STANDARD

ANSI/AMCA Standard 208-18

Calculation of the Fan Energy Index

An American National Standard
Approved by ANSI on January 24, 2018

ANSI Accredited Standards Developer

Air Movement and Control Association International

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AMCA Publications

Authority AMCA Standard 208-17 was adopted by the membership of the Air Movement and Control Association International Inc. on November 22, 2017. It was approved as an American National Standard on January 24, 2018

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Calculation of the Fan Energy Index

1. Purpose and Scope

This standard defines the calculation method for the fan energy index (FEI), which is an energy efficiency metric for fans inclusive of motors and drives. This metric provides a standardized and consistent basis to compare fan energy performance across fan types and sizes at a given fan duty point.

Fan specifiers can use FEI to understand and communicate the fan efficiency design intent. Legislative or regulatory bodies can use FEI to define the energy efficiency requirements of fans.

The scope includes all fan and motor sizes and all applications, including fans with fan air performance based on tests in accordance with one of the following fan test standards: ANSI/AMCA Standard 210, ANSI/AMCA Standard 230, ANSI/AMCA Standard 250, ANSI/AMCA Standard 260, ISO 5801, or ISO 13350. All other fans are excluded (including air curtain units that are tested in accordance with ANSI/AMCA Standard 220).

2. Normative References

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

1. ANSI/AMCA Standard 99-16
   Standards Handbook
2. ANSI/AMCA Standard 207-17
   Fan System Efficiency and Fan System Input Power Calculation
3. ANSI/AMCA Standard 210-16/ASHRAE Standard 51-16
   Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating
4. AMCA Publication 211
   Certified Ratings Program Product Rating Manual for Fan Air Performance
5. ANSI/AMCA Standard 230-15
   Laboratory Methods of Testing Air Circulating Fans for Rating and Certification
6. ANSI/AMCA Standard 250-12
   Laboratory Methods of Testing Jet Tunnel Fans for Performance
7. ANSI/AMCA Standard 260-13
   Laboratory Methods of Testing Induced Flow Fans for Rating
8. IEC 60034-2-1 Ed. 2.0 b:2014
   Rotating electrical machines—Part 2-1: Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles)
9. IEC 60034-30-1 Ed. 1.0 (2014-03)
   Rotating electrical machines—Part 30-1: Efficiency classes of line operated AC motors (IE code)
10. IEEE 112-2004
    IEEE Standard Test Procedure for Polyphase Induction Motors and Generators
11. IEEE 114-2010
    IEEE Standard Test Procedure for Single-Phase Induction Motors
12. ISO 5801:2007
    Fans—Performance testing using standardized airways
13. ISO 13350:2015
    Fans—Performance testing of jet fans

14. NEMA MG 1-2016 (with 2017 Supplement [Part 34]) *Motors and Generators*
15. GB/T 1032-2012
    Test procedures for three-phase induction motors

3. Definitions/Units of Measure/Symbols

3.1 Definitions

For the purposes of this document, the terms and definitions given in ANSI/AMCA Standard 207, ANSI/AMCA Standard 99 and the following apply.

3.1.1 General definitions

3.1.1.1 Duty point
A single airflow and pressure point within the published operating range of the fan.

3.1.1.2 Reference fan
A conceptual fan used to relate all fans to a common baseline. The reference fan is one capable of producing the required airflow and fan pressure at a specified shaft input power, uses a V-belt transmission, has a motor efficiency based on a four-pole, 60 Hz, IE3 motor and does not include a speed control.

3.1.1.3 Regulated motor
A motor whose efficiency or power usage is subject to regulations under IEC 60034-30, GB 18613 or Subpart B or X in Part 431 of Title 10 of the Code of Federal Regulations (10CFR 431).

3.1.1.4 Default motor efficiency
A default efficiency assigned to the motor at its operating point when either the specific motor is not identified or the efficiency of the motor used is unknown. The assumed motor efficiency is representative of a premium efficiency (IE3) three-phase, four-pole, general purpose squirrel-cage induction motor.

3.1.1.5 Embedded fan
A fan that is set or fixed firmly inside or attached to a surrounding piece of equipment whose purpose exceeds that of a fan or is different than that of a standalone fan. This equipment may have safety or energy efficiency requirements of its own. Examples of embedded fans include supply fans in air handling units, condenser fans in heat rejection equipment, tangential blowers in air curtain units and induced or forced draft combustion blowers in boilers or furnaces.

3.1.1.6 Standalone fan
A fan in at least a minimum testable configuration, as defined in Section 4.1. This includes any motor, transmission or motor controller if included in the rated fan. It also includes any appurtenances included in the rated fan, and it excludes the impact of any surrounding equipment whose purpose exceeds or is different than that of the fan. Standalone fans do not include provisions for air conditioning, air filtration, air mixing, air treatment or heating. Examples include power roof ventilators, side-wall exhaust fans, whole house fans, inline fans, ceiling fans, jet tunnel fans and induced-flow laboratory exhaust fans.

3.1.1.7 Bare shaft fan
A fan without motor, transmission or motor controller.

3.1.1.8 Continuous control fan
A fan that has the capability to vary the operation of the fan continuously over the fans operating range either by varying the speed of the fan or varying the pitch of the impeller.

3.1.1.9 Non-continuous control fan
A fan that varies its operation to a discrete number of non-continuous operating points.

3.1.1.10 Fan
A rotary bladed machine used to convert power to air power, with an energy output limited to 25 kJ/kg of air, consisting of an impeller, a shaft, bearings and a structure or housing. It includes any transmissions, driver and/or controls if integrated, assembled or packaged by the manufacturer at the time of sale.

3.1.1.11 Impeller
A rotary bladed aerodynamic component that transfers mechanical energy to the airstream delivered by the fan.

3.1.1.12 Structure
Any component(s) of the fan necessary to support the impeller.

3.1.1.13 Housing
Any component or components of the fan that direct airflow into or away from the impeller and/or provide protection to the internal components. A housing may serve as a fan's structure.

3.1.1.14 Inlet
The area in contact with the fan's inlet area.

3.1.1.15 Outlet
The area in contact with the fan's outlet area

3.1.1.16 Motor controller
Any device that can be used to control the speed of the fan.

3.1.1.17 Driven fan
A fan configuration including a driver and, if included by the manufacturer, transmissions and controls.

3.1.1.18 Transmission
Any component that transfers energy from a driver to an impeller.

3.1.1.19 Direct-driven fan
A driven fan configuration in which the fan impeller is connected directly to the driver.

3.1.1.20 Belt-driven fan
A driven fan configuration in which the fan impeller is connected to the driver through a set of belts and sheaves mounted on the driver shaft and fan shaft. This includes fans with V-belt or synchronous belt power transmission.

3.1.1.21 V-belt power transmission
Drive belts having a substantially trapezoidal cross section that use sheaves (pulleys) having smooth contact surfaces. Conventional V-belts have a constant cross section along their length, while notched V-belts (also known as cogged V-belts) have slots running perpendicular to their length. The slots reduce bending resistance and offer improved efficiency over conventional V-belts. This standard does not account for this improved efficiency.

3.1.1.22 Synchronous belt power transmission
Drive belts having a substantially rectangular cross section containing teeth that engage corresponding teeth on the sheaves (pulleys), resulting in no-slip power transmission. These belts are sometimes called timing or toothed belts.

3.1.2 Impeller types

3.1.2.1 Axial impeller
An impeller (propeller) with a number of blades extending radially from a central hub in which airflow through the impeller is axial in direction; that is, airflow enters and exits the impeller parallel to the shaft axis (i.e., with a fan flow angle less than or equal to 20 degrees). Blades can either be single thickness or airfoil shaped.

3.1.2.2 Centrifugal impeller
An impeller with a number of blades extending between a back plate and shroud in which airflow enters axially through one or two inlets and exits radially at the impeller periphery. The airflow exits either into open space or into a housing with a fan flow angle greater than or equal to 70 degrees. Impellers can be classified as single inlet or double inlet. Blades can be tilted backward or forward with respect to the direction of impeller rotation. Impellers with backward tilted blades can be

airfoil shaped (AF), backward curved single thickness (BC), backward inclined single thickness flat (BI) or radial tipped (RT). Impellers with forward tilted blades are known as forward curved (FC).

3.1.2.3 Radial impeller
A form of centrifugal impeller with a number of blades extending radially from a central hub in which airflow enters axially through a single inlet and exits radially at the impeller periphery into a housing with impeller blades positioned such that the outward direction of the blade at the impeller periphery is perpendicular within 25 degrees to the axis of rotation. Impellers can optionally have a back plate and/or shroud.

3.1.2.4 Mixed flow impeller
An impeller with construction characteristics between those of an axial and centrifugal impeller with a fan flow angle greater than 20 degrees and less than 70 degrees. Airflow enters axially through a single inlet and exits with combined axial and radial directions at a mean diameter greater than the inlet.

3.1.2.5 Fan flow angle
The angle of the centerline of the air-conducting surface of a fan blade measured at the midpoint of its trailing edge with the centerline of the rotation axis, in a plane through the rotation axis and the midpoint of the trailing edge.

3.1.3 Fan types

3.1.3.1 Centrifugal housed fan
A fan with a centrifugal or radial impeller in which airflow exits into a housing that is generally scroll shaped to direct the air through a single fan outlet. Inlets and outlets can optionally be ducted.

3.1.3.2 Centrifugal inline fan
A fan with a centrifugal impeller in which airflow enters axially at the fan inlet and the housing redirects radial airflow from the impeller to exit the fan in an axial direction. Inlets and outlets can optionally be ducted.

3.1.3.3 Centrifugal unhoused fan
A fan with a centrifugal impeller in which airflow enters through a panel and discharges into free space. Inlets and outlets are not ducted. This fan type also includes fans designed for use in fan arrays that have partition walls separating the fan from other fans in the array.

3.1.3.4 Power roof/wall ventilator (PRV)
A fan with an internal driver and a housing to prevent precipitation from entering the building. It has a base designed to fit over a roof or wall opening, usually by means of a roof curb.

