A Revolutionary Method of Saving Energy for Commercial and Industrial Fan Systems

Michael Ivanovich, Mark Bublitz**, Tim Mathson****

**AMCA International; **New York Blower Company; ***Greenheck Fan Company*

ABSTRACT

Fan energy index (FEI) and fan electrical power (FEP) are design-point metrics that emphasize compliant fan selections and as a result break away from the traditional approach of eliminating product models based on best efficiency points and minimum efficiency thresholds. Consequently, FEI and FEP address the challenge inherent in and somewhat unique to fans: separating a fan's energy efficiency capability from the energy efficiency of the fan as applied in a system.

This paper provides background on first-generation fan efficiency metrics and describes FEI and FEP and how these metrics may be used in regulations and rebate programs as second-generation fan-efficiency metrics.

Introduction

U.S. Department of Energy (DOE)[1] actions to regulate commercial and industrial fans and blowers prompted AMCA International[2] to develop a new, more sophisticated metric to supplant a fan-only metric developed in 2010 and employed in model energy codes and standards. The fan industry has consequently set forth a path to evolve from first-generation metrics to second-generation metrics.

Since first-generation fan-efficiency metrics were first published by AMCA International in 2010 (Ivanovich and Jones 2014), the fan engineering community has substantially advanced its understanding and treatment of fan efficiency, leading to the development of second-generation fan-efficiency metrics. DOE provided the motivation for much of the development when they communicated the intention to regulate commercial and industrial fans and blowers in June 2011 (DOE 2011). DOE subsequently released a rulemaking framework document in February 2013 (DOE 2013). In the framework document, DOE indicated a preference for a metric based on electrical power consumption. This was a departure from the first-generation metric, fan efficiency grade (FEG), that was making its way into model codes and standards for energy efficiency and green construction (Ivanovich and Jones 2014).

FEG is an efficiency representation closely tied to what could be described the base fan unit, commonly referred to in the fan industry as a bare fan. The bare fan typically consists of the fan impeller, a drive shaft, and a fan housing, if present, but does not include motors and drives (Cermak and Ivanovich 2013). This metric is incomplete with respect to "extended product"

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[1] The rulemaking is being administered by the Appliance and Equipment Standards Program within the Office of Energy Efficiency and Renewable Energy.

[2] The Air Movement and Control Association International (AMCA) is a not-for-profit manufacturers association for companies that make fans, dampers, louvers and other air-system products.

approaches taken for other motor-driven loads, i.e., clean water pumps, in the U.S. and Europe (EC 2011) (DOE 2016). FEG on its own is not capable of estimating electrical input power to the fan system. The concept of FEG was extended to a wire-to-air metric with the introduction of the fan motor efficiency grade (FMEG) described in ISO Standard 12759 in 2010 (ISO 2010). ISO Standard 12759 is employed in European fan-efficiency regulations effective January 2012 (EC 2011). Although FMEG is a wire-to-air metric, it remains a first-generation metric based on a fan system's capability to operate efficiently. Differences between the FEG and FMEG metrics and how these metrics are applied in U.S. and European fan-efficiency regulations are described in a paper presented at CIBSE/ASHRAE Technical Symposium in Dublin, Ireland, in 2014 (Ivanovich and Jones 2014). Second-generation metrics were also envisioned in this paper, citing DOE regulation as the source. However, at the time of publication, not enough progress was made in the rulemaking to communicate details of a metric.

Since the 2011 notice of preliminary determination and the 2013 framework document, a fan working group of more than 20 stakeholders under the direction of the Appliance Standards and Rulemaking Federal Advisory Committee (ASRAC) was initiated, and the effort was completed with the publication of a term sheet (DOE 2015). During the regulatory development, DOE published three notice of data availability (NODA) packages containing analytical reports and spreadsheets as well as hundreds of comments posted to the public docket. DOE has yet to publish a notice of proposed rule (NOPR) for the test procedure and labeling requirements or the efficiency standard requirements. Consequently, while the regulatory process is well underway, dates of publication for final rules in these matters are indeterminate.

