

ANSI/AMCA Standard 214-21

Test Procedure for Calculating Fan Energy Index (FEI) for Commercial and Industrial Fans and Blowers

An American National Standard
Approved by ANSI on March 1, 2021



Air Movement and Control Association International

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Test Procedure for Calculating Fan Energy Index (FEI) for Commercial and Industrial Fans and Blowers



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Foreword

(This foreword is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ANSI.)

The purpose of AMCA Standard 214, Test Procedure for Calculating Fan Energy Index (FEI) for Commercial and Industrial Fans and Blowers, is to aid federal and state rulemaking efforts to establish energy-efficiency standards for commercial and industrial fans and blowers, providing a consistent method of calculating FEI across the many different options or circumstances that exist in the fan market (fans sold without motors and drives, fans sold with unregulated motors or regulated motors, etc.).

An expressed difficulty in establishing an FEI-based fan regulation is having to work with four AMCA standards and publications: ANSI/AMCA Standard 207, Fan System Efficiency and Fan System Input Power Calculation; ANSI/AMCA Standard 208, Calculation of the Fan Energy Index; ANSI/AMCA Standard 210/ASHRAE Standard 51, Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating; and AMCA Publication 211, Certified Ratings Program Product Rating Manual for Fan Air Performance. AMCA Standard 214 consolidates these documents.

AMCA Standard 214 primarily is for fans that are tested alone or with motors and drives; it does not apply to fans tested embedded inside of other equipment. AMCA Standard 214 covers most fan types and sizes.

For fans that already have been tested for rating using test procedures referenced in this document, no new testing is required for applying this standard. Fan manufacturers may be required to update their internal data-collection, calculation, and documentation systems to acquire the data necessary for the calculation of FEI.

AMCA Standard 214 covers only calculation of FEI and fan electrical power (FEP). It does not cover labeling, compliance filing, surveillance, and other regulatory processes.

Presenting FEI values to the market may also require fan manufacturers to modify fan-selection software and printed materials.

Calculations in AMCA Standard 214 may require fan manufacturers to collect additional information from prospective buyers, such as drive (transmission) configuration and expected motor selection.

Compliance with AMCA Standard 214 requires fan manufacturers to assemble product data not historically presented to the market, such as fan outlet area, fan total pressure, and fan category.

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Test Procedure for Calculating Fan Energy Index (FEI) for Commercial and Industrial Fans and Blowers

1. Scope

This standard applies to fans where air is used as the test gas with the following exceptions:

- Ceiling fans
- Cross-flow fans
- Air Curtain Units

2. References (Normative)

The following referenced documents are required for the application of this document. For dated references only the edition cited applies. For undated references, the latest edition of the referenced document applies.

AHRI Standard 1210 (I-P/2019), Performance Rating of Variable Frequency Drives

ANSI/AMCA Standard 210-16/ASHRAE 51-16, Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating

ANSI/AMCA Standard 230-15, Laboratory Methods of Testing Air Circulating Fans for Rating and Certification

ANSI/AMCA Standard 250-12, Laboratory Methods of Testing Jet Tunnel Fans for Performance

ANSI/AMCA Standard 260-20, Laboratory Methods of Testing Induced Flow Fans for Rating

ANSI/AMCA Standard 99-2016, Standards Handbook

ANSI/ASHRAE Standard 222-2016, Standard Method of Test for Electrical Power Drive Systems

CAN/CSA C747-09, Energy efficiency test methods for small motors

CAN/CSA C838-13, Energy efficiency test methods for three-phase variable frequency drive systems

IEEE 112-2017, Standard Test Procedure for Polyphase Induction Motors and Generators

ISO 5801:2017, Fans – Performance testing using standardized airways

ISO 13350:2015, Fans – Performance testing of jet fans

10 CFR 431.25, Energy conservation standards and effective dates

3. Definitions

3.1 Absolute pressure

The pressure if the datum pressure is absolute zero. It is always positive.

3.2 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 with a fan flow angle less than or equal to 20 degrees. Blades can be either single thickness or airfoil shaped.

3.3 Axial PRV

A powered roof ventilator (PRV) with an axial impeller that either supplies or exhausts air to a building. Inlets and outlets typically are not ducted.

3.4 Axial inline fan

A fan with an axial impeller and a cylindrical housing with or without turning vanes.

3.5 Axial panel fan

An axial fan, without cylindrical housing, that is mounted on a panel, orifice plate or ring.

