INTERNATIONAL STANDARD

ISO 13350

Second edition
2015-10-01

Fans — Performance testing of jet fans

Ventilateurs — Essai de performance des ventilateurs accélérateurs

Reference number
ISO 13350:2015(E)

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.

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

Attention is drawn to the possibility that some of the elements of this document can be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 117, *Fans*.

This second edition cancels and replaces the first edition (ISO 13350:1999) which has been technically revised. The main changes are the following:

— General (dated references on standards updated, e.g. ISO 5801:2007);

— Clause 2 *"Normative references"* (references supplemented and updated);

— Clause 3 *"Terms and definitions"* (addition of 3.2.1 "gross fan outlet area", 3.5.1 "motor input power", 3.5.2 "impeller power", 3.8.2 "thrust/motor input power ratio");

— Figure 1 *"Gross and effective fan outlet areas"* (modified by marking of "gross fan outlet area A_2");

— Clause 4 *"Symbols and abbreviated terms"* (supplemented and updated);

— 6.4 *"Input power"* (correction for density);

— 7.1 *"Determination of thrust"* (correction for density);

— 7.4 *"Test procedures"* (change of recommended calibration intervals);

— Figure 7 *"Thrust measuring enclosure"* (modified by reducing the minimum distance between fan casing and floor/ceiling/wall);

— 8.1 *"Determination of sound level"* (Introduction of possibility to use other International Standards e.g. ISO 13347);

— 8.3 *"Enclosure suitability"* (requirement on running speed of the reference sound source deleted);

— 9.2 *"Test arrangement" for determination of vibration velocity* (Figure 9 "Vibration measuring position for jet fans" and requirement to use this configuration deleted);

— 9.3 *"Test procedure"* (general reference to ISO 14695);

— 10.2 *"Upstream chamber method"* ("venturi nozzle" replaced by "bellmouth");

— 10.4 *"Directly connected flowrate-measuring"* ("venturi nozzle" replaced by "bellmouth");

— 11.2 *"Product performance"* (reference to density 1,2 kg/m^3 added);

— Annex C *(informative)* (change of title: "Conversion rules" replaced by "Non-dimensional coefficients");

— Annex C *(informative)* (several character changed);

— Annex C *(informative)* (subclause on "Non-dimensional thrust/power ratio" added);

— Annex D *(normative)* (new normative Annex on "Efficiency based on thrust measurements").

Introduction

The need for a new edition of ISO 13350 has been evident for some time. The use of the so-called jet fan to assist in the control of quality of air in vehicle and train tunnels has become increasingly popular. Longitudinal methods of ventilation can show advantages in both capital cost and running cost compared to alternative systems. Smoke and pollution control in emergency conditions can be readily provided. Jet fans can also be used for ventilation and smoke control in enclosed car parks.

This International Standard deals with the determination of those performance criteria essential to the correct application of jet fans. In describing the test and rating procedures, numerous references are made to ISO 5801 as well as to other relevant International Standards.

Fans — Performance testing of jet fans

1 Scope

This International Standard deals with the determination of those technical characteristics needed to describe all aspects of the performance of jet fans as defined in ISO 13349. It does not cover those fans designed for ducted applications, nor those designed solely for air circulation, e.g. ceiling fans and table fans.

The test procedures described in this International Standard relate to laboratory conditions. The measurement of performance under on-site conditions is not included.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1940-1, *Mechanical vibration — Balance quality requirements for rotors in a constant (rigid) state — Part 1: Specification and verification of balance tolerances*

ISO 3744, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering methods for an essentially free field over a reflecting plane*

ISO 5801:2007, *Industrial fans — Performance testing using standardized airways*

ISO 13347 (all parts), *Industrial fans — Determination of fan sound power levels under standardized laboratory conditions*

ISO 13349, *Fans — Vocabulary and definitions of categories*

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

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

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

IEC 60034-14, *Rotating electrical machines — Part 14: Mechanical vibration of certain machines with shaft heights 56 mm and higher — Measurement, evaluation and limits of the vibration severity*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13349, ISO 5801 and the following apply.

3.1
effective fan dynamic pressure

p_d

conventional quantity representative of the dynamic component of the fan output, calculated, in the particular case of a jet fan, from the effective fan outlet velocity and the inlet density

Note 1 to entry: The effective fan dynamic pressure will not be the same as the average of the dynamic pressures across the section because it excludes from consideration that part of the dynamic energy flux, which is due only to departures from uniform axial velocity distribution.

3.2.1
gross fan outlet area
A_2
surface plane bounded by the downstream extremity of the air-moving device

Note 1 to entry: Gross fan outlet area is, by convention, taken as the gross area in the outlet plane inside the casing or duct or silencer, (see Figure 1) without taken into account any obstructions inside the fan outlet.

3.2.2
effective fan outlet area
A_{eff}
<jet fan> outlet area with deductions for motors, fairings, or other obstructions (in the particular case of a jet fan)

Note 1 to entry: If the silencer centrebody reaches the outlet plane of the fan, then, the effective fan outlet area is defined as the annulus area at the fan outlet plane, as shown in Figure 1a).

Note 2 to entry: If the fan has a silencer without centrebody [see Figure 1b)], the effective fan outlet area will be close to the cross- sectional area inside the silencer in order to clear any exit bellmouth form.

Note 3 to entry: If the centrebody (motor or silencer core) does not extend to the outlet plane, the effective fan outlet area will approach the annulus area between the casing and the motor, but with some increase, as defined in Figure 1c), for the distance between the centrebody and the outlet. Where the motor is on the upstream side, Figure 1c) is applied to the impeller hub rather than the motor, as illustrated.

Note 4 to entry: For comparisons within the scope of research and development, alternative definitions have been used with some success.

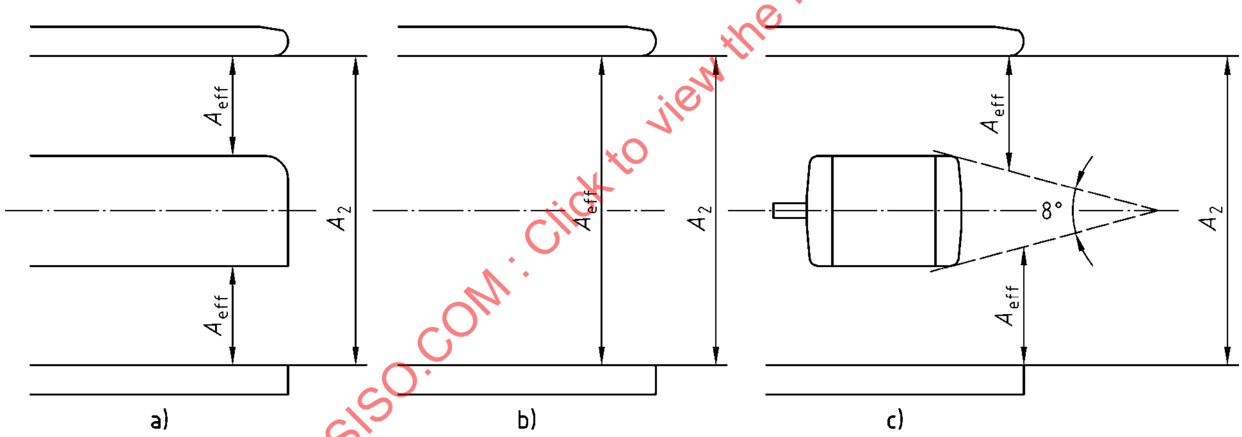


Figure 1 — Gross and effective fan outlet areas

3.3
effective fan outlet velocity
v_{eff}
velocity calculated from thrust at standard conditions, the standard air density, and the effective fan outlet area

Note 1 to entry: See 11.2.

3.4
fan outlet velocity
v_2
velocity calculated from the thrust at standard conditions, divided by gross fan outlet area, A_2

3.5.1
motor input power
P_e
electrical power supplied at the terminals of the electric motor drive

3.5.2
impeller power
P_r
mechanical power supplied to the impeller of the fan

3.5.3
fan air power
P_u
conventional power output at standard conditions; in the particular case of a jet fan, product of inlet volume flow and effective fan dynamic pressure

3.6
impeller tip speed
v_p
peripheral speed of the impeller blade tips

3.7
thrust
T_m, T_c
fan thrust measured (T_m) or calculated (T_c) in accordance with this International Standard at standard conditions

3.8.1
thrust/impeller power ratio
r_r
thrust divided by impeller power

Note 1 to entry: The thrust/impeller power ratio is calculated as $r_r = T_m/P_r$.

3.8.2
thrust/motor input power ratio
r_e
thrust divided by motor input power

Note 1 to entry: The thrust/motor input power ratio is calculated as $r_e = T_m/P_e$.

