

Information

Information

General information

Introduction to Cleanroom

The term “Cleanroom” is something you associate with in modern industries. However, the root of cleanroom design goes back more than a century. Think of the need to control contamination in hospitals and you would be able to imagine the first cleanroom.

It can be seen that the requirement for cleanroom can be broadly divided into two areas:

- That in which inanimate particles are a problem and where their presence may prevent a product functioning or reduce its useful life.
- To ensure the absence of microbe carrying particles whose growth could lead to human infection.

Definition of cleanroom

It is clear that a cleanroom is a room that is clean. However, a cleanroom now has a special meaning and it is defined in ISO 146441 as:

“A room in which the concentration of airborne particles is controlled and which contains one or more clean zones.”

And in ISO 14644-1 as:

“A room in which the concentration of airborne particles is controlled, and which is constructed and used in a manner to minimise the introduction, generation and retention of particles inside the room and in which other relevant particles inside the room and in which other relevant parameters e.g. temperature, humidity and pressure, are controlled as necessary.”

Classification of cleanroom

Cleanroom are classified by the cleanliness of their air. The method most easily understood and universally applied is the one suggested in versions of Federal Standard 209 up to edition “D”.

The Federal Standard FS 209D

Table shows the simplified classification of Cleanroom Class according to the older Federal Standard 209D. This standard has now been superseded by the metric version; Federal Standard 209E which was published in 1992. The basic unit of measurement within a cleanroom is a micron (µm) which is one millionth of a metre.

To classify cleanroom, the number of particles equal to and greater than 0.5 µm is measured in one cubic foot of air and this count is used to identify the Cleanroom Class.

However, because of the simplicity and universal usage of the Federal Standard 209D, it is unlikely to be forgotten or removed. It is also likely that the Federal Standard 209E will supersede it but by the new International Standard Organisation’s (ISO) standard ISO 14644-1.

Cleanroom for different industries

The required standard of cleanliness of a room is dependent on the task performed in it; the more susceptible the product is to contamination, the better the standard.

How small is a sub micro particle?

Objects	Approximate Size [µm]
Human hair	100
Rubbing or abrading an ordinary painted surface	90
Sliding metal surfaces (non-lubricated)	75
Crumpling or folding paper	65
Rubbing an epoxy painted surface	40
Belt drive (Conveyor)	30
Dust	25
Writing with ball pen on ordinary paper	20
Abrading of the skin	04
Oil smoke particles	0.1

The Federal Standard FS 209D

Class	Measured Particle Size [µm]				
	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
1000	NA	NA	NA	1000	7
10000	NA	NA	NA	10000	70
100000	NA	NA	NA	100000	7000

The possible cleanroom requirements for various tasks

ISO Class (FS 209E)	Tasks
ISO Class 3 (Class 1)	Integrated circuit manufacturers manufacturing sub-micron geometries only use these rooms.
ISO Class 4 (Class 10)	Semiconductor manufacturers producing integrated circuits with line widths below 2 µm use these rooms.
ISO Class 5 (Class 100)	Used with a bacteria-free or particulate-free environment is required in the manufacture of aseptically produced injectable medicines. Required for implant or transplant surgical operations.
ISO Class 6 (Class 1000)	Manufacture of high quality optical equipment. Assembly and testing of precision gyroscopes. Assembly and testing of precision gyroscopes. Assembly of miniaturised bearings.
ISO Class 7 (Class 10000)	Assembly of precision of hydraulic or pneumatic equipment, servo-control valves, precision timing devices, high grade gearing.
ISO Class 8 (Class 100000)	General optical work, assembly of electronic components, hydraulic and pneumatic assembly.

Information

General information

International standard of cleanroom

Introduction

The Federal Standard 209E have long been the only definition of cleanroom classification available from a standard organisation. It is from the U.S. General Service Administration and approved for use by all U.S. Agencies. In the absence of an international standard, FS 209E was broadly used internationally.

The need for a new international standard that covered more cleanroom environmental parameters and practices led to the formation of a technical committee of the International Standards Organisation. The technical committee is named TC 209 Cleanroom and Associated Controlled Environments.

The goal of TC 209 is standardization of equipment, facilities and operational methods for cleanroom and associated controlled environments. This includes procedural limits and testing procedures to achieve desired attributes to minimise micro contamination.”

The ISO committee will produce 11 new standards documents that relate to cleanroom or clean zones.

Cleanroom standard adopted by different countries

Some countries completely adopted FS 209, while others made their own national version, similar to FS 209. Some made minor changes of the classes to comply with the metric system, but all changed the denomination of the classes.

Because of the different naming of the classes in different countries, care must be taken not to mix up the standards.

Some major national standards exist today:

- British standard: BS5295
- Japanese standard: JIS B 9920
- Australian standard: AS 1386
- French standard: AFNOR X 44101
- Dutch standard: VCCN-RL-1
- Russian standard: GOST R50766-95

Germany standard: VDI2083

The German Engineering Association, known as VDI, has published the VDI 2083 as "Cleanroom engineering" guideline, for the first time in 1976. The various tasks and measures associated with cleanroom technology are described the VDI guideline series VDI 2083.

This guideline, which was

developed just recently, is the only guideline, which can be used for the classification of operating materials. The aim of this guideline is to provide a standardized procedure for qualifying or comparing operating materials with regards to their airborne particle emission.

FESTO is applying this guideline for the particle emission tests it conducts.

The table shows major national standards exist today.

Country	Standard	Year	Description
Australia	AS 1386	1989	Cleanroom and clean work stations
France	AFNOR X44101	1981	Definition of cleanroom levels
Germany	VDI 2083.3	1993	Contamination control measuring technique for clean air rooms
Holland	VCCN 1	1992	Dust and micro-organism classification of air
Japan	JIS-B-9920	1989	Measuring methods for airborne particles in cleanroom and evaluating methods, etc.
Russia	Gost-R 50766	1995	Cleanroom classification, General requirements
UK	BS 5295	1989	Environmental cleanliness in enclosed spaces
US	FS 209E	1992	Airborne particulate cleanliness classes in cleanroom and clean zones

A comparison of major engineering cleanroom classes in the world

USA 209E 1992	ISO 14644-1 1997	Japan B 9920 1989	France X44101 1981	Germany VDI 2083 1990	UK BS 5295 1989	Australia AS 1386 1989
	ISO Class 1	1				
	ISO Class 2	2		0		
1	ISO Class 3	3		1	C	0.035
10	ISO Class 4	4		2	D	0.35
100	ISO Class 5	5	4000	3	E,F	3.5
1000	ISO Class 6	6	-	4	G,H	35
10000	ISO Class 7	7	400000	5	J	350
100000	ISO Class 8	8	4000000	6	K	3500
	ISO Class 9			7	L	

Information

General information

International standard for cleanroom

Introduction

After 40 years, the FS 209E has been officially retired. This paves the way for worldwide harmonisation promised by the new cleanroom protocols from the International Organisation for Standardisation (ISO). The Institute of Environmental Sciences and Technology (IEST) submitted a request to retire the federal standard and it was approved. The Federal Standard 209E was officially retired by the US Government on 29 November 2001.