3.1.3.5 Centrifugal PRV exhaust
A PRV with a centrifugal impeller that exhausts air from a building. Inlets are typically ducted, but outlets are not ducted.

3.1.3.6 Centrifugal PRV supply
A PRV with a centrifugal impeller that supplies air to a building. Inlets are not ducted, and outlets are typically ducted.

3.1.3.7 Axial PRV
A PRV with an axial impeller that either supplies or exhausts air to a building. Inlets and outlets are typically not ducted.

3.1.3.8 Axial inline fan
A fan with an axial impeller and a cylindrical housing with or without turning vanes. Inlets and outlets can optionally be ducted.

3.1.3.9 Axial panel fan
A fan with an axial impeller mounted in a short housing that can be a panel, ring or orifice plate. The housing is typically mounted to a wall separating two spaces and the fans are used to increase the pressure across this wall. Inlets and outlets are not ducted.

3.1.3.10 Laboratory exhaust fan
A fan designed specifically for exhausting contaminated air vertically away from a building. Fan outlets are typically constricted to achieve a high outlet velocity. Induced flow lab exhaust fans use their high velocity discharge to entrain additional air to mix with contaminated building exhaust air. Inlets can optionally be ducted, and outlets are not ducted.

3.1.3.11 Jet fan
A fan used for producing a high velocity flow of air in a space. Typical function is to add momentum to the air within a tunnel. Inlets and outlets are not ducted.

3.1.3.12 Circulating fan
A fan used for moving air within a space that has no provision for connection to ducting or separation of the fan inlet from its outlet. It is designed to be used for the general circulation of air.

3.1.3.13 Crossflow fan
A fan with a housing that creates an airflow path through the impeller in a direction at right angles to its axis of rotation and with airflow both entering and exiting the impeller at its periphery. Inlets and outlets can optionally be ducted.

3.1.3.14 Fan array
A common application of fans using multiple fans in parallel between two plenum sections for a factory packaged or field erected air handling unit.

3.2 Symbols

Symbol	Description	SI Unit	I-P Unit
A	Fan outlet or discharge area	m^2	ft^2
A, B, C, D, E	Constants	dimensionless	
F_t	Force due to thrust, jet fans	N	lbf
$FEI_{t,i}$	Fan energy index, fan total pressure basis, at duty point *i*	dimensionless	
$FEI_{s,i}$	Fan energy index, fan static pressure basis, at duty point *i*	dimensionless	
FEP_{ref}	Fan electrical input power, reference	kW	kW
FEP_{act}	Fan electrical input power, actual	kW	kW
$H_{i,ref}$	Fan shaft power, reference	kW	hp
$H_{i,act}$	Fan shaft power, actual	kW	hp
$H_{t,ref}$	Motor output power, reference	kW	hp
$H_{t,act}$	Motor output power, actual	kW	hp
$H_{t,def}$	Motor output power, default	kW	hp
P_o	Pressure constant	Pa	in. wg
$P_{s,i}$	Fan static pressure at duty point *i*	Pa	in. wg
$P_{t,i}$	Fan total pressure at duty point *i*	Pa	in. wg
Q_i	Fan airflow at duty point *i*	m^3/s	cfm
Q_0	Airflow constant	m^3/s	cfm
η_0	Fan efficiency constant	dimensionless	
$\eta_{trans,ref}$	Transmission efficiency, reference	dimensionless	
$\eta_{trans,act}$	Transmission efficiency, actual	dimensionless	
$\eta_{mtr,ref}$	Motor efficiency, reference	dimensionless	
$\eta_{mtr,act}$	Motor efficiency, actual	dimensionless	

$\eta_{ctrl,ref}$	Motor controller efficiency, reference	dimensionless	
ρ	Fan air density	kg/m^3	lbm/ft^3
ρ_{std}	Standard air density	kg/m^3	lbm/ft^3

4. General

4.1 Minimum testable configuration

The FEI calculation is based on fan performance derived from tests in accordance with recognized fan test standards. See Annex A to determine the appropriate test standard for each fan type. These test standards each require some minimum configuration in order to run the tests. This standard is also based on tests of fans in at least a minimum testable configuration, including the following:

1. Impeller
2. Shaft and bearings and/or motor to support the impeller
3. Structure or housing, unless the fan does not require these (e.g., an unshrouded circulating fan)

4.2 FEI pressure basis

The FEI is calculated using either fan total pressure or fan static pressure, based on the fan type. See Annex A for a complete explanation of the pressure basis and to learn which pressure to use.

4.3 Appurtenances

Certain accessories or appurtenances can be used to improve fan performance, including but not limited to inlet bells, diffusers, stators or guide vanes. The effect of these appurtenances can be included in the FEI calculation only if they were present during the test and are supplied with the fan. Test ducts included during testing are not required to be supplied with the fan.

Other appurtenances placed at or near the fan inlet or discharge will often result in reduced overall fan performance. These include but are not limited to guards, dampers, filters or weather hoods. The effect of these appurtenances on fan performance can be tested and published to aid in fan selection, but it is not included in the fan test used to determine FEI.

As illustrated in Figure 1, the reduced performance of a fan with appurtenances (the curve labeled *2*) can be published and matched against system pressures in order to make proper fan selections. The process of fan selection includes determining the fan speed and/or blade pitch needed to achieve the required system pressure (P_{req}) at the required airflow (Q_{req}) (point B in Figure 1). Once the required fan speed and/or blade pitch are determined, the FEI is determined from the standalone fan performance (the curve labeled *1* in Figure 1) at the same airflow, fan speed and blade pitch (point A in Figure 1).

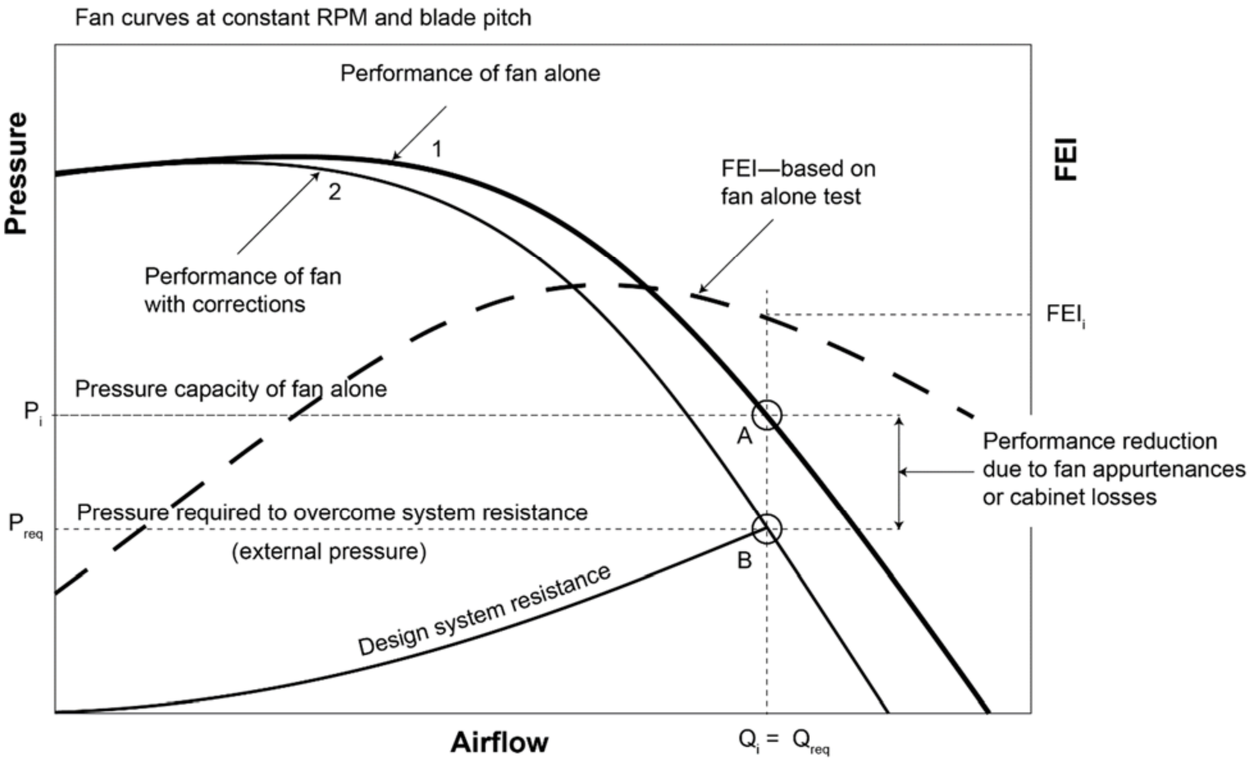

Figure 1—Fan Curves at Constant RPM and Blade Pitch

4.4 Fans embedded in other equipment

This standard does not apply to fan performance when tested embedded inside of other equipment. However, the standard can be used to calculate FEI for a fan that, while tested in a standalone configuration, will be embedded into other equipment. As with appurtenances and referring to Figure 1, corrections may need to be applied to the standalone fan performance data to account for a difference between how the fan was tested and how it is applied. The FEI for the embedded fan is determined from the standalone fan performance at the same airflow, fan speed and blade pitch of the fan as embedded in the equipment.

See Annex D for detailed guidance on the conversion of standalone fan performance to that of an embedded fan.

Each rated fan model must be rated according to the applicable fan type listed in Table A.2 of Annex A, as defined in Section 3, in accordance with with how that fan is distributed in commerce. For example, if a fan meets the definition of a PRV, it must be rated as a PRV with all necessary appurtenances, and performance ratings for a standalone centrifugal or axial fan used inside a PRV must not be used to describe the performance of the PRV itself.

