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Fans — Performance testing using standardized airways

Ventilateurs — Essais aérauliques sur circuits normalisés

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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 may 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 voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

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

This third edition cancels and replaces the second edition (ISO 5801:2007), which has been technically revised. It also incorporates the Technical Corrigendum ISO 5801:2007/Cor.1:2008.

Introduction

This document is the result of almost 50 years of discussion, comparative testing and detailed analyses by leading specialists from the fan industry and research organizations throughout the world.

It was demonstrated many years ago that the codes for fan performance testing established in different countries do not always lead to the same results.

The need for an International Standard has been evident for some time and Technical Committee ISO/TC 117 started its work in 1963. Important progress has been achieved over the years and, although the International Standard itself was not yet published, the successive revisions of various national standards led to much better agreement among them.

It has become possible since 1997 to complete this document by agreement on certain essential points. It is to be borne in mind that the test equipment, especially for large fans, is very expensive and it was necessary to include in this document many setups from various national codes in order to authorize their future use. This explains the sheer volume of the first edition (ISO 5801:1997).

The second edition (ISO 5801:2007) of this document was the result of a survey of ISO members, deleting those methods that were the least frequently used. A significant reduction in the number of pages had been achieved.

For the third edition, the contents were reorganized to define and allow all possible configurations of defined component parts as standardized test setups. A further significant reduction of volume has been achieved by streamlining the content.

Essential features of this document are as follows.

— **Installation categories and test configurations** (see Clause 5 and Clause 6).

Since the connections of a duct to a fan inlet and/or outlet affect the fan's performance, a number of installation categories and test configurations need to be recognized.

— **Common segments** (see Clause 8).

It is essential that all standardized test airways to be used with fans need to have portions in common adjacent to the fan inlet and/or outlet sufficient to ensure consistent determination of fan pressure.

Geometric variations of these common segments are strictly limited.

— **Flow rate measurement** (see 12.5 and Annex A).

Determination of flow rate has been separated from the determination of fan pressure. A number of standardized methods may be used.

— **Test results** (see Clause 15).

Methods of measurement and calculation for the flow rate, for the fan pressure and for the fan efficiencies are established taking into account all compressibility effects of the air. For fan pressure less than 2 000 Pa, the change of density between fan inlet and fan outlet is allowed to be neglected. Other compressibility effects are allowed to be neglected for reference velocity values not higher than 65 m/s (see Clause 13).

Fans — Performance testing using standardized airways

1 Scope

This document specifies procedures for the determination of the performance of fans of all types except those designed solely for air circulation, e.g. ceiling fans and table fans. Testing of jet fans is described in ISO 13350.

This document provides estimates of uncertainty of measurement and rules for the conversion, within specified limits, of test results for changes in speed, gas handled and, in the case of model tests, size are given.

2 Normative references

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

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

ISO 5167–1, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 1: General principles and requirements*

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

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

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

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

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

IEC 60034-1:2010, *Rotating electrical machines — Part 1: Rating and performance*

IEC 60034-2-1:2014, *Rotating electrical machines — Part 2-1: Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles)*

IEC 60051-2, *Direct acting indicating analogue electrical measuring instruments and their accessories — Part 2: Special requirements for ammeters and voltmeters*

IEC 60051-3, *Direct acting indicating analogue electrical measuring instruments and their accessories — Part 3: Special requirements for wattmeters and varmeters*

3 Terms and definitions

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

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

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

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

3.1
air
working fluid for tests with standardized airways shall be atmospheric air

3.2
standard air
air (3.1) with a density of 1,2 kg/m^3

Note 1 to entry: See 12.9.4.

3.3
upstream
direction from where the air flow comes

3.4
downstream
direction to where the air flow discharges

3.5
cross sectional area
A
area contained in a boundary

3.6
fan inlet area
A_1
cross sectional area (3.5) of fan inlet as defined in ISO 13349

3.7
fan outlet area
A_2
cross sectional area (3.5) of fan outlet as defined in ISO 13349