Basically, the quality of air in a cleanroom has not changed, what has changed is the measuring system. ISO standards use only the metric system. Almost all countries now use the new ISO 14644 standard.

ISO classification 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. ISO has set up a technical committee (TC 209) and will produce 10 new standards documents that relate to cleanroom or clean zones. The first two standards have been published: ISO 14644-1 and -2.

ISO 14644-1 classification of air cleanliness

Cleanliness class designations and quantity have changed from FS 209E. Along with the obvious change to metric measure of air volume, ISO 14644-1 adds three additional classes – two cleaner than Class 10 and one dirtier than Class 100,000.

ISO 14644-2 cleanroom testing for compliance

ISO 14644-2 determines the type and frequency of testing required conforming to the standard. Table 2.12 indicates which tests are mandatory and Table 2.13 indicates which tests are optional.

Summary of FS 209E and ISO 14644-1 and -2

The cleanliness classification levels defined by FS 209E and ISO 14644-1 are approximately equal, except the new ISO standard uses new class designations, a metric measure of air volume and adds three additional classes – two cleaner than Class 10 and one dirtier than Class 100,000. The second new ISO standard, ISO 14644-2, gives requirements for monitoring a cleanroom or clean zone to provide evidence of its continued compliance

ISO 14644-1

Airborne Particulate Cleanliness Classes ISO 14644-1						
Class	Number of Particles per Cubic Meter by Micrometer Size					
	0.1 µm	0.2 µm	0.3 µm	0.5 µm	1 µm	5 µm
ISO 1	10	2				
ISO 2	100	24	10	4		
ISO 3	1000	237	102	35	8	
ISO 4	10000	2370	1020	352	83	
ISO 5	100000	23700	10200	3520	832	29
ISO 6	1000000	237000	102000	35200	8320	293
ISO 7				352000	83200	2930
ISO 8				3520000	832000	29300
ISO 9				35200000	8320000	293000

ISO 14644-2

Schedule of Tests to Demonstrate Continuing Compliance			
Test Parameter	Class	Maximum Time Interval	Test Procedure
Particle Count Test	≤ ISO 5	6 months	ISO 14644-1 Annex A
	≥ ISO 5	12 months	
Air Pressure Test	All Classes	12 months	ISO 14644-1 Annex B5
Air Flow	All Classes	12 months	ISO 14644-1 Annex B4

Table compares the FS 209E to the new ISO 14644-1 classifications.

ISO 14644-1	FED STD 209E	
ISO Class	English	Metric
1	-	-
2	-	-
3	1	M1.5
4	10	M2.5
5	100	M3.5
6	1000	M4.5
7	10000	M5.5
8	100000	M6.5
9	-	-

Information

General Information

Basic principles for designing cleanroom equipment

Introduction

The design of cleanroom equipment plays an important role in cleanroom technology. It would be wasteful to design a state-of-the-art cleanroom and do not place any importance on the equipment used in the cleanroom. When designing cleanroom equipment, care must be taken right from the initial stage.

Using pneumatic cylinder in cleanroom

When you lower the piston speed, the particle count will greatly reduce as the impact at the end position is reduced.

To help reduce the impact, cylinders with cushioning will significantly help in the reduction of particles generated.

When there is a need to have end position stopping, do not use rubber stoppers, use shock absorbers as they generate lesser particles.

Using rotary moving elements

Whenever possible rotary movements should be employed, as lesser particles are generated by rotary moving elements. Furthermore, it is easier to seal rotating elements from the clean environment.

Minimising sliding friction

The design should minimise sliding friction. Do not use sliding tracks, it is better if you could use roller tracking. Lip sealing is also not allowed and tries to avoid unnecessary functional contact.

Principle of arranging task integration

Reduce the number of components used to a minimum, if possible make use of single components which can assume several functions.

Analysing ways of gripping products

If you need to use a gripper in the production, avoid gripping in the same direction as the direction of the first airflow. Keep the product contact to a minimum either by the equipment or the operator.

If you grip either from the side or from beneath the product, the gripper does not affect the airflow around the product and the airflow obstruction caused by the gripper is kept to a minimum.

If the gripper can only be used above the product, then keep moving elements next to the product and select the shape of the gripper and its distance away from the product in such a way that stagnant areas do not reach the product

Choice of materials / surface finish

With regard to the choice of materials, the following are recommended:

- Use materials with low electrostatic charge properties
- Combination of materials: plastic - metal: avoid insulated partial systems
- Surfaces should be smooth where possible, no sharp edges
- Easier to clean, minimising influence on airflow
- In semiconductor industry:
- No moving elements made of copper or brass
- Better: special steel, aluminium

Secondary measures and alternatives

The following are some additional guidelines, which should be considered:

- Encapsulating components

- All moving parts enclosed
- Vacuum Suction
- Accurately aimed local airflow direction

Unconventional sources of contamination

In addition to dust and other particles, surface contamination can be any one of the following – reaction layers of chemical compounds, absorbed layers of mostly hydrocarbons and moisture, or variable composition contaminants due to preferential diffusion of one component through a substrate.

ESD behavior of operating materials

ESD stands for Electrostatic Discharge. It is the rapid transfer from static charged bodies of materials to or from Electrostatic Discharge Sensitive Electronic Devices.

Virtually all electronic devices are ESD sensitive; the sensitivity is based on product and design. ESD occurs when charge is generated, stored on an object and rapidly transferred.

