Fan Efficiency Standards for Commercial & Industrial Buildings

Revised for 2014

An introduction to ANSI/AMCA Standard 205: *Energy Efficiency Classification for Fans*, and how it is referenced in model U.S. codes and standards for energy efficiency and green construction

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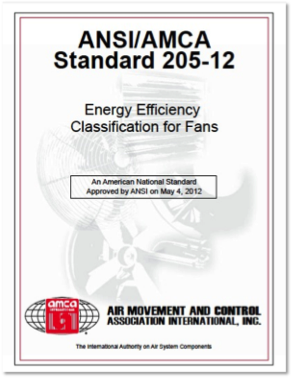
Fan Efficiency Standards: Here They ~~Come~~ ARE!

In 2010, AMCA International published the first version of a fan efficiency rating standard, AMCA 205 *Energy Efficiency Classification for Fans*. AMCA 205 has since become the reference standard for minimum fan efficiency requirements in

- ASHRAE 90.1-2013;
- International Green Construction Code 2012; and
- International Energy Conservation Code 2015.



AMCA 205 defines how to rate fan efficiency independent of motors and drives using a calculated index called a Fan Efficiency Grade (FEG).

AMCA 205 also prescribes that fans be sized and selected such that all operating points are within 15 percentage points of the fan's rated peak total efficiency. All model codes and standards referenced above prescribe minimum FEGs and sizing/selection windows.

This document provides background information on what FEGs are and how to apply the sizing/selection windows that are in the codes and standards. Included are technical articles that have been published in *ASHRAE Journal, AMCA inmotion, HPAC Engineering,* and *Consulting-Specifying Engineer* magazines.

These articles span several years of publishing. This document, and all articles within it can be downloaded directly or through hyperlinks at www.amca.org/feg/best-practices.aspx.

For more information, please feel free to contace me directly via email at mivanovich@amca.org.

Thank you.

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New!!
Find certified FEG ratings at www.amca.org/feg/FEG-Finder.aspx

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Special report:

Fan efficiency guidelines

New and proposed fan-efficiency provisions in commercial energy codes and standards are fostering cost-effective energy savings in HVAC systems.

BY MICHAEL IVANOVICH, *AMCA International, Arlington Heights, Ill.*

Despite the fact that fans in commercial HVAC systems consume more than 1 Quad of energy (10^{15} Btus) annually in the U.S., they have not had explicit efficiency requirements in federal regulations or model codes and standards for energy efficiency and high-performance/green construction.

Those days are over.

The 2012 International Green Construction Code (IgCC) and ASHRAE 90.1: Energy Standard for Buildings Except Low-Rise Residential Buildings (2013 Edition) have requirements for minimum fan efficiency. These requirements are based on a standard published by the Air Movement and Control Association International (AMCA International), AMCA 205: Energy Efficiency Classification for Fans. AMCA 205 was first published in 2010, and its 2012 revision is ANSI accredited. The 2012 IgCC's fan efficiency provisions are based on AMCA 205-10; ASHRAE 90.1-2013's provisions are based on ANSI/AMCA 205-2012.

Additionally, AMCA and ASHRAE collaborated on fan-efficiency proposals for the 2015 International Energy Conservation Code (IECC), which were based on the ASHRAE 90.1-2013 language. The proposals cleared the first level of hearings in April 2013 and will undergo public review later in the year leading up to final-action hearings in October. AMCA International also is developing a proposal for ASHRAE 189.1: Standard for Construction of High-Performance, Green Buildings Except Low-Rise Residential Buildings.

Meanwhile, the U.S. Dept. of Energy recently initiated the development of a federal efficiency regulation for commercial and industrial fans, with completion of the regulation expected in 2015/2016 and enforcement beginning as early as 2019/2020.

This article describes the fan efficiency provisions that are in place in IgCC-2012

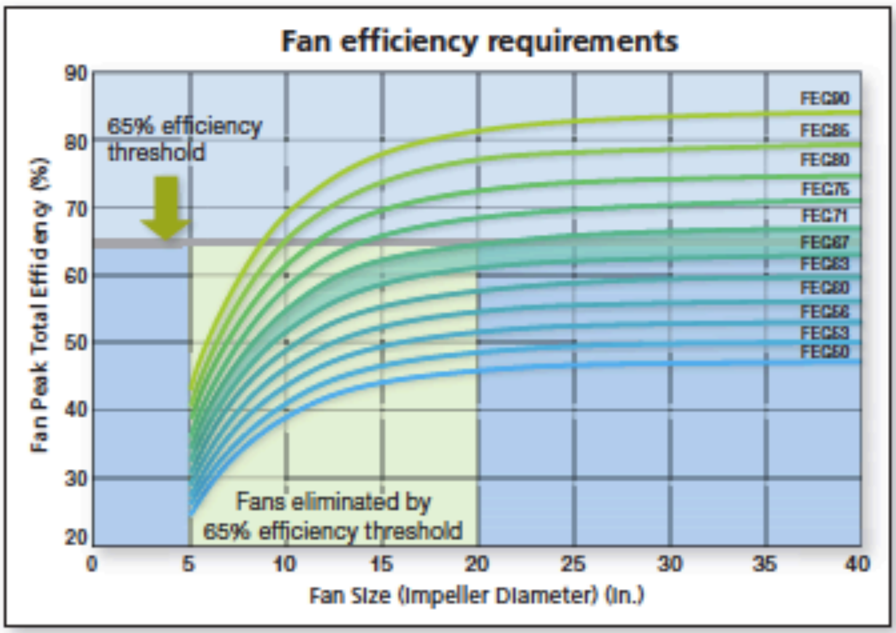

Figure 1: A straight-line 65% efficiency requirement would eliminate fans under 20-in. diameter for most types of fans. A fan efficiency provision based on curves that account for smaller fan types (such as fan efficiency grades defined by AMCA Standard 205) solves this problem. All graphics courtesy: AMCA International

Table 1: Fan output

Diameter (in.)	FEG rating	Total efficiency (%)	Operating power (hp)	Price ($)	Operating cost per year ($)	Weight (lbs)
36	85	56	114	21,100	37,797	2,330
40	85	62	90	16,100	29,939	2,850
44	85	68	74	16,900	24,402	3,570
49	85	77	60	17,600	19,926	4,170
54	85	78	56	20,300	18,401	5,200
60	85	81	51	23,800	16,976	6,310
66	85	81	50	27,400	16,478	7,490

Table 1: Output from fan sizing/selection software offers a range of sizes to meet airflow and pressure requirements. Note all sizes have the same FEG, but there's a considerable difference in energy consumption. The yellow-highlighted row shows a typical fan selection. The green-highlighted row indicates more efficient and long-term cost effective fan selection. The energy savings of the 60-in. fan will repay the higher first cost in less than 2 years.

and ASHRAE 90.1-2013, and briefly discusses what could lie ahead in future codes, standards, and regulations.

Rating fan efficiency

AMCA 205 defines a metric, called a fan efficiency grade (FEG), that rates a fan's ability to convert shaft power to air power, independent of motors and drives. FEGs are indices calculated from data taken at the peak total efficiency point on a fan curve developed during ratings certification tests.

AMCA developed FEGs as a dimensionless index to characterize the aerodynamic quality of a fan. The metric accounts for the reduced peak total efficiency that occurs for smaller fans compared to that of larger fans of the same type. This characteristic is due to nongeometric manufacturing tolerances, disproportionate bearing losses, and other aerodynamic factors that have a greater impact on smaller fans than on larger fans. When plotted as a graph, the differences in efficiency across fan sizes define a banana-shaped curve. The nature of this curve prohibits setting a straight-line efficiency requirement (e.g., all fans must have a minimum efficiency of 65%) because doing so would eliminate many smaller fan sizes of even the most efficient types of fans (see Figure 1). Smaller fans inherently have smaller efficiencies because bearing losses, manufacturing tolerances, and the fan structure all have a larger impact than they do for larger fans of the same design. The smaller fans, however, are designed for specific applications and duty points (airflow and pressure). Eliminating them wholesale via an efficiency standard would not serve the industry well.

Figure 1 also superimposes FEG curves defined by AMCA 205 on the straight-line efficiency of 65%. Setting a fan efficiency requirement based on FEGs is as simple as a straight-line efficiency requirement (e.g., all fans must have a minimum efficiency of FEG 67). Note in Figure 1 how the FEG curves penetrate the box that defines the smaller sizes that would have been prohibited by a straight-line efficiency requirement.

The FEG curves are defined in such a way that all fans of a particular design, having geometric proportionality, should have the same FEG, although there are sometimes exceptions to this rule.

If an energy code has a minimum fan efficiency requirement of FEG 67, any fan model with that rating or higher will comply. The FEG is a simple metric to segregate fans that do or do not meet a specific code requirement or regulation.

Limiting sizing/selection practice

Commercial HVAC fans are usually sized and selected using software that yields a range of fan sizes for a specific fan model for given airflow (cfm) and pressure conditions. Construction budgets generally favor lowest-first-cost approaches, so the smallest fan size is generally selected. Although they may have the same FEG rating (as described earlier), the difference in actual efficiency and energy performance between the smallest and largest fan sizes is considerable.

Consequently, setting a minimum fan efficiency grade will not guarantee reduced fan-energy consumption unless care is taken to properly design the air distribution system and an appropriate fan selection is made. For this reason, AMCA 205 also prescribes that fans should be sized and selected to operate within 15 percentage points of the fan's peak total efficiency. The sizing/selection window helps practitioners to right-size fans so they operate in their most efficient ranges of speed and pressure. The result is a higher first cost, but energy savings quickly recoup the higher cost. Table 1 shows the output of a manufacturer's sizing/selection program for a double-width, double-inlet fan sized/selected for 80,000 cfm at 3-in. static pressure. The operating costs are based on a run time of 16 hr per day, 250 days per year, and electricity cost of $0.10 per kWh.

Structuring a fan efficiency requirement

Fan-efficiency codes and standards written around AMCA 205 define a minimum FEG and a sizing/selection window.

Special report: Fan efficiency guidelines

Fan efficiency provisions can be further refined by specifying applicable sizes, types, and exemptions, as well as requirements for third-party certified FEGs and energy labels. The following are examples of where fan-efficiency requirements based on AMCA 205 have been adopted or proposed for model codes and standards for energy efficiency and green/high-performance construction.

