INTERNATIONAL STANDARD

ISO 13348

Second edition
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Industrial fans — Tolerances, methods of conversion and technical data presentation

Ventilateurs industriels — Tolérances, méthodes de conversion et présentation des données techniques

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Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 13348 was prepared by Technical Committee ISO/TC 117, *Industrial fans*.

This second edition of ISO 13348 cancels and replaces the first edition (ISO 13348:2006), which has been technically revised and now makes reference to series-produced non-certified fans.

Introduction

This International Standard endeavours to clarify those technical aspects of contracts where fan performance is concerned, and the accuracy and consistency of performance details published in technical catalogues.

In this International Standard a distinction is drawn between specially designed fans to suit a specific purpose, to meet a contract specification, and series-produced fans where the performance data is contained in a catalogue.

For purpose-designed fans the methods of calculating performance data under contract conditions, from performance data obtained under test conditions, are described in Clause 5 for both air and sound data. Four tolerance grades are given, each appropriate to a particular type of fan and/or its application. These procedures have been found satisfactory; however, the supplier and user could agree to adopt alternative methods.

For the series-produced non-certified fans, the associated technical data will be contained in a catalogue (electronic and/or printed form). In this case the recommended method of applying tolerances is as described in Clause 5.

For the series-produced fans in certified ratings programmes, the associated technical data will be contained in a catalogue (electronic and/or printed form). In this case the recommended method of applying tolerances is as described in Clause 6, based on the rules of AMCA (Air Movement and Control Association) International, Inc. for the certified ratings programme [11], [12], [13]. An independent accredited body, under a certified ratings programme, can be called in to verify this data.

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

1 Scope

This International Standard specifies performance tolerances and the technical data presentation of industrial fans of all types. It does not apply for fans designed solely for low-volume air circulation, such as those used for household or similar purposes (ceiling and table fans, extractor fans, etc.). For jet fans refer to ISO 13350.

The upper limit of fan work per unit mass is normally 25 kJ kg^{-1}, corresponding to an increase of fan pressure of approximately 30 kPa for a mean density in the fan of 1,2 kg m^{-3}. For higher values, agreement is to be reached between the supplier and the user.

This International Standard embraces the four installation categories defined in ISO 5801:

A free inlet, free outlet;

B free inlet, ducted outlet;

C ducted inlet, free outlet;

D ducted inlet, ducted outlet.

The performance of a fan can vary considerably with the installation category it is operating within. Therefore, these categories form an important part of the definition of the fan's technical data presentation.

NOTE International acceptance of the four installation categories provides the opportunity to base a contract on the most appropriate fan category for the end user and the system designer. Correspondingly, the likelihood of the fan providing the agreed performance, without compromise or concession, is enhanced.

2 Normative references

The following referenced documents are indispensable for the application 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 5801:1997, *Industrial fans — Performance testing using standardized airways*

ISO 5802, *Industrial fans — Performance testing* in situ

ISO 13347-1, *Industrial fans — Determination of fan sound power levels under standardized laboratory conditions — Part 1: General overview*

ISO 14694, *Industrial fans — Specifications for balance quality and vibration levels*

ISO 14695, *Industrial fans — Method of measurement of fan vibration*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

NOTE In some cases, more complete definitions are to be found in ISO 5801, ISO 5802 and ISO 13349.

3.1
industrial fan
fan other than that used for household or similar purposes such as air circulation, climatization

NOTE For the purpose of this International Standard and other industrial fan standards, a household fan is defined as having a single-phase motor operating at a maximum of 250 V and 16 A. With a sufficiently soft start, this equates to an input power of not more than 3 kW.

3.2
series-produced fan
catalogue fan
fan whose detailed performances is widely available in a catalogue (electronic and or printed), and which is frequently manufactured in significant quantities and available on short delivery

3.3
average stagnation pressure at a section x
p_{sgx}
sum of the conventional dynamic pressure, p_{dx}, corrected by the Mach factor coefficient, F_{Mx}, at the section, and the average absolute pressure, p_{x}

$$p_{\mathrm{sgx}} = p_{\mathrm{x}} + p_{\mathrm{dx}} F_{\mathrm{Mx}}$$

NOTE 1 The average stagnation pressure can be calculated by

$$p_{\mathrm{sgx}} = p_{\mathrm{x}} \left(1 + \frac{\kappa - 1}{2} Ma_{\mathrm{x}}^2 \right)^{\frac{\kappa}{\kappa - 1}}$$

NOTE 2 It is expressed in pascals (Pa).

3.4
average total pressure at a section x
p_{tx}
sum of the conventional dynamic pressure, p_{dx}, corrected by the Mach factor coefficient, F_{Mx}, at the section, and the average gauge pressure, p_{ex}

$$p_{\mathrm{tx}} = p_{\mathrm{ex}} + p_{\mathrm{dx}} F_{\mathrm{Mx}} = p_{\mathrm{sgx}} - p_{\mathrm{a}}$$

NOTE 1 When the Mach number, Ma, is less than 0,122, the Mach factor, F_{Mx}, can be neglected

NOTE 2 See ISO 5801, ISO 5802 and 13349 for definitions.

3.5
characteristic error
flow rate change produced along the actual system characteristic by the maximum fan performance deviation allowed by the tolerance grade selected

NOTE 1 Characteristic error is a function of the tolerance grade, the measurement uncertainty allowed, and the shape (local slope) of the fan and actual system characteristics

NOTE 2 For the actual system characteristics, see ISO 5801.

3.6
fan aerodynamic characteristic curves
fan pressure, power, efficiency, etc., against flow rate under specified ambient conditions and at a constant speed, or when fitted with a specified motor

3.7
fan dynamic pressure at outlet
p_{d2}
conventional dynamic pressure at the fan outlet calculated from the mass flow rate, the average gas density at the outlet and the fan outlet area

$$p_{d2} = \rho_2 \frac{v_{m2}^2}{2} = \frac{1}{2\rho_2}\left(\frac{q_m}{A_2}\right)^2$$

NOTE It is expressed in pascals (Pa).

3.8
fan flow coefficient
φ
non-dimensional quantity equal to the mass flow rate divided by the product of the mean density, the peripheral speed of the impeller and the square of the diameter of the impeller

$$\varphi = \frac{q_m}{\rho_m u D_r^2} \qquad \text{if } Ma \geqslant 0{,}122$$

$$\varphi = \frac{q_V}{u D_r^2} \qquad \text{if } Ma < 0{,}122$$

3.9
fan outlet area
A_2
area inside the fan outlet casing flange

NOTE It is expressed in square metres (m^2).

3.10
fan pressure
p_F
difference between the stagnation pressure at the fan outlet and the stagnation pressure at the fan inlet

$$p_F = p_{sg2} - p_{sg1} \qquad \text{if } Ma \geqslant 0{,}15$$

$$p_F = p_{tF} = p_{t2} - p_{t1} \qquad \text{if } Ma < 0{,}15$$

NOTE 1 When expressing fan pressure, reference should be made to the installation category A, B, C or D.

NOTE 2 It is expressed in pascals (Pa).

3.11
fan static pressure
p_{sF}
conventional quantity defined as the difference between the fan pressure and the fan dynamic pressure corrected by Mach factor F_{M2}

$$p_{sF} = p_{sg2} - p_{d2} F_{M2} - p_{sg1} = p_2 - p_{sg1} \quad \text{if } Ma \geqslant 0{,}122 \text{ at the fan outlet area}$$

$$p_{sF} = p_{t2} - p_{t1} - p_{d2} \quad \text{if } Ma < 0{,}122 \text{ at the fan outlet area}$$

NOTE It is expressed in pascals (Pa).

3.12
Mach factor
F_M
correction factor applied to the dynamic pressure at a point

$$F_M = \frac{p_{sg} - p}{p_d}$$

NOTE 1 The Mach factor can be calculated by

$$F_M = 1 + \frac{Ma^2}{4} + \frac{(2-\kappa)Ma^4}{24} + \frac{(2-\kappa)(3-2\kappa)Ma^6}{192} + \ldots \quad \text{valid for } \kappa = 1{,}4$$

NOTE 2 It is dimensionless.

3.13
Mach number at a point
Ma
ratio of the gas velocity at a point to the velocity of sound

$$Ma = \frac{v}{\sqrt{\kappa R_w \Theta}} = \frac{v}{c}$$

where

c is the velocity of sound, $c = \sqrt{\kappa R_w \Theta}$;

R_w is the gas constant of humid gas.

NOTE It is dimensionless.

3.14
Mach number at a section x
Ma_x
average gas velocity divided by the velocity of sound at the specified airway cross-section

$$Ma_x = \frac{v_{mx}}{\sqrt{\kappa R_w \Theta_x}}$$

NOTE It is dimensionless.

3.15
optimum efficiency
η_{opt}
maximum efficiency achieved on the fan air characteristic with all operational parameters, except the air system resistance, being fixed

NOTE It is expressed as a percentage.

3.16
peripheral Reynolds number
Re_u
Reynolds number based on the tip speed, u

NOTE It is dimensionless.

3.17
power coefficient
λ
non-dimensional quantity related to the impeller power using the mean fluid density at inlet

$$\lambda = \frac{P_\mathrm{r}}{\rho_\mathrm{m} u^3 D_\mathrm{r}^2}$$

3.18
pressure coefficient
ψ
non-dimensional number related to the fan pressure using the mean density of the gas and the tip speed of the impellor

$$\psi = \frac{p_\mathrm{F}}{\rho_\mathrm{m} u^2}$$

3.19
tip speed
u
peripheral speed of the impeller blades at their maximum diameter

NOTE It is expressed in metres per second ($\mathrm{m \cdot s^{-1}}$).

3.20
total sound power level
L_W
unweighted sound power level defined as 10 times the logarithm to the base 10 of the ratio of the sound power in watts to a reference value of 10^{-12} W (1 picowatt [pW])

NOTE It is expressed in decibels (dB).

3.21
octave band sound power level
$L_{W\mathrm{fc}}$
sound power level in an octave band with a defined centre frequency, defined as 10 times the logarithm to the base 10 of the ratio of the sound power in watts to a reference value of 10^{-12} W (1 picowatt [pW])

NOTE It is expressed in decibels (dB).

3.22
A-weighted sound power level
L_{WA}
total sound power level using A-weighting

NOTE 1 See IEC 61672-1 for a definition of A-weighting.

NOTE 2 It is expressed in decibels (dB).

3.23
total sound pressure level
L_p
unweighted total sound pressure level at a specified point and under specified conditions, normally in the octave bands with centre frequencies from 63 Hz to 8 kHz, defined as 10 times the logarithm to the base 10 of the ratio of the square of the sound pressure to the reference value of 20 μPa

NOTE It is expressed in decibels (dB).

3.24
A-weighted sound pressure level
L_{pA}
total sound pressure level using A-weighting

NOTE 1 For a definition of A-weighting, see IEC 61672-1.

NOTE 2 It is expressed in decibels (dB).

3.25
tolerance zone
range of values of the specified parameters allowed, according to the applicable tolerance grade

3.26
tolerance grade
designation defining the limit deviations from the agreed or published technical performance parameters

3.27
dimensionless frequency
χ
non-dimensional logarithmic function of the ratio between the centre frequency of an octave or third-octave band, and the rotational speed of the fan

$$\chi = 10\lg\frac{f_\mathrm{c}}{n}$$

4 Symbols and units

For the purposes of this docuemnt the following symbols apply:

Symbol	Term	Unit
A_2	Fan outlet area	m^2
c	Velocity of sound	$\mathrm{m \cdot s^{-1}}$
D_r	Diameter of impeller	m
e	Uncertainty of measurement	—
F_Mx	Mach factor for correction of dynamic pressure at section x	—

Symbol	Term	Unit
f_c	Octave centre frequency	Hz
G	Index of agreed value	—
k	Parabolic constant $k = \psi_p/\varphi^2$	—
L_p	Sound pressure level	dB
L_{pA}	A-weighted sound pressure level	dB (A)
L_W	Sound power level	dB
L_{WA}	A-weighted sound power level	dB (A)
L_{Wfc}	Octave band sound power level	dB
M	Index of measured value	—
Ma	Mach number at a point	—
Ma_x	Mach number at section x	—
n	Rotational speed/rotational fequency	$r \cdot s^{-1}$
P_a	Mechanical power supplied to the fan shaft	W
P_m	Shaft power of electric motor	W
P_r	Mechanical power required by the fan impeller	W
p_a	Atmospheric pressure	Pa
p_{ex}	Mean gauge pressure in space and time at section x	Pa
p_F	Fan pressure	Pa
p_{dF}	Fan dynamic pressure	Pa
p_{d2}	Fan dynamic pressure at outlet	Pa
p_{sF}	Fan static pressure	Pa
p_{sg}	Absolute stagnation pressure	Pa
p_t	Average total pressure	Pa
p_x	Mean absolute pressure in space and time at a point	Pa
q_m	Inlet mass flow rate	$kg \cdot s^{-1}$
q_V	Inlet volume flow rate	$m^3 s^{-1}$
Re_u	Peripheral Reynolds number	—
R_w	Gas constant of fluid handled	$J \cdot kg^{-1} \cdot K^{-1}$
T	Air flow test tolerance	%
t	Limit deviation specified	—
u	Tip speed	$m \cdot s^{-1}$
v	Fluid velocity	$m \cdot s^{-1}$
κ	Ratio of specific heats of air, $\kappa = \frac{c_p}{c_v}$, where c_p is the massic heat capacity at constant pressure, and c_v is the massic heat capacity at constant volume	—
η	Fan efficiency	—
η_{opt}	Fan optimum efficiency	—
θ_x	Fluid absolute temperature at section x	K
λ	Power coefficient	—

Symbol	Term	Unit
μ	Dynamic viscosity	Pa·s
ρ	Density	kg·m^{-3}
ρ_m	Mean density of gas in fan	kg·m^{-3}
ρ_1	Density at fan inlet	kg·m^{-3}
ρ_2	Density at fan outlet	kg·m^{-3}
φ	Fan flow coefficient	—
χ	Dimensionless frequency	—
ψ	Pressure coefficient	—

5 Performance tolerances for purpose-designed fans and series-produced non-certified fans

5.1 Information to be provided by the purchaser

5.1.1 Operational

The following information shall be provided.

a) Volume flow rate, q_V, rate at the fan inlet or mass flow rate q_m.

b) Total pressure increase, p_t, between fan inlet and outlet, or static pressure increase, p_s, at a specified discharge area.

c) Distribution of total pressure losses in the system between inlet and outlet side of fan.

d) Absolute pressure at fan inlet.

e) Density, ρ_1, of handled fluid at fan inlet.

f) Temperature of the gas handled at the fan inlet for normal operation relevant for the fan performance, and the maximum and minimum temperatures for which the fan is to be designed.

g) Dust, mist or vapour content of gas at fan inlet for normal operation, the properties of these, and their maximum content. Information as to whether the dust, mist or vapour is combustible, noxious, aggressive or sticky.

h) Maximum permissible A-weighted sound power level, in A-weighted decibels, as specified in ISO 13347-1.

i) Maximum permissible levels of mechanical vibration in service, as specified in ISO 14694.

j) System characteristic, if necessary.

k) Design speed cycles: i.e. the number of speed cycles per 24 h, the range of speed, if variable speed, plus the total number of start-stops the fan is to be designed for.

l) Other specifications (e.g. preferred rotational speed, type and range of control, orientation of the inlet and discharge, impeller rotation, as viewed from the driver). See ISO 13349.

5.1.2 Tolerance grade

The tolerance grade shall be stated in accordance with the requirements specified in 5.3.1.

A supplier will only be able to provide a fan for a particular application once the customer has provided him with all the information necessary to complete the order. This should take place before the tender is prepared or, at the latest, before a sales agreement has been reached. Such information is to include details on fan design, arrangement, construction, materials and scope of supply, and should be based on the customer's own calculations, measurements and experience in this field.

5.2 Information to be provided by the supplier

5.2.1 Essential information

If the supplier cannot refer to catalogue information, installation, maintenance or operation instructions, he shall generally provide the following information.

a) Operational parameters at design conditions, especially volume or mass flow, fan pressure, absorbed power and fan speed. The exact scope of supply, as well as any other accessories that the supplier considers necessary for installation and connection (e.g. motors, devices to prevent accidental contact, flexible connectors, control and shut-off devices, inlet boxes).

b) The major dimensions for connection, installation and transport.

c) The total mass of the assembly and the mass of the essential components supplied.

d) Important design features where essential for assembly, e.g. materials of construction. Other information should be supplied on request, or if necessary.

e) Motor output power.

f) Other information, e.g. the electric or pneumatic connected load, provision of sealing gas, cooling air and water.

g) Installation, operation, and maintenance instructions.

NOTE In many installations the electric drive motor is supplied directly by the supplier. As such, it may not be possible to state the type of drive, its rating and speed, etc.