A DOE-mandated metric and test procedure would provide a basis to develop utility rebate programs, and lacking these items creates a challenge. However, the rulemaking has progressed sufficiently enough that industry is confident the DOE test procedure will be based on AMCA Standard 210 and that FEP and FEI will be employed in any fan efficiency regulation. This confidence stems from the publication of the term sheet report published by DOE following ASRAC full-committee approval of the fan working group's agreed-upon recommendations on key components of a fan efficiency regulation (DOE 2015). Among these key components are the test procedure basis and the FEP and FEI metrics. FEP would be the basis for representing the compliance metric for fan efficiency, and a second new metric, FEI, could be used by industry for communicating fan efficiency for purposes other than DOE compliance, such as utility rebate programs and marketing literature (Persful et al. 2016).

To provide a basis for energy efficiency initiatives, AMCA is developing a rating standard (AMCA Standard 208) to define FEP and FEI so that these new metrics can be used in conjunction with the AMCA Standard 210 test standard for commercial and industrial fan rebate programs (AMCA 2016). Furthermore, AMCA has recently published a standard that enables calculation of FEP and FEI using measured and default values for motors, variable speed drives, and belt drives. AMCA Standard 207, *Fan System Efficiency and Fan System Input Power Calculation,* is a rating standard that provides a method to estimate the input power and overall efficiency of an extended fan system (AMCA 2017a).

At the time of this writing, the revision to AMCA Standard 210 that includes support for testing extended fan systems is complete and publicly available. AMCA Standard 207 is also complete and undergoing ANSI accreditation. It is likely to be available to the public in June 2017. AMCA Standard 208 is being drafted with a target publication date in the summer of 2017.

The Requirement for a New Metric

Although fans have existed for centuries, it was not until the 2007 timeframe that fan energy efficiency entered the regulatory spotlight. An early fan efficiency regulatory approach was to impose a minimum total efficiency performance of 65 percent on fans (Cermak and Ivanovich 2013). The impact of such an approach is graphically portrayed in Figure 1. As can be seen, such an approach would eliminate many fans on the market in the range of approximately 20 inches in diameter or smaller. The performance of most fans can be estimated across sizes using affinity laws, or fan laws, as they are commonly referred to in the fan industry. The fan laws require geometric similarity, however. As fan diameter is reduced, smaller fans suffer from what is often described as a size-effect. Manufacturing constraints such as material thicknesses do not scale perfectly with size and, along with other influences such as bearings, impose a larger proportional impact on the performance of smaller fan sizes. Above 20 inches, the size effect diminishes and efficiencies stabilize and, in general, the size effect becomes insignificant above 40 inches in diameter.

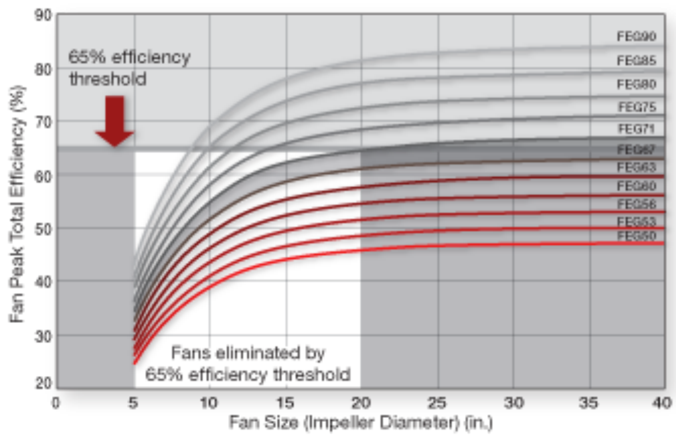

Figure 1: Single-point efficiency threshold versus fan efficiency grade curves.

The FEG metric was designed around this characteristic of fans. Using numerical analysis on fan test data from a variety of manufacturers around the world and covering different fan types and sizes, FEG curves were developed to provide an index that remains constant over a range of fan sizes of a similar model (Cermak and Ivanovich 2013). This approach applies to fan types and sizes where a peak total efficiency can be calculated (AMCA 2012). FEG curves and associated mathematical equations embodied in AMCA Standard 205 and ISO 12759 can be used by fan manufacturers to calculate FEG ratings and by regulators to set minimum FEG requirements.