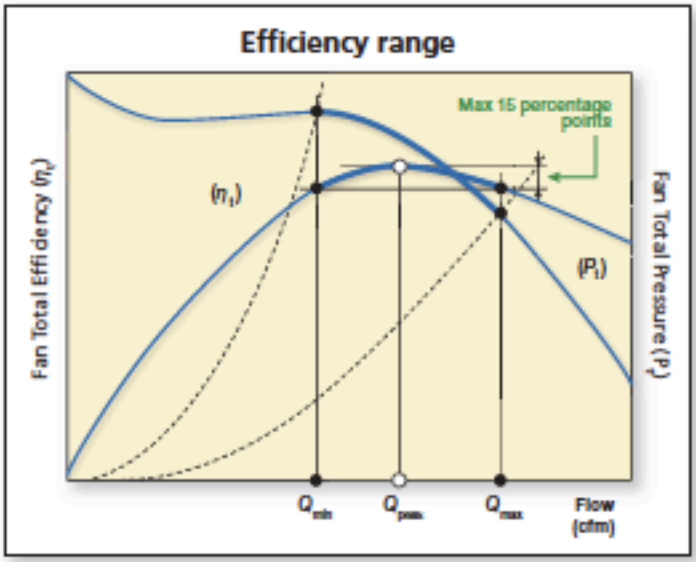

Figure 2: The allowable selection range shown is based on operation within 15 percentage points of the fan's peak total efficiency, as specified in ANSI/AMCA 205-12.

IgCC-2012: The 2012 IgCC's fan-efficiency provision includes a minimum FEG rating of 71 and sizing/selection window of 10 percentage points from peak static or total efficiency. It applies to stand-alone supply, return, and exhaust fans in buildings less than 25,000 sq ft.

This provision was based on AMCA 205-2010, which had a sizing/selection window of 10%, not 15%. AMCA 205-2010 also listed fan types that it does not cover, including air curtains and jet fans, because these types do not conform to the conditions supporting FEG calculations. AMCA will be proposing significant changes to this language for the 2016 version of this model code.

ASHRAE 90.1-2013: The significance of having a new fan efficiency requirement in ASHRAE 90.1 cannot be overstated. ASHRAE 90.1 is the benchmark state energy code for federal efficiency programs, many utility rebate programs, and state energy codes. It also is a compliance path for the model energy code, International Energy Conservation Code. ASHRAE 90.1 also forms the basis for the ASHRAE standard for high-performance (green) construction (Standard 189.1), and the International Association of Plumbing and Mechanical Officials (IAPMO) Green Supplement to the Uniform Mechanical Code and Uniform Plumbing Code.

Fan efficiency provisions in ASHRAE 90.1-2013 are written into the section that includes fan power limits. The fan power limits section encourages low-static-pressure air distribution systems, which save energy; however, it does not place appreciable constraints on efficient fan efficiency or right-sizing of fans.

ASHRAE 90.1-2013 specifies a minimum FEG rating of 67 and a sizing/selection window of 15 percentage points of the fan's peak-total-efficiency rating (Figure 2).

The Standard 90.1 provision applies to fans with a nameplate hp rating > 5 hp and fan arrays that have an aggregate motor nameplate rating > 5 hp. The provision has a number of exemptions, including powered roof/wall ventilators, fans intended to operate only during emergencies, and fans in packaged equipment that has a third-party certification for air or energy performance. These exemptions will help engineers, contractors, building owners/operators, commissioning providers, and code officials learn how to implement fan efficiency requirements for the first time.

To learn more about the ASHRAE 90.1 fan efficiency requirement, read the article by John Cermak, PhD, and Michael Ivanovich in the April 2013 issue of *ASHRAE Journal*. To learn how fan power limits and fan efficiency grades interact during a fan selection, read the article by Michael Brendel, PhD, in the May 2013 issue of *HPAC Engineering*.

IECC-2015: The fan efficiency provisions in ASHRAE 90.1-2013 were proposed for IECC-2015, with a few refinements: FEG ratings would have to be "approved" and "labeled," measures that are defined within the IECC, and were included to support compliance checking and enforcement:

APPROVED: Approval by the code official as a result of investigation and tests conducted by him or her, or by reason of accepted principles or tests by nationally recognized organizations.

LABELED: Equipment, materials or products to which have been affixed a label, seal, symbol or other identifying mark of a nationally recognized testing laboratory, inspection agency or other organization concerned with product evaluation that maintains periodic inspection of the production of the above-labeled items and whose labeling indicates either that the equipment, material or product meets identified standards or has been tested and found suitable for a specified purpose.

ASHRAE 189.1: AMCA has recently developed a "continuous maintenance proposal" that would insert a fan efficiency provision into ASHRAE 189.1. The provision is identical to the ASHRAE 90.1-2013 language, with the one exception being that the peak-total-fan-efficiency sizing/selection window is 10 percentage points instead of 15 percentage points. If the proposal passes committee votes, it could come out as an addendum for public peer review later in 2013.

U.S. Dept. of Energy: Development of the U.S. Dept. of Energy's fan efficiency standard achieved a significant milestone with the publication of the Framework Document in the Federal Register on Feb. 1, 2013. The Framework Document presents DOE's perspective of the fan market and the options it is considering for regulating commercial and industrial fans. AMCA International is collaborating with a number of industry stakeholders, including the American Council for an Energy Efficient Economy (ACEEE), the Appliance Standards Awareness Project, and the California public to jointly develop a proposal to DOE for the efficiency requirement.

Among the most significant differences a DOE standard will introduce is that a variety of fan types (DOE calls them classes) will be defined, and fan efficiency metrics and minimum energy efficiency performance requirements will be set for each class. Based on best-available information, a DOE requirement could be in place with enforcement between 2019 and 2020.

Future fan efficiency requirements

DOE's approach to defining fan classes and assigning a potentially unique efficiency requirement for each of them is one that AMCA is looking to apply to future proposals for model energy codes and standards.

Among the most significant differences: a variety of fan types will be defined, and fan efficiency metrics and minimum energy efficiency performance requirements will be set.

Additionally, because some types of fans are structurally integrated with motors and drives, a metric that incorporates the drive, motor, and control, is being developed. AMCA is working with European and Asian standards bodies and manufacturers to develop an internationally harmonized metric for "wire-to-gas" efficiency ratings, which could be applied to fan-motor and fan-motor-drive combinations. Also, some fan products, such as powered roof/wall ventilators, are assembled and sold with motors and drives, making a wire-to-gas metric more consistent with them, as well.

An example of a wire-to-gas metric is cfm-per-Watt, or W/cfm, which would provide a convenient way to establish fan efficiency requirements for fan-motor assemblies while FEGs are retained fans less motor and drive.

Beginning with the publication of AMCA 205 in 2010, the development of fan-efficiency provisions in model codes and standards for energy efficiency and green/high-performance construction began in 2012, and is picking up pace. A federal efficiency standard is under development by the DOE and might be active as early as 2019. Energy savings will come from requirements for minimum fan efficiency grades; however, greater energy savings is expected from provisions that have sizing/selection windows that encourage larger-diameter fans running at slower speeds and closer to peak-efficiency ratings.

First-generation fan efficiency provisions in U.S. model codes and standards are written around AMCA 205 and contain a minimum FEG rating, a sizing/selection window, and exemptions that limit applicability to specified sizes, types, and applications. Future, or second-generation fan efficiency requirements may include additional metrics, such as a wire-to-gas rating. |cse|

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Figure 3: This sticker can be applied to fans bearing AMCA-certified ratings for fan efficiency grade, and it can also appear in literature and software programs in accordance with AMCA 211-2005 (rev 1-13) Certified Ratings Program - Product Rating Manual for Fan Air Performance.

Certified FEG ratings support compliance, enforcement

Many code jurisdictions are concerned about the growth and complexity of energy codes and standards, making compliance checking and enforcement time-consuming and difficult. Consequently, more codes and standards are being written to require certified efficiency ratings and supporting labels, stickers, or other marks that facilitate online verification and visual inspection.

AMCA's Certified Ratings Program began certifying fan efficiency grades in 2010, after the AMCA 205 standard was published. Currently, more than 40 companies and more than 250 fan models have certified FEG ratings. AMCA also certifies manufacturers' sizing and selection software to produce FEG ratings and fan-total-pressure data. Literature and software outputs that have certified FEG ratings are licensed to bear the AMCA FEG label (Figure 3). AMCA's online database of certified ratings can be searched by manufacturer and type of product at www.amca.org. For a shortcut on finding certified FEGs, visit www.amca.org/feg.

Fan Efficiency Requirements

For Standard 90.1-2013

By **John Cermak, Ph.D., P.Eng.**, Member ASHRAE; and **Michael Ivanovich**, Member ASHRAE

Although fans have been used in their current form since Georgius Agricola described their applications for ventilating mines in 1556,[1] it wasn't until 2007 that explicit requirements for minimum fan efficiency in energy and construction codes began to take form. The pace has accelerated since then for developing a means and metrics for determining and expressing fan efficiency, and developing explicit energy efficiency requirements for fans in commercial and industrial applications.

ANSI/ASHRAE/IES Standard 90.1-2013 is the most recent national code or standard to adopt AMCA 205, *Energy Efficiency Classification for Fans*, which was first published in 2010. AMCA 205 was updated in 2012 and certified by ANSI.[2] To date, AMCA 205 is referenced by one model construction code (2012 International Green Construction Code[3] [IgCC]) and one model energy code (ANSI/ASHRAE/IES Standard 90.1-2013[4]).

By 2015, fan efficiency requirements will likely be in all U.S. model energy and construction codes. With U.S. fan-energy consumption in commercial HVAC systems estimated to be around 1.25 quads (1.32 EJ) annually,[5] the U.S. Department of Energy Appliance and Equipment Standards Program has initiated the development of a federal efficiency standard for commercial and industrial fans, blowers, and fume hoods.[6]

This article describes the fan efficiency requirement within Standard 90.1-2013, and AMCA 205. The article begins with a brief history of the development of fan efficiency standards in the U.S. and Europe, and concludes with an outlook for future fan efficiency requirements in the U.S.

Brief History

The development of fan efficiency classification standards is a story of international collaboration leading to separate but harmonized standards. In 2007 and 2008, committees, subcommittees, and working groups within ASHRAE, Air Movement and Control Association (AMCA) International, and the International Standards Organization (ISO) began to work separately and collaboratively to develop means to classify fan efficiency, and to draft language for insertion into codes, standards, and regulations for energy efficiency and green/high-performance building construction.

ISO published Standard 12759 *Fans—Efficiency classification for*

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fans[7] in 2010 and AMCA International published Standard 205 in the same year. The AMCA standard focuses on defining a fan efficiency metric, called a fan efficiency grade (FEG) based on the aerodynamic quality of the fan separate from its motor and drive. The ISO standard has a harmonized definition of FEG, but also defines a metric that includes the motor/drive assembly, i.e., fan motor efficiency grade (FMEG).

