Military Standard 1246C

1. SCOPE

1.1 Scope. This standard provides a basis and a uniform method for specifying product cleanliness levels and contamination control program requirements. The emphasis is on contaminants that cause damage through physical interactions rather than chemical interactions.

1.2 Use. These requirements are unusual and are not required for all products but are intended for use in military procurement and design contracts for only those items where contamination control, by measurement for parts, components, or fluids, is necessary to ensure reliability.

1.3 Applicability. When this standard is made part of a procurement contract, the procuring activity shall be responsible for identifying the applicable requirements contained herein that apply to the particular contract.

1.4 Background. The log-log^2 distribution of particles with a slope of 0.926 is based on a lognormal distribution with the maximum number of particles at the 1 μm size. This lognormal distribution was derived from measurements of precision cleaned hardware and, therefore, is representative of cleaned products. Products exposed to contaminating environments can be expected to collect different distributions of particles.

1.5 Safety. The use of the techniques and materials described here may have significant health, safety, and environmental impacts. Appropriate sources of information should be consulted before the use of such techniques and materials.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and the supplement thereto, cited in the solicitation (see 6.2).

STANDARDS

Federal

FED-STD-209	Airborne Particulate Cleanliness Classes in Cleanrooms and Clean Zones.

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Standardization Documents Order Desk, Bldg. 4D, 700 Robbins Ave., Philadelphia, PA 19111-5094.)

2.2 Non-Government publications. The following documents form a part of this standard to the extent specified herein. Unless otherwise specified, the issue of the documents which are DoD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation (see 6.2).

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM E595	Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment
ASTM E1216	Standard Practice for Sampling for Surface Particulate Contamination by Tape Lift
ASTM E1234	Standard Practice for Handling, Transporting, and Installing Nonvolatile Residue (NVR) Sample Plates Used in Environmentally Controlled Areas for Spacecraft
ASTM E1235	Standard Test Method for Gravimetric Determination of Nonvolatile Residue (NVR) in Environmentally Controlled Areas for Spacecraft
ASTM F25	Standard Test Method for Sizing and Counting Airborne Particulate Contamination in Clean Rooms and Other Dust-Controlled Areas Designed for Electronic and Similar Applications
ASTM F50	Standard Practice for Continuous Sizing and Counting of Airborne Particles in Dust-Controlled Areas and Cleanrooms Using Instruments Capable of Detecting Single Sub-Micrometer and Larger Particles
ASTM F51	Standard Test Method for Sizing and Counting Particulate Contaminants In and On Clean Room Garments
ASTM F302	Standard Practice for Field Sampling of Aerospace Fluids in Containers
ASTM F303	Standard Practice for Sampling Aerospace Fluids from Components
ASTM F306	Standard Practice for Sampling Particulates from Man-Accessible Storage Vessels for Aerospace Fluids by Vacuum Entrainment Technique (General Method)
ASTM F307	Standard Practice for Sampling Pressurized Gas for Gas Analysis.

ASTM F311	Practice for Processing Aerospace Liquid Samples for Particulate Contamination Analysis Using Membrane Filters
ASTM F312	Methods for Microscopical Sizing and Counting Particles from Aerospace Fluids on Membrane Filters
ASTM F318	Standard Practice for Sampling Airborne Particulate Contamination in Clean Rooms for Handling Aerospace Fluids
ASTM F327	Standard Practice for Sampling Gas Blow Down Systems and Components for Particulate Contamination by Automatic Particle Monitor Method
ASTM F331	Standard Test Method for Nonvolatile Residue of Halogenated Solvent Extract from Aerospace Components (Using Rotary Flash Evaporator)
ASTM F1094	Standard Test Methods for Microbiological Monitoring of Water Used for Processing Electron and Microelectronic Devices by Direct Pressure Tap Sampling Valve and by the Pre-Sterilized Plastic Bag Method

(Applications for copies of referenced ASTMs should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187.)

SOCIETY OF AUTOMOTIVE ENGINEERS, INC.

ARP 598	The determination of Particulate Contamination in Liquids by the Particle Count Method.
ARP 743	Procedure for Determination of Particulate Contamination of Air in Dust controlled Spaces by the Particle Count Method.

(Applications for copies of referenced SAE documents should be made to the Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096.)

(Non-government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

2.3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however supersedes applicable laws and regulations unless specific exemption has been obtained.

3. DEFINITIONS

3.1 Cleanliness level. An established maximum allowable amount of contamination in a given area or volume, or on a component.

3.2 Collected volatile condensable material (CVCM). The mass that outgasses from a material and subsequently condenses on a collector surface as specified in ASTM E595 expressed as a percentage of the initial specimen mass. See also Total Mass Loss.

3.3 Contaminant. A specific type of contamination.

3.4 Contamination. Unwanted material.

3.5 Contamination control. Any organized action taken to control the level of contamination.

3.6 Demonstrated equivalence. The condition where a method of measurement has passed a series of tests to show that it gives equivalent results to those of a standard measurement.

3.7 Micrometer (μm). A unit of measurement equal to one-millionth of a meter, or approximately thirty-nine millionths of an inch (0.000039 inch), or, 25 microns is approximately 0.001 inch. The micrometer has replaced the micron in the SI system of measurement.