Materials become charged via:

- First air flowing onto them
 - Friction from other materials
 - Particles generated are not removed by the first air flow
 - Contamination adheres to charged materials
 - Formation of larger agglomerates
 - Sporadic, intermittent detachment of very large forms of contamination
- ESD is harmful to the system and must be removed. Recommended ways of removing of electrostatic charges are:

Magnetic influences

When handling components, which are subject to magnetic influences, care must be taken to ensure that they are shielded from the electromagnetic effects.

Another option would be keeping critical products away from Electric motors, permanent magnets, coils and electromagnetic fields.

Properties of materials

The properties of the materials used in the equipment affects the level of contamination. If the wrong choice were made there would be more particles emitted and would greatly affect the cleanroom.

Take note of the following points when choosing the right material: Know the emission of particles from the material in use

- Constantly
- Sporadically
- Which size of particle, critical/uncritical?
- Which combinations of materials emit particles
- Know the life span of material
- Correlation between the wear and tear of materials used and tool life

Outgassing

When the equipment is under extremes of temperature, there is the likely occurrence of "Outgassing" which is simply the release of gases or volatile substances from a material other than a change of state of the material.

Make sure that the emission levels of volatile substances do not exceed limits. They must not be harmful to either the product or the personnel working the area. The materials chosen must pass tests at extremes of temperature.

Information

General Information

Qualifying equipment for cleanroom used

Qualification tests are carried out to assess the cleanroom suitability of operating materials that include equipment.

It is very important to note here that “No operating material may be allocated to a cleanroom class”. It is therefore wrong to say that “Our product has the Cleanroom ISO Class 3”

The reasons are:

- Cleanroom classes were drawn up only for the acceptance and classification of cleanroom.
- Operating materials do not fulfil these fundamental conditions.
- Missing of specifications for the classification of operating materials.
- Correlation of cleanroom classification / air volume
 - Air volume
 - Defined degree of cleanliness per volume of air
- Procedures for classification standards are related to cleanroom

Moreover we could not just transfer the cleanroom classifications to operating materials, because these are standards based on degree of cleanliness per volume of air and not for qualifying equipment used in the cleanroom.

It is important to note that the Federal Standard and ISO standard does not cover this area. VDI 2083 Part 8 "Cleanroom suitability of equipment", which was developed just recently, is the only guideline, which can be used for the classification of operating materials.

This guideline is applicable to operating materials which are introduced into a cleanroom. The aim of this guideline is to provide a standardized procedure for qualifying or comparing operating materials with regards to their airborne particle emission.

FESTO is applying this guideline for the particle emission tests it conducts on all Festo cleanroom products.

Introduction of VDI2083 Part 8

Operating materials are often responsible for contaminating the production environment in cleanroom. An operating material does not process a cleanliness class, rather only a suitability for use in cleanroom classes. This means that an operating material may only be assessed with respect to its use in cleanroom with a defined level of particle cleanliness of the air.

The design, construction and operation of an operating material (geometry and dynamics) should be selected in such a way that airflow patterns in the cleanroom environment are affected as little as possible. This can also be checked by performing airflow visualization tests.

The standardized assessment of airborne particle emission, supported by a statistical analysis of the results, should enable a comparison and assessment of operating materials. This should lend transparency to the assessment of operating materials concerning their suitability for use in cleanroom.

Cleanroom suitability

Cleanroom suitability assesses the suitability of an operating material for use in cleanroom which have been specified in accordance with a regulating body for assessing air cleanliness. The classification criterion in this instance is the emission of particles from the operating material.

Measurement technology

Only optical particle counters (OPC) have been used in this guideline for measuring airborne particles. Further information concerning the use, handling and method of function of OPC's can be found in the guidelines VDI 3489 Part 3 and VDI 2083 Part 3.

Procedure

The highest concentration of particulate contamination emitted from the operating material into the system or product space is measured. The size distribution of particles emitted from the operating material being assessed for its cleanroom suitability may vary considerably. As the distribution characteristics of each operating material are not always known, it does not suffice to investigate only one range of particle size. Therefore, at least three representative particle size ranges are to be selected. These must be as distant from one another as possible.

The concentration measured is then compared with the limiting values given by the regulating body concerned with air cleanliness and thus an assessment made of suitability for use in a specific air cleanliness class defined by that regulating body.

The procedure for carrying out cleanroom suitability tests in accordance with regulating bodies for assessing air cleanliness may be summarized as follows:

- Specification of operating parameters;
- Localization of particle sources;
- Classification measurements;
- Statistical analysis;
- Classification of the operating material

Measurement classification

The parameters required for the classification measurements are either prescribed or have been ascertained from the measurements taken beforehand:

- Typical operating conditions of the operating material during the measurement procedure;
- Measuring points on the operating material;
- Positions of the OPC sampling probe at the operating material measuring points.

Statistical analysis

The suitability of an operating material for a given cleanroom class is determined using a statistical method. For this, all particle size ranges measured must be taken into consideration. In order to obtain significant data for all the statistical observations to be carried out, there must be a random distribution of particles in the air.

Information

General Information

Measurement of airborne particle in cleanroom

One of the major sources of contamination is operating materials. Contamination caused by operating materials can be either:

- Chemical
- Physical
- Biological
- Radiological
- Ionic

Particle contamination falls under the umbrella of physical contamination. Particles is caused by:

- When leakage from the pneumatic components will lead to particle contamination. The air, which leaks, might bring along particles with it.
- When operating materials come into contact with one another, there is bound to be abrasion, make sure that the abrasion is to a minimum as particles are generated.
- When the pneumatic components move from end to end, there tend to be knocking at the end position, this will lead to minor vibration and also cause particles to be released.

The optical particle counter OPC

It is a microprocessor-based instrument that detects airborne particles, analyses and stores the data in eight size classes, and produces reports. It displays real time data on a CRT and contains a printer, which can be used to produce hard copies of reports.

During the airborne particle emission measurements, the operating parameters of the optical particle counter are set as follows:

- Air volume : 1.0 cfm
- Sampling time : 60 seconds
- Delay time : 1 second
- Measurement time : 5 minutes

Measuring the test environment

In order to get correct particle count results, the test environment, in which the tests are carried out should have little or no influence on the particle measurements. The parameters, which influence the particle count, are the particle count in the:

- Environment
- Air velocity
- Degree of turbulence
- Relative humidity

The purpose of measuring the test environment is to determine whether the given environment is suitable for particle measurement.