3.6 Barometric pressure

The absolute pressure exerted by the atmosphere.

3.7 Base tests

The laboratory test or tests used in concert with rating development procedures to determine the performance of each model in a product line.

3.8 Direct drive

A form of transmission where the impeller is mounted directly on a motor without the use of belts or couplings. Impeller speed is identical to motor speed.

3.9 Centrifugal housed fan

A fan with a centrifugal or mixed flow impeller in which airflow exits into a housing that is generally scroll-shaped to direct the air through a single fan outlet. A centrifugal housed fan does not include a radial impeller.

3.9a 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).

3.10 Centrifugal inline fan

A fan with a centrifugal or mixed-flow 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.

3.11 Centrifugal power roof ventilator exhaust (PRV-E) fan

A PRV with a centrifugal or mixed-flow impeller that exhausts air from a building. It is typically mounted on a roof or a wall.

3.12 Centrifugal power roof ventilator supply (PRV-S) fan

A PRV with a centrifugal or mixed-flow impeller that supplies air to a building. It is typically mounted on a roof or a wall.

3.13 Centrifugal unhooded fan

A fan with a centrifugal or mixed-flow 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.

3.14 Ceiling fan

A nonportable device that is suspended from a ceiling or overhead structure for circulating air via the rotation of fan blades as defined in 10 CFR 430.2.

3.15 Circulating fan

A fan that is not a ceiling fan that is used to move air within a space but has no provision for connection to ducting or separation of the fan inlet from its outlet. The fan is designed to be used for the general circulation of air.

3.16 Compressibility coefficient

The ratio of the mean airflow rate through the fan to the airflow rate at fan air density; the ratio of the fan total pressure that would be developed with an incompressible fluid to the fan total pressure that is developed with a compressible fluid. The compressibility coefficient is a thermodynamic factor that must be applied to determine fan total efficiency from fan airflow rate, fan total pressure and fan input power. The coefficient is derived in ANSI/AMCA Standard 210-16, Annex D, or ISO 5801, Section 15.1.9.3.

3.17 Default motor efficiency

A default efficiency assigned to the motor at its operating point if 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.

3.18 Drive

Components used to power a fan, including a driver, may include a motor controller and/or transmission.

3.19 Driven fan

A fan equipped with a driver.

3.20 Driver

A machine, such as a motor, used to provide mechanical power to the impeller, either directly or through a transmission.

3.21 Dual-use fan

A fan with two operating modes to serve long-term ventilation purposes as well as short-time emergency duty at higher speed for fire or smoke extraction.

3.22 Duty point

A single airflow, pressure point and fan air density within the fan's operating range.

3.23 Dynamic (velocity) pressure

The portion of air pressure that exists by virtue of the rate of motion of the air.

3.24 Erosion-resistant fan

A fan designed with features intended to reduce erosion by particles or liquids passing through the fan, thereby extending its useful life. Such features may include wear plates, deflector vanes and/or thick coatings of erosion-resistant material, which will reduce the fan's efficiency.

3.25 Fan

A rotary-bladed machine used to convert electrical or mechanical power to air power, with an energy output limited to 25 kJ/kg of air. It consists of an impeller, shaft and bearings and/or driver to support the impeller as well as a structure or housing. A fan may include a transmission, driver and/or motor controller.

3.25.1 Bare shaft fan

A fan offered in commerce without a drive.

3.25.2 Driven fan

A fan equipped with a driver and, if included, transmission and motor controller.

3.25.3 Standalone fan

A fan in at least a minimum testable configuration. This includes any driver, 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.

3.25.4 Embedded Fan

A fan that is part of a manufactured assembly where the assembly includes functions other than air movement.

3.26 Fan air density

The density of the air corresponding to the total pressure and the stagnation (total) temperature of the air at the fan inlet.

3.27 Fan airflow rate

The volumetric airflow rate at fan air density.

3.28 Fan array

Multiple fans in parallel and in a single enclosure between two plenum sections in an air- distribution system, where a plenum means is a compartment or chamber that forms a part of the air- distribution system, and that is not used for occupancy or storage

3.29 Fan dynamic (velocity) pressure

A pressure calculated from the average air velocity and fan air density at the fan outlet.

3.30 Fan electrical power (FEP)

The electrical power required to operate a fan, including any motor controllers, at a given duty point.

- FEP_{ref} is the reference FEP used to calculate the FEI at a given fan duty point.
- FEP_{act} is the actual FEP at the same given fan duty point as FEP_{ref} .