3.8 Non-Volatile Residue (NVR). Material remaining after evaporation of a liquid. Units are determined by the test method used.

3.9 Particulate percent area coverage. The fraction of the surface that is covered by particles, reported as total particle projected area divided by total surface area.

3.10 Particle size. The maximum linear dimension of the particle.

3.11 Point of contact. A designated individual position in an organization, the occupant of which has the responsibility for assuring that contractual contamination control requirements are met. This position is identified and serves as a focal point for all activities concerning contamination control.

3.12 Significant surface. Any surface of an item or product which is required to meet established cleanliness level requirements.

3.13 Total Mass Loss (TML). The mass that outgases from a material, as specified in ASTM E595, expressed as a percentage of the initial mass of the specimen.

3.14 Turbidity. The cloudiness of a liquid caused by the presence of finely divided suspended material.

3.15 Volatile condensable material (VCM). Gaseous products released from a material under specified conditions of temperature and pressure, that condense at other specified conditions of temperature or pressure or both.

4. GENERAL REQUIREMENTS

4.1 Contamination control program.

4.1.1 Responsibility.

4.1.1.1 Prescribing product cleanliness. The responsibility for selecting or determining the degree of product cleanliness shall rest with the engineering organization initially responsible for the product to be produced or processed.

4.1.1.2 Achieving and maintaining product cleanliness. The responsibility for achieving and maintaining product cleanliness shall rest with the organization whose function is to process or produce the product from the design and related specification requirements.

4.1.1.3 Assuring the integrity and continuity of the contamination control effort. The responsibility for a continuing contamination control effort shall rest with a designated point of contact, as defined herein with the authority to assure that the product meets design and specification requirements.

4.2 Methods for specifying product cleanliness levels. Only the cleanliness level or levels specified for a particular product are applicable to that product. Product cleanliness shall be specified in the following manner:

MIL-STD-1246 LEVEL X Y, Z

Z = Alternative or additional cleanliness levels, consisting of one or more abbreviations from the following list and the maximum limit(s) expressed in the units described herein:
PAC = Percent Area Covered
PC = Particle Count specified independently of table I (see 5.1.2.5)
CVCM = Collected Volatile Condensable Material in accordance with ASTM E595
VCM = Volatile Condensable Material determined by methods other than ASTM E595
NTU = Nephelometric Turbidity Units (see 5.1.2.7).
TML = Total Mass Loss, in accordance with ASTM E595

Y = Non-volatile residue cleanliness level designation from table II.

X = Numerical particle cleanliness level from table I.

Only the cleanliness level applicable to a particular product shall be specified. If no level is specified, then the designation shall be omitted. Examples follow:

a. "MIL-STD-1246 Level 200", refers to particulate only.

b. "MIL-STD-1246 Level 200F", refers to particulate and NVR.

c. "MIL-STD-1246 Level F", refers to NVR only.

d. "MIL-STD-1246 Level 200F, CVCM=0.1%, TML=1%", refers to particulate, NVR, collected volatile condensable material, and total mass loss.

e. "MIL-STD-1246 Level 200, CVCM=0.1%", refers to particulate and collected volatile condensable material.

f. "MIL-STD-1246 Level CVCM=0.1%", refers to collected volatile condensable material only.

TABLE I. Particle cleanliness levels. 1/

Level	Particle Size, µm	Count per 1 ft^2	Count per 0.1 m^2	Count per Liter
1	1	1.0	1.08	10
5	1	2.8	3.02	28
5	2	2.3	2.48	23
5	5	1.0	1.08	10
10	1	8.4	9.07	84
10	2	7.0	7.56	70
10	5	3.0	3.24	30
10	10	1.0	1.08	10
25	2	53	57	530
25	5	23	2438	230
25	15	3.4	3.67	34
25	25	1.0	1.08	10
50	5	166	179	530
50	15	25	27.0	230
50	25	7.3	7.88	34
50	50	1.0	1.08	10
100	5	1785	1930	17850
100	15	265	286	2650
100	25	78	84.2	780
100	50	11	11.9	110
100	100	1.0	1.08	10
200	15	4189	4520	41890
200	25	1240	1340	12400
200	50	170	184	1700
200	100	16	17.3	160
200	200	1.08	10.0	1.0
300	25	7455	8050	74550
300	50	1021	1100	10210
300	100	95	103	950
300	250	2.3	2.48	23
300	300	1.0	1.08	10
500	50	11817	12800	118170
500	100	1100	1190	11000
500	250	26	28.1	260
500	500	1.0	1.08	10

TABLE I. Particle cleanliness levels, continued.

Level	Particle Size, µm	Count per 1 ft^2	Count per 0.1 m^2	Count per Liter
750	50	95807	105000	958070
750	100	8919	9630	89190
750	250	214	231	2140
750	500	8.1	8.75	81
750	750	1.0	1.08	10

1000	100	42658	46100	426580
1000	250	1022	1100	10220
1000	500	39	42.1	390
1000	750	4.8	5.18	48
1000	1000	1.0	1.08	10

1/ Limits on particle count at indicated particle size for surface or liquid to meet the level of cleanliness. Sampling areas other than $0.1m^2$ shall be calculated to the basis of $0.1m^2$. Areas may be estimated if total area is considered by both parties to be too difficult to measure within two significant figures. This condition shall be noted and low/high ranges shall be used. Parts with a total significant surface area less than $0.1m^2$ and which have had the entire critical surface area sampled shall be accepted on the basis of actual count.

