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Fans — Efficiency classification for fans —

Part 6:
Calculation of the fan energy index

Ventilateurs — Classification du rendement des ventilateurs —
Partie 6: Calcul de l'indice énergétique des ventilateurs

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 117, *Fans*.

A list of all parts in the ISO 12759 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The fan industry is of a global nature, with a considerable degree of exporting and licensing. To ensure that the defining fan performance characteristics are common throughout the world, a series of standards have been developed. It is the belief of the industry that there is now a need for minimum efficiency standards to be recognized.

To encourage their implementation, a classification system is proposed which incorporates a series of efficiency bands. With improvements in technology and manufacturing processes, the minimum efficiency levels can be reviewed and increased in time.

This document differs from others in this series in that the fan is not evaluated at its peak efficiency value. Rather, the fan is evaluated at every duty point within its stated performance range. In doing so, this document addresses both the design and selection of fans for reduced power consumption.

The fan energy index provides a consistent basis to compare fan energy performance across fan types and sizes at a given fan duty point. This document can be used by fan specifiers to communicate fan efficiency design intent and by those selecting fans to compare the energy use of various fan options. With improvements in technology and manufacturing processes, the minimum allowable fan energy index can be reviewed and increased in time.

Fans — Efficiency classification for fans —

Part 6: Calculation of the fan energy index

1 Scope

This document defines the calculation method for determining the fan energy index (FEI), which is an energy efficiency metric for fan duty points. This metric provides a standardized and consistent basis to compare fan energy performance across fan types and sizes at a given fan duty point.

This document is applicable to fans driven by electric motors and fans without drives. It is not applicable to circulating fans or air curtains.

The fan energy index can only be calculated for fan duty points above a minimum air power of 125 W (where air power is the product of volume flow rate and fan static pressure) or above a minimum volume flow rate of 2,0 m^3/s.

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.

ISO 5801:2017, *Fans — Performance testing using standardized airways*

ISO 12759-1, *Fans — Efficiency classification for fans — General information for fans*

ISO 12759-2:2019, *Fans — Efficiency classification for fans — Part 2: Standard losses for drive components*

ISO 13348, *Industrial fans — Tolerances, methods of conversion and technical data presentation*

ISO 13349-1, *Fans — Vocabulary and definitions of categories — Part 1: Vocabulary*

ISO 13350, *Fans — Performance testing of jet fans*

IEC 60034-30-1:2014, *Rotating electrical machines—Part 30-1: Efficiency classes of line operated AC motors (IE code)*

IEC 60034-2-1, *Rotating electrical machines—Part 2-1: Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles)*

IEC 60034-2-3, *Rotating electrical machines—Part 2-3: Specific test methods for determining losses and efficiency of converter-fed AC motors*

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

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

3 Terms, definitions and symbols

For the purposes of this document, the terms and definitions given in ISO 13349-1 and ISO 12759-1 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1 Terms and definitions

3.1.1 General terms

3.1.1.1
fan
rotary-bladed machine that receives mechanical energy and utilizes it by means of one or more *impellers* (3.1.1.2) fitted with blades to maintain a continuous flow of air or other gas passing through it and whose work per unit mass does not normally exceed 25 kJ/kg

Note 1 to entry: See ISO 13349-1:2022, 3.1.1 for a more complete definition.

3.1.1.2
impeller
rotating part of the *fan* (3.1.1.1) that imparts energy to the air stream

[SOURCE: ISO 13349-1:2022, 3.7.3, modified – changing gas flow to air stream]

3.1.1.3
housing
stationary part of the *fan* (3.1.1.1) that interacts with the air stream passing through the *impeller* (3.1.1.2)

Note 1 to entry: A housing can be an element around the *impeller* (3.1.1.2) which guides the air stream towards, through and from the impeller.

Note 2 to entry: A housing can have additional parts included within or attached to it that affect the performance of the *fan* (3.1.1.1), such as an inlet bell (also known as venturi), inlet cone, inlet radius, inlet ring, inlet guide vane, outlet guide vane or outlet diffuser.

3.1.1.4
fan without drives
non-driven fan
bare shaft fan
fan (3.1.1.1) without motor, *transmission* (3.1.1.8), or *motor controller* (3.1.1.14)

Note 1 to entry: In this definition, the term drive refers to motors, transmissions, and motor controllers.

3.1.1.5
driven fan
fan (3.1.1.1) driven by an electrical motor, with or without a *transmission* (3.1.1.8) or *motor controller* (3.1.1.14)

Note 1 to entry: In this document, the term motor always refers to an electric motor.

[SOURCE: ISO 13349-1:2022, 3.1.3, modified – Note 1 included in the body of the term]

3.1.1.6
direct driven fan
driven fan (3.1.1.5) configuration in which the *impeller* (3.1.1.2) is connected directly to the motor

3.1.1.7
belt driven fan
driven fan (3.1.1.5) configuration in which the *impeller* (3.1.1.2) is connected to the motor through a set of belts and pulleys mounted on the motor shaft and fan shaft

Note 1 to entry: This includes fans with *V-belt transmissions* (3.1.1.10) or *synchronous belt transmissions* (3.1.1.11).

3.1.1.8
transmission
component that transfers energy from a motor to an impeller

EXAMPLE Pulleys, belts, gears, couplings.

3.1.1.9
V-belt transmission
form of *transmission* (3.1.1.8) utilizing drive belts having a substantially trapezoidal cross-section that use pulleys having smooth contact surfaces

Note 1 to entry: 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.

3.1.1.10
synchronous belt transmission
form of *transmission* (3.1.1.8) utilizing drive belts having a substantially rectangular cross-section containing teeth that engage corresponding teeth on the pulleys, resulting in no-slip power transmission

Note 1 to entry: These belts are sometimes called timing or toothed belts.

3.1.1.11
standalone fan
fan (3.1.1.1) in at least a minimum testable configuration

Note 1 to entry: 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. See 4.1.

Note 2 to entry: Standalone fans do not include provisions for air conditioning, air filtration, air mixing, air treatment or heating.

EXAMPLE Power roof ventilators, side-wall exhaust fans, inline fans, jet fans and induced-flow laboratory exhaust fans.

[SOURCE: ISO 13349-1:2022, 3.1.4, modified — addition of an example and of more detail to the notes]

3.1.1.12
embedded fan
integrated fan
fan (3.1.1.1) that is set or fixed firmly inside or attached to a surrounding piece of equipment whose purpose exceeds that of a *fan* (3.1.1.1) or is different than that of a *standalone fan* (3.1.1.11)

Note 1 to entry: The surrounding equipment can have safety or energy efficiency requirements of its own.

Note 2 to entry: Embedded fans are also known as integrated fans.

EXAMPLE 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.

3.1.1.13
motor controller
device that is used to control the speed of the motor and subsequently the *fan* (3.1.1.1)

3.1.1.14
regulated motor
motor whose efficiency or power usage is subject to regional or national regulation

EXAMPLES Europe: Commission Regulation (EU) 2019/1781

China: GB 18613

United States: Code of Federal Regulations 10CFR Part 431

3.1.1.15
default motor efficiency
default efficiency assigned to the motor at a given motor output power when either the specific motor is not identified or the efficiency of the motor used is unknown

Note 1 to entry: The use of a default efficiency is designed to represent typically available motors. Since motor efficiency regulations are controlled regionally, the default motor efficiency shall reflect these regulations. See 5.3.5 for examples.

3.1.1.16
duty point
single volume flow rate (q_V) and pressure (p_f or p_{fs}) point within the published operating range of the *fan* (3.1.1.1)

3.1.1.17
reference electrical power
reference power used to relate the performance of all fans to a common baseline

Note 1 to entry: The reference electrical power defines a single value of fan electrical input power for a given volume flow rate and fan pressure.

3.1.2 Impeller types

NOTE See ISO 13349-1 for a more complete description of the variations between impeller types. The definitions below include only the differentiation needed for this standard.

3.1.2.1
axial impeller
propeller
impeller (3.1.1.2) 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* (3.1.2.5) ≤ 20°)

Note 1 to entry: Blades can either be single thickness or aerofoil shaped.