3.31 Fan energy index (FEI)

A ratio of the electrical input power of a reference fan to the electrical input power as described in Section 4.

3.32 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.

3.33 Fan inlet and outlet boundaries

The interfaces between a fan and the remainder of the air system; the respective planes perpendicular to an airstream entering or leaving a fan.

3.34 Fan input boundary

The point at which power input to the fan is measured. If fan shaft power is reported, it is the interface between a fan and its drive. If fan electrical power is reported, it is the interface between drive and the mains.

3.35 Fan shaft power

The mechanical input power to the shaft that is connected directly to the impeller.

3.36 Fan output power

The power delivered to air by the fan; it is proportional to the product of the fan airflow rate, the fan total pressure and the compressibility coefficient.

3.37 Fan performance ratings

Quantities used to describe aerodynamic performance of a fan at one or more duty points. Fan performance ratings can include any of the following:

- Airflow
- Fan static pressure
- Fan total pressure
- Fan velocity pressure
- Fan air density
- Fan thrust
- Fan shaft power
- Fan static efficiency
- Fan total efficiency

- Fan electrical power, actual (FEP_{act})
- Driven fan static efficiency
- Driven fan total efficiency
- FEI

3.38 Fan speed

The rotational speed of the impeller. If the fan has more than one impeller, fan rotational speed is the rotational speed of each impeller.

3.39 Fan series

A group of fan models that are geometrically similar per the requirements of Annex K.

3.40 Fan static efficiency

The fan total efficiency multiplied by the ratio of fan static pressure to fan total pressure.

3.41 Fan static pressure

The difference between the fan total pressure and the fan dynamic (velocity) pressure. Therefore, it is the difference between static pressure at the fan outlet and total pressure at the fan inlet.

3.42 Fan total efficiency

The ratio of fan output power to fan shaft power.

3.43 Fan total pressure

The difference between the total pressure at the fan outlet and the total pressure at the fan inlet.

3.44 Flexible coupling

A form of transmission utilizing a coupling to transmit torque from one shaft to another in a coaxial configuration where the two shafts are at the same speed. A flexible coupling allows for minor shaft misalignment.

3.45 Housing

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

3.46 Impeller

A fan's rotary bladed aerodynamic component that transfers mechanical energy to the airstream.

3.47 Induced-flow fan

A type of laboratory exhaust fan with a nozzle and windband; the fan's outlet airflow is greater than the inlet airflow due to induced airflow. All airflow entering the inlet exits through the nozzle. Airflow exiting the windband includes the nozzle airflow as well as the induced airflow.

3.48 Inlet area

The area in contact with the fan's inlet.

3.49 Inlet bell

A gradual transition of a duct, ring or cone located at a fan's inlet, which decreases in cross-sectional area with the airflow direction.

3.50 Inline mixed-flow fan

A fan with a mixed-flow 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.

3.51 Jet fan

A fan designed and marketed specifically to produce a high-velocity air jet in a space to increase its air momentum. Jet fans are rated using thrust. Inlets and outlets are not ducted but may include acoustic silencers.

3.52 Laboratory exhaust fan

A fan designed and marketed specifically for exhausting contaminated air vertically away from a building using a high-velocity discharge.

3.53 Minimum testable configuration

A fan having at least an impeller; shaft and bearings and/or driver to support the impeller; and its structure or its housing.

3.54 Mixed-flow fan

A fan with a fan flow angle greater than 20 degrees and less than 70 degrees.

3.55 Mixed-flow impeller

An impeller featuring construction characteristics between those of an axial and centrifugal impeller. A mixed-flow impeller has 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.

3.56 Motor controller

Any device connected between the motor and the electric supply that can be used to control the motor's speed.

3.57 Outlet area

The area in contact with the fan's outlet.

3.58 Power roof/wall ventilator (PRV)

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

3.59 Radial-housed fan

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

3.60 Radial impeller

A form of centrifugal impeller with several blades extending radially from a central hub. Airflow enters axially through a single inlet and exits radially at the impeller periphery into a housing with impeller blades; the blades are positioned so their outward direction is perpendicular within 25 degrees to the axis of rotation. Impellers can have a back plate and/or shroud.

3.61 Polyphase regulated motor

A three-phase motor regulated under 10 CFR 431.25.

3.62 Series calculated fan

The fan models for which performance data was calculated based on a series tested fan from the same fan series using fan laws per the requirements of Annex E.