4.3 Log-log^2 distribution of particles. The log-log^2 distribution of acceptable particle contamination is shown in figure 1.

TABLE II. Non-volatile residue cleanliness levels.

Level	Limit, NVR mg/0.1m^2 *1/ (or µg/cm^2)	Limit, NVR mg/liter
A/100	0.01	0.1
A/50	0.02	0.2
A/20	0.05	0.5
A/10	0.1	1.0
A/5	0.2	2.0
A/2	0.5	5.0
A	1.0	10.0
B	2.0	20.0
C	3.0	30.0
D	4.0	40.0
E	5.0	50.0
F	7.0	70.0
G	10.0	100.0
H	15.0	150.0
J	55.0	250.0

1/ Limits on non-volatile residue (NVR, mg) for surface, liquid, or gas to meet the level of cleanliness.

* One square foot = 0.0929 m^2.

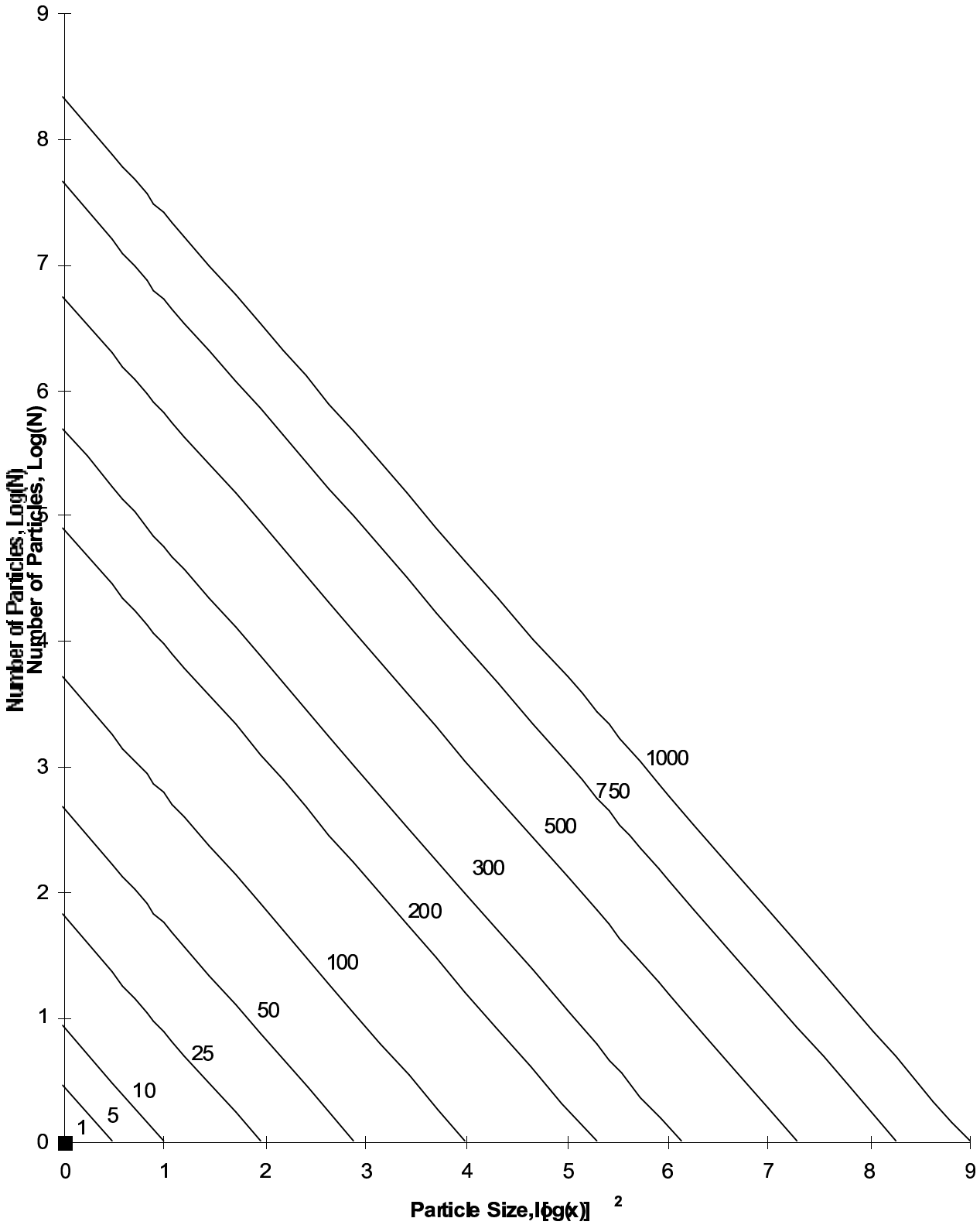

FIGURE 1. Product cleanliness levels.

5. DETAILED REQUIREMENTS

5.1 Cleanliness levels. Tables I and II prescribe the cleanliness levels established to provide a uniform set of criteria for specifying product cleanliness in terms of particles or non-volatile residues (NVR) or both. Use of these cleanliness levels provides a basis for specifying and determining conformance to cleanliness requirements.