Beginning in 2012, AMCA Standard 205 became the basis for fan efficiency provisions appearing in all U.S.-based model energy codes and standards: International Green Construction Code (ICC 2013), ASHRAE 90.1 (ASHRAE 2013), ASHRAE 189.1 (ASHRAE 2014), and the International Energy Conservation Code (ICC 2015). The FEG provision remains in the subsequent editions of each of these publications and is slowly making its way into state energy codes. To date, 11 states are known to have FEG-based fan efficiency provisions adopted in model codes and standards[3]. FMEG remains in effect in Europe, with a revision underway that does not fundamentally change the metric being used (Kemma, van den Boom, and van Elburg. 2015).

DOE initiated the rulemaking for commercial and industrial blowers in June 2011 (DOE 2011), well after the path had been set for FEG in model codes and standards. With the publication of the DOE framework document for the fan rulemaking in February 2013 (DOE 2013), the future of FEG as a metric used in regulation appears to be questionable. The framework document signaled DOE’s preference for a wire-to-air metric based on electrical input power consistent with recent regulatory approaches toward electrically driven pumps.

A significant shortcoming of FEG is that the metric alone is not sufficient to establish energy-saving regulations or code provisions. This is due to a characteristic of FEG, as well as characteristics of fans in general. As mentioned earlier, by design, FEG ratings remain constant across different sizes of the same geometrically similar model even though fan efficiency varies, sometimes radically, for a given operating point (Figure 1). For example, a manufacturer’s hypothetical fan Model #123 may be geometrically similar across all fan sizes offered and have an FEG rating of 67 across all its sizes. Thus, when an engineer is selecting a fan for a given application, the sizing/selection software could provide an array of sizes to select from, say, 18-inch (460 mm) diameter to 36-inch (920 mm) diameter (Table 1) (Rizzo and Wolf 2016). These results, however, can result in sizes that have an identical FEG rating yet consume significantly different amounts of power and have correspondingly different efficiency values at the operating point or point of rating.

A unique characteristic of fans is that those of similar geometric design but different sizes (based on impeller diameter) can operate at a similar duty point, with a duty point defined as a fan delivering a specified flow and pressure. Figure 2 below demonstrates this phenomenon. Although only one fan size consumes the minimum power, other sizes of fan can deliver an identical flow-pressure operating condition. These fans, in theory, would have identical FEG ratings. Yet when they are applied, they consume vastly different amounts of energy.

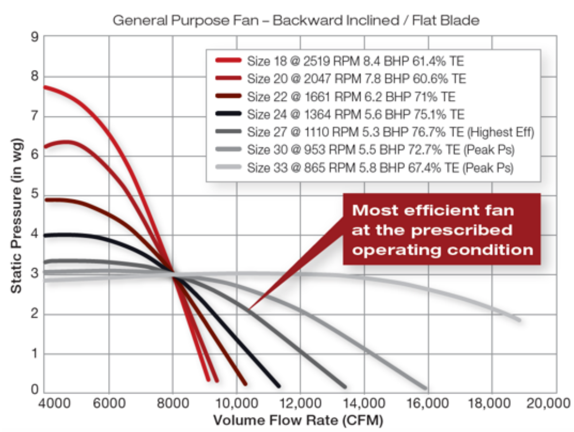

Figure 2. Variety of Fans of Similar Geometric Design Operating at an Identical Duty Point. Source: New York Blower Co.

[3] FEG uptake into state energy codes is coming through gradual adoption of the 2015 edition of International Energy Conservation Code and ASHRAE 90.1-2013. AMCA looked at the state-by-state adoption record of these editions at Building Codes Assistance Project (BCAP at http://bcapcodes.org/code-status/state/) and examined the published state codes to ensure the FEG provision carried through the adoption process.

This condition is similarly displayed in Table 1. Table 1 displays the output of a manufacturer's sizing/selection program for a double-width, double-inlet fan sized/selected for 80,000 cfm (37,755 l/s) at three-inch (747 pa) static pressure. The operating costs are based on a run time of 16 hours per day, 250 days per year, and electricity cost of $0.10 per kWh.

