

## CLASSIFICATION OF CLEANROOMS AND CLEANROOM STANDARDS

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Cleanrooms are classified by the cleanliness of their air. The method most easily understood and universally applied is the one suggested in the earlier versions (A to D) of Federal Standard 209 in which the number of particles equal to and greater than 0.5  $\mu\text{m}$  is measured in one cubic foot of air and this count is used to classify the room. The most recent 209E version has accepted a metric nomenclature.

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### Federal Standard 209

This standard was first published in 1963 in the USA and titled "Cleanroom and Work Station Requirements, Controlled Environments". It was revised in 1966 (209A), 1973 (209B), 1987 (C), 1988 (D) and 1992 (E). It is available from:

[Institute of Environmental Sciences](#)  
940 East Northwest Highway  
Mount Prospect  
Illinois, 60056  
USA  
Tel: 0101 708 255 1561  
Fax: 0101 708 255 1699  
e-mail: [Instenvsci@aol.com](mailto:Instenvsci@aol.com)

The cleanroom classifications given in the earlier 209 versions are shown in Table 2. In the new 209E the airborne concentrations in the room have been given in metric units, i.e per  $\text{m}^3$  and the classifications of the room defined as the logarithm of the airborne concentration of particles  $\geq 0.5 \mu\text{m}$

e.g. a Class M3 room has a particle limit for particles  $\geq 0.5 \mu\text{m}$  of  $1000/\text{m}^3$ . This is shown in Table 3.

**Table 2 Federal Standard 209D Class Limits**

CLASS	MEASURED PARTICLE SIZE (MICROMETERS)				
	0.1	0.2	0.3	0.5	5.0

1	35	7.5	3	1	NA
10	350	75	30	10	NA
100	NA	750	300	100	NA
1,000	NA	NA	NA	1,000	7
10,000	NA	NA	NA	10,000	70
100,000	NA	NA	NA	100,000	700

**Table 3 Federal Standard 209E Airborne Particulate Cleanliness Classes**

Class Name		Class Limits									
		0.1m m		0.2m m		0.3m m		0.5m m		5m m	
		Volume Units		Volume Units		Volume Units		Volume Units		Volume Units	
SI	English	(m <sup>3</sup> )	(ft <sup>3</sup> )	(m <sup>3</sup> )	(ft <sup>3</sup> )	(m <sup>3</sup> )	(ft <sup>3</sup> )	(m <sup>3</sup> )	(ft <sup>3</sup> )	(m <sup>3</sup> )	(ft <sup>3</sup> )
M 1		350	9.91	75.7	2.14	30.9	0.875	10.0	0.283	--	--
M 1.5	1	1 240	35.0	265	7.50	106	3.00	35.3	1.00	--	--
M 2		3 500	99.1	757	21.4	309	8.75	100	2.83	--	--
M 2.5	10	12 400	350	2 650	75.0	1 060	30.0	353	10.0	--	--
M 3		35 000	991	7 570	214	3 090	87.5	1 000	28.3	--	--
M 3.5	100	--	--	26 500	750	10 600	300	3 530	100	--	--
M 4		--	--	75 700	2 140	30 900	875	10 000	283	--	--
M 4.5	1 000	--	--	--	--	--	--	35 300	1 000	247	7.00
M 5		--	--	--	--	--	--	100 000	2 830	618	17.5
M 5.5	10 000	--	--	--	--	--	--	353 000	10 000	2 470	70.0
M 6		--	--	--	--	--	--	1 000 000	28 300	6 180	175
M 6.5	100 000	--	--	--	--	--	--	3 350 000	100 000	24 700	700
M 7		--	--	--	--	--	--	10 000 000	283 000	61 800	1 750

With a little thought it can be appreciated that the airborne contamination level of a given cleanroom is dependent on the particle generating activities going on in the room. If a room is empty, a very low particle concentration can be achieved, this closely reflects the quality of air supplied by the high efficiency filter. If the room has production equipment in it and operating, there will be a greater particle concentration but the greatest concentrations will occur when the room is in full production. The classification of the room according to FS 209D may therefore be carried out when the room is:

(a) as built, ie complete and ready for operation, with all services connected and functional but without production equipment or operating personnel.

(b) at rest, ie complete, with all services functioning and with equipment installed and operable or operating, as specified but without personnel in the facility.

(c) operational, ie in normal operation, with all services functioning and with equipment and personnel, if applicable, present and performing their normal work functions in the facility.