5.2.2 Optional parameters

The following information may also be provided.

a) Fan power (see ISO 5801) as a function of the parameters listed in 5.1.

b) Rotational speed of the impeller as a function of the parameters listed in 5.1, and maximum permissible rotational speed.

c) A-weighted sound power level as specified in ISO 13347-1. Sound pressure levels are not recommended as they can be heavily influenced by the room acoustics and sound propagation from connecting ducts. In addition, they can be significantly influenced by directional characteristics, especially if the fan is of the open-inlet or outlet type. Sound pressure levels can only be stated under free-field conditions and may not be representative of actual room conditions.

d) Fan performance characteristic, if specifically requested by the purchaser. The following additional parameters may be supplied if specifically requested:

   1) fan efficiency (see ISO 5801) as a function of the parameters listed in 5.1;

   2) vibration values (see ISO 14695);

   3) balance quality (see ISO 14695).

e) The mass moment of inertia of the rotating parts, or if applicable, the starting torque curve.

5.3 Tolerances

5.3.1 Tolerance grades

Measuring uncertainties shall be considered differently from manufacturing tolerances.

At each stage of the fan design and manufacturing cycle, including conversion from prototype performance data or calculation, fabrication and testing of a purpose-designed fan, finite uncertainties will prevail and acceptance tolerances shall be applied.

Zero or exclusively positive tolerances can neither be supported in theory or practice and are not recommended.

Uncertainties are spurious, random or systematic factors which affect design, fabrication and therefore fan performance. Uncertainties are not absolute and because of this are handled statistically, i.e. a level of confidence is attributed to the measured quantity lying within the uncertainty boundary of the true value.

Tolerances are the definition of acceptability for uncertainties. They are absolute and can vary according to the application. They effectively define an absolute limit for uncertainties which would otherwise have to be expressed statistically. The user is therefore provided with an absolute criteria for fan selection and acceptance.

This International Standard acknowledges that there are two different sources of uncertainty influencing performance tests.

Design and manufacturing processes have inherent dimensional uncertainties leading to deviations of important mechanical dimensions from the target value. This, again, will lead to inevitable deviations in performance data:

$\pm t_{q_\mathrm{V}}$ limit deviation of volume flow;

$\pm t_{p_\mathrm{F}}$ limit deviation of fan pressure;

$\pm t_{P_\mathrm{a}}$ limit deviation of fan shaft power;

$- t_{\eta}$ limit deviation of fan efficiency;

$+ t_{L_{W\mathrm{A}}}$ limit deviation of A-weighted fan sound power level.

The design and manufacturing accuracy obtainable in practice is defined in a number of International Standards. Design tolerances are treated in Clause 6 of this International Standard. Higher accuracy will, as a rule, require more expensive production methods. The fan user shall decide which uncertainties in performance data are permissible, bearing in mind the consequences on cost.

This can be illustrated for an axial fan with a cast impeller. The impeller could be a rough sand casting or a more accurate die casting. The surface could be improved by polishing or remain untreated. The tip diameter may be machined or remain as-cast. The aerodynamic effects of electric motors placed in the air stream may reduce the fan performance. For low uncertainty it is not sufficient to achieve small tolerances for the tip gap, etc. Larger or smaller deviations from the intended mechanical dimensions, and uncertainties in the conversion of test data, will affect each performance value differently. For example, a variation of the width of a radial impeller will have a larger influence on the volume flow-rate than on the fan pressure. Measurements also have inherent uncertainties.

Limitations in the measuring accuracy of the instruments used, and deviations from the standardized test-duct arrangements according to ISO 5801, will influence the confidence that can be applied to the uncertainty of the resulting characteristic values, such as capacity, fan pressure, power consumption, speed and sound power level. These values, being measured independently by different instruments, will have errors that are unrelated and, as such, their influence on test results shall be considered independently. The following tolerances are identified, taking into account potential imperfections of the measuring arrangement:

$\pm \Delta_{q_V}$ tolerance of volume flow measurements;

$\pm \Delta_{p_F}$ tolerance of fan pressure measurements;

$\pm \Delta_{P_a}$ tolerance of fan shaft power measurements;

$\pm \Delta_{L_W}$ tolerance of fan noise power measurements.

These tolerances are not limited to the errors of the instruments or the test arrangement employed. They also allow for human error associated with the reading of the instruments and the interpolation of intermediate values. This is particularly relevant for large fans, where the difficulty in achieving standardized test arrangements may be the largest source of error.

To provide for the variety of fan types and applications, a list of four tolerance grades, with typical applications, has been defined in Table 1. As indicated above, these range from accurately machined impellers for special-purpose fans to sheet-metal fabricated impellers with wide tolerances used for applications where other criteria are more important than optimum fan performance. It should be noted that the tolerance grades of classes are only examples for possible applications

Table 1 — Guide for fan “air and noise” tolerance grades 1 to 4

Tolerance grade (air and noise)	Typical application	Material of, and manufacturing processes used for, major aerodynamic components	Approx. min. power [a] kW
AN1	Mining (e.g main fan), process engineering, power stations (e.g. exhaust fan), wind tunnels, tunnels, etc.	Machined in some places, cast (high accuracy)	> 500
AN2	Mining, power stations, wind tunnels, tunnels, process engineering, air conditioning	Sheet or plastic material, partly machined, cast (medium accuracy)	> 50
AN3	Process engineering, air conditioning, industrial fans, tunnels, power station fans and industrial fans for harsh (abrasive or corrosive) conditions	Sheet material, cast (medium to low accuracy), special surface protection (e.g. hot-dip galvanizing, moulded plastics	> 10
AN4	Process engineering, ships fans, agriculture, small fans, power station fans and industrial fans for harsh (abrasive or corrosive) conditions	Sheet material, special surface protection (e.g. rubber coating), moulded or extruded plastics	—

[a] For each class, a recommendation has been given only for the lower power limit; an upper limit is not essential. For example, even if the power is greater than 500 kW, any one of the grades may be assigned.

The information given in Table 1 may be used as a guide only. It shall be considered with which degree of accuracy the expected performance data has been established, often requiring agreement between purchaser and supplier when selecting a suitable grade. Uncommon installation conditions — for example, distorted inlet flow — or a system with components situated in the inflow, such as protective screens or structural supports, shall be allowed for. Special agreements shall be made for fans whose drive causes marked fluctuations in rotational speed.

Motors used for direct-driven axial flow fans may be in the airstream without an aerodynamic fairing. This could produce an additional aerodynamic blockage. In such cases an allowance for motor effect should be agreed between the supplier and purchaser.

It should be remembered that specifications which require zero and/or exclusively positive tolerances, with respect to fan pressure and flow, are not recommended. They can neither be supported in theory nor in practice, and lead to substantial over-design and unnecessarily increased operating cost.

5.4 Purchasing arrangements

Before a contract is signed it shall be agreed whether a performance test shall be included. This is not normally required, especially if the fan is subject to a certified ratings programme (see Clause 6) or if the supplier has an accredited laboratory.

5.5 Contractual testing

5.5.1 Tolerance magnitude near optimum efficiency

Four tolerance grades are given in Table 2 for the fan volume flow, pressure, shaft power and sound power level (see also Figure 1). In the normal case these grades are applicable to all contractual agreements between the purchaser and his supplier, and if not, a separate agreement should be obtained. The operating point is assumed to lie where the efficiency, as stated by the supplier, is at least 0,9 times the stated best efficiency η_{opt}. Outside this range, tolerances are applied as detailed in clause 5.5.2

Table 2 — Manufacturing tolerance grades

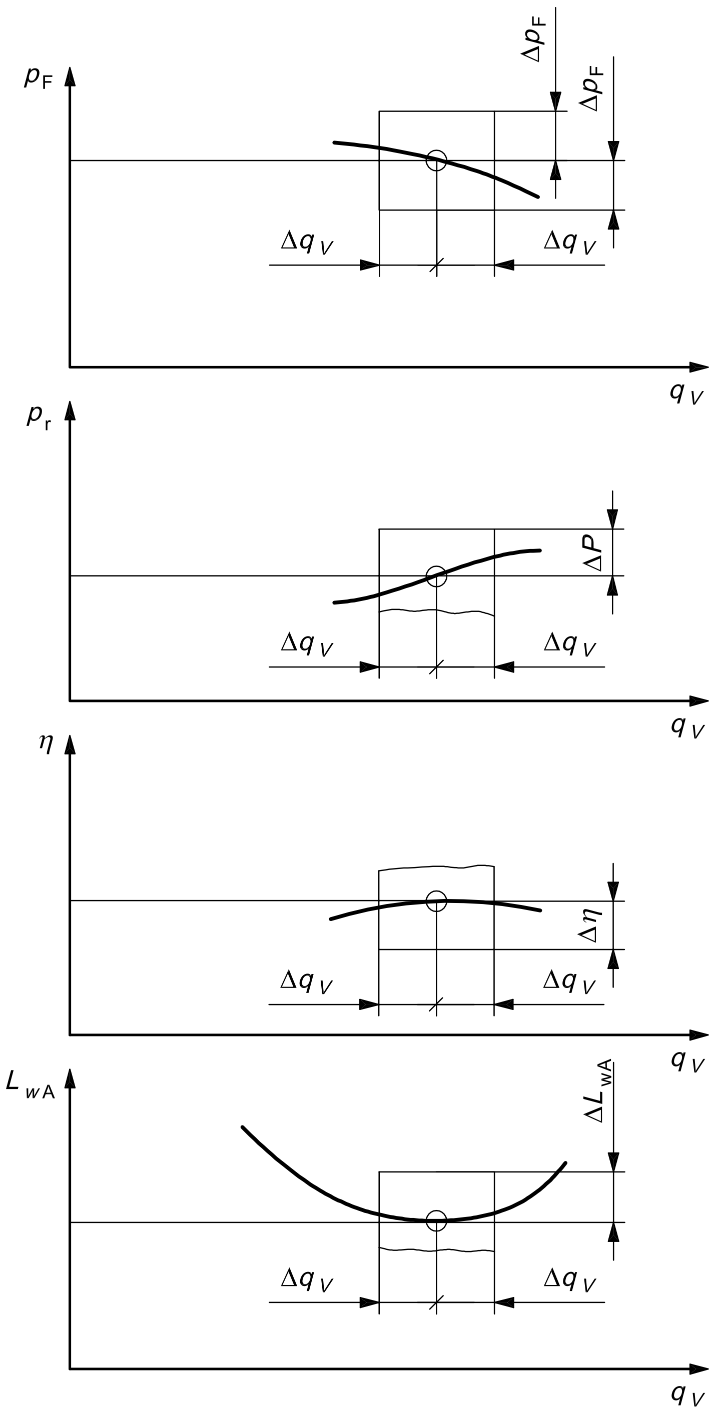
Parameter	Tolerance grade (air and noise)				Additional information
	AN1	AN2	AN3	AN4	
Volume flow rate, q_V	± 1 %	± 2,5 %	± 5 %	± 10 %	$\Delta_{q_V} = t_{q_V} \cdot q_V$
Fan pressure p_F	± 1 %	± 2,5 %	± 5 %	± 10 %	$\Delta_{p_F} = t_{pF} \cdot p_F$
Power, P_r [a, b]	+ 2 %	+ 3 %	+ 8 %	+ 16 %	$\Delta_P = t_P \cdot P_r$ Negative deviations are permissible. For small fans, P, shall be the motor input power.
Efficiency, η	− 1 %	− 2 %	− 5 %	− 12 %	$\Delta_\eta = t_\eta$ i.e. the value of t_η is identical with the permissible tolerance of the efficiency. Positive deviations are permissible.
A-weighted sound power level, L_{WA} [c]	+ 2 dB	+ 3 dB	+ 4 dB	+ 6 dB	$\Delta_{L_{WA}} = t_{L_{WA}}$ The value of $t_{L_{WA}}$ is a permissible tolerance of the sound power level. Negative deviations are permissible.

NOTE Sound pressure levels are dependant on the environment. Tolerances will be higher due to wave length effects, local resonances, directional factors, room effects, etc. In particular, sound pressure levels measured close to fan casings are heavily influenced by “near-field” effects and, as such, great care should be taken when using sound pressure measurements. As a guide the tolerances, given above for sound power may have to be doubled.

[a] The power should be clearly defined: i.e. whether it is impeller power, shaft power (including bearing losses), overall fan power (including transmission losses, e.g. coupling or vee-belt drive losses), or motor input power (applicable especially to small fans). See also ISO 5801, ISO 13349 and IEC 60034-2.

[b] The power measurement of electric motors shall be carried out with a sinusoidal supply on nominal frequency and voltage. The voltage from frequency converters could give higher power values due to additional losses within the motor.

[c] The measuring uncertainty of octave or one-third octave band sound power levels increases significantly, while universal scaling rules are not accepted. (see 7.2.3.1). It is therefore recommended that tolerance band levels not be included in contractual terms.

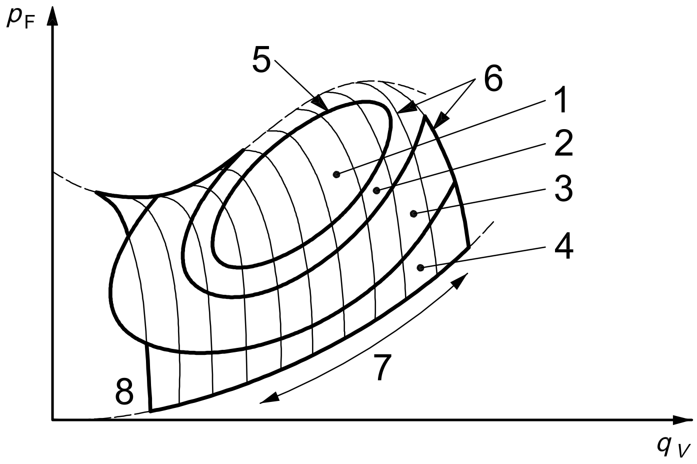


Key

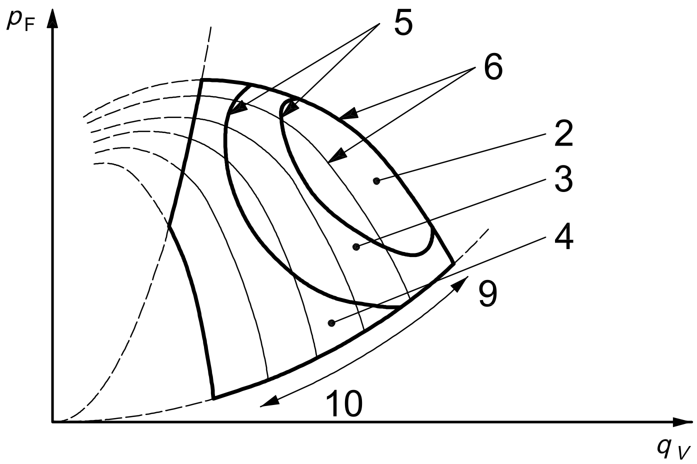
p_F fan pressure
P_r fan power
η fan efficiency
L_{WA} A-weighted fan sound power level
q_V inlet volume flow rate

NOTE While the uncertainty field is elliptical, a rectangular shape is used for practical reasons.

Figure 1 — Limit deviations (tolerance ranges) for agreed operational parameters in accordance with Table 1

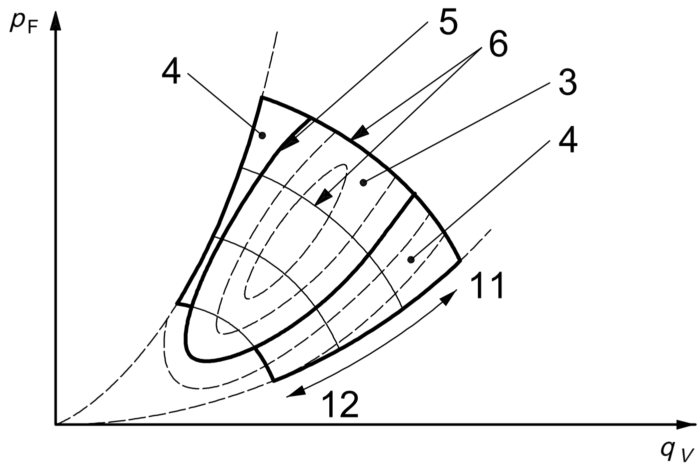


a) Performance chart for an axial flow fan for different impeller blade pitch angles showing four tolerance grades (constant speed)



b) Performance chart for a centrifugal flow fan for different flow control device settings showing three tolerance grades (constant speed)

Figure 2 — Examples of assigning tolerance grades to adjustable fans



c) Performance chart for different impeller rotational speeds showing two tolerance grades

Key

p_F fan pressure
q_V inlet volume flow rate
1 tolerance grade selected (e.g. AN1), i.e. $\eta > 0{,}9\eta_{opt}$
2 η range for one lower tolerance grades (e.g. AN2), i.e. $\eta < 0{,}9\eta_{opt}$
3 η range for two lower tolerance grades (e.g. AN3), i.e. $\eta < 0{,}8\eta_{opt}$
4 η range for three lower tolerance grades (e.g. AN4), i.e. $\eta < 0{,}6\eta_{opt}$
5 fan efficiency contours
6 fan pressure/volume output characteristic curves
7 impeller blade pitch angles
8 minimum blade pitch angle
9 flow control device settings
10 flow control device closing
11 impeller speed increasing
12 impeller speed decreasing

Figure 2 (*continued*)

5.5.2 Operation at other than optimum efficiency

The fan tolerance grades specified in Table 2 are based on the assumption that the fan is operated within the optimum range specified by the supplier. This, for fixed geometry and speed fans, is the volume flow rate range in which the efficiency is at least 0,9 η_{opt}, and for adjustable fans, the range in the ($p_F - q_V$) graph in which the efficiency given by the supplier is at least 0,9 η_{opt}. Lower uncertainty grades shall apply outside this range as follows (see Figures 2 and 3):

a) for η from 0,8 η_{opt} to less than 0,9 η_{opt}, one tolerance grade lower;

b) for η from 0,6 η_{opt} to less than 0,8 η_{opt}, two tolerance grades lower;

c) for η less than 0,6 η_{opt}, three tolerance grades lower, provided lower uncertainty grades are still available [see Table 1 and Figure 2 b)].