Table 1: Impact of Fan Size on Annual Power Consumption and Operating Cost

Diameter (in.) [mm]	FEG Rating	Total Efficiency (%)	Operating Power (hp) [kW]	Price ($)	Operating Cost Per Year ($)	Weight (lbs) [kg]
36 [920]	85	56	114 [85]	21,200	37,797	2,330 [1,056]
40 [1016]	85	62	90 [67]	16,100	29,939	2,850 [1,293]
44 [1118]	85	68	74 [55]	16,900	24,402	3,570 [1,619]
49 [1245]	85	77	60 [45]	17,600	19,926	4,170 [1,891]
54 [1372]	85	78	56 [42]	20,300	18,401	5,200 [2,359]
60 [1524]	85	81	51 [38]	23,800	16,976	6,310 [2,862]

Data courtesy of Greenheck Fan Corp.

As can be seen, the fans of smaller diameter operate less efficiently and, as a result, consume more energy than fans of larger diameters to meet the airflow requirements at a given pressure. An investment of the $7,700 price differential for the larger fan could pay for itself in less than one year from reduced electrical costs of approximately $12,960 per year.

To encourage engineers to select fans closer to their optimum energy efficiency capability as applied, FEG-based code provisions needed to include a clause to limit fan operating points to be "within 15 percentage points of the fan's peak total efficiency" (Figure 3) (Cermak, J., and M. Ivanovich. 2013) (ASHRAE 2016) (ASHRAE 2014) (ICC 2015). This clause results in FEG-based provisions being difficult to enforce because labels alone cannot be used for compliance. Code officials must refer to engineering submittals to verify compliance with the sizing/selection requirements.

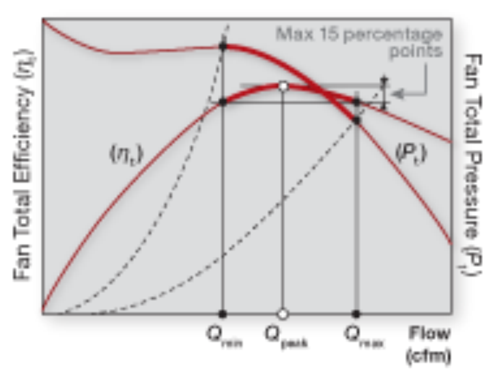

Figure 3. Typical fan curve showing total efficiency vs flow vs total pressure.

FEI, however, as will be shown later, has the operating point characteristics incorporated in the calculation, so compliance officials for any program, code, or regulation need only check the FEI rating on the label to ensure compliance (Persful et al. 2016). Table 2 exemplifies the advantage of FEI over FEG for compliance purposes. In Table 2, a baseline FEP rating has been assumed to compute an FEI value. Fan sizing/selection data are displayed for a design point of 10,000 cfm (4,719 l/s) at 3.0 inches (747 pascal) total pressure.

Table 2: Data Comparing FEG with FEI for Multiple Sizes of the Same Fan Model

Fan Size [in.] (mm)	Fan Speed (rpm)	Fan Power (bhp) [kW]	Actual Total Efficiency (%)	Baseline Power	FEG	FEI
18 (460)	3,238	11.8 [8.8]	40.1	7.96	85	0.67
20 (510)	2,561	9.6 [7.2]	49.5	7.96	85	0.83
22 (560)	1,983	8.0 [6.0]	59.0	7.96	85	0.99
24 (610)	1,579	6.8 [5.0]	69.1	7.96	85	1.16
27 (685)	1,289	6.2 [4.6]	75.8	7.96	85	1.28
30 (770)	1,033	5.7 [4.3]	82.5	7.96	85	1.39
36 (920)	778	6.0 [4.5]	78.7	7.96	85	1.32

Table 2 clearly shows fans of similar geometric design, thus carrying a similar FEG rating, having their respective energy consumption values and efficiencies communicated through FEI values. Data courtesy of Greenheck Fan Corp.

Second Generation Metrics: FEP and FEI

FEP and FEI are wire-to-air metrics consistent with the regulatory approaches being taken for other motor-driven loads, such as pumps and air compressors. AMCA considers FEP and FEI as second-generation metrics because they employ duty-point ("sizing and selection") specifications in the metric in a manner acceptable to DOE. ("Acceptable" is based on DOE carrying them into the most recent NODA (DOE 2017)). With these basic conditions in place, FEP and FEI stand to introduce novel ways efficiency programs can be developed, and they stand to completely change how fans are sized, selected, and specified by practitioners.