3.63 Series tested fan

The fan model tested in a laboratory to provide performance data for a fan series.

3.64 Stagnation (total) temperature

The temperature that exists by virtue of the internal and kinetic energy of the air. If the air is at rest, the stagnation (total) temperature will equal the static temperature.

3.65 Standard air

Air with a standard density of 1.2 kg/m³ (0.075 lbm/ft³).

3.66 Static pressure

The portion of air pressure that exists by virtue of the state of the air. If expressed as a gauge pressure, it may be positive or negative.

3.67 Static temperature

The temperature that exists by virtue of the internal energy of the air. If a portion of the internal energy is converted into kinetic energy, the static temperature is decreased accordingly.

3.68 Structure

Any fan component(s) necessary to support the shaft, bearings and/or driver.

3.69 Synchronous belt drive

A form of transmission utilizing drive belts that have a substantially rectangular cross section containing teeth that engage with corresponding teeth on the sheaves (pulleys), resulting in no-slip power transmission. The belts are sometimes called timing or toothed belts.

3.70 Total pressure

The air pressure that exists by virtue of the state of the air and the rate of motion of the air. It is the algebraic sum of velocity pressure and static pressure at a point. If air is at rest, its total pressure will equal the static pressure.

3.71 Transmission

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

3.72 V-belt drive

A form of transmission utilizing drive belts that have a substantially trapezoidal cross section and sheaves (pulleys) with smooth contact surfaces.

3.73 Windband

A generally cylindrical fan component that surrounds and mounts above the outlet of an upblast fan, protecting the fan outlet from crosswinds. In the case of an induced-flow fan, the windband also allows for the induction of ambient air and mixing with exhaust air prior to leaving the windband.

4. Calculation of the FEI for a Single Duty Point

The FEI is defined as the ratio of the reference fan electrical power to the actual fan electrical power, where each of these are calculated at the same duty point.

$$FEI_t \text{ or } FEI_s = \frac{\text{Reference Fan Electrical Power}}{\text{Actual Fan Electrical Power}} = \frac{FEP_{ref}}{FEP_{act}}$$

Where:

FEI_t is the FEI value calculated using total pressure as a pressure basis per Table 7.1

FEI_s is the FEI value calculated using static pressure as a pressure basis, per Table 7.1

FEP_{ref} is the reference fan electrical power, kW (see Section 5)

FEP_{act} is the actual fan electrical power, kW (see Section 6)

5. Reference Fan Electrical Power (FEP_{ref})

The reference fan concept is used to normalize the FEI calculation to a consistent power level independent of fan type and fan drive components. The reference fan electrical power is a function of airflow, fan air density and fan air pressure.

$$FEP_{ref} = H_{i,ref} \left(\frac{1}{\eta_{trans,ref}} \right) \left(\frac{1}{\eta_{mtr,ref}} \right) \quad [\text{SI}]$$

$$FEP_{ref} = H_{i,ref} \left(\frac{1}{\eta_{trans,ref}} \right) \left(\frac{1}{\eta_{mtr,ref}} \right) \times 0.7457 \quad [\text{I-P}]$$

Where:

FEP_{ref} is reference fan electrical power

$H_{i,ref}$ is reference fan shaft power determined in accordance with Section 5.1.

$\eta_{(trans,ref)}$ is reference transmission efficiency determined in accordance with Section 5.2.

$\eta_{(mtr,ref)}$ is reference motor efficiency determined in accordance with Section 5.3.

5.1 Reference fan shaft power ($H_{i,ref}$)

The reference fan shaft power, $H_{i,ref}$, is calculated on either a fan total pressure basis or a fan static pressure basis. See Section 7 for a complete description and a list of fan types as well as the FEI pressure basis.

5.1.1 Fan total pressure basis

For fans using a fan total pressure basis, the reference fan shaft power at a given duty point is calculated according to the following equation:

$$H_{i,ref} = \frac{(Q + Q_0) \left(P_t + P_0 \times \frac{\rho}{\rho_{std}} \right)}{1000 \times \eta_o} \quad [\text{SI}]$$

$$H_{i,ref} = \frac{(Q + Q_0) \left(P_t + P_0 \times \frac{\rho}{\rho_{std}} \right)}{6343.3 \times \eta_o} \quad [\text{I-P}]$$

Where:

$H_{i,ref}$ is reference fan shaft power in kW (SI) or hp (I-P)

Q is fan airflow rate in m^3/s (SI) or cfm (I-P)