3.1.2.2
centrifugal impeller
impeller (3.1.1.2) 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, either into open space or into a housing, with a *fan flow angle* (3.1.2.5) ≥ 70°

Note 1 to entry: *Impellers* (3.1.1.2) can be classified as single inlet or double inlet.

Note 2 to entry: Blades can be tilted backward or forward with respect to the direction of impeller rotation. Impellers with backward tilted blades can be aerofoil 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
form of *centrifugal impeller* (3.1.2.2) 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°to the axis of rotation

Note 1 to entry: Radial impellers can optionally have a back plate and/or shroud.

3.1.2.4
mixed flow impeller
impeller (3.1.1.2) with construction characteristics between those of an *axial impeller* (3.1.2.1) and *centrifugal impeller* (3.1.2.2) with a *fan flow angle* (3.1.2.5) between 20° and 70°

Note 1 to entry: Airflow enters axially through a single inlet and exits with combined axial and radial directions at a mean diameter greater than the inlet.

Note 2 to entry: Mixed flow impellers are sometimes known as diagonal impellers.

Note 3 to entry: Mixed flow impellers are abbreviated as MF in Table A.1.

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

3.1.3 Fan types

NOTE See ISO 13349-1 for a more complete description of the variations between fan types. The definitions below include only those fan types that are tested differently, function differently, or have a unique advantage, other than efficiency, over other fan types (e.g., sound levels, compact size) such that they can be expected to operate at a different FEI range than other fan types. Additional information on typical duct connections is also provided.

3.1.3.1
centrifugal housed fan
radial-flow fan
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

Note 1 to entry: Inlets and outlets can optionally be ducted.

3.1.3.2
centrifugal inline fan
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

Note 1 to entry: Inlets and outlets can optionally be ducted.

3.1.3.3
centrifugal unhoused fan
plenum fan
fan with a centrifugal impeller in which airflow enters through a panel and discharges into free space

Note 1 to entry: Outlets are not ducted.

Note 2 to entry: 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 ventilator
PRV
fan with an internal motor and a housing to prevent precipitation from entering the building

Note 1 to entry: 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
PRV with a centrifugal impeller that exhausts air from a building

Note 1 to entry: Inlets are typically ducted, but outlets are not ducted.

3.1.3.6
centrifugal PRV supply
PRV with a centrifugal impeller that supplies air to a building

Note 1 to entry: Inlets are not ducted, and outlets are typically ducted.

3.1.3.7
axial PRV
PRV with an axial impeller that either supplies or exhausts air to a building

Note 1 to entry: Inlets and outlets are typically not ducted.

3.1.3.8
axial inline fan
fan with an axial impeller and a cylindrical housing with or without turning vanes

Note 1 to entry: Inlets and outlets can optionally be ducted.

3.1.3.9
axial panel fan
fan with an axial impeller mounted in a short housing consisting of a panel, ring or orifice plate

Note 1 to entry: 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.

Note 2 to entry: These fans are sometimes known as propeller fans or plate-mounted axial fans.

3.1.3.10
laboratory exhaust fan
fan designed specifically for exhausting contaminated air vertically away from a building, with fan outlets typically constricted to achieve a high outlet velocity

Note 1 to entry: Laboratory exhaust fans can be designed with or without induced flow. Induced flow lab exhaust fans use their high velocity discharge to entrain additional air to mix with contaminated building exhaust air.

Note 2 to entry: Inlets can optionally be ducted, and outlets are not ducted.

3.1.3.11
jet fan
fan used for producing a high velocity flow of air in a space

Note 1 to entry: Typical function is to add momentum to the air within a tunnel. Inlets and outlets are not ducted.

3.1.3.12
circulating fan
fan used for the general circulation of air within a space that has no provision for connection to ducting or separation of the fan inlet from its outlet

3.1.3.13
crossflow fan
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

Note 1 to entry: Inlets and outlets can optionally be ducted.

3.1.3.14
fan array
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	Represented quantity	Unit
A_2	Fan outlet or discharge area	m^2
A, B, C, D, E	Constants	dimensionless
I	Fan energy index (FEI)	dimensionless
$P_{ed,ref}$	Reference electrical input power	kW
$P_{ed,act}$	Actual fan electrical input power	kW
$P_{a,ref}$	Reference fan shaft power	kW
$P_{a,act}$	Actual fan shaft power	kW
$P_{o,ref}$	Reference motor output power	kW
$P_{o,act}$	Actual motor output power	kW
$P_{o,def}$	Default motor output power	kW
p_0	Pressure constant	Pa
p_{fs}	Fan static pressure at duty point	Pa
p_f	Fan total pressure at duty point	Pa
q_V	Fan volume flow rate at duty point	m^3/s
q_0	Volume flow rate constant	m^3/s
T_m	Force due to fan thrust	N
η_0	Fan efficiency constant	dimensionless
$\eta_{T,ref}$	Reference transmission efficiency	dimensionless
$\eta_{T,act}$	Actual transmission efficiency	dimensionless
$\eta_{mot,ref}$	Reference motor efficiency	dimensionless
$\eta_{mot,act}$	Actual motor efficiency	dimensionless
$\eta_{mc,act}$	Actual motor and controller efficiency	dimensionless
$\eta_{c,ref}$	Reference motor controller efficiency	dimensionless
$\eta_{mot,def}$	Default motor efficiency	dimensionless
P	Fan air density	kg/m^3
ρ_{ref}	Standard air density	kg/m^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 document is also based on tests of fans in at least a minimum testable configuration, including the following:

— impeller;

— motor or separate shaft with bearings to support the impeller;

— structure, housing or stator, unless the fan does not require these (e.g. an unshrouded circulating fan).

Each rated fan model shall be rated according to the applicable fan type listed in Table A.1, in accordance with how that fan is distributed in commerce. For example, if a fan meets the definition of a jet fan, it shall be tested and rated as a jet fan according to Table A.1.

4.2 FEI pressure basis

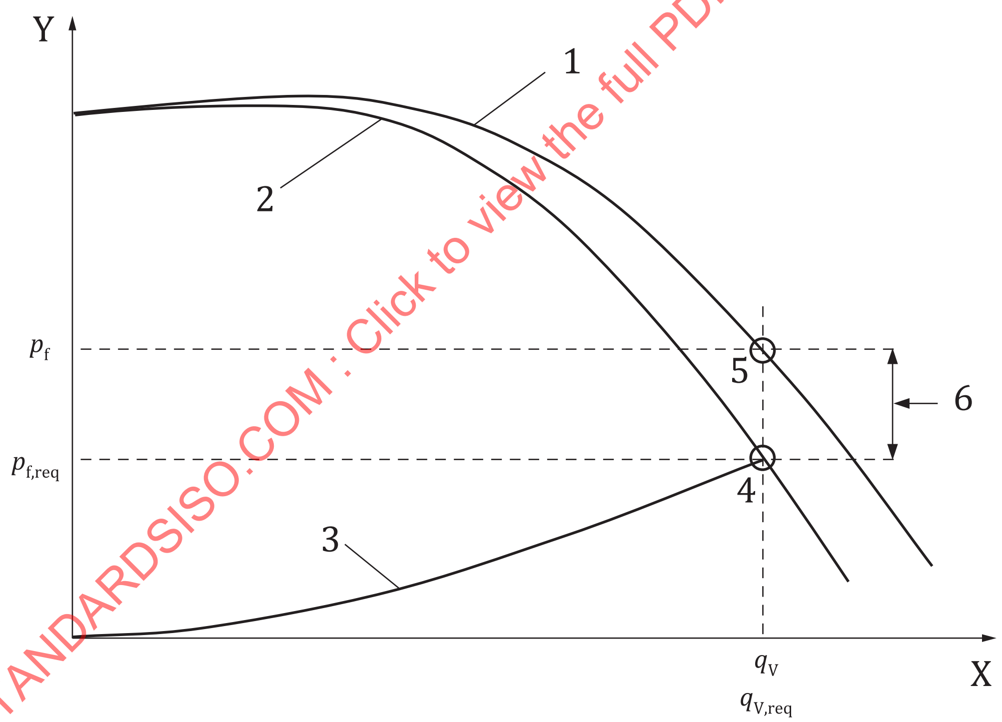
The FEI shall be calculated using the fan total pressure or the fan static pressure, based on the fan type. See Annex A for a complete explanation of the pressure basis and to learn which pressure to use.