In 2011, the European Commission published the fan efficiency regulation, (EU) No. (327)/2011 that internalized sections of ISO 12759 that apply only to motorized fans using the FMEG metric, with modifications.[8] EU 327 took effect on Jan. 1, 2013 with initial efficiency requirements. In 2015, a second, more stringent, tier of efficiency requirements will take effect. For more information about (EU) 327/2011, visit www.amca.org/feg/fmeg.aspx. The remainder of this article covers AMCA Standard 205 and U.S. fan efficiency codes and standards.

In the U.S., the 2012 International Green Construction Code adopted AMCA 205-10 for expressing fan efficiency requirements for supply, return, and exhaust fans greater than 1 hp (750 W) for buildings less than 25,000 ft^2 (2323 m^2). The requirement has a minimum FEG rating of 71, and a fan sizing/selection window of 10 percentage points from peak total or static efficiency.

Earlier versions of Standard 90.1 had some fan efficiency requirements through the section on "fan power limits." However, this section primarily limits fan energy consumption through static efficiency requirements on air distribution systems. It did not encourage manufacturers to produce more efficient fans.[9] Explicit fan efficiency requirements were adopted in Standard 90.1-2013 through ASHRAE's continuous maintenance process as Standard 90.1-2010 Addendum *u*. Addendum *u* underwent an advisory public peer review in 2011, and a conventional public peer review in 2012.[10] The final language is shown in the sidebar, *Fan Efficiency Requirements*.

Because the AMCA 205 standard and FEG metric are relatively new to the industry, they are summarized below.

Fan Efficiency Requirements

When Standard 90.1-2013 is published later this year, it will contain some new fan efficiency requirements.

6.5.3.1 Fan System Power and Efficiency.

6.5.3.1.3 Fan Efficiency. Fans shall have a Fan Efficiency Grade (FEG) of 67 or higher based on manufacturers' certified data, as defined by AMCA 205. The total efficiency of the fan at the design point of operation shall be within 15 percentage points of the maximum total efficiency of the fan.

Exceptions:

a. Single fans with a motor nameplate horsepower of 5 hp (4 kW) or less.

b. Multiple fans in series or parallel (e.g., fan arrays) that have a combined motor nameplate horsepower of 5 hp (4 kW) or less and are operated as the functional equivalent of a single fan.

c. Fans that are part of equipment listed under 6.4.1.1 Minimum Equipment Efficiencies – Listed Equipment – Standard Rating and Operating Conditions.

d. Fans included in equipment bearing a third-party-certified seal for air or energy performance of the equipment package.

e. Powered wall/roof ventilators (PRV).

f. Fans outside the scope of AMCA 205.

g. Fans that are intended to only operate during emergency conditions.

AMCA Standard 205

The scope of AMCA 205 is limited to fans having an impeller diameter of 5 in. (125 mm) or greater, operating with a shaft power 1 hp (750 W) and above, and having a total efficiency calculated in accordance with procedures specified in established fan test standards including:

- ANSI/AMCA 210 (ANSI/ASHRAE 51), *Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating;*
- ANSI/AMCA 230, *Laboratory Methods of Testing Air Circulating Fans for Rating and Certification;*
- AMCA 260, *Laboratory Methods of Testing Induced Flow Fans for Rating*; and
- ISO 5801, *Industrial Fans—Performance Testing Using Standardized Airways*.

Fans that cannot be tested to one of these standards are excluded from AMCA 205 and any code or standard with fan efficiency requirements based on AMCA 205.

AMCA 205 defines FEG as "the efficiency grade of a fan without consideration of the drives" and as "an indicator of the fan's aerodynamic ability to convert shaft power, or impeller power in the case of a direct driven fan, to air power." The FEG is calculated using the fan's peak total efficiency, fan size, and application defined by its test configuration.

The FEG is an indicator of the fan's aerodynamic quality. It accounts for all the energy delivered to the airstream. As such, the fan total pressure is used in the determination of the FEG. For more information on fan peak total efficiency, see Reference 11.

FEG calculation procedures are provided in Annex A of AMCA 205. Generally, AMCA or fan manufacturers, not HVAC system designers, contractors, or code officials, use these calculations to establish the FEG. Once the FEG is determined, it is simply reported as fan data in manufacturers' brochures and electronic software to engineers, contractors, equipment packagers, etc., so they can establish compliance with the applicable code or standard. Manufacturers can elect

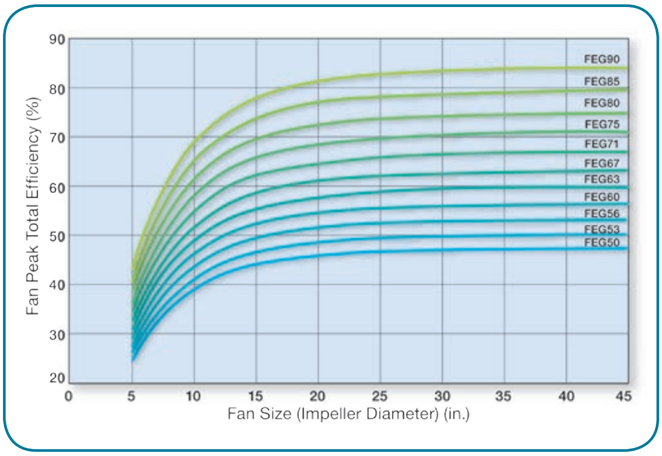

Figure 1: Fan efficiency grade curves for FEG50–FEG90. *Source*: AMCA 205-12 Energy Efficiency Classification for Fans.

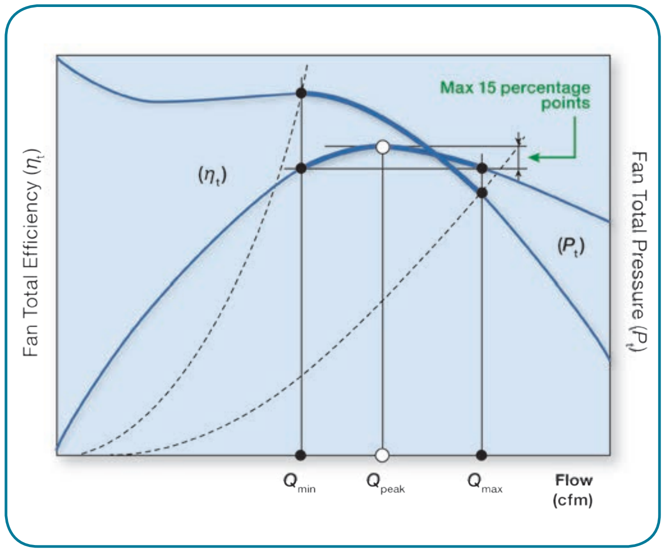

Figure 2: Allowable selection range based on operation within 15 percentage points of the peak total efficiency.

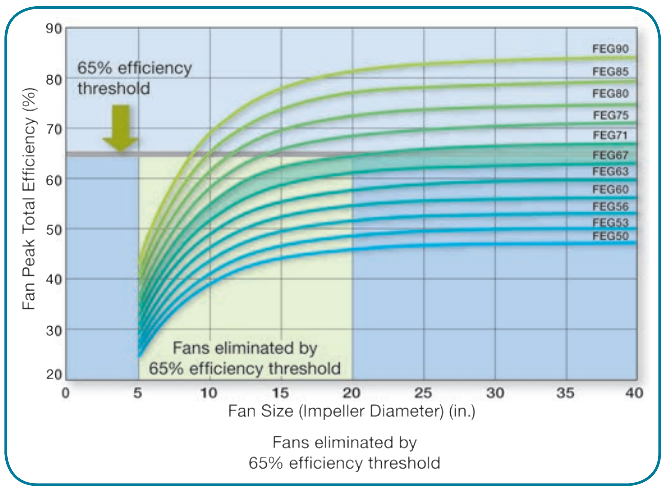

Figure 3: FEG curves in comparison with a straight-line single efficiency requirement. Regulating fans based on simple efficiency would eliminate many types based on fan size. For example, an efficiency based on 65% would eliminate many fans under 20 in. (508 mm) in diameter.

to have FEG ratings for fans certified by AMCA's Certified Ratings Program.

To streamline the application of AMCA 205, AMCA developed FEG curves with discrete bands based on fan size (impeller diameter) and fan peak total efficiency (*Figure 1*). The fan efficiency bands came about by collecting fan efficiency data on a variety of fan types and sizes from manufacturers around the world. The efficiencies were plotted and the bands were developed from the data.

The shape of the discrete bands helps accommodate an entire fan product line with the same FEG rating. As defined by AMCA 205, a fan belongs to a FEG if, for the fan impeller diameter, the fan peak efficiency falls between the upper and lower limits for that grade.

Not only is high peak efficiency important, so is selection of the fan to operate near peak efficiency. AMCA 205 states that the "fan operating efficiency at all intended operating point(s) shall not be less than 15 percentage points below the fan peak total efficiency" (*Figure 2*). AMCA encourages codes and standards bodies adopting AMCA 205 to include a selection window of this type in their fan efficiency requirement. Standard 90.1 has a selection window of 15 percentage points; the IgCC has a more restrictive 10 percentage points.

U.S. Fan Efficiency Codes and Standards

When fan efficiency requirements were first considered in 2007, the initial concept was to set a requirement at a single efficiency threshold, i.e., 65%. However, setting a simple efficiency threshold would eliminate many fans based on fan diameter (*Figure 3*). This is what drove the development of a fan efficiency classification system (i.e., FEGs) that could be used in codes and standards for energy and construction.

As mentioned previously, reducing fan energy consumption must go beyond the fan peak efficiency, hence, a complete fan efficiency requirement within a code or standard will have at least two clauses: one that establishes a baseline fan efficiency grade, and another that specifies a selection window relative to the fan's peak total efficiency.

As shown in the sidebar, the fan efficiency requirement in Standard 90.1-2013 has these two parts: one sets the efficiency requirement at FEG67 based on AMCA 205; the other requires the sizing/selection window to be within 15 percentage points of the peak fan total efficiency.

The 2012 International Green Construction Code, in a section that pertains only to buildings 25,000 ft^2 (2323 m^2) and less, being a "green" standard has more stringent requirements: a higher FEG level, FEG71, and a smaller selection window of 10 percentage points.