For nonadjustable fans operating away from the optimum efficiency point, there may still be a requirement, for example, where the system resistance can vary over a wide range, for a specified tolerance for a second operating point. In this case, a higher uncertainty is applicable and should be agreed using the above principles as a guideline.

For adjustable fans, operation away from the optimum efficiency is likely to be a requirement. Hence the tolerance grades are extended to cater for this condition using efficiency contours. The base tolerance for the fan still relates to the operating point of the agreed or published performance envelope, but flow variation induced by blade angle, inlet vane angle or speed changes, is catered for by the variations shown (see above). In all cases, the design flow will be that applicable to the blade angle, flow control device setting or speed as appropriate (see Figure 2).

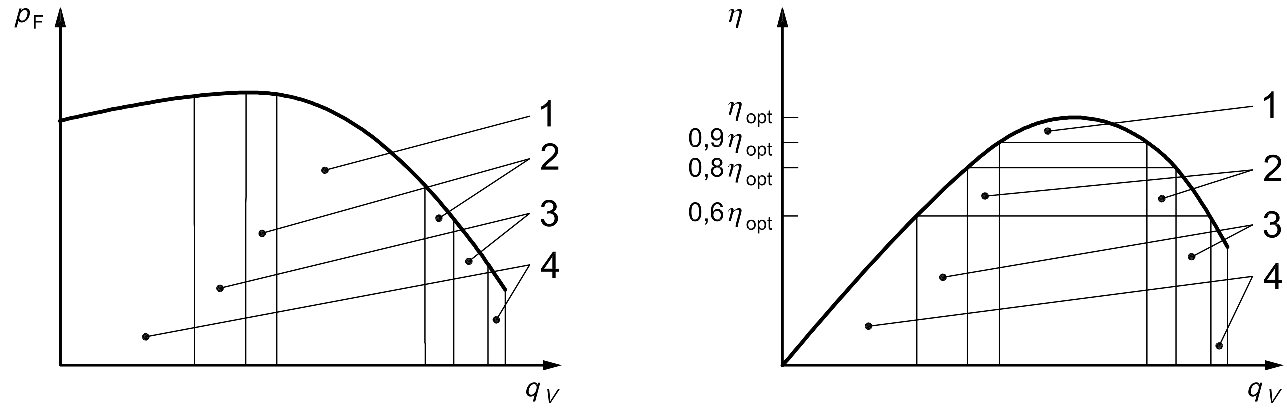
If the speed of the fan is adjustable, for example, by inverter control, the tolerance grade may be based on a precise speed. However, as is more usually the case, if the tolerance grade is to be applied to a fan and motor combination, then the grade selected shall consider the possibility of the motor speed being slightly different from that quoted or published by the motor supplier and additional motor losses shall be considered. In all cases of speed control, the design flow shall be related to that applicable at the precise operating speed.

5.5.3 Performance acceptance testing

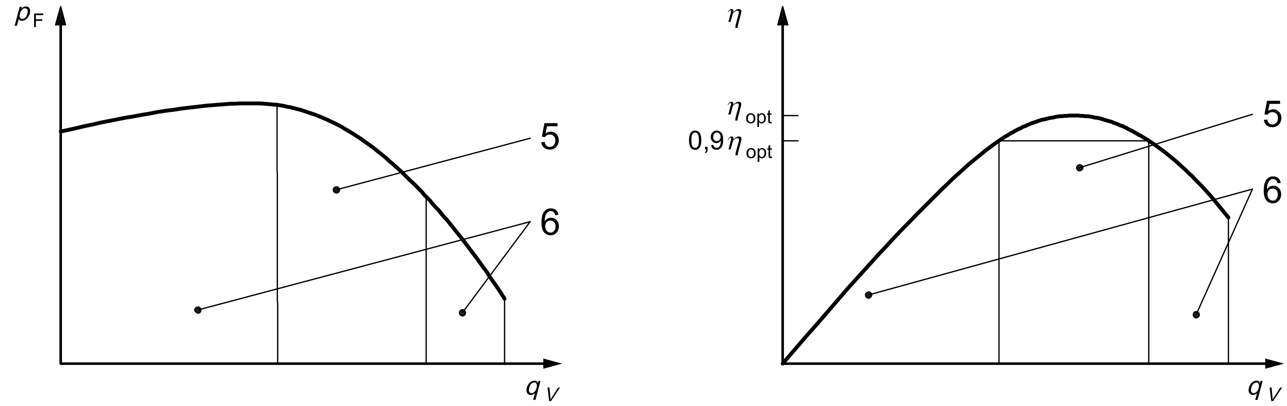
5.5.3.1 General

The full performance testing of a fan can be extremely expensive and with small fans can even exceed the cost of the fan itself. Suppliers and purchasers should always consider, in the first instance, whether this expense is justified.

At the customer's request, and by agreement with the supplier, the specified operational parameters shall be verified by the supplier. The method and scope and price of testing shall be agreed between the customer and supplier. The scope of testing shall take into account aspects such as the tests required, the size of the fan, the facilities available and the agreed tolerance grade.



a) Graphs showing four accuracy classes



b) Graphs showing two tolerance grades

Key

p_F fan pressure

η fan efficiency

q_V inlet volume flow rate

1 volume flow rate for the tolerance grade selected (e.g. AN1) for $\eta \geqslant 0,9\eta_{opt}$

2 volume flow rate range for one lower tolerance grade (e.g. AN2) for $0,8\eta_{opt} \leqslant \eta < 0,9\eta_{opt}$

3 volume flow rate range for two lower tolerance grade (e.g. AN3) for $0,6\eta_{opt} \leqslant \eta < 0,8\eta_{opt}$

4 volume flow rate range for three lower tolerance grade (e.g. AN4) for $\eta < 0,6\eta_{opt}$

5 volume flow rate for the tolerance grade selected (e.g. AN3) for $\eta \geqslant 0,9\eta_{opt}$

6 volume flow rate range for one lower tolerance grade (e.g. AN4) for $0,8\eta_{opt} \leqslant \eta < 0,9\eta_{opt}$

Figure 3 — Examples of assigning tolerance grades to nonadjustable fans

5.5.3.2 Agreements in performance testing

5.5.3.2.1 When the customer specification calls for measurements to be carried out to verify compliance with the contractual data, it shall be agreed as to how this is carried out. The options are as follows:

a) performance testing according to ISO 5801, ISO 13347-1 and ISO 14694;

b) performance testing using a geometrically similar model, according to the standards detailed above and converting, using the fan laws (see 7.1 and ISO 5801:1997, 15.1);

c) performance testing on-site according to ISO 5802, noting that this introduces additional uncertainties and also that, where inlet and outlet connections to the fan are not straight, an unknown system effect factor should be considered.

5.5.3.2.2 Arrangements for performance verification using standardized airways, subject to contractual agreement with the purchaser, may be made as follows.

a) The purchaser commissions the supplier to carry out the tests and supervises them himself or has them supervised by a qualified independent expert.

b) The purchaser commissions an accredited independent testing agency to carry out the tests. In this case, the supplier shall be informed and agree to the test set-up prior to the test.

c) The purchaser carries out the tests himself. In this case, the supplier shall be informed and agree to the test set-up prior to the test.

5.5.3.2.3 In all cases, standardized measuring methods shall use instrumentation that has been independently calibrated and shall have a valid certification traceable back to national or International Standards.

5.5.3.2.4 If a model is used to verify the specified performance criteria, the conversion rules for relating the model test data to the full-scale fan performance data shall be previously agreed between the purchaser and supplier. As appropriate, these rules shall meet the requirements of, or be based on the information contained in, ISO 5801 and ISO 13347-1.

5.5.3.2.5 On-site measurements on fans should be made as soon as possible after installation and preferably during the commissioning trials to ensure that all components of the “system” associated with the fan, including any controls, are operating correctly. This will assist in determining a proper judgement of the fan performance.

Before site tests are carried out, the supplier shall be given the opportunity to review scale drawings of the ducting arrangement, followed by an inspection of the site installation. If site electrical supplies are available, preliminary measurements should be taken.

5.5.3.2.6 If on-site performance test results show that a specified operating point does not, allowing for the tolerance grade specified, lie on the actual system lines, it shall be agreed by what method the operating point can be temporarily changed for the performance test (e.g. by short-circuiting or providing additional resistance). Alternatively, any permissible deviations from the specified operating points that result from a different system line shall be agreed. If this cannot be done, then tests should be carried out, by mutual arrangement between the purchaser and suppliers, in accordance with 5.5.3.2.1 b) or 5.5.3.2.1 c).

5.5.3.2.7 If certain installation conditions prevent testing to be undertaken in accordance with subclause 5.5.3.2.1, the purchaser and supplier shall either agree on other measurement conditions/positions, or in the light of the actual installation, specify permissible deviations from the specified operating points. If this cannot be done, then the performance tests may be conducted in accordance with subclauses 5.5.3.2.1 b) and 5.5.3.2.1 c).

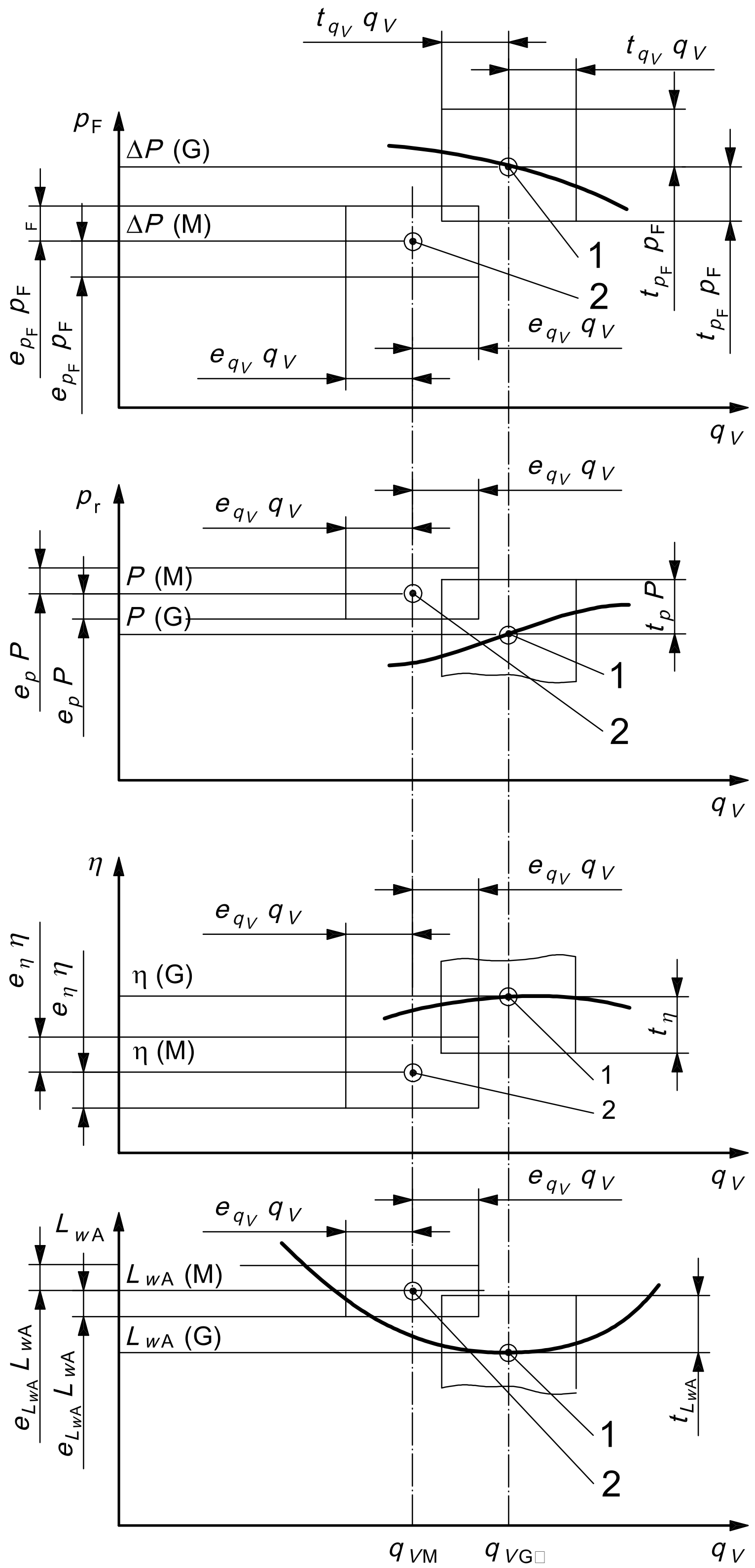
5.5.3.2.8 Sound testing may be carried out using standardized airways under laboratory conditions, or alternatively may be performed on site (where due account shall be taken of environmental influences. For example: reflection from building walls). An appropriate method from ISO 13347-1 shall be agreed. Any deviations from the specified levels shall be assessed in relation to the agreed tolerance grade.

5.5.3.2.9 Vibration tests may also be carried out on site or alternatively with the fan connected, via flexible connections, to a standardized airway. In either case the measurement procedures shall follow those laid down in ISO 14695. Deviations from the agreed levels selected from ISO 14694, shall be assessed in accordance with the balance and vibration tolerance grade chosen.

5.5.3.2.10 Fans check-tested with calibrated motors shall be tested at the same voltage as used for the motor calibration.

5.5.3.2.11 Fans rated at a specified speed shall preferably be tested at a speed within 5 % of this value. Values for each parameter shall in any case be converted to the agreed conditions (see 5.5.3.3).

5.5.3.2.12 The test speed of a belt-driven fan tested with a calibrated motor shall be within 5 % of the specified speed. Values for each parameter shall in any case be converted to the agreed conditions (see 5.5.3.2.11).



Key

p_F	fan pressure
P	fan power
L_{WA}	A-weighted fan sound power level
η	fan efficiency
q_V	volume flow rate
1	agreed operating point
2	measured value (actual operating point)

NOTE 1 "t" represents the tolerance specified for the operating point.

NOTE 2 "e" represents the uncertainty of measurement.