Therefore, the 'ground contamination level' of the test environment has to be measured for the cleanroom as well as the Mini-environment (MENV). The lower the "ground contamination level", the more accurate the particle measurements will be.

Zero the count measurement

Before any test is done, a zero-count measurement is made. When doing a zero-count measurement, it is a functional test. For this test, a zero-filter is attached to the OPC and the counter takes measurement for about 3 minutes. The reading obtained should be zero. Then the environment is ready for use.

Base Measurement of Airborne Particulate in MENV

Similar to the zero-count measurement, which is used for the OPC, the base measurement is used for the Mini-environment.

VTH Measurement

Three major environment parameters:

- Air velocity (V)
 - Air Temperature (T)
 - Relative Humidity (H)
- are measured in the cleanroom and MENV to ensure the meet the requirements. We obtain these readings by using the Kanomax Climomaster. This is a precision measuring instrument, which has velocity, temperature and humidity sensors.

Simultaneous measurements of air velocity air temperature and relative humidity can be obtained with a single probe of this instrument.

The measurement time is 3 minutes, 1.0 ft³ and at maximum airflow velocity of the MENV. The measurement point used is the center of MENV on operational level of component.

The Climomaster is setup as follows:

- Data sampling time : 60 seconds
- Data sampling interval : 1 second
- Number of sampling data : 1
- VTH measurement time : 3 minutes

Upon completion of the test, the readings must be within the parameters:

- First airflow velocity : 0.45 ± 0.05 m/s
- Temperature : 20.0 ± 2.0°C
- Relative humidity : 55 ± 10%

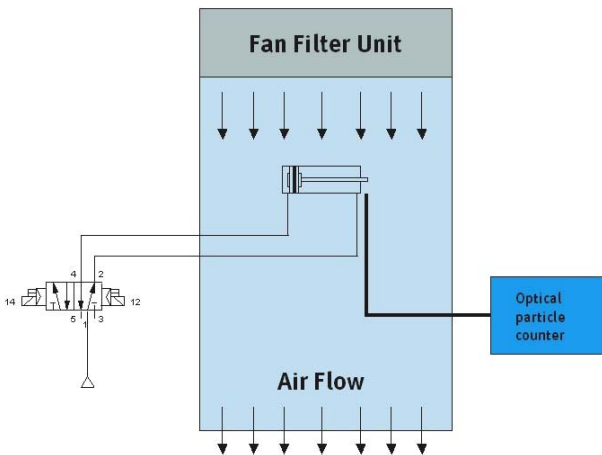


Information

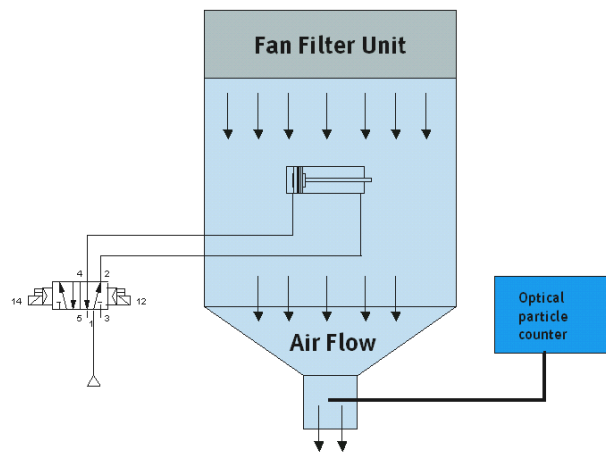
General Information

The principle of measuring contamination level of pneumatic components

The Direct Measurement Principle



The Average Measurement Principle



Introduction

Basically there are two different measuring principles how to assess the clean room suitability of operating materials. One principle is to localize the particle source and to measure the particle emission directly at its source.

Another principle is to assess the total particle emission, by measuring the average particle emission in the space surrounding the operating material.

The direct Measurement Principle

Applying the direct measurement the specimen is operated inside a clean room or mini environment. There should be laminar, vertical air flow around the specimen.

While the specimen is operated a particle counter with a movable measurement probe is used to screen the entire product for sources of particles. Subsequently, the particle emission is measured for 100 minutes at every particle source, which has been located before, in order to establish the particle emission behavior.

The major advantage of this principle is that it can be applied to operating equipment of almost any size. Furthermore, it provides some information about the particle distribution and concentration around the operating material. This measurement principle is described in detail in the VDI 2083-8 guideline.

The average Measurement Principle

Using the average measurement principle, the specimen is operated inside a container. The container is then supplied with a defined volume of clean dry air. Simultaneously, the particle emission is measured inside the container, by using an optical particle counter. All air, which does not flow through the particle counter, is released through an exhaust opening. In order to get the measurement results, the ratio between the exhaust air and the amount of air flowing through the particle counter has to be known.

The major disadvantages of this method are that the result largely depends on the placement of the measurement probe inside the container as the particle emission is not necessarily consistent.

This makes the measurement principle also very unsuitable for measuring larger operating materials, as the particle emission gets more inconsistent inside of larger containers.

The advantage of this method is that it allows a direct comparison among several test specimens. Furthermore, it is a lot easier to handle.

There is no guideline available from any independent organization, such as ISO, VDI, DIN, FDA etc., describing this measurement principle.

How does FESTO measure?

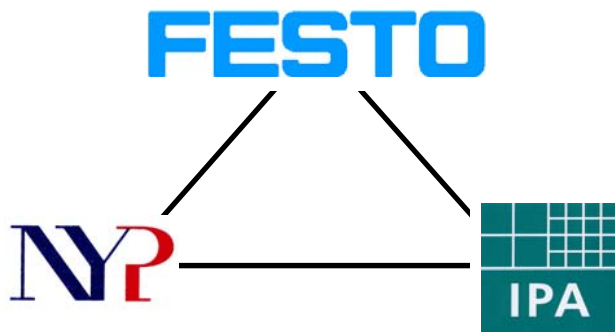
FESTO decided to apply the direct measurement method, as this measurement allows the user to gain information about the highest particle concentration around the product. Furthermore, this measurement method is described in the VDI-2083-8 guideline, which gives FESTO the possibility to have a neutral reference for the measurements.

