



Designation: E 2042 – 9904

Standard Practice for Cleaning and Maintaining Controlled Areas and Clean Rooms¹

This standard is issued under the fixed designation E 2042; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the procedures to be followed for the initial cleaning and normal maintenance of cleanrooms and controlled areas. This practice is applicable to aerospace clean areas where both particles and molecular films (NVR) must be controlled.

1.2 The values stated in SI units are to be regarded as the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

¹ This practice is under the jurisdiction of ASTM Committee E-21 on Space Simulation and the Applications of Space Technology and is the direct responsibility of Subcommittee E21.05 on Contamination.

Current edition approved ~~Oct. 10, 1999~~, Apr. 1, 2004. Published ~~February 2000~~, April 2004. Originally approved in 1999. Last previous edition approved in 1999 as E 2042 – 99.

2. Referenced Documents

2.1 *ASTM Standards:*²

D 1193 Specification for Reagent Water

E 1234 Practice for Handling, Transporting, and Installing Nonvolatile Residue (NVR) Plates Used in Environmentally Controlled Areas for Spacecraft

E 1235 Test Method for Gravimetric Determination of Nonvolatile Residue (NVR) in Environmentally Controlled Areas for Spacecraft

E 1549 Specification for ESD Controlled Garments Required in Cleanrooms and Controlled Environments for Spacecraft for Non-Hazardous and Hazardous Operations

E 1560 Test Method for Gravimetric Determination of Nonvolatile Residue from Cleanroom Wipers

E 2352 Practice for Aerospace Cleanrooms and Associated Controlled Environments—Cleanroom Operations

F 24 Method for Measuring and Counting Particulate Contamination on Surfaces

F 25 Test Method for Sizing and Counting Airborne Particulate Contamination in Clean Rooms and Other Dust-Controlled Areas Designed for Electronic and Similar Applications

F 50 Practice for Continuous Sizing and Counting of Airborne Particles in Dust-Controlled Areas and Clean Rooms Using Instruments Capable of Detecting Single Sub-Micrometer and Larger Particles

2.2 *IEST Standards:*³

IEST-RP-CC007 Testing ULPA Filters

IEST-RP-CC016 The Rate of Deposition of Nonvolatile Residue in Cleanrooms

~~IEST-RP-CC0018-2~~ Cleanroom Housekeeping and Monitoring Procedures

IEST-RP-CC003 Garment System Considerations for Cleanrooms and Other Controlled Environments

IEST-RP-CC026 Cleanroom Operations

IEST-STD-CC1246D Product Cleanliness Levels and Contamination Control Program⁴

2.3 *US Federal Standards:*⁵

~~FED-STD-209E~~ Airborne Particulate Cleanliness Classes in Cleanrooms and Clean Zones⁶

TT-I-735 Isopropyl Alcohol

O-A-51 Acetone⁵

2.4 *US Department of Defense Standards:*

~~MIL-STD-1246C Product Cleanliness Levels and Contamination Control Program~~⁶

~~T.O. 00-25-203 Contamination Control of Aerospace Facilities, U.S. Air Force~~⁶ Standards:⁵

MIL-D-16791 Detergents, General Purpose (Liquid, Non-Ionic)

2.5 *International Standards:*⁷

ISO 14644-1 Cleanrooms and Associated Controlled Environments—Part 1: Classification of Air Cleanliness

ISO 14644-2 Cleanrooms and Associated Controlled Environments—Part 2: Specifications for Testing and Monitoring to Prove Continued Compliance with ISO 14644-1

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *clean zone, n*—a defined space in which the concentration of airborne particles is controlled to specified limits.

3.1.2 *cleanroom, n*—a room in which the air filtration, air distribution, utilities, materials of construction, equipment, and operating procedures are specified and regulated to control airborne particle concentrations to meet appropriate airborne particulate cleanliness classifications, as defined by ~~FED-STD-209~~ ISO 14644-1.

3.1.3 *cleanroom, as-built, n*—a cleanroom that is complete and ready for operation, with all services connected and functional, but without equipment or operating personnel in the room.

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards*, Vol 11.01, volume information, refer to the standard's Document Summary page on the ASTM website.

Annual Book

³ Available from Institute of ASTM Standards, Vol 15.03: Environmental Science and Technology (IEST), 5005 Newport Dr., Suite 506, Rolling Meadows, IL 60008-3841.

⁴ Discontinued; see 1992 *Annual Book of ASTM Standards*, Vol 15.03.

⁴ IEST-STD-CC1246D replaced MIL-STD-1246.

⁵ Available from IEST, 940 E. Northwest Highway, Mount Prospect, IL 60056. Superintendent of Documents, US Government Printing Office, Washington, DC 20402.

⁶ Cancelled Nov. 29, 2001 and replaced with ISO 14644-1 and 14644-2. FED-STD-209E may be used by mutual agreement between buyer and seller. Available from Superintendent of Documents, US U.S. Government Printing Office, Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401. FS209E cleanroom classes are given for reference in parentheses after the ISO classes.