3.9
fan guard
guard designed to prevent the ingestion of relatively large foreign bodies, such as drink cans, and sometimes fitted to the inlet and outlet of jet fans

Note 1 to entry: Guards can have a marked effect on the thrust performance and noise level. Where they are specified, measurements should be made with these guards in place.

3.10
chamber
airway in which the air velocity is small compared with that at the fan inlet or outlet

3.11
test enclosure
room, or other space protected from draught, in which the fan and test airways are situated

3.12
impeller balance grade
G grade as specified in ISO 14694

3.13
fan vibration velocity
unfiltered root mean square (r.m.s.) vibration velocity over the frequency range 10 Hz to 10 kHz measured in accordance with this International Standard and with ISO 14695

3.14
fan impeller efficiency
η_r
fan air power divided by impeller power

3.15
fan overall efficiency
η_e
fan air power divided by motor input power

3.16
sound pressure level
L_p
ten times the logarithm to the base 10 of the ratio of the square of the sound pressure radiated by the sound source under test to the square of the reference sound pressure

3.17
sound power level
L_W
ten times the logarithm to the base 10 of the ratio of the sound power radiated by the sound source under test to the reference sound power

3.18
inlet sound power level
L_{W1}
sound power level of the fan determined at the fan inlet

3.19
outlet sound power level
L_{W2}
sound power level of the fan determined at the fan outlet

3.20
noise frequency range of interest
<general>frequency range including the octave bands with centre frequencies between 63 Hz and 8 000 Hz and the one-third octave bands with centre frequencies between 50 Hz and 10 000 Hz

4 Symbols and abbreviated terms

The following symbols and units shall apply for the parameters listed.

Abbreviated term/represented quantity	Symbol	SI unit
Impeller annulus area	A_a	m^2
Gross fan outlet area	A_2	m^2
Effective fan outlet area	A_{eff}	m^2
Nominal fan diameter	D_R	m
Length of upstream chamber side	D_3	m
Sound pressure level	L_p	dB (re 20 µPa)
Average sound pressure level of the measured device	$L_{p(m)}$	dB (re 20 µPa)
Average sound pressure level of the reference sound source	$L_{p(r)}$	dB (re 20 µPa)
Sound power level	L_W	dB (re 1 pW)
Inlet sound power level	L_{W1}	dB (re 1 pW)
NOTE: (T) denotes the term or quantity stated to be a function of the thrust (see Annex D). Example: η_e(T) is the fan overall efficiency based on thrust.		

Abbreviated term/represented quantity	Symbol	SI unit
Outlet sound power level	L_{W2}	dB (re 1 pW)
Sound power level of the reference sound source	$L_{W(r)}$	dB (re 1 pW)
Rotational speed	n	revolution/s
Differential pressure across a flow measuring device	p	Pa
Gauge pressure at the fan outlet	p_{e2}	Pa
Gauge pressure in the fan chamber	p_{e2}	Pa
Effective fan dynamic pressure	p_d	Pa
Volume flow	q_v	m^3/s
Impeller balance grade (ISO 14694)	G	µm
Motor input power	P_e	W
Impeller power	P_r	W
Fan air power	P_u	W
Thrust/impeller power ratio	r_r	N/W
Thrust/motor input power ratio	r_e	N/W
Non-dimensional thrust/power ratio	r_t	—
Calculated thrust	T_c	N
Measured thrust	T_m	N
Impeller tip speed	v_p	m/s
Effective fan outlet velocity	v_{eff}	m/s
Fan outlet velocity	v_2	m/s
Mean throughflow velocity in a tunnel at a specified section	v_t	m/s
Total pressure rise	Δp	Pa
Standard air density 1,2 kg/m^3	ρ	kg/m^3
Inlet density taken as equal to the density in the test enclosure	ρ_a	kg/m^3
Efficiency based on thrust	$\eta_r(T)$	—
Fan overall efficiency	η_e	—
Motor efficiency	η_m	—
Fan impeller efficiency	η_r	—
Fan overall efficiency based on thrust	$\eta_e(T)$	—
Flow coefficient	φ	—
Thrust coefficient	Θ	—
Power coefficient	ϕ_r	—
NOTE: (T) denotes the term or quantity stated to be a function of the thrust (see Annex D). Example: $\eta_e(T)$ is the fan overall efficiency based on thrust.		

5 Characteristics to be measured

5.1 General

In order that a jet fan be correctly applied and give satisfactory performance and reliability in service, it is necessary to determine a number of technical performance characteristics in addition to knowing the more obvious mechanical features, such as mass, overall dimensions, and installation dimensions.

5.2 Thrust

Friction on the tunnel walls, inlet, and outlet losses and sometimes traffic drag, combined with climatic effects at tunnel portals, create a pressure drop through the tunnel. The pressure drop is matched by the sum of the pressure increases by the jet fans due to the momentum transfer between fan discharge airflow and airflow in the tunnel. As it is impossible to measure the momentum of the fan discharge airflow, and the rate of change in momentum is equal and opposite to the thrust, thrust is measured instead.

5.3 Input power

In order to design the tunnel installation, it is necessary to know the input power to the fan motor. Also, it is needed to determine the overall efficiency of the jet fan.

5.4 Sound levels

Sound levels, usually at inlet and outlet, are established in order to ensure that the jet fan and silencer combination is optimized to match the tunnel sound level requirements.

NOTE The fan manufacturer can only guarantee the sound power level of the fan. The sound pressure in the tunnel will depend on the size and sound absorption characteristics of the tunnel, which are outside the fan manufacturer's responsibility.

5.5 Vibration velocity

For reasons of safety, reliability, and maintainability, it is essential that a realistic vibration velocity is specified and recorded on jet fans. These shall be measured in accordance with ISO 14695.

5.6 Volume flowrate

Volume flowrate need only be measured if required for contractual reasons. It is the effective fan outlet velocity which is used to evaluate the optimum number, size, and spacing of jet fans in a tunnel, and is calculated in accordance with 11.2.

6 Instrumentation and measurements

6.1 Dimension and areas

The measurement of dimensions and the determination of areas shall be in accordance with ISO 5801:2007, Clause 11.

6.2 Rotational speed

The rotational speed of the impeller shall be determined in accordance with ISO 5801:2007, Clause 9.

6.3 Thrust

6.3.1 Force balance systems

By the use of calibrated weights, force balance systems shall permit the determination of force or thrust with an uncertainty of ±5 %.

6.3.2 Force transducers

After calibration by the use of calibrated weights, force transducers shall permit the determination of thrust with an uncertainty of ±5 %.

6.4 Input power

Determination of the power input to the electric motor or to the impeller shall be carried out in accordance with ISO 5801:2007, Clause 10. P_e and P_r are determined by correcting the measured power for a density of 1,2 kg/m^3.

6.5 Sound level

The sound-level measuring system, including microphones, windshields, cables, amplifiers, and frequency analyser, shall be in accordance with the requirements given in ISO 13347.

6.6 Vibration velocity

Instruments to measure root mean square (r.m.s.) vibration velocity shall be used to record fan vibration velocities. These shall be in accordance with ISO 14695.

6.7 Volume flowrate

6.7.1 Instruments for the measurement of pressure

Manometers for the measurement of differential pressure and barometers for the measurement of atmospheric pressure in the test enclosure shall comply with the requirements of ISO 5801:2007, Clause 6.

6.7.2 Instruments for the measurement of temperature

Thermometers shall comply with the requirements of ISO 5801:2007, Clause 8.

7 Determination of thrust

7.1 General

There are two basic configurations acceptable for the determination of fan thrust, T_m, by direct measurement, these are

— suspended configuration, and

— supported configuration.

T_m is determined by correcting the measured thrust value for a density of 1,2 kg/m^3, i.e. $T_m = Thrust_{measured} \cdot 1{,}2\ [\text{kg/m}^3]/\rho_a\ [\text{kg/m}^3]$.

In addition to the need to measure force accurately, the first method requires that the low friction suspension elements be kept precisely vertical and parallel with a vertical plane(s) passing through the fan axis, while the second method requires accurate construction, low friction, and levelling of the support assembly. In either case, thrust shall be determined by the use of calibrated weights, spring balance, or force transducer.

