Cleanroom Design

A cleanroom is an environment in which specific particle control must be maintained for manufacturing and aseptic functions. Precise control of temperature, humidity, pressure, noise, and vibration are often part of cleanroom design criteria. Cleanrooms range in size from minienvironment enclosures to thousands of square feet, as is required for microelectronics fabrication (fab).

Cleanrooms are classified by standards that reference particle presence by quantity and size. Federal Standard 209E references the number of 0.5 micrometer (um or microns) particles per cubic foot. (A micrometer is 10^{-6}meter.) The International Organization for Standardization (ISO) is developing a series of integrated standards for cleanrooms. ISO standards reference the number of 0.1 micron particles per cubic meter.

Cleanroom applications expand with the advance of technology. Cleanroom contamination can originate from workers and materials and includes human skin cells, spittle, hair (100 microns), tobacco smoke, cosmetics, bacteria (0.2 to 0.12 microns), viruses, dust, pollen, solvents, and moisture.

High-efficiency particulate air (HEPA) filters are very efficient (nominally 99.99 percent) in removing particles down to 0.3 micron in supply air. Ultra-low penetration air (ULPA) filters are very efficient (nominally 99.9995 percent) down to 0.12 micron particles. Supply air is distributed downward through modular ceiling filters (nominally 2 ft by 4 ft) gell-sealed into tracks.

Cleanroom air velocity can range from 10 ft per minute (FPM) in Class 10,000 (M6.5) up to 100 FPM in Class 1 (M1.5) with up to 600 air changes per hour. The percentage of room filter coverage affects contamination control. Filter coverage is based on the cubic ft per minute (CFM) of air required for the cleanroom classification and the CFM of air delivered per filter.

Class 1 cleanrooms utilize 100 percent ULPA coverage with air supplied vertically downward with minimal turbulence through a perforated raised-access floor. This airflow pattern is generally known as vertical laminar flow (VLF). VLF resists depositing contaminants on surfaces and captures particles in the cleanroom. The free area of floor panels and adjustment dampers below the panels balance the cleanroom airflow.

In higher cleanroom classes, air may be supplied with controlled turbulence for diffused coverage and returned through low wall return grilles. Pharmaceutical and food applications require aseptic detailing, with smooth, impervious, and cleanable surfaces. The walls and floor join with a radiused cove and require return air extraction by low wall return grilles.

Pressurization is a delicate balance between process exhaust and makeup air replenishment. Manufacturing cleanrooms are usually maintained at positive pressure with respect to adjacent areas to resist particle infiltration from the other areas. Cleanrooms with biohazards, however, are precisely controlled to a negative pressure. As the biohazard increases, the pressure must be maintained at a greater negative pressure.

The Centers for Disease Control and Prevention (CDC) and the National Institutes of Health (NIH) establish practices for biohazard containment including protocol, safety clothing and equipment (primary barrier), and the facility (secondary barrier). CDC/NIH have determined the biosafety levels (BSLs) for materials, which range from BSL-1 (low) to BSL-4 (high). Safety equipment includes class I, II, and III biological safety cabinets (BSC), which are small clean room-type workstations. A class III BSC is completely closed to the room environment. BSL-3 or BSL-4 cannot recirculate any room air, and exhaust air must be treated.

Portable clean ooms and component modularity allow workspace reconfiguration for changing processes and equipment. Cleanroom design is supported by operational protocol, including having workers wear specified apparel and enter through gowning rooms and air showers. All materials entering or exiting cleanrooms must move through pass-through openings with interlocked doors. Operational protocols must be in place from the beginning of construction through testing and certification of the cleanroom as well as during use.

Cleanrooms constructed for microelectronics mitigate conductivity and static control interference with special materials

and coatings. To minimize airborne molecular contamination, cleanroom construction materials are evaluated and selected for low outgassing characteristics. Vibration control is essential to cleanroom manufacturing processes involving photolithography, optics, and lasers.