Information

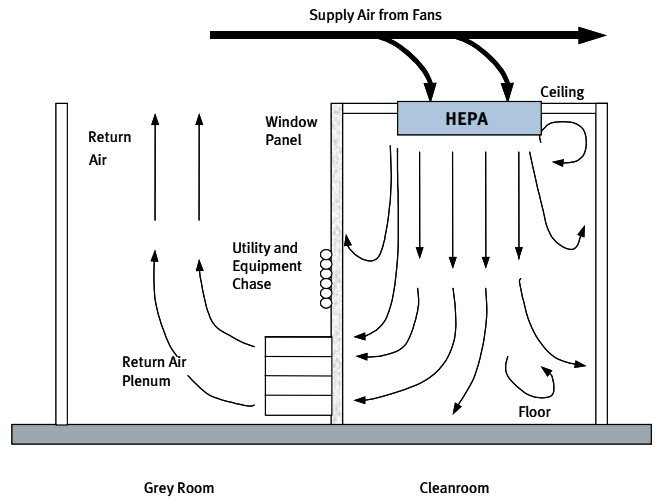
Festo Cleanroom project

Festo cleanroom project - A collaboration among 3 parties

Festo's cooperation with Fraunhofer of Germany and Nanyang Polytechnic of Singapore



The cleanroom environment in Nanyang Polytechnic of Singapore



The cleanroom project initiated by Festo is a collaboration among Fraunhofer Institute for Manufacturing Engineering and Automation in Germany, Nanyang Polytechnic (NYP) of Singapore and Festo Singapore.

The objective is to work together in the field of particle emission of Festo products.

Furthermore, it is Festo's intention to improve the experience in the field of particle measurements, contamination control as well as cleanroom applications in general.

We're doing the measurement according to the VDI 2083-8 guideline which is described on page 82 and the following pages. Fraunhofer Institute approved this measurement principle and attested this in a 'Certificate of qualification'.

The certification covers: The support for the performance of testing the cleanroom suitability of pneumatic components of the company Festo AG & Co.

Cleanroom environment

The cleanroom environment in Nanyang Polytechnic is ISO Class 6 cleanroom. The design of this cleanroom is shown. This is a cleanroom typical layout.

This is a "ballroom" type cleanroom with the area of 120 m². The air flows in a unidirectional way from a ceiling of High Efficiency Particular Air (HEPA) filters down to the floor of the cleanroom. The return air passes through a return air plenum in the Grey Room. The Grey Room, which is located just beside the cleanroom, where it is used for service.

Information

Festo Cleanroom project

Test procedure of Festo cleanroom components

Mini-environment (MENV)

A Class 1 clean Mini-Environment (MENV) is used within a cleanroom to provide the high level of protection to products against contamination and ESD events. The specification of MENV is shown. This MENV is a cleanroom test cabinet with one clear antistatic front panel and three side panels. The dimension of MENV is 1.2m x 0.6m internal area and with 2.2m height. In order to achieve high cleanliness class, Ultra Low Penetration Air (ULPA) Fan Filter Unit (99.9995% efficiency on 0.12 micron) is installed on the ceiling of the MENV. The unidirectional supply of air flows vertically from the Fan Filter Unit (FFU), and the air velocity can be adjusted up from 0.2 m/s to 0.6 m/s.

In accordance with the US FED-STD-209E, a cleanroom is classified to be of Class 1 if only one particle of the size of 0.5 µm or larger can be found in a reference volume of one cubic foot of the first air (filtered air supplied).

In accordance with the ISO 14644-1, a cleanroom is classified to be of Class 3 if only 35 particles of the size of 0.5 µm or larger can be found in a reference volume of one cubic meter of the first air (filtered air supplied).

There is no tabletop installed in the mini environment. Instead a removable clean room trolley with perforated tabletop is used. The height of the trolley/table is approx. 1.10 m

Summary specification of MENV

- Design: Vertical Laminar Flow
- Internal Dimensions: 1200 x 600 mm
- Cleanliness: ISO Class 3
- Air Velocity: 0 ... 0.6 m/s infinitely adjustable
- Light Intensity: 800 ... 1000 lux
- Main Body: Aluminium
- Front Design: Clear Front Cover
- Power Supply: 230 V, single phase 50 Hz

Optical Particle Counter

The LASAIR 210 OPC is used to detect the concentration of particles. The flow volume of this counter is 1.0 CFM (cubic foot per minute) or 28.3 liters per minute. The counter is able to detect particle size from 0.2 µm to 5.0 µm. The particle counter has eight channels.

The setting of OPC is:

- Data Sampling Time: 60 seconds
- Data Sampling Interval: 1 second
- Measurement Time: 120 minutes



Measuring Instrument

The two most important test instruments for the particle measurements are Optical Particle Counter (OPC) and Flow Meter.

A LASAIR 210 Optical Particle Counter, manufactured by Particle Measuring Systems Incorporation, and Model 6521 Climomaster (airflow, relative humidity and temperature measurement), manufactured by KANOMAX Japan incorporation, are used in the particle measurements.

Flow Meter

The flow meter – Model 6521 Climomaster is used to measure the airflow parameters. Simultaneous measurements of air velocity, air temperature and relative humidity can be obtained with a single probe of this precision instrument.

The setting of flow meter is

- Data Sampling Time: 60 seconds
- Data Sampling Interval: 1 second
- Number of Sampling Data: 1
- Measurement Time: 3 minutes



Information

Festo Cleanroom project

Test procedure of Festo cleanroom components

Testing of Festo cleanroom pneumatic product range

The VDI-2083-8 guideline describes, how particle measurements have to be carried out, in order to establish the particle emission of individual equipment. If a whole range of equipment is to be tested, it becomes viable to define, whether all types and sizes of the equipment has to be tested or whether it would be sufficient to test a defined share and to apply the results to the remaining products. Such a procedure becomes especially important if extensive product ranges are involved.

To achieve the above mentioned, this guideline has been developed. The guideline is based on the measurement procedures applied by F-SG. This guideline is not a FESTO Standard.

Subject of test

FESTO products, which are part of the clean room product range. It does not apply to the testing of standard product or special applications.

Specimen Selection

The number of specimen to be tested is determined by the size and the number of products in one product range. In every product range, the smallest and the largest type is tested. The terms small and large are defined as follows:

- For cylinders, slide units, shock absorbers and grippers, small and large are defined by the piston diameter.
- For valves and filters, service units, small and large are defined by the flow rate.
- For tubes and fittings, small and large are defined by the tube diameter.

