The Thrust of ANSI/AMCA Standard 230-15

Circulator Fan Performance Testing Standards

BY CHRISTIAN TABER, BEMP, HBDP, MEMBER ASHRAE

Inventor Philip Diehl is credited with creating the first electric ceiling fan out of a modified sewing machine motor in the 1880s.[1] The invention led to a manufacturing boom, and fans of different sizes, with varying numbers of blades and blade shapes, soon became available to consumers. Manufacturers sought to stand out from one another, and early 1900s print advertisements show the same selling points we see today—including efficiency claims (*Photo 1*).

However, for more than 100 years after the inception of the electric ceiling fan, there was no widely accepted standard to back up those claims, and fan manufacturers published data based on different assumptions, using disparate conditions and rating methods.

The Journal of the Institution of Electrical Engineers acknowledged the problem as far back as the 1920s:

> "It appears to be the practice to state the volume of air displaced per minute by a ceiling fan without any reference to the conditions under which the measurements are made.... When ceiling fans are being compared on the basis of air displacement, such comparison is useless unless the measurements have been made under similar conditions."
>
> -E. Hughes, 1926[2]

It wasn't until 1999 that the Air Movement and Control Association (AMCA) introduced ANSI/AMCA Standard 230-99, *Laboratory Methods of Testing Air Circulating Fans for Rating and Certification*, which set uniform requirements for testing the performance of circulating fans. Energy Star created a standard specifically for residential ceiling fans three years later. AMCA Standard 230-99, while widely accepted for nonresidential fans, didn't account for a new type of industrial fan that was invented at roughly the same time: high-volume, large-diameter (HVLD) fans. The primary issue was the standard's requirement that the ceiling height of the test chamber be three times the diameter of the fan; for a 24 ft (7.3 m) industrial fan, this would require a testing facility with a 72 ft (21.9 m) ceiling.

The emerging HVLD fan industry found itself where the residential ceiling fan industry as a whole had been 100 years prior—without a practical standard for measuring performance. Therefore, manufacturers of HVLD ceiling fans used numerous rating methods and test

Christian Taber is a senior research engineer at Big Ass Solutions, Lexington, Ky. He is a member of ASHRAE SSPC 90.1 and SSPC 189.1, and of the AMCA Standard 230 committee.

conditions (often of their own making), or modifications of existing standards like AMCA Standard 230, to measure the efficiency and performance of large fans. But without a viable testing standard in place, design professionals have been unable to accurately compare the performance of different fan models.

ANSI/AMCA Standard 230-15, which is expected to be published next month, will finally correct this. It will provide new means for determining and expressing ceiling fan efficiency and efficacy for both standard and HVLD fans.

While data produced by the standard won't tell design professionals precisely which fan is best for any given application—for example, whether an 8 ft (2.4 m) or 24 ft (7.3 m) diameter fan is better for a facility—it will solve the "E. Hughes problem," allowing a direct comparison of similar fans based on a variety of performance metrics, backed by uniform testing conditions and third-party certification. Another standard, proposed ASHRAE Standard 216P, *Methods of Test for Determining Application Data of Overhead Circulator Fans*, will provide a better way to compare how different fans work in a given space (see "Future Considerations").

Past Iterations of AMCA Standard 230

In general, AMCA Standard 230 sets uniform testing procedures for determining fan performance, including airflow rate (cfm or m^3/s), power consumption (W), efficiency, thrust (lb_f or N) and efficacy (cfm/W or $m^3/s{\cdot}W$). The standard has gone through several revisions since it was first published in 1999. The following is an overview of changes made during each iteration.

AMCA Standard 230-99. The first version of the standard measured the load differential generated by the fan and power consumed by the fan. Thrust and airflow rate were calculated from load differential, and all values were at ambient conditions. However, the equation for airflow (EQ9.5) significantly overestimated the airflow generated by the fans. Clearance requirements (1 fan diameter above; whichever was larger of 2 diameters or 10 ft [3 m] below; and 2 diameters from the center of the fan to the wall) limited the ability to test large-diameter fans. See Test Figure 1 from AMCA Standard 230-99 (*Figure 1*).