4.3 Appurtenances

Certain accessories or appurtenances can be used to improve fan performance, including but not limited to inlet bells, diffusers, stators and guide vanes. If an appurtenance improves the performance of the fan and is always supplied with the fan when distributed in commerce, it shall be tested with the fan. Test ducts included during testing are not required to be supplied with the fan.

Appurtenances that reduce the performance of a fan are not included in their minimum testable configuration used to determine FEI. These include but are not limited to guards, dampers, filters and weather hoods. The effect of these appurtenances on fan performance can be tested and published to aid in fan selection, but the appurtenances are not included in the fan test used to determine FEI.

As illustrated in Figure 1, the reduced performance of a fan with appurtenances (Figure 1, key reference [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 or blade pitch needed to achieve the required system pressure ($p_{f,req}$) at the required volume flow rate ($q_{V,req}$) (Figure 1, key reference [4]). Once the required fan speed or blade pitch are determined, the FEI is determined from the standalone fan performance (Figure 1, key reference [1]) at the same volume flow rate, fan speed and blade pitch (Figure 1, key reference [5]), combined with the fan electrical power at this standalone fan duty point.



Key

X volume flow rate, expressed in m^3/s

Y total or static pressure, expressed in Pa

1 pressure curve of fan alone

2 pressure curve of fan with appurtenances

3 system resistance curve external to fan and appurtenances

4 fan duty point with appurtenances

5 fan alone duty point used for FEI calculation

6 pressure reduction due to fan appurtenances

q_v volume flow rate of fan alone

p_f pressure capacity of fan alone

$q_{V,req}$ required volume flow rate of fan

$p_{f,req}$ pressure required to overcome system resistance

Figure 1 — Fan performance curves at constant fan speed and blade pitch with and without appurtenances

4.4 Fans embedded in other equipment

This document does not apply to fan performance when the fan is tested embedded inside of other equipment. However, this document may be used to calculate FEI for a fan that, while tested in a standalone configuration, will be embedded into other equipment. The FEI for the embedded fan is assigned to be equal to the standalone fan performance at the same volume flow rate, fan speed and blade pitch.

Under no circumstances shall a test of an embedded fan inside the equipment be used to predict the FEI of the standalone fan. See Annex D for additional information on issues related to embedded fan performance.

5 Fan energy index

5.1 General

The fan energy index (FEI) is defined as a ratio of the reference electrical input power to the electrical input power of the actual fan for which the FEI is calculated, both calculated at the same duty point, which is characterized by a value of fan volume flow rate (q_V) and pressure (p_f or p_{fs}). FEI values (I) can be calculated for each point on a fan curve according to Formula (1).

$$I = \frac{P_{ed,ref}}{P_{ed,act}} \tag{1}$$

where

$P_{ed,ref}$ is the reference electrical input power in kW;

$P_{ed,act}$ is the actual fan electrical input power in kW.

Use the total pressure or the static pressure consistently throughout Clause 5, and it is important to state how the FEI has been determined, whether using total or static pressure (see 5.2.2.1 and Annex B).

5.2 Reference electrical input power

5.2.1 General

The reference 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 electrical input power is ultimately a function of only fan volume flow rate and fan pressure, but requires an iterative calculation beginning with Formula (2). Details of the basis for the reference electrical input power, including the constants q_0, p_0, and η_0, are contained in Annex F.

$$P_{ed,ref} = P_{a,ref} \times \left(\frac{1}{\eta_{T,ref}}\right) \times \left(\frac{1}{\eta_{mot,ref}}\right) \times \left(\frac{1}{\eta_{c,ref}}\right) \tag{2}$$

where

$P_{a,ref}$ is the reference fan shaft power in kW;

$\eta_{T,ref}$ is the reference transmission efficiency;

$\eta_{mot,ref}$ is the reference motor efficiency;

$\eta_{c,ref}$ is the reference motor controller efficiency.

5.2.2 Reference shaft power

5.2.2.1 General

The fan performance at the duty point shall be obtained by testing in accordance with the standards listed in Table A.1 or calculated in accordance with the fan laws and conversion rules specified in ISO 13348. If needed, the interpolation methods in Annex E may also be used.

The reference shaft power, $P_{a,ref}$, shall be 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.

Throughout Clause 5, it is required to use total or static pressure consistently. Both $P_{a,ref}$ (5.2) and $P_{a,act}$ (5.3) are a function of fan pressure and shall use the same pressure basis. For example, if the required pressure basis from Annex A is fan total pressure, the powers $P_{a,ref}$ and $P_{a,act}$ are calculated at the same fan total pressure, even if the fan performance is ultimately published in terms of fan static pressure.

5.2.2.2 Total pressure basis

For fan types identified in Annex A as using a total pressure basis, the reference shaft power ($P_{a,ref}$) at a given duty point is a function of fan volume flow rate (q_V) and fan total pressure (p_f) at that duty point, calculated according to Formula (3):

$$P_{a,ref} = \frac{(q_V + q_0) \times \left(p_f + p_0 \times \frac{\rho}{\rho_{ref}} \right)}{1\,000 \times \eta_0} \tag{3}$$

where

q_V is fan volume flow rate in m^3/s;

p_f is fan total pressure in Pa;

ρ is air density in kg/m^3;

ρ_{ref} is standard air density, 1,2 kg/m^3;

q_0 = 0,118 m^3/s;

p_0 = 100 Pa;

η_0 = 66 %.

5.2.2.3 Static pressure basis

For fan types identified in Annex A as using a static pressure basis, the reference shaft power ($P_{a,ref}$) at a given duty point is a function of fan volume flow rate (q_V) and fan static pressure (p_{fs}) at that duty point, calculated according to Formula (4):

$$P_{a,ref} = \frac{(q_V + q_0) \times \left(p_{fs} + p_0 \times \frac{\rho}{\rho_{ref}} \right)}{1\,000 \times \eta_0} \tag{4}$$

where

q_V is fan volume flow rate in m^3/s;

p_{fs} is fan static pressure in Pa;

ρ is air density in kg/m^3;

ρ_{ref} is standard air density, 1,2 kg/m^3;

q_0 = 0,118 m^3/s;

p_0 = 100 Pa;

η_0 = 60 %.

5.2.3 Reference transmission efficiency

The reference transmission efficiency ($\eta_{T,ref}$) shall be calculated using Formula (5):

$$\eta_{T,ref} = 0{,}96 \times \left(\frac{P_{a,ref}}{P_{a,ref} + 1{,}64} \right)^{0{,}05} \tag{5}$$

where $P_{a,ref}$ is reference shaft power in kW.

NOTE This formula is from ISO 12759-2:2019, 4.2.2.

5.2.4 Reference motor efficiency

The reference motor output power ($P_{o,ref}$) shall be calculated using Formula (6):

$$P_{o,ref} = \frac{P_{a,ref}}{\eta_{T,ref}} \tag{6}$$

where

$P_{a,ref}$ is reference shaft power in kW;

$\eta_{T,ref}$ is reference transmission efficiency.

The reference motor efficiency shall be calculated according to Formula (7) using the coefficients A–E found in Table 1.

$$\eta_{mot,ref} = \frac{A \times \left[\lg\left(P_{o,ref}\right)\right]^4 + B \times \left[\lg\left(P_{o,ref}\right)\right]^3 + C \times \left[\lg\left(P_{o,ref}\right)\right]^2 + D \times \left[\lg\left(P_{o,ref}\right)\right]^1 + E}{100} \tag{7}$$

where

$P_{o,ref}$ is reference motor output power in kW;

A, B, C, D, E are coefficients found in Table 1.

Table 1 — Reference motor efficiency coefficients

	$P_{o,ref}$ < 185 kW	$P_{o,ref}$ ≥ 185 kW
A	−0,381 2	0
B	2,583 4	0
C	−7,257 7	0
D	12,555 9	0
E	85,027 4	96,2

5.2.5 Reference motor controller efficiency

The reference motor controller efficiency ($\eta_{c,ref}$) is as assigned a value of 100 % since there is no motor controller in the reference model.