As referenced in the ASRAC term sheet, FEI is calculated as the ratio of the actual fan system efficiency to a baseline fan system efficiency (Equation 1), both calculated at a given airflow and pressure point (DOE 2015). The phrase "fan system" is used to imply the incorporation of motors, transmission systems, and controls in the efficiency calculation. Because the actual and baseline efficiencies are calculated at the same airflow and pressure, FEI is also defined as the ratio of the baseline electrical power to the actual electrical power of a fan (Equation 2) (DOE 2015).

$$FEI = \frac{Fan\ \text{System}\ Efficiency}{Baseline\ Fan\ \text{System}\ Efficiency} \quad \text{Eq. 1}$$

$$FEI = \frac{Baseline\ Fan\ Electrical\ Input\ Power}{Electrical\ Input\ Power} \quad \text{Eq. 2}$$

Equation 2 is equivalent to Equation 1, but because the goal of mandatory and voluntary programs is to reduce energy consumption, Equation 2 is preferred. Reducing electrical power consumption and the corresponding calculation of energy savings has more relevancy and value to regulatory bodies than merely increasing energy efficiency. Equation 2 also is easier to apply and has the added benefit of working along the entire fan curve.

Equation 2 implies an intermediary calculation leading to FEI—the measurement or calculation of FEP. FEP is obtained either by directly measuring fan electrical input power during rating tests, or it is calculated by measuring fan shaft power and incorporating default values for motors, drives, and controls (DOE 2015). The default values are defined in AMCA Standard 207, *Fan System Efficiency and Fan System Input Power Calculation* (AMCA 2017a). Fan rating tests can be conducted using AMCA Standard 210 (AMCA 2016), which the ASRAC fan working group agreed to as being the basis of the DOE test standard per the ASRAC term sheet (DOE 2015).

Once the FEP rating of a fan system is calculated, it is compared against a baseline FEP, called FEP_{std}, as shown in Equation 3. Note FEP has engineering units of kW corresponding to electrical input power (DOE 2015). Also note FEI is a unitless ratio.

$$FEI = \frac{FEP_{std}}{FEP\ rating} \qquad \text{Eq. 3}$$

Table 3 displays possible applications of FEI for regulations and voluntary incentive programs (Persful et al. 2016).

Table 3: How FEI can be applied in regulatory and voluntary programs.

Fan Regulatory or Voluntary Program Body	Possible FEI Requirement
U.S. Department of Energy	FEI ≥ 1.0 at Design Point
ASHRAE 90.1 or International Energy Conservation Code	FEI ≥ 1.0 at Design Point
ASHRAE 189.1	FEI ≥ 1.1 at Design Point
Utility Incentive Programs	FEI ≥ 1.1 at Design Point

A useful characteristic of FEI is that for FEI ratings greater than one, the amount of energy savings over the baseline can be directly calculated. Subtracting 1 from the FEI rating results in a percentage reduction in energy consumption. For example, a fan rated FEI = 1.1 uses 10 percent less energy than the baseline requirement. This makes FEI useful for calculating relative energy savings between any two fans or between a fan and the FEI threshold in a fan code/standard/regulation provision.

Applying the FEI Metric

Instead of specifying a minimum peak efficiency level for the each of the various fan types, the FEI establishes a baseline efficiency and resulting baseline power that varies with both airflow and pressure that can be universally applied to all fan categories (AMCA 2017b). FEI defines a compliant range of operation, not a single compliant efficiency threshold. For a single speed fan curve, the compliant range is a subsection of the total fan curve. This is shown graphically in Figure 4 below (Mathson 2016).