P_t is fan total pressure at density ρ in Pa (SI) or in. wg (I-P)

ρ is fan air density at duty point in kg/m^3 (SI) or lbm/ft^3 (I-P)

ρ_{std} is standard air density, $1.2 \text{ kg}/\text{m}^3$ ($0.075 \text{ lbm}/\text{ft}^3$)

Q_0 = $0.118 \text{ m}^3/\text{s}$ (SI) or 250 cfm (I-P)

P_0 = 100 Pa (SI) or 0.40 in. wg (I-P)

η_o = 66% (0.66)

5.1.2 Fan static pressure basis

For fans using a fan static pressure basis, the reference fan shaft power at a given duty point is calculated according to the following equation:

$$H_{i,ref} = \frac{(Q + Q_0) \left(P_s + P_0 \times \frac{\rho}{\rho_{std}} \right)}{1000 \times \eta_o} \quad [\text{SI}]$$

$$H_{i,ref} = \frac{(Q + Q_0) \left(P_s + P_0 \times \frac{\rho}{\rho_{std}} \right)}{6343.3 \times \eta_o} \quad [\text{I-P}]$$

Where:

$H_{i,ref}$ is reference fan shaft power in kW (SI) or hp (I-P)

Q is fan airflow rate in m^3/s (SI) or cfm (I-P)

P_s is fan static pressure at fan air density ρ in Pa (SI) or in. wg (I-P)

ρ is fan air density at duty point in kg/m^3 (SI) or lbm/ft^3 (I-P)

ρ_{std} is standard air density, $1.2 \text{ kg}/\text{m}^3$ ($0.075 \text{ lbm}/\text{ft}^3$) (I-P)

Q_0 = $0.118 \text{ m}^3/\text{s}$ (SI) or 250 cfm (I-P)

P_0 = 100 Pa (SI) or 0.40 in. wg (I-P)
 η_0 = 60% (0.60)

5.2 Reference fan transmission efficiency

The reference fan transmission efficiency is calculated using the following equations:

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

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

Where:

$H_{i,\text{ref}}$ is reference fan shaft power in kW (SI) or hp (I-P)
 $H_{\text{trans,ref}}$ is reference fan transmission efficiency (dimensionless)

5.3 Reference fan motor efficiency

Reference fan motor output power:

$$H_{t,\text{ref}} = \frac{H_{i,\text{ref}}}{\eta_{\text{trans,ref}}}$$

Where:

$H_{i,\text{ref}}$ is reference fan shaft power in kW (SI) or hp (I-P)
 $H_{\text{trans,ref}}$ is reference fan transmission efficiency (dimensionless)
 $H_{t,\text{ref}}$ is reference fan motor output power in kW (SI) or hp (I-P)

The reference fan motor efficiency is calculated according to the following equation using the coefficients A–E in Table 5.1:

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

$$\eta_{\text{mtr,ref}} = A \cdot [\log_{10}(H_{t,\text{ref}} \times 0.7457)]^4 + B \cdot [\log_{10}(H_{t,\text{ref}} \times 0.7457)]^3 + C \cdot [\log_{10}(H_{t,\text{ref}} \times 0.7457)]^2 + D \cdot [\log_{10} H_{t,\text{ref}} \times 0.7457] + E \quad [\text{I-P}]$$

Where:

$H_{t,\text{ref}}$ is reference fan motor output power in kW (SI) or hp (I-P)
 $\eta_{\text{mtr,ref}}$ is reference fan motor efficiency (dimensionless)

Table 5.1 — Constants Used to Calculate Reference Fan Motor Efficiency

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

6. Determination of Actual Fan Electrical Input Power (FEP_{act})

FEP_{act} is determined using one of the following methods listed in Table 6.1.

Table 6.1 — Selection of Sections to be Used for Calculating FEP_{act}

Driver	Motor Controller	Transmission	Fan Shaft Power Known?	Must be Tested at Duty Point	Section
Electric motor	Yes or No	Any	No	Yes	6.1
Electric motor	Yes or No	Any	No	No	6.2
Regulated polyphase motor	Variable Frequency Drive (VFD) or None	Direct drive, V-belt drive, flexible coupling or synchronous belt drive	Yes	No	6.4
Electric motor	Yes or No	Direct drive, V-belt drive, flexible coupling or synchronous belt drive	Yes	No	6.5
None Supplied	None Supplied	None Supplied	Yes	No	6.3
Non-electric	N/A	N/A	Yes	No	6.3

6.1 Wire-to-air testing at the required duty point

The FEP_{act} of the driven fan is determined at the duty point using one of the methods described in Section 7.