⁷ The sole source of supply of the apparatus known to the committee at this time is Miracle Wipe 4000, Texwipe Alpha Wipe, Texwipe Alpha 10, Texwipe/ICPTX 4012, Anticon 100, Alter Al Sorb. If you are aware of alternative suppliers, please provide this information to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

⁷ Available from International Organization for Standardization (ISO), 1 rue de Varembe, Case postale 56, CH-1211, Geneva 20, Switzerland.

3.1.4 *cleanroom, at-rest, n*—a cleanroom that is complete, with all services functioning and with equipment installed and operable or operating, as specified, but without operating personnel in the room.

3.1.5 *cleanroom, operational, n*—a cleanroom in normal operation, with all services functioning and with equipment and personnel, if applicable, present and performing their normal work functions in the room.

3.1.6 *clean facility, n*—the total real property required to accomplish the cleanroom functions.

3.1.6.1 *Discussion*—In addition to the cleanroom and associated clean areas, this includes utility rooms, storage areas, offices, lockers, wash-rooms, and other areas that do not necessarily require precise environmental control.

3.1.7 *controlled area, n*—an environmentally controlled area, operated as a cleanroom, but without the final stage of HEPA filters. Controlled areas would meet ISO Class 8.5 (FED-STD-209E equivalent to Class 300 000) per Table 1.

3.1.7.1 *Discussion*—Only rough filters (50 to 60 % efficiency) and medium efficiency filters (80 to 85 % efficiency) are required for a controlled area. The maximum allowable airborne particle concentrations in a controlled area are 11 100 000/m³ per ISO Class M 7 (283 000) 8.5 for particles $\square \geq 0.5 \mu\text{m}$ and Class M 6.5 (100 000) for particles $\square \geq 5.0 \mu\text{m}$. This limit, for sizes $\square \geq 5.0 \mu\text{m}$, is 24 700 particles/m³ or 700 particles/ft³ 92 500/m³ (2620 particles/ft³ per Class 300 000/ft³ FED-STD-209E) for particles $\geq 5.0 \mu\text{m}$.

3.1.8 *DI water, n*—deionized water.

3.1.9 *discrete-particle counter (DPC), n*— an instrument, such as an optical particle counter or condensation nucleus counter, capable of resolving responses from individual particles.

3.1.10 *HEPA filter, n*—(high-efficiency particulate air filter) a throwaway, extended-medium, dry-type filter in a rigid frame,

TABLE 1 Airborne Particulate Concentration of ISO 14644-1 and FED-STD-209E Cleanliness Classes

ISO Class Name	ISO Class		FED-STD-209E Class		Particle Concentrations	
	0.2	1 μm	0.4	0.5	3 μm	0.5 μm
ISO Class 1	10	2	SI	English	(m ³)	(ft ³)
ISO Class 2	(m ³)	(ft ³)	(m ³)	(ft ³)	(m ³)	(ft ³)
FS209E Class 0.4	(m ³)	(ft ³)	4	—	—	—
FS209E Class 0.1	3	1	—	—	—	—
M1	—	350	9.91	75.5	2.14	—
ISO Class 3	1000	237	102	35	8	—
FS209E Class 4	30.9	0.875	10.0	0.283	—	—
FS209E Class 1	35	7	3	1	—	—
M1.5	4	1240	35.0	265	7.50	—
ISO Class 4	10 000	2370	1020	352	83	—
FS209E Class 10	106	3.00	35.3	1.00	—	—
FS209E Class 10	350	75	30	10	2	—
M2	—	35 000	99.1	757	21.40	329
ISO Class 5	100 000	23 700	10 200	3520	832	29
FS209	8.75	750	300	100	2.83	—
FS209E Class 100	3500 ^B	750	300	100	24	—
ISO Class 6	1 000 000	237 000	102 000	35 200	8320	293
ISO Class 6	1 000 000	237 000	102 000	35 200	8320	293
M2.5	40	12400	—	350	2650	75
FS209E Class 1000	35 000 ^B	7500 ^B	3000 ^B	1000	236	7
0	—	—	—	106 0	30.0	34470
ISO Class 6.7 ^C	—	—	—	176 000	41 700	1470
FS209E Class 53	—	—	—	10.0	—	—
FS209E Class 5000 ^B	—	—	—	5000	1180	42
M3	—	—	—	35000	994	7572930
ISO Class 7	—	—	—	352 000	83 200	2930
FS209E Class 10 000	—	—	—	214	3090	87.50
FS209E Class 10 000	—	—	—	10 000	2360	70
ISO Class 8	—	—	—	1000	28.3	—
ISO Class 8	—	—	—	3 520 000	832 000	29 300
FS209E Class 100 000	—	—	—	100 000	23 600	700
FS209E Class 100 000	—	—	—	100 000	23 600	700
M3.5	400	—	—	26500	750	1060
ISO Class 8.5 ^C	—	—	—	11 100 000	2 630 000	92 500
0	—	—	—	300	3530	100
FS209E Class 300 000 ^D	—	—	—	300 000	74 500	2620
ISO Class 9	—	—	—	35 200 000	8 320 000	293 000
FS209E Class 1 000 000 ^D	—	—	—	1 000 000	236 000	8280

^A No 1 μm designation is listed in FS209E Table 1 for particulate classes. The values shown are equivalents of the ISO values.

