Development of a fan filter unit test standard, laboratory validations, and applications across industries

Standard testing of FFU performance provides useful data for better understanding and characterization of FFU products

By Tengfang (Tim) Xu, PhD, PE, Lawrence Berkeley National Laboratory

Lawrence Berkeley National Laboratory (LBNL) is now finalizing the Phase 2 Research and Demonstration Project on characterizing 2-foot x 4-foot fan filter units (FFUs) in the market using the first-ever standard laboratory test method developed at LBNL.[1–3]

FFUs deliver recirculated air and provide particle filtration control for clean environments. Much of the energy in cleanrooms (and minienvironments) is consumed by 2-foot x 4-foot or 4-foot x 4-foot FFUs that are typically located in the ceiling (25 to 100 percent coverage) of cleanroom environments.

Thanks to funding support by the California Energy Commission's Industrial Program of the Public Interest Energy Research (PIER) Program, and significant participation from manufacturers and users of FFUs from around the world, LBNL has developed and performed a series of standard laboratory tests and reporting on a variety of 2-foot x 4-foot FFUs. Standard laboratory testing reports have been completed and reported back to anonymous individual participants in this project. To date, such reports on standard testing of FFU performance have provided rigorous and useful data for suppliers and end users to better understand, and more importantly, to quantitatively characterize performance of FFU products under a variety of operating conditions.[4] In the course of the project, the standard laboratory method previously developed at LBNL has been under continuous evaluation and update.[5] Based upon the updated standard, it becomes feasible for users and suppliers to characterize and evaluate energy performance of FFUs in a consistent way.

Research findings

After numerous peer reviews across industries, this standard energy and airflow test method for FFUs is used to quantify total pressure efficiency and power consumption of FFUs across a range of operating conditions—defined in terms of actual airflow rates (or velocity) and pressure loss throughout the recirculation system. LBNL has tested 17 different FFUs from manufacturers in Asia, Europe, and North America.

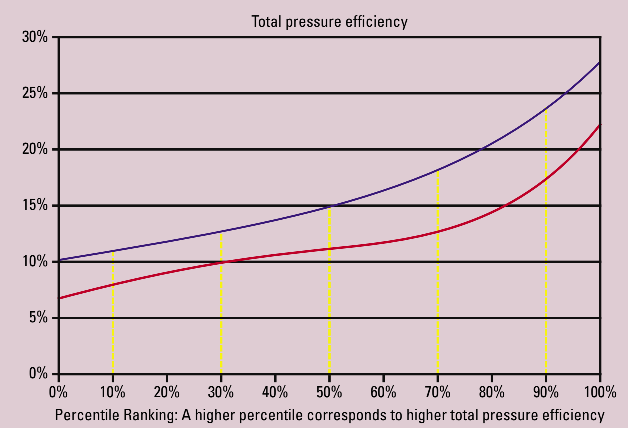
Among these, we have seen electric power demand ranging from under 100 W to 400 W per FFU, and huge (in excess of ten times) intravariations in efficiencies depending upon operating conditions dictated by the pressure rise and airflow rates needed and provided by the FFU.

In addition, for a given typical operating condition we have observed variation, by a factor of three or more, in energy efficiency levels from unit to unit. For example, total pressure efficiency is a yardstick for quantifying a unit's energy efficiency levels, which is defined as the ratio of actual pressure power to total electric power demand for the unit.[6]

Two curves in Figure 1 show the FFU efficiency level as a function of percentile ranking developed from the actual standard test data. While the two curves correspond to different operating conditions, respectively, they both illustrate significant variations in energy efficiency from unit to unit. Under the same operating condition, the efficiency level of the most efficient unit (shown at the right-hand side in the graph, e.g., 99 percentile) was as much as over three times that of the efficiency level of the least efficient unit (shown at the left-hand side in the graph, e.g., 1 percentile).

Further analyses of the test data indicate that actual energy performance of the FFU is related to FFU motor type, housing and air-path design, size of the unit, and filtration materials. Much more experimental work needs to be pursued in order to quantify the impact from each of these parameters.

Figure 1: Energy efficiency level vs. percentile ranking of sample FFUs



Standard adoption and market impacts

The LBNL standard has been and is being adopted by specifiers and owners to understand FFU performance. The results are used in their process of selecting and purchasing FFUs with better and improved energy performance. In addition, the outcomes of the standard tests are now being considered by utilities seeking to promote applications of energy efficient FFUs. A successful energy-rebate program would allow a utility to provide financial incentive for end users to specify and purchase energy-efficient FFUs. Furthermore, some end users have been proactively pursuing ways to reduce cleanroom operating costs and life-cycle costs by selecting energy-efficient FFUs. For example, in designing and constructing large cleanrooms, some large companies in the U.S. and Asia, including Texas Instruments, have required FFU suppliers or bidders to perform and report characterization tests according to the LBNL standard, which allows provision and comparison of performance data in a consistent way.[7]

Identifying and selecting energy efficient units in cleanroom applications can bring about savings in energy costs over their lifetimes while maintaining and improving the effectiveness of contamination control.[8–14] Through this research and demonstration project, it becomes feasible for end users or cleanroom owners to become better informed of energy performance to aid in their planning and selection for use in new facility construction or renovation. For example, they may now require suppliers to provide a unit's performance as obtained through the LBNL standard. Also, more FFU manufacturers are becoming motivated to quantitatively understand performance of their units, and to improve design, operation and controls of their FFUs to better serve industries. Furthermore, utility companies or other public interest programs may use the results and recommendations to establish energy-rebate criteria, and implement additional programs to encourage the use of efficient units. Last but not the least, this work will continue to add to and enhance the development of an industrial standard, such as IEST-RP-CC036.1.[15]

Evaluating and advancing FFU technologies

With energy costs nearly double or triple what they were a few years ago, cleanroom owners industrywide and worldwide are now working toward battling high utility bills as part of curtailing expenses.[16] For numerous cleanroom managers and designers, the trends in cleanroom design over the years to come are becoming clearer in that energy and resource conservation, as well as consolidation, are critical.