6.2 Calculated ratings based on wire-to-air testing

The FEP_{act} of the driven fan is calculated at the duty point as described in Section 8.2.3 and Annex G.

6.3 Bare Shaft Fans

This section covers the determination of the actual fan electrical power of a fan (FEP_{act}) at each fan duty point i based on fan shaft power ($H_{i,act}$) measurement combined with default motor and transmission efficiency values. It applies only to bare shaft fans and fans sold with a driver other than an electric motor.

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

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

Where:

FEP_{act} is actual fan electrical power (kW or hp)
 $H_{i,act}$ is actual fan shaft power, (kW or hp), determined per Section 7 or Section 8
 $\eta_{trans,def}$ is default transmission efficiency, calculated per the requirements of Section 6.3.1
 $\eta_{mtr,def}$ is default motor efficiency, calculated per the requirements of Section 6.3.3

6.3.1 Calculation of FEP_{act} for bare shaft fans where the motor, transmission and motor controller are unknown

For bare shaft fans that can only have a direct-drive transmission:

$$\eta_{trans,def} = 1$$

For all other bare shaft fans and fans with drivers other than motors:

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

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

Where:

$\eta_{trans,def}$ is default transmission efficiency,

$H_{i,act}$ is actual fan shaft power (kW or hp)

Fan shaft power is determined at the duty point using one of the methods described in Section 7 or rated at the duty point using one of the methods described in Section 8.2.1.

6.3.2 Default motor output power

The default power output of the motor.

$$H_{m,def} = \frac{H_{i,act}}{\eta_{trans,def}}$$

Where:

$H_{m,def}$ is default motor output power at the duty point (kW or hp)

$H_{i,act}$ is actual fan shaft power (kW or hp)

$\eta_{trans,def}$ is default transmission efficiency calculated from Section 6.3.1

6.3.3 Default motor efficiency

The default motor efficiency is calculated using the following equation. Constants A, B, C, D and E are found in Table 6.2:

$$\eta_{mtr,def} = A \cdot [\log_{10}(H_{m,def})]^4 + B \cdot [\log_{10}(H_{m,def})]^3 + C \cdot [\log_{10}(H_{m,def})]^2 + D \cdot [\log_{10}(H_{m,def})] + E \quad [\text{SI}]$$

$$\eta_{mtr,def} = A \cdot [\log_{10}(H_{m,def} \cdot 0.7457)]^4 + B \cdot [\log_{10}(H_{m,def} \cdot 0.7457)]^3 + C \cdot [\log_{10}(H_{m,def} \cdot 0.7457)]^2 + D \cdot [\log_{10}(H_{m,def} \cdot 0.7457)] + E \quad [\text{I-P}]$$

Where:

$\eta_{mtr,def}$ is default motor efficiency

$H_{m,def}$ is default motor output power calculated at the duty point per Section 6.3.2

Table 6.2 — Default Motor Efficiency Coefficients

	60 Hz, IE3	
Applicability Examples	U.S., Canada, Mexico	
	$H_{m,def} < 185 \text{ kW}$ ($H_{m,def} < 250$ BHP)	$H_{m,def} \geq 185 \text{ kW}$ ($H_{m,def} \geq 250$ BHP)
A	-0.003812	0
B	0.025834	0
C	-0.072577	0
D	0.125559	0
E	0.850274	0.962

6.4 Fans with Polyphase Regulated Motors

The calculation of FEP_{act} is permitted for driven fans meeting the requirements shown in Section 6.4.1.

6.4.1 Requirements for driven fan components

The calculation method can be used only if all requirements in this subsection are met for the fan, transmission, motor and VFD (if included)

6.4.1.1 Requirements for the fan

The fan shaft power is determined at the duty point using one of the methods described in Section 7 or rated at the duty point using one of the methods described in Section 8.2.1.

6.4.1.2 Requirements for the transmission

The transmission must be V-belt drive, synchronous belt drive, flexible coupling or direct drive.

6.4.1.3 Requirements for the motor

The motor must be a polyphase regulated motor.