AMCA Standard 230-07. The first revision of the standard retained similar measurement

PHOTO 1 Early 1900s fan print advertisement.

requirements. There were no changes to clearance requirements from the original standard. For lab-to-lab consistency, thrust was corrected from ambient air conditions to standard air conditions. Airflow rate and the associated equations were removed from the standard. This revision had a somewhat limited adoption because thrust is not as commonly understood as airflow rate.

AMCA Standard 230-12. Airflow rate was reintroduced with a revised equation, and new metrics were introduced for the first time, including total pressure, fan total efficiency (input power divided by power in the output air) and fan efficacy (airflow rate of the fan divided by the power consumed by the fan). The scope of the standard was limited to ceiling fans under 6 ft (1.8 m) in diameter.

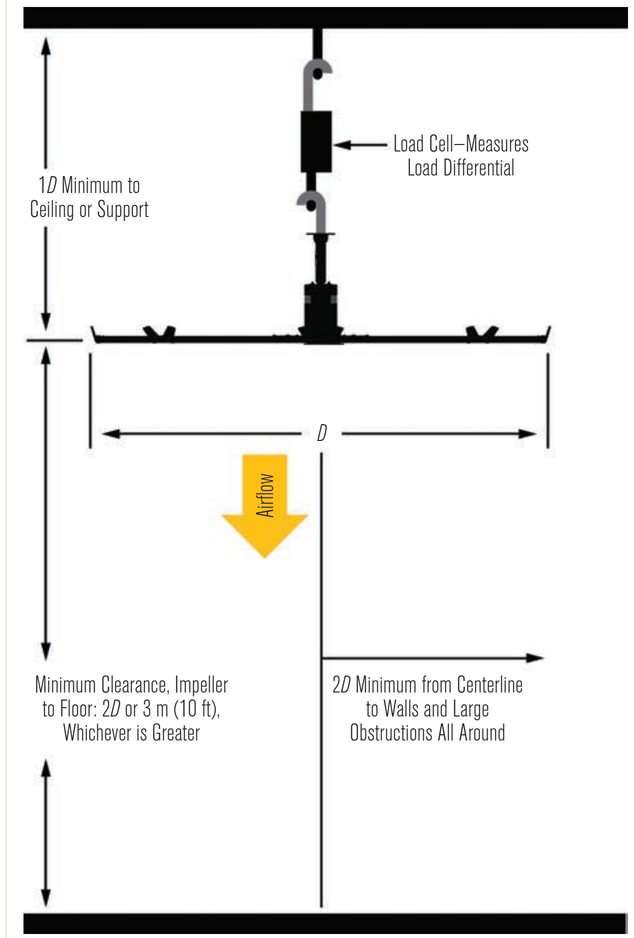
Summary of Major Changes in 2015

The 2015 version of the standard will allow for more than the testing of large-diameter ceiling fans alone; it will also provide clarity to testing procedures for fans of all sizes. The following changes will be made in the 2015 version:

- New clearance requirements: 0.4 diameter above; the larger of 0.8 diameter or 15 ft (4.6 m) below; and 1.5 diameters from the center of the fan to the walls. Thorough testing was done to establish the minimum clearances that will not impact fan performance.

- Removal of the 6 ft (1.8 m) diameter limit for ceiling fans. The maximum fan size will be determined by the size of the test chamber and the minimum clearance requirements.
- Clarification that forward and reverse flow are covered by the standard. Since some fan manufacturers recommend reverse operation during heating season, Test Figure 1 will be revised to show both forward and reverse airflow. Reverse flow performance will be added to the purpose section of the standard.
- Revision of efficiency and efficacy metrics, including which values will be reported at ambient conditions and which will be reported at standard conditions. Power, efficacy, and total fan efficiency will be reported at ambient conditions, while thrust will be reported at standard conditions.
- Fans will be rated at 20%, 40%, 60%, 80%,and 100% of maximum speed (defined by rpm). As the efficiency of the motor and associated variable speed device (if applicable) change at part-load conditions, the fan affinity laws provide the general shape of the performance curve, not accurate values for real-world fan performance.
- Clarification of calibration, sampling intervals, and minimum measurement time, which provide consistent measurements for tests carried out at different certified test labs.
- The location of the measurement for input power changed from the motor input to fan system input, before any associated variable speed device. This will allow the total fan system energy consumption (wire-to-air) to be measured.
- Measurement for the input power to the fan system will be done simultaneously on all phases of power to ensure accurate measurement of the electricity consumed by the fan system.
- The requirements for the final test report will be clarified, including general test information, data collected during testing, calculated values and calibration information. This will provide consistent reporting of data from certified labs for verification of fan performance.