Furthermore, at least, 25% of all products within one product range have to be tested. Each test is conducted with a number of two identical specimens.

Definition of a Product Range

The selection of test samples does apply only, if the product design is consistently the same, throughout a product range. This is defined as follows:

- The working principle of all products within the product range is identical.
- All materials of all products within the product range are identical, including all lubricants.
- The geometry of all products within the product range is identical, especially the geometry of all seals.
- The working pressure of all products within the product range is the same.

If not all products of a product range fulfill the above-mentioned requirement, all products of that particular product range have to be tested.



Information

Festo Cleanroom project

Test procedure of Festo cleanroom components

Standard operation procedure (SOP) are done before actual commencement of the test. These procedure are standard regardless of the type of test specimen.

Step 1: Inward transfer of test samples

Before any test is done, the components need to be prepared. The preparation for the cleanroom suitability assessment involves the cleaning of these components according to the Festo-SG guidelines "Operating Conditions for Cleanroom Tests". The cleaning sequence is outlined below:

- Decontamination of test samples (inner and outer parts) with Isopropanol saturated wipers and ultrapure compressed dry air. Sequence:
 - Pre-cleaning by blowing component surface with ultra-pure compressed dry air.
 - Cleaning of component surface using pre-saturated wipers containing a blend of Isopropyl alcohol.
 - Final cleaning by blowing component surface with ultra-pure compressed dry air.
- Bringing the test samples into the CR-environment and MENV
- Arranging the test samples (with gloves, intermediate decontamination, cleaning)

Step 2: Testing of instrument

It is also important to note that each time before the tests are made the required zero count measurement, base measurement and VTH measurement are carried out as follows:

- OPC airflow
- OPC laser-reference
- OPC zero-particle-count (measurement time: 3 minutes, with zero-filter attached)
- MENV air flow velocity (maximum power of FFU)
- Relative humidity (measurement time: 1 minute with measurement intervals of 1 second)
- Airflow-velocity (measurement time: 1 minute with measurement intervals of 1 second)
- Temperature (measurement time: 1 minute with measurement intervals of 1 second)
- Base measurements of MENV, airborne particulate contamination (measurement time 3 minutes, 1.0 cft, at maximum air flow velocity of MENV, measurement point in the center of MENV on operational level of component)

Step 3: Adjustment of the operating parameters for the test sample

After mounting the component on a test support fixture, it is ready for the test.

- Adjustment of operating parameters e.g. cushioning on actuator, speed of actuator
- Statement about performed duty cycles at the time of testing
- Documentation of adjustment (sketch or photograph)

Step 4: Localization measurements

Determination of points of highest concentrations of particle emission (according to VDI 2083 part 8)

- Coarse localization measurement
- Localization measurement

Step 5: Classification measurements

During the test, the airborne particle generated by the component is measured using a discrete particle counter (DPC).

- Particle size is $\geq 0.2 \mu\text{m}$, $\geq 0.7 \mu\text{m}$, $\geq 1.0 \mu\text{m}$, $\geq 2.0 \mu\text{m}$, $\geq 3.0 \mu\text{m}$, and $\geq 5.0 \mu\text{m}$ are selected.
- Measurement time:
 - standard-classification: 100 minutes (according to VDI 2083 part 8) at the measurement points that were found during the Localization measurements
 - lifecycle-test: several days, up to months
- Documentation of measurements points (sketch or photograph)

Step 6: Statistical evaluation

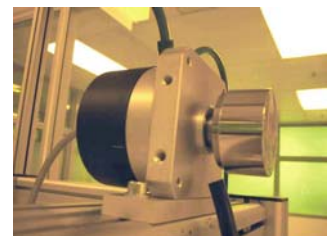
Evaluation according to guideline VDI 2083 part 8

Step 7: Visual inspection

Visual inspection of tested components (e.g. wear and tear, deposition of lubricants and particles, product failure...)

Step 8: Classification

Classification of test specimen according to statistical evaluation and visual inspection (see guideline VDI 2083 part 8)



Information

Festo Cleanroom project

Test procedure of Festo cleanroom components

Step 9: Documentation

Complete documentation should contain the following information

- Title, Date , Place of test
- Person responsible
- Test environment
 - Operating Parameters
 - Temperature
 - Relative humidity
 - Air flow velocity
 - Particulate concentration in test environment
- Measurement technology
 - Type
 - Model
 - Detection limits
 - Air flow
 - Description of sample technique
- Sample Characteristics
 - Type
 - Supplier
 - Serial Number
 - Component description
- Operating parameters of components
 - Break-in load
 - Running-in time
 - Mounting position
 - Operating frequency
 - Attached load
 - Supply (air- power supply etc.)

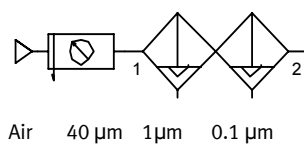
- Description of measurement points
 - Sketches or photographs
- References to applied standards and guidelines
- Documentation
 - Particle concentration at measurement points
 - Graphical visualization of particle emission
- Interpretation of results and conclusion
 - Classification related to applied standards/ guidelines
 - General Assessment
 - Potential for optimization

Operating condition for testing Festo components in cleanroom

Operating Conditions are defined by Festo-SG individually for different Festo products. The guidelines for product range, cylinders, rotary actuators, valves, grippers and service units are listed in page 88 and 89.