6.4.1.4 Requirements for the VFD, if included

The VFD must meet the following requirements:

- Be pulse-width modulated
- Output voltage cannot exceed the voltage listed on the motor nameplate
- Output frequency cannot exceed 120 Hz at the duty point
- Be programmed for variable torque using a constant V/Hz ratio for operating points under 60 Hz or another method that yields the same or higher efficiency

6.4.2 Calculation of FEP_{act}

FEP_{act} is calculated using the equations in this section and the tables in Annexes A through D. The values of fan shaft power $H_{i,act}$, measured in accordance with Section 6.4.1.1, must be used to calculate FEP_{act} as follows:

For driven fans where no VFD is included, the equation is:

$$FEP_{act} = H_{i,act} \left(\frac{1}{\eta_{trans,act}} \right) \left(\frac{1}{\eta_{mtr,act}} \right) \quad [\text{SI}]$$

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

Where:

FEP_{act} is actual fan electrical power (kW)

$H_{i,act}$ is actual fan shaft power, determined per Section 6.4.1.1 (kW or hp)

$\eta_{trans,act}$ is actual transmission efficiency, calculated per the requirements of Section 6.4.2.1

$\eta_{mtr,act}$ is actual motor efficiency, calculated per the requirements of Section 6.4.2.4

For driven fans where a VFD is included, the equation is:

$$FEP_{act} = H_{i,act} \left(\frac{1}{\eta_{trans,act}} \right) \left(\frac{1}{\eta_{mtr-ctl,act}} \right) \quad [\text{SI}]$$

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

Where:

FEP_{act} is actual fan electrical power (kW)

$H_{i,act}$ is actual fan shaft power, determined per Section 6.4.1.1 (kW or hp)

$\eta_{trans,act}$ is actual transmission efficiency, calculated per the requirements of Section 6.4.2.1

$\eta_{mtr-ctl,act}$ is actual combined motor/VFD efficiency, calculated per the requirements of Section 6.4.2.4

6.4.2.1 Calculation of transmission efficiency ($\eta_{trans,act}$)

Transmission efficiency must be calculated using the appropriate equation for the type of transmission included with the fan.

6.4.2.1.1 V-belt drive

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

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

Where:

$\eta_{trans,act}$ is actual transmission efficiency

$H_{i,act}$ is actual fan shaft power (kW or hp)

6.4.2.1.2 Synchronous belt drive

SI:

$$H_{i,act} \leq 1.00 \text{ kW}, \eta_{trans,act} = 0.94$$

$$1.00 \text{ kW} < H_{i,act} \leq 5.00 \text{ kW}, \eta_{trans,act} = 0.01 \cdot H_{i,act} + 0.93$$

$$H_{i,act} > 5.00 \text{ kW}, \eta_{trans,act} = 0.98$$

I-P:

$$H_{i,act} \leq 1.34 \text{ hp}, \eta_{trans,act} = 0.94$$

$$1.34 \text{ hp} < H_{i,act} \leq 6.70 \text{ hp}, \eta_{trans,act} = 0.007456 \cdot H_{i,act} + 0.93$$

$$H_{i,act} > 6.70 \text{ hp}, \eta_{trans,act} = 0.98$$

Where:

$\eta_{trans,act}$ is actual transmission efficiency

$H_{i,act}$ is actual fan shaft power (kW or hp)

6.4.2.1.3 Flexible coupling

$$\eta_{trans,act} = 0.98$$

6.4.2.1.4 Direct drive

$$\eta_{trans,act} = 1$$

6.4.2.2 Calculation of actual motor output power

The actual motor output power at the duty point is calculated using this equation:

$$H_{m,act} = \frac{H_{i,act}}{\eta_{trans,act}}$$

Where:

$H_{m,act}$ is actual motor output power, at the duty point (kW or hp)

$H_{i,act}$ is actual fan shaft power, (kW or hp)

$\eta_{trans,act}$ is actual transmission efficiency, calculated from Section 6.4.2.1

6.4.2.3 Motor efficiency if no VFD is included

The calculation method for motor efficiency if the driven fan does not include a VFD.

$$\eta_{mtr,act} = \eta_r \left(\frac{aL_m}{b + L_m} + cL_m^2 \right)$$

Where:

$\eta_{mtr,act}$ is actual motor efficiency

η_r is polyphase regulated motor nominal full-load efficiency per Section 6.4.2.3.1

a, b, c are constant values per Section 6.4.2.3.2

L_m is motor load ratio calculated per Section 6.4.2.3.3

6.4.2.3.1 Nominal full-load efficiency table lookup

For polyphase regulated motors, the minimum- required nominal full-load efficiency is found in Annex A.