5.3 Actual fan electrical input power

5.3.1 General

$P_{ed,act}$ is the fan electrical input power associated with a given fan duty point in terms of volume flow rate and pressure.

Actual fan electrical input power shall be determined by one of the methods found in 5.3.2 to 5.3.5. The methods to determine fan electrical input power are defined as a function of the fan configuration being rated and are summarized in Table 2.

Table 2 — Methods to determine fan electrical input power

Fan configuration	Motor type	Subclause	$P_{ed,act}$ determination	Example applications
Fan for which the motor is not yet selected	N/A	5.3.5	Default motor efficiency calculation	— Fans sold without motors — Catalogues used for fan selection prior to motor selection
Fan with motor	Any	5.3.2	Electrical power measurement, calculations according to Annex E	— Electrical power 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 ISO 12759-2:2019, Annex B, C, and D	5.3.3	ISO 12759-2 calculation	— Three-phase regulated motors ≥ 0,75 kW — Three-phase non-regulated motors ≥ 0,75 kW (e.g. AO, XP, two-speed)
	Motor for which 5.3.3 does not apply and the performance can be measured in accordance with a known test standard	5.3.4	Motor test according to recognized standard	— Single-phase regulated motors — Single-phase non-regulated motors — Three-phase motors below 0,75 kW
Fan with motor and motor controller	Any	5.3.2	Electrical power measurement, calculations according to Annex E	— Electrical power measurement and density and/or speed corrections of fans rated with a motor and controller — Motors with controllers for which no test standards apply
	Motor and controller for which 5.3.3 does not apply and the performance can be measured in accordance with a known test standard	5.3.4	Motor and controller test according to recognized standard	— Electronically commutated (EC), permanent magnet (PM) motors with integral or separate motor controllers
	Polyphase induction motors, both regulated and non-regulated, with nameplate power and poles that fall within the range covered in ISO 12759-2:2019, Annex B, C, and D.	5.3.3	ISO 12759-2 calculation	— Three-phase regulated motors ≥ 0,75 kW — Three-phase non-regulated motors ≥ 0,75 kW (e.g. AO, XP, two-speed)

5.3.2 Measurement of fan electrical input power

This subclause covers direct measurement of fan electrical input power in accordance with ISO 5801, ISO 13350, ANSI/AMCA Standard 230 or ANSI/AMCA Standard 260. Interpolation of fan electrical input power from these measurements may also be done in accordance with Annex E. This method may be used for all fans except fans without drives. It covers direct measurement of fan electrical input power at the tested duty points and conversion of measured values to other duty points.

The fan electrical input power ($P_{ed,act}$) is the motor input power (P_e) for fans without motor controllers and is the motor controller input power (P_{ed}) for fans with motor controllers included.

5.3.3 Fan electrical input power calculation using ISO 12759-2

This subclause covers measurement of fan shaft input power in accordance with ISO 5801, ISO 13350 or ANSI/AMCA Standard 260, or rating of fan shaft input power in accordance with ISO 13348, combined with power drive component efficiency calculations of ISO 12759-2. This method is applicable to (i) fans with motors that fall directly within the scope of ISO 12759-2 or (ii) other three-phase induction motors with nameplate power and number of poles that otherwise fall within the scope of ISO 12759-2, either with or without motor controllers. Fan electrical input power is calculated based on the tested fan performance, the known full load motor efficiency, and calculated part load losses.

For fans with motors that fall within the scope of ISO 12759-2, fan electrical input power ($P_{ed,act}$) shall be calculated according to ISO 12759-2, except that the nominal regulated motor efficiency (η_{mreg}) in ISO 12759-2:2019, 4.2.3 shall be either the nominal efficiency as listed in ISO 12759-2:2019,Annex B, C, or D, or the certified full-load efficiency of the motor as required to meet relevant regional regulations.

For fans with three-phase induction motors outside the scope of ISO 12759-2 but with nameplate power and number of poles that otherwise fall within the scope of ISO 12759-2, fan electrical input power shall be calculated according to ISO 12759-2, with the following exceptions:

a) If the motor nameplate power is listed in the tables in ISO 12759-2:2019, Annex B, C, or D, then the nominal regulated motor efficiency (η_{mreg}) in ISO 12759-2:2019, 4.2.3 shall be the minimum of that shown on the motor nameplate and that of ISO 12759-2:2019, Annex B, C, or D. The motor nameplate power and efficiency shall be the full-load motor output power and efficiency determined based on testing in accordance with IEC 60034-2-1 or NEMA MG-1 (Section IV, Part 34, for air over motors), as applicable.

b) If the motor nameplate power falls between those listed ISO 12759-2:2019, Annex B, C, or D, then the nominal regulated motor efficiency (η_{mreg}) in ISO 12759-2:2019, 4.2.3 shall be the minimum of that shown on the motor nameplate and that of the next smallest motor listed in ISO 12759-2:2019, Annex B, C, or D. The load ratios and part load efficiency constants used in the ISO 12759-2 calculations shall be based on that of the next smallest motor size in the tables of ISO 12759-2:2019, Annexes B to H. The motor nameplate power and efficiency shall be the full-load motor output power and efficiency determined based on testing in accordance with IEC 60034-2-1 or NEMA MG-1 (Section IV, Part 34 for air over motors), as applicable.

The fan electrical input power ($P_{ed,act}$) is the motor input power (P_e) for fans without motor controllers and is the motor controller input power (P_{ed}) for fans with motor controllers included.

5.3.4 Combined fan shaft power with tested motor or motor and controller

This subclause covers measurement of fan shaft input power in accordance with ISO 5801, ISO 13350, or ANSI/AMCA Standard 260, or rating of fan shaft input power in accordance with ISO 13348, combined with full or part load efficiency of the motor established through testing. For motors without controllers, testing shall be done in accordance with IEC 60034-2-1. For air over motors, testing shall be done in accordance with NEMA MG-1 (Section IV, Part 34 for air over motors). For motors with controllers, testing shall be done in accordance with the input-output measurement method for power drive systems of IEC 61800-9-2:2017, 7.7.2. Any tested motor efficiency values shall be obtained 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. The tested motor or motor and controller part load efficiency values corresponding with the fan duty point shall be applied to fan shaft input power to calculate fan electrical input power ($P_{ed,act}$) according to Formulae (8) to (12).

For motors without controllers:

$$P_{ed,act} = P_{a,act} \times \left(\frac{1}{\eta_{T,act}}\right) \times \left(\frac{1}{\eta_{mot,act}}\right) \tag{8}$$

where

$P_{a,act}$ is actual fan shaft power in kW;

$\eta_{T,act}$ is actual transmission efficiency;

$\eta_{mot,act}$ is actual motor efficiency.

For motors with controllers:

$$P_{ed,act} = P_{a,act} \times \left(\frac{1}{\eta_{T,act}}\right) \times \left(\frac{1}{\eta_{mc,act}}\right) \tag{9}$$

where

$P_{a,act}$ is actual fan shaft power in kW;

$\eta_{T,act}$ is actual transmission efficiency;

$\eta_{mc,act}$ is actual motor and controller efficiency.

For direct driven fans:

$$\eta_{T,act} = 1 \tag{10}$$

For V-belt driven fans:

$$\eta_{T,act} = 0{,}96 \times \left(\frac{P_{a,act}}{P_{a,act} + 1{,}64}\right)^{0{,}05} \tag{11}$$

where $P_{a,act}$ is actual fan shaft power in kW.

Actual motor output power:

$$P_{o,act} = \frac{P_{a,act}}{\eta_{T,act}} \tag{12}$$

where

$P_{a,act}$ is actual fan shaft power in kW;

$\eta_{T,act}$ is actual transmission efficiency.

For motors without controllers, $\eta_{mot,act}$ is the motor part load efficiency determined from test data interpolated to the actual load $P_{o,act}$ using a polynomial curve fit.

For motors with controllers, $\eta_{mc,act}$ is the combined motor and controller part load efficiency determined from test data interpolated to the actual speed and load using the interpolation method of IEC 60034-2-3.

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.

