

Best Practices for Energy Efficient Cleanrooms: Fan-Filter Units

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Efficient HVAC Air Systems

Fan-filter Units

Summary

The HVAC systems in cleanrooms may use 50 percent or more of the total cleanroom energy use. Fan energy use accounts for a significant portion (e.g., over 50%) of the HVAC energy use in cleanrooms such as ISO Classes 3, 4, or 5. Three types of air-handling systems for recirculating airflows are commonly used in cleanrooms: 1) fan-tower systems with pressurized plenum, 2) ducted HEPA systems with distributed-fans, and 3) systems with fan-filter units. Because energy efficiency of the recirculation systems could vary significantly from system type to system type, optimizing aerodynamic performance in air recirculation systems appears to be a useful approach to improve energy efficiency in cleanrooms.

Providing optimal airflows through careful planning, design and operation, including air change rate, airflow uniformity, and airflow speed, is important for controlling particle contamination in cleanrooms. In practice, the use of fan-filter units (FFUs) in the air-handling system is becoming more and more popular because of this type of system may offer a number of advantages. Often modular and portable than traditional recirculation airflow systems, FFUs are easier to install, and can be easily controlled and monitored to maintain filtration performance. Energy efficiency of air handling systems using fan-filter units can, however, be lower than their counterparts and may vary significantly from system to system because of the difference in energy performance, airflow paths, and the operating conditions of FFUs.

Principles

An FFU usually consists of a small fan, controller, and a HEPA/ULPA filter enclosed in a box, which fits into common cleanroom ceiling grids, typically 2x4 ft or 4x4 ft. The small fans force air through filters and thereby consume considerable energy in providing cleanroom air recirculation.

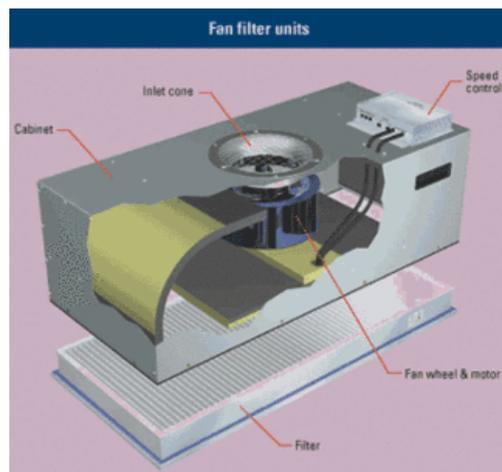


Figure 1. Fan-filter Unit

FFU systems are required for many specific applications; however, FFU systems tend to be less energy efficient than pressurized plenum systems for recirculating air in a cleanroom (Figure 2).

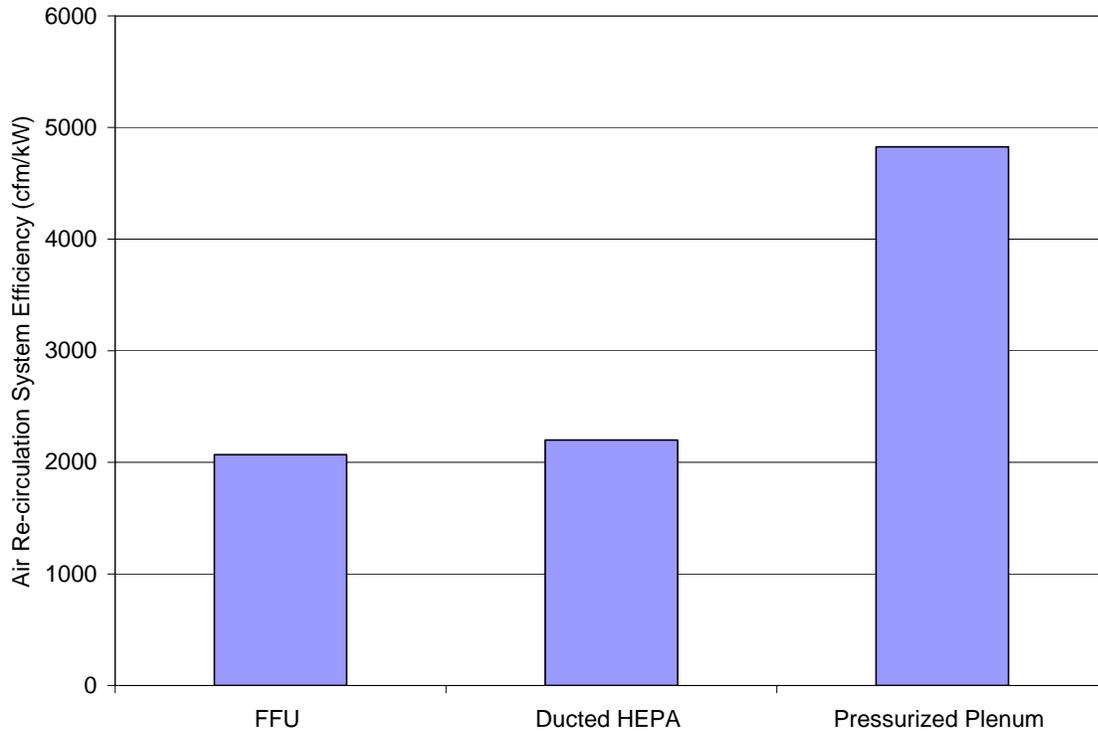


Figure 2. Energy efficiency of air recirculation systems

Fan power is proportional to the cube of airflow rate or airflow speed. A reduction in the air change rate by 10% may result in a power reduction of approximately 27%. Providing the flexibility of speed control for the unit may help to improve energy efficiency of the units in operation.