Federal Standard 209 is a document which mainly gives information on the airborne particle limits that are required to specify the airborne quality of cleanrooms and also gives the methods used to check what concentrations are present. It does not give any information on how a cleanroom should be operated. This information had been included in a series of Recommended Practices which are written by the same Institute as has written the Federal Standard 209, namely the Institute of Environmental Sciences. Some of the RP's which are of particular interest to those who test and run cleanrooms are discussed later in this document.

### **British Standard 5295:1989**

This standard is available from:

B S I Standards  
389 Chiswick High Road  
London W44 AL  
Tel 0181 996 9000  
Fax 0181 996 7400

The British Standard is in five parts. These are:

**Part 0** - General introduction and terms and definitions for cleanrooms and clean air devices. (4 pages)

**Part 1** - Specification for cleanrooms and clean air devices. (14 pages)

**Part 2** - Method for specifying the design, construction and commissioning of cleanroom and clean air devices. (14 pages)

**Part 3** - Guide to operational procedures and disciplines applicable to cleanrooms and clean air devices. (6 pages)

**Part 4** - Specification for monitoring cleanrooms and clean air devices to prove continued compliance with BS 5295. (10 pages)

The contents of the above parts are as follows:

**Part 0 - 'General introduction, terms and definitions for cleanrooms and clean air devices'**

The definitions have been drawn together and presented in this section. This part also provides a basic introduction to the main parts of the standard, particularly for those unfamiliar with cleanrooms or the standard itself.

**Part 1 - 'Specification for cleanrooms and clean air devices'**

The Standard contains ten classes of environmental cleanliness. Shown in Table 4 are the classes given in the standard. All classes have particle counts specified for at least two particle size ranges to provide adequate confidence over the range of particle size relevant to each class.

Some classes of rooms, except for 0.3 m m particles, have an identical specification. For example, Class F is equivalent to Class E except for the 0.3 m m particle specification. This is deliberate, as many users, e.g. pharmaceutical manufacturing, do not wish to be associated with the small particle technology that is not appropriate to their industry.

**Table 4 BS 5295 Environmental cleanliness classes**

Class of environmental cleanliness	Maximum permitted number of particles per m <sup>3</sup> (equal to, or greater than, stated size)					Maximum floor area per sampling position for cleanrooms (m <sup>2</sup> )	Minimum pressure difference*	
	0.3 m m	0.5 m m	5 m m	10 m m	25 m m		Between classified areas and unclassified areas (Pa)	Between classified area and adjacent areas of lower classification (Pa)
C	100	35	0	NS	NS	10	15	10
D	1 000	350	0	NS	NS	10	15	10
E	10 000	3 500	0	NS	NS	10	15	10
F	NS	3 500	0	NS	NS	25	15	10
G	100 000	35 000	200	0	NS	25	15	10
H	NS	35 000	200	0	NS	25	15	10
J	NS	350 000	2 000	450	0	25	15	10
K	NS	3 500 000	20 000	4 500	500	50	15	10
L	NS	NS	200 000	45 000	5 000	50	10	10
M	NS	NS	NS	450 000	50 000	50	10	NA

BS 5295:1989 identifies three states of operation similar to FS208E:

- as built - on completion, prior to moving in
- unmanned - operational but not in use
- manned - in full operational use
- Also given in the specification of Part 1 are other requirements for cleanrooms to comply with. These are:
  - minimum pressure difference between the cleanroom and adjacent areas (see Table 4)
  - filter installation test leakage
  - freedom of leakage from construction joints or openings

Testing to satisfy the requirements of Part 1 of the British Standard is discussed later in this document in that section which deals with the testing and validation of cleanrooms.

### ***Part 2 - 'Method for specifying the design, construction and commissioning of cleanrooms and clean air devices'***

A major consideration in the rewrite of BS 5295 was to ensure its usefulness as a purchase and operational specification and as supporting documentation to a contract. Part 2 has therefore been restructured into a format which enables a purchaser to specify what type of room or device is required and, where relevant, how it is to be achieved. To assist with its use as part of contractual documentation it has been given specification status, i.e. it is mandatory.

### ***Part 3 - 'Guide to operational procedures and disciplines applicable to cleanroom and clean air devices'***

This incorporates guidance for those drawing up procedures for personnel, operations, cleaning, garments and garment laundering.

### ***Part 4 - 'Specification for monitoring cleanrooms and clean air devices to prove continued compliance with BS 5295: Part 1'***

Cleanroom and clean air equipment standards have for many years defined classes of cleanliness and how they are to be assessed. However there has never been any requirement to test a cleanroom at any point in its often very long lifetime, other than at the time of handover from supplier to purchaser. Once accepted from the supplier, the facility then repaid its capital cost, over a life span of ten to twenty years, sometimes without ever being tested. Yet over this period customers were provided with products which were stated to be 'produced under Class X'. This can no longer be the case.

