HVAC Filter and Flow Control Systems for Cleanrooms

In any cleanroom, the HVAC (heating, ventilating, and air conditioning) system, the air filters, and the airflow controls are crucial to good operation. The HVAC system must be capable of providing a uniform flow of conditioned air at sufficient velocity and pressure to overcome the airflow resistance of the air ducts, air conditioning components, and filters. Very large airflow is required for modern-day cleanrooms. Even for a mixed-flow class 100,000 cleanroom, sufficient airflow to provide 20 to 30 air changes per hour may be required. A mixed-flow cleanroom that is 50 feet wide and 100 feet deep with a 10-foot ceiling requires a blower system capable of providing at least 17,000 cubic feet per minute airflow for this air change rate. The airflow should be provided at a pressure at least 0.5 inches water above ambient to assure maintenance of positive pressure in the cleanroom and to overcome the pressure drop of the filters and the HVAC components. A vertical unidirectional flow cleanroom of the same size requires a much larger blower system. For a 5,000-square-foot room with 100% filter ceiling, the airflow requirement is 450,000 cubic feet per minute for the 90-feet-per-minute air velocity specified for such cleanrooms. Energy costs just to operate the blowers to provide this airflow make up an important part of cleanroom costs.

Heating and cooling coils are needed to maintain air temperature and relative humidity as required for the particular cleanroom. Pharmaceutical manufacturing areas can be a special problem in that some product components must be washed with water, and regular room and component sterilization is usually a wet procedure. Walls and floors may require mopping with bactericide, or the room contents may be exposed to moist disinfectant gas. In some pharmaceutical manufacturing areas, it has been

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decided that an ideal operating temperature is $66^\circ F \pm 2^\circ F$ (Cattaneo 1984). Operators using sterile gowns perspire and emit excessive particles at temperatures much above $68^\circ F$ but are uncomfortable when working in cleanroom garments at temperatures below $64^\circ F$. Relative humidity limits ranging from 45% to 55% have been found satisfactory to control mold growth in these rooms, with reasonable worker comfort.

Depending on the cleanroom location and the time of the year, external ambient conditions may require use of either humidification or drying to keep the cleanroom moisture content at the desired level. Some process equipment operations may generate excessive heat in the cleanroom, resulting in a requirement for air cooling. To maintain the desired relative humidity levels, it may be necessary to remove moisture added by processes and personnel in the cleanroom. The HVAC system should be laid out to minimize duct pressure loss; otherwise, power costs can soar as pressure drop imposes additional load on the air-moving system. The ducts should be large enough within the limits of allowable space so that high air velocity does not cause excessive noise. Stainless-steel ducts minimize particle emission, but galvanized iron ducts can be used in many temperate zone areas with suitable precautions. The HVAC system must be designed for intake of enough makeup air to keep gaseous contaminants at an acceptable level, as they may build up in normal operations. Typical cleanroom makeup air quantity is 10 to 20% of total airflow. Higher quantities of makeup air result in excessive costs to filter and heat or cool large quantities of external air. A typical cleanroom HVAC system is shown in Figure 16-1. There are some possible choices for flow control; for example, return air can be vented through a raised floor or side wall return air grilles. Supply air can be directed through individual plenums containing individual or banked HEPA filters or to an overall ceiling filter system for an entire cleanroom. The cleanroom HVAC system may also include components in addition to filters that clean the air of gaseous and particulate contamination. Ionizers may also be required to reduce charge levels, both for prevention of electrostatic discharge hazard to sensitive electronic products and for reduction of particle deposition in any area.

The HVAC system performance requires a variety of components in order to condition the air and to move it properly. The major elements include fans and blowers to move the air to the cleanroom, ducting and control dampers to control its motion, grilles and vents to emit it into or remove it from the cleanroom, humidifiers, heating and cooling coils to control its temperature and moisture content, filters to remove particulate contaminants, adsorbing beds to control gaseous contaminants, and instruments to verify that each of these elements is operating correctly.

Some of the requirements and operating limits for these elements are