Figure 4 — Comparison of values measured during performance test with agreed operating points

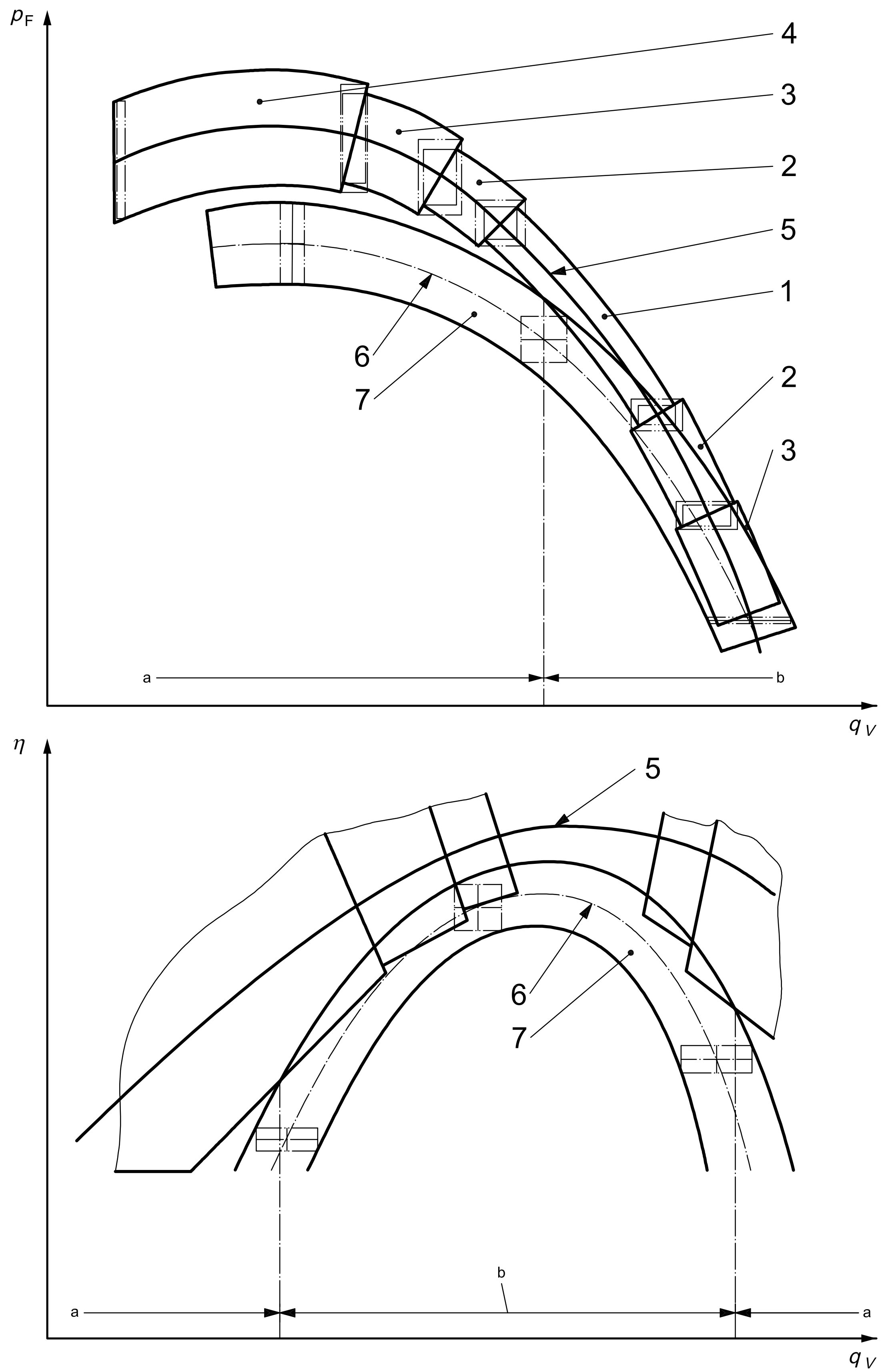


Figure 5 — Comparison of range of values measured during performance test with agreed operating points for specific parameters (efficiency and pressure increase)

Key

p_F fan pressure
η fan efficiency
q_V volume flow rate
1 limit deviation for agreed tolerance grade (e.g. AN1) i.e. for $\eta \geqslant 0{,}9\eta_{opt}$
2 limit deviation for agreed tolerance grade (e.g. AN2) i.e. for $0{,}8\eta_{opt} \leqslant \eta < 0{,}9\eta_{opt}$
3 limit deviation for agreed tolerance grade (e.g. AN3) i.e. for $0{,}6\eta_{opt} \leqslant \eta < 0{,}8\eta_{opt}$
4 limit deviation for agreed tolerance grade (e.g. AN4) i.e. for $\eta < 0{,}6\eta_{opt}$
5 agreed fan characteristic curve
6 measured fan characteristic
7 range of measured values (variability)

[a] Agreement not satisfied.

[b] Agreement satisfied.

Figure 5 (*continued*)

5.5.3.3 Criteria for compliance with specified operating points

The values measured for each parameter (operating points) shall be converted to the agreed conditions (rotational speed, temperature and density) using the fan laws. The specified operating points, when plotted as single points, shall be deemed as having been reached if the measured values fall within, or just touch, the tolerance zones specified for the relevant parameter (see Figure 4). The variability of values measured is a function of the uncertainty of measurement and of the limits of error of the measuring equipment (See ISO 5801:1997, Clause 17).

If the performance charts are used to plot the operating points of adjustable fans (see Figure 2), then the limit deviations as specified in Table 2 apply only to the specified tolerance zones. For nonadjustable fans, see Figure 3. The specified operating points shall be deemed as having been reached if the measured values (including scatter) fall within, or just touch, the tolerance zone specified for the relevant parameter, which is a function of the selected accuracy class (see Figure 4). By way of example, the boundary of the performance chart may coincide with part of a characteristic, which is the case for a fan having adjustable rotational speeds (see Figure 2). Figure 5 then shows the range of measured values against the specified characteristic (with the limit deviations being indicated as a function of the agreed accuracy class).

Regardless of the fan "setting" (e.g. inlet vane-control blade opening angle, axial fan blade pitch angle), a specified operating point shall be identified as having been reached if the other operating points, measured at a defined volume flow rate and converted to the agreed conditions, fall within or just touch the tolerance zones specified for the relevant parameters.

5.5.3.4 Performance uncertainties

Any test for fan performance is subject to error, and the range within which these testing errors may be expected to lie is defined numerically as the uncertainty of measurement. In addition, the true performance of the fan (if it could be ascertained) would be found to differ from that of another nominally identical fan, owing to inevitable variations in manufacture. The expected range of this manufacturing variation shall be added to the uncertainty of measurement to determine the minimum tolerance required for a performance specification.

6 Performance tolerances for series-produced fans in certified ratings programmes

6.1 General

Clause 6 does not apply to series-produced non-certified fans, which shall be treated in accordance with Clause 5.

Certified ratings programmes also deal with the subject of fan tolerances, but in a different way. These programmes are applicable to series-produced fans where the entire gas path dimensions and angles of a range of fans are geometrically similar one to another.

For details, consult the appropriate programmes in their latest version. Generally, these are based on the tests of all sizes or tests of smaller fans which are then extrapolated to larger sizes. The tests form the basis for approved catalogue data and may be verified by random data check-tests.

Contrary to the approach adopted in 5.3, the influence of manufacturing measuring tolerances on the volume flow is checked, assuming the fan is working in an idealized system, where the pressure losses are proportional to the square of the volume flowrate.

6.2 Fan laws

The fan laws (as defined in 7.1.5.1 and ISO 5801) shall serve as the basis for calculating the performance ratings of fans from tests of other sizes and speeds. Fan laws shall not be used for calculating the performance of a smaller sized fan from the testing of larger fans.

6.3 Check-tests

Products licensed under a certified ratings programme shall be subject to periodic check-tests at not more than at intervals of 36 months. When products are check-tested, the performance should be within the tolerance for airflow, pressure, power and efficiency (if certified), as defined below, when compared to the catalogue data published by the manufacturer. The check-tests shall be made using the same laboratory set-up and installation category as used by the fan manufacturer to collect the original data.

For products catalogued using constant or as-run speed tables, the tolerance shall be applied to the catalogue points only. For products catalogued using multi-rating tables or curves, the tolerance shall be applied over the performance range catalogued.

6.4 Air performance tolerances

6.4.1 Check-test tolerances

The check-test tolerances apply to all fans defined in the certified rating programme.

When fans are check-tested under the certified rating programme, the test performance shall be within the tolerance for airflow, pressure, power, and efficiency (if certified) as defined below, when compared to the catalogue data published by the manufacturer.

The tolerances allowed on air performance are based on the typical measurement uncertainties that can be experienced in a fan performance test conducted under laboratory conditions. Since both the original test, used to develop the catalogued data, and the check-test, are subject to measurement uncertainties, the applied tolerances make allowance for the combined uncertainties of the two tests and recognize variations occurring in the production of the fan.

Fans rated at a constant speed shall be tested at a speed within 5 % of the catalogued speed, corrections in accordance with the fan laws being applied.

The test speed of a belt-driven fan tested with a calibrated motor shall be within 5 % of the catalogue speed.

The air performance of fans tested at “as-run” speed shall be adjusted to the standard air density.

Fans check-tested with a calibrated motor shall be tested at the same voltage as that used for the motor calibration.

6.4.2 Airflow tolerance

The low limit fan pressure curve for acceptable fan air performance is derived by applying the airflow tolerance curve, defined by the equation in Figure 6, to the catalogue air performance data.

The low limit for airflow is

$$q_V\left(1-\frac{T}{100}\right)$$

The low limit for pressure is

$$p_{\text{sF}}\left(1-\frac{T}{100}\right)^2 \quad \text{or} \quad p_{\text{F}}\left(1-\frac{T}{100}\right)^2$$

where

T is the air flow check-test tolerance as a percentage (%);

q_V is the inlet volume flow rate expressed in cubic metres per second (m^3/s);

p_{sF} is fan static pressure expressed in pascals (Pa);

p_{F} is fan total pressure expressed in pascals (Pa).

The check-test performance shall not be less than the lower limit fan performance (curve or points) over the performance range catalogued.

6.4.3 Power tolerance

The power required by the check-test fan at the catalogued speed shall not exceed the rated power (curve or points) at the measured airflow rate by more than 5 % or 37 W, whichever is the greater. For units rated in motor input watts, the measured input watts shall not exceed the rated input watts by 5 % or 50 W, whichever is the greater. The tolerance allowed for fan power is applied to the catalogued power for each airflow rate.

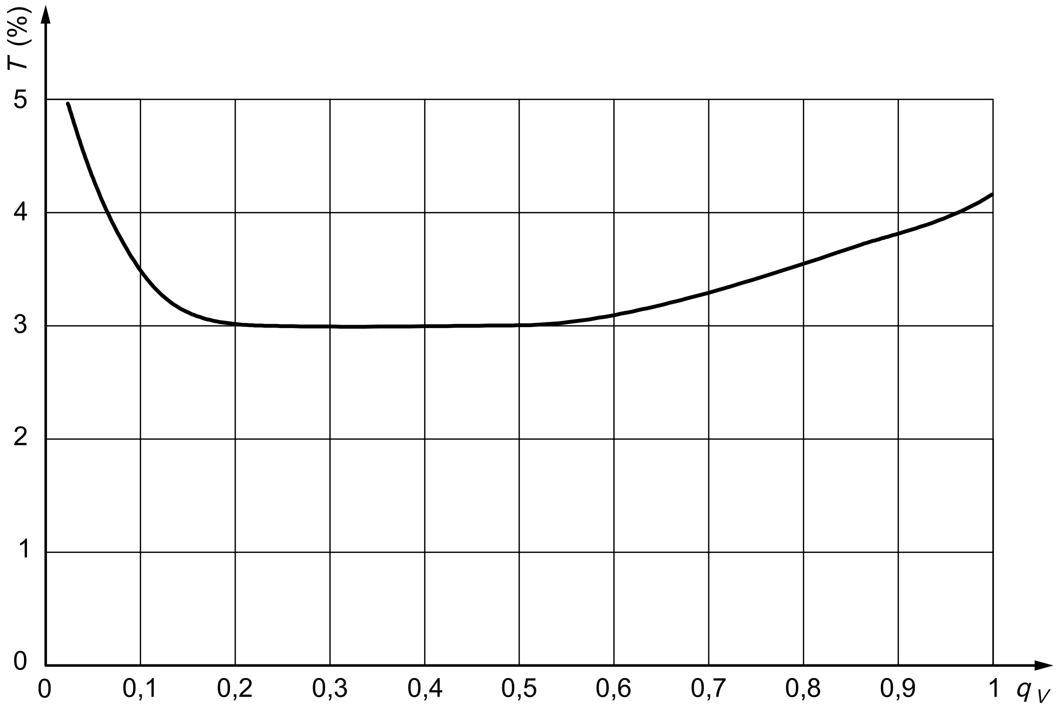
6.4.4 Efficiency tolerance

The efficiency of the check-test fan shall not be more than 6 percentage points below the catalogued efficiency at the measured airflow rate. The manufacturer shall clearly state over what range of airflow the efficiencies are certified.

6.4.5 Application of tolerances

Figure 7 illustrates how the tolerances are applied to the catalogue fan performance rating.

For fans catalogued at constant or as-run speed tables, the tolerance shall be applied to the catalogue points only. For fans catalogued using multi-rating tables or curves, the tolerance shall be applied over the performance range catalogued.



$$T = (A_0 + A_1 q_F + A_2 q_F^2 + A_3 q_F^3 + A_4 q_F^4 + A_5 q_F^5 + A_6 q_F^6) \times 100$$

where A_0 = 0,058 398; A_1 = – 0,404 055; A_2 = 2,249 039; A_3 = – 6,227 258; A_4 = 9,037 960; A_5 = – 6,527 091, A_6 = 1,854 642.

Key

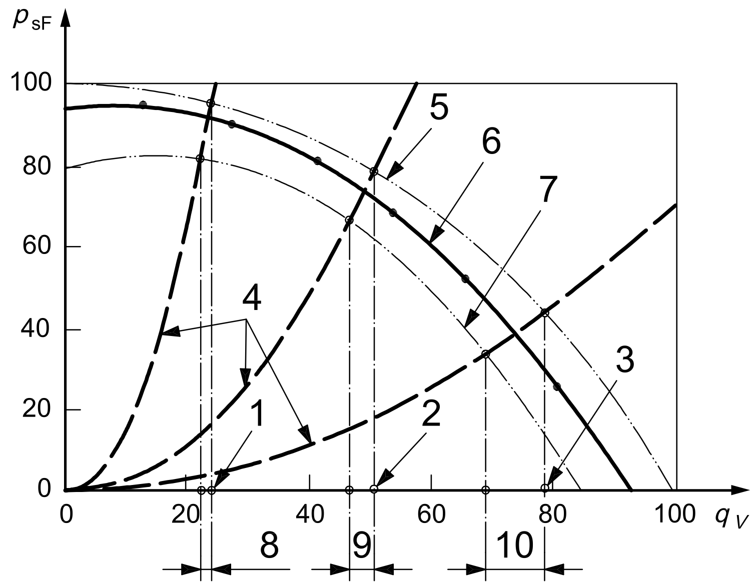
T airflow tolerance (%)

q_F fraction of free delivery fan airflow rate at the catalogued duty point, $q_F = q_1/q_0$

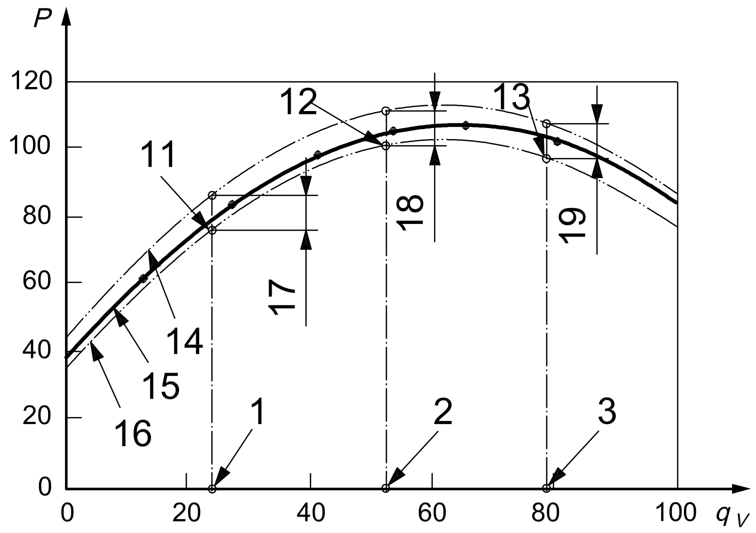
q_1 fan airflow rate at the catalogued duty point

q_0 fan-catalogued free delivery airflow rate

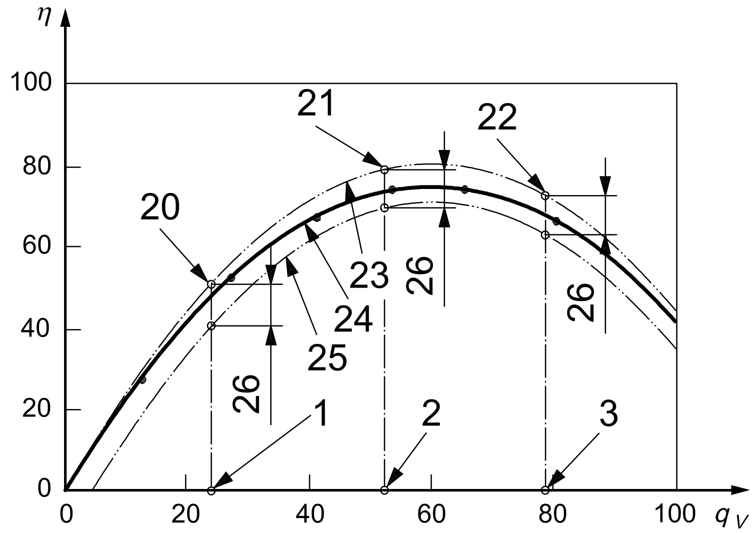
Figure 6 — Airflow tolerance curve



a) Application of tolerance on fan static pressure



b) Application of tolerance on fan power



c) Application of tolerance on fan efficiency

Figure 7 — Tolerances applied over the full range of fan performance

Key

p_{sF} fan static pressure
P fan power
η fan efficiency (%)
q_V fan volume flow rate
1 Q_1 rated
2 Q_2 rated
3 Q_3 rated
4 parabolic system resistance curves
5 rated fan pressure curve
6 measured pressure curve from fan test
7 lowest allowable fan pressure curve
8 airflow tolerance given by (T_Q/100 × Q_1 rated)
9 airflow tolerance given by (T_Q/100 × Q_2 rated)
10 airflow tolerance given by (T_Q/100 × Q_3 rated)
11 rated fan power W_1 at Q_1
12 rated fan power W_2 at Q_2
13 rated fan power W_3 at Q_3
14 highest allowable fan power curve
15 measured fan power curve at test
16 rated fan power curve
17 fan power tolerance at Q_1 flow given by (T_W/100 × W_1 rated)
18 fan power tolerance at Q_2 flow given by (T_W/100 × W_2 rated)
19 fan power tolerance at Q_3 flow given by (T_W/100 × W_3 rated)
20 rated fan efficiency at Q_1
21 rated fan efficiency at Q_2
22 rated fan efficiency at Q_3
23 rated fan efficiency curve
24 calculated fan efficiency curve from fan test
25 lowest allowable fan efficiency curve
26 tolerance T

NOTE The values of the tolerance in the graphs have been exaggerated for the sake of clarity.