Unless otherwise specified, cleanliness levels shall be in terms of maximum amounts per unit extent (area, volume, mass), such as counts per 0.1m2. Use of a particular unit of extent does not imply that the measurements are to be taken over this extent, but rather that the total amount is to be divided by the total extent. In general, higher accuracy is fostered by the measurement of larger extents.

For contaminant levels other than particles or, NVR, limits shall be designated by the user in units prescribed in 5.1.1.

5.1.1 Application of cleanliness levels. The cleanliness levels of tables I and II shall apply to surfaces, assemblies, components, fluids, or materials. Documentation shall include sampling details and acceptance criteria. The following units of measure shall be used:

(a) Surfaces. Particles categorized by size and count per 0.1 square meter (1 square foot = 0.0929 square meter) of significant surface area (areas may be estimated). Percent area coverage (PAC) measured as total particle projected area divided by total significant surface area. NVR in milligrams per 0.1 square meter of significant surface area (areas may be estimated).

(b) Assemblies, components, or materials. Particles categorized by size and count per 0.1 square meter of significant surface area (areas may be estimated). Limits may also be specified on a per item basis rather than per unit area, volume, or mass. PAC measured as total particle projected area divided by total significant surface area. NVR in milligrams per square centimeter of significant surface area (areas may be estimated). Volatile condensable material (VCM) from bulk material may be reported in milligrams per 0.1 square meter of significant area or per unit mass of bulk material.

(c) Liquids. Particles categorized by size and count per unit volume in accordance with ARP 598 or demonstrated equivalent. NVR measured in mass per unit volume. Turbidity is characterized by Nephelometric Turbidity Units (NTU).

(d) Gases. Particles categorized by size distribution in units of count per unit volume.

5.1.2 Measurement of cleanliness levels.

5.1.2.1 Direct measurements. Direct measurement is the analysis of part of the surface, liquid or gas of interest. Examples are counting particles on the surface by using a microscope or performing NVR analysis on a sample of liquid of interest. Direct measurement of particles or NVR in situ, is the most accurate technique, although limited methods exist. A requirement for direct, non-contact microscopic examination of particles on a surface is only feasible if the surface optical properties allow such examination. Alternative surface or fluid measurement techniques are acceptable, having demonstrated equivalence.

5.1.2.2 Extractive sampling. Extractive sampling of surfaces, liquids or gases for off-line measurement is the most widely used approach for particle and NVR cleanliness determination. Sample collection techniques and measurement methods to determine cleanliness shall be accomplished using the ASTM procedures (partial listing) shown in table III, or by demonstrated equivalents. Extractive sampling is the analysis of a medium other than that of interest. Examples are counting particles on tape that has been used to remove particles from a surface of interest in accordance with ASTM E1216 or demonstrated equivalent; or analyzing liquid used to flush a surface of interest. Successful extractive sampling requires a technique of known extraction efficiency (preferably close to 100 percent efficiency). Multiple extractions should produce

concentrations that approach those of the extraction fluid itself; otherwise, complete removal has not occurred or contaminants generation may be occurring or both.

In some cases the medium of interest is gas or liquid coming from contact with a possibly contaminated surface. This is direct measurement of the gas or liquid, and extractive sampling of the surface. Because of uncertainty in sampling efficiency, direct sampling is preferable to extractive sampling.

5.1.2.3 Indirect sampling. Indirect witness samples are the third and least accurate method for particles and NVR cleanliness determination, but may be the only method available when direct scanning or physical sampling of a product is not feasible. One method for NVR witness samples is documented in ASTM E1234 and ASTM E1235. Particles witness samples shall take any form which represents the actual condition, and measurement methods shall follow the same requirements specified above.

TABLE III. Sampling and measurement techniques for surfaces, liquids, and gases.

	Sampling Techniques	Measurement Techniques
Surfaces	ASTM F51 ASTM F303 ASTM F306 ASTM E1216 ASTM E1234	ASTM F311 ASTM F312 ASTM F331 ASTM E1235
Liquids	ASTM F302 ASTM F303 ASTM F1094	ASTM F311 ASTM F312 ASTM F331 ARP 598
Gases	ASTM F25 ASTM F50 ASTM F307 ASTM F318 ASTM F327	ASTM F25 ASTM F50 ASTM F312 ASTM F331 ARP 743

5.1.2.4 Percent area coverage. An alternative method of specifying particulate levels on a surface is expressed as percent area coverage (PAC). Particle area may be directly measured using image analysis or other techniques. Otherwise, particle sizing and counting must be performed and the values converted to a PAC value. Table IV provides the conversion formula and is based on a sample size of 0.1 square meter. Other possible methods for PAC include obscuration or light scattering, after having demonstrated equivalence with actual measured projected areas.

5.1.2.5 Alternative particle count specifications. In some cases, it is desirable to specify a particle count limit in a manner different from that shown in table I. As examples, one might specify total count per unit extent for particles in a specified size range, or the maximum quantity of particles smaller than 1 micrometer, or the maximum quantity of particles measuring 10 to 50 micrometers, or maximum quantity of particles larger than 20 micrometers, or specification of another size distribution limit.

Another approach would be to specify certain particles types to be limited. For example, those that contain sodium or are magnetic. Alternative particle count specifications shall identify what is to be measured, how it is to be measured, and define the limit in terms of count per unit extent.