^B These values were not directly listed in FS209E. Allowances are made in FS209E for intermediate classes and associated calculations have been shown. If used, a notation should be made indicating that they have been derived.

^C ISO 14644-1 does not include Class 6.7 or 8.5. The values shown are equivalent to those derived for FED-STD-209E Class 5000 and 300 000.

^D FS209E does not include Class 300 000 and 1 000 000. The values shown are equivalents of the ISO values for ISO Class 8.5 and 9.

having a minimum particle-collection efficiency of 99.97 % (that is, a maximum particle penetration of 0.03 %) for 0.3-µm particles of thermally generated DOP of specified alternative aerosol.

3.1.11 *HVAC, n*—heating, ventilating, and air conditioning.

3.1.12 *nonvolatile residue (NVR), n*—matter remaining after solvent containing such matter has been evaporated or cleaned.

3.1.13 *ULPA filter, n*—(ultra-low-penetration air filter) a throwaway, extended-medium, dry-type filter in a rigid frame, having a minimum particle-collection efficiency of 99.999 % (that is, a maximum particle penetration of 0.001 %) for particles in the size range of 0.1 to 0.2 µm, when tested in accordance with the methods of IES-RP-CC007.1.

4. Significance and Use

4.1 This practice identifies methods for cleaning and maintaining controlled areas and clean rooms as defined by ~~FED-STD-209-ISO 14644-1 and ISO 14644-2~~. Cleaning procedures are described, and cleaning frequency for different classes of facility are given. Compliance with this practice will make it easier and more likely that the required level of facility cleanliness will be maintained. A cleaner facility also will help to protect flight hardware from contamination and should reduce the frequency for cleaning flight hardware. This practice does not discuss operation and operational procedures for cleanrooms and controlled areas. Other documents such as IEST-RP-CC026 and Practice E 2352 provide recommended practices for operating cleanrooms and controlled areas.

5. Cleanrooms and Clean Zones

5.1 *Airborne Particle Concentrations* —The types of cleanrooms and clean zones used in this practice are based on airflow, air filtration, and airborne particle concentration limits. The classification of airborne particle concentration limits in cleanrooms, clean zones, and controlled areas are defined in Table 1 which is based on ~~FED-STD-209-ISO 14644-1 and ISO 14644-2~~.

	<u>Airflow</u>	<u>Air Filtration</u>	<u>Typical Airborne Particle Concentration Limits Under Operational Conditions In Accordance With FED-STD-209</u>
	<u>Airflow</u>	<u>Air Filtration</u>	<u>Typical Airborne Particle Concentration Limits Under Operational Conditions In Accordance With ISO 14644-1</u>
Type I	Unidirectional, formerly known as "laminar flow"	HEPA or ULPA filtered with prefilters	Classes less than M-5.5 (Classes less than 10 000)
<u>Type I</u>	<u>Unidirectional, formerly known as "laminar flow"</u>	<u>HEPA or ULPA filtered with prefilters</u>	<u>Classes less than 7 (Classes less than 10 000 per FED-STD-209E)</u>
Type II	Nonunidirectional, formerly known as "turbulent" flow	HEPA filtered with prefilters	Classes M-5.5 to M-7 (Classes 10 000 to 283 000)
<u>Type II</u>	<u>Nonunidirectional, formerly known as "turbulent" flow</u>	<u>HEPA filtered with prefilters</u>	<u>Classes 7 to 8.5 (Classes 10 000 to 300 000 per FED-STD-209E)</u>
Type III	Nonunidirectional	without HEPA or ULPA filters but with prefilters	Classes M-6.5 to 7 (Classes 100 000 to 283 000)
<u>Type III</u>	<u>Nonunidirectional</u>	<u>without HEPA or ULPA filters but with prefilters</u>	<u>Classes 8 to 8.5 (Classes 100 000 to 300 000 per FED-STD-209E)</u>

5.2 *NVR Concentrations*—There are two categories for NVR requirements in clean areas:

5.2.1 *Category I*—Critical clean areas that require specific control and removal of molecular contaminants because of products that either are very sensitive to NVR or can not be cleaned. Quantitative NVR measurements may be required as defined in ~~IEST-STD-CC1246D and IES-RP-CC-016-A~~. NVR deposition criteria are defined in Tables 2 and 3.