5. Fan Energy Index

5.1 General

The fan energy index (FEI) is defined as a ratio of the electrical input power of a reference fan to the electrical input power of the actual fan for which the FEI is calculated, both calculated at the same duty point, *i*, which is characterized by a value of airflow (Q_i) and pressure ($P_{t,i}$ or $P_{s,i}$). FEI can be calculated for each point on a fan curve.

$$FEI_{t,i} \text{ or } FEI_{s,i} = \frac{\text{Reference Fan Electrical Input Power}}{\text{Actual Fan Electrical Input Power}} = \frac{FEP_{ref,i}}{FEP_{act,i}} \quad \text{Eq. 5.1}$$

5.2 Reference fan electrical input power

The reference fan concept is used to normalize the FEI calculation to a consistent power level independent of fan type, fan drive components or any regulatory requirements. The reference fan electrical input power is a function of airflow and fan pressure. The reference fan is defined as one that requires a certain reference fan shaft power, uses a V-belt drive, has a motor efficiency based on the IE3 level for a four-pole 60 Hz motor and does not have a speed control.

$$FEP_{ref,i} = \mathrm{H_{i,ref}}\left(\frac{1}{\eta_{\mathrm{trans,ref}}}\right)\left(\frac{1}{\eta_{\mathrm{mtr,ref}}}\right)\left(\frac{1}{\eta_{\mathrm{ctrl,ref}}}\right) \qquad \text{Eq. 5.2 SI}$$

$$FEP_{ref,i} = \mathrm{H_{i,ref}}\left(\frac{1}{\eta_{\mathrm{trans,ref}}}\right)\left(\frac{1}{\eta_{\mathrm{mtr,ref}}}\right)\left(\frac{1}{\eta_{\mathrm{ctrl,ref}}}\right) \times 0.7457 \qquad \text{Eq. 5.2 I-P}$$

5.2.1 Reference fan shaft power

The reference fan shaft power, $H_{i,ref}$, is calculated either on a fan total pressure basis or a fan static pressure basis, depending on the fan type. See Annex A for a complete description and a list of fan types and the FEI pressure basis.

5.2.1.1 Total pressure basis

For fans identified in Annex A as using a total pressure basis, the reference fan shaft power at a given duty point is a function of airflow (Q_i) and fan total pressure ($P_{t,i}$) at that duty point. It is calculated according to the following equation:

$$\mathrm{H_{i,ref}} = \frac{(Q_i+Q_0)(P_{t,i}+P_0\times\frac{\rho}{\rho_{std}})}{1000\times\eta_o} \qquad \text{Eq. 5.3 SI}$$

$$\mathrm{H_{i,ref}} = \frac{(Q_i+Q_0)(P_{t,i}+P_0\times\frac{\rho}{\rho_{std}})}{6343\times\eta_o} \qquad \text{Eq. 5.3 I-P}$$

Where

Q_i		is fan airflow in m^3/s (SI) or cfm (I-P)
$P_{t,i}$		is fan total pressure in Pa (SI) or in. wg (I-P)
ρ		is air density in kg/m^3 (SI) or lbm/ft^3 (I-P)
ρ_{std}		is standard air density, 1.2 kg/m^3 (0.075 lbm/ft^3)
Q_0	=	0.118 m^3/s (SI) or 250 cfm (I-P)
P_0	=	100 Pa (SI) or 0.40 in.wg (I-P)
η_0	=	66%

5.2.1.2 Static pressure basis

For fans identified in Annex A as using a static pressure basis, the reference fan shaft power at a given duty point is a function of airflow (Q_i) and fan static pressure ($P_{s,i}$) at that duty point. It is calculated according to the following equation:

$$\mathrm{H_{i,ref}} = \frac{(Q_i+Q_0)(P_{s,i}+P_0\times\frac{\rho}{\rho_{std}})}{1000\times\eta_o} \qquad \text{Eq. 5.4 SI}$$

$$\mathrm{H_{i,ref}} = \frac{(Q_i+Q_0)(P_{s,i}+P_0\times\frac{\rho}{\rho_{std}})}{6343\times\eta_o} \qquad \text{Eq. 5.4 I-P}$$

Where

Q_i		is fan airflow in m^3/s (SI) or cfm (I-P)
$P_{s,i}$		is fan static pressure in Pa (SI) or in. wg (I-P)
ρ		is air density in kg/m^3 (SI) or lbm/ft^3 (I-P)
ρ_{std}		is standard air density, 1.2 kg/m^3 (0.075 lbm/ft^3)
Q_0	=	0.118 m^3/s (SI) or 250 cfm (I-P)
P_0	=	100 Pa (SI) or 0.40 in.wg (I-P)
η_0	=	60%

5.2.2 Reference fan transmission efficiency

For consistency, the reference fan is defined as one having a V-belt drive transmission, regardless of the drive arrangement of the actual fan for which the FEI is calculated. The reference fan transmission efficiency is calculated using the same equations as found in ANSI/AMCA Standard 207 for V-belt drives:

$$\eta_{\mathrm{trans,ref}} = 0.96\left(\frac{\mathrm{H_{i,ref}}}{\mathrm{H_{i,ref}}+1.64}\right)^{.05}$$ Eq. 5.5 SI

$$\eta_{\mathrm{trans,ref}} = 0.96\left(\frac{\mathrm{H_{i,ref}}}{\mathrm{H_{i,ref}}+2.2}\right)^{.05}$$ Eq. 5.5 I-P

5.2.3 Reference fan motor efficiency

The reference fan is defined as having a motor efficiency based on the IE3 level for a four-pole 60 Hz motor. In order to simplify the calculation of part load efficiency for this reference fan motor and to avoid sizing and otherwise identifying a specific motor for this reference fan, a curve fit is used through the IE3 motor efficiency requirements. The result is a reference motor efficiency that varies continuously based on the required motor output power.

Reference fan motor output power:

$$\mathrm{H_{t,ref}} = \frac{\mathrm{H_{i,ref}}}{\eta_{\mathrm{trans,ref}}}$$ Eq. 5.6

The reference fan motor efficiency is calculated according to Equation 5.7 using the coefficients A–E found in table 5.1:

$$\eta_{\mathrm{mtr,ref}} = \mathrm{A}\cdot\left[\log_{10}\left(\mathrm{H_{t,ref}}\right)\right]^4 + \mathrm{B}\cdot\left[\log_{10}\left(\mathrm{H_{t,ref}}\right)\right]^3 + \mathrm{C}\cdot\left[\log_{10}\left(\mathrm{H_{t,ref}}\right)\right]^2 + \mathrm{D}\cdot\left[\log_{10}\left(\mathrm{H_{t,ref}}\right)\right]^1 + \mathrm{E}$$

Eq. 5.7 SI

$$\eta_{\mathrm{mtr,ref}} = \mathrm{A}\cdot\left[\log_{10}\left(\mathrm{H_{t,ref}}\times 0.7457\right)\right]^4 + \mathrm{B}\cdot\left[\log_{10}\left(\mathrm{H_{t,ref}}\times 0.7457\right)\right]^3 + \mathrm{C}\cdot\left[\log_{10}\left(\mathrm{H_{t,ref}}\times 0.7457\right)\right]^2 + \mathrm{D}\cdot\log_{10}\left(\mathrm{H_{t,ref}}\times 0.7457\right) + \mathrm{E}$$

Eq. 5.7 I-P

Table 5.1—Reference Motor Efficiency Coefficients

	$H_{t,ref}$<185 kW (<250 BHP)	$H_{t,ref}$≥185 kW (≥250 BHP)
A	-0.003812	0
B	0.025834	0
C	-0.072577	0
D	0.125559	0
E	0.850274	0.962

5.2.4 Reference fan motor controller efficiency

The reference fan is defined as a constant speed fan. Therefore, the motor controller efficiency is 100%.

$$\eta_{ctrl,ref} = 1$$ Eq. 5.8

5.3 Actual fan electrical input power FEP_{act}

FEP_{act} is the fan electrical input power associated with a given fan duty point in terms of airflow and pressure.

Actual fan electrical input power must be determined by one of the methods found in Sections 5.3.1 through 5.3.4. The applicable methods to determine fan electrical input power are defined as a function of the fan configuration being rated, as defined in Table 5.2:

Table 5.2—FEP_{act} Methods

Fan Configuration	Motor Type	Applicable AMCA 208 Section	FEP Determination	Example Applications
Fan for which the motor is not yet selected	N/A	5.3.4	Default motor efficiency calculation	• Fans sold without motors • Catalogs used for fan selection prior to motor selection
Fan with motor	Any	5.3.1	Wire-to-air measurement, AMCA 211 ratings	• Wire-to-air measurement and density corrections of fans rated with motors • Motors for which no test standards apply
	Polyphase induction motors, both regulated and non-regulated, with nameplate power and poles that fall within the range covered in Annex A of AMCA 207	5.3.2	AMCA 207 calculation	• 3 phase integral regulated motors • 3 phase integral non-regulated motors (AO, XP, 2 speed, etc.)
	Motor for which 5.3.2 does not apply and the performance can be measured in accordance with a known test standard	5.3.3 (as applicable)	Motor test according to industry-recognized standard	• Single phase regulated motors • Single phase non-regulated motors • 3 phase fractional motors
	Motor for which 5.3.2 or 5.3.3 do not apply	5.3.4	Default motor efficiency calculation	• No motor test results available
Fan with motor and speed control	Any	5.3.1	Wire-to-air measurement, AMCA 211 ratings	• Wire-to-air measurement and density and/or speed corrections of fans rated with a motor and controller. • Motors with controllers for which no test standards apply
	Polyphase induction motors, both regulated and non-regulated, with nameplate power and poles that fall within the range covered in Annex A of AMCA 207	5.3.2	AMCA 207 calculation	• 3 phase integral regulated motors • 3 phase integral non-regulated motors (AO, XP, 2 speed, etc.)

5.3.1 Measurement of fan electrical input power

This section covers direct measurement of fan electrical input power to the fan motor or, if present, motor controller per ANSI/AMCA Standard 210, ANSI/AMCA Standard 230, ANSI/AMCA Standard 260 or ISO 5801 (i.e., wire-to-air testing) or rating of fan electrical input power from these measurements in accordance with AMCA Publication 211. This method can be used by all fans except those without motors. It covers direct measurement of fan electrical input power at the tested operating points and conversion of measured values to other operating points.

