HVAC for Cleanroom Facilities

An Online Continuing Education Course for Engineers

Course Number: HV-6008

Credit: 6 Hours / 6 PDH / 6 CPD

© 2023 Decatur Professional Development, LLC. All rights reserved.

HVAC for Cleanroom Facilities

A. Bhatia, Mechanical Engineer

Indoor air quality is of paramount importance for human comfort and health. Air, whether it is from outside or re-circulated within the area, acts as a vehicle for airborne contaminants brought in by the movement of people, material, etc. Since many of these airborne contaminants are harmful either to products or people working in such environments their removal is necessary on medical, legal, social or financial grounds.

Cleanrooms are specially constructed, environmentally controlled enclosed spaces where the concentration of airborne particles (contaminants) is kept within specified limits. In industry, cleanrooms are used in the manufacturing of electronic hardware such as integrated circuits (ICs) and hard drives. In biotechnology and medicine, cleanrooms are used when it is necessary to ensure an environment free of bacteria, viruses, or other pathogens.

Four fundamental rules apply to cleanrooms.

1) First, contaminants must not be introduced into the controlled environment from the outside.
2) Second, the apparatus or equipment within the controlled environment must not generate or otherwise give rise to contaminants (for example because of friction, chemical reactions, or biological processes).
3) Third, contaminants must not be allowed to accumulate in the controlled environment.
4) Fourth, existing contaminants must be eliminated to the greatest extent possible, and as rapidly as possible.

These requirements are defined in Federal industry standard 209 and ISO 14644-1. It takes an incredible amount of technology to achieve and maintain these objectives. The HVAC system for cleanrooms is a specialized field requiring thorough understanding of cleanliness guidelines, airflow streams, room pressurization, temperature, humidity and filtration requirements, knowledge of codes and standards, specialty equipment, instrumentation and control, and many more details.

This course will describe some basic requirements of HVAC design for cleanroom applications.

Airborne particles Characteristics

Airborne particles are solids suspended in the air. For our purposes, particles are defined as bodies with:

Portions ©2013, 2018 Decatur Professional Development, LLC All rights reserved

1) Definite physical boundaries in all directions.
2) Diameters ranging from 0.001 micron to 100 microns*.
3) Liquid or solid phase material characteristics.

*The size of contaminants and particles are usually described in microns; one micron is one-millionth of a meter. In English units one micron equals 1/25,400 inch. To give a perspective, a human hair is about 75-100 microns in diameter. A particle of 0.5 micron (200 times smaller than the human hair) can cause major disaster in a cleanroom.

Sources of Contamination

The airborne contamination level of a cleanroom is largely dependent on the particle generating activities in the room, besides the personnel who also contribute to the contamination levels. It has been found that many of these contaminants are generated from five basic sources (1) the facilities, (2) people, (3) tools, (4) fluids and (5) the product being manufactured. Review the list below to gain a better understanding of where the contamination originates.

1) Facilities
   - Walls, floors and ceilings
   - Paint and coatings
   - Construction material (sheet rock, saw dust etc.)
   - Air conditioning debris
   - Room air and vapors
   - Spills and leaks

2) People
   - Skin flakes and oil
   - Cosmetics and perfume
   - Spittle
   - Clothing debris (lint, fibers etc.)
   - Hair

3) Tool Generated
   - Friction and wear particles
   - Lubricants and emissions
   - Vibrations
   - Brooms, mops and dusters

4) Fluids
   - Particulates floating in air
   - Bacteria, organics and moisture
   - Floor finishes or coatings

Portions ©2013, 2018 Decatur Professional Development, LLC All rights reserved

- Cleaning chemicals
- Plasticizers (out-gasses)
- Deionized water

5) Product generated
   - Silicon chips
   - Quartz flakes
   - Cleanroom debris
   - Aluminum particles

This is a partial list of some of the commonly known contaminants. Preventing these contaminants from entering the cleanroom environment is the key objective of cleanroom design and use.

What is a Cleanroom?

A cleanroom is defined by ISO14644-1 as a room in which the concentration of airborne particles is controlled, and which is constructed and used in a manner to minimize the introduction, generation, and retention of particles inside the room and in which other relevant parameters, e.g. temperature, humidity, and pressure, are controlled as necessary.