FIGURE 1 AMCA Standard 230-99 test Figure 1.



Performance Data: Efficiency & Efficacy

Input power, volumetric airflow rate, and efficacy have long been the standard metrics for comparing fan performance. They will still likely be components of the data used for comparisons going forward. However, fans tested under AMCA Standard 230-15 will also provide a wealth of other data, which will help engineers, designers and end users compare fans. With this plethora of data soon to be available, designers and end users should be aware of some potential pitfalls. Below are examples of how performance data has been (and may continue to be) misleading, along with some suggestions on how to better use that data for fan comparison purposes.

An example of two fan efficacy curves generated at the required five measurement speeds is provided in *Figure 2*. Glancing at the graph, it appears that Fan 2 has a higher efficacy at all speeds, averaging 85 cfm/W (0.04 $m^3/s{\cdot}W$) more than Fan 1. However, there is a

FIGURE 2 Fan efficacy versus fan speed.

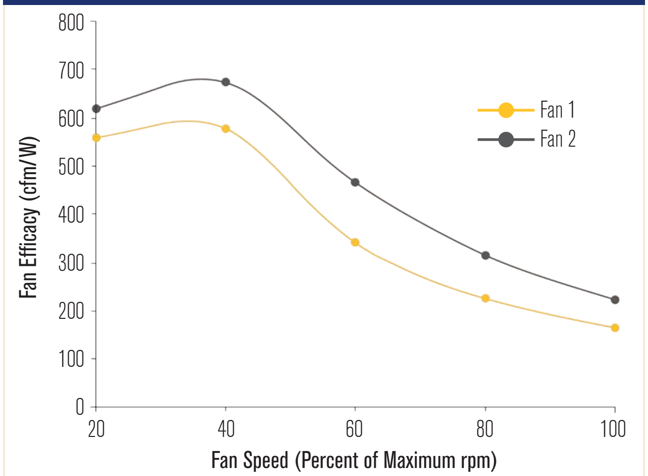
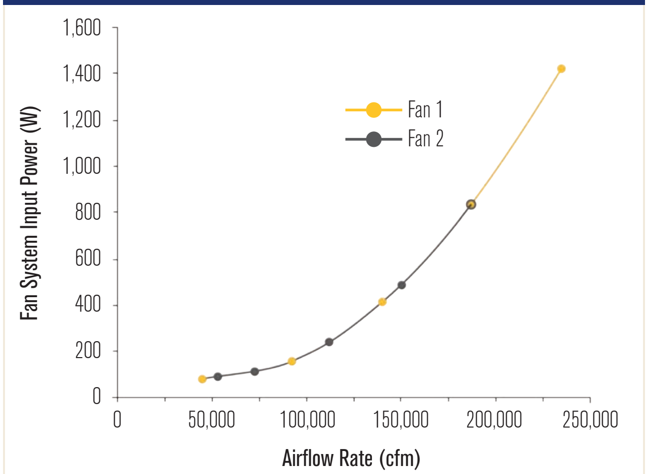


FIGURE 3 Fan power versus airflow rate.



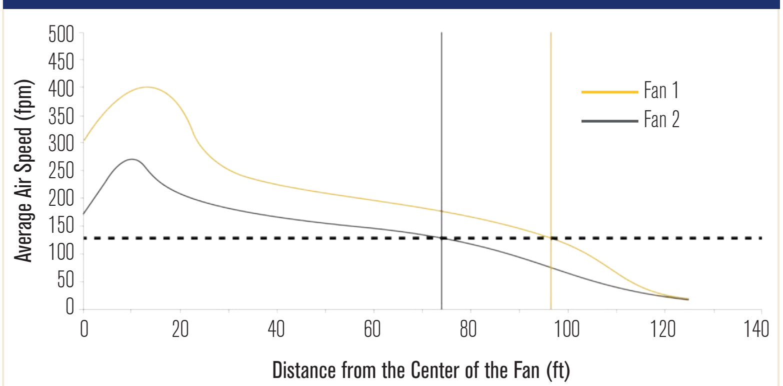
fundamental issue with rating or comparing fans based only on efficacy and using percentage of maximum speed as a basis for the comparison. A simple way to improve fan efficacy is to simply decrease the maximum speed of the fan.