The fan electrical input power (FEP_{act}) is the motor input power for fans without speed control and is the motor controller input power for fans with speed control included.

5.3.2 Fan electrical input power calculation using ANSI/AMCA Standard 207

This section covers measurement of fan shaft input power per ANSI/AMCA Standard 210, ANSI/AMCA Standard 250, ANSI/AMCA Standard 260, ISO 5801 or ISO 13350, or rating of fan shaft input power ($H_{i,act}$) in accordance with AMCA Publication 211 or ISO 13348, combined with power drive component efficiency calculations of ANSI/AMCA Standard 207. This method is applicable to (1) fans with motors that fall directly within the scope of ANSI/AMCA Standard 207 or (2) other three-phase induction motors with nameplate power and number of poles that otherwise fall within the scope of ANSI/AMCA Standard 207, either with or without speed controllers. It calculates the fan electrical input power based on the tested fan performance, the known full load motor efficiency and assumed default losses.

For fans with motors that fall within the scope of ANSI/AMCA Standard 207, fan electrical input power (FEP_{act}) is calculated according to ANSI/AMCA Standard 207, except that the nominal regulated motor efficiency, η_R, in Section 4.1.3 of ANSI/AMCA Standard 207 shall be either the nominal efficiency as listed in Annex A of ANSI/AMCA Standard 207 or the certified full-load efficiency of the motor as determined in accordance with the relevant regulations (10CFR 431—subpart B, IEC 60034-2-1, or GB/T 1032).

For fans with three-phase induction motors outside the scope of ANSI/AMCA Standard 207 but with nameplate power and number of poles that otherwise fall within the scope of ANSI/AMCA Standard 207, fan electrical input power is calculated according to ANSI/AMCA Standard 207 with the following exceptions:

1. If the motor nameplate power is listed in the tables in Annex A of ANSI/AMCA Standard 207, then the nominal regulated motor efficiency, η_R, in Section 4.1.3 of ANSI/AMCA Standard 207 shall be the minimum of that shown on the motor nameplate and that of Annex A of ANSI/AMCA Standard 207. The motor nameplate power and efficiency must be the full-load motor output power and efficiency determined based on testing in accordance with IEEE 112 (polyphase), IEC 60034-2-1 or NEMA MG-1 (Section IV, Part 34, for air over motors), as applicable.
2. If the motor nameplate power falls between those listed in Annex A of ANSI/AMCA Standard 207, then the nominal regulated motor efficiency, η_R, in Section 4.1.3 of ANSI/AMCA Standard 207 shall be the minimum of that shown on the motor nameplate and that of the next smaller motor listed in Annex A of ANSI/AMCA Standard 207. The load ratios and part load efficiency constants used in the ANSI/AMCA Standard 207 calculations shall be based on that of the next smaller motor size in the tables of Annex A–D of ANSI/AMCA Standard 207. The motor nameplate power and efficiency must be the full-load motor output power and efficiency determined based on testing in accordance with IEEE 112 (polyphase), IEC 60034-2-1 or NEMA MG-1 (Section IV, Part 34 for air over motors), as applicable.

The fan electrical input power (FEP_{act}) is the motor input power for fans without speed control and is the motor controller input power for fans with speed control included.

5.3.3 Fan electrical input power calculation for fans with motors of known part-load efficiency

This section covers measurement of fan shaft input power per ANSI/AMCA Standard 210, ANSI/AMCA Standard 250, ANSI/AMCA Standard 260, ISO 5801 or ISO 13350, or rating of fan shaft input power ($H_{i,act}$) in accordance with AMCA Publication 211 or ISO 13348. This is combined with a specific motor that is not within the scope of Section 5.3.2 (i.e., single-phase motors and polyphase motors with nameplate power and/or number of poles beyond those addressed by ANSI/AMCA Standard 207) but where the full and part load efficiency of the motor is established through testing of the same model motor. This testing must be done in accordance with IEEE 112 (polyphase), IEEE 114 (single phase), IEC 60034-2-1 or NEMA MG-1 (Section IV, Part 34 for air over motors), as applicable. Any tested motor efficiency values must be generated by testing in accordance with an applicable referenced motor test standard. For example, only NEMA MG-1 (Section IV, Part 34) is applicable to air over motors. None of the referenced motor test standards are applicable to fans tested with motors and speed controls. This method is only applicable to fans where the motor part load efficiency has been tested in accordance with these standards. The tested motor part load performance values (motor speed and motor efficiency) corresponding with the fan duty point *i* shall be applied to fan shaft input power to calculate fan input electrical power as follows:

$$\mathrm{FEP_{act}} = \mathrm{H_{i,act}}\left(\frac{1}{\eta_{\mathrm{trans,act}}}\right)\left(\frac{1}{\eta_{\mathrm{mtr,act}}}\right) \qquad \text{Eq. 5.12 SI}$$

$$FEP_{act} = H_{i,act}\left(\frac{1}{\eta_{trans,act}}\right)\left(\frac{1}{\eta_{mtr,act}}\right) \times 0.7457 \quad \text{Eq. 5.12 I-P}$$

For direct driven fans:

$$\eta_{trans,act} = 1 \quad \text{Eq. 5.13}$$

For fans using V-belt drives:

$$\eta_{trans,act} = 0.96\left(\frac{H_{i,act}}{H_{i,act}+1.64}\right)^{.05} \quad \text{Eq. 5.14 SI}$$

$$\eta_{trans,act} = 0.96\left(\frac{H_{i,act}}{H_{i,act}+2.2}\right)^{.05} \quad \text{Eq. 5.14 I-P}$$

Actual motor output power:

$$H_{t,act} = \frac{H_{i,act}}{\eta_{trans,act}} \quad \text{Eq. 5.15}$$

$\eta_{mtr,act}$ is the motor part load efficiency determined from IEEE 112, IEEE 114 or IEC 60034-2-1 test data interpolated to the actual load $H_{t,act}$ using a polynomial curve fit. In no case shall the interpolated motor efficiency exceed the nearest tested values, nor shall the motor efficiency be extrapolated, either in load or speed, beyond tested values.

5.3.4 Fan electrical input power calculation for fans with motors of unknown efficiency
This section covers measurement of fan shaft input power per ANSI/AMCA Standard 210, ANSI/AMCA Standard 250, ANSI/AMCA Standard 260, ISO 5801 or ISO 13350, or rating of fan shaft input power in accordance with AMCA Publication 211 or ISO 13348. It specifically refers to those that are (1) provided with no motors, (2) provided with motors that have not yet been chosen (fan selection tables) or (3) provided with a specific motor not conforming to Sections 5.3.2 or 5.3.3. This method uses default motor efficiency values and is applicable only when Sections 5.3.2 or 5.3.3 do not apply. Speed controllers are not considered with this method.

$$FEP_{act} = H_{i,act}\left(\frac{1}{\eta_{trans,act}}\right)\left(\frac{1}{\eta_{mtr,def}}\right) \quad \text{Eq. 5.16 SI}$$

$$FEP_{act} = H_{i,act}\left(\frac{1}{\eta_{trans,act}}\right)\left(\frac{1}{\eta_{mtr,def}}\right) \times 0.7457 \quad \text{Eq. 5.16 I-P}$$

For fans only offered as direct drive:

$$\eta_{trans,def} = 1 \quad \text{Eq. 5.17}$$

For fans offered as V-belt driven only or as either belt or direct driven:

$$\eta_{trans,act} = 0.96\left(\frac{H_{i,act}}{H_{i,act}+1.64}\right)^{.05} \quad \text{Eq. 5.18 SI}$$

$$\eta_{trans,act} = 0.96\left(\frac{H_{i,act}}{H_{i,act}+2.2}\right)^{.05} \quad \text{Eq. 5.18 I-P}$$

Required motor output power:

$$H_{t,def} = \frac{H_{i,act}}{\eta_{trans,act}}$$ Eq. 5.19

The default motor efficiency is calculated according to Equation 5.20 with the coefficients A–E found in Table 5.3. These coefficients are derived from curve fits of IE3 nominal efficiency limits for four-pole motors as listed in IEC 60034-30-1. These defaults shall only be used in regions or jurisdictions where motor IE3 levels (or equivalent) reflect the minimum motor efficiency requirements in that jurisdiction. Other jurisdictions with lower motor efficiency requirements must establish their own default values.

$$\eta_{mtr,def} = A \cdot \left[\log_{10}\left(H_{t,def}\right)\right]^4 + B \cdot \left[\log_{10}\left(H_{t,def}\right)\right]^3 + C \cdot \left[\log_{10}\left(H_{t,def}\right)\right]^2 + D \cdot \left[\log_{10}\left(H_{t,def}\right)\right]^1 + E$$

Eq. 5.20 SI

$$\eta_{mtr,def} = A \cdot \left[\log_{10}\left(H_{t,def} \times 0.7457\right)\right]^4 + B \cdot \left[\log_{10}\left(H_{t,def} \times 0.7457\right)\right]^3 + C \cdot \left[\log_{10}\left(H_{t,def} \times 0.7457\right)\right]^2 + D \cdot \log_{10}\left(H_{t,def} \times 0.7457\right) + E$$

Eq. 5.20 I-P

Table 5.3—Default Motor Efficiency Coefficients

	60 Hz IE3		**50 Hz IE3**		
Applicability Examples	**USA, Canada, Mexico**		**Europe, China**		
	$H_{t,def}$<185 kW ($H_{t,def}$ <250 BHP)	$H_{t,def}$ ≥185 kW ($H_{t,def}$ ≥250 BHP)	$H_{t,def}$ <0.75 kW ($H_{t,def}$ <1.0 BHP)	0.75≤ $H_{t,def}$≤ 200 kW (1.0≤ $H_{t,def}$≤ 270 BHP)	$H_{t,def}$ >185 kW ($H_{t,def}$ >270 BHP)
A	-0.003812	0	0	0	0
B	0.025834	0	0.076356	0.000773	0
C	-0.072577	0	0.048236	-0.018951	0
D	0.125559	0	0.210903	0.092984	0
E	0.850274	0.962	0.860998	0.837025	0.960

Notes:
1. Jurisdictions with motor efficiency requirements lower than IE3 levels (or equivalent) shall not use these default coefficients.