5.1.2.6 Volatile condensable material. Volatile condensable material (VCM) is determined from a preconditioned sample subjected to a specified temperature with the VCM collected at a lower specified temperature. Cleanliness requirements are specified as CVCM (see 4.2) when tested in accordance with ASTM E595 and as VCM when tested by methods other than ASTM E595.

TABLE IV. Calculating particle percent area coverage .

Particle Size Range	Particles per 0.1 m^2	X	Coefficient =	% Area Coverage
>1 - 10 µm	1/	X	1.737×10^{-8} =	
>10 - 25 µm		X	1.528×10^{-7} =	
>25 - 50 µm		X	7.078×10^{-7} =	
>50 - 100 µm		X	2.435×10^{-6} =	
>100 - 150 µm		X	5.186×10^{-6} =	

>150 - 250 µm		X	7.484×10^{-6} =	
>250 - 500 µm		X	6.522×10^{-6} =	
>500 - 750 µm		X	1.048×10^{-5} =	
>750 µm		X	1.922×10^{-5} =	

(Sum all values to obtain total percent coverage area.)

1/ Value may be estimated by multiplying counts within the 10-25 µm range for count in the 1-10 µm range by 3.24. These are empirical coefficients based on the work of Ma, Fong, and Lee, (see 6.4).

5.1.2.7 Turbidity. Turbidity is measured by either the reduction in transmission or the increase in scattering of light by particles in a liquid. The units of measurement are Nephelometric Turbidity Units (NTUs).

5.2 Statistical analysis of data. Data shall be analyzed with statistical techniques, such as those listed below so as to derive 95 percent confidence limits (see 6.3).

5.2.1 Poisson statistics (single sample particle count).
If only one sample has been obtained and it has a count of N (for N > 50), then the 95 percent confidence limits for the true (unknown) mean count can be estimated from the expression Upper 95% limit = (N+1.92) + (1.960 times the square root of [N + 1.0]), and Lower 95% limit = (N+1.92) - (1.960 times the square root of [N + 1.0]). This expression is an approximation when N = 1 to 50. For a count of N = 0, the limits are 0 to 3.7.

5.2.2 Student's t analysis. Let the number of measurements be n, with n > 1. Let the values of the measurements be x(1), x(2),...,x(n). The sample mean is the sum of the x values divided by the number of measurements taken:

$M = \Sigma x/n$. The sample mean is the best estimate of the true mean.

The sample standard deviation is approximately the square root of the mean of the squared differences between the sample mean and the readings:

$s = \text{square root } [(\Sigma (x-M)^2 / (n-1)]$.

The upper 95 percent confidence limit for the mean is M + (t)(s)/square root (n) and the lower 95% confidence limit for the mean is M - (t)(s)/square root(n), where t is obtainable from tables of Student's t in most statistics texts. For n > 10, t is about 1.65. The quantity s/square root(n) is known as the standard error of the mean.

5.2.3 Transformation of data. For particle counts, N, the transformation y = square root(N) will produce a variable, y, that often has a distribution that is more nearly normal (Gaussian) than is the distribution of N. For particle counts or concentration values that have a negligible fraction of values that equal zero, the transformation z = log (x) will produce a variable, z, that often has a distribution that is more nearly normal (Gaussian) than the distribution of x is. Such transformation can improve the accuracy of the Student's t analysis.

5.2.4 Number of samples. If the time interval or the spatial interval over which n samples are taken has a uniform concentration except for random deviations about the mean concentration, then the difference between one mean of n samples and another mean of n samples would be approximately proportional to 1/square root (n). If there are systematic differences of concentration over the time interval or spatial interval, then differences between means will often be inversely proportional to powers of n that are larger than square root(n), such as 1/n or $1/n^2$. Comparing the means of two or more samples of size n can aid in determining how many samples are needed to get a desired confidence limit magnitude.

5.3 Recording data. As a minimum, the following information is normally recorded:

(a) Item name and description
(b) Person doing sampling/Analyst
(c) Sample size
(d) Number of samples
(e) Identification of replicate samples
(f) Location
(g) Date/time
(h) Operating conditions
(i) Environment
(j) Equipment
(k) Method
(l) Results.

If it is desired to display the data graphically, figure 1 indicates the levels of table 1 plotted on axes of log of the count versus the square of the logarithm of the particle size in micrometers. Figure 1 is approximate and should not be used to define the requirements given in table I.

5.4 Detailed requirements for the contamination control program. Based on the specification of product cleanliness, a contamination control program shall be implemented. The program shall encompass, but is not limited to, the following:

5.4.1 Design requirements. The cleanliness level of the product and its sensitivity to contamination shall be determined by the product design activity unless otherwise specified. Contamination limits are to be prescribed by design drawings or specifications consistent with the product requirements. When the product design activity cannot predetermine the cleanliness level, a proposed method for determining this level through investigation, experimentation or assessment shall be included. A product design review in terms of contamination sensitivity shall be conducted to finalize requirements.

5.4.2 Contamination control responsibility. The designated point of contact with the authority to insure that the product meets design criteria and specification requirements shall describe the organizations responsible for implementation of the program.

5.4.3 Processes and controls. Processes and controls applicable to the product, at each state of manufacture or processing, including parts, components, assemblies, and materials that will affect the cleanliness of the product, shall be specified. These processes and controls shall addressed according to the requirements of the contamination control program.

