFO of 300 ppm is regarded as the visibly clean level and other optical projects usually have a surface particulate contamination limit at delivery of 2000 ppm on non optical surfaces and better than 200 ppm on surfaces near optical elements, the optical elements themselves cannot usually be handled or touched thus it is not feasible to test the surfaces for particulate contamination.

Note that the measure of ppm is not dependant on maximum particle size distribution ie one large particle or a large number of small particles can constitute the maximum PFO measurement reading. In practice particles below 5μm in diameter can be ignored on surfaces as their fallout is prevented by the viscosity and motion of the surrounding air. (Poiseiulle's law). If particles with diameters less than 5μm do appear on surfaces it is because of electrostatic or magnetic charges that attract and hold small particles, the normal electrostatic grounding measures used on spacecraft will reduce this phenomena to a minimum.

Particles above 100μm diameter are visible to the unaided human eye (20:20 vision) under normal white light at a distance of about 100 mm (Human eye resolution limit). The use of black UV light will reduce this limiting visible diameter as particles (mainly organic) fluoresce which increases the apparent diameter, a measure of this increase is not known at present.

The combined effect of this is to reduce the PFO reading for a visibly clean surface to below about 100 ppm which approximates to a Mil Std 1246 D class of 250.

RAL should consider the cleanliness level required for optical and other surfaces in terms of obscuration factor or Particle Fallout (PFO) which is expressed in parts per million: $mm^2$ per $m^2$ or μm per $mm^2$.

RAL should be able to calculate the maximum obscuration factor that can be accepted on the optical elements before the performance of the system is affected. The PFO requirement deduced by this method should include some safety factor and an allowable tolerance on measurements

The allowable obscuration factor should not include any element for particle sizes below 5 μm as they are not present in any significant numbers, or for particles above 100 μm as they are visible and can be removed by local vacuuming or blasting with dry research grade Nitrogen.

MMS can test obscuration factor for particle sizes in the range 5 to 100 μm by exposing witness plates in the vicinity of the optical elements and analysing them at different magnifications with image analysis.

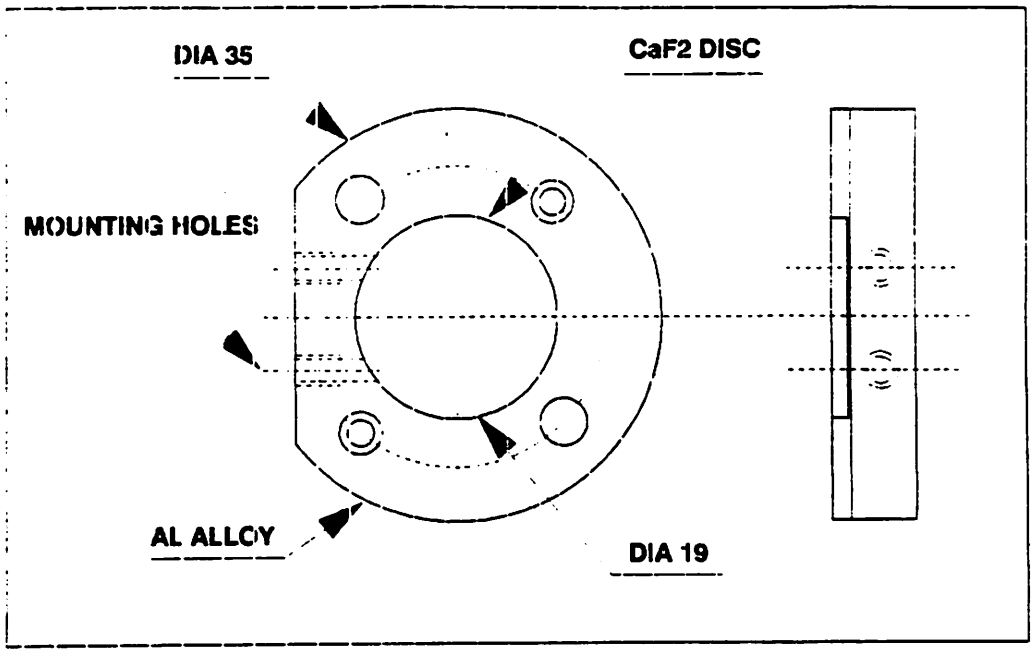


Figure 1. IR spectroscopy test sample configuration.

