INTERNATIONAL
STANDARD

ISO
5801

First edition
1997-06-01

Industrial fans — Performance testing using standardized airways

Ventilateurs industriels — Essais aérauliques sur circuits normalisés

Reference number
ISO 5801:1997(E)

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X.400 c=ch; a=400net; p=iso; o=isocs; s=central

Printed in Switzerland

Annexes

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.

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.

International Standard ISO 5801 was prepared by Technical Committee ISO/TC 117, *Industrial fans*, Subcommittee SC 1, *Fan performance testing using standardized airways*.

Annexes A, B and C form an integral part of this International Standard. Annexes D and E are for information only.

Introduction

This International Standard is the result of almost thirty 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 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 subsequent revisions of various national standards led to much better agreement among them.

It has now become possible to complete this International Standard by agreement on certain essential points. It must be borne in mind that the test equipment, especially for large fans, is very expensive and it was necessary to include in the present International Standard many set-ups from various national codes in order to authorize their future use. This explains the sheer volume of this document.

Essential features of the present standard are as follows:

a) Types of installation

Since the connection of a duct to a fan outlet and/or inlet modifies its performance, it has been agreed that four standard installation types should be recognized.

These are:

- Type A: free inlet and outlet;
- Type B: free inlet and ducted outlet;
- Type C: ducted inlet and free outlet;
- Type D: ducted inlet and outlet.

A fan adaptable to more than one installation type will have more than one standardized performance characteristic. The user should select the installation type closest to his application.

b) Common parts

The differences obtained by testing the same fan according to various test codes depend chiefly on the flow pattern at the fan outlet and, while often minor, can be of substantial significance. There is general agreement that it is essential that all standardized test airways to be used with fans 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.

However, conventional agreement has been achieved for some particular situations:

1) For centrifugal or cross-flow fans without outlet swirling flow, it is possible to use a simplified outlet duct as described in 30.2 f) without straightener when discharging to the atmosphere or to a measuring chamber.

2) For large fans (outlet diameter exceeding 800 mm) it may be difficult to carry out the tests with standardized common airways at the outlet including a straightener. In this case, by mutual agreement between the parties concerned, the fan performance may be measured using the set-up described in 30.2 f) with a duct of length $2D$ on the outlet side. Results obtained in this way may differ to some extent from those obtained using the normal type D installation, especially if the fan produces a large swirl. Establishment of a possible value of differences, is still a subject of research.

c) Calculations

Fan pressure is defined as the difference between the stagnation pressure at the outlet of the fan and the stagnation pressure at the inlet of the fan. The compressibility of air must be taken into account when high accuracy is required. However, simplified methods may be used when the reference Mach number does not exceed 0,15.

A method for calculating the stagnation pressure and the fluid or static pressure in a reference section of the fan, which stemmed from the work of the ad hoc group of Subcommittee 1 of ISO/TC 117, is given in annex C.

Three methods are proposed for calculation of the fan power output and efficiency. All three methods give very similar results (difference of a few parts per thousand for pressure ratios equal to 1,3).

d) Flowrate measurement

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

Industrial fans — Performance testing using standardized airways

1 Scope

This International Standard deals with the determination of the performance of industrial fans of all types except those designed solely for air circulation e.g. ceiling fans and table fans.

Estimates of uncertainty of measurement are provided 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 standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 3966:1977, *Measurement of fluid flow in closed conduits — Velocity area method using Pitot static tubes.*

ISO 5167-1:1991, *Measurement of fluid flow by means of pressure differential devices — Part 1: Orifice plates, nozzles and Venturi tubes inserted in circular cross-section conduits running full.*

ISO 5168:—1), *Measurement of fluid flow — Evaluation of uncertainties.*

ISO 5221:1984, *Air distribution and air diffusion — Rules to methods of measuring air flowrate in an air handling duct.*

IEC 34-2:1972, *Rotating electrical machines — Part 2: Methods for determining losses and efficiency of rotating electrical machinery from tests (excluding machines for traction vehicles).*

IEC 51-2:1984, *Direct acting indicating analogue electrical-measuring instruments and their accessories — Part 2: Special requirements for ammeters and voltmeters.*

IEC 51-3:1984, *Direct acting indicating analogue electrical-measuring instruments and their accessories — Part 3: Special requirements for wattmeters and varmeters.*

IEC 51-4:1984, *Direct acting indicating analogue electrical-measuring instruments and their accessories — Part 4: Special requirements for frequency meters.*

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1) To be published. (Revision of ISO 5168:1978)

3 Definitions

For the purposes of this International Standard, the definitions given in ISO 5168 and the following definitions apply.