5.4.4 Environmental control. Requirements for the cleanliness, environmental controls, operation, certification, and data tracking for facilities used to fulfill the requirements of this standard shall be specified in the plan. Methods and practices for control of particulate and nonparticulate contaminants, temperature, relative humidity, or other conditions (see 6.3) critical to the product shall be addressed. Where specification of airborne particulate concentration is required, the specification shall be in accordance with FED-STD-209.

5.4.5 Sub-tier contractor. A method shall be determined for imposing contamination control requirements on sub-tier contractors.

5.4.6 Calibration procedures. Calibration procedures and frequencies for instruments and equipment used directly or indirectly for cleanliness verification shall be addressed.

5.4.7 Quality control. Quality control procedures and record keeping shall be addressed to ensure surveillance and compliance.

5.4.8 Product protection. Materials and methods for product protection shall be addressed to maintain the required product cleanliness level .

5.4.9 Personnel. Personnel training, motivation, control methods, or other considerations (see 6.3) shall be addressed.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. This standard is intended to be used as a basis and a uniform method for establishing product cleanliness and contamination control.

6.2 Issue of DODISS. When this standard is used in acquisition, the issue of the DODISS to be applicable to this solicitation must be cited in the solicitation (see 2.1.1 and 2.2).

6.3 Additional information. The following sources have been found useful in the conduct of contamination control programs:

(a) Institute of Environmental Sciences, Handbook of Recommended Practices, Contamination Control Division, 940 East Northwest Highway, Mount Prospect IL

(b) Wilson E.B.jr., "An Introduction to Scientific Research", McGraw, NY, 1952

(c) Box G.E.P., Hunter W.G., Hunter J.S., Statistics for Experimenters, Wiley, NY, 1978

(d) ASTM Standards for Cleanrooms, 1993

(e) Ma, P.T., Fong, M.C., and Lee, A.L., "Surface Particle Obscuration and BRDF Predictions", SPIE vol. 1165, Scatter from Optical Components, 1989.

6.4 Subject term (key word) listing.

Contaminant
Level, clean
Material, collected, condensable, volatile
Micrometer
Residue, non-volatile
Particle
Surface, significant

6.5 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

Custodians:
Army - MI
Navy - YD
Air Force - 99
DLA - GS

Review activities:
Army - AV, AT, GL, AL, AR
Navy - AS
Air Force - 70, 71, 84
DLA - GS

User activities:
Army - ME
Navy - OS, SH
Air Force - 79
DLA - ES

Preparing activity:
Army - MI

Project No. 3694-0034

APPENDIX

CLEANING METHODS AND MATERIALS

10. GENERAL

10.1 Scope. The purpose of this appendix is to provide non-mandatory supplemental guidance for the preparation of documents relating to contamination control programs. The selection of cleaning processes and equipment is strongly influenced by the design of items, their constructive material and surface treatments, and the fabrication process which produce them. Early consideration of the need to clean can result in design, materials and process changes which do not decrease utility but result in items which can be more effectively cleaned at a lower cost. Included in the considerations should be the health, safety and environmental impacts of the total manufacturing and cleaning process. Many materials may be subject to local, state or federal statutory control effecting use and disposal.

20. APPLICABLE DOCUMENTS

20.1 Government documents. Not applicable

20.2 Non-Government publications. The following documents form a part of this standard to the extent specified herein. Unless otherwise specified, the issue of the documents which are DoD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation (see 60.2).

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM A380	Standard Practice for Cleaning and Descaling of Stainless Steel Parts, Equipment, and Systems

30. DEFINITIONS. This section is not applicable to this appendix.

40. GENERAL REQUIREMENTS.

40.1 Cleaning methods and materials.

40.1.1 Gross cleaning. This method is use to achieve visibly clean articles. Gross cleaning removes contaminants such as weld scale, heat treat scale, corrosion, oxide films, oils, grease, shop soil, fuel, and carbon deposits. The cleanliness level achieved by gross cleaning does not normally require verification beyond visual inspection. (Wipe test, water break test, ultraviolet inspection, special light and mirrors, are considered aids to visual inspection.) Gross cleaning is considered a normal shop process and usually does not require especially clean conditions beyond accepted good practice.

APPENDIX

40.1.1.1 Gross cleaning types. The following types of cleaners, or their equivalents, may be used for removing gross forms of contamination. NOTE: Chemical cleaning agents must be compatible to prevent excessive attack or latent degradation.

40.1.1.1.1 Acid cleaners. Acid cleaners are used to remove contamination, such as, weld scale, corrosion and oxide films not removable by other solutions. Examples are nitric acid, inhibited hydrochloric acid, inhibited sulfuric acid, inhibited phosphoric acid, mixed acid deoxidizers and alcoholic-phosphoric acid.

40.1.1.1.2 Alkaline cleaners. Alkaline cleaners are used for the removal of organic and inorganic contamination, such as grease, shop soil, scale and soluble metal oxides. Alkaline cleaners dissolve (etch) certain metals such as aluminum or zinc. Examples are alkaline rust strippers, heavy duty alkaline cleaners, molten alkalis, alkali, alkali with nitrate or phosphate.