In *Figure 3*, we plot the airflow rate and power of the two fans shown in *Figure 2*. It quickly becomes clear that Fans 1 and 2 are actually the same fan; the only difference is that Fan 2 had its maximum speed reduced to 80% of Fan 1's maximum speed. For efficacy-based comparisons, it is important that the work done by the fan, the airflow rate, be factored into the assessment. Comparing fan efficiency at similar airflow rates provides a more accurate picture of fan performance than comparing efficacy at a percent of maximum speed. Designers can now evaluate not only efficiency and efficacy, but airflow rate and power data at part-load conditions.

TABLE 1 Fan efficiency and power reduction.

PERCENT OF MAXIMUM SPEED	20%	40%	60%	80%	100%
FAN 1 OVERALL EFFICIENCY	15%	23%	31%	33%	35%
INPUT POWER REDUCTION	50 W	50 W	50 W	50 W	50 W
FAN 2 OVERALL EFFICIENCY	41%	34%	35%	35%	36%
REQUIRED EFFICIENCY INCREASE	26%	11%	4%	2%	1%

FIGURE 4 Average air speed versus distance from the center of the fan.



Fan overall efficiency is the ratio of the power in the air exiting the fan to the fan system input power. *Table 1* shows the fan overall efficiency for two fans that have equal airflow rates at each rated speed. The efficiency of the motor in Fan 2 was increased to provide a 50 W power savings at each operating speed.

When dealing with fan overall efficiency, it is important to remember that at low operating speeds, the power consumption of the fan is dramatically reduced. The power savings offered by high part-load efficiency may not be as large as the difference the fan overall efficiency indicates. To save 50 W at 100% of maximum rpm, a 1% increase in fan overall efficiency is required. At 20% of maximum rpm, a 26% increase in fan overall efficiency is required to achieve the same power reduction.

In short, the fan with the highest efficacy or overall efficiency at a certain operating speed may appear to be the best choice, but reducing the fan's output to alter the efficacy or efficiency can limit the fan's usefulness in any given application, potentially requiring additional fans to meet the design performance requirements.

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The following example demonstrates how the new data from AMCA Standard 230-15 can be helpful in applying fan models in a given space.

Example Use of Data

The 2015 version of the standard will provide certified performance data for thrust (lb_f or N), airflow rate (cfm or m^3/s), power consumption (W), efficiency, and efficacy (cfm/W or $m^3/s \cdot W$) at five operating speeds. How will a designer use this information in an actual application?

A hypothetical 575 ft long (175 m), 150 ft wide (45.7 m), 40 ft tall (12.2 m) airplane hangar in Lexington, Ky., illustrates how ceiling fans can be applied in a space, as well as how performance data from Standard 230-15 can be used to compare fans and estimate annual operating cost.

Based on thermal comfort calculations using the ASHRAE Thermal Comfort Tool, it has been determined that 125 fpm (0.64 m/s) of average air speed at occupant level is required to achieve acceptable thermal comfort in this application (as per ANSI/ASHRAE Standard 55-2013[3]). Fan 1 and Fan 2 from the first example (*Figures 2* and *3*) will be used to provide the elevated air speed.

Air speed provided by Fan 1 falls below 125 fpm (0.64 m/s) at approximately 95 ft (29 m) from the center of the fan. Fan 2, which had its top speed reduced by 20%, provides 125 fpm (0.64 m/s) of air speed at approximately 75 ft (22.9 m) from the center of the fan (*Figure 4*, Page 32).

Therefore, three Fan 1 products or four Fan 2 products would be required for complete coverage of the hangar (*Figure 5*).

The annual energy consumption of the fans can be estimated using the proposed control sequence for the HVLD fans, the power data at five operation speeds from Standard 230-15, and bins of estimated indoor air temperatures for the building.