5.3.5 Fan electrical input power calculation for fans with motors of unknown efficiency

This subclause covers measurement of fan shaft input power in accordance with ISO 5801, ISO 13350 or ANSI/AMCA Standard 260, or rating of fan shaft input power in accordance with ISO 13348. It specifically refers to fans that are (i) provided with no motors, or (ii) provided with motors that have not yet been chosen (fan selection tables). This method uses default motor efficiency values and is applicable only when 5.3.3 or 5.3.4 do not apply. Motor controllers are not considered with this method. The default motor efficiency corresponding with the fan duty point shall be used to calculate fan electrical input power ($P_{ed,act}$) as follows.

$$P_{ed,act} = P_{a,act} \times \left(\frac{1}{\eta_{T,act}} \right) \times \left(\frac{1}{\eta_{mot,def}} \right) \quad (13)$$

where

$P_{a,act}$ is actual fan shaft power in kW;

$\eta_{T,act}$ is actual transmission efficiency;

$\eta_{mot,def}$ is default motor efficiency.

For fans only offered as direct driven:

$$\eta_{T,act} = 1 \quad (14)$$

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

$$\eta_{T,act} = 0,96 \times \left(\frac{P_{a,act}}{P_{a,act} + 1,64} \right)^{.05} \quad (15)$$

where $P_{a,act}$ is actual fan shaft power in kW

Required motor output power:

$$P_{o,def} = \frac{P_{a,act}}{\eta_{T,act}} \quad (16)$$

where

$P_{a,act}$ is actual fan shaft power in kW;

$\eta_{T,act}$ is actual transmission efficiency.

Since the motor size and speed are unknown at the time of this calculation, the default motor efficiency ($\eta_{mot,def}$) represents a consistent approximation of motor efficiency.

For 50 Hz regions, the default motor efficiency ($\eta_{mot,def}$) shall be calculated according to the formula in IEC 60034-30-1:2014, 5.4.5 using a rated power equal to $P_{o,def}$ and the coefficients in IEC 60034-30-1:2014, Tables 11 and 12 for 4-pole motors corresponding to the minimum motor efficiency requirements in that jurisdiction (IE1 through IE4). The resulting calculated efficiency shall be divided by 100 before being used in Formula (13).

For 60 Hz regions, the default motor efficiency ($\eta_{mot,def}$) shall be calculated according to Formula (17) with the coefficients *A*–*E* found in Table 3. These coefficients are derived from curve fits of IE3 nominal efficiency limits for 4-pole motors as listed in IEC 60034-30-1:2014, Table 8. These defaults shall only be used in regions or jurisdictions where IE3 levels (or equivalent) are the minimum motor efficiency requirements in that jurisdiction. Jurisdictions with motor efficiency requirements lower or higher than IE3 levels (or equivalent) shall not use these default coefficients, but shall establish their own default values.

$$\eta_{\text{mot,def}} = \frac{A\times\left[\lg\left(P_{\text{o,def}}\right)\right]^4 + B\times\left[\lg\left(P_{\text{o,def}}\right)\right]^3 + C\times\left[\lg\left(P_{\text{o,def}}\right)\right]^2 + D\times\left[\lg\left(P_{\text{o,def}}\right)\right]^1 + E}{100} \quad (17)$$

where

$P_{\text{o,def}}$ is default motor output power in kW;

A, B, C, D, E are coefficients found in Table 3.

Table 3 — Default motor efficiency coefficients for 60 Hz, IE3

	$P_{\text{o,def}}$ < 185 kW	$P_{\text{o,def}}$ ≥ 185 kW
A	−0,381 2	0
B	2,583 4	0
C	−7,257 7	0
D	12,555 9	0
E	85,027 4	96,2

6 Use of FEI

6.1 Requirements for use of FEI

This subclause includes the requirements for fan manufacturers using FEI. Additional information, including examples of published FEI and use by consumers and code and regulatory bodies, is provided in Annex B. Published FEI values shall be accompanied by a statement of the pressure basis (total or static) used for calculation.

6.2 Published FEI values

Published FEI values shall be rounded to the nearest hundredth and presented alongside other fan performance parameters (e.g. volume flow rate, pressure, power) in fan selection tables and graphs. When FEI values are published in a catalogue 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 catalogue 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 5.3.5 and shall be clearly identified as such.

Annex A
(normative)

Fan types, test configurations and FEI pressure basis

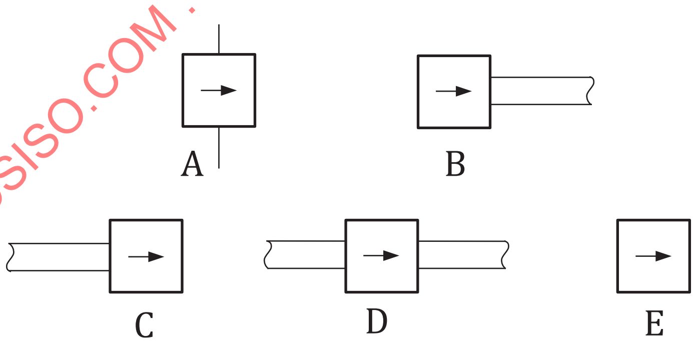
A.1 Use of test configurations

The fan test configuration has 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 (Figure A.1). These configurations are consistent with the test requirements of ISO 5801, ISO 13350, ANSI/AMCA Standard 230 and ANSI/AMCA Standard 260, 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 can 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 determines 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 dynamic 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 dynamic 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 15 m/s to 25 m/s 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 dynamic pressure at the fan outlet.



Key

A test configuration A – free inlet, free outlet with partition

B test configuration B – free inlet, ducted outlet

C test configuration C – ducted inlet, free outlet

D test configuration D – ducted inlet, ducted outlet

E test configuration E – free inlet, free outlet without partition

Figure A.1 — Test configurations and ducting

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.

Table A.1 — Fan types, test configurations and FEI pressure basis

Fan type	Impeller type	Housing examples	Test standard	Test configuration	FEI pressure basis
Centrifugal housed [a]	AF, BC, BI, MF, FC, radial, radial tipped	Single or double inlet scroll (not inline)	ISO 5801	B or D	Total
				A or C	Static
Centrifugal inline [a]	AF, BC, BI, MF, FC	Square, rectangular, cylindrical	ISO 5801	B or D	Total
				A or C	Static
Centrifugal unhoused [b]	AF, BC, BI, MF	None	ISO 5801	A	Static
Centrifugal PRV exhaust [c]	AF, BC, BI, MF, FC	Spun aluminium, upblast, hooded, wall housing	ISO 5801	A or C	Static
Centrifugal PRV supply [a c]	AF, BC, BI, MF, FC	Hooded or otherwise enclosed	ISO 5801	B	Total
				A	Static
Axial inline [a]	Axial	Cylindrical (tube axial or vane axial)	ISO 5801	D	Total
				C	Static
Axial panel	Axial	Panel, ring	ISO 5801	A	Static
Axial PRV	Axial	Supply and exhaust, spun aluminium, upblast, hooded, wall housing	ISO 5801	A or C	Static
Laboratory exhaust [d e]	Any	High velocity discharge	ISO 5801	A or C	Total
	Any	Induced flow	AMCA 260	A or C	Total
Jet fan [d f]	Axial or AF, BC, BI	Unidirectional, reversible	ISO 13350	E	Total
Circulating [d g]	Axial	Cylindrical, panel, unhoused	AMCA 230	E	Total
Crossflow	Crossflow		ISO 5801	A or C	Static
				B, D or E	Total

[a] 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 may be tested using test configuration A or C with fan static pressure used for the FEI calculation.

[b] The centrifugal unhoused fan type also includes fans with integral housings used to separate multiple fans in a fan array. Centrifugal unhoused fans shall be tested using test configuration A with fan static pressure used for the FEI calculation. Fans used in fan arrays use a calculation procedure found in Annex C.

[c] 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) and shall be evaluated on a fan total pressure basis, or may be tested using test configuration A with fan static pressure used for the FEI calculation.

[d] 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.

[e] Induced flow laboratory exhaust fans shall use the fan total pressure based on the velocity pressure at the discharge nozzle as a basis for FEI calculation. The volume flow rate, q_V, used in this document is the inlet volume flow rate determined from the test in ANSI/AMCA Standard 260. The fan total pressure, p_f, used in this document is difference between the dynamic pressure at the nozzle outlet and the inlet total pressure as described in ANSI/AMCA Standard 260.