Figure 7 (*continued*)

6.5 Sound tolerances

6.5.1 Check-test tolerances

If both air performance and sound performance certification is required, the fan selected for the check-test shall be used for both air and sound performance check-tests. The requirements specified in 6.1.4 apply to the sound check.

6.5.2 Sound tolerances in octave bands

The sound ratings of the check-test fan, while performing within the air performance tolerances specified in 6.1.4, shall not exceed the published ratings of sound power levels by more than 6 dB in the first (63 Hz) octave band and 3 dB in any other octave band.

6.5.3 Sone value tolerance

The sone value, calculated from the sound ratings of the check-test fan reduced by 6 dB in the first octave band and 3 dB in any other band, shall not exceed the published sone value.

6.5.4 A-weighted sound power level tolerance

The A-weighted sound power level, calculated from the sound ratings of the check-test fan with the sound levels being reduced by 6 dB in the first octave band and 3 dB in all other octave bands, shall not exceed the published value of the A-weighted sound power level.

7 Methods of conversion

7.1 Conversion of air performance test data

7.1.1 General

The test results can only be compared directly with the guaranteed values when, during the acceptance tests, the measurements of the performance of the fan are taken under the specified conditions (see ISO 5801).

In most fan tests it is not possible to exactly reproduce and maintain the operating and/or driving conditions on the test airway as specified in the operating conditions.

Calculations may be required and the converted results may then be compared with the specified values.

For very large fans, model tests may be conducted in standardized airways when a full-scale test is impracticable owing to the limitations on power supply and/or the dimensions of standardized test airways.

Where performance data for a range of fans is to be generated from a limited number of tests, and the flow can be treated as incompressible, (see ISO 5801:1997, 13.9), alternative procedures may be used even when strict geometric similarity is not maintained. The procedures are detailed in 7.1.4.

7.1.2 Similarity and the fan laws

See ISO 5801:1997, 15.1.

7.1.3 Conversion rules

See ISO 5801:1997, 15.2.

7.1.4 Conversion rules for series-produced fans

7.1.4.1 Direct tests: no change of impeller size

There are two restrictions on the use of direct conversions: the change in compressibility and the change in peripheral Reynolds number. Within the scope of 7.1.4, the effects of compressibility are ignored on the assumption that the limits of ISO 5801:1997, 15.2.2 are not exceeded.

The peripheral Reynolds number at the rated conditions shall be greater than 0,67 times and less than 1,5 times the peripheral Reynolds number at the test conditions. Thus:

$$0{,}67 Re_{u\mathrm{Te}} < Re_u < 1{,}5 Re_{u\mathrm{Te}}$$

NOTE Subscript suffix “Te” denotes the fan test condition.

7.1.4.2 Indirect tests: change of fan size, speed and inlet density

There are two restrictions on the use of direct conversions: the change in compressibility and the change in peripheral Reynolds number. The comments on compressibility are the same as those for the direct tests given in 7.1.4.1. For an indirect test there are two aspects to the restriction on peripheral Reynolds number.

Firstly the impeller diameter of the fan to be rated shall be at least greater than or equal to that of the fan tested, i.e.

$$D_r \geqslant D_{rTe}$$

and secondly, that the peripheral Reynolds number at the rated conditions shall be greater than 0,7 times the test peripheral Reynolds number, i.e.

$$Re_u > 0{,}7 Re_{u\mathrm{Te}}$$

$$\frac{D_r{}^2 \times N \times \rho_1}{\mu} \geqslant \frac{0{,}7 \times D_{r\mathrm{Te}}^2 \times N_{\mathrm{Te}} \times \rho_{1\mathrm{Te}}}{\mu}$$

7.1.5 Conversion rules for extrapolation

7.1.5.1 Fan laws

The conversion rules for both direct and indirect conversions are given by the following relationships.

$$\frac{q_V}{q_{V\mathrm{Te}}} = \frac{n}{n_{\mathrm{Te}}} \times \frac{D_r^3}{D_{r\mathrm{Te}}^3}$$

$$\frac{p_{\mathrm{tF}}}{p_{\mathrm{tFTe}}} = \frac{p_{\mathrm{sF}}}{p_{\mathrm{sFTe}}} = \frac{p_{\mathrm{dF}}}{p_{\mathrm{dFTe}}} = \frac{n^2}{n_{\mathrm{Te}}^2} \times \frac{D_r^2}{D_{r\mathrm{Te}}^2} \times \frac{\rho_1}{\rho_{1\mathrm{Te}}}$$

$$\frac{P_r}{P_{r\mathrm{Te}}} = \frac{n_r^3}{n_{r\mathrm{Te}}^3} \times \frac{D_r^5}{D_{r\mathrm{Te}}^5} \times \frac{\rho_1}{\rho_{1\mathrm{Te}}}$$

NOTE 1 For direct tests $D_r = D_{r\mathrm{Te}}$.

NOTE 2 Subscript suffix Te denotes the fan test condition.

7.1.5.2 Efficiency of other sizes

Since larger fans in a geometrically similar range tend to perform better than smaller fans, it is preferable to test a number of fans in the series such that the performance of a fan is never calculated from a larger size.

Where this cannot be achieved, then by agreement between the purchaser and the manufacturer, a formula such as the Ackeret formula may be used to calculate the efficiency of either a larger or smaller fan. For better safety, use half the increase, for increased size, or the full decrease for a smaller size. The following formula is only applicable in the vicinity of the best fan efficiency:

$$\eta = 1 - 0{,}5\left(1 - \eta_{\mathrm{Te}}\right)\left[1 + \left(\frac{Re_u}{Re_{u\mathrm{Te}}}\right)^{0{,}2}\right]$$

where

η	is the efficiency of the fan to be calculated;
η_{Te}	is the efficiency of the test fan;
Re_u	is the peripheral Reynolds number of the fan to be calculated;
$Re_{u\mathrm{Te}}$	is the peripheral Reynolds number of the test fan.

Re_u, $Re_{u\mathrm{Te}}$ shall not differ by more than 40 %.

Other parameters shall be calculated strictly in accordance with the fan laws. It should be noted that experience of the use of Ackeret formula is limited and that it has not always proved correct.

7.1.6 Outline scaling procedures using interpolation of test data

Within a series of geometrically similar fans, it may be possible to estimate the performance of a fan of an untested size by the interpolation of test data. Interpolation between three fan sizes may yield better results than between two. The performance of a fan of intermediate size is estimated by interpolating data from tests on units of greater and lesser size. There are two limiting conditions: that the size of the larger unit may not be more than twice that of the smaller unit and that the peripheral Reynolds numbers of the larger and smaller units shall not differ by more than a factor of four.

Illustration of a possible interpolation scheme is probably most easily demonstrated by example. Assume that a manufacturer has decided to test three fans of diameters 400 mm, 710 mm and 1250 mm at a constant rotational speed and to derive the performance of units of 500 mm, 630 mm, 800 mm, 900 mm and 1 000 mm by interpolation. The fan of 710 mm is less than twice the diameter of the 400 mm unit and more than half the diameter of the 1 250 mm fan so that the first limitation is satisfied. Similarly, since the rotational speed is constant the peripheral Reynolds number limitation is also satisfied.

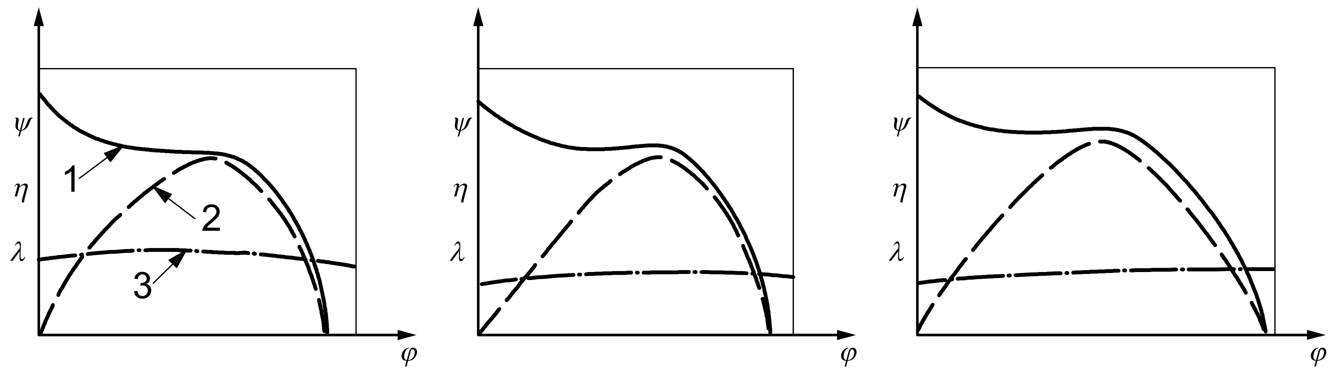
All experimental testing shall be performed following the procedures of ISO 5801. It should be noted that in scaling the performance, the efficiency likely to scale is the impeller efficiency. Allowance shall therefore be made for drive and transmission efficiencies when deriving the impeller efficiency.

Having measured the performance of the selected fans, the performance may be non-dimensionalized in terms of the non-dimensional flow coefficient φ, pressure coefficient ψ, power coefficient λ, and the efficiency η.

For each fan ψ, λ, and η can be plotted as a function of φ, see Figure 8. Parabolic lines of the form

$$\psi = k\varphi^2$$

can be drawn on the ψ versus φ plot for a range of values k, as shown in Figure 9.

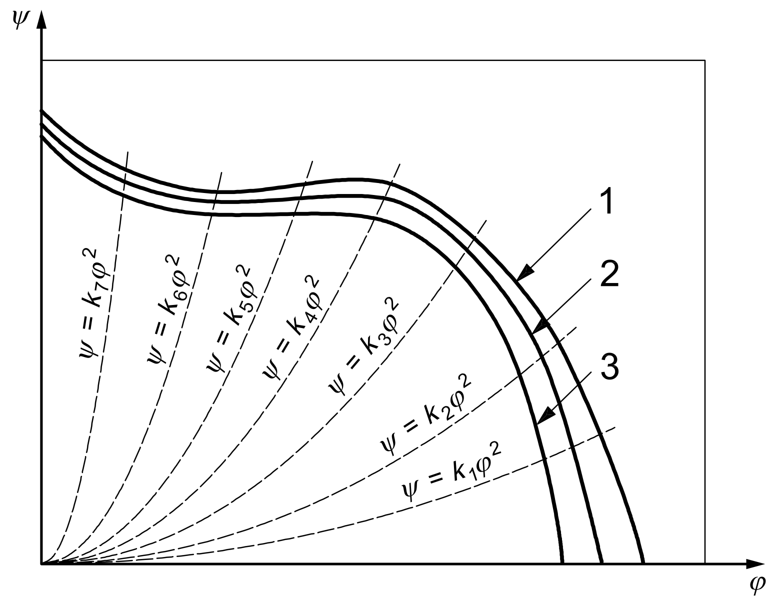


a) Diameter 400 mm **b) Diameter 710 mm** **c) Diameter 1 250 mm**

Key

- φ flow coefficient
- ψ pressure coefficient
- η efficiency
- λ power coefficient
- 1 fan pressure coefficient characteristic curve
- 2 fan efficiency curve
- 3 fan power coefficient characteristic curve

Figure 8 — Non-dimensional presentation of measured fan performance



Key

- φ non-dimensional flow coefficient
- ψ non-dimensional pressure coefficient
- 1 impeller diameter of 1 250 mm
- 2 impeller diameter of 710 mm
- 3 impeller diameter of 400 mm

Figure 9 — Non-dimensional performance with system lines superimposed

For any given value of k, it is now possible to read off the values of φ and ψ for each fan size and, for each value of φ, to read off the corresponding values of λ and η. Thus we can have the tabulated information as given in Table 3, for example.

Table 3 — Values of φ, ψ, λ and η for different parabolic constants and impeller diameters at constant rotational speed

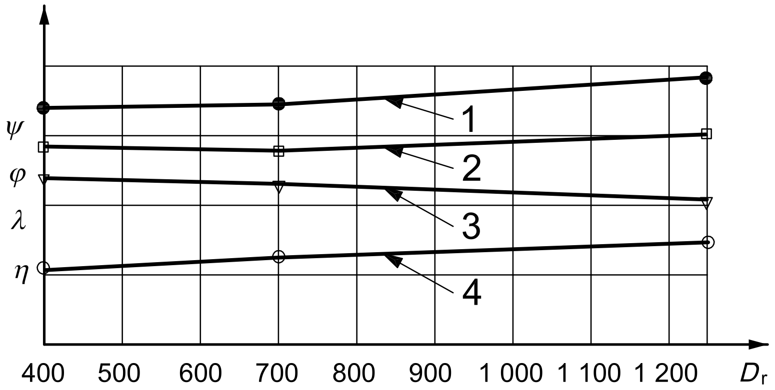
Parabolic constant $k = k_1$	D_r = 400 mm	D_r = 710 mm	D_r = 1 250 mm
Flow coefficient, φ	φ_{400}	φ_{710}	$\varphi_{1\,250}$
Fan pressure coefficient, ψ	ψ_{400}	ψ_{710}	$\psi_{1\,250}$
Fan power coefficient, λ	λ_{400}	λ_{710}	$\lambda_{1\,250}$
Fan efficiency, η	η_{400}	η_{710}	$\eta_{1\,250}$
Parabolic constant $k = k_2$	D_r = 400 mm	D_r = 710 mm	D_r = 1 250 mm
Flow coefficient, φ	φ_{400}	φ_{710}	$\varphi_{1\,250}$
Fan pressure coefficient, ψ	ψ_{400}	ψ_{710}	$\psi_{1\,250}$
Fan power coefficient, λ	λ_{400}	λ_{710}	$\lambda_{1\,250}$
Fan efficiency, η	η_{400}	η_{710}	$\eta_{1\,250}$
Parabolic constant $k = k_3$	D_r = 400 mm	D_r = 710 mm	D_r = 1 250 mm
Flow coefficient, φ	φ_{400}	φ_{710}	$\varphi_{1\,250}$
Fan pressure coefficient, ψ	ψ_{400}	ψ_{710}	$\psi_{1\,250}$
Fan power coefficient, λ	λ_{400}	λ_{710}	$\lambda_{1\,250}$
Fan efficiency, η	η_{400}	η_{710}	$\eta_{1\,250}$

The next stage is, for each value of k, to plot the test points as shown in Figure 10 where the ordinate axis, size is linear. The test points should be joined up with straight lines.

If there is a change in the value of the gradient of two adjacent segments, it will be necessary to investigate the effect further by performing extra tests at intermediate sizes (see Figure 11). If there is a significant change of gradient between two adjacent segments, some additional information should be produced (see Figure 12) to substantiate the validity of the test data.

If the manufacturer has evidence — for example, from a previous, more detailed investigation — that a better fit to the test data would be a smooth curve, a smooth curve should be drawn through the points.

