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Standard Practice for Cleaning and Maintaining Controlled Areas and Clean Rooms[1]

This standard is issued under the fixed designation E2042/E2042M; 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 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with 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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1193 Specification for Reagent Water

E1234 Practice for Handling, Transporting, and Installing Nonvolatile Residue (NVR) Sample Plates Used in Environmentally Controlled Areas for Spacecraft

E1235 Test Method for Gravimetric Determination of Nonvolatile Residue (NVR) in Environmentally Controlled Areas for Spacecraft

E1549 Specification for ESD Controlled Garments Required in Cleanrooms and Controlled Environments for Spacecraft for Non-Hazardous and Hazardous Operations

E1560 Test Method for Gravimetric Determination of Nonvolatile Residue From Cleanroom Wipers

E2352 Practice for Aerospace Cleanrooms and Associated Controlled Environments—Cleanroom Operations

F24 Test Method for Measuring and Counting Particulate Contamination on Surfaces

F25 Test Method for Sizing and Counting Airborne Particulate Contamination in Cleanrooms and Other Dust-Controlled Areas

F50 Practice for Continuous Sizing and Counting of Airborne Particles in Dust-Controlled Areas and Clean Rooms Using Instruments Capable of Detecting Single Sub-Micrometre 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 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 Program[4]

2.3 *US Federal Standards:*[5]

FED-STD-209E Airborne Particulate Cleanliness Classes in Cleanrooms and Clean Zones[6]

TT-I-735 Isopropyl Alcohol

O-A-51 Acetone[5]

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

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[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* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from Institute of Environmental Science and Technology (IEST), 5005 Newport Dr., Suite 506, Rolling Meadows, IL 60008-3841.

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

[5] Available from 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 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.

2.4 *US Department of Defense 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 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.

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/m^3 per ISO Class 8.5 for particles ≥0.5 µm and 92 500/m^3 (2620 particles/ft^3 per Class 300 000/ft^3 (FED-STD-209E) for particles ≥5.0 µm.

3.1.8 *DI water, n*—deionized water (see Specification D1193).

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

TABLE 1 Comparison of ISO 14644-1 and FED-STD-209E Cleanliness Classes

ISO Class N Nominal FS209E Class	Particle Concentrations Maximum Number of Particles per Cubic Meter / Cubic Foot of Air for Particle Sizes Equal to or Greater than the Stated Size					
	0.1 µm	0.2 µm	0.3 µm	0.5 µm	1 µm[A]	5 µm
ISO Class 1	10	2	—	—	—	—
ISO Class 2	100	24	10	4	—	—
FS209E Class 0.1	3	1	—	—	—	—
ISO Class 3	1000	237	102	35	8	—
FS209E Class 1	35	7	3	1	—	—
ISO Class 4	10 000	2370	1020	352	83	—
FS209E Class 10	350	75	30	10	2	—
ISO Class 5	100 000	23 700	10 200	3520	832	29
FS209E Class 100	3500[B]	750	300	100	24	—
ISO Class 6	1 000 000	237 000	102 000	35 200	8320	293
FS209E Class 1000	35 000[B]	7500[B]	3000[B]	1000	236	7
ISO Class 6.7[C]	—	—	—	176 000	41 700	1470
FS209E Class 5000[B]	—	—	—	5000	1180	42
ISO Class 7	—	—	—	352 000	83 200	2930
FS209E Class 10 000	—	—	—	10 000	2360	70
ISO Class 8	—	—	—	3 520 000	832 000	29 300
FS209E Class 100 000	—	—	—	100 000	23 600	700
ISO Class 8.5[C]	—	—	—	11 100 000	2 630 000	92 500
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.

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, 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 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 E2352 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 ISO 14644-1 and ISO 14644-2.

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

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-CC016. 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 (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 IEST-STD-CC1246D (µg/cm^2 or mg/0.1 m^2). 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 E1234 and Test Method E1235 or other methods that are compatible with the product requirements and types of NVR. Typical NVR

TABLE 2 Product Cleanliness Levels for NVR Based on IEST-STD-CC1246D

NVR Level	NVR Limit[A]	
	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 m^2 = 1 µg/cm^2 = 0.929 mg/ft^2 = 10-nm-thick uniform film (ρ = 1 g/cm^3).

TABLE 3 NVR Rate Levels from IEST-RP-CC016.2

NVR Rate Level[A]	Maximum Average Deposition Rate Levels		
	pg·m^{-2}·s^{-1}[B]	mg·0.1 m^{-2}·mo^{-1} or µg·cm^{-2}·mo^{-1}[C]	Average Rate of Thickness Increase nm·s^{-1}[D]
0	1.0 E+00	2.4 E-04	1.0 E-09
0.6	4.0 E+00	9.7 E-04	4.0 E-09
1	1.0 E+01	2.4 E-03	1.0 E-08
1.6	4.0 E+01	9.7 E-03	4.0 E-08
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

[A] The NVR deposition rate level is the $\log_{10}$ of the NVR deposition rate in pg·m^{-2}·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.

[B] The deposition rate in pg·m^{-2}·s^{-1} is the baseline deposition rate. All other deposition rates are derived from this.

[C] This 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.

[D] This 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 µg/m^2 or 1 nm thickness (approximately a molecular monolayer) indicates a nonuniform distribution.

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.,* see Note 1 and Note 2.

NOTE 1—Any available source not packaged in pink poly or other material that can transfer molecular contaminants.

NOTE 2—Garments worn for maintenance should be the same type and quality as those worn by workers in the cleanroom during normal operations. (See Test Method E1549 and IEST-RP-CC003.)

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.

6.6 *Non-Ionic Detergent,* MIL-D-16791, Type 1.[10]

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.

[8] The sole sources of supply of the product known to the committee at this time are Miracle Wipe 4000, ITWTexwipe Alpha Wipe, ITWTexwipe Alpha 10, ITWTexwipe/ICP TX 4012, Anticon 100, Allter Al 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] 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] The sole sources of supply of the product known to the committee at this time are Van Waters 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 the responsible technical committee, which you may attend.

6.10 *Mop,* 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.[11]

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.

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 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.

[11] The sole sources of supply of the apparatus known to the committee at this time are Hako Minuteman KX series with filtered motor cooling air and Nilfisk GS series or Tornado Model 320. 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.