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Particulate contamination control in clean rooms by particle fallout (PFO) measurements

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ABSTRACT

This method is intended to determine the particle fallout (PFO) on or near critical spacecraft systems, in clean working areas, test facilities, storage or transport containers, etc. The PFO is measured by means of a photometer.

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1. SCOPE

This method is intended to determine the particle fallout (PFO) on or near critical spacecraft systems, in clean working areas, test facilities, storage or transport containers, etc. The PFO is measured by means of a photometer.

2. GENERAL

2.1 INTRODUCTION

In the past, certain harmful effects of particulate contamination on critical spacecraft systems have been discerned, e.g. optical degradation of mirrors, windows and lenses due to scattering, short circuits in electronics, failures of precision mechanisms, etc. In practice, no strict correlation has been found between the number of airborne particles and particle fallout (PFO). A theoretical value is based on a known (or supposed) size distribution of airborne particles, on a known settling velocity and on air-flow conditions.

The MIL-STD-1246A gives cleanliness levels corresponding to specific particle distributions. A calculation can be made to convert these cleanliness levels to obscuration factors.

According to FED-STD-209B, small particles, 0.5 to 5 µm, determine the airborne class figure to an extent of more than 99%. Particles larger than 5 µm determine the particle fallout to an extent of 99%. Particulate contamination during assembly, testing, storage and transport of a critical spacecraft system is a matter of particle fallout, so for spacecraft systems the expression of particle-contamination levels in PFO units is much more useful than the airborne-particle-content units. The obscuration factor, expressed in parts per million of area (ppm) is the ratio of the projected area of the dust particle to the total area expressed in mm^2/m^2.

2.2. RESPONSIBILITIES

It is recommended that 'design' define, for each system, the maximum obscuration factor tolerable to each stage of the manufacturing process up to and including transportation. This definition should take into account factors additional to the specific requirements for the system, such as exposure time to the environment, possibilities of cleaning to remove contamination, etc.

2.3 APPLICABLE DOCUMENTS

The following documents are applicable to the extent specified herein.

ESA PSS-01-201 Contamination and Cleanliness Control

2.4 DEFINITIONS

The definitions listed in Annex 'A' shall apply.

2.5 REFERENCE DOCUMENTS

FED-STD-209B	Clean Room and Work Station Requirements, Controlled Environment.
MIL-STD-1246A	Product Cleanliness Levels and Contamination Control Program.

3. INSTRUMENTATION

3.1 PFO-PHOTOMETER

- **Measuring principle:** Light scattering due to particles settled on a "sensor" is measured. The PFO-meter reading is a function of the total projected surface of the particles. In the internal calibration mode, the reading is given in ppm; the area covered by dust in mm^2 per m^2 surface area.

- **Measuring range:** From 1 to 2000 ppm, depending upon internal calibration setting.

- **Measuring area:** 15 mm diameter

- **Feature:** Counting and sizing of particles with a microscope; (with possibility of a photographic document).

- **Visibility of particles:** 2 µm using built-in microscope.

Note: Microscopic sizing and counting of particles per unit area can also be applied, but this technique is more time consuming.
The particle fallout instrument is the former Saab-Scania photometer (or Dustometer), updated by Uramec Bilthoven (NL).

3.2 PFO-SENSOR

The sensor consists of a smooth, black glass plate, protected from unintentional sedimentation by a cover plate.

Dimensions : closed 63 x 54 mm
open 105 x 54 mm

Dimensions black glass plate : 40 x 45 mm

4. HANDLING OF PFO-SENSORS

4.1. CLEANING OF THE SENSORS

The cleaning shall be performed in a laminar flow bench, having a maximum particle fallout of 5 ppm/24 hrs. The sensor surface is cleaned by wiping it with lintfree lens tissue paper wetted by immersion in spectral-grade methanol. Wiping is always performed in one direction, i.e. from the sample holder to the free end of the plate. The sensor is then measured to define the background level.

If a background level < 20 ppm cannot be reached after several wipings, even if there are no particles visible through the microscope, the glass plate shall be rinsed with spectral-grade chloroform with the aid of a syringe.

Note: Normally levels ≤ 5 ppm can be reached.

4.2. PACKING OF PFO-SENSORS

The cleaned sensor must be packed in a re-usable self-sealing clean antistatic polyethylene bag, to which it must be returned after exposure. Packing must be carried out in such a way as to avoid friction between sensor and bag, since this can generate particles. Having been placed in this intimate packing, the sensors are to be stored in a container suitable for transport. The cleaned sensor is to be packed on the bench on which it was cleaned. All precautions must be taken to avoid contamination.

4.3. TRANSPORT OF PFO-SENSORS

Sensors must always be transported in the sealed bag provided and in a horizontal position, the sampling surface upwards. Transportation shall be kept to a minimum by having equipment close to measurement sites.

4.4. EXPOSURE OF PFO-SENSORS

Handling of the sensor shall be limited to an absolute minimum. Once exposed in one mode or position, the sensor shall never be re-used before assessment of the contamination and cleaning. An exposed sensor shall not be moved unnecessarily.

The intimate packing of the sensor shall only be opened in situ and the sensor deployed as soon as possible to its fixed position. The sensor shall be deployed in such a way as to avoid any contact with, or any passage above, the measuring surface.