Energy efficiency of FFU systems can vary significantly from system to system. There are many factors contributing to the overall efficiency. These factors include the size and layout of the overall recirculation systems, the efficiency of individual fans and fan-filter units, the filter media, the controllability of the airflows, and pressures in the air systems.

Approaches

FFU applications in recirculation air systems are becoming more popular in cleanrooms and minienvironments. The energy efficiency and airflow performance of such systems can vary significantly.

The design and layout of air delivery systems for air-cooling has significant effect on the overall energy efficiency of the whole air recirculation system using FFUS. In addition, an important step to improve FFU system efficiency is to use and install energy efficient FFUs in cleanrooms or minienvironments. Selecting energy efficient FFUs is critical because they tend to be more efficient under a range of typical operating conditions compared with less-efficient ones do. At the same time, it is critical that users need to understand and optimize the operating conditions by monitoring and controlling the FFU systems so that maximal energy efficiency can be achieved while maintaining effective contamination control.

For best practice, users and designers should require certain efficiency criteria for the FFUs during the planning, design, and construction process. Owners should require that suppliers provide energy performance information for the units, along with other performance data such as particle filtration, vibration, and noise. The energy performance data should be based upon a uniform laboratory testing method developed by LBNL and IEST. Using performance test data obtained with this method, users will be able to select the units that are more efficient and functional. Figure 3 indicates that total efficiency of FFUs varied from unit to unit and for various operating conditions when a consistent test method was used in laboratory settings. Under certain conditions, some FFUs may or may not be able to perform, i.e., to provide the pressure rise that is needed to overcome system resistance. The relative magnitude of performance variations is so significant that it is important to select an efficient and functional unit based upon the laboratory testing for the anticipated design and operating conditions.

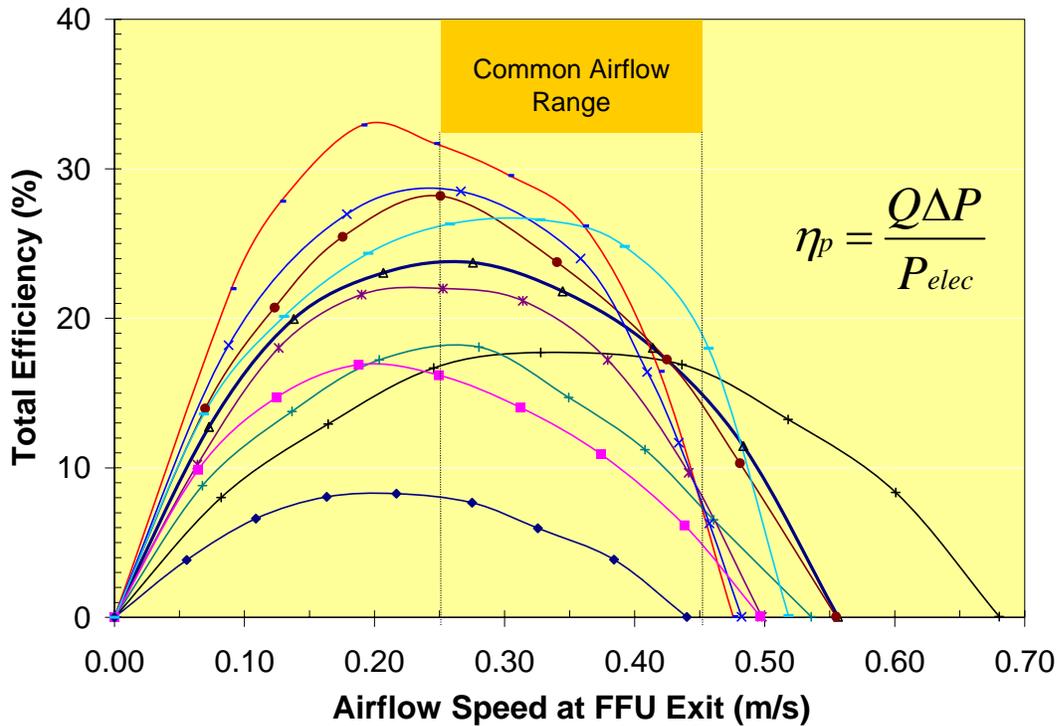


Figure 3. Total efficiency of FFUs tested in laboratory

The best practice for FFUs is to adopt FFUs with higher efficiency, and optimize the operation and control of such systems so that maximum efficiency can be achieved. In some industries, such as biotechnology and pharmaceutical areas, cleanrooms are commonly designed to follow current good manufacturing practice (cGMP). For example, higher airflow speeds are typically accepted (e.g., 90 fpm) for cleanroom air recirculation. In these applications, best practice to lower airflow or air change rates could be feasible but would be challenging. In any case, improving the efficiency of FFU systems operating at the accepted higher airflow speeds can result in more energy savings, however. Variable-speed drives (VSDs) should be used with fan-filter units to provide flexibility and efficiency.

