

## Introducing a Standard Testing Method for Fan-filter Units

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### Introduction

Cleanroom HVAC systems, especially those requiring fan-filter units (FFU) for recirculating air, typically account for a large portion of energy use in cleanrooms. Performance of HVAC systems varies significantly from cleanroom to cleanroom largely because of various factors, such as contamination control requirements, air handling unit designs, air system resistance, and efficiency levels offered by system components<sup>[1]</sup>. The studies not only uncovered energy-saving opportunities in many cleanroom applications, but also indicated that optimizing aerodynamic performance in air recirculation systems appears to be a useful approach to improve energy efficiency in cleanrooms.

Because of their ease of installation, adaptability, and specific contamination-control schemes, fan-filter units are being used more and more in air recirculation systems in cleanrooms. The large number of small fans can consume considerable energy in providing air recirculation. Therefore, understanding the performance of FFUs is important and can help to promote best practices in cleanroom design and operation. To date, typical manufacturer's data sheets usually contain claims that are seemingly similar; however, they usually do not reveal test methods, if at all exist. Furthermore, statements of performance data that include power, airflow, and sound are commonly vague and could be misleading. In recent years, industries have shown growing interest in having a uniform method for testing and reporting FFU performance. Lawrence Berkeley National Laboratory (LBNL) is performing research to improve energy efficiency in contamination control facilities such as cleanrooms. This project is to develop a standard testing method of evaluating the performance of a fan-filter unit (FFU)<sup>[2]</sup>.

This article describes the activities that LBNL has led in developing the standard for FFU's energy performance. It also summarizes results of laboratory-measured performance of 20 fan-filter units (FFUs) tested by Industrial Technology Research Institute (ITRI)<sup>[3,4]</sup>.

### Partnerships

This procedure is intended for industry use, including fan-filter unit manufacturers, end users, utility companies, and designers. During the development of the standard procedure for testing FFUs' energy performance, we have built strong partnerships with these industry stakeholders and other industry associations. The key partners include:

- California Energy Commission (CEC) and California utility companies
- Industrial Technology Research Institute (ITRI), Taiwan
- The Institute of Environmental Sciences and Technology (IEST)
- Air Movement and Control Association International (AMCA)
- SEMATECH International
- Suppliers and users

### LBNL Laboratory-test Method

#### Principles

Laboratory testing to obtain accurate measurements under various operating conditions

#### Device Layout

The FFU to be tested will be mounted horizontally or vertically on the exit of the air chamber

#### Control and Method

Use an ancillary fan and a damper to control the airflow rate across the FFU tested

#### Instrumentation

- Unit airflow rate<sup>[5]</sup>
- Total power usage
- Static (and total) pressure across the FFU

### Total Pressure (Power) Efficiency

**Total Pressure (Power) Efficiency** is the ratio of airflow velocity power to total electric power input to an FFU; a higher value indicates higher operating efficiency. Figure 1 shows total pressure efficiency curves of individual 4 ft x 2 ft FFUs as a function of airflow speeds at the FFU exit. The total pressure efficiency of one unit could be two-to-three-times as much as others at a typical test condition. The best efficiency of these FFUs at an airflow speed of, say, 0.40 m/s, is around 25%, which

was not surprisingly lower than that of a regular industrial fan with approximately the same capacity. On the other hand, the majority of the 4 ft x 2 ft units tested in this study were able to produce airflow within the range of 0.30 and 0.50 m/s, which is common in cleanroom applications, at a static pressure of about 100 Pa (or about 0.4 inch water) [3].