In this example, the proposed control sequence would increase fan speed based on the indoor air temperature during the cooling

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season. The indoor air temperature for the hangar was estimated using simulation software and code minimum lighting and envelope values from ANSI/ASHRAE/IES Standard 90.1-2010.[4] Fan 1 Scenario assumes three Fan 1 products. Fan 2 Scenario assumes four Fan 2 products. During the heating season, the fans are operated at 20% of maximum speed in the forward direction for destratification. Since some manufacturers recommend reversing the fan in the heating season, a reverse winter scenario has been included. The Fan 2 Reversed Scenario assumes those same four Fan 2 products operated in the reverse direction at 50% of maximum rpm during the heating season, rather than 20% in the forward direction. The annual energy consumption and operating cost for three scenarios is shown in *Table 2*.

Based on the estimated installed cost, annual energy consumption and annual energy cost (among other factors), the designer can evaluate the most appropriate fan selection for the space.

Future Considerations

Accurate air speed performance data is not currently available from most circulator fan manufacturers. The proposed ASHRAE Standard 216P, *Methods of Test for Determining Application Data of Overhead Circulator Fans*, will complement the data available in AMCA Standard 230-15 to help users more accurately compare air speed performance data.

It is also worth noting the U.S. Department of Energy is currently working on minimum efficiency requirements for all ceiling fans. (See rulemaking docket EERE-2012-BT-STD-0045.) Under the proposed requirements, fans less than or equal to 7 ft (2.1 m) in diameter will be covered under modified ENERGY STAR testing requirements. For ceiling fans larger than 7 ft (2.1 m) in diameter, it is likely that a modified version of Standard 230-15 will be the basis of the testing procedures.

Conclusions

The 2015 version of AMCA Standard 230 will provide a level playing field for the testing of large fans for the first time in history. It

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FIGURE 5 Overhead view of fans in a hypothetical hangar.

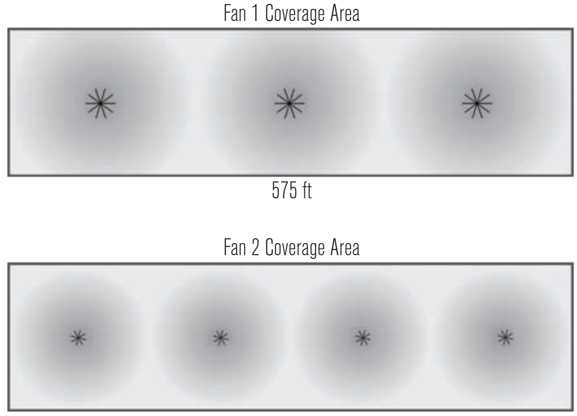

TABLE 2 Annual fan energy consumption and cost for three design scenarios.

INDOOR TEMPERATURE	FAN SPEED	ANNUAL HOURS	FAN 1 (KWH)	FAN 2 (KWH)	FAN 2** (KWH)
83°F+	100%	507	2,159	1,686	1,686
81°F to 83°F	80%	212	529	408	408
79°F to 81°F	60%	817	1,007	783	783
77°F to 79°F	40%	562	270	242	242
Heating (65°F)	20%	3,202	776	1,099	2,224
Total	–	5,300	4,741	4,218	5,344
Annual Operating Cost*	–	–	$375	$334	$423
Estimated Installed Cost	–	–	$21,000	$28,000	$28,000

* Cost of electricity is $0.0792/kWh per U.S. EIA, Electric Power Monthly, Table 5.6B, March 2015
** Assumes fan is reversed in the heating season only and operating at 50% of maximum speed

will also provide a more consistent method of testing across the circulator fan industry by reducing lab-to-lab variation. Tests conducted under the standard will provide useful information for designers of large spaces, and careful application of that data can help designers select fans for any facility or purpose. However, mindful evaluation of the data is required to achieve an accurate and useful comparison.

References

1. Diehl, P. 1891. "Electric fan." U.S. Patent 417,474.

2. Hughes, E., W.G. White. 1927. "Testing of ceiling fans." *Journal of the Institution of Electrical Engineers* 65(363): 367–372.

3. ANSI/ASHRAE Standard 55-2013, *Thermal Environmental Conditions for Human Occupancy.*

4. ANSI/ASHRAE/IES Standard 90.1-2013, *Energy Standard for Buildings Except Low-Rise Residential Buildings.* ■