The tests specified are those contained in Part 1, thus providing a continuity back to the original purchase specification. The intervals between tests are related to the class of room or device and are given later in this manual in that section relating to the validation and testing of cleanrooms.

## ***ISO Standard***

Because of the large number of cleanroom standards produced by individual countries it is very desirable that one world-wide standard of cleanroom classification is produced. The International Standards Organisation is producing such a document. Because of the number of countries involved and the problems with translation it may be over a year before it is published. However, it is unlikely that it will be different from table 5.

**Table 5. Selected ISO 209 airborne particulate cleanliness classes for cleanrooms and clean zones.**

numbers (N)	Maximum concentration limits (particles/m <sup>3</sup> of air) for particles equal to and larger than the considered sizes shown below					
	0.1m m	0.2m m	0.3m m	0.5m m	1m m	5.0m m
ISO 1	10	2				
ISO 2	100	24	10	4		
ISO 3	1 000	237	102	35	8	
ISO 4	10 000	2 370	1 020	352	83	
ISO 5	100 000	23 700	10 200	3 520	832	29
ISO 6	1 000 000	237 000	102 000	35 200	8 320	293
ISO 7				352 000	83 200	2 930
ISO 8				3 520 000	832 000	29 300
ISO 9				35 200 000	8 320 000	293 000

The table is derived from the following formula:

$$C_n = 10^N \times \left[ \frac{0.1}{D} \right]^{2.08}$$

where:

C<sub>n</sub> represents the maximum permitted concentration ( in particles/m<sup>3</sup> of air ) of airborne particles that are equal to or larger than the considered particle size. C<sub>n</sub> is rounded to the nearest whole number.

N is the ISO classification number, which shall not exceed the value of 9. Intermediate ISO classification numbers may be specified, with 0.1 the smallest permitted increment of N.

D is the considered particle size in m m.

0.1 is a constant with a dimension of m m.

Table 5 shows a crossover to the old FS 209 classes e.g. ISO 5 is equivalent to the old FS 209 Class 100.

The standard also gives a method by which the performance of a cleanroom may be verified i.e. sampling locations, sample volume etc.. These are similar to FS 209. It also includes a method for specifying a room using particles outside the size range given in the table 5. Smaller particles (ultra fine) will be of particular use to the semiconductor industry and the large ( $\geq 5\text{ m m}$  macro particles) will be of use in industries such as parts of the medical device industry, where small particles are of no practical importance. Fibres can also be used. The method employed with macro particles is to use the format:

'M(a; b);c'

where

a is the maximum permitted concentration/ $\text{m}^3$

b is the equivalent diameter.

c is the specified measurement method.

An example would be

'M(1 000; 10m m to 20m m); cascade impactor followed by microscopic sizing and counting'.

### ***Pharmaceutical Cleanroom Classification***

The most recent set of standards for Europe has come into operation on the 1 January 1997. This is contained in a 'Revision of the Annexe to the EU Guide to Good Manufacturing Practice-Manufacture of Sterile Medicinal Products'.

The following is an extract of the information in the standard that is relevant to the design of cleanrooms:

*'General*

*The manufacture of sterile products should be carried out in clean areas, entry to which should be through airlocks for personnel and/or for equipment and materials. Clean areas should be maintained to an appropriate cleanliness standard and supplied with air which has passed through filters of an appropriate efficiency.*

*The various operations of component preparation, product preparation and filling should be carried out in separate areas within the clean area. Manufacturing operations are divided into two categories; firstly those where the product is terminally sterilised, and secondly those which are conducted aseptically at some or all stages.*

Clean areas for the manufacture of sterile products are classified according to the required characteristics of the environment. Each manufacturing operation required an appropriate environmental cleanliness level in the operational state in order to minimise the risks of particulate or microbial contamination of the product or materials being handled.

In order to meet "in operation" conditions these areas should be designed to reach certain specified air-cleanliness levels in the "at rest" occupancy state. The "at-rest" state is the condition where the installation is complete with production equipment installed and operating but with no operating personnel present. The "in operation" state is the condition where the installation is functioning in the defined operating mode with the specified number of personnel working.

For the manufacture of sterile medicinal products normally 4 grades can be distinguished.

Grade A: The local zone for high risk operations, e.g. filling zone, stopper bowls, open ampoules and vials, making aseptic connections. Normally such conditions are provided by a laminar air flow work station. Laminar air flow systems should provide an homogeneous air speed of 0.45 m/s +/- 20% (guidance value) at the working position.

