

Lawrence Berkeley National Laboratory

Recent Work

Title

Introducing a standard testing method for fan-filter units

Permalink

<https://escholarship.org/uc/item/1s82k58w>

Journal

Advancing Application in Contamination Control, 7(9)

Author

Xu, Tengfang

Publication Date

2004-06-14

Introducing a Standard Testing Method for Fan-filter Units

Tengfang Xu, Lawrence Berkeley National Laboratory, txu@lbl.gov

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^[1]. 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)^[2].

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)^[3,4].

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^[5]
- 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].

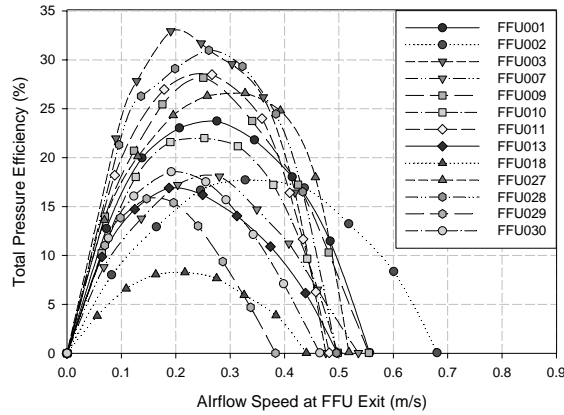


Figure 1. 4’x2’ FFU total pressure efficiency vs. airflow speed at FFU exit

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 m³/min (or 0.32 W/cfm), meaning that 50% of the FFUs tested perform better than 11.3 W per m³/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 m³/min (or 0.21 W/cfm) to 13.5 watts per m³/min (or 0.38 W/cfm), with the median value of less than 8.0 watts per m³/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 m³/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.

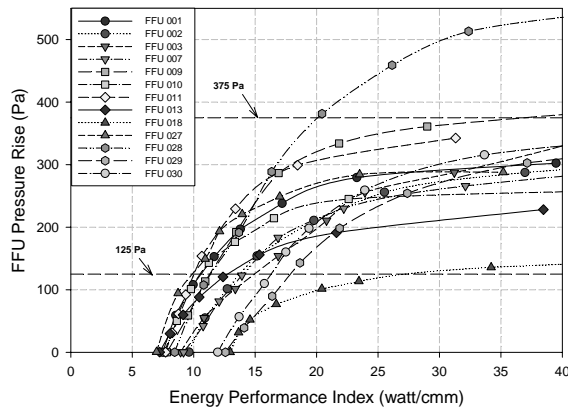


Figure 2. 4’x2’ FFU pressure rise vs. EPI

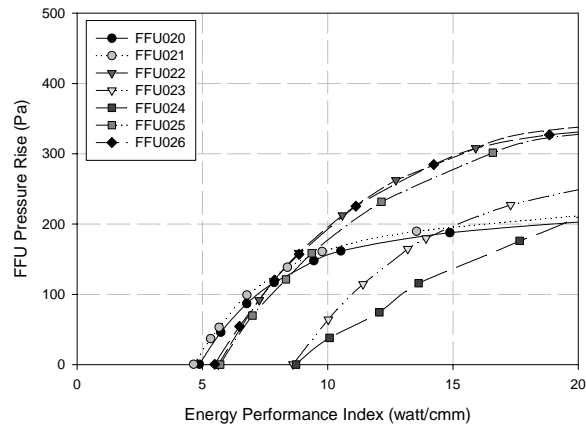


Figure 3. 4'x4' FFU pressure rise vs. EPI

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.

Acknowledgement

This article is based upon a summary of two recent papers published by The Institute of Environmental Sciences and Technology (IEST) [3] and Semiconductor Equipment and Materials International (SEMI) [4]. The project is funded by the California Energy Commission's Industrial section of the Public Interest Energy Research (PIER) program (<http://www.energy.ca.gov/>). This work was supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, Office of Building Technology, State, and Community Programs, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

Article (LBNL-55462) submitted to A2C2 for publication in September 2004 Issue

Author's Bio and Contact Information

Tengfang Xu, Ph.D., PE, TTXu@lbl.gov, 510.486.7810. Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory. He is the project leader and developer of the LBNL standard test procedure ^[2], which is available for public review. Dr. Tengfang Xu is a member of IEST and a voting member in various IEST Working Groups (WGs) in Contamination Control Division. He is the Vice Chair of IEST CC-WG 36 "Fan-filter Unit." A PE and a Ph.D. from UC-Berkeley, he has over sixteen years R&D and consulting experience in building, energy, and environmental sciences. Dr. Xu is a Technical Editor for the Journal of the IEST, and was recently honored by the IEST with 2004 Willis J. Whitfield Award for contributions in contamination control.

References

- [1] Xu, T. 2004. *Efficient Airflow Design for Cleanrooms Improves Business Bottom Lines*. IEST Proceedings of The 49th Annual Technical Meeting: April 2003, Phoenix, AZ. Institute of Environmental Sciences and Technology (IEST), Rolling Meadows, IL. LBNL-52004.
- [2] Xu, T. 2004. *Laboratory Method of Testing Energy Performance of Fan-Filter Units (2nd draft for public review)*. Lawrence Berkeley National Laboratory Report, LBNL-54626, Berkeley, CA.
- [3] Xu, T. and M. Jeng. 2004. *Laboratory Evaluation of Fan-filter Units' Aerodynamic and Energy Performance*. Journal of the IEST, Vol. 47 (2004 Edition), The Institute of Environmental Sciences and Technology (IEST). 5005 Newport Drive, Rolling Meadows, Illinois 60008-3841, USA. LBNL-54250.
- [4] Jeng M., T. Xu, and C. Lan. 2004. *Toward green systems for cleanrooms: Energy efficient fan-filter units*. Proceedings of SEMI® Technical Symposium: Innovations in Semiconductor Manufacturing (STS: ISM), SEMICON® West 2004, San Francisco, CA. Semiconductor Equipment and Materials International, July 2004. LBNL-55039.
- [5] ASHRAE/ANSI Standard 51 (ANSI/AMCA 210-99). 1999. *Laboratory Methods of Testing Fans for Rating*, Air Movement and Control Association International, Inc., Arlington Height, IL, USA.
- [6] The Institute of Environmental Sciences and Technology (IEST). 1997. *IEST-RP-CC006.2: Testing Cleanrooms*. ISBN: 1-877862-26-6. 5005 Newport Drive, Rolling Meadows, Illinois 60008-3841, USA.
- [7] International Organization for Standardization (ISO). 2002. *ISO/DIS 14644-3: Cleanrooms and associated controlled environments. Part 3: Metrology and Test Methods*. The Institute of Environmental Sciences and Technology (IEST), 5005 Newport Drive, Rolling Meadows, Illinois 60008-3841, USA.
- [8] International Organization for Standardization (ISO). 1999. *ISO/DIS 14644-1 Cleanrooms and associated controlled environments. Part 1: Classification of Air Cleanliness*. The Institute of Environmental Sciences and Technology (IEST), 5005 Newport Drive, Rolling Meadows, Illinois 60008-3841, USA