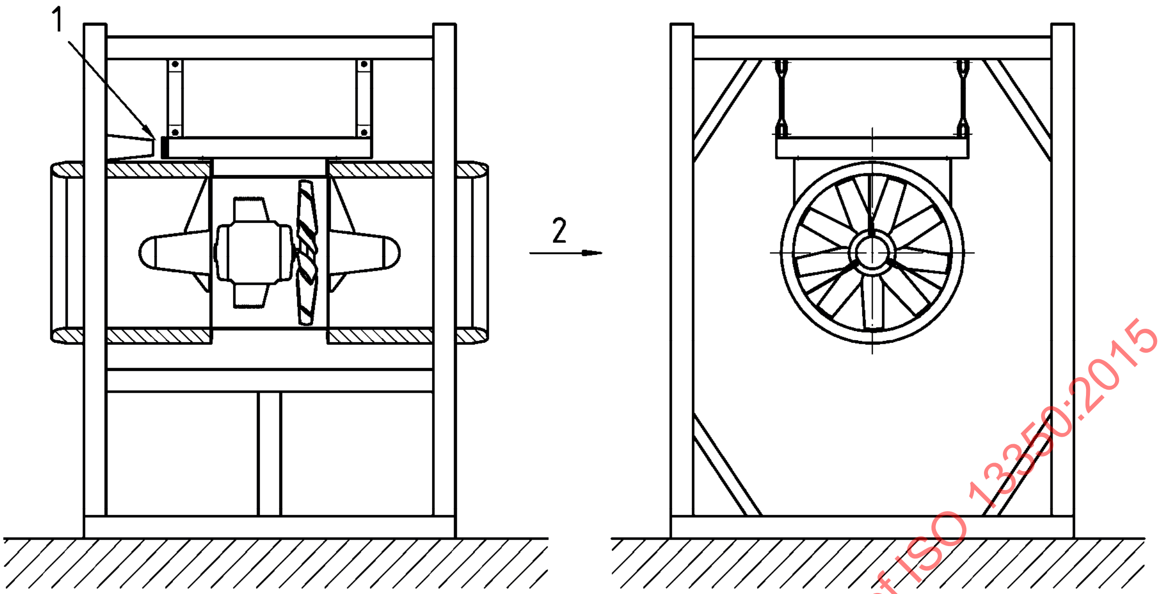
7.2 Suspended configuration

Figures 2 and 3 show typical arrangements of suspended configurations. The fan is suspended from a framework or gantry with the suspension elements at least one fan-diameter long. The frame should allow free airflow, particularly at the fan inlet. Below or surrounding the fan is a rigid framework which serves a threefold function to

a) provide the reference point for the fan test assembly under static conditions,

b) provide support for a pulley system to take calibrated weights or a spring balance, and

c) provide a reaction point for a force transducer.



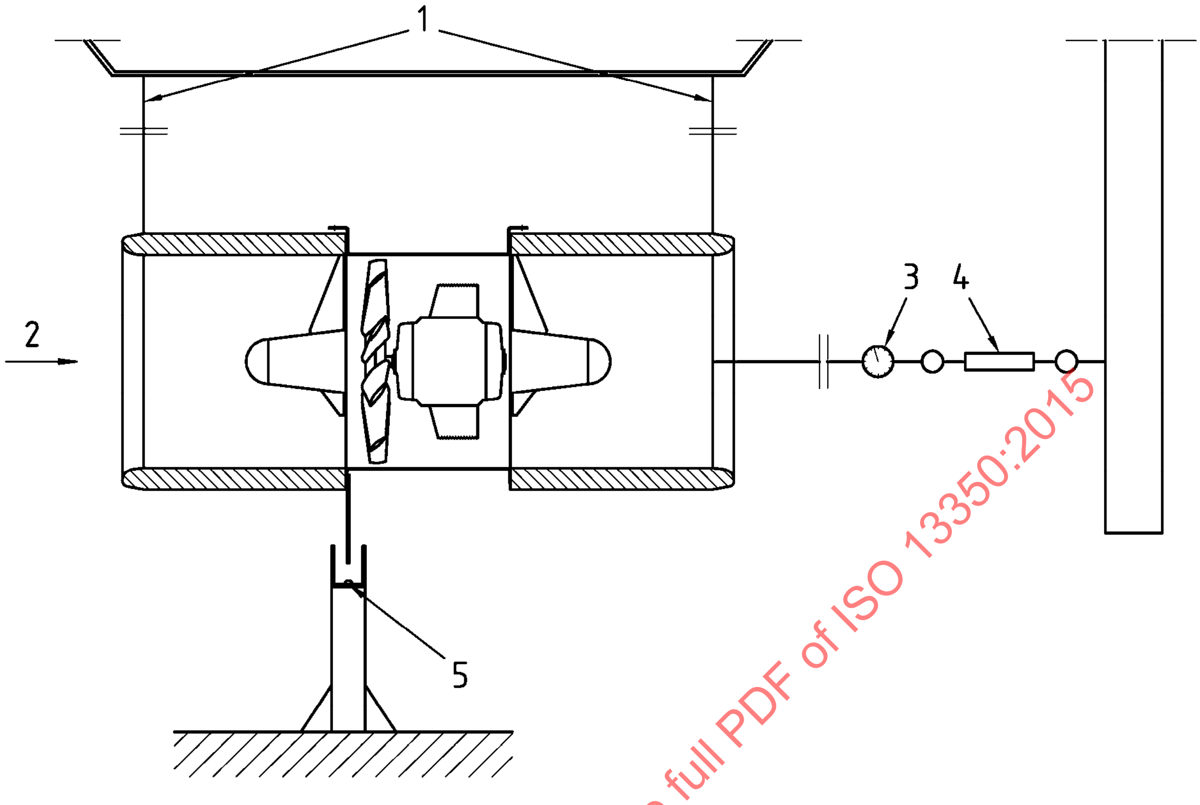
Key

1 adjustable position of transducer/measuring system

2 air flow

The fan should be accurately levelled prior to testing.

Figure 2 — Thrust measuring layout example (suspended method 1)



Key

1 suspension cables
2 air flow
3 spring balance
4 adjustable restraint
5 reference point

The fan should be accurately levelled prior to testing.

Figure 3 — Thrust measuring layout example (suspended method 2)

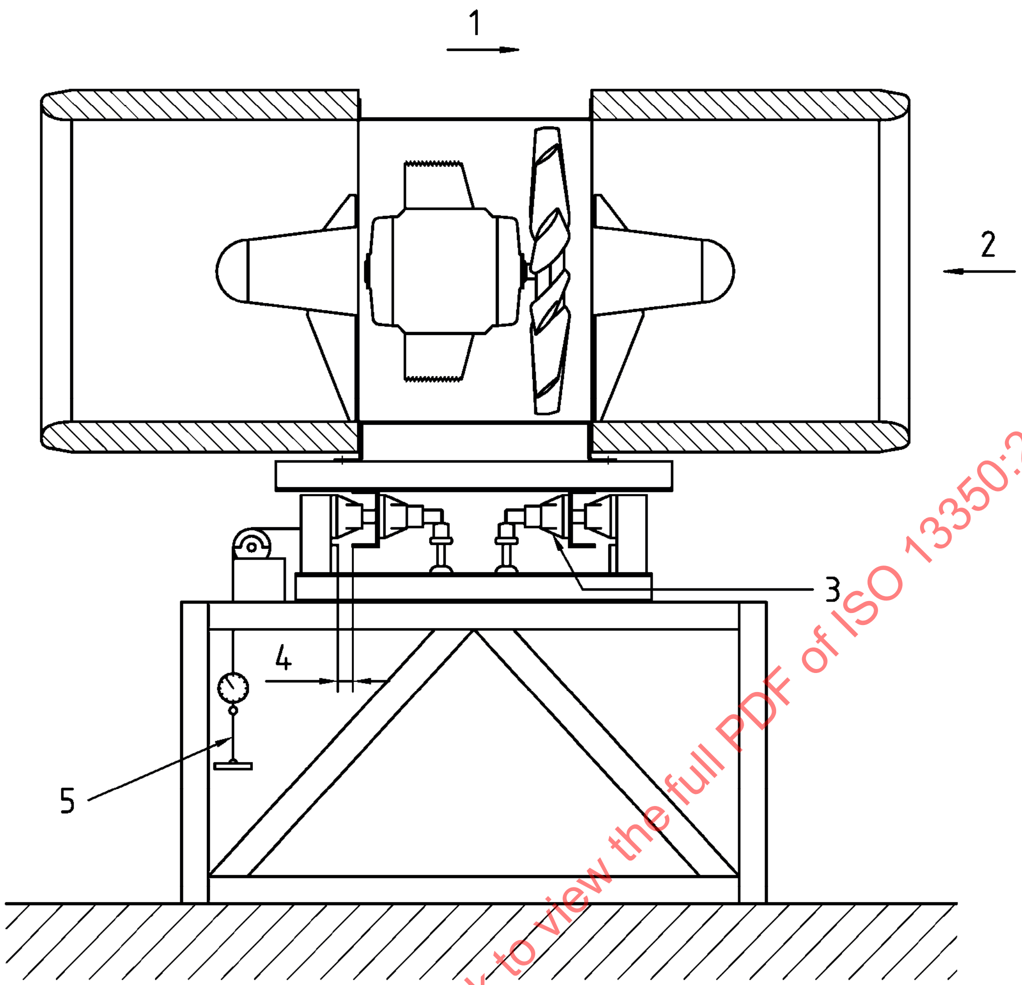
Under operating conditions, the measuring system loads are adjusted to return the fan to the static positions, to within ±2 mm, and thus ensure that the suspension elements are precisely vertical. The thrust can then be measured directly.