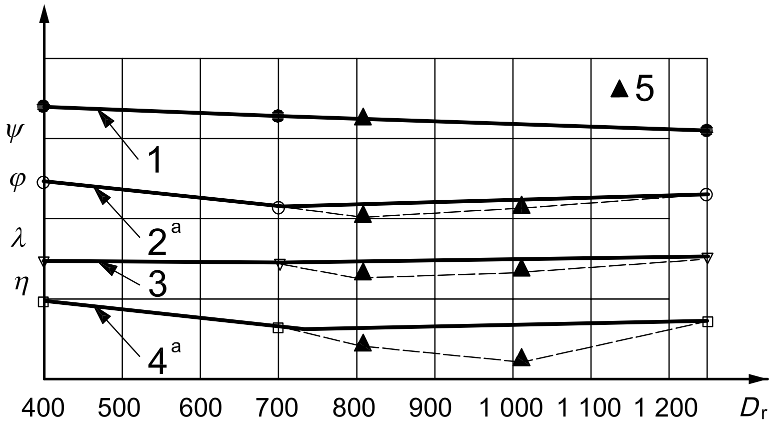
Interpolated values of φ, ψ, λ and η can then be read off the plots at the desired size for each value of the parabolic constant, k, and from the known size and speed the dimensional performance can be deduced.



Key

- φ flow coefficient
- ψ pressure coefficient
- η efficiency
- λ power coefficient
- D_r diameter of impeller, mm
- 1 fan pressure coefficient
- 2 fan flow coefficient
- 3 fan power coefficient
- 4 fan efficiency coefficient

Figure 10 — Interpolation at constant system condition



Key

- φ flow coefficient
- ψ pressure coefficient
- η efficiency
- λ power coefficient
- D_r diameter of impeller, mm
- 1 fan pressure coefficient
- 2 fan efficiency coefficient
- 3 fan power coefficient
- 4 fan flow coefficient
- 5 additional test point required

[a] Parameters showing a change in gradient.

Figure 11 — Interpolation at constant system condition showing sign or gradient change and benefit of additional test points

7.1.7 Interpolation for fans incorporating one systematic geometrical change

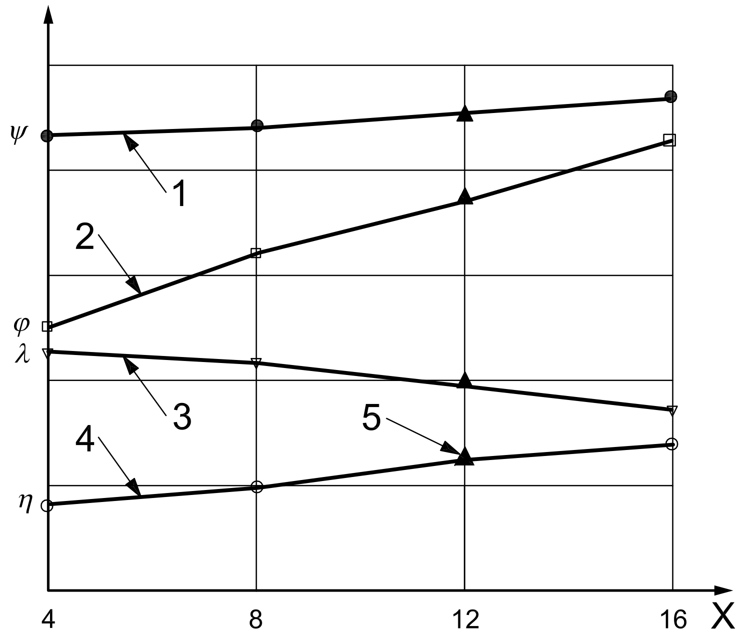
A range of fans is often developed in a manner in which units of a differing size are not geometrically similar, but are geometrically related. Examples of this type include changes to the width of centrifugal impellers, the production of an axial fan range from a single hub, and blade moulding to form fans of different diameter by cropping the blade tips. On many occasions it could be possible to estimate the performance of the complete fan range by interpolating data obtained from tests on a limited number of fans within the range.

It is recommended that the performance test be carried out on a minimum of three sizes of fans; however, since the effect of geometrical changes is liable to be non-linear, more tests could be required.

One possible scaling procedure is to follow the method outlined in 7.1.6 to produce plots of the type shown in Figure 12, which are analogous to those of Figure 10. The test points should be joined with straight lines. If there is a change in the sign of the gradient of adjacent segments, additional tests at intermediate sizes shall be performed in order to further investigate the effect. If there is a significant change in gradient between adjacent segments, additional information should be produced to substantiate the validity of the test data.

If the manufacturer has evidence, for example, from a previous detailed investigation that a better fit to the test data would be a smooth curve, then a smooth curve may be drawn through the points.

Interpolated values of φ, ψ, λ and η can then be read off the plots at the desired conditions and the fan dimensional performance deduced.



Key

- φ flow coefficient
- ψ pressure coefficient
- η efficiency
- λ power coefficient
- X number of impeller blades
- 1 fan pressure coefficient
- 2 fan flow coefficient
- 3 fan power coefficient
- 4 fan efficiency coefficient
- 5 additional test point required

Figure 12 — Interpolation at constant system condition showing significant change of gradient and incorporation of additional test points

7.1.8 Other identities

The performance of a series of axial flow fans that are geometrically similar but not identical can also be derived for units where an important dimension and/or attribute have been altered. Examples of this would include, but are not limited to, changing blade numbers and chord while maintaining blade similarity, and tip solidity (ratio of total of blade chords divided by swept circumference). In such cases it may be possible to derive the aerodynamic performance of the fan range, or parts thereof, by the testing of a number of units (a minimum of three sizes) and demonstrating that a clear identity exists between the fan performance and the variable(s). It is incumbent on the manufacturer to establish the validity of the relationship and to ensure that it results in a rating of the fan within the specified performance tolerances.

The procedure for establishing the relationship is the responsibility of the manufacturer, but it shall be based on accepted theory supported by data from experimental tests conducted to the same standard and using the same test method as that used for the remainder of the range. It is recommended that a check-test of one or more fans be carried out by an independent laboratory to validate the procedure.

7.2 Conversion of sound power test data

7.2.1 General

Similarly to the situation regarding the establishment of air performance data, it will not be practical to establish sound data at all speeds, densities and sizes covered by a particular fan series.

Conversion rules in accordance with 7.2.3 may be used to complete the fan catalogue sound data.

7.2.2 Conditions and limits for application of conversion rules to total sound power level

7.2.2.1 Applicability

Conversion rules for the total sound power level though with additional restrictions, can be used under similar circumstances to those outlined in 7.1.4. It shall be appreciated, however, that the conversion of sound data applies to the same points of fan rating as related by the conversion rules for air performance data given in 7.1.4.

7.2.2.2 Conversion rules for total sound power level

The conversion rule, which follows, only relates to the sound generated by the fan. Other sources of noise, such as bearings, drives or motors, are excluded.

Further it is applicable to changes of speed only, with the purpose of correcting the sound power level to a fixed or specified speed not differing by more than 5 % higher or 10 % lower than test speed.

The estimated change of total sound power level in decibels for a change of speed for the linear sound power level at the test point can be estimated from the formula

$$L_W = L_{W\mathrm{Te}} + 50\ \lg \frac{n}{n_{\mathrm{Te}}}$$

NOTE 1 Subscript “Te” denotes the fan test condition.

NOTE 2 This formula does not apply to A-weighted total sound power levels.

Guidance for conversion for speed changes greater than those specified in ISO 13347-1:2004, Annex A for changes of size with geometrically similar fans is given in the following subclauses. However, because of the complex nature of sound generation in fans, the uncertainties of such sound power level predictions are greater than those obtained from a direct test.

7.2.3 Generalized methods for sound power level prediction

7.2.3.1 General

Because of the complex nature of sound generation in fans, the method given in this subclause may be taken only as a guide, with no general recommendations as to the likely magnitude of the uncertainties of the results. This formula has been found to be suitable for axial-type fans, but its use with centrifugal fans should be used with caution due to the problems of acoustic or mechanical resonances. The starting data for these methods are unweighted octave band or, better, third octave band sound power levels, not A-weighted values.

The method relates only to the aerodynamic source of the noise and a separate prediction for the mechanical noise content needs to be made if this is likely to be significant.

It applies to fans having geometric similarity and the same number of blades, in the same type of installation and operating at the same point on the fan characteristic, that is at the same non-dimensional system parabolic constant k. Inlet and outlet noise should be separately analysed and predicted.

NOTE Changes in obstructions such as bearings or motor-supports, leakage clearances and similar features affecting flow can have a significant effect upon the sound spectrum. Their dimensions commonly decline as a proportion of D_r with increasing size, so that an empirical factor for departures from geometric similarity could improve prediction.

7.2.3.2 Outline of the method

The octave band sound power level, L_{Wfc}, at any required centre frequency, f_c, and for any specified size and speed of fan in the series investigated will be given by

$$L_{Wfc} = L_g + 10(6 + a)\lg n + 10(8 + 2a + b)\lg D_r$$

where

n is the rotational speed, in revolutions per second r/s;

D_r is the impeller tip diameter, in metres (m);

f_c is the band centre frequency, in hertz (Hz);

L_g is an experimental function of f_c and n;

a, b are the experimental indices for the series.

Octave band levels are predicted by this method. Third-octave levels could be predicted if desired by changing the test values of L_{WTe} to third-octaves with corresponding revision to L_{go} and L_g, L_{go} being the sound power level at a specified speed, see 7.2.3.3.

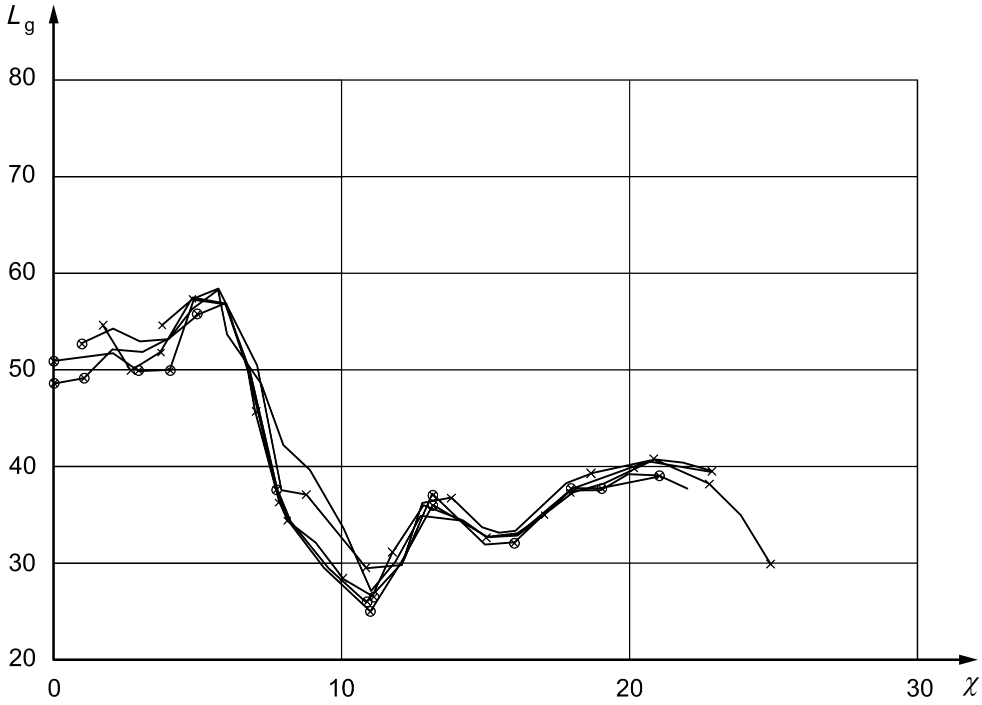
The function L_g is derived from a programme of tests on members of the fan series covering the range of n and D_r and determining values for a and b. It has the form of a single generalized spectrum of octave-band sound power level plotted against χ and may be extrapolated by not more than one octave beyond the last plotted value of χ, following the general shape of the spectrum approaching each end, where $\chi = 10\lg(f_c/n)$.

A set of data, taken from one-third octave tests on some mixed-flow fans, is shown by way of illustrating the type of plot which should result from the programme of tests in Figures 13 and 14.

The error in L_W caused by ignoring variations in ambient conditions will not exceed 0,5 dB provided that

a) ambient pressure lies between 90 kPa and 110 kPa, and

b) ambient temperature lies between 10 °C and 30 °C.



Key

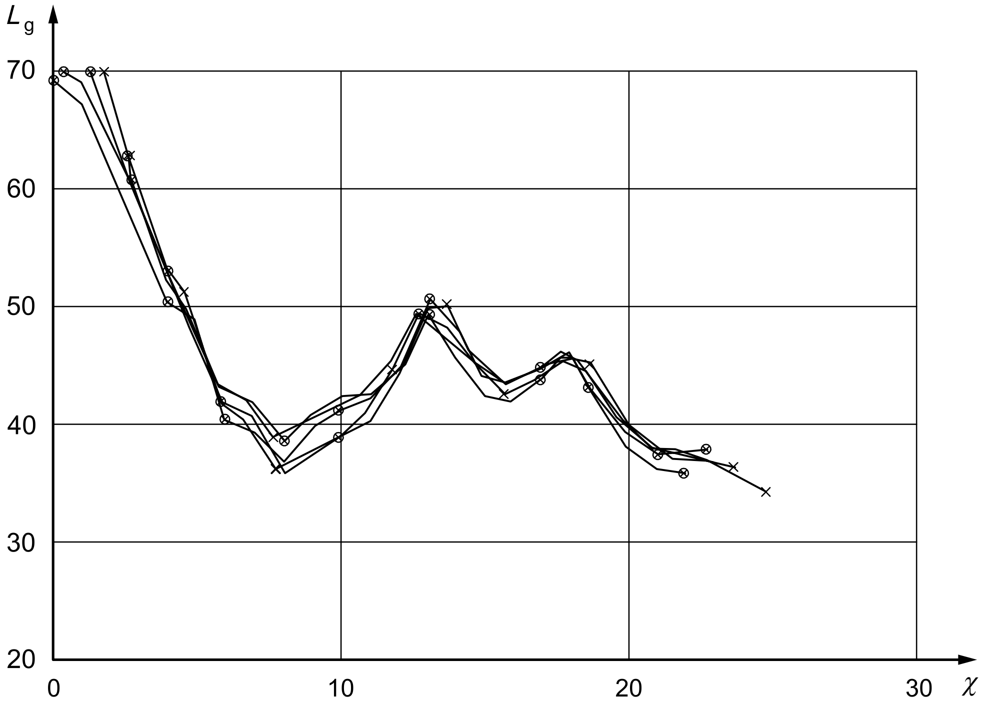
L_g experimental function of f_c and n

χ = 10lg(f_c/n)

⊗ D_r = 315 mm

× D_r = 630 mm

Figure 13 — Plot of L_g against χ for a mixed-flow fan at inlet, with φ = 0,45



Key

L_g experimental function of f_c and n

χ = 10lg(f_c/n)

⊗ D_r = 315 mm

× D_r = 630 mm

Figure 14 — Plot of L_g against χ for a mixed-flow fan at outlet with φ = 0,45

7.2.3.3 Determination of experimental constants a, b and L_g

The experimental programme should include several sizes of fan from the series, including the smallest and largest that can be tested with accuracy. Each size should be tested over the widest possible range of speed. For all the tests, the value of φ shall be the same and the air conditions at fan inlet preferably within the limits given in 7.2.3.2. If ambient pressure covers a wider range, correct approximately to atmospheric pressure p_a by subtracting 5lg(p/p_a) from each observed L_W.

At each value of D_r and n the fan sound power level should be measured in the 24 third-octave bands from 50 Hz to 10 kHz. For calculation purposes, 8-octave band levels can then be evaluated by adding the three adjacent third-octave sound powers around each third-octave centre frequency from 63 Hz to 8 kHz.

$$L_W = 10\lg\left[10^{\left(\frac{L_{W63}}{10}\right)} + 10^{\left(\frac{L_{W80}}{10}\right)} + 10^{\left(\frac{L_{W100}}{10}\right)}\right]$$

Read off (by interpolation if necessary) the octave band level L_W at the same value of f_c/n in each of the tests defined by D_r and n. Calculate L_{go} from the equation given in 7.2.3.2, but with the assumptions that $a = 0$ and $b = 0$.

$$L_W = L_{WTe} - 60\lg n - 80\lg D_r$$

L_{go} should then be plotted against 10lg Re_u. If the points over the range of n at one value of D_r lie approximately on a straight line, its slope will be a.

If the points for other values of D_r lie about the same line, it shows that geometrical similarity is well maintained; a is normally negative.

If departures from geometric similarity progress regularly with size, a series of parallel straight lines with slope "a" should be formed at successive values of D_r. Join points having the same value of nD_r and, if approximately straight lines are formed, their slope will be $(a + b)$; b is normally negative. See Figure 15.

If points at a common nD_r are quite irregularly scattered, it will be necessary to take $b = 0$ and determine a separate value of L_g for each D_r.