Effective best practice would be to specify performance data such as power consumption and airflows for the expected conditions. The provided information should be based upon a consistent testing method to allow comparisons of performance claims. This will help designers and users to make informed life-cycle-cost comparisons.

Case Studies

Energy efficiency of FFU systems could vary by a factor of three or more depending on the design of cleanroom systems, operating conditions, and the units (Figure 4). For example, the benchmarking data suggests that the efficiency of FFU systems in ISO Class 5 facilities could range from 1276 cfm/kW to 4224 cfm/kW, with all recirculation air systems providing the required cleanliness levels (Figure 4). In the case of 4224 cfm/kW, sensible cooling coils were

integrated with the FFU recirculation air system, which didn't require additional fans to deliver the cooled air. The integration of sensible cooling device with the air-recirculation system significantly improved the overall air-delivery efficiency of the FFU recirculation system, compared to separate sensible cooling device that requires additional fans to deliver cooled airflows as part of air recirculation.

On one hand, cleanroom operators may use a lower air change rate (or a lower airflow speed) than those recommended without compromising either production or cleanliness requirements; on the other hand, if the whole recirculation air systems can be designed, installed, and operated with efficient units and control, the energy use for air systems can be significantly lowered while maintaining effective contamination control.

FFU systems can monitor and control individual fan operation and are advantageous in efficiently achieving effective contamination control when coupled with demand control filtration.

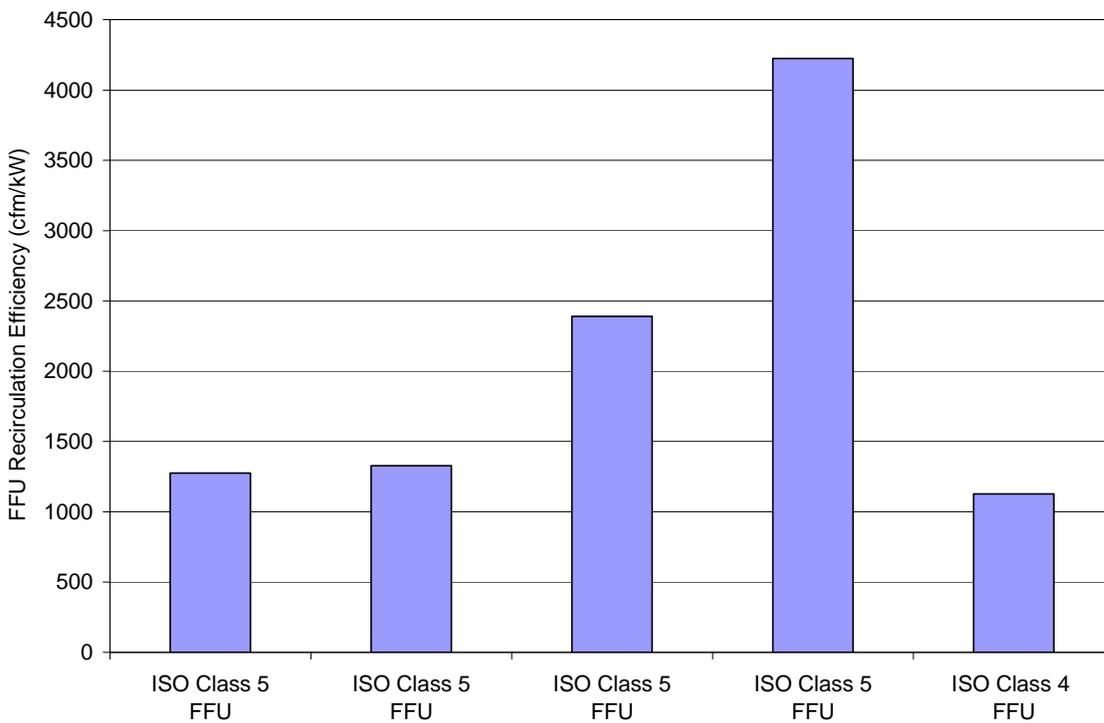


Figure 4. FFU efficiency for ISO Class 5 cleanrooms (kW/cfm)

Related Best Practices

- ◆ Air-change Rate

- ◆ Minienvironments
- ◆ Demand-control Filtration
- ◆ Fan Efficiency
- ◆ Right Sizing
- ◆ Filters

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