5.2.2 *Category II*— Standard clean areas that do not require quantitative measurements of NVR. All aerospace clean facilities, including support shops for the fabrication of components for aerospace hardware, must limit the deposition of nonvolatile residue

TABLE 2 Product Cleanliness Levels for NVR Based on M I-EST-STD-CC1246D

NVR Level	NVR Limit ^A	
	Surface	Volume
mg/0.1 m ²	mg/L	
Surface mg/0.1 m ²	Volume mg/L	
AA5	0.00001	
AA4.7	0.00002	
AA4.3	0.00005	
AA4	0.0001	
AA3.7	0.0002	
AA3.3	0.0105	
AA3	0.001	
AA2.7	0.002	
AA2.3	0.005	
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
B	2.0	20
C	3.0	30
D	4.0	40
E	5.0	50
F	7.0	70
G	10.0	100
H	15.0	150
J	25.0	250

^A 1 mg/0.1 m² = 1 µg/cm² = 0.929 mg/ft² = 10-nm-thick uniform film (ρ = 1 g/cm³).

(NVR), also known as molecular films. The cleaning supplies recommended in this practice are selected for the minimal production of NVR.

5.2.2.1 Some clean areas require very low levels of NVR to be compatible with product cleanliness requirements. These areas require cleaning methods that will remove NVR. The user will state when Category I is required and allowable levels of NVR on surfaces, that is, NVR level in accordance with M I-EST-STD-CC1246D (µg/cm² or mg/0.1 m²). Category II is assumed unless Category I is expressly specified.

5.2.3 *NVR Verification*— Measurement of NVR in clean facilities may be done in accordance with Practice E 1234 and Test Method E 1235 or other methods that are compatible with the product requirements and types of NVR. Typical NVR compounds that are found in cleanrooms include hydrocarbons, esters, and silicones.

6. Materials Used

6.1 *Wipers, Cleanroom*, polyester or cellulose, low NVR and low particle generation.⁸

6.2 *Gloves, Cleanroom*, polyurethane, nitrile or latex.⁹

6.3 *Gloves, Cleanroom*, lint and powder free, latex.⁹

6.4 *Coveralls, Hoods, Shoe Covers*.^{10,11}

6.5 *Deionized Water*, shall have a minimum resistance of 50 000 ohms and be filtered to remove all particles greater than 30 µm in size. Total solids (both dissolved and undissolved) shall not exceed 25 ppm.

⁸ The sole sources of supply of the apparatus product known to the committee at this time are Pioneer Trionic E-194, QRP Q095, Q125, and Q145 (according to length) and 27G-2700 (conductive) and Ansell-Edmont Nitrile, Miracle Wipe 4000, ITWTexwipe Alpha Wipe, ITWTexwipe Alpha 10, ITWTexwipe/ICP TX 4012, Anticon 100, Allter AI Sorb. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,¹ which you may attend.

⁹ Any available source not packaged in pink poly or other material that can transfer molecular contaminants.

⁹ The sole sources of supply of the products known to the committee at this time are Pioneer Trionic E-194, QRP Q095, Q125, and Q145 (according to length) and 27G-2700 (conductive) and Ansell-Edmont Nitrile. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,¹ which you may attend.

¹⁰ Garments worn for maintenance should be the same type and quality as those worn by workers

¹⁰ Any available source not packaged in the cleanroom during normal operations: pink poly or other material that can transfer molecular contaminants.

¹¹ The sole source of supply of

¹¹ Garments worn for maintenance should be the apparatus known to the committee at this time is Van Waters same type and Rogers 9N9 and GAF Corp. Igepal CO-630. If you are aware of alternative suppliers, please provide this information to ASTM Headquarters. Your comments will receive careful consideration at a meeting of quality as those worn by workers in the responsible technical committee, which you may attend: cleanroom during normal operations.

TABLE 3 NVR Deposition Rates in Cleanrooms from IEST-RP-CC016.12

NVR Rate Level ^A	Maximum Average Deposition Rate Levels		
	NVR Rate Level ^B pg·m ⁻² ·s ⁻¹	mg·0.1 m ⁻² ·2 ⁻¹ or month ⁻² ·1 ⁻¹ ^C	Average Rate of Thickness Increase nm·s ⁻¹ ^D
I	0 E+00	2.4 E-04	10 ⁻
0	1.0 E+00	2.4 E-04	1.0 E-09
II	0 E+00	9.304	4.0 E-09
0.6	4.0 E+00	9.7 E-04	4.0 E-09
III	1.0 E+01	2.4 E-03	1.0 E-08
1	1.0 E+01	2.4 E-03	1.0 E-08
IV	4.0 E+01	9.7 E-03	—0 ⁻
1.6	4.0 E+01	9.7 E-03	4.0 E-08
V	1.0 E+02	2.4 E-02	1.0 E-07
2	1.0 E+02	2.4 E-02	1.0 E-07
2.6	4.0 E+02	9.7 E-02	4.0 E-07
3	1.0 E+03	2.4 E-01	1.0 E-06
3.6	4.0 E+03	9.7 E-01	4.0 E-06
4	1.0 E+04	2.4 E+00	1.0 E-05
4.6	4.0 E+04	9.7 E+00	4.0 E-05
5	1.0 E+05	2.4 E+01	1.0 E-04
5.6	4.0 E+05	9.7 E+01	4.0 E-04
6	1.0 E+06	2.4 E+02	1.0 E-03
6.6	4.0 E+06	9.7 E+02	4.0 E-03
7	1.0 E+07	2.4 E+03	1.0 E-02
7.6	4.0 E+07	9.7 E+03	4.0 E-02
8	1.0 E+08	2.4 E+04	1.0 E-01
8.6	4.0 E+08	9.7 E+04	4.0 E-01
9	1.0 E+09	2.4 E+05	1.0 E+00
9.6	4.0 E+09	9.7 E+05	4.0 E+00
10	1.0 E+10	2.4 E+06	1.0 E+01
10.6	4.0 E+10	9.7 E+06	4.0 E+01