Beyond setting a FEG and selection window, codes and standards adopting AMCA 205 need to specify scope, such as fan sizes and applications. Fan efficiency regulations are new, and the industry must come to grips with understanding, applying, and enforcing a new class of requirements. Therefore, the Standard 90.1 requirement has a number of exceptions that will ease the burden of the standard while the industry climbs the learning curve. For example, the exceptions also take into account that regulating life/safety fans that operate only during emergencies would save little energy.

Among the Standard 90.1 exceptions is one for powered roof/wall ventilators. Standard 90.1 is the first widely adopted energy standard to include requirements for fan efficiency. Throughout the development of this new requirement, it was envisioned to use a single minimum energy efficiency metric for simplicity of implementation and enforcement. Consequently, some popular fan types and applications cannot presently meet the requirement without undue burden on designers and the fan industry in general. So certain fans, such as powered roof/wall ventilators, were exempted from the standard to allow fan manufacturers time to make design improvements or offer alternate solutions. AMCA International is working closely with Standard 90.1's committee, and others, to formulate more appropriate efficiency minimums that better serve powered ventilator applications, and to account for fans that currently fall outside the scope of AMCA 205.

Different codes and standards bodies are free to specify different FEG levels and sizing/selection windows, and develop their own list of exceptions.

Future Considerations

Current fan efficiency requirements and proposals specify a single FEG rating as a minimum efficiency threshold. While convenient for regulating fan efficiency for the first time, this may not be the best long-term solution, considering that energy efficiency requirements will likely become more stringent over time. *Figure 4* shows the peak total efficiency levels for centrifugal and mixed flow fans. As minimum FEG thresholds are increased, some fan types would no longer satisfy the requirement at a reasonable cost, thereby potentially disappearing from the market. One way to maintain a large selection of fan types would be to set different FEG thresholds for different types of fans. (EU) 327/2011 takes this approach.

Future developments for fan efficiency regulations include adoption of requirements based on AMCA 205 into other codes and standards. Proposals have been submitted to the 2015 International Energy Conservation Code and the 2014 IAPMO Green Supplement. Proposals are in the works for ANSI/ASHRAE/IES/USGBC Standard 189.1 and California Title 24.

Development of the U.S. Dept. of Energy's fan efficiency standard is just beginning; the Framework Document was published in the *Federal Register* on Feb. 1, 2013, which presents DOE's perspective of the fan market and the options it is considering for regulating commercial and industrial fans.[12] AMCA International is working with ACEEE, the Appliance Standards Awareness Project, and other organizations to jointly develop a proposal to DOE for the efficiency requirement and testing standards. Based on best-available information, a DOE requirement could be in place with enforcement between 2018 and 2020. To follow developments in fan efficiency codes, standards, and regulations, visit www.amca.org/feg.

Conclusion

The insertion of a fan efficiency requirement into ASHRAE Standard 90.1-2013 is significant because it will have HVAC designers, contractors, commissioning providers, code officials, and facility owners/operators thinking explicitly about fan efficiency grades and sizing/selection practice on a large scale. This scale is expected to grow as fan efficiency requirements make their way into the IECC, and ASHRAE Standard 189.1. The work done by ASHRAE's committees and subcommittees, and those of AMCA International, has helped set the stage for a DOE fan efficiency regulation.

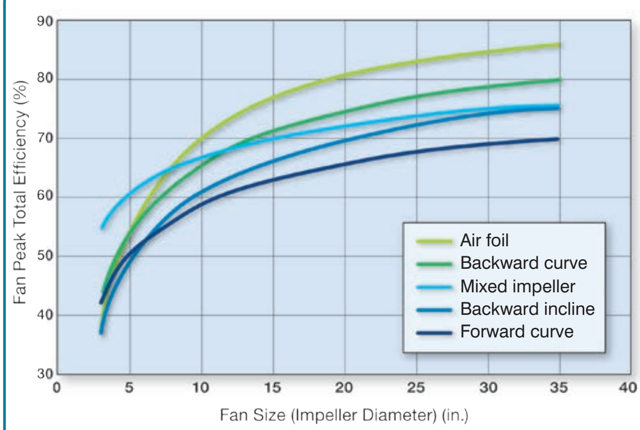

Figure 4: Fan efficiency curves based on fan type and size. Note the similarity of the curves to the FEG curves in *Figure 1*.

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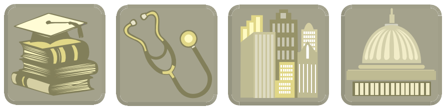

The Role of Fan Efficiency in Reducing Energy Use

How the new fan-efficiency requirement in ASHRAE 90.1-2013 will work with the standard's fan-power limitation

By MICHAEL BRENDEL, PhD
Lau Industries
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In the United States, HVAC systems generally consume the largest portion of a commercial building's energy budget, with supply, return, and exhaust fans accounting for approximately 1.25 quads—or roughly the equivalent of 225 million barrels of oil—of energy use annually (Figure 1). Expected in the fall, the 2013 version of ANSI/ASHRAE/IES Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, will include a new fan-efficiency requirement based on ANSI/AMCA Standard 205-12, *Energy Efficiency Classification for Fans*. This article explores the role fan efficiency plays in Standard 90.1, with specific attention paid to how the new fan-efficiency requirement will work with the standard's fan-power limitation.

Basics

Thermal loads and ventilation requirements determine the amount of airflow necessary to achieve HVAC performance targets. Fans provide the motive power to generate required airflow. Resistance to airflow is overcome by a fan through the addition of energy to an air stream. The rate at which energy is added to an air stream by a fan is called air power, which is calculated simply by taking the product of airflow rate and fan total pressure rise. Fan total pressure rise exactly balances system total pressure drop (see the sidebar "Fan Static and Total Pressure").

It is important to note that there is a significant difference between total pressure drop and static pressure drop

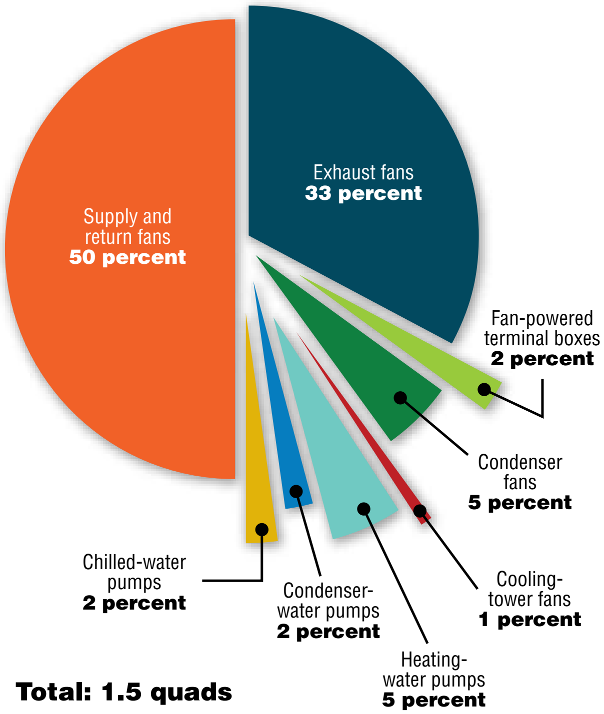

FIGURE 1. "Parasitic energy use" in commercial HVAC systems.[1]

in an air-distribution system. Except for the fan, airflow through an air-distribution system always is experiencing a total energy loss, largely because of air friction. This energy loss is represented by total pressure drop, not static pressure drop. Static pressure does not always decrease and may be exchanged for velocity pressure

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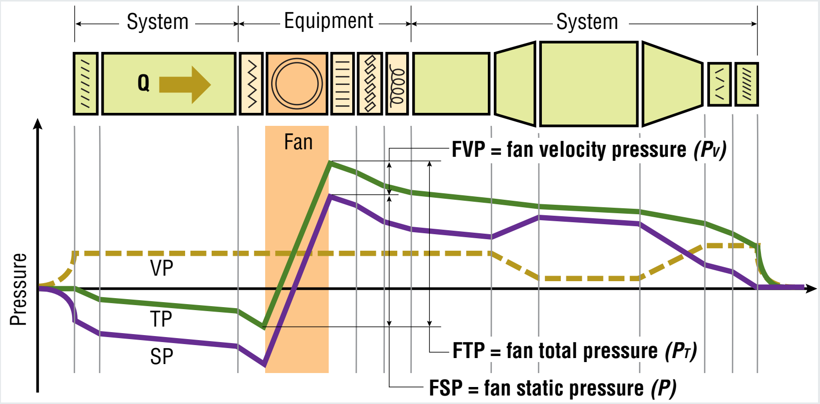
in duct expansions, in duct contractions, or at branches.

Likewise, fan efficiency is appropriately described by fan total efficiency, as this represents the ratio of energy delivered (air power) to power input at the fan shaft. The common practice of basing fan selection on fan static pressure is incorrect and will need to be reconsidered as energy conservation becomes more important.[2]

For a given operating point, airflow, and pressure, the fan with the highest efficiency will consume the least power. But simply selecting the most efficient fan does not ensure minimal energy consumption, especially when an air-distribution system is poorly designed and/or installed. For example, consider two competing systems with a 20,000-cfm flow requirement. System A has a total pressure drop of 5.5 in. wg, while System B has a total pressure drop of 7 in. wg because of inappropriately placed elbows (Figure 2). System A's fan operates at 65 percent total efficiency, while System B's operates at 70. At first glance, one might conclude the more efficient fan consumes less power, but that is not the case. Basic calculations show System A's fan is consuming 26.6 hp, while System B's is consuming 31.4. The difference is driven by the higher total pressure drop imposed by System B, not fan efficiency.

FAN STATIC AND TOTAL PRESSURE

Below, a typical air system driven by a single fan is shown, along with corresponding total, static, and velocity pressures. The total pressure is everywhere, decreasing except at the fan. Total pressure drop represents the energy loss attributed to airflow and is best described by the fan total pressure. This further demonstrates the importance of fan total pressure, rather than fan static pressure, in fan selection.



Minimizing total pressure drop through careful air-distribution-system design is the first step to ensuring minimum fan energy consumption. Think of a fan as the motor driving a system (load). The smaller the load, the less energy the motor must provide. Think responsible system design and careful installation first and selection of the most efficient fan second.