[f] Jet fans shall be tested using test standard ISO 13350. Jet fans shall use fan total pressure based on the dynamic pressure at the fan outlet for FEI calculation (see A.2).

[g] Circulating fans shall be tested using test standard ANSI/AMCA Standard 230. Circulating fans shall use fan total pressure based on the dynamic pressure at the fan outlet for FEI calculation (see A.2).

A.2 Fans tested using thrust

For fans with fan volume flow rate determined in accordance with ANSI/AMCA Standard 230, the fan total pressure at a given volume flow rate shall be calculated according to Formula (A.1).

$$p_f = \frac{\rho}{2} \times \left(\frac{q_V}{A_2} \right)^2 \quad \text{(A.1)}$$

where

A_2 is fan outlet or discharge area, m^2;

p_f is fan total pressure, Pa;

q_V is volume flow rate, m^3/s;

ρ is air density, kg/m^3.

For fans with thrust determined in accordance with ISO 13350, fan total pressure shall be calculated according to Formula (A.1) and volume flow rate shall be calculated according to Formula (A.2).

$$q_V = \sqrt{\frac{A_2 \times T_m}{\rho}} \quad \text{(A.2)}$$

where

A_2 is gross fan outlet or discharge area, m^2;

T_m is force due to thrust, N;

q_V is volume flow rate, m^3/s;

ρ is air density, kg/m^3.

Annex B
(informative)

Usage of FEI

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

B.2.1 General

Specific requirements for published FEI values are contained in 6.2. This subclause provides examples of published fan performance, showing how FEI is used to supplement other fan performance data to help the consumer in making good fan selections.

B.2.2 Fan performance table using default motor efficiencies

Figure B.1 is an example of a fan performance table as found in manufacturers' catalogues 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.

Volume flow rate q_V (m³/s)		Fan static pressure, p_{fs} (Pa)					
		0	**250**	**500**	**750**	**1000**	**1250**
4	*N* (rpm)	1 010	1 180	1 331	1 468		
	P_a (kW)	1,39	2,59	3,88	5,21		
	FEI	**1,67**	**1,54**	**1,46**	**1,40**		
5	*N* (rpm)	1 230	1 378	1 505	1 626	1 738	1 843
	P_a (kW)	2,02	3,41	4,88	6,47	8,09	9,71
	FEI	**1,42**	**1,45**	**1,43**	**1,40**	**1,38**	**1,36**
6	*N* (rpm)	1 467	1 590	1 709	1 814	1 912	2 009
	P_a (kW)	2,93	4,50	6,19	7,91	9,74	11,65
	FEI	**1,18**	**1,31**	**1,35**	**1,37**	**1,36**	**1,35**
7	*N* (rpm)	1 712	1 819	1 921	2 021	2 112	2 196
	P_a (kW)	4,10	5,92	7,78	9,75	11,75	13,79
	FEI	**0,98**	**1,16**	**1,25**	**1,29**	**1,31**	**1,33**
8	*N* (rpm)	1 961	2 058	2 146	2 233	2 320	2 402
	P_a (kW)	5,64	7,73	9,78	11,92	14,15	16,45
	FEI	**0,81**	**1,01**	**1,13**	**1,20**	**1,24**	**1,27**
9	*N* (rpm)	2 214	2 301	2 382	2 459	2 535	2 612
	P_a (kW)	7,60	9,90	12,25	14,57	16,97	19,45
	FEI	**0,67**	**0,89**	**1,02**	**1,11**	**1,17**	**1,21**

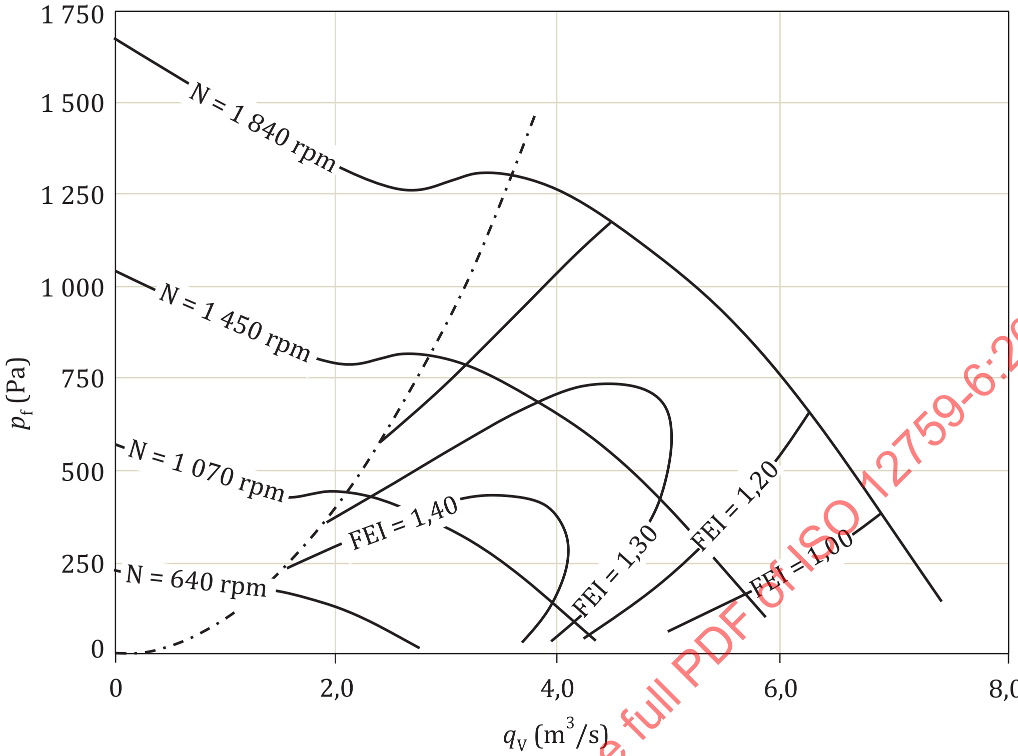
Performance shown is for installation type A: free inlet, free outlet. Power rating (Pa) does not include transmission losses. Performance ratings do not include the effects of appurtenances (accessories). FEI values are calculated in accordance with ISO 12759-6 and are based on default motor efficiency values using 60 Hz IE3 levels. FEI values for fans with specific motors can vary slightly from those shown.

Figure B.1 — Example fan performance table

B.2.3 Fan performance curves showing lines of constant FEI using default motor efficiencies

Figure B.2 is an example of fan performance curves as found in manufacturers' catalogues 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. In this case, the fan was tested at a number of rotational speeds to obtain a number of fan characteristics and fan laws were used, within the boundaries of the conversion rules specified in ISO 13348, to calculate performance at all other speeds. FEI values were calculated at intermediate speeds in order to determine lines of constant FEI.

It should be noted that the shapes of the FEI lines in Figure B.2 are typical for a fan with airflow rates and pressures as shown. The general shapes of these curves may change as airflow rates drop below q_0 and pressures drop below p_0.



Performance shown is for installation type B: free inlet, ducted outlet. Performance ratings do not include the effects of appurtenances (accessories). FEI values are calculated in accordance with ISO 12759-6 and are based on default motor efficiencies. FEI values for fans with specific motors will vary slightly from those shown.

Figure B.2 — Example fan performance curves

B.2.4 Electronic fan selection software showing specific motor selections

Figure B.3 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 fan volume flow rate (4,72 m^3/s) at the required fan total pressure (1 190 Pa). These are belt driven fan models with specific motor sizes selected, all of which are covered within the scope of ISO 12759-2. 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 (kW)	Motor size (kW)	Elect. input power (kW)	Outlet area (m^2)	Outlet velocity (m/s)	TE (%)	FEI
18	III	3 047	11,4	15	12,8	0,178	26,5	49 %	**0,83**
20	II	2 448	9,69	11	10,9	0,214	22,1	58 %	**0,98**
22	II	1 940	8,35	11	9,42	0,265	17,8	67 %	**1,13**
24	II	1 621	7,53	11	8,49	0,321	14,7	75 %	**1,25**
27	I	1 378	7,32	11	8,27	0,389	12,1	77 %	**1,28**
30	I	1 185	7,38	11	8,33	0,480	9,83	76 %	**1,27**
33	I	1 058	7,83	11	8,82	0,582	8,11	72 %	**1,20**

Performance shown is for test configuration B: free inlet, ducted outlet. Shaft power rating (kW) does not include transmission losses. Performance ratings do not include the effects of appurtenances (accessories). FEI values are calculated in accordance with ISO 12759-6 and are based on 4-pole IE3 motors of the size shown.

