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Development of a Fan-Filter Unit Test Standard, Laboratory Validations, and its Applications across Industries

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Development of a Fan-Filter Unit Test Standard, Laboratory Validations, and its Applications across Industries

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Lawrence Berkeley National Laboratory (LBNL) is now finalizing the Phase 2 Research and Demonstration Project on characterizing 2-foot x 4-foot (61-cm x 122-cm) fan-filter units in the market using the first-ever standard laboratory test method developed at LBNL.[1][2][3]

Fan-filter units deliver re-circulated 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 (61-cm x 122-cm) or 4-foot x 4-foot (122-cm x 122-cm) fan-filter units that are typically located in the ceiling (25-100% coverage) of cleanroom controlled 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 fan-filter units 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 (61-cm x 122-cm) fan-filter units (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.[1] In the course of the project, the standard laboratory method previously developed at LBNL has been under continuous evaluation and update.[2][3] Based upon the updated standard, it becomes feasible for users and suppliers to characterize and evaluate energy performance of FFUs in a consistent way.

1. Research Findings

After numerous peer-reviews across industries, this standard energy and airflow test method for FFUs is used to quantify FFUs' total pressure efficiency and power consumption across a range of operable 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 intra-variations in efficiencies (in excess of ten-times) depending upon operating conditions dictated by the pressure rise and airflow rates needed and provided by the fan-filter unit.

In addition, for a given typical operating condition we have observed a factor of three or more variation 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.[3][4]

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 corresponded 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 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 indicates 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.

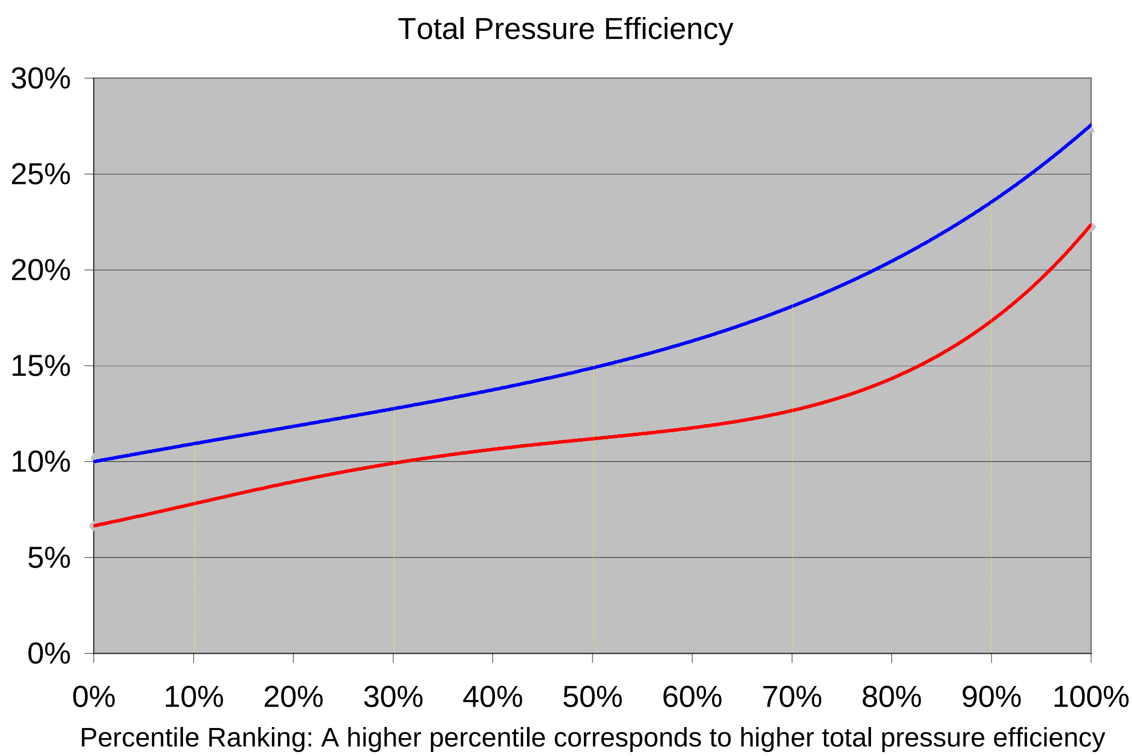

Figure 1 Energy Efficiency Level vs. Percentile Ranking of Sample FFUs

2. 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 fan-filter units 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 fan-filter units. Furthermore, some end-users have been proactively pursuing ways to reduce cleanroom operating costs and life-cycle costs by selecting energy-efficient fan-filter units. For example, in designing and constructing large cleanrooms, some large companies in the US 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.[2][3]