Note With the thrust/weight ratios typical of a jet fan, it is doubtful whether the desired accuracy of thrust measurement can be attained by other means, such as measuring the angle of the suspension elements from the vertical or the change in height between the fan switched off and operational, and then calculating the thrust.

7.3 Supported configuration

Arrangements of the supported configuration are shown in Figures 4, 5 and 6. The fan is supported, through low-friction bearings or leaf springs, on a rigid framework. The fan, to an extent limited by stops, is free to move in either direction. Before commencing any tests, the assembly shall be carefully levelled in each direction, such that the same effort is required to move the assembly along the axis of the fan in either direction.

Under operating conditions, the measuring system loads are adjusted to ensure the movement is not being restrained by the stops. Thrust can then be measured directly. In the case of the use of a force transducer, the fan can be allowed to abut the sensor directly.



Key

1 direction of fan movement

2 air flow

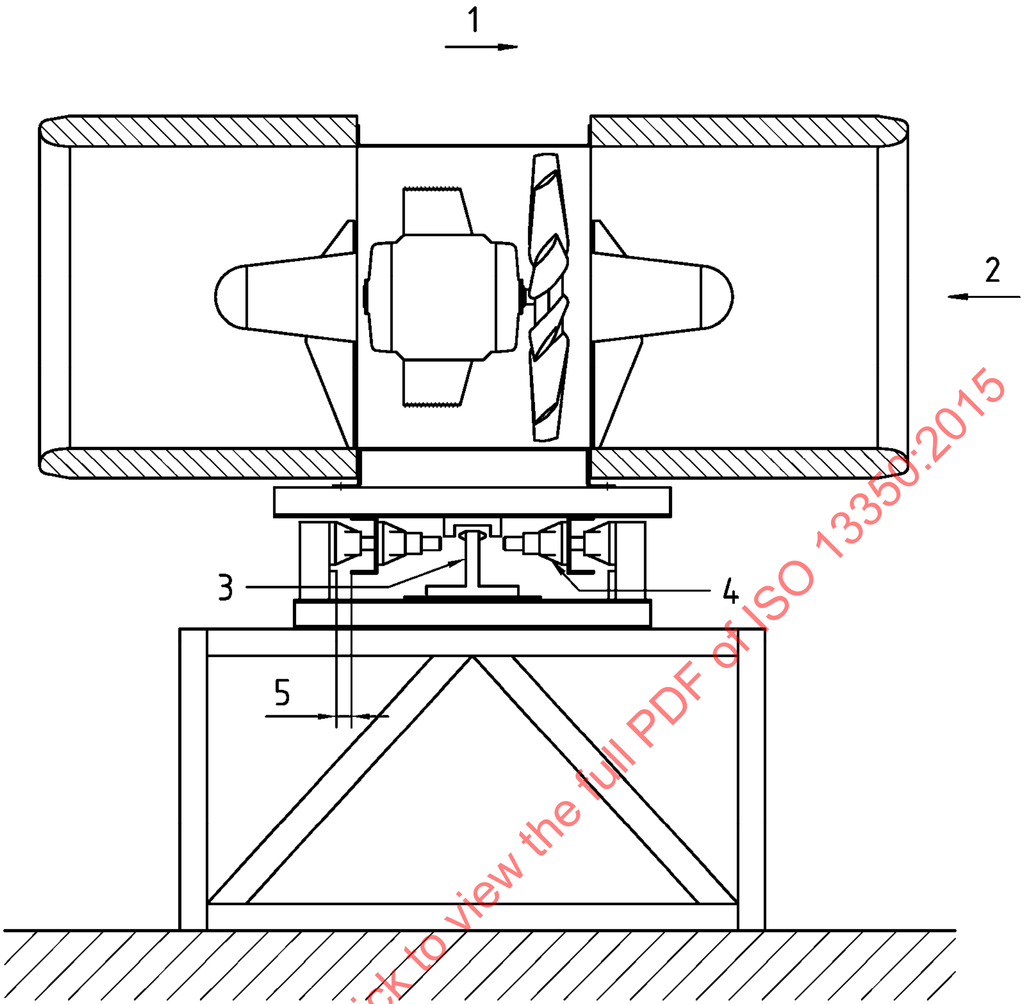
3 bearings

4 fan movement possible

5 thrust gauge (measurement in kg direct off gauge + mass of gauge in suspension = thrust)

The fan should be accurately levelled prior to testing.

Figure 4 — Thrust measuring layout example (supported method 1)



Key

1 direction of fan movement

2 air flow

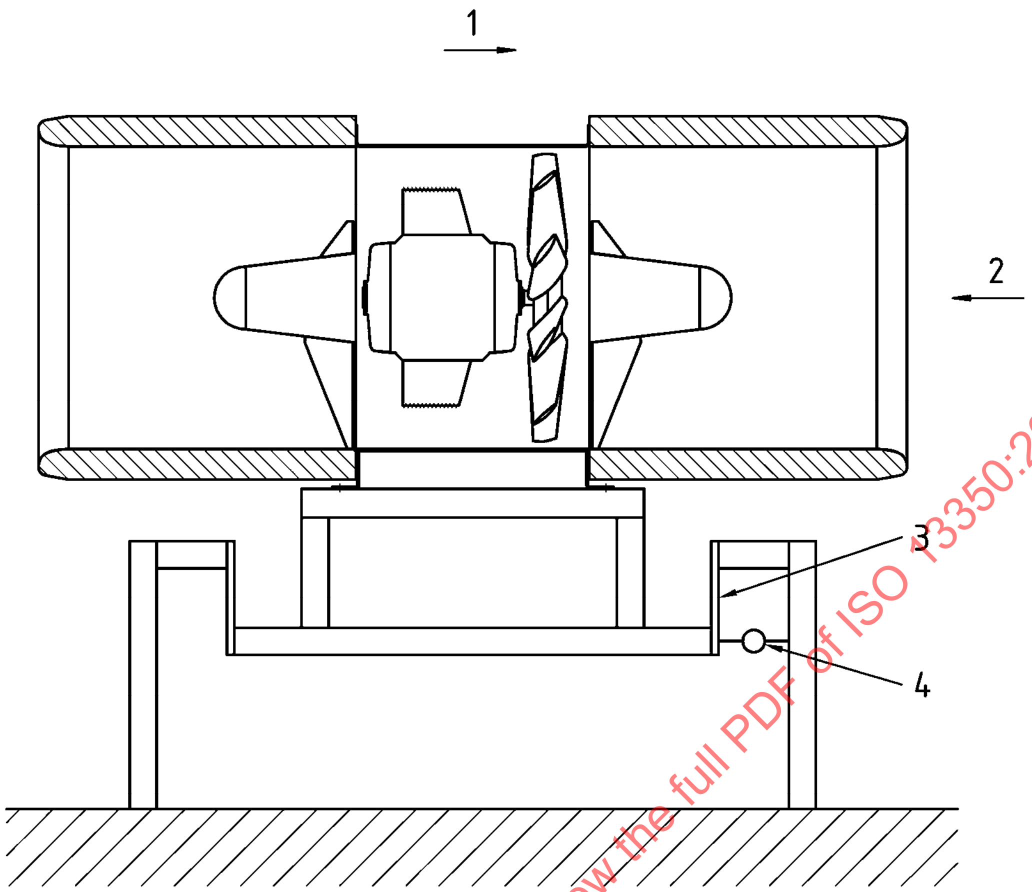
3 transducer/measuring system

4 bearings

5 fan movement possible

The fan should be accurately levelled prior to testing.

Figure 5 — Thrust measuring layout example (supported method 2)



Key

1 direction of fan movement

2 air flow

3 leaf spring

4 load cell

The fan should be accurately levelled prior to testing.

Figure 6 — Thrust measuring layout example (supported method 3)

7.4 Test procedures

To ensure that thrust is measured to the required accuracy, steps shall be taken to minimize errors due to setting-up/rigging of the test arrangement. Though calibrated weights or spring balances are specified, if a spring balance is employed to register thrust and it is supported through a pulley, its mass should be accurately known and added to the measured thrust.