Figure B.3 — Example fan performance selection software

B.2.5 Fan performance table for a distributer catalogue sold without motors

Figure B.4 is an example of a fan performance table as found in a distributor's catalogue. 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.

Fan Speed, N (rpm)	Max shaft input power, $P_{a,max}$ (kW)		Fan static pressure, p_{fs} (Pa)				
			0	**31**	**63**	**94**	**125**
400	1,50	q_V:	13,2	11,5	6,61		
		FEI:	**1,44**	**1,65**	**1,50**		
450	2,13	q_V:	14,9	13,0	10,5	5,19	
		FEI:	**1,16**	**1,34**	**1,44**	**1,02**	
500	2,93	q_V:	16,5	15,1	12,7	7,93	6,14
		FEI:	**0,95**	**1,14**	**1,23**	**1,13**	**1,02**
550	3,90	q_V:	18,2	16,8	15,1	12,7	7,55
		FEI:	**0,79**	**0,96**	**1,08**	**1,15**	**0,94**

Performance shown is for test configuration A: free inlet, free outlet. Performance ratings do not include the effects of appurtenances (accessories). FEI values are calculated in accordance with ISO 12759-6 and are based on default motor efficiency values using 50 Hz IE3 levels. FEI values for fans with specific motors can vary slightly from those shown.

Figure B.4 — Example fan performance table in distributor catalogue

B.3 Examples of consumer use of FEI

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

ISO 12759-6: 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"). The reference to ISO 12759-6 should be added to any specification section that contains fans.

As for specification language, insert the following:

"Fans shall meet or exceed the minimum FEI scheduled at the specified volume flow rate and pressure."

As previously mentioned, the minimum FEI can vary by fan type, project, and so on. 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 alternative product.

Consumers performing fan selection for a specific application should use FEI values as one tool to evaluate various fan options. $P_{ed,ref}$ is always based on the required fan volume flow rate and pressure. Various fans can be compared using FEI values. Fans with higher FEI values will consume less power for the same volume flow rate and pressure than fans with lower FEI values.

B.4 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, labelling requirements and any product or application exemptions.

Legislative, regulatory and code entities can 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
(informative)

Fan arrays

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. In some fan array applications, the spacing of fans is less than optimal and results in a system effect, or performance reduction, from standard tested performance of a single fan. These effects are not covered in this document.

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

a) Calculate $P_{\mathrm{ed,ref}}$ for the fan array using 5.2, with q_V equal to the total volume flow rate shared among all fans in the array.

b) Calculate $P_{\mathrm{ed,ref}}$ for an individual fan by dividing $P_{\mathrm{ed,ref}}$ for the fan array by the number of fans used in the array.

c) Calculate $P_{\mathrm{ed,act}}$ for an individual fan as normal, using 5.3.

NOTE Performance corrections for suboptimal fan spacing can be applied but are not covered in this document.

d) Calculate FEI as normal, using 5.1.

C.3 Labelling

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 according to this annex, they shall be clearly labelled as to the number of fans used in the array.

C.4 Example

Total required volume flow rate through a fan array is 23,6 m^3/s at a fan static pressure of 1,5 kPa at standard air density. Multiple quantities of fans are being considered for this application.

$P_{ed,ref}$ is calculated as in 5.2 for the total volume flow rate through the array (treated as a single fan). All other fan quantities considered use a fraction of this $P_{ed,ref}$ 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. Examples are shown in Table C.1 for various numbers of fans.

Table C.1 — Example fan array FEI values calculated correctly

No, Fans (n)	Volume flow rate (m³/s)	$P_{a,ref}$ (kW)	$\eta_{T,ref}$	$\eta_{mot,ref}$	$P_{ed,ref}$ (kW)	η_{fs}	$P_{a,act}$ (kW)	$\eta_{T,def}$	$\eta_{mot,def}$	$P_{ed,act}$ (kW)	Total P_{ed} (kW)	FEI
1	23,6	63,2	95,9 %	95,2 %	69,1	65 %	54,5	95,9 %	95,0 %	59,8	59,8	1,16
2	11,8	63,2	95,9 %	95,2 %	34,6	65 %	27,2	95,7 %	94,1 %	30,2	60,4	1,15
4	5,9	63,2	95,9 %	95,2 %	17,3	65 %	13,6	95,5 %	93,1 %	15,3	61,2	1,13
10	2,36	63,2	95,9 %	95,2 %	6,92	65 %	5,43	94,7 %	91,3 %	6,29	62,9	1,10
20	1,18	63,2	95,9 %	95,2 %	3,46	65 %	2,71	93,8 %	89,3 %	3,25	65,0	1,06

If the procedure described above is not used and $P_{ed,ref}$ is calculated from the individual fan airflow, the results will be as shown in Table C.2. This table illustrates that, if incorrectly calculated from individual fan airflow, FEI can become misleading as an indicator of total input power.

Table C.2 — Example fan array FEI values calculated from individual fan airflow

No, Fans (n)	Volume flow rate (m³/s)	$P_{a,ref}$ (kW)	$\eta_{T,ref}$	$\eta_{mot,ref}$	$P_{ed,ref}$ (kW)	η_{fs}	$P_{a,act}$ (kW)	$\eta_{T,def}$	$\eta_{mot,def}$	$P_{ed,act}$ (kW)	Total P_{ed} (kW)	FEI
1	23,6	63,2	95,9 %	95,2 %	69,2	65 %	54,5	95,9 %	95,0 %	59,8	59,8	1,16
2	11,8	31,8	95,8 %	94,3 %	35,2	65 %	27,2	95,7 %	94,1 %	30,2	60,4	1,17
4	5,9	16,0	95,5 %	93,3 %	18,0	65 %	13,6	95,5 %	93,1 %	15,3	61,2	1,18
10	2,36	6,61	94,9 %	92,1 %	7,56	65 %	5,44	94,7 %	91,3 %	6,29	62,9	1,20
20	1,18	3,46	94,2 %	90,7 %	4,04	65 %	2,72	93,8 %	89,3 %	3,25	65,0	1,24

In the second case, the option with the highest FEI value 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 For this example and for illustration purposes only, the calculation of $P_{ed,act}$ 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 in 5.3.2 or 5.3.3 would have varying efficiencies depending on the specific motor being used. These two factors combined can result in a certain combination of fans having an optimal FEI or a minimum total input power value.

Annex D
(informative)

Practical issues with embedded fans

Air-system design processes can 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 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 (e.g. coils, filters, internal control enclosures);

— motor proximity;

— the presence of bearings, pulleys, and other drive components;

— full face opening discharge losses;

— fan orientation;

— discharge orientation;

— fan guarding.

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

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.

Annex E
(informative)

Electrical power measurement — Calculation to other speeds and densities

E.1 General

The fan affinity laws (commonly known as the fan laws) are part of ISO 13348. They are used extensively in developing fan ratings. The fan law for power strictly applies to fan impeller power and not to fan electrical input power because drive component efficiencies change with load.

This annex defines an estimation method based on interpolation between tested speeds and densities to obtain fan performance ratings at an intermediate speed or different density. This interpolation provides the fan pressure, airflow, and electrical input power at the same or new density given the electrical input power and associated performance of the fan at two rotational speeds – one speed greater and one speed less than the desired speed. The Reynolds number limits of ISO 13348 should be used to limits test speeds. Greater accuracy is obtained with smaller changes in rotational speed.

This annex should only be used in cases of incompressible flow. In cases of compressible flow, a polytropic approach as described in ISO 5801:2017, Annex J should be used.