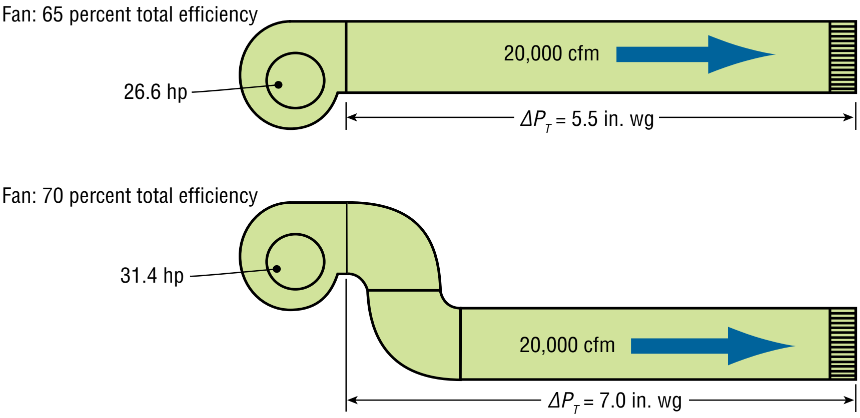
Existing Requirements

For many years, Standard 90.1 has imposed a fan-power limitation influencing both system design and fan efficiency. To illustrate, Option 2 in the fan-power limitation (Standard 90.1 Table 6.5.3.1.1A) requires net shaft power for all applicable fans in a system to be less than a specified maximum value. Equation 1 shows the requirement in generic form:

$$H \leq \alpha Q + A \qquad (1)$$

where:

H = fan-power limit, brake horsepower



	System A	System B
Required flow rate, cubic feet per minute	20,000	20,000
Total system resistance, inches of water gauge	5.5	7.0
Fan total efficiency, percent	65	70
Shaft power, horsepower	26.6	31.4

FIGURE 2. Design and corresponding energy-efficiency differences of two air systems with a 20,000-cfm flow requirement.

α = coefficient dependent on system type (constant volume or variable volume)

Q = supply-air flow rate, cubic feet per minute

A = pressure-drop adjustment factor allowing certain system configurations and/or special components

In practice, all fans that supply, return, or exhaust conditioned air are included in the fan-power calculation. For this article, we will consider a simple system consisting of a single supply fan to illustrate the influence of the fan-power limitation on system design and fan efficiency.

Dividing both sides of Equation 1 by flow rate (Q) results in an expression for specific fan power (SFP) (Equation 2). When considering a single fan, it is important to realize SFP is equivalent to the ratio of fan pressure to fan efficiency:

$$\text{SFP} = \frac{H}{Q} = \frac{P_T}{\eta_T} \leq \alpha + \frac{A}{Q} \qquad (2)$$

where:

P_T = fan total pressure

η_T = fan total efficiency

For small values of SFP, fan total pressure (P_T) must be low and/or fan total efficiency (η_T) must be high. Because fan efficiency always is less than 100 percent, the fan-power limitation effectively places an upper limit on fan total pressure, which is equivalent to system total pressure drop. Because this is equivalent to the ratio of system pressure to fan efficiency, system designers are encouraged to minimize system pressure drop and select a high-efficiency fan.

In the absence of pressure-drop adjustments (A = 0) and using the variable-air-volume (VAV) coefficient (α) of 1.3 hp per thousand cubic feet per minute (kcfm), as found in Standard 90.1, the maximum system resistance allowed for various fan selections can be calculated. For example, a system with a total pressure drop of 6.5 in. wg requires a minimum operating fan total efficiency of 79 percent to meet the 1.3-hp-per-kcfm requirement. Meanwhile, a system with a 2-in.-wg fan total pressure requires a minimum fan total efficiency of only 25 percent. The higher the system pressure drop, the higher the fan efficiency needed to meet the standard.

The relationship between the fan-power limitation and fan total efficiency for a single-fan system is shown in Figure 3. Here, fan total efficiency is plotted as a function of fan

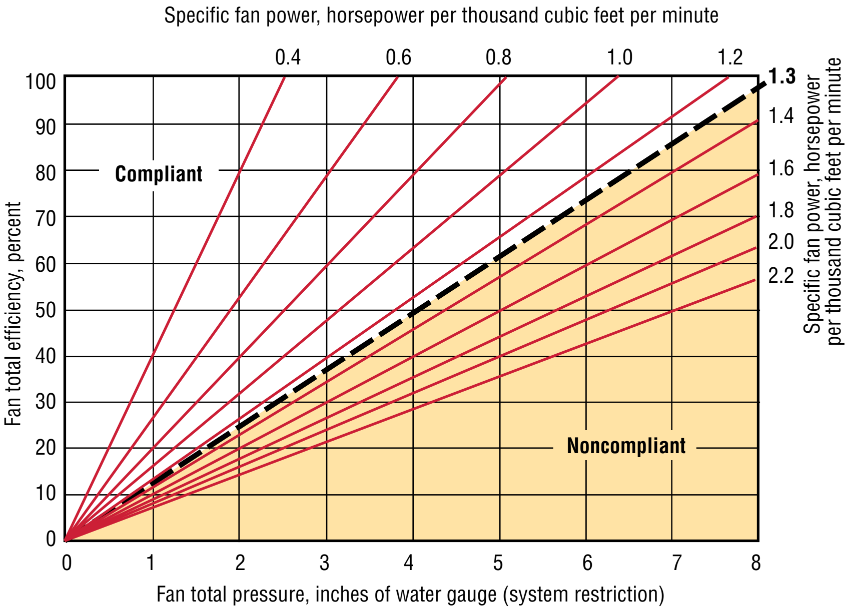


FIGURE 3. Fan total efficiency required to meet the Standard 90.1 fan-power limitation as a function of fan total pressure.

total pressure. Radial lines extending from the origin are lines of constant SFP. All combinations of fan pressure and efficiency to the left of the 1.3-hp-per-kcfm line comply with the fan-power limitation, while those to the right do not. Systems with low total-pressure requirements can meet the standard with low fan total efficiency.

The SFP limit amounts to an implicit fan-efficiency requirement that is a function of system pressure drop. The 1.3-hp-per-kcfm limit would be higher if pressure-drop adjustments were applicable. For example, a 0.5-in.-wg-pressure-drop credit is given for systems with fully ducted returns. Note that all pressure-drop adjustments allowed by the standard result in an allowable SFP increase satisfied by a 65-percent-efficient fan.

In general, compliance with the fan-power limitation can be achieved with careful system design and existing fan technology. The fan-power limitation is especially easy to meet when system pressure drop is low.

Further energy savings can be realized by requiring fans to meet a minimum energy efficiency—especially when low-efficiency fans can meet the fan-power limitation by a wide margin. However, a requirement based on a single value of minimum fan efficiency can have unintended consequences. Small fans are less efficient than large fans because of a variety of factors, including air-viscosity effects, lack of proportional manufacturing tolerances, and other losses that do not scale with traditional fan laws. Generally, a fan with a 10-in. impeller will have a lower peak efficiency than a geometrically similar fan with a 25-in. impeller.

Setting minimum fan efficiency too high could eliminate smaller fans and the equipment that uses them. However, there now is another option for rating fan energy efficiency.

Fan Efficiency Grade

Fan efficiency grade (FEG) is a new metric recognizing the relationship between impeller diameter and peak total efficiency. FEG is defined by ANSI/AMCA Standard 205 and ISO 12759, *Fans -- Efficiency Classification for Fans*. FEG is based on peak total efficiency and is an indicator of the aerodynamic quality of a fan. For a given impeller diameter, a fan with a FEG of 85 is capable of greater aerodynamic efficiency than a fan with a FEG of 67, but it does not represent the operating efficiency for a particular application. (A more detailed look at FEG and its integration into Standard 90.1-2013 can be found in an article by Cermak and Ivanovich.[3])

The Standard 90.1-2013 fan-efficiency requirement places a minimum FEG of 67 on all fans moving conditioned air, with the exception of fans in certain energy-rated equipment, fans with motors of 5 hp and less, power roof ventilators, and emergency fans. The standard also requires the selection of fans within 15 points of their peak total efficiency. (Note: ANSI/AMCA Standard 205 simply defines FEG and explains how to calculate it. The 15-percentage-point sizing/selection requirement is in a normative appendix.)

A FEG of 67 is considered an acceptable starting point for a new requirement for fans, with revisions likely to bring higher levels and perhaps tighter selection limits. In the meantime, most fans on the market easily can meet the new requirement.

For air-distribution systems with pressure drops greater than approximately 5 in. wg, Standard 90.1 encourages fans with FEGs higher than 67 to meet the fan-power limitation. Table 1 shows several fan selections for a single-fan VAV system without additional pressure-drop adjustments. No additional steps or calculations are required, just a fan with a FEG of 67 or higher and the operating-efficiency condition being met. FEG, operating total efficiency,

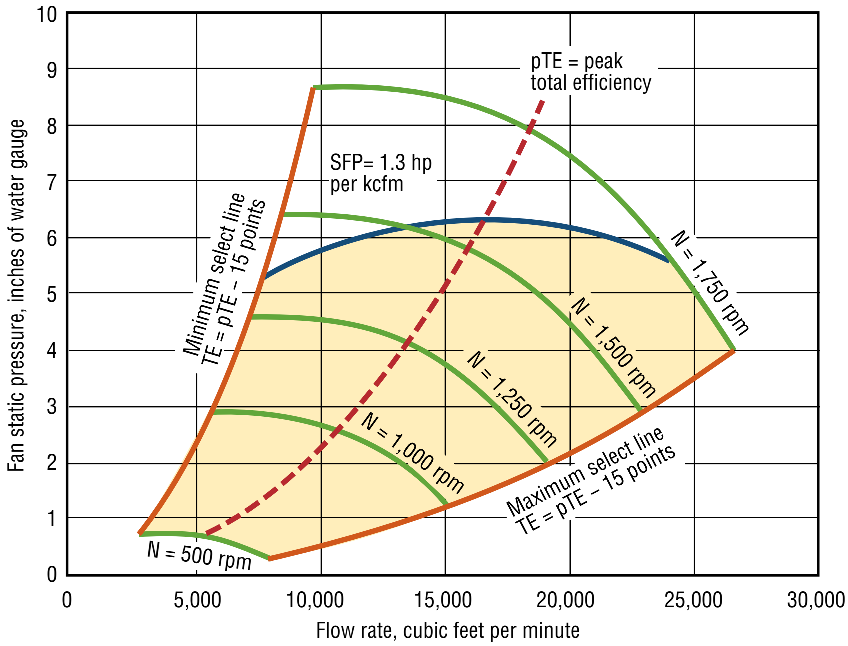


FIGURE 4. Operating envelope for a 27-in. double-width-double-inlet airfoil fan with a fan efficiency grade of 85.

and peak total efficiency are supplied through a fan manufacturer's catalog data or selection software.