Cleanroom Classification

Cleanroom specifications for particulate matter (such as dust) are defined according to the maximum allowable particle size (diameter), and according to the maximum allowable number of particles per unit volume. For non-particulate contaminants, the maximum allowable density in terms of microbes per cubic meter, or molecules per cubic meter, is specified.

The determination of how clean an area is depends on the class number that it is designed to. According to Federal Standard 209, class number refers to the maximum number of particles of 0.5-micron size or bigger that would be allowed in one cubic foot of cleanroom air.

Portions ©2013, 2018 Decatur Professional Development, LLC All rights reserved

Maximum number of particles in Air (particle per cubic feet of air)

Class	0.1 µm	0.2 µm	0.3 µm	0.5 µm	5 µm
1	35	7	3	1	
10	350	75	30	10	
100	3500	750	300	100	
1,000				1,000	7
10,000				10,000	70
100,000				100,000	700

A Class 100 cleanroom, for example, would not contain more than 100 particles bigger than *0.5 micron in a cubic foot of air*.

A Class 10,000 - Particle count not exceeding a total of 10,000 particles per cubic foot of a size 0.5 microns and larger or 70 particles per cubic foot of a size 5.0 microns and larger.

Classes and their Typical Uses

- Class 1 & 10 - production laboratories for electronic integrated circuits…
- Class 100 - production areas for photo labs, medical implants...
- Class 10,000 - production locales for TV tubes, hospital operating theaters...
- Class 100,000 - production of ball bearings…

ISO Classification of Cleanrooms

ISO 14644 classification for cleanrooms is based on the formula Cn = 10N (0.1 / D) 2.08

Where

- Cn = maximum permitted number of particles per cubic meter equal to or greater than the specified particle size, rounded to whole number
- N = is the ISO class number, which must be a multiple of 0.1 and be 9 or less
- D = is the particle size in micrometers

Portions ©2013, 2018 Decatur Professional Development, LLC All rights reserved

Maximum Concentration Limits (particles/m^3 of air)

Class	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

An ISO 1 cleanroom has the lowest levels of contamination, while an ISO 9 has the highest allowable level. To give a perspective, the ambient air outside in a typical urban environment might contain as many as 35,000,000 particles per cubic meter, 0.5 um and larger in diameter, corresponding to an ISO class 9 cleanroom.

Cleanroom class comparison (ISO v/s Federal Std. 209)

ISO is based on metric measurements whereas Federal Standard 209 is based on imperial measurements. The classes, according to ISO14644, are in terms of class levels 3, 4, 5…of airborne particulate cleanliness corresponding to 1, 10, 100…..class Fed 209 standards. A Class 5 means that less than 3,520 particles (0.5 microns in size) are present per cubic meter, which equals 100 particles per cubic foot.

ISO	Federal Std.
ISO 3	1
ISO 4	10
ISO 5	100
ISO 6	1,000
ISO 7	10,000
ISO 8	100,000

*In the United States, Federal Standard 209E (FED-STD-209E) was used until the end of November 2001 to define the requirements for cleanrooms. On November 29, 2001, these

Portions ©2013, 2018 Decatur Professional Development, LLC All rights reserved

standards were superseded by the publication of ISO specification 14644.

Key Elements of Cleanroom Design

Four basic components define a controlled environment

1) *Cleanroom Architecture* – Materials of construction and finishes are important in establishing cleanliness levels and are important in mini… internal generation of contaminants from the surfaces.

2) *The HVAC System* … reated by the pressure differential compa… on and air-conditioning system. The HVAC …

   - Supplying airflo… he cleanliness rating of the room.
   - Introducing air ir… les could accumulate.
   - Filtering the outs… ticulate air (HEPA) filters.
   - Conditioning the a… ity requirements.
   - Ensuring enough c… ositive pressurization.

3) *Interaction Technology* …) the movement of materials into the area… …ntenance and cleaning. Administrative instruct… …ons are necessary to be made about the logistics, operation strat… …maintenance and cleaning.

4) *Monitoring systems* - Monitoring systems include a means of indicating that the cleanroom is functioning properly. The variables monitored are the pressure differential between the outside environment and the cleanroom, temperature, humidity and, in some cases, noise and vibrations. Control data should be recorded on a routine basis.

To view the remainder of the course material and to take the quiz for PDH credit, you must purchase the course.

Close this window and click "Add to cart" on the product page.

Portions ©2013, 2018 Decatur Professional Development, LLC All rights reserved