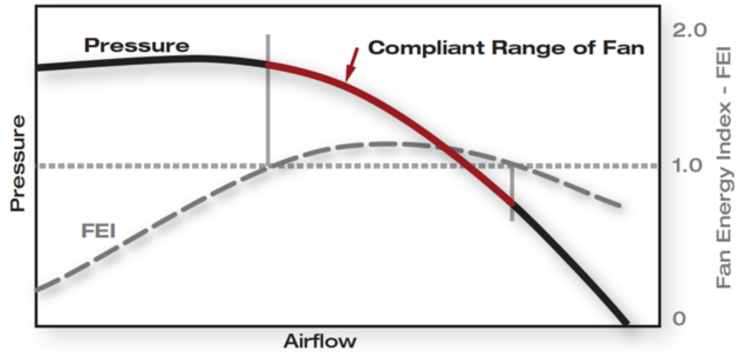

Figure 4. Compliant Range of Operation for a Fan Operating at a Single Speed.

When fan curves are created at multiple speeds, as would be the case when operated with a variable frequency drive (VFD), these compliant zones take on the appearance of bubbles, with the size of the bubble being proportional to fan efficiency. Generally, the more efficient the fan, the larger the compliance bubble. In some cases, however, fans can be very efficient over a small operating range. The shaded regions in Figure 5 shows the FEI 1.0 bubble (AMCA 2017b). Assuming an FEI value of 1.0 indicates compliance, the shaded regions indicate fan operating conditions that would be in compliance.

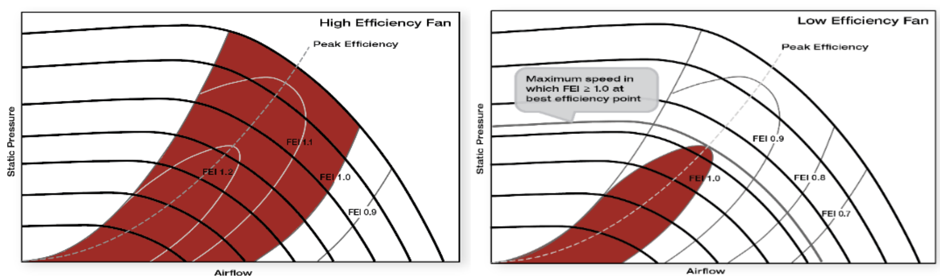

Figure 5. Compliance bubble for a high-efficiency fan and compliance bubble for a low-efficiency fan.

In Figure 5, a label for fan speed indicates the maximum speed at which the fan can be operated and comply. This gives operators and engineers an opportunity to set up variable speed drives and belts to restrict fan speed. Manufacturers would include such diagrams or their tabular equivalents in product literature and sizing/selection software.

The ratio of fan power to this baseline power at design conditions is used to package the metric and make it easier to use for customers, owners, regulatory bodies, and utility rebate programs. The baseline represents a reasonable efficiency level that is common to all fan types as they are normally applied.

Selection of the baseline value for the calculation of FEP_{std} is an important component of the approach and the corresponding calculation of FEI (DOE 2015). FEP_{std} will need to be specified to represent a reasonable efficiency. Regulations can be written around FEP_{std} as documented in the ASRAC term sheet (DOE 2015). However, a regulation or program written around a FEI of 1.0 could serve as an optimal FEI requirement, for example, for most types of fans. Exceptions for an FEI value less than 1.0 could include fans used for variable air volume

(VAV) systems to encourage more use of VAV systems (AMCA 2017b); fans used infrequently, such as emergency fans; or fans used for material handling.

Table 3 also implies high-performance-building standards (such as ASHRAE 189.1) or utility rebate programs could set FEI requirements to be greater than the baseline requirement. In the current fan efficiency provision in ASHRAE 189.1, additional stringency is added to the corresponding ASHRAE 90.1 provision by making the sizing/selection window smaller—from 15 percentage points to 10 (ASHRAE 2014). This is because more energy is saved by further restricting fan selections to operate close to their peak efficiency capabilities rather than increasing the FEG rating from 67 to the next level up, FEG 71. The approach taken by ASHRAE 189.1 further validates the utility of having sizing/selection criteria incorporated into a metric.