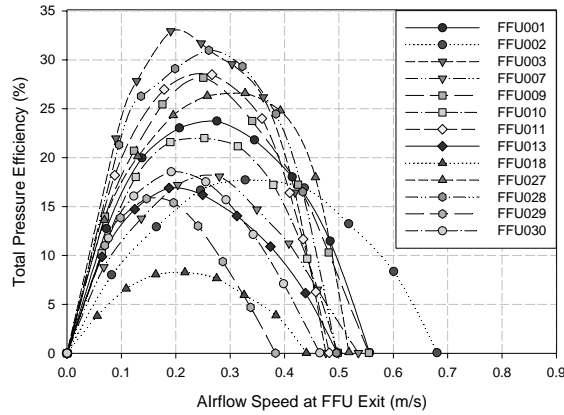


Figure 1. 4’x2’ FFU total pressure efficiency vs. airflow speed at FFU exit

### Energy Performance Index

**Energy Performance Index (EPI)** is the unit’s total power usage normalized by the actual airflow rate through the FFU under certain conditions; a lower value indicates to better capability of delivering more airflow through the FFU supplied by the same level of electric power. Figure 2 shows the EPI values for the thirteen 4 ft x 2 ft FFUs. The median value of the performance index at 125 Pa (or about 0.5 inch water) is approximately 11.3 W per m<sup>3</sup>/min (or 0.32 W/cfm), meaning that 50% of the FFUs tested perform better than 11.3 W per m<sup>3</sup>/min (or 0.32 W/cfm). Figure 3 shows the EPI of 4 ft x 4 ft FFUs at 125 Pa falls in the range of 7.5 watts per m<sup>3</sup>/min (or 0.21 W/cfm) to 13.5 watts per m<sup>3</sup>/min (or 0.38 W/cfm), with the median value of less than 8.0 watts per m<sup>3</sup>/min (or 0.23 W/cfm), which is lower (more efficient) than that of the 4 ft x 2 ft FFUs (11.3 watts per m<sup>3</sup>/min, or 0.32 W/cfm). Overall, the difference between the FFU’s EPI values can be many times as much under a certain operating condition. This indicates that there is potential for many of the FFU suppliers to improve FFU energy performance; in the meanwhile, users will have opportunities to select more efficient units as a means of improving the performance of their cleanroom systems.

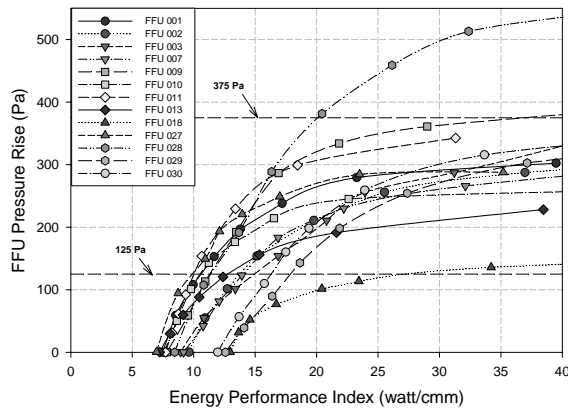


Figure 2. 4’x2’ FFU pressure rise vs. EPI

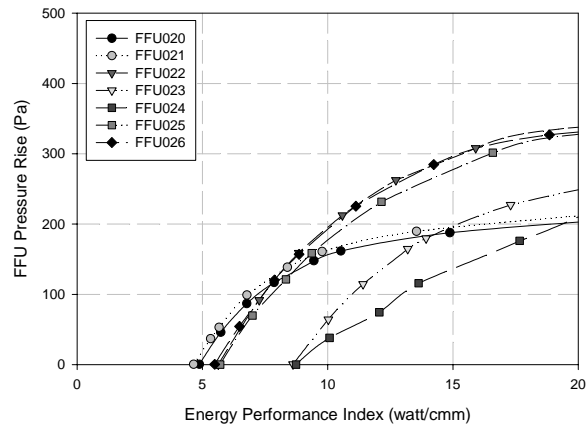


Figure 3. 4'x4' FFU pressure rise vs. EPI

### Summary

The laboratory-test method developed by LBNL [2] applies specifically to evaluating fan-filter units' energy and air movement performance in a laboratory setting. It does not include other performance metrics such as sound, vibration, filtration efficiency, outlet flow uniformity, or in-situ performance. These are nonetheless important to overall FFU performance; and some of these are covered in relevant standards, certification documents, or recommended practices [6, 7, 8]. Currently the procedure is available for public review.

Laboratory testing of FFU energy performance provides useful data for suppliers and end users to understand the performance of FFU products. Significant benefits are expected by having such a method in place and specified by a majority of users. Where FFU applications are required, having comparable information on FFU energy performance would enable selection of more efficient units to improve energy efficiency, while maintaining and improving contamination control. For instance, using such a standard method for testing and reporting the energy performance of fan-filter units, suppliers, users, and designers can make informed decisions to design and select more energy efficient models when FFUs are required. Market transformation toward energy-efficient cleanroom systems could be accelerated through utility incentive programs based upon measured performance data. Utilities and other public interest programs promoting energy efficiency may be able to encourage use of more energy efficient models. Implementing such energy incentive programs will lead to large energy savings in buildings that required FFUs, such as cleanrooms, hospitals, and even post offices. Another ripple effect would be that suppliers would be encouraged to pursue innovative FFU designs that are more energy efficient. In addition, LBNL is collaborating with IEST in developing a new, more comprehensive FFU recommended practice guideline for industry use. Currently the IEST Working Group 36 (WG36) is planning to integrate the LBNL laboratory testing method into its RP development.

Looking forward to the next steps, future R&D efforts would include 1) conducting tests of additional FFUs of various types, with different controls, and different designs; 2) improving FFU designs through investigating additional factors contributing to actual performance levels, such as motor types, and fan wheel design; 3) establishing an industry recommended practice guideline and developing an international standard; and 4) examining the applicability of efficient FFUs in contamination control in a wider market such as hospitals and even post offices.

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