6. Use of FEI

6.1 Requirements for use of FEI

This section includes only the mandatory requirements for fan manufacturers using FEI. Additional information including examples of published FEI and use by consumers and code and regulatory bodies are provided in Annex B.

6.1.1 Manufacturers' FEI calculations

Fan manufacturers shall calculate FEI values for each duty point offered for sale or required by a code or regulatory body.

6.1.2 Published FEI values

Published FEI values shall be rounded to the nearest hundredth and presented alongside other fan performance parameters (airflow, pressure, power, etc.) in fan selection tables and graphs. When FEI values are published in a catalog or submittal and a specific motor size and type are specified, the FEI values shown shall be calculated for that specific motor. When FEI values are published in a catalog or submittal and the same fan performance could apply to multiple motor sizes, the FEI values shown shall be calculated using default motor efficiencies according to Section 5.3.4 and shall be clearly identified as such.

Annex A
Fan Types, Test Configurations and FEI Pressure Basis (Normative)

A.1 Use of test or installation types

The fan test configuration [“Installation Type” in ANSI/AMCA Standard 210 and “Installation Category” or “Test Configuration” in ISO 5801] will have an impact on the determination of the fan air performance and efficiency. The test configuration distinguishes the arrangement of ducting to the inlet and outlet of the fan during the test (see Table A.1). These configurations are consistent with the test requirements of ANSI/AMCA Standard 210, ANSI/AMCA Standard 230, ANSI/AMCA Standard 250, ANSI/AMCA Standard 260, ISO 5801 and ISO 13350, although not all configurations are found in each standard.

Test duct conditions do not necessarily determine how the fan is applied in the field. While performance corrections may need to be applied to test data to account for a difference between how the fan was tested and how it is applied, these corrections are not used in the calculation of FEI.

In general, the presence of an outlet duct during the original test will determine whether the FEI is calculated based on fan total or fan static pressures. This is specifically done to encourage the use of total pressure when selecting fans for ducted systems. For fans that are installed with an outlet duct, system pressures are typically calculated in terms of total pressure. Both the static and velocity pressures at the outlet of the fan contribute to overcome system losses. For these fans, the FEI calculation is based on the fan total pressure. However, for fans that are installed without outlet ducts (free outlet), the velocity pressure at the fan discharge is immediately dissipated, and only the fan static pressure can be used to overcome system losses. For these fans, the FEI calculation is based on the fan static pressure.

There are a few exceptions to this requirement. Circulating fans and jet fans are non-ducted, but their sole purpose is to increase the momentum of the air. Laboratory exhaust fans typically require a minimum discharge velocity of 3000–5000 fpm in addition to their fan static pressure requirement. Each of these non-ducted fan types uses the fan total pressure as a basis for FEI calculation to more appropriately account for the velocity pressure at the fan outlet.

Table A.1—Test Configuration or Installation Types for Fans

Test Configuration	Configuration of Ducts
A	Free inlet, free outlet with partition
B	Free inlet, ducted outlet
C	Ducted inlet, free outlet
D	Ducted inlet, ducted outlet
E	Free inlet, free outlet without partition

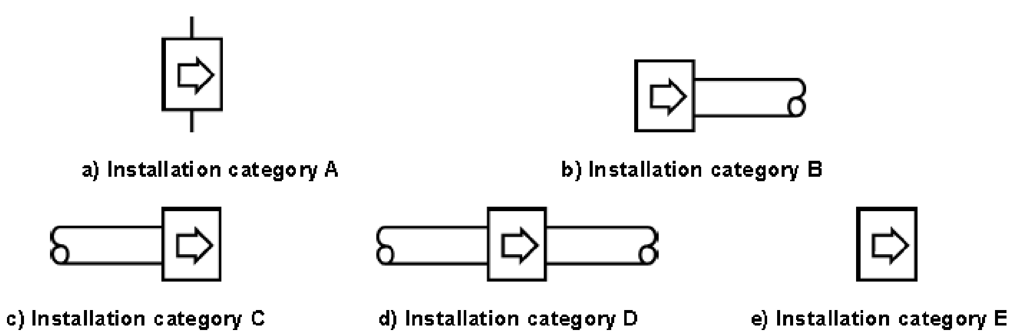

Figure 2—Installation Categories

Table A.2—Fan Types, Test Configurations and FEI Pressure Basis
The following fan types are used to define consistent test standards, test procedures and the pressure used for FEI calculation. These fan types do not imply that all fans within a given type must be regulated by code bodies or that they must be assigned the same minimum FEI requirements.

Fan Type	Impeller Type	Housing Type/ Examples	Test Standard	Test Config/ Installation Type	FEI Pressure Basis	Notes
Centrifugal housed	AF, BC, BI, MF, FC, Radial, Radial tipped	Single or double inlet scroll (not inline)	AMCA 210, ISO 5801	B or D	Total	1
			AMCA 210 ISO 5801	A or C	Static	
Centrifugal inline	AF, BC, BI, MF, FC	Square, rect, cylindrical	AMCA 210 ISO 5801	B or D	Total	1
				A or C	Static	
Centrifugal unhoused	AF, BC, BI, MF	None	AMCA 210 ISO 5801	A	Static	2
Centrifugal PRV exhaust	AF, BC, BI, MF, FC	Spun alum, upblast, hooded, wall housing	AMCA 210 ISO 5801	A or C	Static	3
Centrifugal PRV supply	AF, BC, BI, MF, FC	Hooded or otherwise enclosed	AMCA 210 ISO 5801	B or D	Total	1,3
				A or C	Static	
Axial inline	Propeller	Cylindrical (tube axial or vane axial)	AMCA 210 ISO 5801	B or D	Total	1
				A or C	Static	
Axial panel	Propeller	Panel, ring	AMCA 210 ISO 5801	A	Static	
Axial PRV	Propeller	Sup and ex, spun alum, upblast, hooded, wall housing	AMCA 210 ISO 5801	A or C	Static	
Laboratory exhaust	Any	High Velocity Discharge	AMCA 210 ISO 5801	A or C	Total	4
	Any	Induced flow	AMCA 260	A or C	Total	4,5
Jet fan	Propeller or AF, BC, BI	Unidirectional, reversible	AMCA 250 ISO 13350	E	Total	4,6
Circulating	Propeller	Cylindrical, panel, unhoused	AMCA 230	E	Total	4,7
Crossflow	Crossflow		AMCA 210 ISO 5801	A or C	Static	
				B, D or E	Total	

Notes:

1. Centrifugal housed, centrifugal inline, centrifugal PRV supply and axial inline fans shall be tested using Test Configuration B or D with fan total pressure used for the FEI calculation or can be tested using Test Configuration A or C with fan static pressure used for the FEI calculation.

2. The centrifugal unhoused fan type also includes fans with integral housings used to separate multiple fans in a fan array. These fans use fan static pressure for the FEI calculation and also use a special procedure found in Annex C.
3. Centrifugal PRVs are typically used with ducted air systems. Exhaust fans shall be tested without discharge ducts (A or C) and shall be evaluated on a fan static pressure basis. Supply fans shall be tested with discharge ducts (B or D) and shall be evaluated on a fan total pressure basis, or can be tested using Test Configuration A or C with fan static pressure used for the FEI calculation.
4. Fan types that are tested without an outlet duct but normally applied where a high velocity discharge is required for proper function use fan total pressure as a basis for FEI calculation.
5. Induced flow laboratory exhaust fans use the fan total pressure based on the velocity pressure at the discharge nozzle as a basis for FEI calculation. The airflow, Q_i, used in this standard is the inlet airflow, Q_1 determined from the test in Section 7.1 of ANSI/AMCA Standard 260. The fan total pressure, $P_{t,i}$, used in this standard is the fan total pressure, P_{v2}-P_{t1}, determined from the test in Section 7.1 of ANSI/AMCA Standard 260.
6. Jet fans use test standards ANSI/AMCA Standard 250 or ISO 13350. Jet fans use fan total pressure based on the dynamic pressure at the fan outlet for FEI calculation (see Section A.2).
7. Circulating fans use test standard ANSI/AMCA Standard 230. Circulating fans use fan total pressure based on the dynamic pressure at the fan outlet for FEI calculation (see Section A.2).

A.2 Fans tested using thrust

For fans with airflow determined per ANSI/AMCA Standard 230, the fan total pressure at a given airflow shall be calculated according to the following equations:

$$P_{t,i} = \frac{\rho}{2}\left(\frac{Q_i}{A}\right)^2$$ Eq. A.1 SI

$$P_{t,i} = \rho\left(\frac{Q_i}{1097.8 \times A}\right)^2$$ Eq. A.1 I-P

Where,

A = Fan outlet or discharge area, m^2 (ft^2)
$P_{t,I}$ = Fan total pressure, Pa (in. wg)
Q_i = Airflow rate, m^3/h (cfm)
ρ = Air density, kg/m^3 (lbm/ft^3)

For fans with thrust determined per ANSI/AMCA Standard 250 or ISO 13350, fan total pressure shall be calculated according to Equation A.1. Airflow shall be calculated according to the following equations:

$$Q_i = \sqrt{\frac{AF_t}{\rho}}$$ Eq. A.2 SI

$$Q_i = 340.3\sqrt{\frac{AF_t}{\rho}}$$ Eq. A.2 I-P

Where,

A = Fan outlet or discharge area, m^2 (ft^2)
F_t = Force due to thrust, N (lbf)
Q_i = Airflow rate, m^3/h (cfm)
ρ = Air density, kg/m^3 (lbm/ft^3)

Annex B
Usage of FEI (informative)

B.1 General

This annex provides guidance to fan manufacturers, fan consumers and code and regulatory bodies in the use and specification of FEI values.