Regulators determine baselines for energy conservation standards by balancing goals for energy savings, the benefit to consumers, and the impact on stakeholders. Different regulatory entities may have different imperatives and cost-benefit analysis processes, as well as diverse stakeholders promoting a variety of advocacy positions. The FEI metric also supports expected increases in codes and regulations over time as fan technology improves. The baseline FEI can be changed, for example, from 1.0 to 1.1. This would nudge requirements higher while also preserving the integrity of fans labeled with FEI ratings set previously. A fan's label showing FEI 1.0, indicating compliance with a current requirement of FEI 1.0, would be valid in the future if the requirement was raised to a higher FEI value. A building owner replacing the fan under the future regulation could replace the FEI 1.0 fan with a FEI 1.2 fan.

AMCA Standards

AMCA remains committed to increasing fan efficiency and reducing energy consumption independent of regulatory activities. AMCA promotes bringing FEP and FEI into the market through the development of two new rating standards, AMCA Standard 207 and AMCA Standard 208, that work with data taken from tests performed in accordance with AMCA Standard 210 to enable calculation of wire-to-air fan system energy.

AMCA Standard 207 provides a method to estimate the input power and overall efficiency of an extended fan system. As mentioned earlier, FEP can be directly measured, and while direct measurement of fan system performance may be preferred, the large number of fan system configurations possible from assembling commodity components makes testing impractical. It is reasonable to assume a hypothetical fan manufacturer could have one fan model consisting of five sizes with five options of motors and five options of drive packages. The number of testable configurations would be 5^3, or 75, tests. It is also reasonable to assume this manufacturer offers dozens of models with dozens of motor and drive options across the different sizes. Testing costs quickly escalate into the hundreds of thousands of dollars, if not millions.

AMCA Standard 207 offers a standardized method to estimate fan system performance by modeling commonly used components (AMCA 2017a). Calculations reported in accordance with this standard offer fan users a tool to compare alternative fan system configurations in a consistent and uniform manner. The scope of AMCA Standard 207 includes all electric motor driven fan systems that utilize a specific combination of components as defined below:

- Fan airflow performance tested in accordance with

    - ANSI/AMCA Standard 210, *Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating,*
    - ISO Standard 5801, *Industrial fans—Performance Testing Using Standardized Airways*, or

      Otherwise rated in accordance with AMCA Publication 211, *Certified Ratings Program—Product Rating Manual for Fan Air Performance*
- Polyphase induction motors within the scope of
    - EISA-2007 (Code of Federal Regulations Title 10, Chapter II, Subchapter D, Part 431, Subpart B),
    - IEC 60034-30 *Rotating electrical machines—Part 30-1: Efficiency classes of line operated AC motors*, or
    - GB 18613, *Minimum Allowable Values of Energy Efficiency and Energy Efficiency Grades for Small and Medium Three-Phase Asynchronous Motors*
    - Other types of motors are explicitly excluded
- Pulse-width modulated VFD for use with single motors
- Mechanical power transmissions that utilize V-belts
- Note: Single VFDs that service multiple parallel fan motors are excluded

AMCA has been working with ISO to incorporate AMCA Standard 207 into ISO Standard 12759. ISO standards have a presence in some countries where AMCA standards do not. As a result, AMCA has collaborated with ISO during the revision cycle for 12759 in an effort to create a broader range of applications for fan energy efficiency ratings. AMCA Standard 207 has been approved by the AMCA Board of Directors and is now undergoing accreditation by ANSI as the final step leading to publication. Publication is expected in June 2017.

AMCA Standard 208 is currently being drafted by an AMCA committee and will use the ASRAC term sheet as a basis to rigorously define FEP and FEI and provide examples for how they can be applied

Rebate Programs

AMCA has been involved with the Extended Motor Product Label Initiative (EMPLI) program since its inception. EMPLI is a "collaborative effort involving over two dozen representatives from the motor-drive equipment manufacturing sector, trade organizations, utilities, energy efficiency program administrators, and energy efficiency nongovernmental organizations" (Rogers 2014).

Absent a draft or final DOE labeling requirement, Figure 6 shows a label mocked up by Twin City Fan Companies for consideration in a rebate program being developed for motor-driven loads (Persful et al. 2016).