If the motor nameplate output power value is not shown in the table, follow these instructions:

1. (1) A horsepower at or above the midpoint between the two consecutive horsepower shall be rounded up to the higher of the two horsepower.
- 2.
3. (2) A horsepower below the midpoint between the two consecutive horsepower shall be rounded down to the lower of the two horsepower.
- 4.
5. (3) A shaft power rating in kilowatt shall be directly converted from kilowatts to horsepower using the formula 1 kilowatt = (1/0.746) horsepower. The conversion should be calculated to three significant decimal places, and the resulting horsepower shall be rounded in accordance with paragraph (1) or (2) of this section, whichever applies.

6.4.2.3.2 Motor constants without VFD

The values for a and b are found in Annex D. Constant c is calculated with this equation:

$$c = 1 - \frac{a}{b + 1}$$

6.4.2.3.3 Motor load ratio

This is the ratio of the load on the motor to the motor nameplate output power calculated with the following equation:

$$L_m = \frac{H_{m,act}}{H_{mo}} \quad [0 < L_m < 1.5]$$

Where:

L_m is motor load ratio

$H_{m,act}$ is motor output power (kW or hp) in accordance with Section 6.4.2.2

H_{mo} is motor nameplate output power (kW or hp) in accordance with Section 6.4.2.3.1

6.4.2.4 Combined motor-VFD efficiency

This is the calculation method for the efficiency of a motor-VFD combination if the driven fan includes a VFD. The general equation is:

$$\eta_{mtr-ctl,act} = \eta_{mtr'act} \times \eta_{VFD}$$

Where:

$\eta_{mtr-ctl,act}$ is combined Motor-VFD efficiency, actual

$\eta_{mtr'act}$ is motor efficiency if used in combination with a VFD

η_{VFD} is VFD efficiency at the required motor electrical power input

6.4.2.4.1 Motor efficiency if used in combination with a VFD

How to calculate the efficiency of the motor if it is combined with a VFD.

$$\eta_{mtr',act} = \eta_r \left(\frac{gL_m}{h + L_m} + iL_m^2 \right)$$

Where:

$\eta_{mtr',act}$ is actual motor efficiency if used in combination with a VFD
 η_r is nominal full load efficiency per Section 6.4.2.4.1.1
 g, h, i are constant values per Section 6.4.2.4.1.2
 L_m is motor load ratio calculated per Section 6.4.2.4.1.3

6.4.2.4.1.1 Nominal full-load efficiency table lookup

For polyphase regulated motors, nominal full-load efficiency is obtained from Annex A. It is based on the motor enclosure (open or enclosed), the number of poles and the motor nameplate output power (H_{mo}).

If the motor nameplate output power value is not shown in the table, the following instructions shall be used:

- (1) A horsepower at or above the midpoint between the two consecutive horsepower shall be rounded up to the higher of the two horsepower.
- (2) A horsepower below the midpoint between the two consecutive horsepower shall be rounded down to the lower of the two horsepower.
- (3) A shaft power rating in kilowatt shall be directly converted from kilowatts to horsepower using the formula 1 kilowatt = (1/0.746) horsepower. The conversion should be calculated to three significant decimal places, and the resulting horsepower shall be rounded in accordance with paragraph (1) or (2) of this section, whichever applies.

6.4.2.4.1.2 Motor constants if combined with VFD

The values for g and h are found in Annex B. Table B.1 shall be used for motors rated in horsepower. Table B.2 shall be used for motors rated in kilowatts.

$$i = 1 - \frac{g}{h + 1}$$

Where:

g, h, i are constants used in Section 6.4.2.4.1

6.4.2.4.1.3 Motor load ratio

The ratio of the load on the motor to the motor nameplate output power is calculated using the following equation:

$$L_m = \frac{H_{m,act}}{H_{mo}}$$

Where:

L_m is motor load ratio
 $H_{m,act}$ is motor output power (kW or hp)
 H_{mo} is motor nameplate output power (kW or hp)

6.4.2.4.2 VFD efficiency at the required motor electrical power input

The method for calculating VFD efficiency for a given power output. A single VFD may operate one or many motors.

$$\eta_{VFD} = \frac{dL_c}{e + L_c} + fL_c$$

Where:

η_{VFD} is VFD efficiency at the required motor electrical power input
 d, e, f are constants determined per Section 6.4.2.4.2.1
 L_c is VFD load ratio determined per Section 6.4.2.4.2.2