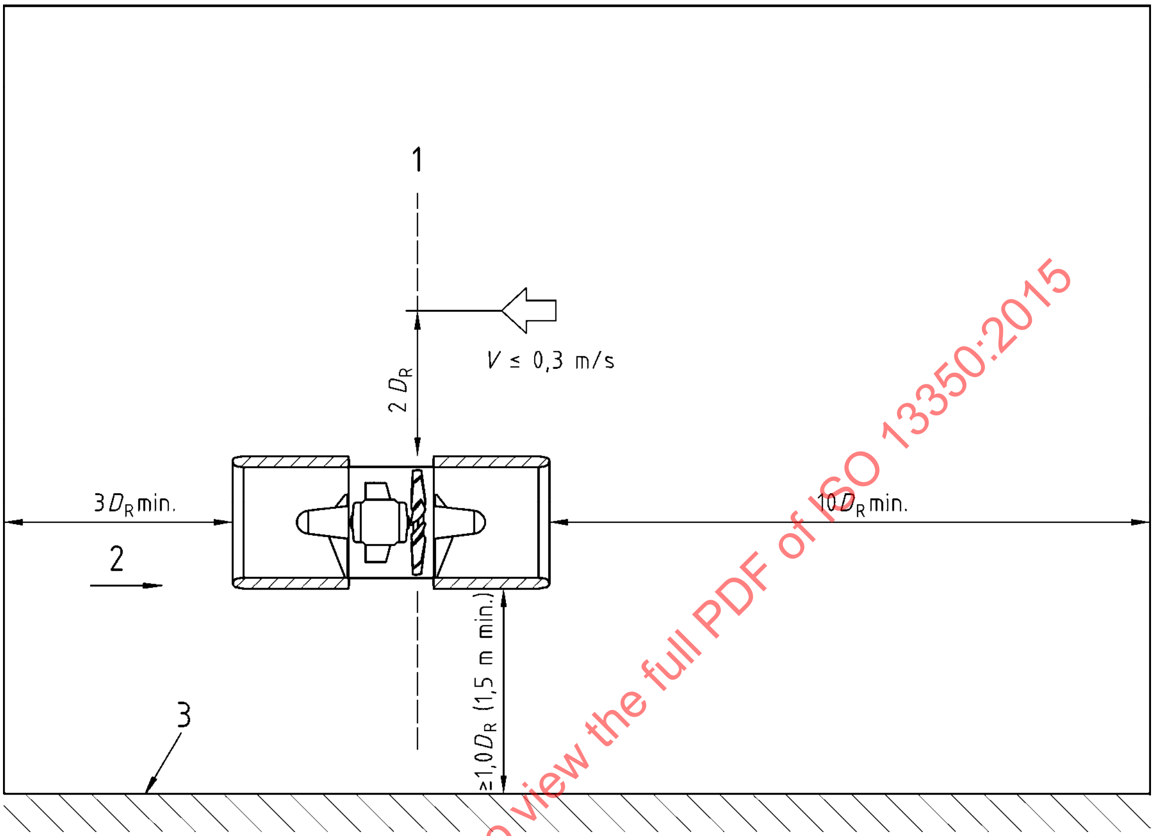
If a force transducer is being used to measure thrust, it is recommended that it is calibrated, for example, by using a pulley and weight system at no more than 3-monthly intervals. Where the deviation is more than 1 % of the reading, then, recalibration shall be reduced to 1-monthly intervals.

Where the supported method is being used, precautions shall be taken to ensure that the force required to move the fan in either direction is the same and that the assembly is therefore level.

Thrust readings shall be recorded when both the thrust and power input readings have stabilized, or at least 10 min after start-up.

7.5 Test enclosure

Figure 7 shows the clearances required in the test enclosure.



Key

1 plane through impeller
2 air flow
3 floor, ceiling, or wall

Figure 7 — Thrust measuring enclosure

8 Determination of sound level

8.1 General

Sound levels are measured by the semi-reverberant method. The method is essentially practical and, apart from the sound-measuring instrumentation, minimal facilities are required, such as the following:

— a suitable enclosure;

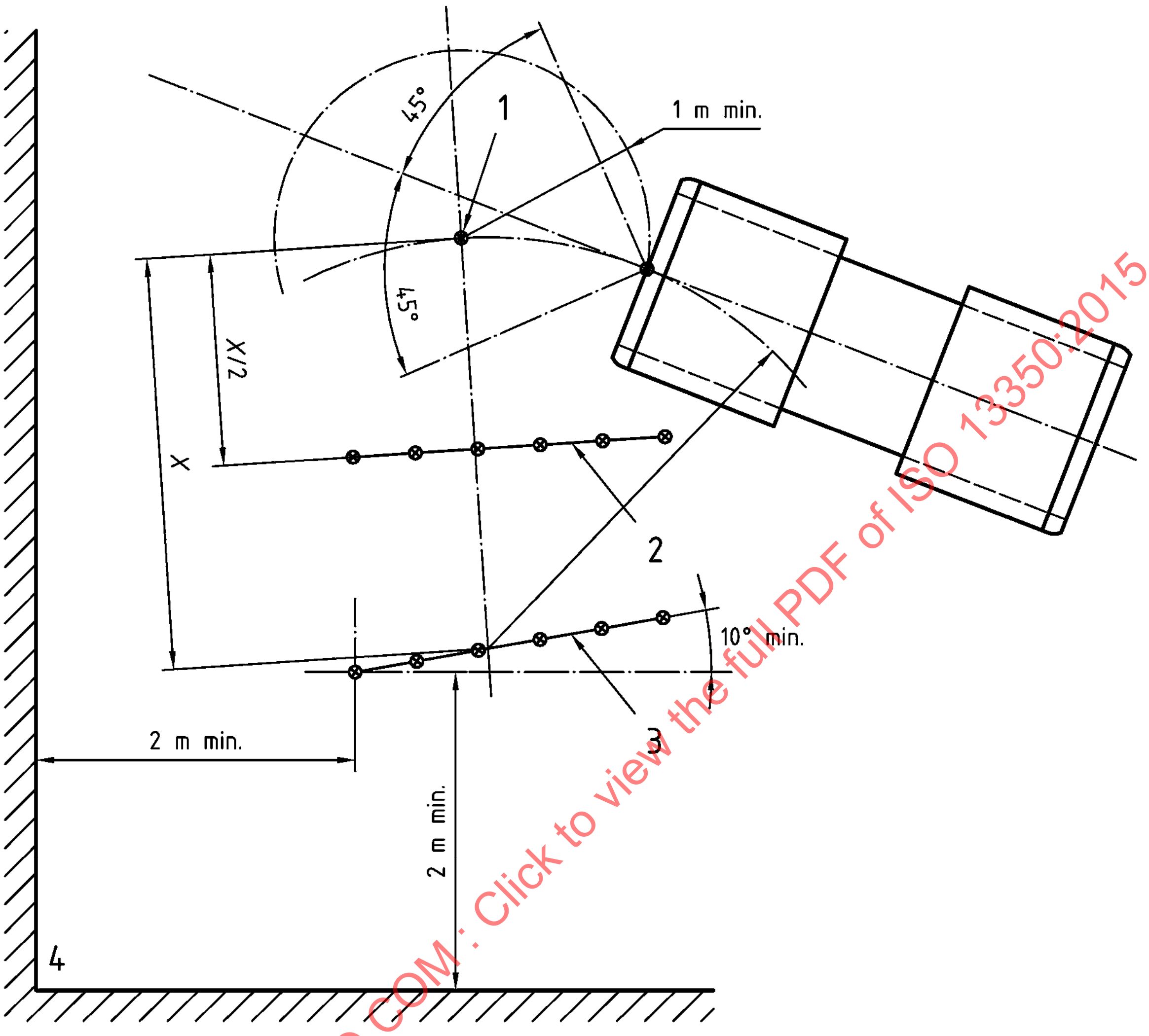
— a calibrated sound source.

As the fan has only one operating point, at zero resistance, there are no complications which could arise from the noise generated by the "loading means." Similarly, since only open inlet or open outlet sound levels are required, anechoic terminators are unnecessary. It should be recognized that the method measures the noise radiated by the fan, whether from the fan inlet or outlet or from the fan casing, thus, representing the same situation as when the fan is installed in a tunnel.

Alternatively, other International Standards for measuring fan sound levels can be used, such as ISO 13347.

8.2 Test arrangement

Positioning of the fan, calibrated reference sound source, and the microphone paths are shown in Figure 8.