^AM The NVR deposition rate level is the \log_{10} of the NVR deposition rate in $\text{pg}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$. It is permissible to interpolate within the table or extrapolate to larger rate levels. The precisions and accuracies of measurements and number of significant figures shall be considered when specifying rate levels and reporting data.

^BThe deposition rate in $\text{pg}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ is the baseline deposition rate. All other deposition rates are derived from this.

^CThis assumes a month to be four weeks (28 days). The deposition rate is rounded to two significant figures. The precision and accuracy for many applications allow the use of one significant figure.

^DThis deposition rate assumes the NVR has a density of 1 g/cm^3 and is uniformly distributed over the surface. A nonuniform distribution has a higher probability than a uniform distribution. Less than approximately $1 \text{ }\mu\text{g/m}^2$ or 1 nm thickness (approximately a molecular monolayer) indicates a nonuniform distribution.

6.6 *Non-Ionic Detergent*, MIL-D-16791, Type 1.¹²

6.7 *Isopropyl Alcohol (IPA)*, TT-I-735, Grade A.

6.8 *Acetone*, ACS reagent STD11 or Federal Specification O-A-51.

6.9 *Buckets*, food grade, stainless steel or polypropylene or polyethylene. Buckets with two compartments are recommended.

6.10 *Mop, synthetic sponge knit polyester head*, roller type, with corrosion resistant handle and mechanism; or knit polyester or polyvinyl acetate string mop.

6.11 *Vacuum Cleaning System*—Either a central facility with vacuum outlets in the cleanroom or a portable, HEPA-filtered, cleanroom vacuum with filters that have not been tested with DOP or other volatile aerosols.¹³

6.12 *Tacky Roll Mop*, for cleaning walls and ceiling. (**Warning**—Tacky roll mops can generate a static discharge and may be unsuitable in the presence of ESD sensitive items.)

7. Cleaning

7.1 Four types of cleaning operations are performed before clean operations can begin in cleanrooms: construction, preliminary, gross or primary, and final or precision cleaning.

¹² The sole sources of supply of the apparatus product known to the committee at this time is Hako Minuteman KX series with filtered motor cooling air are Van Waters and Nifisk GS series or Tornado Model 320; Rogers 9N9 and GAF Corp. Igepal CO-630. If you are aware of alternative suppliers, please provide this information to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

¹³ This practice is under the jurisdiction of ASTM Committee E21 on Space Simulation and the Applications of Space Technology and is the direct responsibility of Subcommittee E21.05 on Contamination.

Current edition approved Apr. 1, 2004. Published April 2004. Originally approved in 1999. Last previous edition approved in 1999 as E 2042 – 99.

7.2 A new facility must proceed through all four stages of cleaning.

7.3 If a cleanroom has been operated previously but has been shut down, has been decertified due to contamination, or is visibly dirty when observed from a distance of 2 to 3 m (6 to 9 ft) under normal room illumination, then both gross and final cleaning must be performed.

7.4 If a cleanroom that is in operation has been cleaned and meets current requirements but must be certified to a more stringent requirement then only a final cleaning is required. The final cleaning operations shall be continued until the requirements are met.

7.5 Construction/Renovation Cleaning :

7.5.1 Cleaning during the construction has been found to improve significantly the cleanliness within cleanrooms when they are placed in operation.

7.5.2 Construction shall be complete before the start of preliminary cleaning. Construction includes the installation of any utilities, sprinkler heads, penetrations, and all other permanent installations.

7.5.3 Debris and dust shall be removed frequently to prevent deterioration of room surfaces as a result of abrasion or denting and the accumulation of contaminants in areas that are inaccessible and cannot be cleaned later.

7.5.4 HVAC ducts; piping for compressed gases, process water, and other fluids; and electrical outlets shall be maintained clean, cleaned when installed, and protected from contamination and corrosion until facility cleaning is complete.

7.5.5 Installed environmental monitoring instruments, such as single-particle counters for measuring airborne particle concentrations, shall be protected during construction and cleaning operations until final cleaning is complete.