Examples

The following examples show the results of selecting a fan based on Standard 90.1 fan-power limits and the new FEG criteria with a 15-percentage-point selection window. In all cases, the fan operating point is 20,000 cfm and 6-in.-wg fan total pressure.

• Example 1: A FEG-85-rated fan operating one point from peak total efficiency is selected. The calculated SFP is 1.14 hp per kcfm; thus, the FEG, fan-power-limitation, and efficiency criterion are met.

• Example 2: The fan is rated at FEG 80 and selected four points from peak efficiency. The calculated SFP is 1.28 hp per kcfm; thus, the FEG, fan-power limitation, and efficiency criterion are met.

• Example 3: The fan is rated at FEG 67 and selected two points from peak efficiency. However, the calculated SFP is 1.50 hp per kcfm, which does not comply with the standard.

• Example 4: The fan is rated at FEG 85, but selected too far (18 points) from peak total efficiency, and the SFP exceeds the limit of 1.3 hp per kcfm.

• Example 5: The fan is rated at FEG 63, which disqualifies it. The selection is close to peak total efficiency (two points), but the SFP is not in compliance.

While these simple examples illustrate the relationship between fan efficiency and fan-power limitation, most practical systems contain multiple fans operating at different conditions. The new efficiency rules will require all applicable fans to have a FEG of at least 67, but the fan-power limitation will continue to encourage high-efficiency fans to offset any low-efficiency fans used in a system.

Example*	Shaft power, horsepower	Fan total efficiency, percent	Peak fan total efficiency, percent	Efficiency difference	FEG	Specific fan power, hp per kcfm	Result
1	22.8	83	84	1	85	1.14	Pass
2	25.6	74	78	4	80	1.28	Pass
3	30.0	63	65	2	67	1.50	Fail
4	28.7	66	84	18	85	1.43	Fail
5	31.5	60	62	2	63	1.58	Fail

*All examples for 20,000 cfm at 6 in. wg (fan total pressure)

TABLE 1. Fan efficiency grade (FEG) and the Standard 90.1 fan-power limitation.

The 15-point selection criterion is a key component of the new requirement and helps to ensure fans are selected near their peak efficiency.

To illustrate the scope of the 15-point selection requirement, a typical operating envelope for a 27-in. double-width-double-inlet airfoil fan with a FEG of 85 is shown in Figure 4. The minimum and maximum system curves correspond to the peak total efficiency less 15. The 15-point restriction is relatively broad and covers a large portion of the fan's performance envelope. In fact, it is fairly similar to the performance envelope that would be presented by the manufacturer in print catalogs or selection software. Also shown in Figure 4 is a curve indicating the SFP of 1.3 hp per kcfm. For a single fan in a VAV application and in the absence of any pressure adjustments, selections can be made only in the shaded region below the line to meet the current standard. This again stresses the fact the fan-power limitation encourages system designs with low resistance.

Summary

While regulating fans leads to energy savings, much more substantial savings can come from the design and installation of low-pressure-drop systems and the use of high-efficiency fans. Standard 90.1-2013 will encourage good system design and the use of high-efficiency fans to achieve energy goals.

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Did you find this article useful? Send comments and suggestions to Executive Editor Scott Arnold at scott.arnold@penton.com.

Fan Efficiency Regulations:

Where Are They Going?

By MICHAEL IVANOVICH, Director of Strategic Energy Initiatives, AMCA International

The U.S. Department of Energy (DOE) estimates that commercial fans and blowers consume 139,533 million kWh of electricity per year and industrial fans and blowers consume 90,057 million kWh of electricity per year. In total, this amounts to 0.79 quads of energy, which is equivalent to consuming approximately 28.4 million tons of coal per year.

To date, DOE has not regulated the energy efficiency of commercial and industrial fans and blowers, nor have model codes and standards for energy or green construction promulgated fan-efficiency requirements.

But things are set to change—drastically.

Since AMCA published AMCA 205 Energy Efficiency Classification for Fans in 2010, groundwork for establishing fan-efficiency requirements that began in 2007 has increased in momentum and is beginning to appear in published regulatory documents.

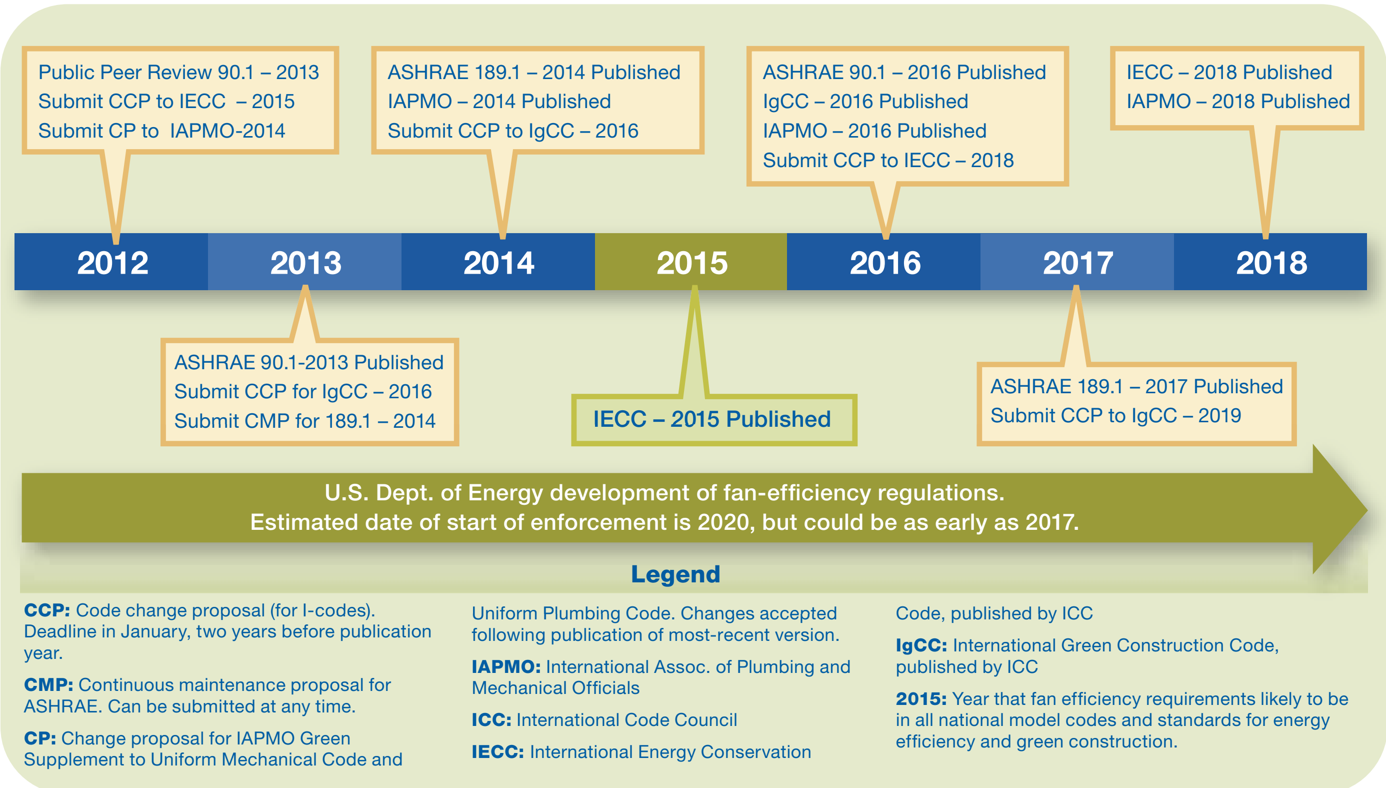
As shown in Figure 1, beginning with the 2012 International Green Construction Code (IgCC), fan efficiency requirements are expected to appear in the next issue of the model codes and standards as follows:

- 2012: International Green Construction Code
- 2013: ANSI/ASHRAE/IES 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings
- 2014: ANSI/ASHRAE/IES/USGBC 189.1 Design of High-Performance, Green Buildings Except Low-Rise Residential Buildings
- 2014: IAPMO Green Supplement to Uniform Mechanical Code and Uniform Plumbing Code
- 2015: International Energy Conservation Code.

IgCC

As mentioned earlier, the 2012 IgCC fan efficiency requirement is already available to the public. For buildings 25,000 ft^2 and less, stand-alone exhaust, supply, and return fans that are larger than 1 hp must have a fan efficiency grade (FEG) of 71 or more, and be selected to operate within 10 percentage points of their peak total efficiency. The 2012 IgCC references AMCA 205-10, the 2010 version of the standard.

Figure 1: Timeline of national codes and standards for adding fan-efficiency specifications in national codes and standards. Also, note that the U.S. Dept. of Energy is establishing a fan-efficiency standard for regulatory purposes during the entire timeline.



ASHRAE 90.1

Next in line is ASHRAE 90.1, for which a "continuous maintenance proposal" is well into the ASHRAE process as Addendum u. Addendum u underwent an advisory public peer review in 2011, and is slated for an official public peer review during the summer of 2012. Because ASHRAE 90.1 is a baseline standard, the FEG level is 67 instead of 71, and selection band is within 15 percentage points of peak total efficiency, not 10. The Addendum also has exceptions for fans 5 hp or less; powered roof ventilators; fans that will operate only during emergencies; and fan arrays with an aggregate motor nameplate rating of 5 hp or less.

Addendum u is expected to complete the ASHRAE process in time for the publication of Standard 90.1-2013.

ASHRAE 189.1

The completion of Addendum u for 90.1 will trigger the development of a continuous maintenance proposal for 189.1. At that time, AMCA and other industry stakeholders will determine the appropriate FEG level, fan selection criteria, and exceptions.

IAPMO Green Supplement

IAPMO began publishing its Green Supplement to the Uniform Mechanical Code and Uniform Plumbing Code in 2010. The Supplement is on a biannual cycle, and is roughly split into plumbing and HVAC sections. The HVAC section is tightly connected to ASHRAE 90.1 through similar language and by reference. In 2012, AMCA International submitted a change proposal for the 2014 version of the Supplement that would insert language identical to the then-current version of Addendum u. Should Addendum u be modified as a result of public peer review, the IAPMO proposed language can be modified while the proposal is being evaluated.

IECC

The completion of Addendum u will also trigger the development of a code change proposal for the International Energy Conservation Code, so that it is harmonized with 90.1. The publication of the 2015 IECC will complete the first complete cycle of national model codes and standards for energy and green construction to have fan-efficiency requirements for buildings (except low-rise residential buildings).