Key

1 reference source

2 secondary microphone path

3 primary microphone path

4 all surfaces hard finish

Figure 8 — Semi-reverberant enclosure

Equipment or vane placement is not restricted by this International Standard provided the following conditions are met:

— Microphone traverse plane should be greater than 10° from parallel to any surface;

— Maximum air velocity over microphone is 1 m/s;

— Microphone, RSS, fan sound sources cannot be within 0,3 m of room centrelines.

Room volume is not specified, but the room should be large enough in volume, such that the volume of the test fan and associated duct work does not exceed 1 % of that room volume.

Note Room shape is not specified in this International Standard, but rooms having certain proportions will perform more successfully.

8.3 Enclosure suitability

The semi-reverberant chamber shall meet the requirements of ISO 13347.

A primary microphone path shall be located on an arc or straight line of length between 1,5 m and 3 m at a distance of not less than 2 m from any major reflecting surface. No point on this path shall be within 45° of the centreline of the fan sound source, and the path itself shall form an angle greater than 10° with any chamber surface and shall be located towards a corner of the chamber. The path shall be so located that the microphone is not subjected to an air velocity in excess of 2 m/s (see Figure 8).

A reference sound source shall be located, such that, its acoustic centre is the same distance from the midpoint of the microphone path as the centre of the fan sound, but not nearer than 1 m to the latter, or to any major reflecting surface. The reference sound source shall meet the requirements of ISO 13347.

With the reference sound source operating, but with the test fan impeller stationary, readings of sound pressure level shall be made in each octave band along the primary microphone path and the average value along the path estimated. A secondary microphone path, similar to the primary microphone path and of the same length, shall be established at a position halfway between the reference sound source and the midpoint of the original microphone path, and at right angles to the line joining them. The average sound pressure level along this path in each octave band shall not be more than 3 dB above the average for the primary microphone path, both values being corrected for background noise as recommended in Annex B.

8.4 Measurement procedure

Before conducting actual measurements, and with both the test fan and the reference sound source inoperative, the average sound pressure level, in each octave band shall be determined along the primary microphone path. This shall be at least 6 dB in each octave band lower than the average sound pressure level measured from either the fan sound source or the reference sound source. Corrections for background noise should be made as recommended in Annex B.

With the reference sound source in operation, but with the test fan impeller stationary, readings of sound pressure shall be made, in each octave band, along the primary microphone path, and the average sound pressure level $L_{p(r)}$ determined. With the reference sound source removed and the test fan running, readings of sound pressure level shall be made and the average sound pressure level $L_{p(m)}$, in each octave band, determined. The values of $L_{W(r)}$ and $L_{p(m)}$ are corrected, where necessary, as recommended in Annex B, and the open inlet or open outlet sound power level of the fan L_W calculated, in each octave band, from:

$$L_W = L_{p(m)} - L_{p(r)} + L_{W(r)} \tag{1}$$

where

L_W is the overall sound power level;

$L_{p(m)}$ is the average sound pressure level of the measured device;

$L_{p(r)}$ is the average sound pressure level of the reference sound source;

$L_{W(r)}$ is the sound power level of the reference sound source.

The fan shall be turned through 180° and the measurement repeated. The highest levels in each case shall be reported.

The conformal surface method specified in ISO 3744 can be alternatively used, provided that this is clearly stated, noting that the measuring points can be in the acoustic near field and additional readings might accordingly be necessary.

9 Determination of vibration velocity

9.1 General

Because the jet fan, for practical purposes, has only one operating point as far as standard laboratory tests are concerned, the arrangements for testing vibration velocity can be simplified when compared with those specified in ISO 14695.

9.2 Test arrangement

Tests shall be taken with the same jet fan configuration as will be supplied to the customer. In other works, upstream and/or downstream silencers should be fitted as appropriate. Where vibration isolators are specified and vibration levels are required to be measured, the minimum static deflections given in Table 1 shall be used for the purpose of the measurement.

Unless agreed otherwise between client and supplier, the impeller of the fan unit shall be balanced to grade G6.3 of ISO 1940-1 and the electric motor shall be supplied to the normal vibration level for the motor frame size in accordance with IEC 60034-14.

Table 1

Rotational speed r/min	**Minimum static deflection** mm
850 to 1 000	15
1 100 to 1 800	8
2 800 and above	2,5

NOTE For practical reasons, the minimum static deflections in Table 1 are very much reduced in actual operating conditions.

9.3 Test procedure

Unless agreed otherwise between client and supplier, vibration velocities shall be measured in accordance with ISO 14695.

9.4 Acceptance vibration velocity

The maximum acceptance vibration velocities are given in Table 2.

Table 2

Mounting method	**Maximum acceptance vibration velocity** mm/s root mean square (r.m.s.)
Vibration isolators as in Table 1	4,5
Hard-mounted	2,8

10 Determination of flowrate

10.1 General

It should be noted that the flow through a jet fan has no direct relationship with the flow through a tunnel, and that this is not a primary requirement in the specification of a jet fan.

There are three methods available for the determination of flowrate:

a) the first method makes use of an upstream chamber test configuration. In this case, a booster fan forms part of the test set-up, enabling the fan operating point to be simulated correctly;

b) the second method uses a Pitot traverse at the jet fan inlet;

c) the third method, which is the most convenient but probably the least accurate, uses a Venturi nozzle or conical inlet, connected upstream of the jet fan, as the flow-measuring device.

10.2 Upstream chamber method

Installation of the fan in the chamber is illustrated in Figure 9. The arrangement simulates a type A installation. Upstream sections of the test assembly shall be in accordance with ISO 5801:2007, 30.2.

A bellmouth or conical inlet can be used to determine flowrate in accordance with ISO 5801:2007, Clause 23.

In order to establish the correct fan operating point, with no adverse pressure across the fan, a test system booster fan shall be controlled, such that

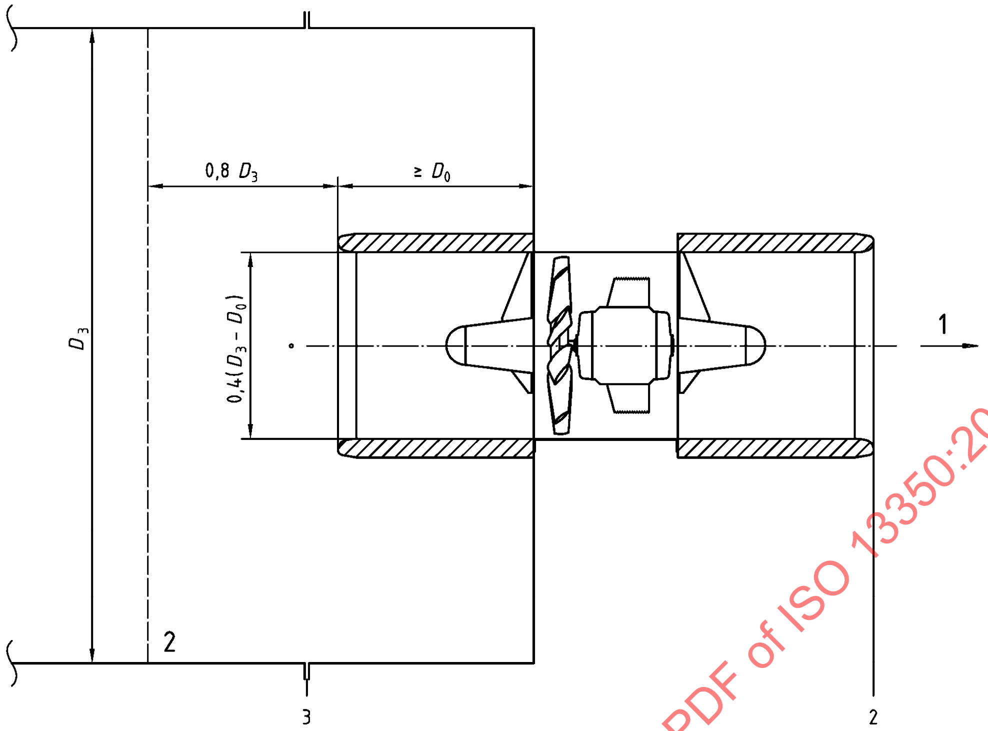
$$p_{e3} = p_{e2} = 0 \tag{2}$$

where

p_{e3} is the gauge pressure in the fan chamber;

p_{e2} is the gauge pressure at the fan outlet.

If it is not possible to control the booster accurately, it might be necessary to measure the flow at more than one operating point.