7.6 Preliminary Cleaning:

7.6.1 On completion of construction, all tools, hardware, and debris shall be removed from the cleanroom, gowning room, and other associated clean areas.

7.6.2 All clean areas shall be cleaned in unison, that is, preliminary cleaning shall be completed for all adjoining rooms before progressing to gross cleaning in any area.

7.6.3 Any debris that is too large to be removed by vacuuming shall be manually removed from the area.

7.6.4 Paint spots, grease drips, stains, and other gross contaminants shall be removed at this time.

7.6.5 Floors shall be broom cleaned.

7.6.6 All room surfaces shall be inspected for dents, scratches, damaged paint, holes, cracks, and other deterioration that may compromise the cleanliness of the room. All deterioration and damage shall be repaired before proceeding to gross cleaning.

7.7 Gross Cleaning:

7.7.1 After completion of preliminary cleaning, the HVAC system shall be operated and airflow and filter performance shall be verified.

7.7.2 The room shall be operated as a contamination controlled area during gross cleaning.

7.7.3 All personnel shall wear clean garments based on the operating requirements of the room and the cleaning operations being performed. Restrictions on personnel operations and materials shall be enforced as specified by the operating instructions for the room. Garments worn during gross cleaning shall not be used for final or precision cleaning unless the garments have been recleaned by an approved cleanroom laundry and are acceptable for use.

7.7.4 When not in use, garments will be stored in a clean, protected area such as the gowning room.

7.7.5 Cleaning shall start in the upper areas of the room and proceed from the top down, starting with ceilings, light fixtures, and cranes.

7.7.6 Cleaning shall also start in the “cleanest” areas, such as the filter bank in a horizontal flow room, and proceed toward the “dirtier” areas such as the entrance and gowning room. Begin cleaning in the back and progress towards the entry door and gowning room. Gowning rooms shall be cleaned and maintained to the same level as the cleanroom.

7.7.7 All surfaces shall be vacuumed using a house vacuum system or a HEPA filtered, portable cleanroom vacuum cleaner.

7.7.8 When vacuum cleaning is complete, all surfaces shall be wiped with cleanroom wipers, clean water, and non-ionic detergent mixed in approved buckets.

7.7.9 Sponge mops may be used on large smooth surfaces such as walls and floors. Gloves shall be worn for this operation.

7.7.10 All surfaces shall be visibly clean when inspected at no more than 2 to 3 m (6 to 9 ft) under room illumination.

7.7.11 Certification of Type II and Type III areas may start during and be completed following this cleaning operation.

7.8 Final or Precision Cleaning :

7.8.1 Cleanrooms that are to be certified at ISO Class M-5.5-(10 000) 7 (Class 10 000 per FED-STD-209E) or better will generally require one or more iterations of hand cleaning to achieve the required levels following the primary cleaning.

7.8.2 Category I (low NVR) and ISO Class M-3.5-(100) 5 (100 per FED-STD-209E) and better cleanrooms will generally require at least one complete wipe down with a solvent or hydrocarbon removing detergent solution to remove residues to the required cleanliness levels.

NOTE 1—Isopropyl alcohol, acetone, or other appropriate solvents may be used to remove residues that are difficult to remove with the cleaning solution; however, solvents should be tested on the materials of construction before use to verify compatibility to prevent degradation or damage to the surfaces. Exercise extreme care when using flammable solvents, as cleaning may generate static discharge that could possibly ignite vapors.

7.8.3 During cleaning, cleaning solutions shall be replaced when they become visibly dirty or darkened.

7.8.4 Wipers shall be repeatedly folded to expose clean surfaces and discarded or collected for laundering when they become visibly dirty.

7.8.5 For ~~ISO Class M 4.5 (1000)~~ 6 (1000 per FED-STD-209E) or better cleanrooms, a fresh wiper surface shall be used for each pass. Water shall not be allowed to drip or pool at any time to prevent uncontrolled transport of dirt.

7.8.6 Hand wiping shall be repeated except that all wiping shall be linear, moving contamination from the top down or from the center to the edge. Overlap areas during wiping. Wiping should be done with unidirectional strokes. Wiping in a circular or scrubbing motion is not permitted. Wipers may be draped over the head of a sponge mop to reach large, flat areas.

7.8.7 All surfaces shall be wiped using the specified detergent solution followed immediately (before drying) with a wipe using pure water to remove detergent residue.

7.8.8 Cleaning solutions shall not be allowed to drip or pool at any time during the cleaning process.

7.8.9 Upon completing a cleaning cycle, the room shall be operated in the at-rest condition (no activity) for at least 8 h.

7.8.10 Certification/verification measurements shall start at this time. This includes meeting the required airborne particle concentrations (in accordance with ~~FED-STD-209~~), ISO 14644-1 and ISO 14644-2), NVR deposition requirements, and other requirements specified for the cleanroom.