Market Impact

Although the establishment of fan efficiency requirements in national codes and standards is certain, the timing and size of market impact is much less so. It is up to states and local jurisdictions to adopt model codes and standards, and some may eliminate fan efficiency requirements when they do so. Enforcement is another issue, as time-strapped code officials view safety codes as a higher priority. Moreover, AMCA's Fan Efficiency Grade metric is new to the industry, so training is needed so engineers, contractors, commissioning providers, test-and-balance-contractors, owner/operators, and code officials understand them and apply/enforce them correctly.

Federal Regulation

Also shown in Figure 1, the U.S. Department of Energy (DOE) signaled its intent to establish a federal efficiency standard for commercial and industrial fans, blowers, and fume hoods in June 2011. According to the DOE, its regulatory processes could have a fan efficiency regulation in effect and being enforced between 2017 and 2020.

DOE estimates that 20% energy savings for fans are possible, apart from system effects and other factors. The American Council for an Energy Efficient Economy (ACEEE) recently published an estimate of energy savings resulting from DOE regulation of fan efficiency in The Efficiency Boom: Cashing In on the Savings from Appliance Standards, 2012. The report "assumes that cost-effective energy savings of 10% were possible for centrifugal fans, and 56% for axial fans," based on options like including improved blade orientation, reduced friction losses, and improved design."

Based on ACEEE's estimate of average incremental cost of $1,400, a 2.2 year payback would be realized by a DOE efficiency standard, which would realize cumulative annual savings summing to 8.5 TWh in 2035 at a present value savings of $2 billion.

It's too early to tell what form the DOE efficiency standard will take, and how much energy it could ultimately save; however, AMCA International is working proactively with DOE and organizations that advocate for efficiency standards, such as ACEEE and the Appliance Standards Awareness Project.

Conclusion

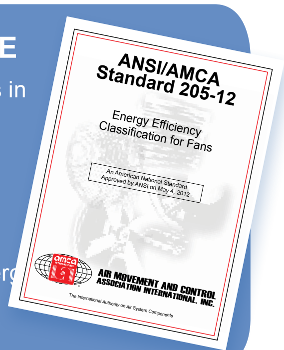
Commercial and industrial fans and their application are now in the crosshairs of efficiency regulation. All forms of regulation are now in play:

- Baseline energy codes and standards (ASHRAE 90.1 and IECC)
- Stretch/green codes (ASHRAE 189.1, IgCC, and IAPMO)
- Federal efficiency standards.

The full suite of existing baseline and green codes and standards are expected to have fan efficiency standards by 2015. Federal regulation is expected to be complete and enforced between 2017 and 2020.

Follow Developments HERE

AMCA regularly reports developments in all codes, standards, and regula-tions impacting fan efficiency at www.amca.org/feg/codes-and-standards.aspx. You can also download a free copy of ANSI/AMCA 205-12 Energy Efficiency Classification for Fans at this location.



By TIM MATHSON, principal engineer for centrifugal, vane axial, and industrial products, Greenheck Fan Corp., Schofield, Wis.; and MICHAEL IVANOVICH, director of strategic energy initiatives, AMCA International, Arlington Hts., Ill.

AMCA's Fan Efficiency Grades:

Answers to Frequently Asked Questions

Learn what FEGs are and how they are applied for HVAC systems in commercial and industrial buildings. It has become clear that fan system design improvements and higher efficiency fans could have substantially reduced HVAC energy use in commercial and industrial buildings. Until recent-ly, fan selection guidance and metrics that allow quick comparison of fan efficiencies have not been available. One ap-proach has been to specify a fan efficiency rating based on the aerodynamic properties of the fan itself, and to specify where on the fan efficiency curve the fan operation point should sit.

In essence, this is what AMCA International, working with ASHRAE's TC 5.1 fan committee, has done with the development of a new fan efficiency classification system, called the Fan Efficiency Grade (FEG).

Work that began in 2007 to address fan efficiency classifications is now paying off. FEGs were formalized with the publication of AMCA 205 in 2010, and an AMCA Certified Ratings Program is now in place to provide third-party verification of FEGs as specified in AMCA 211.

This article answers questions that engineers, building owners, operators, regulators, and contractors may have about FEGs.

What is a Fan Efficiency Grade?

A fan efficiency grade (FEG) is a numerical rating that classifies fans by their aerodynamic ability to convert mechanical shaft power, or impeller power in the case of a direct driven fan, to air power. Essentially, it reflects fan energy efficiency, allowing engineers to more easily differentiate between fan models: more efficient fan models will have higher FEG ratings. FEGs apply to the efficiency of the fan only and not to the motor and drives. FEG ratings can be applied to custom-built single fans and to series-produced fans manufactured in large quantities.

In 2007, the ASHRAE Standing Standard Project Committee (SSPC) 90.1's, mechanical subcommittee, invited ASHRAE TC 5.1, Fans, to participate in the development of the requirements for fan efficiency. An ad hoc working group was formed promptly. With assistance from the AMCA Fan Committee, the group first developed a system for energy-efficiency classification of fans. The group recognized that a highly efficient fan will operate inefficiently if used in the low-efficiency region of the fan curve. This led to a requirement that fans be specified within 10 percentage points of the peak total efficiency (Figure 1).

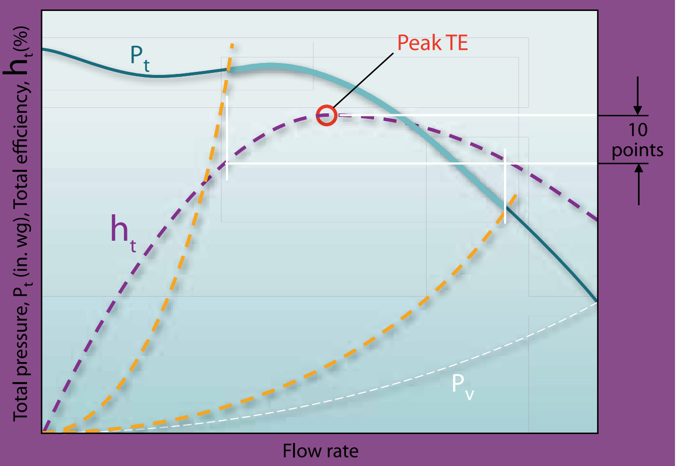


Figure 1: A typical fan curve showing the 10-point total efficiency band.

FEGs were developed by AMCA in response to regulators in the U.S. and abroad taking interest in reducing fan energy consumption and the environmental impacts of that consumption. Simultaneously, the International Standards Organization (ISO) was considering a similar efficiency rating for European energy standards and regulations.

For the U.S. market, where fans are normally cataloged as bare-shaft fans and purchased with standard NEMA motors, FEGs were defined through AMCA Standard 205-10, *Energy Efficiency Classification for Fans*. AMCA Publication 211, *Product Rating Manual for Fan Air Performance,* describes the certification process for rating a fan for FEG.

For the European Union, where fans are often packaged with integral motors, ISO Standard 12759-2010, *Efficiency classification for fans,* defines fan-motor efficiency grades (FMEG). Note that these two grades are not equivalent and in no circumstances should FEG and FMEG be used simultaneously to evaluate fan performance.

What are FEGs used for?

FEG ratings are used by code authorities or by specifying engineers to define a minimum requirement for energy efficiency of a fan for a given application. The specifications can use a single-value FEG for each application.

The use of a single number is possible because the shapes of the FEG bands closely follow the actual peak efficiencies for typical fan designs (Figure 2). Smaller fans are typically less efficient

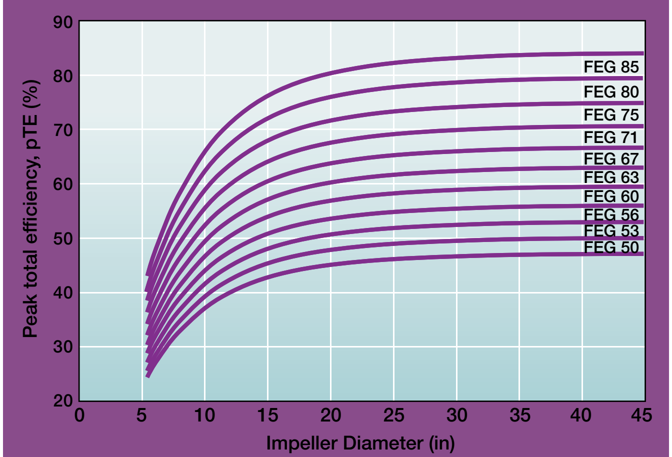


Figure 2: FEGs for various fan efficiencies and sizes.

than larger fans for a given fan type, and this trend is reflected in the shape of the efficiency bands. Rather than making individual fan selections to determine a minimum efficiency target for each duty point, the specifying engineer can simply establish a minimum FEG for the application (i.e., FEG71 for all supply fans, FEG67 for all exhaust fans, etc.). Minimum FEGs can also be adopted by energy codes and standards, such as ANSI/ASHRAE/IES 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings,* and the International Code Council's *International Green Construction Code* (IGCC).

How are FEG ratings calculated?

FEGs are based on peak total efficiency for a given fan size. The FEG is established by plotting the peak total efficiency at the appropriate impeller diameter, then reading the associated FEG band in which this point falls. For example, a fan with an impeller diameter of 15 in. and a peak total efficiency of 71% would have an FEG of 80 (Figure 3).

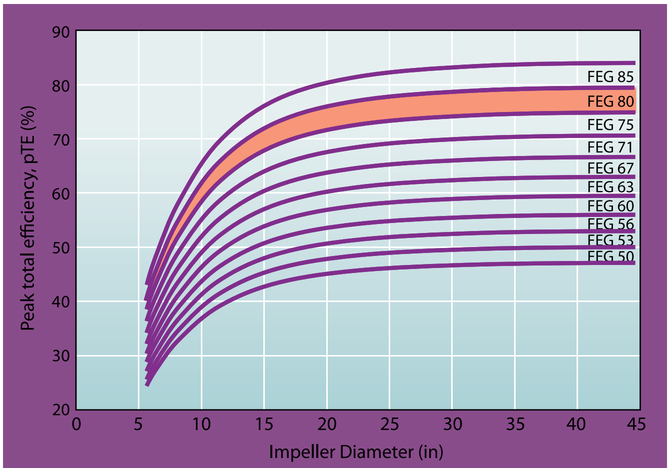


Figure 3: FEG band area for FEG80.

Annex A to AMCA 205-10 provides equations for the upper and lower boundaries of each fan efficiency grade, as well as a table of peak fan total efficiency versus fan size that can be used to calculate the FEG.