NOTE 1 All the symbols used in this International Standard are listed with their units in clause 4.

3.1 area of the conduit section, A_x: Area of the conduit at section x.

3.2 fan inlet area, A_1: Surface plane bounded by the upstream extremity of the air-moving device.

The inlet area is, by convention, taken as the gross area in the inlet plane inside the casing.

3.3 fan outlet area, A_2: Surface plane bounded by the downstream extremity of the air-moving device.

Fan outlet area is, by convention, taken as the gross area in the outlet plane inside the casing.

3.4 temperature, t: Air or fluid temperature measured by a temperature sensor.

3.5 absolute temperature, Θ: Thermodynamic temperature.

$$\Theta = t + 273{,}15$$

NOTE 2 In this document, Θ represents the absolute temperature and t the temperature in degrees Celsius.

3.6 specific gas constant, R:

For an ideal dry gas, the equation of state is written

$$\frac{p}{\rho} = R\Theta$$

$R = 287\ \mathrm{J \cdot kg^{-1} \cdot} K^{-1}$ for dry air.

3.7 isentropic exponent, κ:

For an ideal gas and an isentropic process,

$$\frac{p}{\rho^{\kappa}} = \text{constant}$$

$\kappa = 1{,}4$ for atmospheric air.

3.8 specific heat capacity at constant pressure, c_p:

For an ideal gas,

$$c_p = \frac{\kappa}{\kappa - 1} R$$

3.9 specific heat capacity at constant volume, c_V:

For an ideal gas,

$$c_V = \frac{1}{\kappa - 1} R$$

3.10 compressibility factor, Z:

For an ideal gas, $Z = 1$

For a real gas,

$$Z = \frac{p}{\rho R \Theta}$$

and Z is a function of the ratios p/p_c and Θ/Θ_c

where

p_c is the critical pressure of the gas;

Θ_c is the critical temperature of the gas.

3.11 stagnation temperature at a point, Θ_{sg}: Absolute temperature which exists at an isentropic stagnation point for ideal gas flow without addition of energy or heat.

The stagnation temperature is constant along an airway and, for an inlet duct, is equal to the absolute ambient temperature in the test enclosure.

3.12 static or fluid temperature at a point, Θ: Absolute temperature registered by a thermal sensor moving at the fluid velocity.

For a real gas flow,

$$\Theta = \Theta_{sg} - \frac{v^2}{2c_p}$$

where v = fluid velocity at a point, in metres per second ($\text{m} \cdot \text{s}^{-1}$).

In a duct, when the velocity increases the static temperature decreases.

3.13 dry-bulb temperature, t_d: Air temperature measured by a dry temperature sensor in the test enclosure, near the fan inlet or airway inlet.

3.14 wet-bulb temperature, t_w: Air temperature measured by a temperature sensor covered by a water-moistened wick and exposed to air in motion.

When properly measured, it is a close approximation of the temperature of adiabatic saturation.

3.15 stagnation temperature at a section x, Θ_{sgx}: Mean value, over time, of the stagnation temperature averaged over the area of the specified airway cross-section.

3.16 static or fluid temperature at a section x, Θ_x: Mean value, over time, of the static or fluid temperature averaged over the area of the specified airway cross-section.

3.17 absolute pressure at a point; absolute pressure, p: Pressure, measured with respect to absolute zero pressure, which is exerted at a point at rest relative to the air around it.

3.18 atmospheric pressure, p_a: Absolute pressure of the free atmosphere at the mean altitude of the fan.

3.19 gauge pressure, p_e: Value of the pressure when the datum pressure is the atmospheric pressure at the point of measurement.

It may be negative or positive.

$$p_e = p - p_a$$

3.20 absolute stagnation pressure at a point, p_{sg}: Absolute pressure which would be measured at a point in a flowing gas if it were brought to rest via an isentropic process:

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

where Ma is the Mach number at this point (see 3.23).