E.2 Calculation of performance ratings

E.2.1 General requirements

This subclause describes a method to develop ratings for a fan tested with a motor and controller when electrical input power is measured. To perform these calculations, the fan for which the performance and electrical input power is required at an untested speed or density, should have at least two tests conducted at fan speeds that encompass the desired speed (see Formula (E.1)). If performance ratings are available at three or more speeds, only the two speeds adjacent to the desired speed should be used.

$$N_1 < N_c < N_2 \tag{E.1}$$

where

N_c is the calculated impeller rotational speed (r/min);

N_1 is the lower tested impeller rotational speed (r/min);

N_2 is the higher tested impeller rotational speed (r/min).

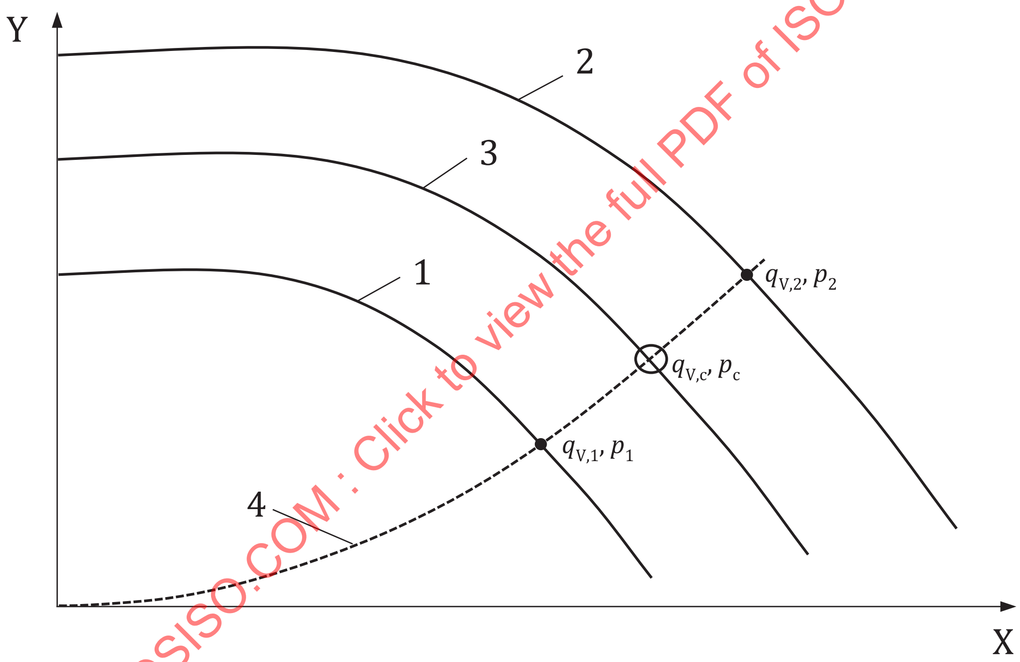
As with the traditional fan laws, all determination points in this annex are on the same system curve, where $p / \left(\rho \times q_V^2 \right) = constant$ (see Formula (E.2)). The pressure, p, can be either fan static or fan total pressure. Performance ratings at the known speeds should be at standard air density. See Figures E.1 and E.2. Since this annex covers interpolation between points on two fan curves, interpolation is required along the fan curves to obtain two points at the same system resistance. The details of interpolation along a fan curve are not covered in this annex.

$$\frac{p_1}{\rho_{ref} \times q_{V,1}^2} = \frac{p_c}{\rho_c \times q_{V,c}^2} = \frac{p_2}{\rho_{ref} \times q_{V,2}^2} \tag{E.2}$$

where

p_c	is the calculated fan pressure (Pa);
$q_{V,c}$	is the calculated volume flow rate (m^3/s);
p_1	is the tested fan pressure at lower speed (Pa);
$q_{V,1}$	is the tested volume flow rate at lower speed (m^3/s);
p_2	is the tested fan pressure at higher speed (Pa);
$q_{V,2}$	is the tested volume flow rate at higher speed (m^3/s);
ρ_c	is the calculated fan density (kg/m^3);
ρ_{ref}	is the standard air density (kg/m^3).

The Reynolds number for the desired or calculated rating point should fall within the range of 67 % to 150 % of the Reynolds numbers for test conditions. Reference conversion rules for series produced fans in ISO 13348.



Key

X fan volume flow rate, expressed in m^3/s

Y fan total or static pressure, expressed in Pa

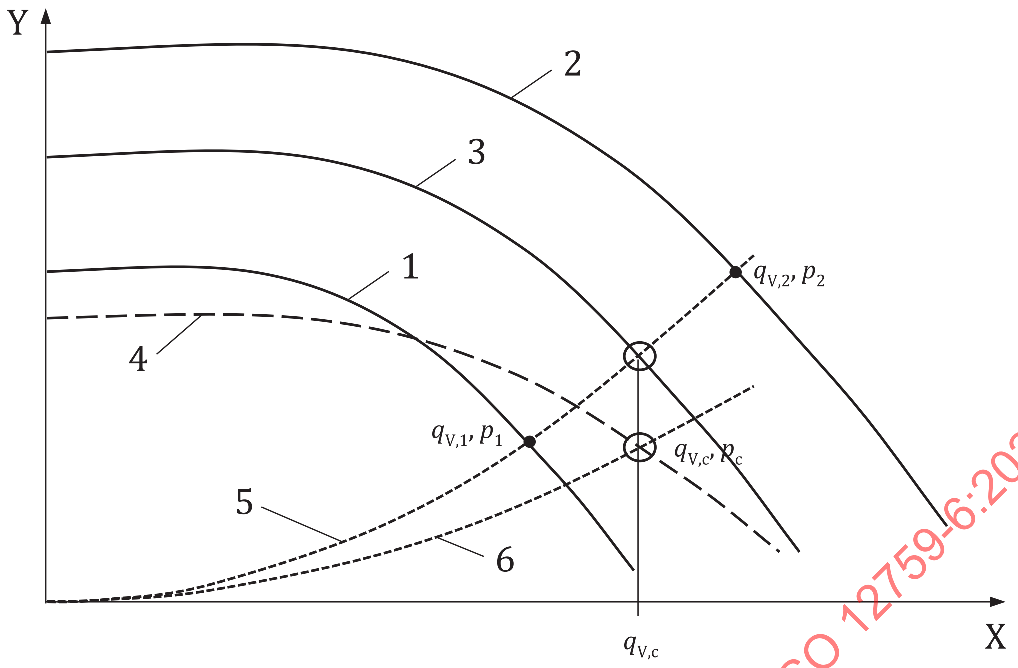
1 fan curve at known speed N_1 and standard density ρ_{ref}

2 fan curve at known speed N_2 and standard density ρ_{ref}

3 fan curve at desired speed N_c and standard density ρ_{ref}

4 system curve at standard air density

Figure E.1 — Specific case at standard air density



Key

X fan volume flow rate, expressed in m^3/s

Y fan total or static pressure, expressed in Pa

1 fan curve at known speed N_1 and standard density ρ_{ref}

2 fan curve at known speed N_2 and standard density ρ_{ref}

3 fan curve at desired speed N_c and standard density ρ_{ref}

4 fan curve at desired speed N_c and desired density ρ_c

5 system curve at standard air density

6 system curve at desired density ρ_c

Figure E.2 — General case including changes in air density

E.2.2 Determination of the fan volume flow rate at the desired speed

The fan volume flow rate between points 1 and 2 varies linearly with fan speed as in Formula (E.3). Note that this is slightly different from the traditional fan laws where volume flow rate is proportional to fan speed.

$$q_{V,c} = q_{V,1} + \left(\frac{N_c - N_1}{N_2 - N_1} \right) \times \left(q_{V,2} - q_{V,1} \right) \qquad \text{(E.3)}$$

where

$q_{V,c}$ is the calculated volume flow rate (m^3/s);

$q_{V,1}$ is the tested volume flow rate at lower speed (m^3/s);

$q_{V,2}$ is the tested volume flow rate at higher speed (m^3/s);

N_c is the calculated impeller rotational speed (r/min);

N_1 is the lower tested impeller rotational speed (r/min);

N_2 is the higher tested impeller rotational speed (r/min).