3.8
hydraulic diameter
D_h
four times the cross sectional area divided by the perimeter which encloses the area

$$D_h = \frac{4 \cdot A}{P_\square}$$

3.9
hydraulic mean depth
H_h
cross sectional area divided by the perimeter which encloses the area

$$H_h = \frac{A}{P_\square}$$

3.10
absolute temperature
θ
temperature expressed in Kelvin and calculated from the relative gas temperature in degree Celsius plus the thermodynamic temperature according to ISO 13349 of absolute zero

$$\theta = T + 273{,}15$$

3.11
absolute temperature of moving air
θ
absolute temperature (3.10) theoretically registered by a thermal sensor moving at the air velocity calculated from the formula

$$\theta = \theta_{sg} \Big/ \left(1 + \frac{\kappa - 1}{2} \cdot Ma^2\right)$$

or

$$\theta = \theta_{sg} - \frac{v^2}{2 \cdot c_p}$$

3.12
stagnation temperature
θ_{sg}
absolute temperature (3.10) measured at an isentropic stagnation point

Note 1 to entry: The stagnation temperature is constant along an airway without exchange of energy or heat.

3.13
specific heat at constant pressure
c_p
amount of heat energy required to raise the temperature of air per unit of mass at constant pressure

3.14
specific heat at constant volume
c_V
amount of heat energy required to raise the temperature of air per unit of mass at constant volume

3.15
isentropic exponent
k
ratio of the specific heat at constant pressure to the specific heat at constant volume

$$\kappa = \frac{c_p}{c_V}$$

3.16
specific gas constant
R
difference between the specific heat at constant pressure versus the specific heat at constant volume

$$R = c_p - c_V$$

use

$$R = \frac{p}{\rho \cdot \theta}$$

where

ρ is the *air density* (3.18) (kg/m^3)

p is the *absolute pressure* (3.27) (Pa)

θ is the *absolute temperature* (3.10) (K)

For dry air, R_{dry} = 287.058 J/(kg·K)

3.17
specific gas constant for humid air
R_{wet}
atmospheric pressure divided by the density of air multiplied by the absolute ambient temperature

$$R_{wet} = \frac{p_a}{\rho \cdot \theta_a}$$

3.18
air density
ρ
air density calculated from the *absolute pressure*, p, (3.27) and the air temperature, θ

$$\rho = \frac{p}{R_{wet} \cdot \theta}$$

3.19
stagnation density
ρ_{sg}
air density (3.18) calculated from the *stagnation pressure*, p_{sg}, (3.29) and the *stagnation temperature*, θ_{sg} (3.12)

$$\rho_{sg} = \frac{p_{sg}}{R_{wet} \cdot \theta_{sg}}$$

3.20
mean density
ρ_m
mean value of the air densities of the fan

$$\rho_m = \frac{\rho_1 + \rho_2}{2}$$

3.21
mean stagnation density
ρ_{sgm}
mean value of the stagnation densities of the fan

$$\rho_{sgm} = \frac{\rho_{sg1} + \rho_{sg2}}{2}$$

3.22
mass flow rate
q_m
mean value, over time, of the mass of air which passes through the airway per unit of time

3.23
volume flow rate
q_{V1}
mass flow rate (3.22) divided by the density at fan inlet

$$q_{V1} = \frac{q_m}{\rho_1}$$

3.24
volume flow rate at stagnation conditions
q_{Vsg1}
mass flow rate (3.22) divided by the *stagnation density* (3.19) at fan inlet

$$q_{Vsg1} = \frac{q_m}{\rho_{sg1}}$$

3.25
average velocity
v
mass volume flow rate divided by the cross sectional area multiplied by the air density

$$v = \frac{q_m}{\rho \cdot A}$$

3.26
reference velocity
$v_{2.ref}$
velocity calculated at fan outlet, A_2, for the maximum *mass flow rate* (3.22) of the fan, $q_{m,max}$, and for the reference density of *standard air* (3.2), $\rho_{ref} = 1{,}200\ kg/m^3$

$$v_{2.ref} = \frac{q_{m.max}}{\rho_{ref} \cdot A_2}$$

Note 1 to entry: See 12.9.3.