When a and b have been determined, calculate L_{gTe} at each test value:

$$L_{gTe} = L_{go} - 10a \lg n - 10(2a + b) \lg D_r$$

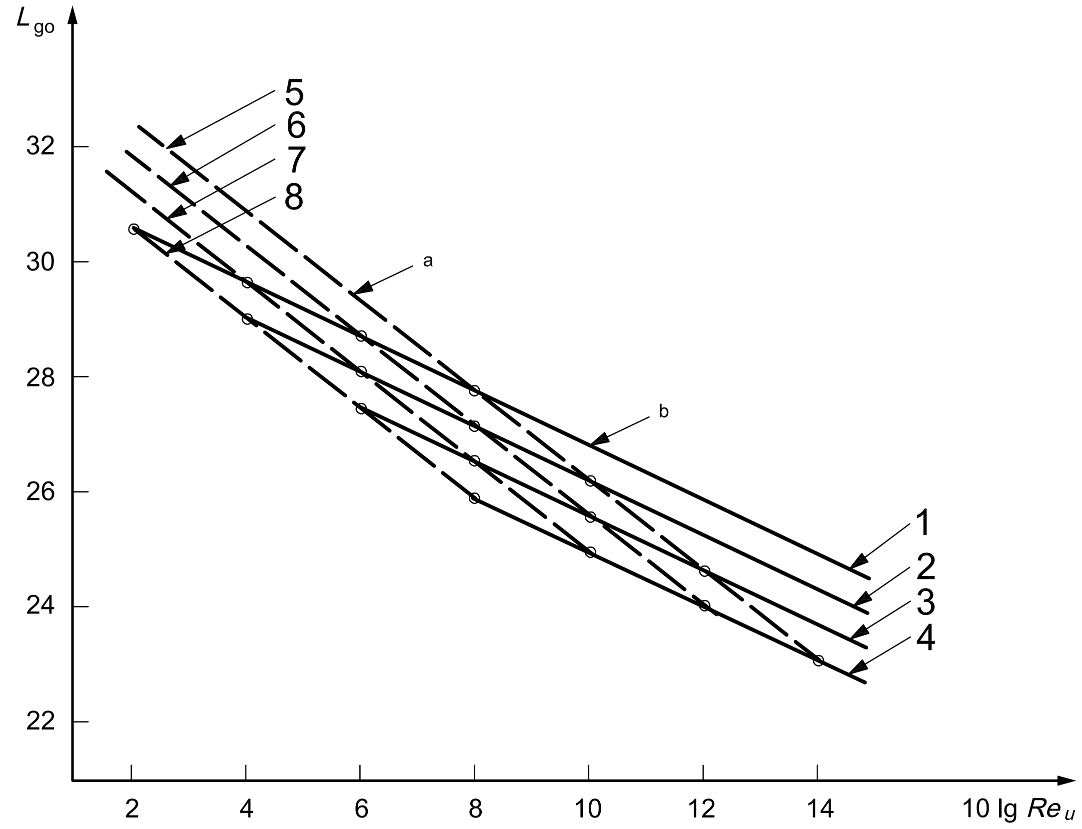
L_g will then be the average of the test values L_{gTe}. The spread of the L_{gTe} values about L_g will establish the level of confidence to be placed in a prediction according to the expression in 7.2.3.2 for the point f_c/n on the generalized spectrum.

NOTE 1 It may be found that at values of χ corresponding to blade passage frequency and its harmonics, a larger scatter of test data is evident. This scatter may be used as a guide to the greater uncertainty of prediction in the band levels containing the blade passage frequency and its harmonics.

Repeat at other values of f_c/n, since it shall be recognized that a and b may not have the same values over the whole spectrum. Plot the generalized spectrum of L_g against $10\lg f_c/n$ as far as constants a and b can be used.

Repeat at other values of φ to find out how far over the fan characteristic the same values of a and b can be used, with new spectra of L_g.

NOTE 2 If the fan series has sizes following the recommendations of ISO 13351, it will be convenient to select test sizes D_r from a preferred number series such as the R5, and to select test speeds from the same series (constant value f_c/n and nD_r and f_c without the need for interpolation.)



Key

L_{go} sound power level at a specified speed
Re_u Reynolds number
1 $D_r = 0{,}25$ m
2 $D_r = 0{,}40$ m
3 $D_r = 0{,}63$ m
4 $D_r = 1{,}00$ m
5 $n \cdot D_r = 25$
6 $n \cdot D_r = 16$
7 $n \cdot D_r = 10$
8 $n \cdot D_r = 6{,}3$

[a] Slope: $a + b = -0{,}8$.

[b] Slope: $a = -0{,}5$.

Figure 15 — Example of determination of a and b for a typical fan series

7.2.3.4 Octave and one-third octave band centre frequencies

The centre frequencies of the standard octave and one-third octave frequency bands are given in Table 4, according to ISO 266:

Table 4 — Octave band centre frequencies

Octave band number	Octave band centre frequency Hz	One-third octave band centre frequency Hz
1	63	50 63 80
2	125	100 125 160
3	250	200 250 315
4	500	400 500 630
5	1 000	800 1 000 1 250
6	2 000	1 600 2 000 2 500
7	4 000	3 150 4 000 5 000
8	8 000	6 300 8 000 10 000

7.2.3.5 A-weighted sound power level

Where it is considered useful to quote a single representative magnitude of sound level, the preferred level for fans fitted with duct connections is the A-weighted sound power level L_{WA} (see 3.22) calculated from the sound power spectrum. The A-weighted corrections, C_i, are given in Table 5

Table 5 — A-weighted octave band correction

Octave band number	Octave band centre frequency Hz	Correction[a] C_i dB
1	63	− 26,2
2	125	− 16,1
3	250	− 8,6
4	500	− 3,2
5	1 000	0
6	2 000	+ 1,2
7	4 000	+ 1,0
8	8 000	− 1,1

[a] Correction values taken from ISO 266.

Applying these corrections to the sound power levels, L_{WTe} in each octave band, and adding logarithmically, gives the A-weighted sound power level. Thus the A-weighted sound power level, in dB(A), is given by

$$L_{WA} = 10\lg\left\{\sum_{i=1}^{8} 10^{\left[\left(L_{Wi}+C_i\right)/10\right]}\right\} \qquad \text{[referenced to } 10^{-12}\text{ W (1 pW)]}$$

7.2.3.6 A-weighted sound pressure level

As an alternative on category A partition-mounted fans, an A-weighted sound pressure level, L_{pA}, assuming hemispherical radiation, may be quoted. Where a single-figure L_{pA} is quoted, it should be accompanied by the following qualifying information:

a) a statement indicating that the L_{pA} decibel value in dB (A) is included for comparative purposes only and that the real sound pressure level experienced will depend on the acoustic characteristics of the area being serviced by the fan, provided there is a uniform field with no directional characteristics;

b) the distance from the source to the microphone to which the L_{pA} value is referred, for example, 3 m;

c) that spherical or hemispherical free field radiation is assumed;

d) that the value is not guaranteed or subject to performance tolerances.

Points b) to d) should be given alongside the L_{pA} value.

8 Technical data presentation

8.1 General

The purpose of this clause is to help provide a clear unambiguous and uniform presentation for fan technical data in publications. The clause is intended for use by manufacturers of series-produced fans and will generally apply to fans where the flow can be considered as incompressible.

8.2 Essential information

The following information shall be provided.

a) Installation categories for which data are presented (A, B, C or D).

b) Test code and method used to establish basic performance data (in accordance with ISO 5801). Outline dimensions and weights including fan inlet and outlet areas.

c) Tolerance grade and scope of applicability — where appropriate.

d) Moment of inertia of driven assembly — where appropriate.

e) Speed, torque or power limitations — where appropriate.

8.3 Fan performance chart

The following information shall be provided. See Figure 16 and Table 6.

a) Density at fan inlet (normally 1,2 kg/m^3), ρ_1.

b) Inlet volume flow, q_V.

c) Rotational speed or frequency, n.

d) Setting of variable geometry means — e.g. blade angle on axial fan or inlet vanes on centrifugal fan — where appropriate.

e) Number of blades — e.g. an axial fan — where appropriate.

f) Fan (total) pressure (type B and D installations), p_F.

g) Fan static pressure (Types A, B, C or D installations), p_sF.

h) Fan dynamic pressure, p_dF.

i) Impeller power as a function of q_V, P_r.

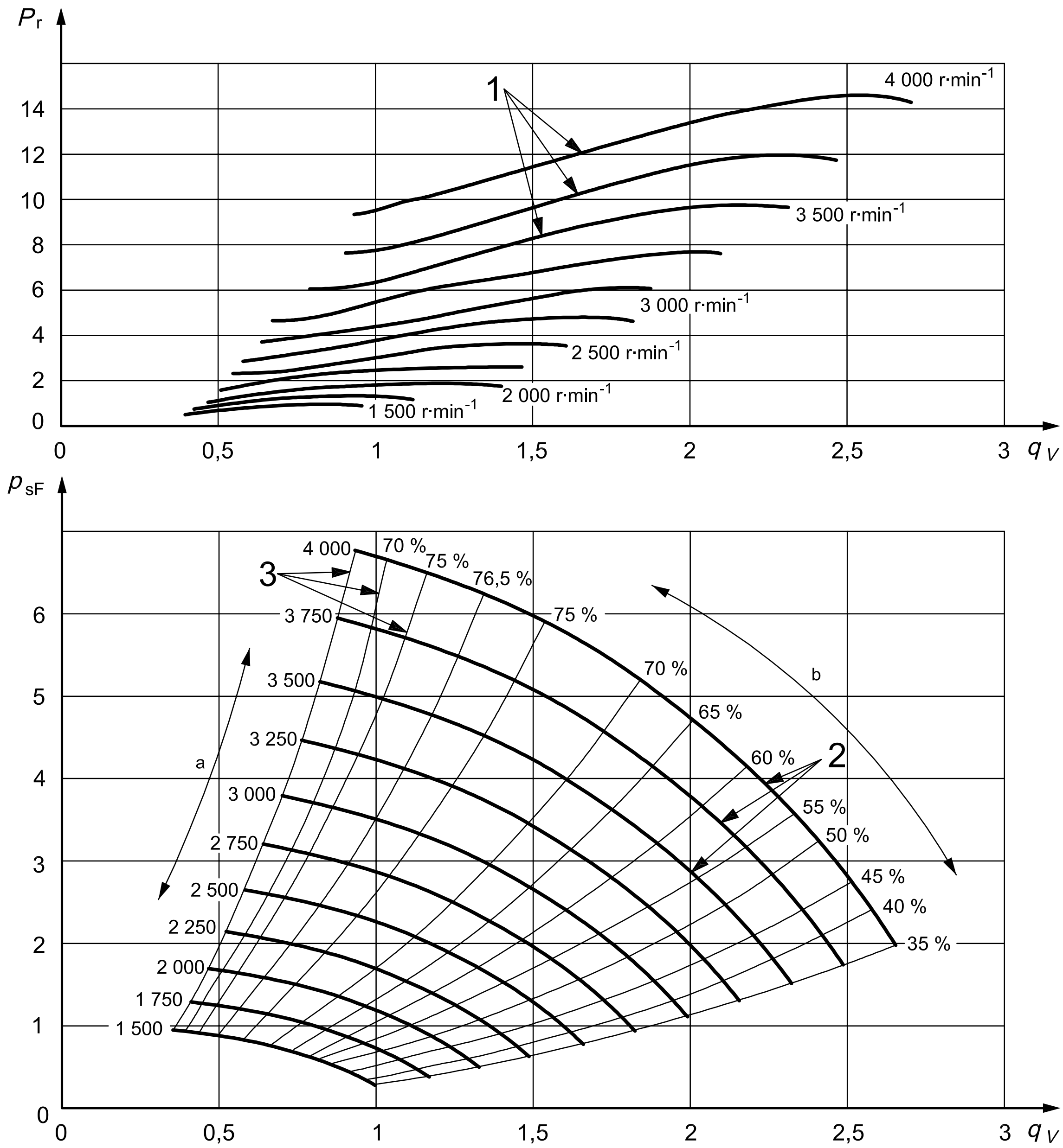
j) Rotational speed (maximum), n_max.

k) Fan (total) efficiency or fan static efficiency, η_t or η_s.

l) Sound power level, L_W.

m) Maximum gas temperature, θ_max.

For items f) to h), at least two of the listed fan pressures should be provided.



Type of ventilator:	centrifugal
Blade type:	backward inclined
Size:	450 mm
Inlet density:	1,2 kg/m^3
Installation category:	D (ducted inlet and outlet)
Fan test method:	ISO 5801

Key

P_r impeller power (kW)
P_{sF} fan static pressure, (Pa)
q_V fan inlet flow rate, (m^3/s)
1 fan absorbed power curves at different fan rotational speeds
2 fan pressure/volume characteristic curves for different rotational speeds
3 lines of constant fan efficiency

a Fan speed in revolutions per minute (r·min^{-1}).

b Fan static efficiency, η_s.

Figure 16 — Typical graphical information for fixed-geometry variable speed fan

Table 6 — In-duct sound power level: decibels referenced to 10^{-12} W (1 pW)

Frequency (Hz)		63	125	250	500	1 000	2 000	4 000	8 000
Rotational speed, n (r·min^{-1})	1 500	77	75	74	73	75	71	69	65
	1 750	80	78	77	76	80	76	74	70
	2 000	83	81	80	79	83	79	77	73
	2 250	86	86	83	82	86	82	81	77
	2 500	89	87	86	85	89	85	84	80
	2 750	91	89	88	87	91	87	86	82
	3 000	93	91	90	89	94	90	89	85
	3 250	95	93	92	91	96	92	91	87
	3 500	97	95	94	93	98	94	93	89
	3 700	98	96	95	94	99	95	95	89
	4 000	100	98	97	96	101	97	97	93

NOTE These values are total outlet sound power levels and relate to performances around maximum efficiency. They can increase by up to 4 dB at either end of the characteristic curve. Ducted inlet sound levels are within ± 3 dB of these values.

8.4 Additional information

8.4.1 Sound data

When presenting information on sound power, the data should be presented for the same installation category as the air performance chart and it should be indicated whether this refers to the fan inlet or outlet.

Sound power levels in each of the eight octave bands with centre frequencies of 63, 125, 250, 500, 1K, 2K, 4K and 8K Hz should be given, together with a qualifying statement concerning the part of the performance chart to which these are related and the expected tolerance.

For an example, see Table 6, which might be considered appropriate to present the sound power spectrum for the region of the best efficiency point. If this is the case, this should be stated, adding that if a customer requires accurate sound power information for other operating points, this should be referred to the manufacturer.

If the fan is intended for use with or without a duct connection, data should be presented to show the sound spectrum levels in both configurations.

In making the above recommendation it is accepted that it is not always practicable to present detailed sound spectra over the whole operating range of the fan. Nevertheless, if it is deemed appropriate to present the additional data, this can be shown in tabular form along with the performance regions where it applies.

When a single subjective and representative figure of sound level is required, the average A-weighted level should be given.

8.4.2 Electrical data

Where the fan is presented complete with an electric motor, sufficient data should be given such that a user can identify cable sizes and starting/control gear. The recommended data is

— rated motor output,

— rated or full-load current, starting current,

- full-load or rated motor efficiency,
- full-load or rated power factor, and
- the operating temperature limits.

If the motor is to be supplied separately, there shall be sufficient information in the catalogue by way of transmission losses or service factors to enable a motor frame or rating to be specified by a user.

8.4.3 Mechanical data

Where appropriate, bearing friction and mechanical transmission losses for the calculation of fan shaft power P_M may be stated. A motor or shaft bearing life related to ISO 281:1990 may also be given.

8.4.4 Air performance

It is optional whether to show impeller power or fan efficiency, or both.