B.2 Published FEI values

Section 6.1.2 includes specific requirements for published FEI values. This section provides examples of published fan performance, showing how FEI is used to supplement this data to help the consumer in making good fan selections.

B.2.1 Fan performance table using default motor efficiencies

The following is an example of a fan performance table as found in manufacturers' catalogs for the purpose of making fan selections. This example is for a single fan model that is belt driven and can be configured for any speed within the range shown, with any number of different motors. This fan was tested and is applied without an outlet duct, so FEI is calculated using a static pressure basis.

Airflow (cfm)		**Static Pressure (in.wg)**					
		0	**1**	**2**	**3**	**4**	**5**
7500	rpm	1010	1180	1331	1468		
	BHP	1.65	3.07	4.60	6.18		
	FEI_S	**1.67**	**1.54**	**1.46**	**1.40**		
10000	rpm	1230	1378	1505	1626	1738	1843
	BHP	2.56	4.32	6.18	8.19	10.23	12.29
	FEI_S	**1.42**	**1.45**	**1.43**	**1.40**	**1.38**	**1.36**
12500	rpm	1467	1590	1709	1814	1912	2009
	BHP	3.86	5.93	8.16	10.43	12.83	15.36
	FEI_S	**1.18**	**1.31**	**1.35**	**1.37**	**1.36**	**1.35**
15000	rpm	1712	1819	1921	2021	2112	2196
	BHP	5.56	8.02	10.55	13.22	15.93	18.70
	FEI_S	**0.98**	**1.16**	**1.25**	**1.29**	**1.31**	**1.33**
17500	rpm	1961	2058	2146	2233	2320	2402
	BHP	7.81	10.70	13.54	16.50	19.58	22.77
	FEI_S	**0.81**	**1.01**	**1.13**	**1.20**	**1.24**	**1.27**
20000	rpm	2214	2301	2382	2459	2535	2612
	BHP	10.69	13.92	17.22	20.48	23.86	27.34
	FEI_S	**0.67**	**0.89**	**1.02**	**1.11**	**1.17**	**1.21**

Performance shown is for installation type A: free inlet, free outlet. Power rating (BHP) does not include transmission losses. Performance ratings do not include the effects of appurtenances (accessories). FEI_s values are calculated in accordance with ANSI/AMCA Standard 208 and are based on default motor efficiencies. FEI_s values for fans with specific motors will vary slightly from those shown.

B.2.2 Fan performance curves showing lines of constant FEI_T using default motor efficiencies:
The following is an example of fan performance curves as found in manufacturers' catalogs for the purpose of making fan selections. This example is for a single fan model that is belt driven and can be configured for any speed within the range shown, with any of a number of different motors. This fan was tested with an outlet duct, so FEI is calculated using a total pressure basis.

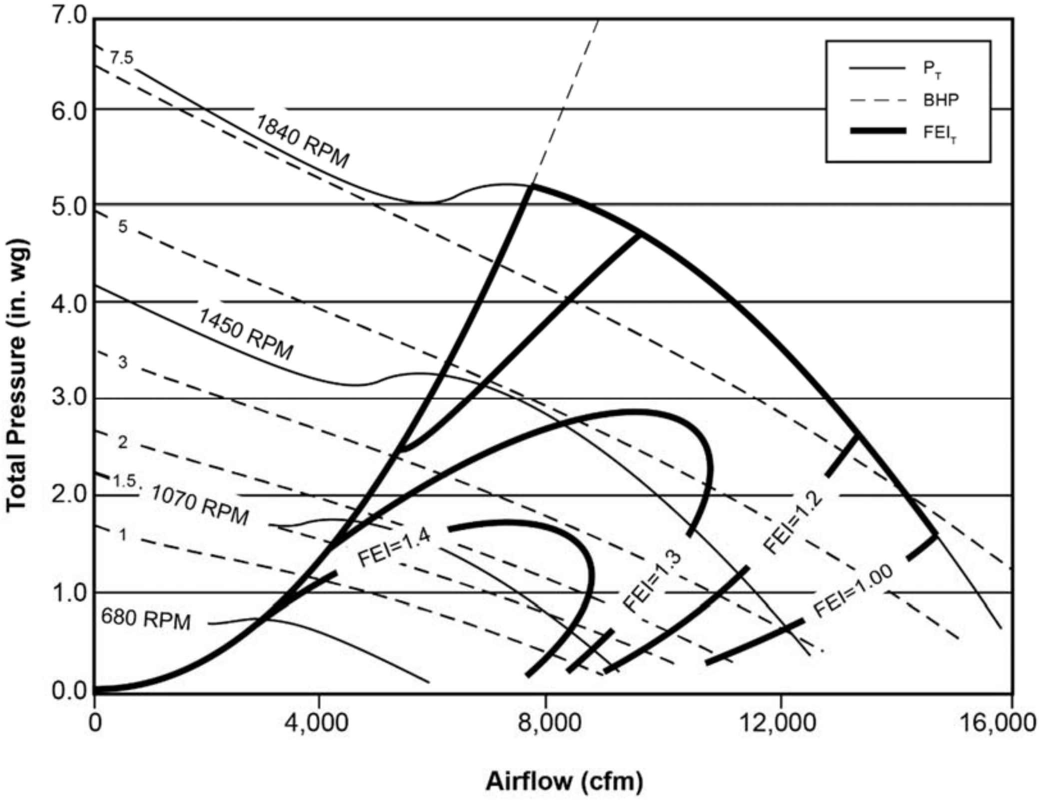

Figure 3—Performance Curves

Performance shown is for installation type B: free inlet, ducted outlet. Power rating (BHP) does not include transmission losses. Performance ratings do not include the effects of appurtenances (accessories). FEI_T values are calculated in accordance with ANSI/AMCA Standard 208 and are based on default motor efficiencies. FEI_T values for fans with specific motors will vary slightly from those shown.

B.2.3 Electronic fan selection software showing specific motor selections
The following is an example of fan performance for multiple fan sizes as found in manufacturers' electronic selection software for the purpose of making fan selections. Each of the sizes shown is selected for, and is capable of, providing the required airflow (10,000 cfm) at the required fan total pressure (4.77 in. wg). These are belt-driven fan models with specific motor sizes selected, all of which are covered within the scope of ANSI/AMCA Standard 207. This fan was tested and is applied with an outlet duct, so FEI is calculated using a total pressure basis.

Fan Size	Fan Class	Fan Speed (rpm)	Fan Shaft Power (BHP)	Elect. Input Power (kW)	Motor Size (hp)	Outlet Area (sf)	Outlet Vel (ft/min)	TE (%)	FEI_T
18	III	3,047	15.3	12.8	20	1.92	5,208	49%	**0.83**
20	II	2,448	13.0	10.9	15	2.30	4,348	58%	**0.98**
22	II	1,940	11.2	9.42	15	2.85	3,509	67%	**1.13**
24	II	1,621	10.1	8.49	15	3.45	2,899	75%	**1.25**
27	I	1,378	9.81	8.27	15	4.19	2,387	77%	**1.28**
30	I	1,185	9.89	8.33	15	5.17	1,934	76%	**1.27**
33	I	1,058	10.5	8.82	15	6.26	1,597	72%	**1.20**

Note: Performance shown is for installation type B: free inlet, ducted outlet. Power rating (BHP) does not include transmission losses. Performance ratings do not include the effects of appurtenances (accessories). FEI_T values are calculated in accordance with ANSI/AMCA Standard 208 and are based on four-pole TEFC motors of the size shown.

B.2.4 Fan performance table for a distributer catalog sold without motors.
The following is an example of a fan performance table as found in a distributor's catalog. This example is for a single fan model that is belt driven, but neither the belt drive nor the motor are supplied with the fan. This fan was tested and is applied without an outlet duct, so FEI is calculated using a static pressure basis.

Model	Prop Dia.	Fan Speed (rpm)	Max Shaft Input Power (BHP)	Airflow (cfm)/FEI_S at Fan Static Pressure Shown				
				0.00	**0.125**	**0.250**	**0.375**	**0.500**
ABC	54 in.	400	2.01	28,000	24,300	14,000		
				1.44	1.65	1.50		
		450	2.86	31,500	27,500	22,200	11,000	
				1.16	1.34	1.44	1.02	
		500	3.93	35,000	32,000	27,000	16,800	13,000
				0.95	1.14	1.23	1.13	1.02
		550	5.23	38,500	35,500	32,000	27,000	16,000
				0.79	0.96	1.08	1.15	0.94

B.3 Examples of consumer use of FEI

FEI requirements should be communicated on the respective equipment schedules. Minimum FEI requirements may vary by fan type, application, locale or on a project-by-project basis. Most specifications contain a section that lists external references. Add to this list:

X. ANSI/AMCA Standard 208: Calculation of the Fan Energy Index (FEI)

Some specifications are structured such that fans have their own section. Other specifications are structured such that fans are a subsection within a larger section (i.e., "Central Station Air Handing Units", "Custom Air Handling Units," "Energy Recovery Units," etc.). The reference to ANSI/AMCA Standard 208 should be added to any specification section that contains fans.

As for specification language, insert some or all of the following:

1. *Fans shall be AMCA-certified for air, sound and FEI (fan energy index).*

2. *Fans shall meet or exceed the minimum FEI scheduled at the specified airflow and pressure.*

Example schedules

Vane Axial Fans					
Tag	Airflow	Fan Total Pressure	Minimum FEI_T	Motor Size (kW/HP)	Fan RPM

Central Station Air Handling Units—Supply Fans (Plenum Type Impellers)					
Tag	Airflow	Fan Static Pressure	Minimum FEI_S	Motor Size (kW/HP)	Fan RPM

As previously mentioned, the minimum FEI may vary by fan type, project, etc. If a current equipment schedule template has a column that defines maximum allowable fan input power or minimum allowable fan efficiency, the minimum FEI value can replace that column. A minimum FEI requirement integrates both maximum allowable fan input power and minimum required fan efficiency into a single value.