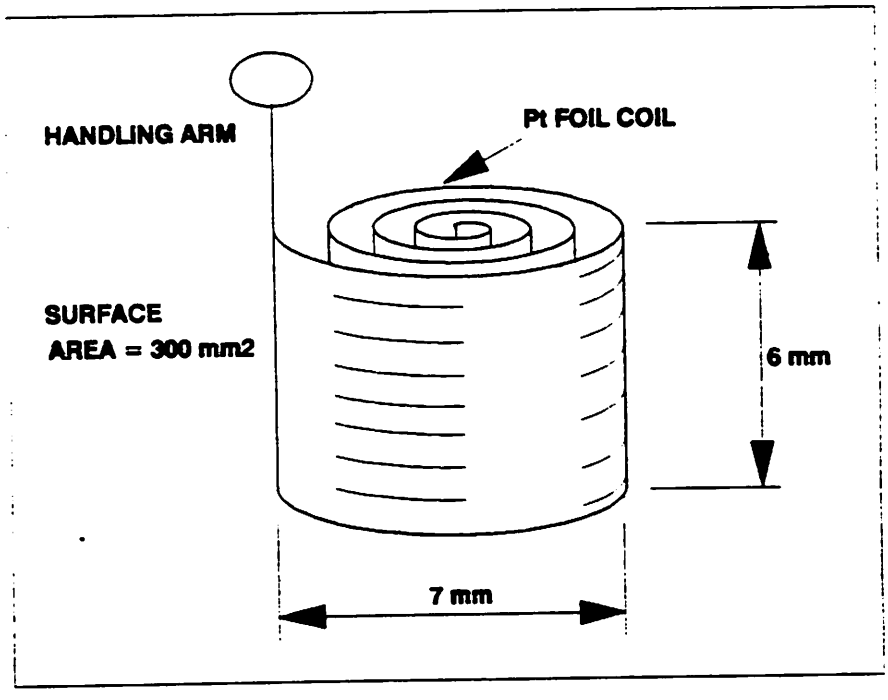


Figure 2. TGA test sample configuration.