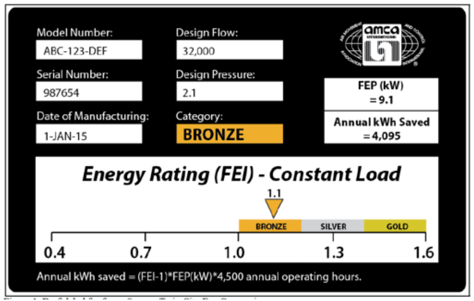

Figure 6. Draft of a possible label supporting fan rebate programs.

The Fine Points and Future of FEI

FEI is calculated as a ratio of the baseline electrical input power compared to the fan system's actual electrical input power—either measured or estimated. The calculation method of AMCA Standard 207 and the measurement method of AMCA Standard 210 are available to establish FEI as a wire-to-air metric. While code authorities and DOE will establish minimum FEI (or maximum fan power) levels as they deem appropriate, fan suppliers and users have the freedom to meet these requirements in any manner they choose. A fan user can utilize any combination of fan, transmission, and motor and speed control if the combined FEI level meets the minimum requirement (DOE 2015).

Even though FEI was developed to focus on fan energy as applied, it can also be used as an application-independent metric when the design operating point is not known (Persful 2016). This would be true for fans sold off the shelf without a motor. In this case, FEI is evaluated at the best efficiency point at the maximum published fan speed. If the fan on the shelf has a motor and drive, the distributor has the information to compute the FEI bubble. By considering this single point, the metric establishes a restricted speed range while remaining consistent with its use at the design point of operation. As shown in Figure 5, the "restricted speed size" is the maximum speed the fan can be operated to remain at FEI = 1.0 or greater.

While driving significant energy savings and technological improvements, FEI also encourages improved fan selection. Everywhere a consumer makes a fan selection decision, including performance tables, fan curves, or electronic selection software, the value of FEI for that selection will be shown. Consumers will know immediately how fan selections compare to the maximum baseline fan electrical input power. They will also know how the energy consumption of one product compares to another, regardless of product type, category, size, or drive method.

As with the adoption of any new metric, complications exist in the adoption of FEI. Potential barriers include the inertia of investment in fan energy efficiency metrics, the need to educate stakeholders regarding the value of the metric, generating advocacy momentum among interested parties, and gaining exposure to rulemaking processes. Code officials have communicated limitations on both time and budget for regulatory activities.

Also, one valuable aspect of FEI may work against it at the same time: the metric takes into account the consumer approach toward energy consumption, complicating the metric in the process. The consumer desired a metric that specified flow and pressure and reflected energy consumed to deliver specified requirements. While this would be a beneficial change from previous metrics, which focused on a product's performance at a peak operating condition, such a step forward cannot be made without increasing complexities in the metric itself. Education and clear communication of the operation of the metric will be the key to a successful adoption of FEI.

Summary

Consider these benefits to FEP and FEI:

- Supports wire-to-air, extended-product consideration of motors and drives
- Incorporates sizing/selection criteria within the metric, thus establishing entirely new ways of regulating or incentivizing energy efficiency
- Supports calculations for energy savings based on comparing fans against minimum requirements and against other fans
- Simplifies compliance checking
- Covers unducted fans, which are exempted from FEG-based code provisions due to impracticalities
- Guides practitioners to reduce wasted fan energy just by using the metric
- Enables engineers to protect specifications against post-design value engineering, resulting in lower cost, lower efficiency fans
- Is backward-compatible with incremental increases in regulatory or voluntary thresholds

Conclusion

FEI is a metric that allows many different types of fans to be compared on equal footing, and it does so by concentrating on the energy consumed by a fan as it is applied. It can be used by regulators and purchasers alike to make a price-sensitive market favor reduced energy consumption, helping consumers see how a fan can be affordable and efficient at the same time. Additionally, FEI can provide manufacturers with assurance they are creating energy-saving products that will appeal to their customers. It is an all-encompassing, high level solution to a complex problem.

FEI was selected by DOE, AMCA, and other industry stakeholders to be the metric around which a federal efficiency standard would be developed. It is expected FEI will replace FEG where used in existing energy codes and standards, and it can be applied in rebate programs for commercial and industrial fans. The long, hard work that has gone into the development of this sophisticated and effective metric and supporting regulatory framework deserves to be brought to conclusion.

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