Grade B: In case of aseptic preparation and filling, the background environment for grade A zone.

Grades C and D: Clean areas for carrying out less critical stages in the manufacture of sterile products.

The airborne particulate classification for these grades is given in the following table.

	maximum permitted number of particles/m <sup>3</sup> equal to or above			
Grade	at rest (b)		in operation	
	0,5m m	5m m	0,5m m	0,5m
A	3 500	0	3 500	0
B(a)	3 500	0	350 000	2 000
C(a)	350 000	2 000	3 500 000	20000
D(a)	3 500 000	20 000	not defined (c)	not defined (c)

Notes:

(a) In order to reach the B, C and D air grades, the number of air changes should be related to the size of the room and the equipment and personnel present in the room. The air system should be provided with appropriate filters such as HEPA for grades A, B and C.

(b) The guidance given for the maximum permitted number of particles in the "at rest" condition corresponds approximately to the US Federal Standard 209E and the ISO classifications as follows: grades A and B correspond with class 100, M 3.5, ISO 5; grade C with class 10 000, M 5.5, ISO 7 and grade D with class 100 000, M 6.5, ISO 8.

(c) The requirement and limit for this area will depend on the nature of the operations carried out.

Examples of operations to be carried out in the various grades are given in the table below. (see also par. 11 and 12).

<b>Grade</b>	<b>Examples of operations for terminally sterilised products. (see par. 11)</b>
A	Filling of products, when unusually at risk.
C	Preparation of solutions, when unusually at risk. Filling of products.
D	Preparation of solutions and components for subsequent filling.
<b>Grade</b>	<b>Examples of operations for aseptic preparations. (see par. 12)</b>
A	Aseptic preparation and filling.
C	Preparation of solutions to be filtered.
D	Handling of components after washing.

The particulate conditions given in the table for the "at rest" state should be achieved in the unmanned state after a short "clean up" period of 15-20 minutes (guidance value), after completion of operations. The particulate conditions for grade A in operation given in the table should be maintained in the zone immediately surrounding the product whenever the product or open container is exposed to the environment. It is accepted that it may not always be possible to demonstrate conformity with particulate standards at the point of fill when filling is in progress, due to the generation of particles or droplets from the product itself.

Additional microbiological monitoring is also required outside production operations, e.g. after validation of systems, cleaning and sanitisation.

<i>Recommended limits for microbial contamination (a)</i>				
<i>GRADE</i>	<i>air sample cfu/m<sup>3</sup></i>	<i>settle plates (dia. 90 mm), cfu/4 hours(b)</i>	<i>contact plates (dia.55 mm), cfu/plate</i>	<i>glove print. 5 fingers.cfu/glove</i>
<i>A</i>	<i>&lt; 1</i>	<i>&lt; 1</i>	<i>&lt; 1</i>	<i>&lt; 1</i>
<i>B</i>	<i>10</i>	<i>5</i>	<i>5</i>	<i>5</i>
<i>C</i>	<i>100</i>	<i>50</i>	<i>25</i>	<i>-</i>
<i>D</i>	<i>200</i>	<i>100</i>	<i>50</i>	<i>-</i>

Notes:

(a) *These are average values.*

(b) *Individual settle plates may be exposed for less than 4 hours.*

(c) *Appropriate alert and action limits should be set for the results of particulate and microbiological monitoring. If these limits are exceeded operating procedures should prescribe corrective action.*

**Isolator and Blow Fill Technology** (extract only)

*The air classification required for the background environment depends on the design of the isolator and its application. It should be controlled and for aseptic processing be at least grade D.*

*Blow/fill/seal equipment used for aseptic production which is fitted with an effective grade A air shower may be installed in at least a grade C environment, provided that grade A/B clothing is used. The environment should comply with the viable and non viable limits at rest and the viable limit only when in operation. Blow/fill/seal equipment used for the production of products for terminal sterilisation should be installed in at least a grade D environment.*

**Terminally sterilised products**

*Preparation of components and most products should be done in at least a grade D environment in order to give low risk of microbial and particulate contamination, suitable for*



	1	M1.5	C	0.035	-	1	3
	10	M2.5	D	0.35	-	2	4
	100	M3.5	E or F	3.5	4 000	3	5
	1 000	M4.5	G or H	35	-	4	6
	10 000	M5.5	J	350	400 000	5	7
	100 000	M6.5	K	3500	4 000 000	6	8

*The above information on cleanroom standards have been extracted from the handbook 'Cleanroom Technology' written by Bill Whyte.*