40.1.1.1.3 Detergents and mild cleaners. These cleaners are used for the removal of organic and inorganic contamination such as oils, fats, shop soil and grease. Examples are inhibited alkaline cleaners (mild alkaline cleaners), soaps, emulsion cleaners, surfactants, and detergents.

40.1.1.1.4 Organic solvent cleaners. These cleaners are used to remove forms of organic contamination such as oils, grease and hydrocarbon fuels. Examples are alcohol and acetone. Class I Ozone Depleting Chemicals (ODCs) and Class II ODCs as defined in paragraph 40.1.2.2.9. of this standard are excluded from use as an organic solvent cleaner.

40.1.1.1.5 Tap water and deionized water. These cleaners are used to remove the residue material left by cleaning solutions and as final flushing or rinsing medium.

40.1.1.1.6 Neutralizing and passivating solutions. These cleaners are used as a supplementary treatment to acid, alkaline and mechanical cleaning. The neutralizing and passivating solutions prevent corrosion and acid etching. Examples are nitrate, phosphate, alkali with nitrate or phosphate to neutralize; nitric acid or nitric acid solutions to passivate.

40.1.1.1.7 Mechanical cleaning. This process removes contamination by abrasive action, and is only used when physical damage to the items being cleaned will not occur. Examples of mechanical cleaning are wire brushing, shot blasting (wet and dry), grinding, sand blasting (wet or dry), the use of aluminum oxide, abrasive coated papers and cloths and related methods. NOTE: Mechanical cleaning often leaves foreign deposits which may require additional cleaning for their removal. Compatibility of dissimilar materials, especially metals, is an important consideration when selecting a mechanical cleaning method.

40.1.1.1.8 Gross cleaning processes. Table V contains the recommended gross cleaning processes and sequences.

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40.1.2 Precision cleaning. This method is used to achieve a level of product cleanliness greater than the level normally detected by visual means. Articles should be visibly clean prior to precision cleaning. Precision cleaning is performed in a controlled environment, and is intended to remove particles, films, biological forms, fibers and other forms of contaminants that are usually not visible, but which could degrade the product or process. The level of precision cleanliness should be verified and evidence of inspection and acceptance provided. Precision cleaned articles should be packaged immediately after verification of cleanliness, or suitably protected prior to leaving the controlled environment.

40.1.2.1 Precision cleaning solutions or fluids. Precision cleaning solutions or material should not react with, combine with, etch or otherwise cause immediate or latent degradation of the item being cleaned. Precision cleaning fluids should be filtered and controlled. Their cleanliness level should be verified as being sufficient to achieve the specified product cleanliness. Selection of precision cleaning fluid must take into consideration the nature of the contaminant to be removed, reactivity of the item being cleaned, health, safety and environmental hazards of the fluid and disposal of waste, including spent cleaning fluid. Control technology to either contain the precision cleaning fluid, reuse it, or both must be provided as health, safety, and environmental hazards dictate. Examples of materials commonly used for cleaning include abrasive solids, air, carbon dioxide snow or pellets, deionized water, detergent, surfactant, inert gas and organic solvents.

40.1.2.2 Precision cleaning methods or processes. Equipment and various methods suitable for precision cleaning are available. The appropriate process and equipment should be selected on the basis of product configuration, compatibility with cleaning fluids, type and quantity of contaminants, desired cleanliness level, economics, safety and environmental risks. The following equipment and methods are available alone or in combination when selecting the appropriate process for a particular product.

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TABLE V. Gross cleaning processes. 1/

Material	Surface Condition	MEC	ORG	ALK	DET	ACD	NEU	DIW	DRY
Aluminum	Bare or machined, free of heat oxidation		X	X				X	X
	Conversion or chemical film coating		X		X			X	X
	Weld scale, corrosion, or heat oxidation	X	X	X				X	X
Copper Brass Bronze	Bare or machined, free of heat oxidation		X	X				X	X
	Conversion or chemical film coating		X		X			X	X
	Weld scale, corrosion, or heat oxidation		X	X		X		X	X
Stainless Steel 2/	Free of scale		X	X		X	X	X	X
	Weld scale, corrosion, or heat oxidation	X	X	X		X	X	X	X
Carbon Steel	Free of scale		X	X		X	X	X	X
	Weld scale, corrosion, or heat oxidation	X	X	X		X	X	X	X
Non-metallic parts, elastomers	As Received				X			X	X
Electroplated parts and dissimilar metals	As received		X	X				X	X

1/ "X" denotes a recommended process for the surface condition indicated, and will normally be accomplished in consecutive order from left to right.
2/ ASTM-A380 describes in detail recommended methods for descaling and cleaning stainless steel.

TABLE V. Gross cleaning processes, continued.

3/ Cleaning processes defined:

MEC = Mechanical descale /clean
ORG = Organic solvent degrease
ALK = Alkaline clean and tap water rinse
DET = Detergent clean and tap water rinse
ACD = Acid pickle and tap water rinse
NEU = Neutralize and passivate and tap water rinse
DIW = Deionized water rinse
DRY = Drying

40.1.2.2.1 Solution cleaning. The item is washed in suitable clean detergent/water solution or solvent, followed by a succession of rinses. Normally, mechanical action such as agitation or brushing is necessary to assure removal of all contaminants.