8. Routine Maintenance Cleaning

8.1 *Cleaning and Maintenance Plan* :

8.1.1 When a cleanroom is operational, a routine cleaning and maintenance plan shall be established. Specific routine cleaning instructions shall be generated for each cleanroom and provided to the appropriate maintenance and quality assurance organizations.

8.1.2 The cleaning plan shall be modified, as required, to reflect the operational needs of hardware being processed in the cleanroom. Cleaning during critical operations could result in damage and contamination of the hardware.

8.1.3 Table 4 shows a typical cleanroom cleaning checklist.

8.2 *Janitorial Responsibilities* —Janitorial responsibilities in cleanrooms shall include emptying and cleaning of trash receptacles, wiping of all installed facility items such as wall vents, garment racks, and ledges and cleaning of floors and equipment such as shoe cleaners.

8.3 *Nonfacility Equipment*—Nonfacility equipment is the responsibility of the using organization and shall be cleaned on a schedule that reflects the product requirements and cleanroom cleaning schedule. This includes work stands, work tables, deliverable hardware items, and ground support equipment.

NOTE 2—Because of the potential for damage and contamination of user equipment and hardware, janitorial personnel shall be instructed to avoid such items when cleaning the room.

8.4 *Facility Equipment*—The responsibility for the scheduling of routine cleaning and maintenance operations of equipment such as cranes and handling fixtures shall be mutually agreed upon by the using and facilities organizations as a part of the cleaning and maintenance plan.

8.5 *Contingency Operations*—In the event of an equipment failure or other condition that requires unplanned cleaning or maintenance operations, the user personnel and the responsible facilities and janitorial personnel shall jointly develop appropriate plans and procedures.

8.6 *Verification*— A log sheet/cleaning checklist shall be maintained for each cleanroom and facility equipment item. The log sheets shall be initialed and verified that all scheduled cleaning and maintenance procedures have been performed. Fig. 1 is an example of a cleaning checklist. The log sheets shall contain space for notes and comments. Any violations of procedures, out of

TABLE 4 Examples of Cleaning Frequencies

NOTE 1—The frequency of cleaning depends upon product cleanliness requirements and the types of operations being performed. The reference to class is based on the assumption that the cleaner the product requirement the smaller the class that is specified.

Task	Maximum Allowable Airborne Particle Concentrations in Operational Mode (Class per <u>ISO 14644-1</u> (FED-STD-209E))				
	M-3/ISO 5 (100)	M-4.5/ISO 6 (1000)	M-5.5/ISO 7 (10 000)	M-6.5/ISO 8 (100 000)	M-7/ISO 8.5 (28300 000)
Damp wipe work benches	daily	daily	daily	every other day	weekly
Vacuum floor	daily	daily	daily	daily	daily
Damp mop floor	daily	daily	every third day	weekly	weekly
Spot clean doors, walls, and so forth	daily	daily	every other day	weekly	monthly
Inspect for and remove visible contamination	daily	daily	daily	daily	daily
Empty waste receptacles	daily	daily	daily	daily	daily
Replace tacky mats ^A	daily	daily	daily	daily	every other day
Inspect and clean shoe cleaners	daily	daily	daily	daily	daily
Wash walls and ceilings ^B	weekly	monthly	every six months	annually	annually
Inspect crane	90 days	90 days	90 days	90 days	six months

^A Replace more often if dirty.

^B Do not perform when flight equipment is present unless the equipment is covered and protected.

recommendations. To prevent the risk of electric shock, shoe cleaners shall always be unplugged before cleaning. The lid shall be removed and the bag checked, if there is one, and replaced if required. The inside of the machine shall be wiped clean and any debris removed. The cover shall then be replaced and the outside wiped. Finally, the machine shall be plugged in and checked for proper operation.

8.7.3 *Trash Collection*—All trash shall be collected before the start of cleaning. Plastic liners from receptacles shall be collected by slowly folding the top of each bag closed, removing it from the container. Personnel shall be instructed to never deflate or “punch down” the bags inside the cleanroom. If debris or dust has escaped into the container, the inside of the container shall be wiped and vacuum cleaned. A new liner shall be replaced by unfolding it inside the container. The outside of the receptacle shall be wiped down. Trash bags shall be removed through the cleanroom exit door.

8.7.4 *Cleaning Solutions and Wiping Procedure*—Cleaning is typically performed with DI water or dilute IPA; although periodic wiping with a cleanroom detergent is recommended to remove residual film buildup. Dilute the detergent in accordance with vendor recommendation. The following procedure is recommended:

8.7.4.1 A two-compartment bucket should be filled with DI water in one and an appropriate cleanroom detergent in the other. Follow recommendations for detergent. Dip in detergent and squeeze dry. After wiping the mop in DI water, proceed by vacuuming or wiping (below). Change the water after wiping each ~~100-ft~~ 10 m²(100 ft²) of surface.

8.7.4.2 ~~The DI~~ DI water or cleaning detergent may be dispensed from a ~~TeFE-fluorcarbon~~ squeeze bottle for smaller surfaces such as bench tops.