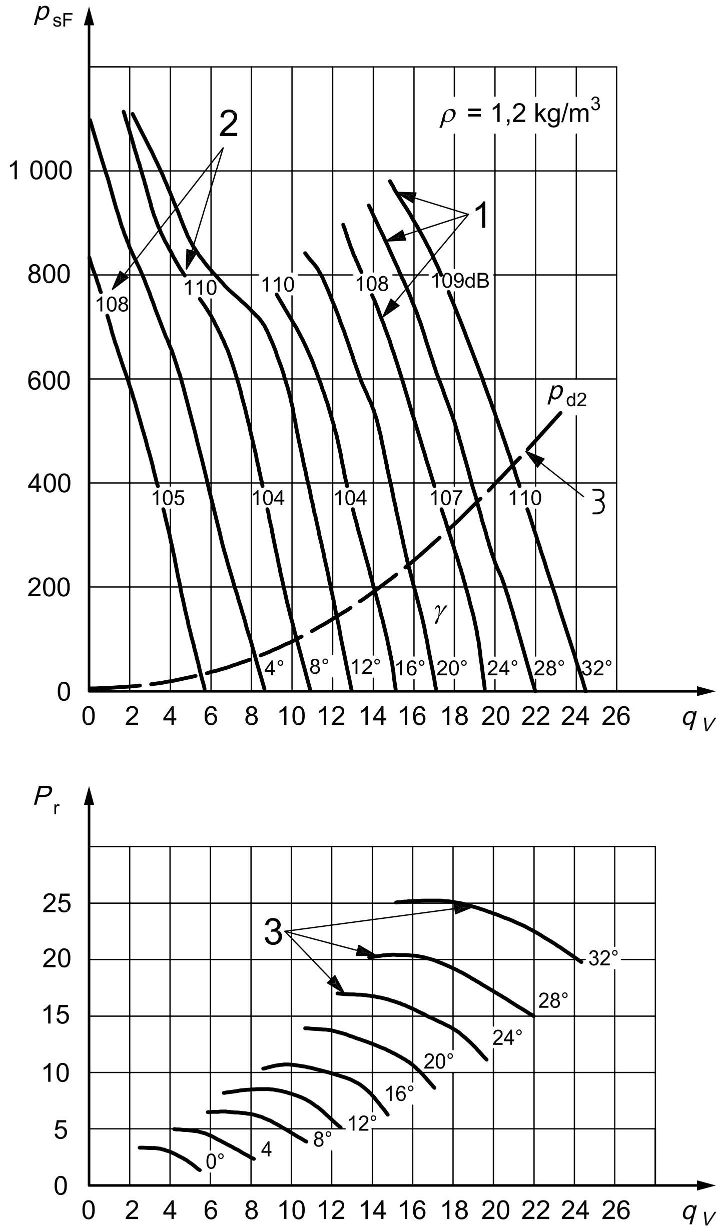
Surge areas or other restricted areas of operations should be indicated. This can either be on the performance charts, or in the texts — for example, in the section covering selection procedure.

8.4.5 Same fan used for different installations

Often, the same fan can be used for different installation categories. Strictly speaking, this calls for a separate fan performance chart for each installation category. However, if tests have shown that the difference in fan total or static pressure can be related to the fan flow rate, it is permissible to use correction scales to give the fan performance data for an installation which is different from the one for which the fan chart is valid. An indication of the accuracy of such data should be given.

An example is shown in Figure 17 and explained as follows. A fan chart is drawn for the fully ducted installation, category D, this being the installation configuration represented by the tests upon which the chart performance is based. When the same fan is fitted with a discharge diffuser, an improvement in static pressure can occur by converting a proportion of the dynamic pressure at the fan discharge, shown by the curve (p_{d2}) in Figure 17, to static pressure. Consequently, a fan chart for one category of fan installation may be used for other installation categories if correction scales have been obtained by test.

Losses caused by any obstacles or protection guards that could be introduced into the fan inlet should preferably be included with the inlet loss information.



Key

p_{sF} fan static pressure (Pa)
P_r impeller power (kW)
q_V fan inlet flow rate (m^3/s)
p_{d2} dynamique pressure at outlet
γ blade pitch angle
1 pressure/volume characteristic curves plotted for different impeller blade pitch angles
2 spot sound levels superimposed on pressure/volume characteristics
3 fan power characteristic curves plotted for different impeller blade pitch angles

NOTE Single figures on performance curves are overall sound power levels: decibels referenced to 1 pW. For sound power levels in eight-octave bands, deduct the following corrections:

Frequency, Hz	63	125	250	500	1 000	2 000	4 000	8 000
In-duct, dB	–10	–7	–5	–7	–8	–12	–18	–24
Free field, dB	–16	–9	–5	–7	–8	–12	–18	–24

Figure 17 — Typical presentation of data for variable-pitch, constant-speed axial fan

Annex A
(normative)

Documentation

A.1 The documentation shall give sufficient information on the design, mode of operation, setting-up, assembly, use and servicing of the fan.

A.2 Normally, the documentation shall include the following

a) operating instructions which cover installation, commissioning, operation, disconnection, inspection, maintenance and servicing, any appropriate drawings and, if necessary, special instructions for certain operating conditions (for explosion-proof fans the requirement of the relevant standards shall be observed);

b) data sheet covering scope of supply;

c) drawings showing the principal dimensions for connection and erection or installation;

d) standard fan characteristic.

For fans that are series-produced according to catalogue information or prepared order form and supplied in large numbers, the scope of documentation may be restricted if the necessary information can be obtained from the catalogue or the delivery specifications.

It shall be agreed whether other items such as spare parts lists and sectional or detailed drawings are to be provided as part of the documentation.

A.3 Contractual agreement is required for any special types or formats of documentation, its scope, the number of copies to be supplied, and any marking (e.g. reference number or purchaser's or supplier's order number).

Annex B
(normative)

Marking

B.1 The fan shall display a permanently affixed, clearly visible identification, made of durable material, that gives the following information:

a) name of manufacturer;

b) model;

c) order number if appropriate;

d) serial number;

e) volume flow rate, q_V, in cubic metres per second ($m^3 \cdot s^{-1}$);

f) fan pressure, p_F, in pascals (Pa), see also ISO 5801;

g) density of gas handled, ρ, in kilograms per cubic metre ($kg \cdot m^{-3}$);

h) temperature of gas handled, θ, in degrees Celsius (°C);

i) rotational speed, n, in revolutions per second (r/s);

j) Fan impeller power or motor power, P_a or P_m, in kilowatts (kW).

For series-produced fans, often taken from stock, it is not always possible to define the duty. In such cases, reference should be made to the source of applicable performance data.

For all fans supplied without driving motors, the maximum safe operating speed and gas temperature should be given on the nameplate.

B.2 The following additional information may be provided:

a) year of manufacture;

b) mass in kilograms (kg);

c) maximum operating temperature, t_{max}, in degrees Celsius (°C);

d) maximum rotational speed, n_{max}, in revolutions per second (r/s);

e) maximum power, P_{max}, in kilowatts (kW).

Annex C
(informative)

System resistance as a function of flowrate

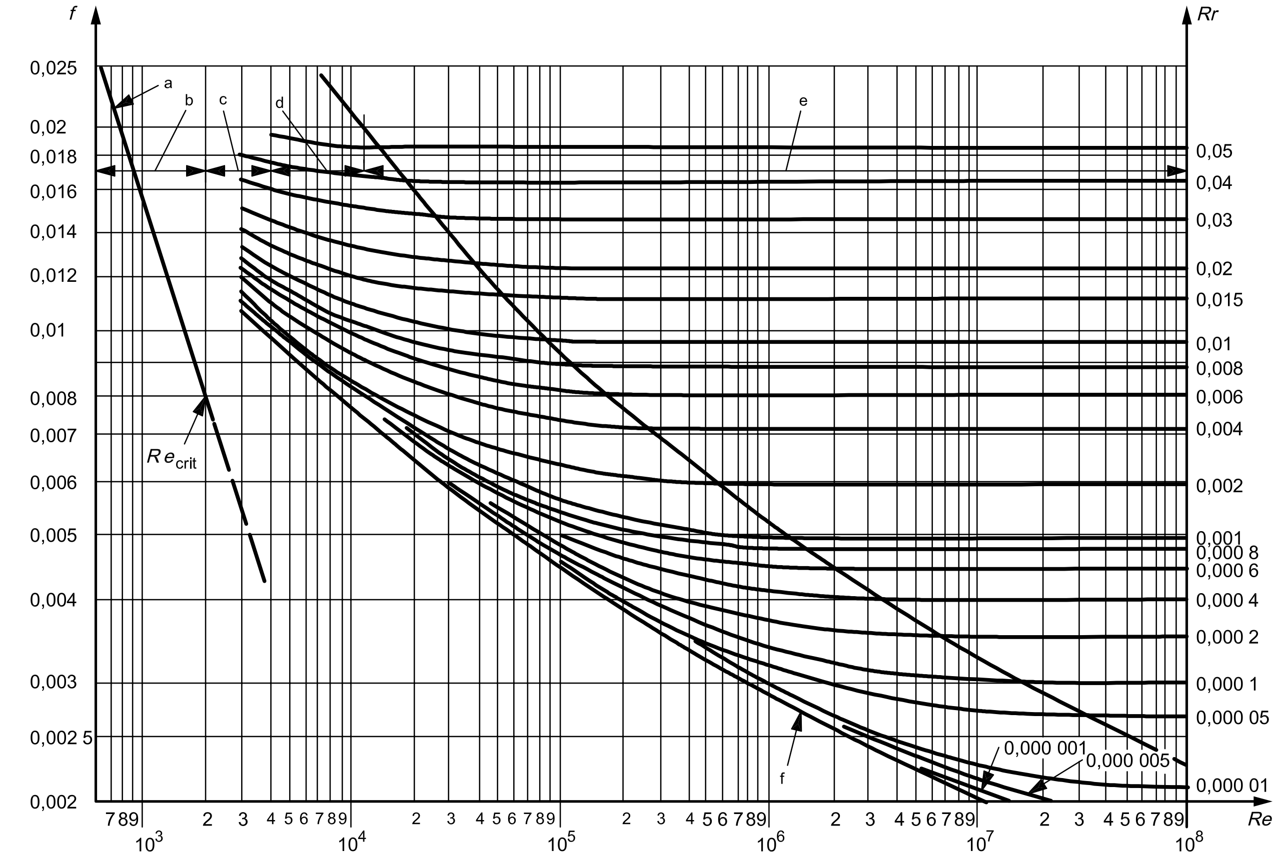
The treatment of tolerances was in some older standards based on the assumption that pressure loss is always a function of the square of airflow. However, this can lead to wrong results, because system resistance varies considerably with Reynolds number, i.e. air flow, as illustrated by Figures C.1 and C.2.

Furthermore, the first term of the Bernoullis equation may not be negligible:

$$\frac{E}{M} = gh + \frac{c^2}{2} + \frac{p}{\rho}$$

It is the responsibility of the fan manufacturer to guarantee a fan characteristic within certain tolerance limits, as in Table 2. The user may then decide which tolerance grades — i.e manufacturing methods — are appropriate for this specific system and which performance data has to be specified in order to obtain a satisfactory service.

In Table 2 there are a number of different manufacturing tolerance grades which are the responsibility of the fan manufacturer. Performance measuring tolerances for flow, pressure, power, etc., on the other hand, must be considered independently (see, for example, ISO 5801).



Key

Re Reynolds number: $Re = \rho v d/\mu$, where ρ is the local density, v is the local speed, d is the pipe diameter and μ is the dynamic viscosity

f friction factor

Rr relative roughness, $Rr = Ra/d$, where Ra is the absolute roughness and d is the pipe diameter

a Laminar flow, $f = 16/Re$.

b Laminar flow.

c Critical zone.

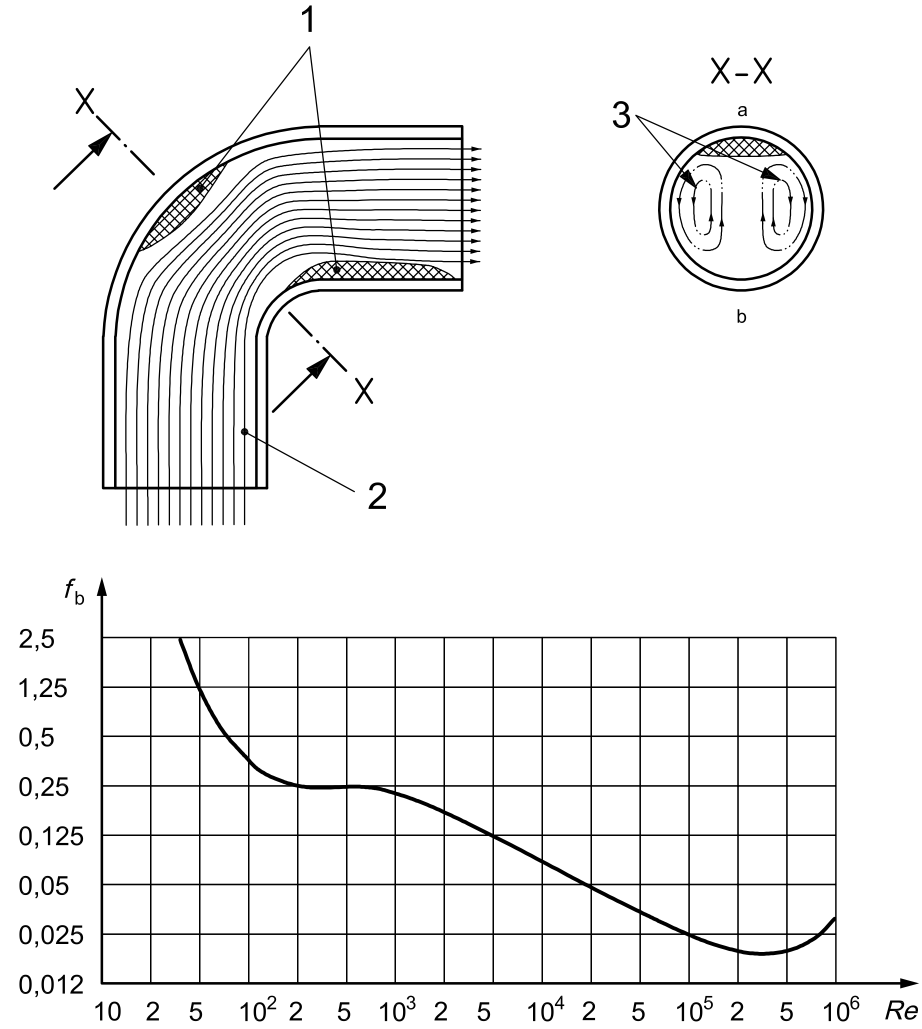
d Transitive zone.

e Complete turbulence: rough pipes.

f Smooth pipes.

Material	*Ra* (mm)
Riveted steel	1 to 10
Concrete	0,3 to 3
Wood stave	0,2 to 1
Cast iron	0,25
Galvanized steel	0,15
Asphalted cast iron	0,12
Commercial steel or wrought iron	0,045
Drawn tubing	0,001 5

Figure C.1 — Friction factor against Reynolds number for straight ducting



Key

Re Reynolds number
f_b friction factor
1 separation zone
2 actual flow in a 90° circular section bend
3 secondary flow

[a] Outer.

[b] Inner.

Bend pressure loss:

$$p_b = f_b \times \text{velocity pressure at bend inlet}$$

NOTE This typical chart of friction factor is specific to a particular geometry of fan.

Figure C.2 — Typical friction factor against Reynolds number for large radius in-duct bends

Bibliography

[1] ISO 31-7, *Quantities and units — Part 7: Acoustics*

[2] ISO 266, *Acoustics — Preferred frequencies*

[3] ISO 281, *Rolling bearings — Dynamic load ratings and rating life*

[4] ISO 5136, *Acoustics — Determination of sound power radiated into a duct by fans and other air-moving devices — In-duct method*

[5] ISO 5168, *Measurement of fluid flow — Procedures for the evaluation of uncertainties*

[6] ISO 10302, *Acoustics — Method for the measurement of airborne noise emitted by small air-moving devices*

[7] ISO 12499, *Industrial fans — Mechanical safety of fans — Guarding*

[8] ISO 13349, *Industrial fans — Vocabulary and definitions of categories*

[9] ISO 13350, *Industrial fans — Performance testing of jet fans*

[10] ISO 13351, *Industrial fans — Dimensions*

[11] AMCA 11, *Certified Ratings Programme Operating Manual*

[12] AMCA 111, *Laboratory Accreditation Program*

[13] AMCA 200, *Air Systems*

[14] AMCA 201, *Fans and Systems*

[15] AMCA 211, *Certified Ratings Program — Air performance*

[16] AMCA 99, *Standards Handbook*

[17] AMCA 301, *Methods for Calculating Fan Sound Ratings from Laboratory test Data*

[18] AMCA 802, *Industrial Process/Power Generation Fans: Establishing Performance using Laboratory Models*

[19] AMCA 311, *Certified Sound Ratings Program for Air Moving Devices*

[20] BSI Certification of Air Moving Equipment, *Fan Rating Procedures — Part 1: Aerodynamic Performance*

[21] Fan Manufacturers Association (UK), *Fan Application Guide*

[22] Fan Manufacturers Association (UK), *Fan and Ductwork Installation Guide*

[23] Fan Manufacturers Association (UK), *Guide to Fan Noise and Vibration*

[24] Fan Manufacturers Association (UK), *Fan Catalogue Performance Data*

[25] VDI 2044, *Acceptance and Performance Tests on Fans*

[26] DIN 24166, *Fans — Technical Delivery Conditions*

[27] MASSEY, B.S. (1989), *Mechanics of Fluids*, 6th ed., Chapman & Hall, London

[28] BOHL, W. (1983), *Ventilatoren*, Vogel Buchverlag, Würzburg

[29] SHEPHERD, D.G. (1971), *Principles of Turbomachinery*, 10th ed., The Macmillan Company, New York

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