The increasing energy costs of operating future cleanrooms have not only prompted end users to seek and select higher-efficiency FFUs in their cleanroom applications,[17] but have also motivated a number of suppliers to better understand their products and to develop higher-efficiency FFUs for future cleanrooms.[18] For example, more and more manufacturers

continued on page 34

continued from page 33

are interested in systematically quantifying the impact of fan-wheel design, sizes of air-path and unit, motor type, and airflow control techniques.

In addition, users are paying attention to airflow uniformity and energy consumption over the lifetime of FFU operation, along with reliability and control readiness in cleanroom contamination control using FFUs. Having such a rigorous test standard available and in place provides a platform for industries to evaluate and advance filtration technologies using FFUs.

While the contamination control industries are moving toward tighter contamination control and increasing desire for higher energy efficiency, it is important to strategize the development and implementation of higher-efficiency FFUs in actual cleanrooms. The following are some important actions that need to be ongoing:

- Disseminating new knowledge in testing and results among technical and professional societies and across industries
- Providing technical assistance to users and manufacturers to select efficient FFUs and improve FFU performance
- Assisting utilities to establish and implement energy-rebate programs to promote FFUs that outperform others
- Interacting with relevant professional societies and standard development bodies to further absorb and adopt the refined standard

Acknowledgments

The project is funded by the California Energy Commission's Industrial Program of the Public Interest Energy Research (PIER). LBNL wishes to acknowledge Paul Roggensack, Anthony Wong, and Pramod Kulkarni of California Energy Commission for their support of this project. 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-AC02-05CH11231.

Dr. Tengfang (Tim) Xu, PE, is a program manager with Lawrence Berkeley National Laboratory. He can be reached at TTXU@LBL.Gov.

References

1. Xu. T. and D. Wang. In progress. "Demonstration of Advanced Filtration Technologies: Developing Energy-rebate Criteria through Performing Standard Laboratory Tests and Statistical Analyses." Lawrence Berkeley National Laboratory Report, LBNL-61684.
2. Xu, T. "Laboratory Method of Testing Energy Performance of Fan filter Units, Version 1.3," LBNL Report, LBNL-54626, Berkeley, CA (2005).
3. Xu, T. "Laboratory Method of Testing Energy Performance of Fan filter Units, Version 2.0," LBNL Report, LBNL- 61685, Berkeley, CA (2006).
4. See reference 1.
5. See references 2 and 3.
6. Xu, T. and M. Jeng. "Laboratory Evaluation of Fan filter Units' Aerodynamic and Energy Performance," *Journal of the IEST* 47 (2004): 116–120.
7. See references 2 and 3.
8. See reference 6.
9. Gale, S. "FFUs: Setting a course for energy efficiency," *CleanRooms* (September 2004).
10. Xu, T. "Introducing a Standard Testing Method for FFUs," *Controlled Environments* (September 2004).
11. M. Jeng, T. Xu, C. Lan. "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. LBNL 55039.
12. Xu, T. "Developing a Standard Method For Evaluating Fan filter Unit Performance–Applications in Utility Incentive Programs," poster distributed to three major California utilities, California Energy Commission, and other stakeholders (2004).
13. Xu, T., C. Lan, and M. Jeng. "Performance of Large Fan Filter Units for Cleanroom Applications," *Building and Environment*, LBNL-58220 (2006).
14. Chen, J., C. Lan, M. Jeng, and T. Xu. (In press). "The Development of Fan Filter Unit with Flow Rate Feedback Control in a Cleanroom," *Building and Environment*, LBNL-60530.
15. The Institute of Environmental Sciences and Technology (IEST). Draft IEST-RP-CC036.1: *Testing Fan Filter Units*. Rolling Meadows, IL. For more information, visit http://www.iest.org.
16. Gale, S. F. "Rising energy costs dictate cleanroom design," *CleanRooms* (February 2006).
17. Hogan, H. "Fabs new and old save millions in contamination-control energy costs," *CleanRooms* (September 2005).
18. See reference 1.


More than just a supplier. Customized solutions to fit you.
Any company can be a supplier. But what you really need is a partner. One that's devoted to the highest level of service.
ARAMARK stands alone in our complete dedication to excellence. That's why we have Quality Assurance Managers at each processing facility, each with a complete staff of QA technicians. So you can rest assured that your cleanroom garments meet our strict standards. With ARAMARK, you can feel confident you have the right solution.
Most cleanroom suppliers conform to standards.
Only one company sets them.
We fit the way you work™
1-800-759-0102
www.ARAMARK-Cleanroom.com
ARAMARK®
Cleanroom Services