Key

1 air flow

2 screen

3 pressure tappings for measuring p_{e3}

Figure 9 — Flow-measuring device (upstream chamber)

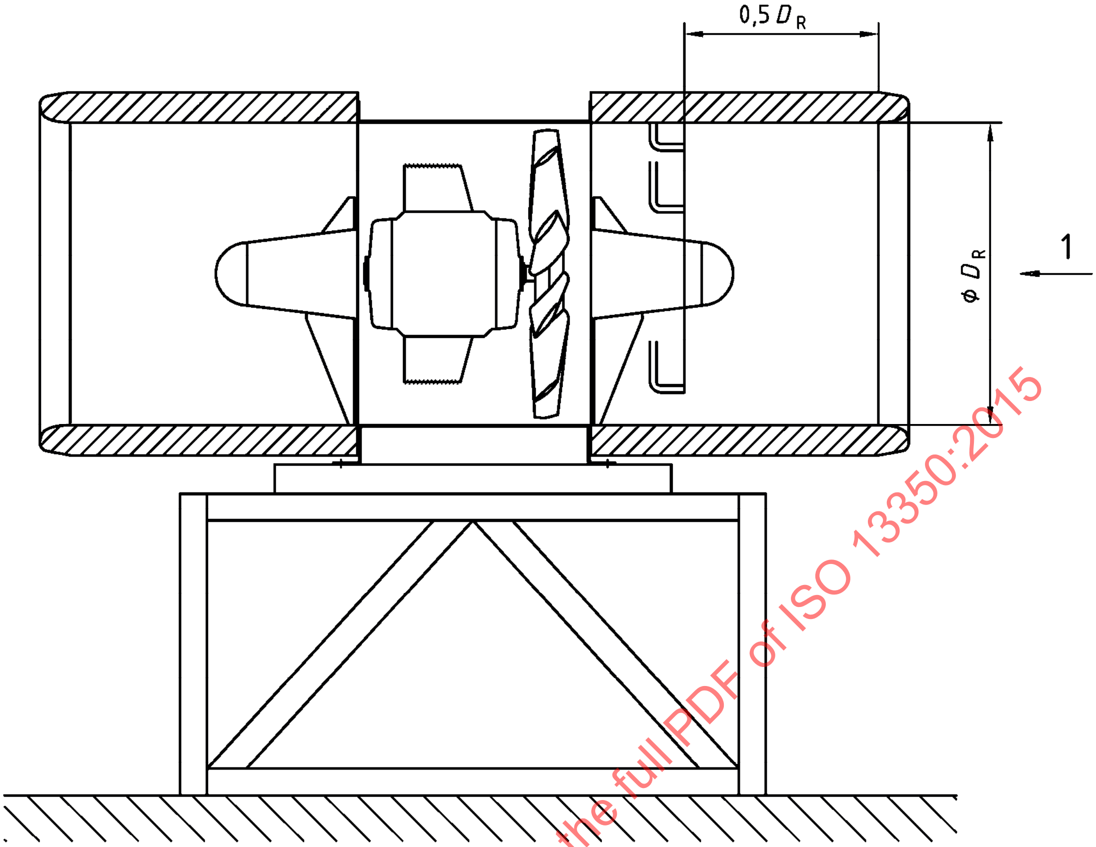
10.3 Upstream Pitot traverse method

For this method, the flowrate should be determined in accordance with ISO 5801:2007, Clause 25 (preferably upstream of the impeller; see Figure 10).

10.4 Directly connected flowrate-measuring device

The flowrate-measuring device shall be connected, by suitable means, to the fan inlet as illustrated in Figure 11. Details of the bellmouth shall be in accordance with ISO 5801:2007, Figure 17, while the conical inlet shall comply with ISO 5801:2007, Figure 17. For the purpose of flowrate determination in accordance with this International Standard, an antiswirl device is not required.

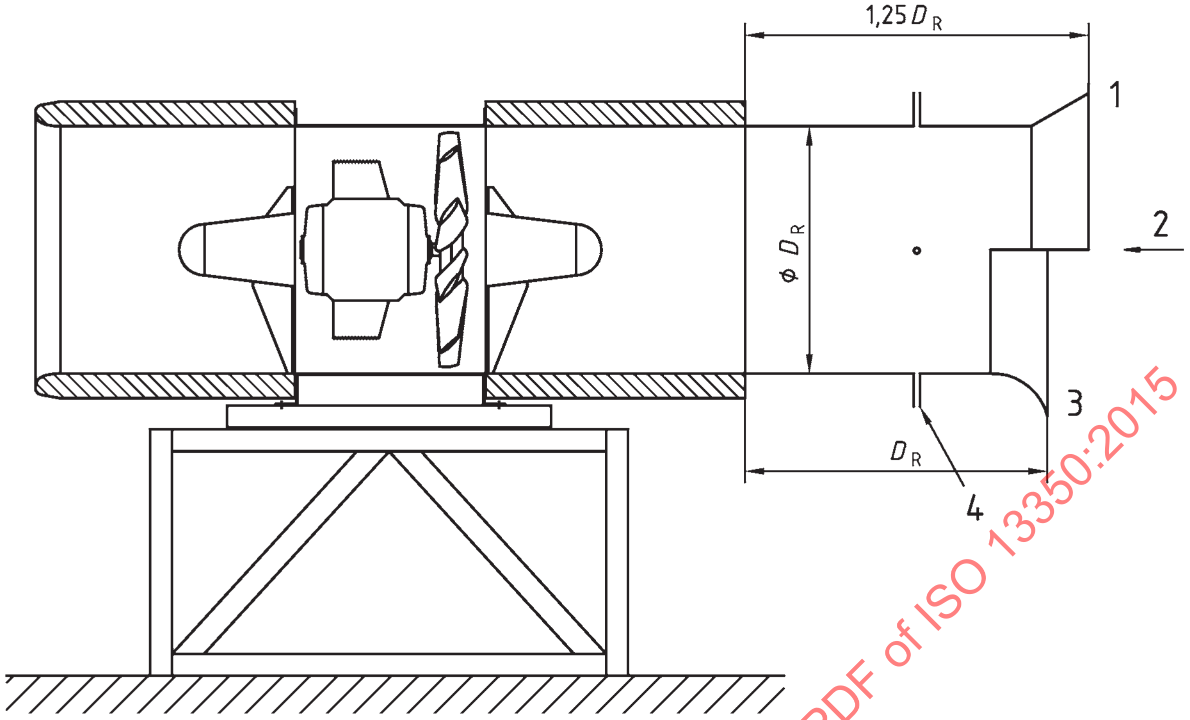
Flowrate for the bellmouth and that for the conical inlet is calculated in accordance with ISO 5801:2007, Clause 23.



Key

1 air flow

Figure 10 — Flow-measuring installation (upstream Pitot traverse)



Key

1 conical inlet
2 air flow
3 bellmouth
4 side tappings

Figure 11 — Flow-measuring installation (direct connection)

11 Presentation of results

11.1 Product description

The product description shall include at least the following information:

a) model reference;

b) nominal size of fan;

c) rotational speed;

d) motor output rating and frame size;

e) electrical supply data;

f) high temperature operating capability;

g) overall dimensions;

h) mounting dimensions;

i) fan assembly mass;

j) accessories, e.g. guards, vibration isolators;

k) condition monitoring equipment.

11.2 Product performance

The performance of the product described in 11.1, which can be given as a listing, shall include at least the following information:

a) thrust (at density 1,2 kg/m^3);

b) effective fan outlet velocity (see Note 1 below);

c) motor input power (at density 1,2 kg/m^3);

d) maximum open inlet, L_{W1},or open outlet, L_{W2}, sound power levels (see Note 2 below);

e) vibration velocities.

By agreement with the client, the data can be provided for "forward" and "reverse" operations.

It shall always be made clear which accessories were fitted when the performance tests were undertaken.

NOTE 1 The effective fan outlet velocity v_{eff} is used to calculate the correction factor k on the thrust due to the mainstream tunnel velocity v_t in the tunnel, where:

$$k = \frac{v_{eff} - v_t}{v_{eff}} \tag{3}$$

v_{eff} can best be defined as:

$$v_{eff} = \left(\frac{T_m}{A_{eff} \cdot \rho} \right)^{1/2} \tag{4}$$

For definition of A_{eff}, fan outlet area, see 3.2.

NOTE 2 It can be preferred, by agreement with the client, to present sound level data in an alternative form. For example, as an A-weighted spherical sound pressure level at 10 m or 3 m, 45° in free field. Also, by agreement with the client, it can be decided whether the sound level is given as a single total figure or in each octave band.

NOTE 3 If required for contractual reasons, the flowrate can be determined by one of the methods given Clause 10.

12 Tolerances and conversion rules

12.1 Tolerances

The performance quoted is the most probable performance, not the minimum or maximum value. The tolerance values apply to jet fans operating without external resistance and as tested in accordance with this International Standard.