3.27
absolute pressure
p
pressure, measured with respect to absolute zero pressure

3.28
mean gauge pressure
differential pressure, measured with respect to ambient pressure $p_e = p - p_a$

3.29
stagnation pressure
p_{sg}
absolute pressure (3.27), if the air were brought to rest via an isentropic process

$$p_{sg} = p \cdot \left(1 + \frac{\kappa - 1}{2} \cdot Ma^2\right)^{\frac{\kappa}{\kappa - 1}} = p + f_M \cdot p_d$$

3.30
dynamic pressure
p_d

pressure calculated from the velocity, v, and the density, ρ

$$p_{\mathrm{d}} = \rho \cdot \frac{v^2}{2}$$

3.31
total pressure
p_{tot}
pressure calculated from the *absolute pressure* (3.27) and the *dynamic pressure* (3.30)

$$p_{\mathrm{tot}} = p + p_{\mathrm{d}}$$

3.32
fan dynamic pressure
p_{fd}
dynamic pressure (3.30) of the fan, defined at the fan outlet with the *average velocity* (3.25)

$$p_{\mathrm{fd}} = p_{d2} = \rho_2 \cdot \frac{v_2^2}{2}$$

3.33
fan pressure
p_{f}
difference between the *stagnation pressures* (3.29) at the fan outlet and the fan inlet

$$p_{\mathrm{f}} = p_{\mathrm{sg2}} - p_{\mathrm{sg1}}$$

or difference between the *total pressures* (3.31) at the fan outlet and the fan inlet

$$p_{\mathrm{f}} = p_{\mathrm{tot2}} - p_{\mathrm{tot1}} \text{ allowed if } v_{2.\mathrm{ref}} \leq 65 \text{ m/s}$$

Note 1 to entry: For the establishment of the value 65 m/s, see Clause 13.

3.34
fan static pressure
p_{fs}
difference between the static pressure at the fan outlet and the *stagnation pressure* (3.29) at the fan inlet

$$p_{fs} = p_2 - p_{\mathrm{sg1}} = p_{\mathrm{sg2}} - p_{\mathrm{d2}} \cdot f_{\mathrm{M2}} - p_{\mathrm{sg1}} = p_{\mathrm{f}} - p_{\mathrm{fd}} \cdot f_{\mathrm{M2}}$$

or difference between the static pressure at the fan outlet and the *total pressure* (3.31) at the fan inlet

$$p_{\mathrm{fs}} = p_2 - p_{\mathrm{tot1}} = p_{\mathrm{tot2}} - p_{\mathrm{d2}} - p_{\mathrm{tot1}} = p_{\mathrm{f}} - p_{\mathrm{fd}} \text{ allowed if } v_{2.\mathrm{ref}} \leq 65 \text{ m/s}$$

Note 1 to entry: For the establishment of the value 65 m/s, see Clause 13.

3.35
fan pressure ratio
r
ratio of the average absolute *stagnation pressure* (3.29) at the outlet section of a fan to that at its inlet section as given by the following formula

$$r = \frac{p_{\mathrm{sg2}}}{p_{\mathrm{sg1}}}$$

Note 1 to entry: The fan pressure ratio is dimensionless.

3.36
rotational frequency of the impeller
n
number of revolutions of the fan impeller per second

3.37
tip speed of the impeller
u
peripheral speed of the impeller blade tips

$$u = \pi \cdot n \cdot D_r$$

3.38
velocity of sound
c
distance travelled per unit time by a sound wave at it propagates through air $c = \sqrt{\kappa \cdot R_{wet} \cdot \theta}$

3.39
Mach number
Ma
ratio of the air velocity to the *velocity of sound* (3.38)

$$Ma = \frac{v}{c}$$

3.40
peripheral Mach number
Ma_u
ratio of tip speed to the *velocity of sound* (3.38) at the fan inlet stagnation conditions

$$Ma_u = \frac{u}{\sqrt{\kappa \cdot R_{wet} \cdot \theta_{sg1}}}$$

3.41
Mach factor
f_M
correction factor applied to the *dynamic pressure* (3.30)

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

Note 1 to entry: The Mach factor f_M may be calculated by:

$$f_M = 1 + \frac{Ma^2}{4} + \frac{(2-\kappa) \cdot Ma^4}{24} + \frac{(2-\kappa) \cdot (3-2\kappa) \cdot Ma^6}{192} + \ldots$$

3.42
fan work per unit mass
y_f
increase in energy of air per unit mass passing through the fan

$$y_f = \frac{p_2 - p_1}{\rho_m} + \frac{1}{2} \cdot f_{M2} \cdot v_2{}^2 - \frac{1}{2} \cdot f_{M1} \cdot v_1{}^2$$

3.43
fan air power