3.21 Mach factor, F_M: Correction factor applied to the dynamic pressure at a point, given by the expression

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

The Mach factor may be calculated by

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

3.22 dynamic pressure at a point, p_d: Pressure calculated from the velocity v and the density ρ of the air at the point.

$$p_d = \rho \frac{v^2}{2}$$

3.23 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.

3.24 gauge stagnation pressure at a point, p_{esg}: Difference between the absolute stagnation pressure p_{sg} and the atmospheric pressure p_a.

$$p_{esg} = p_{sg} - p_a$$

3.25 mass flowrate, q_m: Mean value, over time, of the mass of air which passes through the specified airway cross-section per unit of time.

NOTE 3 The mass flow will be the same at all cross-sections within the fan airway system excepting leakage.

3.26 average gauge pressure at a section x, p_{ex}: Mean value, over time, of the gauge pressure averaged over the area of the specified airway cross-section.

3.27 average absolute pressure at a section x, p_x: Mean value, over time, of the absolute pressure averaged over the area of the specified airway cross-section.

$$p_x = p_{ex} + p_a$$

3.28 average density at a section x, ρ_x: Fluid density calculated from the absolute pressure p_x and the static temperature Θ_x.

$$\rho_x = \frac{p_x}{R_w \Theta_x}$$

where R_w is the gas constant of humid gas.

3.29 volume flowrate at a section x, q_{Vx}: Mass flowrate at the specified airway cross-section divided by the corresponding mean value, over time, of the average density at that section.

$$q_{Vx} = \frac{q_m}{\rho_x}$$

3.30 average velocity at a section x, v_{mx}: Volume flowrate at the specified airway cross-section divided by the cross-sectional area A_x.

$$v_{mx} = \frac{q_{Vx}}{A_x}$$

NOTE 4 This is the mean value, over time, of the average component of the gas velocity normal to that section.

3.31 conventional dynamic pressure at a section x, p_{dx}: Dynamic pressure calculated from the average velocity and the average density at the specified airway cross-section.

$$p_{dx} = \rho_x \frac{v_{mx}^2}{2} = \frac{1}{2\rho_x}\left(\frac{q_m}{A_x}\right)^2$$

NOTE 5 The conventional dynamic pressure will be less than the average of the dynamic pressures across the section.

3.32 Mach number at a section x, Ma_x: Average gas velocity divided by the velocity of sound at the specified airway cross-section.

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

3.33 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:

$$p_{sgx} = p_x + p_{dx} F_{Mx}$$

NOTE 6 The average stagnation pressure may be calculated by the expression

$$p_{sgx} = p_x \left(1 + \frac{\kappa - 1}{2} Ma_x^2\right)^{\frac{\kappa}{\kappa - 1}}$$

3.34 gauge stagnation pressure at a section x, p_{esgx}: Difference between the average stagnation pressure, p_{sgx}, at a section and the atmospheric pressure, p_a.

$$p_{esgx} = p_{sgx} - p_a$$

3.35 inlet stagnation temperature, Θ_{sg1}: Absolute temperature in the test enclosure near the fan inlet at a section where the gas velocity is less than 25 m · s⁻¹.

In this case the stagnation temperature may be considered as equal to the ambient temperature Θ_a.

$$\Theta_{sg1} = \Theta_a = t_a + 273{,}15$$

3.36 stagnation density, ρ_{sg1}: Density calculated from the inlet stagnation pressure p_{sg1} and the inlet stagnation temperature Θ_{sg1}:

$$\rho_{sg1} = \frac{p_{sg1}}{R_w \Theta_{sg1}}$$

3.37 inlet stagnation volume flowrate, q_{Vsg1}: Mass flowrate divided by the inlet stagnation density.

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

3.38 fan pressure, p_F: Difference between the stagnation pressure at the fan outlet and the stagnation pressure at the fan inlet.

$$p_F = p_{sg2} - p_{sg1}$$

When the Mach number is less than 0,15,

$$p_F = p_{tF} = p_{t2} - p_{t1}$$

NOTE 7 Fan pressure should be referred to the installation type A, B, C or D.