Identifying and selecting energy efficient units in cleanroom applications can bring about savings in energy costs in their lifetime while maintaining and improving the effectiveness of contamination control.[4][5][6][7][8][9][10] Through this research and demonstration project, it becomes feasible for end users or cleanroom owners to become better-informed of the 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 the units' performance obtained through the LBNL standard. In addition, more FFU manufacturers are becoming motivated to understand performance of their units, and to improve design, operation and controls of their FFUs in order 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 the development of an industrial standard, such as IEST-RP-CC036.1.[1]

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[1] *The Institute of Environmental Sciences and Technology (IEST). Draft IEST-RP-CC036.1: Testing Fan Filter Unit. Rolling Meadows, IL. To purchase or obtain more information about IEST-RP-CC036.1 or other Recommended Practices and Working Groups, contact IEST at (847) 255-1561, e-mail them at iest@iest.org or, go to the IEST website at http://www.iest.org/technical/ccwgs.html. IEST is located at 5005 Newport Drive, Suite 506, Rolling Meadows, IL 60008-3841.*

About IEST. *Founded in 1953, IEST is an international technical society of engineers, scientists, and educators that serves its members and the industries they represent (simulating, testing, controlling, and teaching the environments of earth and space) through education and the development of recommended practices and standards. IEST is an ANSI-accredited standards-developing organization; Secretariat of ISO/TC 209 Cleanrooms and associated controlled environments; Administrator of the ANSI-accredited US TAG to ISO/TC 209; and a founding member of the ANSI-accredited US TAG to ISO/TC 229 Nanotechnologies.*

3. Trends and Strategies in Evaluating and Advancing FFU Technologies

With energy costs nearly double or triple what they were a few years ago, cleanroom owners industry-wide and worldwide are now working toward battling high utility bills as part of curtailing expenses.[11] For numerous cleanroom managers and designers, the trends in cleanroom design for the years to come are becoming clearer in that energy and resource conservation as well as consolidation is critical.

Increasing energy costs in operating future cleanroom have not only prompt end-users to seek and select higher-efficiency FFUs in their cleanroom applications,[12] but also motivated a number of suppliers to better understand their products and to develop higher-efficiency FFUs for future cleanrooms.[1] For example, more and more manufacturers 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 fan-filter units. Having such a rigorous test standard available and in place provides a platform for industries to evaluate and advance filtration technologies using fan-filter units.

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 includes important actions that need to be taken continuously:

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

4. Issues for Future Development

Through extensive review of the literature, development of the standard laboratory test, and experimental validations in the laboratory, the following issues are identified and need further development.

- Continue to improve rigor and robustness of the standard, e.g., the size impact and air leakage integrity of test rig.

- Characterize internal pressure distribution, e.g., pressure variations across HEPA/ULPA filters.
- Characterize airflow uniformity.

- Characterize design and speed-control impacts on overall performance, e.g., type of motors, internal housing, air path, and size and control of units. For example, characterize fan-filter units of larger sizes such as 4'x4' (122-cm by 122-cm).

5. Xu's Bio

Dr. Tengfang (Tim) Xu, PE, is a Program Manager with Lawrence Berkeley National Laboratory, managing and performing R&D projects to quantify energy efficiency and improve building performance in commercial, residential, and industrial buildings including mission-critical buildings such as cleanrooms and data centers. Xu is the Contamination Control Technical Vice President of IEST. Dr. Xu is a recipient of numerous national awards for best scientific papers, publications, and professional services. At Berkeley Lab, Dr. Xu develops innovative methods and protocols that are instrumental in formulating a standard to characterize fan-filter units; in addition, Xu manages and performs evaluations of energy, airflows and filtration requirements for cleanrooms and minienvironments. Dr. Xu's interests and accomplishments are exemplified by producing and disseminating new knowledge and techniques to improve performance of mission–critical buildings including cleanrooms and minienvironments, and helping the industries (users, suppliers, and utilities) in energy and product management.

For more information on the standard and research, please contact Dr. Tengfang (Tim) Xu at TTXU@LBL.Gov; http://eetd.lbl.gov/Staff/XuTT/.

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