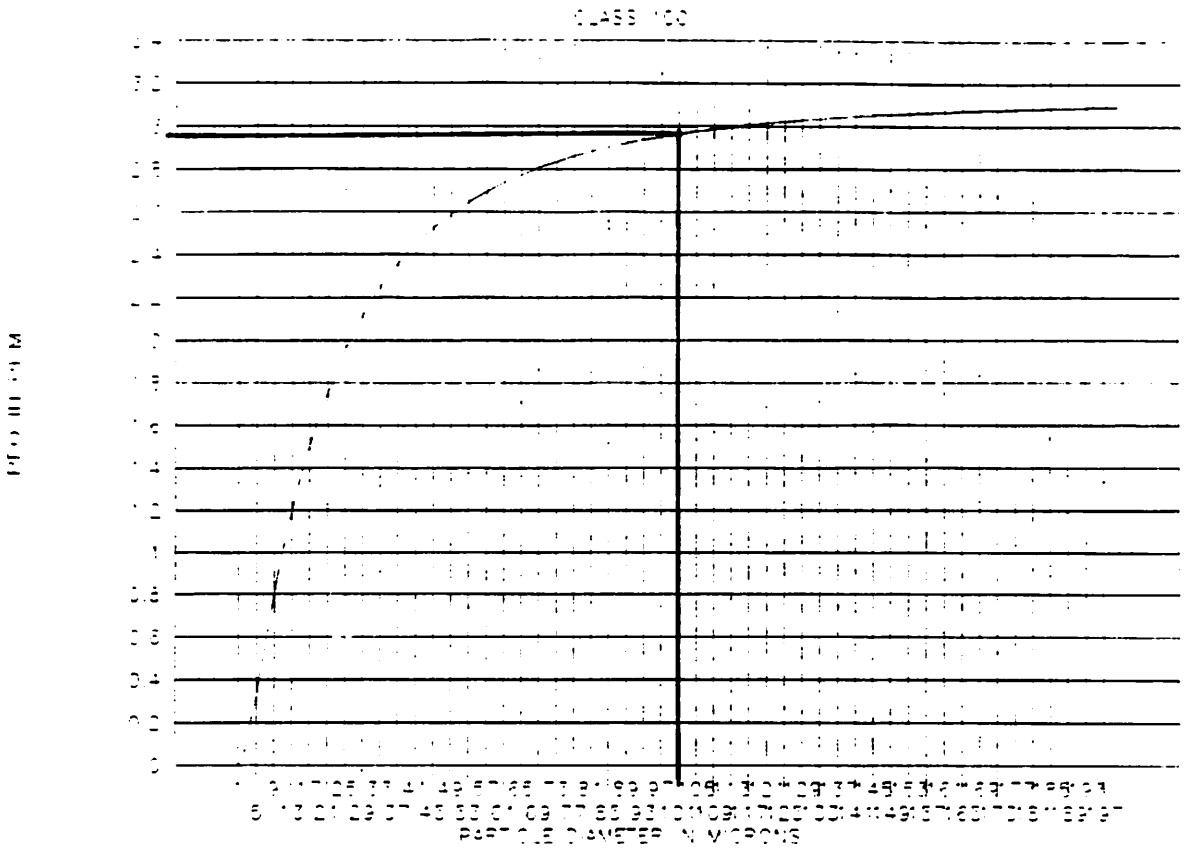

Figure 3. PFO in ppm for Mil Std 1246 D class 100.

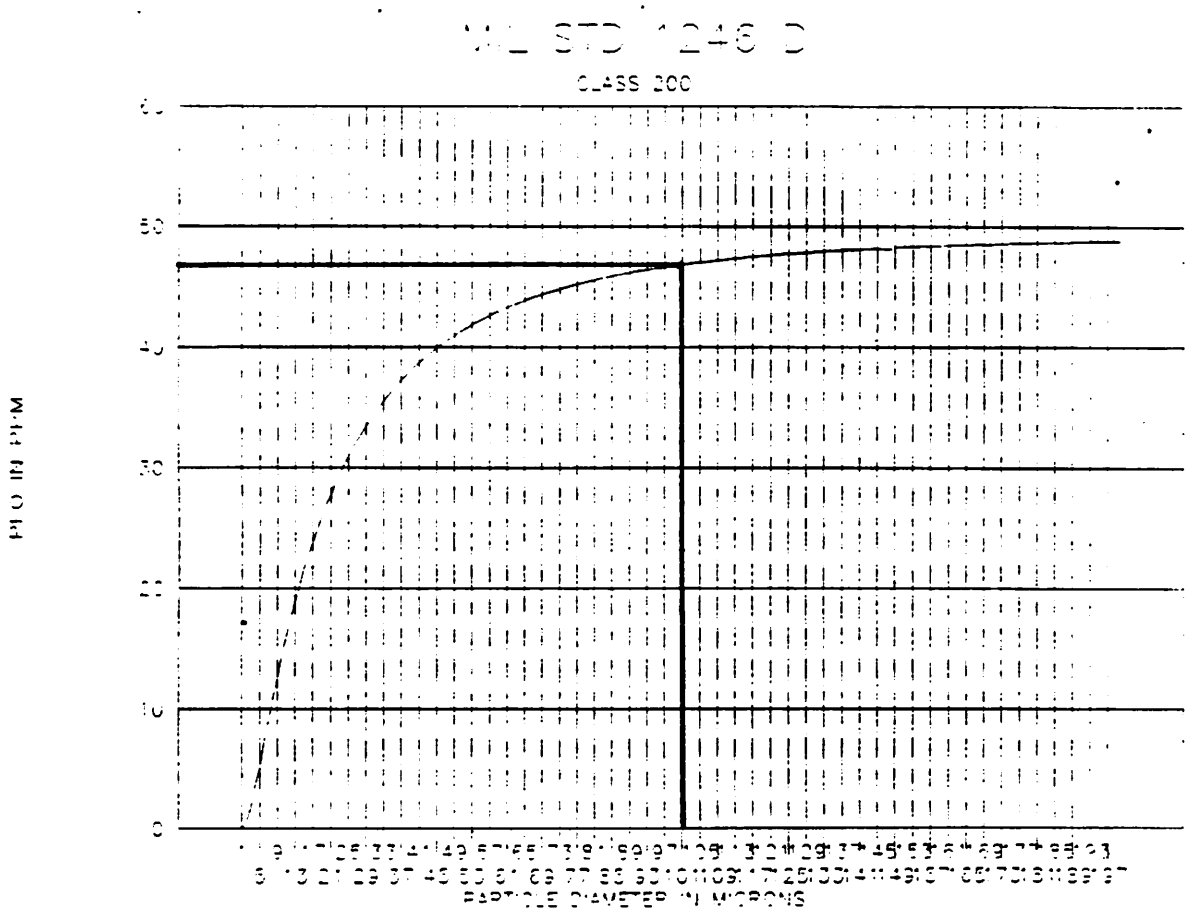


Figure 4. PFO in ppm for Mil Std 1246 D class 200.