The person performing the measurement shall wear clean-room garments as required for the room. Gloves shall not be worn during deployment, but hands washed and dried thoroughly before it. The same precautions have to be taken when the sensors are packed after exposure.

5. LOCATION OF PFO-SENSORS

The number of sensors placed shall be large enough to ensure a representative sampling of the critical area, i.e. three or more.

5.1. MONITORING OF CLEAN ROOMS AND TEST FACILITIES

The sensors shall be placed within the fallout area of possible contamination sources, i.e. :

- Entrance of clean room;
- Centre of work activities or control boards, e.g. keyboards of equipment, printers, tape units;
- Movable parts, e.g. crane;
- Filtered air inlet;
- Facilities, e.g. vibration system, air inlet of vacuum facilities.

5.2. MONITORING OF CRITICAL SYSTEMS IN TEST FACILITIES OR CLEAN ROOMS

The sensor(s) must be located as close as possible to the critical system(s), if possible between the main contamination sources and the critical system(s).

5.3. MONITORING OF CRITICAL SYSTEMS DURING STORAGE AND TRANSPORT

The sensor shall be fixed to the critical system or fixed as close as possible to it, in the same environment. During the transport or storage, the sensor shall be held in a particular position, which permits a representative particle collection with respect to the critical system.

6. FIXATION OF PFO-SENSORS

The use of a stand or tripod is to be preferred to minimise air turbulence in the setting of the sensors. If existing tables, cupboards, cabinets, racks or equipment surfaces are used to put the sensor on, the surface shall be precleaned using wipes or lint-free tissues, wetted by immersion in spectral-grade methanol, ethanol or IPA, to approximately 1 m^2 around the location. Special approved dust-wiping materials can also be used.

If necessary (e.g. during transport, on movable parts), approved adhesive tape can be used, but any contact with the sampling surface must be avoided. For vacuum test facilities, fixation using metal screws must be considered.

7. REPORT

The Contractor shall establish a report consisting of :

(a) Description of the clean room (test-facility)
- Air flow
  - laminar
  - non-laminar
  - velocity of air flow
- Dimension of the room

(b) Outline of the set-up :
- Position and dimension of critical system
- Position and height of sensor
- Position of other items present in the vicinity of the critical system
- Main work-activity centres

(c) Exposure time
- In hours (preferably 8 hours or 24 hours)
- Estimated work activities in man hours
- Number of people present

(d) Description of the main activities and work performed during the exposure.

8. INTERPRETATION

The results are given as an obscuration factor, i.e. the area of the sensor covered by particles in ppm or mm^2/m^2.

(a) The **PFO can be expressed in ppm/24 hrs** for certain activities, such as comparison of clean rooms and facilities.

(b) In most clean operations the main contributors to particulate contamination are men and human activities. The influence of this source can be estimated by giving the **PFO per man hour working activities.**

(c) For further interpretation of data, use specification ESA PSS-01-201. This specification also gives a correlation between **airborne contamination** (according to FED-STD-209B), **cleanliness level** and **obscuration factor** , as evaluated from measurements published by Schneider (JPL) and tests performed in clean rooms at ESTEC. This correlation fits only for the specific condition of the above-mentioned measurements, but can be used as a rough correlation for general evaluation purposes.

9. ACCEPTANCE LIMITS

The particulate acceptance limit for spacecraft systems is normally defined in the cleanliness specification of the relevant project. Typical acceptance limits for clean rooms and clean test facilities are given in Table 1.

As a guideline, the classification based on airborne-particle content according to FED-STD-209B can still be used, it being borne in mind that strict correlation between airborne particles and settled particles does not exist in a real environment.

Table 1

Obscuration factor (ppm/24 hrs)	Typical Applications	FED-STD-209B Class (ESA PSS-01-201)
1.5	Ultra clean facility e.g. precision control equipment, miniature contacts, optics.	100
12	Very clean facility. Electronic assemblies PCB's, bearings, special instruments	1 000
60	Clean facilities. Small instruments, medium tolerance bearings	10 000
225	Medium clean facility Measuring instruments and instrument calibration, electronic equipment, regular hydraulics, pneumatic system.	100 000

Note : The obsuration factor 1.5 equivalent to class 100 is effectively very close to the detection limit. To avoid calibration problems, a longer exposure time than 24 hours is necessary.

ANNEX A

DEFINITIONS

CLEANLINESS

Purity of environment or material in terms of freedom from contaminants and their effects.

CLEAN ROOM

A clean room is an enclosed area designed, equipped, maintained and controlled in such a way that the degree of contamination of a product can be controlled.

CLEAN WORK STATION

A clean work station is a work bench or similar work area characterised by having its own filtered air or gas supply.

CONTAMINATION

Foreign particles, liquids, gases, materials and micro-organisms which by their presence can disturb the performance of an item.

CONTAMINTION-SENSITIVE ITEMS

Items whose function can be impaired by slight contamination and items whose function suffers a major disturbance through contamination.

OBSCURATION FACTOR

The ratio of the projected area [mm^2] of the dust particle to the total area [m^2] is expressed in parts per million of area (ppm).