As shown in Table 3, the tolerances are intended to take into account measurement uncertainty and manufacturing variations. When direct test results are not available, see Annex C.

The effects described in the notes to Table 3 are responsible for the large tolerances given in Table 3, in order to save complicated correction procedures. Addition of these uncertainties can give rise in certain cases to a total tolerance on the absorbed power of more than the 5 % stated.

12.2 Conversion rules

The conversion rules recommended in Annex C apply to fan assemblies with geometric similarity. In the case of jet fans, this means similarity of the following features:

a) silencer lengths;

b) silencer pod geometry;

c) silencer bellmouth shape;

d) impeller hub ratio;

e) impeller spinner profile;

f) blade shape and solidity;

g) blade setting angle;

h) motor support design;

i) motor size;

j) blade tip clearance (smoke-venting designs).

It is accepted that, for practical reasons, it is not reasonable for every configuration of fan to be subjected to a direct test. Also, perfect geometric similarity is not always readily achievable. Nonetheless, it is incumbent on the manufacturer to authenticate any conversion rules used.

Application of conversion rules shall be limited as follows when calculating the performance of another fan from direct test and allowing for some departure from geometric similarity.

— Fan size: ± one R20 step

— Rotational speed: test speed × 1,3 or test speed / 1,3.

Table 3

Measured parameter	Measurement uncertainty	Manufacturing variation	Notes
FAN			
Thrust	±5 %	±1 %	1
Effective fan outlet velocity	±10 %	±3 %	1,2
Input power	±2 %	±3 %	5
Sound level	—	—	3
MOTOR			
1. Efficiency η_m[a] By summation of losses: — machines up to 50 kW — machines above 50 kW By input-output test		 −15 % of (1 - η_m) −10 % of (1 - η_m) −15 % of (1 - η_m)	
2. **Total losses**[a] (applicable to machines above 50 kW)		+10 % of the total losses	
3. **Power factor**, cos ϕ, for induction machines		−0,167 (1 – cos ϕ)	minimum 0,02 maximum 0,07
4. **Slip of induction motors** (at full load and at working temperature) — machines having output 1 kW (or kVA) or more — machine having output less than 1 kW (or kVA)		 ±20 % of the guaranteed slip ±30 % of the guaranteed slip	
5. **Speed of a.c. motors with shunt characteristics** (at full load and at working temperature) — on the highest speed — on the lowest speed		 −3 % of the synchronous speed +3 % of the synchronous speed	

[a] The determination of losses and efficiency is carried out in accordance with IEC 600342-2-1.

NOTE 1 It should be noted that while thrust is measured, the effective fan outlet velocity is calculated from the thrust using density and conventionalized fan outlet area.

NOTE 2 The relatively large uncertainty of the effective fan outlet velocity will, in most cases, have little practical importance in relation to the thrust to be installed in the tunnel, as it only concerns a secondary correction factor.

NOTE 3 Uncertainty of measurement of sound levels are given in ISO 13347 (95% confidence level). Tolerances arising from manufacturing variations are given in ISO 13348.

NOTE 4 It might take some time (say between 1 min and 15 min) before the airflow pattern in the test chamber becomes fully developed. During this time, the fan thrust will fall below its initial value. Additionally, the fan thrust can show pronounced erratic variations with time, which can be caused mainly by turbulence and thermal effects in the movement of air in the chamber, variations of supply voltage, etc.

The measuring equipment should preferably automatically form root mean square (r.m.s.) values over duration of at least 3 min. The reading is recorded when variations from period to period no longer occur which are greater than 0,5 times the measuring tolerances in the case of thrust, power consumption, wind speed or direction.

NOTE 5 The prediction accuracy of the motor input power is limited by the manufacturing variations to be expected for the electric motors. These are given in EN 60034-1. The 2010 version gives a tolerance on the motor efficiency of -0,15 (1 - η_m) for machines having less than 50 kW shaft power. For larger machines, this tolerance is reduced to -0,10 (1 - η_m). This is not the only tolerance, when the absorbed power is considered. For motors above 1 kW (or kVA), the permissible slip tolerance at full load and at rated temperature (normally 40 °C) is equal to ±20 % of the guaranteed slip. As the absorbed shaft power of a fan varies with the cube of the speed, this can lead to considerable variations of the input power and aerodynamic duty. The tolerance of the power factor cos ϕ is given as – 0,167 (1 - cos ϕ), minimum −0,02, maximum −0,07.

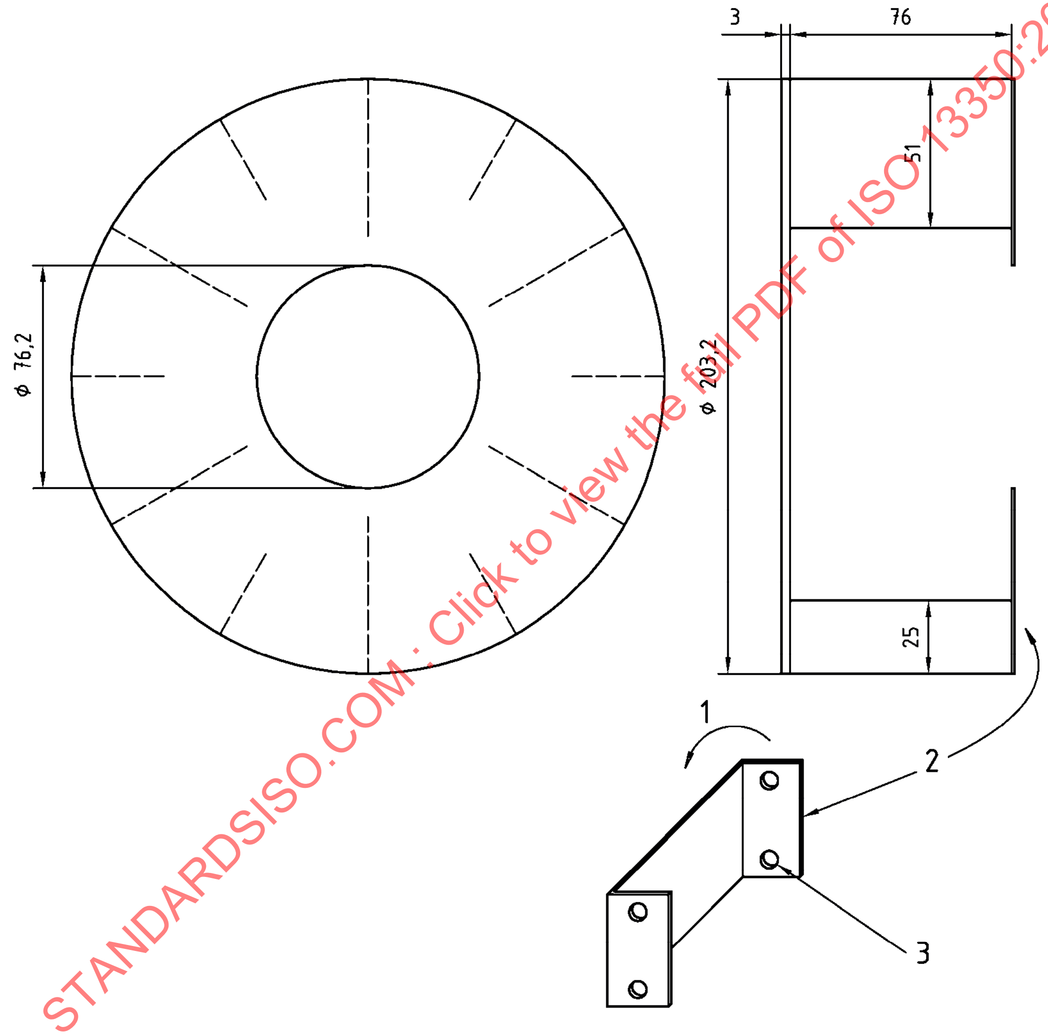
NOTE 6 Motor losses, motor speed, and power factor depend on the motor temperature. The name plate data are normally based on a 40 °C chamber temperature, plus the motor temperature rise at full load with normal motor cooling. These conditions do not normally prevail with a jet fan. The load can differ from normal and the high air speed and an air temperature normally well below 40 °C will result in lower motor temperatures. This will cause lower winding temperatures, higher currents, and also a variation of speed and cosinus. Furthermore, steady-state conditions will take some time to be established. The tolerances of electric motor data given in IEC 60034-1 should also be respected.

Annex A
(informative)

Illustration of reference sound source

If a calibrated reference sound source is not commercially available, an impeller manufactured in accordance with Figure A.1 and correctly calibrated can be used.

Dimensions in millimetres



Key

1 rotation

2 steel sheet, thickness 1 mm

3 securely riveted

Figure A.1 — Blade detail