8.7.5 *Wiping Procedure*:

8.7.5.1 Use wipers with low NVR in accordance with Specification E 1560 and which are nonlinting and absorbent.

8.7.5.2 Wet the cleanroom wiper and gently squeeze to remove excess water.

8.7.5.3 Fold the wiper into quarters.

8.7.5.4 Wipe in a straight line across the surface.

8.7.5.5 With each stroke, overlap the previous stroke.

8.7.5.6 Do not scrub or wipe in a circular manner to prevent the spreading of dirt.

8.7.5.7 After each stroke, refold the wiper to expose a new, clean surface.

8.7.5.8 Discard the wiper after all clean wiper surfaces have been used.

8.7.5.9 Continue wiping until all surfaces have been cleaned.

8.7.5.10 If detergent is used, perform a final wipe with IPA to remove any NVR.

8.7.5.11 Remove the bucket from the cleanroom.

8.7.5.12 Empty, clean, and dry wipe the bucket.

8.7.6 *Walls*—Walls may be cleaned, using DI water, with a tacky roll mop, a ~~damp sponge mop~~, mop head made of knit polyester or polyvinyl acetate, or a sponge mop draped with a damp cleanroom wiper. (**Warning**—A tacky roll mop can generate a significant electric charge and shall not be used near hardware sensitive to electrostatic discharges.)

8.7.7 *Horizontal Surfaces*—Clean horizontal surfaces such as benches, tables, and ledges using DI water and wipers as described in 8.7.4 and 8.7.5.

8.7.8 *Vacuum Cleaning of Floors*—Vacuuming shall be performed using either the facility vacuum cleaning system or a portable, HEPA filtered vacuum cleaner. The cleaning and maintenance plan shall include vacuum cleaning systems to assure that they are in proper working order and dirt is routinely removed from the dust bag or exhaust port. The following procedure is recommended:

8.7.8.1 Draw the vacuum head toward the worker with each stroke overlapping the previous stroke.

8.7.8.2 Lift the cleaning head and place it at the beginning of each stroke. Avoid back and forth motion which will disturb dust and push dirt from the cleaner head.

8.7.8.3 Take precautions to avoid damage to hardware from long, heavy vacuum hoses.

8.7.9 *Wet Mopping of Floors*—The following wet mopping procedure is recommended:

8.7.9.1 Use two buckets or a two compartment bucket.

8.7.9.2 Fill one with DI water and the second with the approved detergent solution.

NOTE 3—Use the precise, recommended detergent concentration. Excess detergent may leave a residue on surfaces.

8.7.9.3 Dip the mop into the detergent solution and squeeze dry for each stroke.

8.7.9.4 Puddling shall be avoided.

8.7.9.5 Rinse the mop in DI water after each stroke.

8.7.9.6 Draw the mop toward the worker with each stroke overlapping the previous stroke.

8.7.9.7 Change to clean water after every 10 m² (100 ft²) of floor area is covered or as specified in the cleaning procedure. The water shall not be allowed to become gray or visibly dirty.

8.7.10 *Frequency of Cleaning*—The frequency of cleaning depends upon the cleanliness requirements of the product being processed in the cleanroom and the types of processing operations being performed. Cleaning schedules when hardware is being processed shall be coordinated with the hardware processing operations. Table 4 shows examples of cleaning frequencies based upon the assumption that the more stringent (cleaner) hardware requirements result in smaller airborne particle concentration requirements (lower class in accordance with ~~FED-STD-209~~-ISO 14644-1).

8.7.11 *Cleaning of Janitorial Equipment* :

8.7.11.1 All janitorial equipment shall be cleaned at the end of each cleaning shift.

8.7.11.2 Equipment shall be dedicated for use in the cleanroom and shall be stored in an approved, clean location in the facility.

8.7.11.3 Cleanroom janitorial equipment shall not be used in non-cleanroom areas in the facility.

9. Personnel Control

9.1 *Training*—Personnel performing cleaning shall be trained and certified in cleanroom disciplines. Additional training shall be provided for personnel performing precision cleaning.

9.2 *Contract Personnel*—Outside contractors are sometimes employed for cleanroom janitorial services. Contractors and their personnel shall have demonstrated prior training and experience in cleanroom janitorial operations. If Category I cleaning is required, experience with NVR control and handling of hazardous solvents is necessary. If contractor personnel do not have the requisite experience, additional training shall be provided.

9.3 *Personnel Operations*:

9.3.1 Personnel operational restrictions and gowning requirements shall conform to those required for operations in the area based on the cleaning plan and special program requirements during primary, final, and routine cleaning. For example, no cleaning should be done when sensitive equipment is exposed, or during critical operations.

9.3.2 Garments shall be changed daily during primary and routine cleaning and in accordance with cleanroom operating procedures during normal operations.

10. Keywords

10.1 cleaning; cleanroom maintenance; cleanroom operations; cleanrooms; controlled areas; maintenance; precision cleaning

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