40.1.2.2.2 Spray cleaning. Spray cleaning may be divided in three pressure ranges in order of overall effectiveness:

(a) High pressure - greater than 10,342 kiloPascals (kPa) (1500 p.s.i.). High pressure water cleaning should not include detergents as foam formation reduces cleaning efficiency. Precision fixtures are also required but can be effective at cleaning complex geometries including threaded, blind and through holes.

(b) Intermediate pressure - 690 to 10,342 kPa (100-1500 p.s.i.). Intermediate pressure is lower in efficiency than high pressure spray cleaning. Addition of low foaming surfactant can improve efficiency in certain cases.

(c) Low pressure - less than 690 kPa (100 p.s.i.). Pressures at this level are relatively ineffective as a primary cleaning process. However, they are very effective at rinsing away contaminants which has been loosened by a previous cleaning process, such as ultrasonic cleaning.

40.1.2.2.3 Sonic cleaning. Sonic cleaning may be divided into two general ranges based on frequency. Each range exhibits unique cleaning characteristics.

(a) Ultrasonic cleaning - 15 to 100 kHz.
Ultrasonic cleaning provides nondirectional cleaning suitable for complex geometries. Cleaning efficiency is severely limited in holes and in similarly tight geometries. Surface damage may occur as a result of cavitation erosion.

(b) Megasonic cleaning - Frequencies greater than 100 kHz.
This method produces highly directional cleaning suitable for simple geometries. Megasonic cleaning tends to produce less surface erosion than ultrasonic cleaning.

40.1.2.2.4 Vapor cleaning. The item to be clean is exposed to heated solvent vapors which condense on the part and wash away contaminants. This is effective for soluble contaminants and is used as a drying method. However, the method is relatively ineffective for small particles.

40.1.2.2.5 Flush clean. The item to be cleaned is flushed with a suitable cleaning solution. The item is agitated thoroughly to wash all surfaces and the solution is drained away.

40.1.2.2.6 Spin rinse and drying. This method is used principally after another cleaning method has been used. In this method, the item being cleaned is rinsed while turning slowly. The item is then accelerated to higher speed in revolutions per minute (RPM). The high angular velocity accelerates the liquid, removing particles by shear stress. The rinsing liquid is also removed, thus drying the part.

40.1.2.2.7 Electropolishing and chemical polishing. The item to be cleaned is immersed in a solution specifically formulated or energized to remove the base material of the part. Fixturing the item is critical for effective treatment. The dissolution of the base material smoothes the surface and releases contaminants embedded on the surface of the part. Treatment baths must be filtered and processing must be followed by rinsing with deionized water to remove chemical residue.

40.1.2.2.8 Other methods. Consideration should be given to other cleaning methods not described previously such as, argon snow, supercritical fluids, plasma, UV-ozone.

40.1.2.2.9 Ozone depleting substances. Substances classified as a Class I Ozone Depleting Substance by the Clean Air Act Amendment of 1990, and certain Class II ozone depleting substances, should not be given consideration or recommendation by this document. Class I substances to be avoided are chlorofluorocarbons (CFCs), carbon tetrachloride, methyl chloroform, methyl bromide, and hydrobromofluorocarbons (HBFCs). Class II substances to be avoided are hydrochlorofluorocarbons (HCFCs) 22, 141b, and 142b.

40.1.2.3 Handling during cleaning. Disassembly, cleaning, reassembly, in-process handling, packaging and other operations involved in cleaning should be conducted in a manner to preserve critical tolerances, finishes, calibration or other sensitive attributes of the product. Adequate tooling, fixtures, handling devices and product protection should be provided. Written instructions for sensitive or critical activities should be provided.

APPENDIX

50. PROTECTION

50.1 Cleanliness protection. All precision cleaned items should be provided with cleanliness protection prior to leaving the controlled environment.

50.2 Precision clean packaging. The precision clean packaging should maintain the cleanliness level specified for the product.

50.3 Storage. Storerooms or inventory control areas should provide adequate protection to the package and the product for the intended storage period.

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60. INSPECTION

60.1 Inspection. Inspection of precision cleaned and packaged products should be performed as required on a regular or cyclic basis to assure continued maintenance of the integrity of the package and the item. The following criteria should constitute cause for rejection of the precision cleaned and packaged item:

a) Identification label or decal missing, broken, illegible or incomplete.
b) Tamper-proof seal missing, broken or incorrectly applied.
c) Improper seal, open seal or closure, lifted tape, etc.
d) Apparently damaged (including pinholes and the like) or violated package or closure.
e) Visibly entrapped moisture (or a change in humidity indicator) or other unwanted material.
f) Any apparent defect that may interfere with the proper function or use of the item.

60.1.1 Breaking of a closure. If it is necessary to break a closure or open a package for inspection, the item should be opened in a controlled environment and repackaged to the same conditions as the original.

60.1.2 Inspection requiring the opening of a package. Inspection requiring opening of a package or closure should be limited to a minimum of occurrences consistent with good practice.

60.1.3 Traceability. To assure traceability of contamination sources, a record should be maintained of all incidents of opening or closure of the packages. The record should show the date, responsible person, the reason for opening the package or closure, and the disposition of the product.

60.2 Issue of DODISS. When this standard is used in acquisition, the issue of the DODISS to be applicable to this solicitation must be cited in the solicitation (see 2.1.1 and 2.2).