Preparing compressed air for testing Festo components in cleanroom

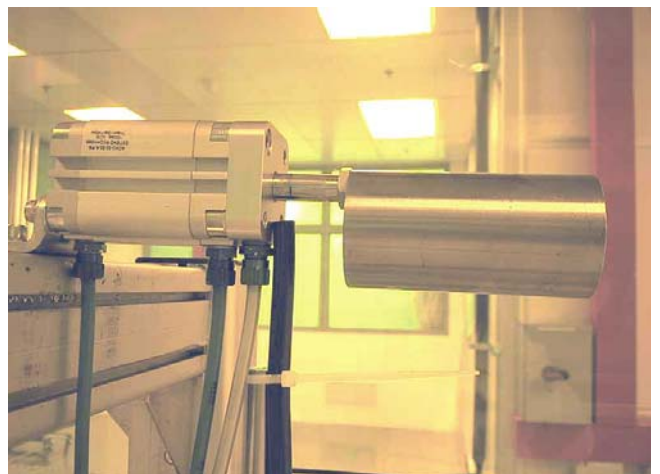
- Compressor
- Air storage
- Refrigeration dryer
- Prefilter regulator of 40 µm
- Fine filter 1 µm
- Micro filter 0.1 µm



Testing of DSNU-...-RR-SA cylinder



Testing of ADVU-...-RR-SA cylinder



Testing of CDN-...-RR-SA cylinder



Information

Festo Cleanroom project

Conditions at which Festo cleanroom components are tested

Operating conditions for Cleanroom tests - Cylinders

Pneumatic linear actuators:

- Single- and double-acting cylinders with and without piston rods
- Guide and slide units

Each test is conducted with a number of two identical specimens. The supply air should be clean dry air. This clean dry air is filtered with micro-filter which eliminates 99.9999% of particles bigger than 0.01 mm. The operating pressure for all samples is 6.0 ± 0.3 bar or maximum pressure, for specimen, whose operating pressure is less than 6.0 bar. The ambient temperature should be 20 ± 2 °C. The medium temperature should not exceed 30 °C. The max. speed is defined as 0.2 m/s for all kinds of cylinders. The speed is adjusted by means of one-way flow control valves, installed as close as possible to the cylinder ports. The adjustment is done in a way, that the piston safely reaches its end-position.

Tables below shows: A pulse/ interval ratio of 1:1 should be used for all frequencies. On the condition of the max. speed 0.2m/s, the different frequencies are defined due to different piston diameter., they are shown as following table. The frequencies can be adjusted by changing PLC programming.

Type	Piston diameter [mm]	Frequency [Hz]
Piston rod cylinder	6 to 8	2
	10 to 20	1.5
	25 to 50	1.0
	63 to 100	0.3
Rodless cylinders	8 to 100	0.5

The end position cushioning should be adjusted in such a way that there is no hard metallic impact in the end positions and the piston does not rebound. For test sample of cylinders, the following stroke lengths are chosen for the various piston rods as:

Piston diameter [mm]	Stroke length * [mm]
6 to 8	20 or max. stroke
10 to 20	50 or max. stroke
25 to 32	100 or max. stroke
40 to 50	200 or max. stroke
63 to 100	300 or max. stroke

Cleanroom test of cylinders should be carried out under different load conditions. However, because of short of time, cylinders are only tested under the condition of horizontally mounted with a load.

Table below shows: Load parameters for piston-rod cylinders without guide or protection against torsion.

Ø [mm]	Additional Mass [kg] (3% theoretical effective force)	Moment due to additional load [Nm] $M = m \times g \times s$
6	0.057	0.0168
8	0.091	0.0357
10	0.145	0.0711
12	0.225	0.1324
16	0.360	0.2825
20	0.570	0.5592
25	0.910	1.1159
32	1.450	2.2759
40	2.225	4.4145
50	3.600	8.8290
63	5.700	16.7751
80	9.100	26.7813
100	14.500	42.6735

In the case of cylinders with protection against torsion, testing should be carried out using 20% of the maximum moment.

Piston Diameter [mm]	Additional Mass [kg] (20% theor. effective force)
8	0.570
10	0.910
12	1.450
16	2.250
20	3.600
25	5.700
32	9.100
40	14.500
50	22.500
63	36.000
80	36.000
100	36.000

Suction rate at vacuum port

Ø [mm]	Min. vacuum flowrate [l/min]	Recommend Vacuum generator [Type]
12...25	23	VN-07-L...
32...50	35	VN-07-L...

Whenever possible compression fittings with sealing rings in combination with polyurethane tubes should be used for the for the air supply. This is to ensure minimum leakage.

For all cylinders with piston rod the mounting position is defined as horizontal, with the supply ports on the bottom of the sample, except for DGPL cylinder and slide units. For the latter the port orientation is determined by the product design. Cylinders without piston rod are tested in horizontal and vertical mounting positions. If possible, standard mounting-accessories should be used. To minimize turbulence, the mounting accessories should disturb the airflow as little as possible.

Prior to every measurement the supply pressure must be checked. The pressure should be 6.0 ± 0.3 bar.

Acoustic/visual/tactile check under test conditions to see that test specimens are operating correctly and that there is not sticking, jamming, stopping short of end positions, jerky motion, bottoming-out of cushioning or leaks which can be felt or heard.

As any leakage leads to high emission of particles, there should be no detectable leakage. If there is any leakage detected, the test should be aborted.

As the amount of particles, emitted by a cylinder, is not constant throughout its service life, particle measurements have to be undertaken at different stages of the service life.

Particle measurement should be carried out after 20,000 duty cycles have been completed

Information

Festo Cleanroom project

Conditions at which Festo cleanroom components are tested

Operating conditions for cleanroom tests - Valves

Pneumatic digital switching valves as follows:

- Mechanically-actuated/ manually-operated digital switching valves
- Pneumatically-actuated digital switching valves
- Solenoid-actuated digital switching valves

Each test is conducted with a number of two identical specimens. The supply air should be clean dry air. This clean dry air is filtered with micro-filter which eliminates 99.9999% of particles bigger than 0.01 µm. The operating pressure for all samples is 6.0 +/- 0.3 bar or maximum pressure, for specimen, whose operating pressure is less than 6.0 bar. The ambient temperature should be 20 +/- 2 degree Celsius. The medium temperature should not exceed 30 degree Celsius.

Table shows: A pulse/interval ratio of 1:1 should be used for all frequencies. The additional volumes should be connected to the outputs of the test specimens via pieces of tubing and appropriate fittings.

Ensure that the tubing connect does not increase the size of the additional volume by more than 20%. Tube size of supply line with maximum length of 100 cm.

Whenever possible compression or barbed fittings in combination with polyurethane tubes should be used for the for the air supply. This is to ensure minimum leakage. For those valves that barbed fittings are not available, push-in fittings are used in the test.

Acoustic/visual/tactile check under test conditions to see that test specimens (and pilot valves) are operating correctly and that there is no failure to switch, sticking, incomplete venting of outputs or leaks which can be felt or heard. Any departures from normal operation should be documented.

As any leakage leads to high emission of particles, there should be no detectable leakage. If there is any leakage detected, the test should be aborted.