Engineers and other practitioners, however, will not have to calculate FEGs; they will find them in manufacturers' literature and software as they become available. AMCA-certified FEG ratings for fans will be identified in search results from the AMCA certified product database at www.amca.org/certified.

Which fan types and sizes are covered, and which ones are not?

AMCA 205 and AMCA 211 have slight differences with respect to minimum fan sizes, and there are a few other differences as well, as shown in Table 1. AMCA 205 is currently being revised, after which it will be harmonized with AMCA 211.

When codes and standards set FEG requirements, they will specify FEG ratings, fan sizes, and exclusions. For example, ASHRAE 90.1 is using FEG67 as its minimum FEG rating, and for fans above 5 hp; and there are a number of exclusions beyond those named in AMCA 211.

*Table 1: Differences in AMCA FEG standards 205-2010 and 211-2011. *Exclusions are listed in the Certified Ratings Program in AMCA 211 because their primary purpose is not to move air, there is no standardized method to determine their fan total efficiency, or their primary function is life safety.*

STANDARD	YEAR	MIN. SIZE	MAX. SIZE	MIN. ANNUAL ENERGY	EXCLUSIONS*
AMCA 205	2010	1/6 hp (125 W)	None	1,000 kWh	None (this will change)
AMCA 211	2011	1 hp (750 W)	None	None	Air curtains; induced flow fans; energy recovery ventilators (heat recovery ventilators); positive pressure ventilators

The IGCC is considering FEG71 as a minimum threshold for fans at or above 1 hp. The IGCC, which is a "reach code" adopted by organizations looking for "beyond code" building energy performance, is scheduled to release Version 1 of the code in 2012. The IGCC requirement is proposed for the prescriptive section of the code, which is applicable for buildings up to 25,000 sq ft.

For the most up-to-date information on AMCA 205 revisions and matching to 211, visit www.amca.org/feg.

How do I consider FEG ratings in my projects when sizing, selecting, and specifying fans? What about fan systems, that is, fans with motors and drives?

Once an engineer has narrowed the list of available fans to only those that meet the minimum FEG rating as specified, the focus should be on actual power consumed. Since FEG ratings are a measure of peak fan energy efficiency and not actual operating efficiency, their main value is in differentiating between different fan types.

For a given duty (flow rate and pressure), several fan types and multiple fan sizes may be considered. When making fan selections, the list of available fans is first checked to ensure they meet the minimum FEG requirement. This means they must meet the required peak total efficiency but also must be selected within 10 percentage points of this peak. After that, the refined list of fans is compared using first cost and operating cost, and any other parameters, such as sound, physical size, and so forth. The actual fan input power becomes the basis for the operating cost used in a payback, ROI, or other economic analysis that can be used to compare annual and lifecycle costs for different fan types and sizes:

From Table 2, note that eight fans are physically capable of the performance required, and each of these fans happens to have the same FEG rating. The smallest three fans are not selected within 10 percentage points of the peak efficiency. These fans would operate near the bottom of their fan pressure curves; therefore, they would not meet Standard 205 and would not be considered for this duty. The remaining fans sizes, which range

TABLE 2 PRESENTS AN EXAMPLE OF FAN SELECTIONS USING FEG AND PEAK TOTAL EFFICIENCY RATINGS.

Table 2: Fan selection example using single-width, single-inlet (SWSI) fans with ducted outlet and 10,000 cfm at 3-in. Pt. *Total efficiency for these selections is not within 10% of peak efficiency.

FAN SIZE (in.)	FAN SPEED (rpm)	FAN CLASS	FAN POWER (bhp)	ACTUAL STATIC-EFFICIENCY	ACTUAL TOTAL EFFICIENCY	PEAK TOTAL EFFICIENCY	FEG	INLET LwA
18	3238	III	11.8	18%	40%	78%	85*	103
20	2561	II	9.56	30%	49%	78%	85*	100
22	1983	II	8.02	44%	59%	79%	85*	96
24	1579	I	6.84	57%	69%	79%	85	90
27	1289	I	6.24	67%	76%	79%	85	88
30	1033	I	5.73	76%	82%	83%	85	84
33	887	I	5.67	79%	83%	83%	85	84
36	778	I	6.01	76%	79%	83%	85	83

from 24-in. to 36-in., could be considered using their actual brake horsepower (bhp) and other selection criteria.

As mentioned earlier, FEG ratings apply only to the fan efficiency and not to the motor and drives. Adding motors and drives to the selection process is partially a matter of complying with national energy regulations. The National Electric Manufacturers Assoc. (NEMA) established Premium Efficiency specifications for motors that were adopted into federal regulations via the U.S. Energy Independence and Security Act (EISA). EISA specifies minimum full load motor efficiencies; for example, a 7.5 hp open motor on the above fan selections has a minimum motor efficiency of 91.7%.

Accounting for drives begins with determining whether the fan will be driven directly or through a V-belt. V-belt drive losses vary considerably with power transmitted, type and number of belts, pulley diameters, tension, and so on. AMCA Publication 203, *Field Performance Measurement of Fan Systems,* has a chart of the typical range of losses for V-belt drives as they relate to power transmitted. The average drive losses range from around 9% for a 1 hp drive to around 4% for 50 hp and higher. Said another way, the drive efficiency would range from around 91% for a 1 hp drive to around 96% for 50 hp and higher. Note that direct driven fans do not encounter these drive losses and, therefore, have an effective drive efficiency of 100%. Direct drive fans should, therefore, be used whenever possible and especially on smaller fans. For the 7.5 hp drive on the above fan selections, the drive loss is estimated at 6% or 0.45 hp.

Variable frequency drives have some internal losses and also cause a slight decrease in motor efficiency. The combined effect is small, approximately 3% to 5% loss. However, their advantages in allowing fans to respond to system requirements and run at reduced speeds far outweigh these losses.

The following is an example of an energy analysis comparing a 24-in. SWSI fan to a 33-in. fan at 10,000 cfm at 3-in. total pressure. The fan operates 16 hours per day, and the electric rate is $0.10 per kW-hour. For simplicity, a VFD is not considered:

Size 24:
Total mechanical power = 6.84 fan shaft bhp + 0.45 hp drive loss = 7.29 hp

Total kW into motor = 7.29 hp × 0.746 kW/hp/ 91.7% motor efficiency = 5.93 kW

Total annual cost = 5.93 kW × 16 hours/day x 365 days/year × $0.10/kW-hour = $3446

Size 33:
Total mechanical power = 5.67 fan shaft bhp + 0.45 hp drive loss = 6.12 hp

Total kW into motor = 6.12 hp × 0.746 kW/hp/ 91.7% motor efficiency = 4.98 kW

Total annual cost = 4.98 kW × 16 hours/day × 365 days/year × $0.10/kW-hour = $2,908

Annual Savings = $3,446 – $2,908 = $538

What codes or standards refer to FEG ratings?

As mentioned earlier, FEGs (and FMEGs) were developed to facilitate regulatory measures that seek to increase fan and fan system efficiency.

AMCA 205 is currently being considered for adoption in an advisory "continuous maintenance proposal" into ANSI/ ASHRAE/IES 90.1-2010. It also is on the path to being adopted into the prescriptive requirements of the IGCC. For more information on these two developments, see related article, "Update on Fan Efficiency Grade Option into ASHRAE 90.1 and the International Green Construction Code." AMCA is reporting progress on AMCA FEG standards and where they are adopted into codes and standards at www.amca.org/feg.

If I want to replace my existing fan with a new fan that has an FEG rating, how do I calculate energy savings? Fan replacement is treated in much the same way as a new in-stallation. If required by code, the replacement fan must meet a minimum FEG rating and be selected within 10 points of the peak fan efficiency. The economic analysis would then be done using actual energy savings of the new fan over the existing fan. Replacement fans present some challenges in getting the new fan to fit in the same overall space as the old fan and physi-cally moving the new fan into this location. Unfortunately, this is made even more difficult when trying to use a larger, more efficient replacement fan.

However, the newer fans and fan systems result in energy (and economic) benefits beyond the fan efficiency. Not only can the actual fan efficiency be improved, older belt driven fans can be converted to direct driven fans with higher efficiency motors. Variable frequency drives can also be added to turn back fan speed during off-peak demand times.

Do FEGs relate to sound performance or other fan-performance parameters?

Fans, like many other machines, produce the least sound when they are operating most efficiently. This relates to FEG ratings in two ways. First, FEG ratings are a measure of peak total efficiency. With more shaft power being converted to usable aerodynamic power, less power is wasted creating heat and unwanted sound. For this reason, a fan with a higher FEG rating will generally have lower sound levels, all else being the same.

Second, fan sound varies considerably along a fan curve. Generally speaking, the most efficient part of the fan curve coincides with the quietest operation of the fan. As the operating point moves up or down the fan curve, sound is typically increased. By requiring the fan selection to be within 10 points of the peak fan efficiency, the louder parts of the fan curve are avoided altogether.

Figure 4: AMCA Certified Rating Program seals for air performance and FEG.

Where do I find FEG ratings?

Because the AMCA 211 standard was only recently updated to include the FEG certification program, there are no "certified" FEG ratings at this time. However, FEG ratings can be calculated from other fan performance data, as described above. Over time, FEG ratings will be included in manufacturers' catalogs, software, and data sheets. Fans that have FEG ratings will display a green AMCA certified rating seal; AMCA-certified fans that do not have an FEG rating will display a blue certified ratings seal (Figure 4).

There are three different types of certified FEG ratings, each with a distinct seal. The generic "FEG" seal, shown in Figure 4, can be used in a catalog when not all sizes in a licensed product line are "FEG" certified. If all sizes are "FEG" certified, then either the "Sound, Air Performance and FEG" or "Air Performance and FEG" seals may be used in the catalog.

Suggested Reading

The following articles are available at www.amca.org/feg:

"The Role of Fan Efficiency in Reducing HVAC Energy Consumption," by Michael Brendel, PhD. *AMCA inmotion*, April 2010.

"Fan Industry Meeting Energy Challenges," by Joe Brooks, PE; John Cermak, PhD, PE; and John Murphy, PhD. *AMCA inmotion,* April 2009.

"Select Fans Using Fan Total Pressure to Save Energy," by John Cermak, PhD, PEng; and John Murphy, PhD. *ASHRAE Journal,* July 2011.

"New Fan Standard for Energy Efficiency," by Mike Duggan. ISO Focus, October 2009. Note: Pertains to ISO 12759 and FMEG.

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