The scheduled minimum FEI value can be used to communicate the minimum level established by a regulatory or program requirement. The scheduled minimum FEI can also be used to communicate the requirement for a lower power solution for a specific application (in this case, the minimum FEI value will be a larger number). The value scheduled for minimum FEI clearly communicates what is required for that specific application. Product substitutions should only be allowed if the specified FEI level and intended utility are met by the alternate product.

Consumers performing fan selections for a specific application should use FEI values as one tool to evaluate various fan options. FEP_{ref} is always based on the required fan airflow and pressure. Various fans can be compared using FEI values. Fans with higher FEI values will consume less power for the same airflow and pressure than fans with lower FEI values. Consumers should verify that each potential fan selection meets any minimum FEI levels established by codes or regulatory bodies.

B.5 Codes and regulatory references

Any code or regulatory reference to FEI should include the scope of products covered. The scope should, include at least the following: the minimum and maximum power, the minimum allowable FEI levels for each covered fan type, labeling requirements and any product or application exemptions.

Utility rebates or other incentives can be created based on FEI. The incentive offered could be based on the fan selection exceeding a specified minimum FEI level. Alternatively, it can be based on the amount that the selected fan’s FEI exceeds a minimum FEI level set by a different code or regulatory entity.

Legislative, regulatory and code entities may allow reduced FEI values for fans with variable speed motor controllers that are applied in variable speed applications. The reduced FEI value shall, at a minimum, account for the increase in input power caused by the fan motor controller. Reduced FEI values shall only be allowed when the fan motor controller is included in the actual fan electrical input power.

Annex C
Fan Arrays (Informative)

C.1 General

Any number of fans can be used in a fan array configuration where the total required airflow is divided among each of the fans. In order to ensure a consistent calculation of FEI regardless of the number of fans used, a fan array is treated as a single fan moving the total required airflow through the array.

The procedures of this annex shall be used to calculate the FEI for fans used in fan arrays. This procedure shall not be applied to all fans operating in parallel but only to fan arrays applied in air handling units (either factory packaged or field erected). The following characteristics of fan arrays shall be met in order to use this procedure:

- The total required airflow enters a single inlet plenum immediately upstream of the fan array, and the total required airflow discharges into a common plenum immediately downstream of the fan array.
- Both plenums are components within a single air handling unit boundary.
- At least one of the plenums is connected to a separate duct system that supplies, returns or exhausts air from zones or rooms within the building.
- The room or area being cooled, heated or ventilated shall not be considered part of the air handling unit.

C.2 Calculation procedure

1. Calculate FEP_{ref} for the fan array using Section 5.2, with *Q* equal to the total airflow shared among all fans in the array.
2. Calculate FEP_{ref} for an individual fan by dividing FEP_{ref} for the fan array by the number of fans used in the array.
3. Calculate FEP_{act} for an individual fan as normal, using Section 5.3.
4. Calculate FEI as normal, using Section 5.1.

C.3 Labeling

Note that a fan evaluated for use in a fan array will have a different FEI rating for the same individual fan performance point depending on the number of fans used in the array. When FEI ratings are calculated for fan arrays per this annex, they must be clearly labeled as to the number of fans used in the array.

C.4 Example

Total required airflow through a fan array is 50,000 cfm at a fan static pressure of 6.0 in. wg. at standard air density. Multiple quantities of fans are being considered for this application.

FEP_{ref} is calculated as in Section 5.2 for the total airflow through the array (treated as a single fan). All other fan quantities considered use a fraction of this FEP_{ref} depending on the number of fans used. The resulting FEI values are inversely proportional to the total input power, thus providing an accurate indication of the total electrical input power.

No. Fans (n)	Airflow (cfm)	$H_{i, ref}$ (BHP)	$\eta_{trans, ref}$	$\eta_{mtr, ref}$	FEP_{ref}/n (kW)	η_s	$H_{i, act}$ (BHP)	$\eta_{trans, def}$	$\eta_{mtr, def}$	FEP_{act} (kW)	Total kW	FEI
1	50,000	84.5	95.9%	95.2%	69.1	65%	72.8	95.9%	95.0%	59.6	59.6	1.16
2	25,000	84.5	95.9%	95.2%	34.5	65%	36.4	95.7%	94.2%	30.1	60.2	1.15
4	12,500	84.5	95.9%	95.2%	17.3	65%	18.2	95.5%	93.1%	15.3	61.1	1.13
10	5,000	84.5	95.9%	95.2%	6.91	65%	7.28	94.7%	91.4%	6.27	62.7	1.10
20	2,500	84.5	95.9%	95.2%	3.45	65%	3.64	93.8%	89.5%	3.23	64.7	1.07

If the procedure described above is not used and FEP_{ref} is calculated from the individual fan airflow, the results will be as shown below. FEI now becomes misleading as an indicator of total input power:

No. Fans	Airflow	$H_{i, ref}$	$\eta_{trans, ref}$	$\eta_{mtr, ref}$	FEP_{re}	η_s	$H_{i, act}$	$\eta_{trans, def}$	$\eta_{mtr, def}$	FEP_{act}	Total kW	FEI
1	50,000	84.5	95.9%	95.2%	69.1	65%	72.8	95.9%	95.0%	59.6	59.6	1.16
2	25,000	42.5	95.8%	94.4%	35.0	65%	36.4	95.7%	94.2%	30.1	60.2	1.16
4	12,500	21.4	95.5%	93.4%	17.9	65%	18.2	95.5%	93.1%	15.3	61.1	1.17
10	5,000	8.83	94.9%	91.8%	7.56	65%	7.28	94.7%	91.4%	6.27	62.7	1.21
20	2,500	4.62	94.2%	90.2%	4.06	65%	3.64	93.8%	89.5%	3.23	64.7	1.26

In the second case, the option with the highest FEI value actually has the highest energy use. The unintended consequence of this would be the use of even more fans resulting in yet a higher FEI value, but with even more actual energy use.

Note that for this example and for illustration purposes only, the calculation of FEP_{act} was based on a fan static efficiency of 65% for every fan. In an actual comparison, various combinations of fans will result in operation at different points on their respective fan curves, and the fan static efficiency will vary accordingly. Also, default motor efficiencies were used for the comparison. Motors covered under Section 5.3.3 of ANSI/AMCA Standard 207 would have varying efficiencies depending on the specific motor being used. These two factors combined could result in a certain combination of fans having an optimal FEI or a minimum total input power value.

Annex D
Embedded Fans (informative)

Air-system design processes result in an ideal fan type, size and speed for ideal conditions. But in practice, actual conditions are often less than ideal. Obstacles to duct runs lead to sharp turns or changes in elevation, and then another correction is needed to resume the planned path. Or there might not be enough room for the ideal length of inlet or outlet duct to establish fully developed airflow. The results of less-than-ideal fan conditions like these are summarily called "system effect."

Once a fan is installed in a cabinet (e.g., an air handling unit or a packaged rooftop), a number of factors can influence performance and thus any metric associated with the energy consumed. The effect of some of these factors can be approximated, but the combinations should be tested for accurate performance. Some common equipment "system effects" include:

- Fan location
- Cabinet proximity
- Component proximity (coils, filters, internal control enclosures, etc.)
- Motor proximity
- The presence of bearings, sheaves and other drive components
- Full face opening discharge losses
- Fan orientation
- Discharge orientation
- Fan guarding

Since existing equipment-test and rating standards include many of these system effects, an equipment test will provide the most accurate estimate of the final in situ performance.

Addressing these effects can have as much, if not more, influence on overall energy use than addressing fan efficiency itself.

D.1 Location of an embedded fan within the unit

The location of the fan relative to other components is an important consideration. When components are located downstream of the fan section in an air handling unit or a rooftop unit, unhoused fans will generally use less energy than housed fans. However, some components require a specific velocity profile—gas heat exchangers and electrical heating elements, for example—and may require trading off small unit size for fan energy efficiency.

Embedded fans can be used as a supply fan or as a return/relief fan for centralized building pressurization control or economizing. The duty point of a supply fan can be very different from the duty point of a return/relief fan, and it often varies widely throughout the year.

D.2 Economizers

Economizing is a method of free cooling for building air conditioning. If done properly, it can save a tremendous amount of energy compared to air conditioning without an economizer, even if the economizer fan efficiency is compromised by non-energy design criteria.

In an economizer application, the return/relief fan can run at two substantially different operating points depending on mode of operation. During economizer operation, the return/relief fan will often operate far to the right of the fan's best efficiency point. Also, if a fan design exhibits an operating area with an unstable characteristic, an optimization for the best fan efficiency may be compromised by the risk for instability.

Codes and standards authorities, when setting minimum FEI requirements, should consider the necessarily wide operating range of economizer fans. Appropriate energy optimization requires estimated annual run hours with associated fan duty points.