Valve port size	Switching frequency [Hz]	Additional volume [ml]	Inner diameter of tube [mm]
M3	3	2	3
M5	3	10	3-4
M7	3	10	4-6
1/8"	3	10	4-6
1/4"	3	25	4-6
3/8"	2	25	6-9
1/2"	2	50	6-9
3/4"	1	100	13
1	1	400	13

Operating conditions for cleanroom tests - Air preparation units

- Filter
 - Filters
 - Fine and micro filters
 - Pressure regulators
 - Manual on-off valve
 - Solenoid actuated on-off valve
 - Soft start valves
- The specifications of test specimens are as:
- Pressure range: 0 to 7 bar
 - Degree of filtration: refer to filter type filter or micro-filter connected
 - Filter type LF or LFMA/B with connector plates are used
 - Pressure gauge connections
 - Manual condensate drain

The supply air should be clean dry air. This clean dry air is filtered with micro-filter which eliminates 99.9999% of particles bigger than 0.01 mm. The compressed air regulator is connected with micro-filter to adjust the pressure. The working pressure during the test is 7 bar. The air preparation unites are measured under the following conditions:

- Primary pressure (input pressure) p1=7 bar
- The controlled pressure (output pressure) p2= 6 bar
- Pressure drop Δp=1 bar

The ambient temperature should be 20 ± 2 °C. The medium temperature should not exceed 30 °C. A minimum flow rate of 125 l/min is necessary for correct operation. However, flow measurement devices such as flow sensors or flowmeters are need to ensure this minimum flow rate. The switch frequency for on-off valves are 2 Hz. The mounting position for is vertical ±5°. The operating voltage for solenoid actuated on-off valve is set as 24 ± 10% V DC. For manual condensate drain, plastic tubing is connected to the barb fitting. This is to ensure minimum leakage. Prior to every measurement the supply pressure must bechecked. The pressure should be 7.0 ± 0.3 bar. Acoustic/visual/tactile check under test conditions to see that test specimens are operating correctly. As any leakage leads to high emission of particles, there should be no detectable leakage. If there is any leakage detected, the test should be aborted.

Although, it should be avoided that any medium such as air or lubricant is leaking out of the pneumatic system, it cannot be entirely avoided if pneumatic actuators are applied. In order to minimize harmful contamination, the medium, mostly compressed air or nitrogen, should be dried and filtered accordance to ISO 8573-1, Class 1.

Compressed Air Quality Standard: ISO8573-1

Class	Dust		Water		Oil
	[um]	[mg/m³]	[DTP]	[g/m³]	[mg/m³]
1	0.1	0.1	-70	0.003	0.01
2	1	1	-40	0.12	0.1
3	5	5	-20	0.88	1
4	15	8	+3	6.0	5
5	40	10	+7	7.8	25
6	-	-	+10	9.4	-
7	-	-	-	-	-

Information

Festo Cleanroom project

Benefits of using Festo cleanroom components

In all automation processes, pneumatics plays an important role. This is the same for cleanroom, pneumatics are used in cleanroom for the following reasons:

- Automation of production sequence with pneumatics
- Lower space requirements with pneumatics
- Lower levels of contamination with pneumatics
- Laminar flow virtually unimpaired by pneumatics

Benefits

- Avoidance or reduction of particle emissions both with stationary components and in an operating sequences
- Minimization of disturbance factors affecting laminar flow
- Counter measures against possible environmental influences (e.g. acids, aggressive media)

Difference in comparison with standard products

The following list is the difference between the standard products and those used in cleanroom.

- Generally suitable for unlubricated operation
- Cleanroom compatible grease used when necessary
- Cleanroom compatible markings
- Ducted exhaust ports and connections for air breather ports
- Extraction by means of vacuum where necessary

Basic principle of Festo cleanroom product range

It is known that there isn't a standard or guideline for cleanroom product design available. In order to develop products for cleanroom application, we mainly base on the principle of "avoiding cleanroom contamination by preventing particles generated from the components".

This principle includes the following three aspects:

- Non-contaminant release very low leakage construction
- Non-contaminant generation special material, surface treatment and special lubrication specification
- Non-contaminant in production processes – component cleaning and double bag packaging

The above three aspects can be achieved for cleanroom compatibility by modifying our standard products to cleanroom products with some special features. The general principle is to design an additional vacuum suction port so that air leakage during operation can be sucked back and extracted by vacuum.

Non contaminants releasing: Drives

- Air leakage from the piston rod is sucked back and extracted by vacuum via a additional vacuum suction port on the front cap or barrel (housing)
- Leak-free design principle

Valves

- Exhaust air from both main valve and pilot valve are released via common exhaust ports
- Breather air from underside of piston is removed via exhaust ports
- Leak-free design principle

Air preparation unit

- Regulator: vent air in the bonnet is sucked through a vacuum connection on an additional ring
- Air filter: drain is discharged from cleanroom via drain guide port

Grippers

- Air leakage is extracted via vacuum suction port

Vacuum and other components

- Exhaust air is ported to the outside of cleanroom
- Shock absorber: replacement of a new housing with a vacuum port
- Fittings & tubing: air leakage is minimized by using the barbed fittings

Non contaminant generating

Piston rod is made of corrosion resistant steel

Non contaminant in production process

- Cleaning individual components by ultrasonic cleaning bath
- All components are cleaned and assembled in a cleanroom
- Functional test in a cleanroom
- Double-packed in plastic bags in a cleanroom

Production sequence of Festo cleanroom product range

Basically, the manufacturing of clean room pneumatics is not any different from the design of any other pneumatic component. It is just, that special care is taken, to avoid any kind of contamination caused by the product.

Design office

Firstly the design of a standard product is modified with a view to cleanroom compatibility.

Assembly

All products are assembled outside the cleanroom, according to the standard assembly procedures. In very special cases, cleanroom grease is applied instead of the standard lubricant.

Testing

Just as any standard product, cleanroom products are tested, concerning their functionality. There is no particle emission test conducted for every product.

Cleaning

Before packing all products are cleaned under cleanroom condition of ISO Class 7. The cleaning is done either by means of an ultrasonic bath or with isopropanol wipers.

Packaging

Packaging is done in antistatic plastic bags. Whereby each product is double packed and sealed. Just as the cleaning, the packaging takes place under cleanroom condition of ISO Class 7. When the product is ready for shipment, it is transferred out of the cleanroom through an airlock.