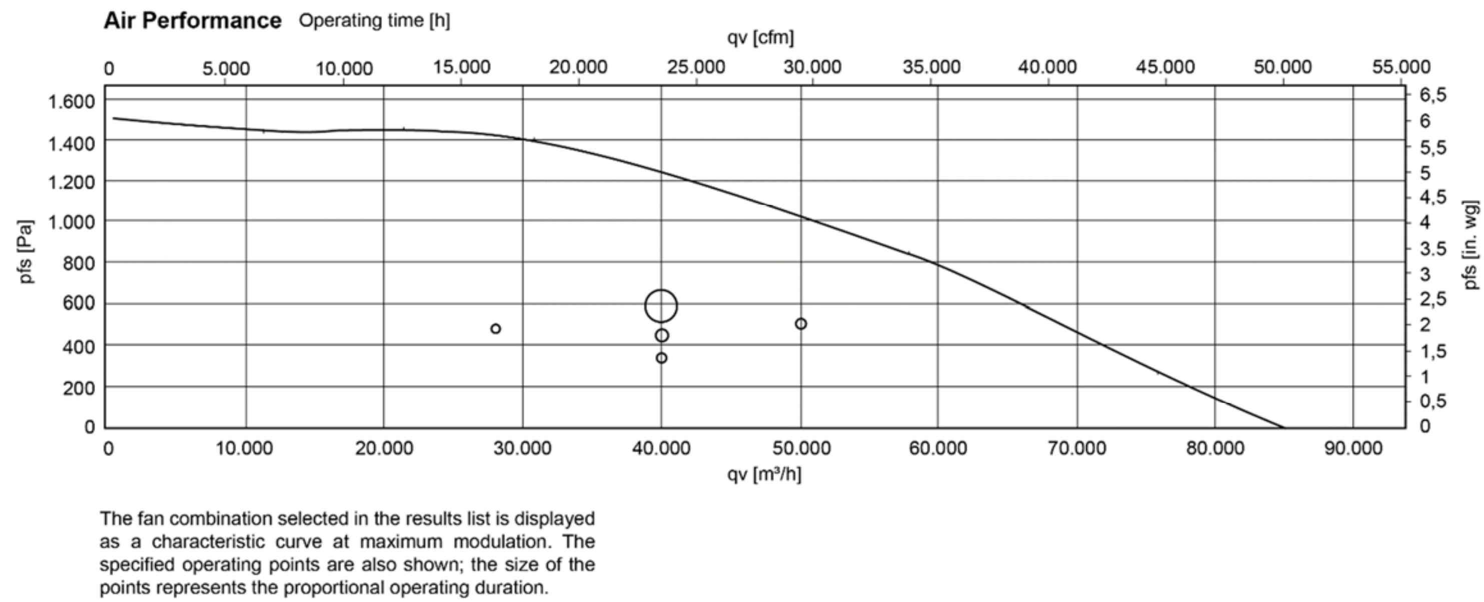

Figure 5—Overview of the Weighted Operating Points in the Air Performance Diagram

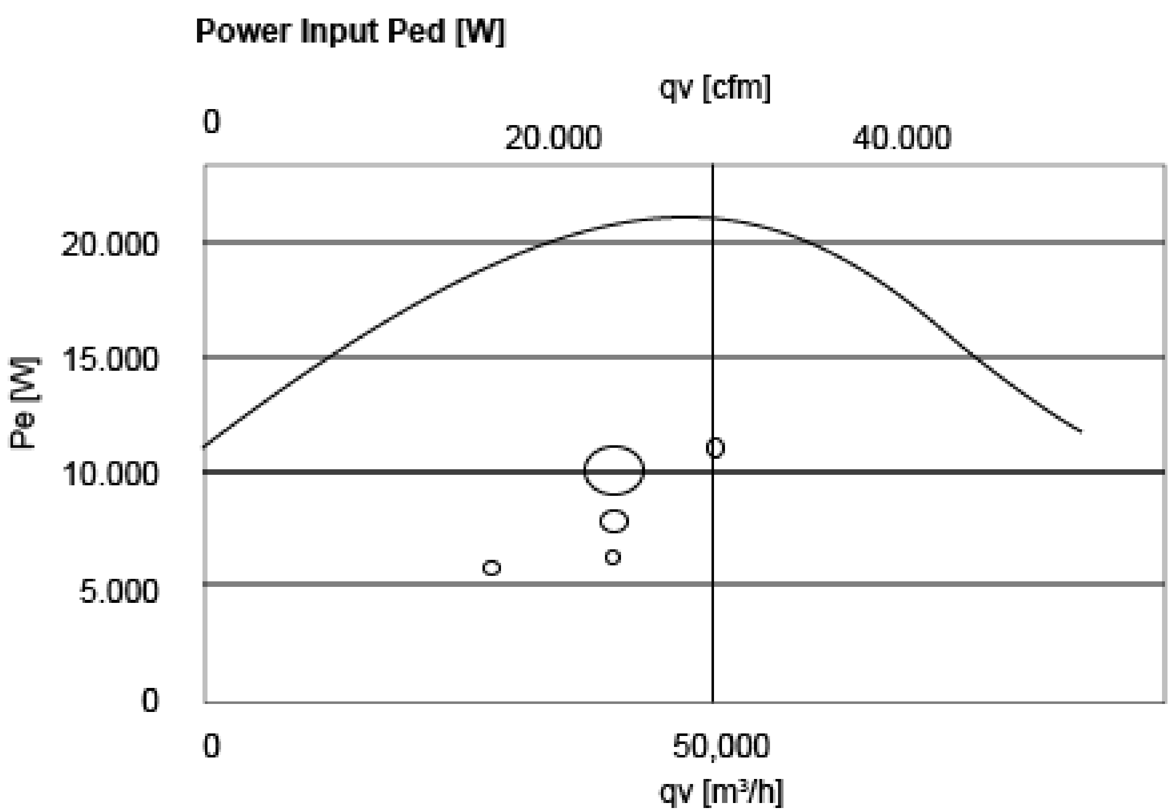

Figure 6—Representation of the Power Consumption of the Corresponding Operating Points

D.3 Application of the embedded fan

A standalone fan test does not always address the wide variety of applications in which fans are used. For example, heat rejection fans are often designed for a specific purpose, and a standalone fan test may not adequately capture the useful work of a fan. A heat rejection fan like one used to reject heat from a condenser coil is designed to balance a number of factors, including the need to maximize heat rejection with minimal input power to the equipment, all forms of energy being considered. Any improvement in velocity profile, for example, will likely not be realized in a standalone fan test. It would be difficult or impractical to apply a correction to approximate any added benefit.

D.4 Applying the FEI to an embedded fan

System effects and optional fan accessories are generally estimated as pressure losses and simply added to a standalone fan's duty point. However, equipment system effects are included or "built in" with the rating data when an equipment test is conducted. To avoid confusion with other, more visible system effects, we will use the term "latent" to describe these built-in effects in what follows.

Recall that the FEI calculation is not intended to apply directly to fan performance obtained with the fan embedded inside other equipment (e.g., furnaces) or with optional accessories (e.g., guarding). To properly evaluate these fans based on the performance obtained in the minimum testable configuration, care must be taken to choose the correct duty point.

D.5 Embedded fans tested in-accordance with an equipment test standard

D.5.1 Certified air handling unit example

Suppose an embedded fan that has been tested in accordance with a test standard has a duty point of 8,500 CFM at 4 in. wg. In the minimum testable configuration, this fan draws 7.42 BHP at 1,538 rpm and results in an FEI of 1.35.

However, when tested in accordance with a test standard, this same fan running at the same duty point (8,500 CFM and 4 in. wg.) actually draws 8.502 BHP at 1,597 rpm. These values are different from the minimum testable configuration because any latent losses are built into the equipment fan curve. Thus, the 8,500 cfm at 4 in. wg. duty point does not represent the fan's actual duty point.

Recognize that a fan duty point can be defined with any two variables from the following: flow, pressure, speed or power consumed. Since the pressure and power values can be affected by latent losses, the duty point of an embedded fan should be defined in terms of flow and speed.

D.5.2 Certified air handling unit example (revisited)

We can approximate the latent loss in our example by finding the performance of a fan in a minimum testable configuration with flow and speed (the higher speed from the embedded fan data set) as inputs. At 8,500 cfm and 1,597 rpm, a fan in a minimum testable configuration would draw 8.32 BHP and result in an FEI of 1.34.

We can also find the pressure corresponding with a duty point of 4.492 in. wg. The embedded fan thus has a latent loss of 4.492 - 4.0 = 0.492 in. wg. and 8.502 - 8.32 = 0.182 BHP. Note how the flow/speed approach does not fully account for the change in power being consumed.

To determine FEP_{ref} by calculation, a pressure must be used. This pressure can be found by using the pressure corresponding with the intersection of flow and speed in the minimum testable configuration (4.492 in. wg., in our example above).

In the field, the determination of FEI or FEP_{act} should be straightforward. Simply use the intersection of flow and speed with a published fan curve or selection software.

D.5.3 Embedded fans without latent losses

Not all equipment, particularly custom or built-up air handling equipment, is tested in accordance with a test standard. Manufacturers of these types of equipment will often estimate the latent loss using guides like AMCA Publication 201, which instructs the user to increase the pressure by a specific amount. In this case, the duty point pressure will be increased and the FEI can be determined using a flow/pressure combination or a flow/speed combination.

D.5.4 Custom air handling unit example

Suppose the same fan above is embedded in a custom air handler that is not tested in accordance with a test standard but is otherwise identical (e.g., same latent loss) to the example above. To account for the unknown latent loss, the equipment manufacturer estimates the loss at 0.2 in. wg. and selects the fan at 8,500 cfm and 4.2 in. wg. of pressure. In the minimum testable configuration, this fan draws 7.78 BHP at 1562 rpm and results in an FEI of 1.35.

D.5.5 Minimum testable configuration drawbacks

Notice that the latent pressure losses were different between the two examples above, despite the fact that the real (if tested in both cases) latent loss is the same. In one case, the loss is known to be 0.492 in. wg., and in the other, it is estimated to be 0.2 in. wg. This is just an example, but it serves to highlight the potential differences in FEI that could be encountered. Also, keep in mind that the flow/speed approach does not fully account for the change in power being consumed.

Although the flow/speed approach suggested above ensures an efficient fan is being operated in an efficient region of the fan curve once embedded, it does not fully account for all potential inefficiencies. As stated previously, an equipment test will yield the most accurate estimate of final, in situ performance. A user should thus continue to review the actual power consumed—not necessarily FEP_{act}—to choose the most efficient equipment or fan for the application.

RESOURCES

AMCA Membership Information
http://www.amca.org/members/members.php

AMCA International Headquarters and Laboratory
www.amca.org

AMCA White Papers
www.amca.org/whitepapers

Searchable CRP Database of AMCA Certified Products
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