# INTERNATIONAL STANDARD

# ISO 21927-3

First edition
2006-11-15

## Smoke and heat control systems —

## Part 3: Specification for powered smoke and heat exhaust ventilators

*Systèmes de contrôle de fumée et de chaleur —*

*Partie 3: Spécifications pour les ventilateurs mécaniques d'évacuation des fumées et de la chaleur*

Reference number
ISO 21927-3:2006(E)

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Published in Switzerland

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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.

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 21927-3 was prepared by Technical Committee ISO/TC 21, *Equipment for fire protection and fire fighting*, Subcommittee SC 11, *Smoke and heat control systems and components*.

ISO 21927 consists of the following parts, under the general title *Smoke and heat control systems*:

— *Part 1: Specification for smoke barriers*

— *Part 2: Specification for natural smoke and heat exhaust ventilators*

— *Part 3: Specification for powered smoke and heat exhaust ventilators*

## Introduction

Smoke- and heat-exhaust ventilation systems create a smoke-free layer above the floor by removing smoke and thus improve the conditions for the safe escape and/or rescue of people and animals and the protection of property and permit the fire to be fought while still in its early stages. They also exhaust hot gases released by a fire in the developing stage.

The use of smoke- and heat-exhaust ventilation systems to create smoke-free areas beneath a buoyant smoke layer has become widespread. Their value in assisting in the evacuation of people from construction works, reducing fire damage and financial loss by preventing smoke logging, facilitating fire fighting, reducing roof temperatures and retarding the lateral spread of fire is firmly established. For these benefits to be obtained, it is essential that smoke- and heat-exhaust ventilators operate fully and reliably whenever called upon to do so during their installed life. A heat- and smoke-exhaust ventilation system is a scheme of safety equipment intended to perform a positive role in a fire emergency.

It is important that components for smoke- and heat-exhaust systems be installed as part of a properly designed smoke and heat system.

Smoke- and heat-exhaust ventilation systems help to

— keep the escape and access routes free from smoke,

— facilitate fire-fighting operations by creating a smoke-free layer,

— delay and/or prevent flashover and thus full development of the fire,

— protect equipment and furnishings,

— reduce thermal effects on structural components during a fire,

— reduce damage caused by thermal decomposition products and hot gases.

Depending on the design of the system and the ventilator, powered or natural smoke and heat ventilators can be used in a smoke- and heat-control system. Powered smoke- and heat-exhaust ventilators can be installed in the roof or upper part of walls of buildings or in a ducted system with the ventilator inside or outside the smoke reservoir or in a plant room.

It is important that powered smoke- and heat-exhaust ventilation systems operate based on powered ventilators. The performance of a powered smoke- and heat-exhaust system depends on

— the temperature of the smoke,

— size, number and location of the exhaust openings,

— the wind influence,

— size, geometry and location of the inlet air openings,

— the time of actuation,

— the location and conditions of the system (for example arrangements and dimensions of the building).

Smoke- and heat-exhaust ventilation systems are used in buildings or construction works where the particular (large) dimensions, shape or configuration make smoke control necessary.

Typical examples are

- single and multi-storey shopping malls,
- single and multi-storey industrial buildings and warehouses,
- atria and complex buildings,
- enclosed car parks,
- stairways,
- tunnels,
- theatres.

Depending on differing circumstances and the situation of the building or construction works that can affect their performance, powered or natural smoke- and heat-exhaust ventilation systems can be used.

It is important that powered and natural exhaust ventilators not be used to extract smoke and hot gases from the same smoke reservoir.

Special conditions apply where gas extinguishing systems (e.g. in accordance with ISO 14520-1) are used.



# Smoke and heat control systems —

# Part 3:
# Specification for powered smoke and heat exhaust ventilators

## 1 Scope

This part of ISO 21927 specifies requirements and gives methods for testing powered smoke- and heat-exhaust ventilators that are intended to be installed as part of a powered smoke- and heat-exhaust ventilation system. It also provides a procedure for approving a range of powered smoke- and heat-exhaust ventilators and their motors, from a limited number of tests.

## 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 834-1, *Fire resistance tests — Elements of building construction — Part 1: General requirements*

ISO 5167 (all parts), *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full*

ISO 5221, *Air distribution and air diffusion — Rules to methods of measuring air flow rate in an air handling duct*

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

ISO 10294-1, *Fire resistance tests — Fire dampers for air distribution systems — Part 1: Test method*

ISO 13943, *Fire safety — Vocabulary*

ISO 21927-2:2004, *Smoke and heat control systems — Part 2: Specification for natural smoke and heat exhaust ventilators*

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

IEC 60034-2, *Rotating electrical machines — Part 2: Methods for determining losses and efficiency of rotating electrical machinery from tests (excluding machines for traction vehicles)*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13943 and the following apply.

**3.1**
**smoke- and heat-control system**
arrangement of components installed in a construction work to limit the effects of smoke and heat from a fire

**3.2**
**smoke- and heat-exhaust system**
smoke-control system that exhausts smoke and heat from a fire in a construction work or part of a construction work

**3.3**
**smoke- and heat-exhaust ventilation system**
**SHEVS**
components jointly selected to exhaust smoke and heat to establish a buoyant layer of warm gases above cooler, cleaner air

**3.4**
**natural ventilation**
ventilation caused by buoyancy forces due to differences in density of the gases because of temperature differences

**3.5**
**powered ventilation**
ventilation caused by the positive displacement of gases through a ventilator

NOTE Fans are usually used.

**3.6**
**ventilator**
device for enabling the movement of gases into or out of a construction work

**3.7**
**exhaust ventilator**
device for the movement of gases out of the construction work

**3.8**
**insulated motor**
motor thermally insulated from the environment which generally includes a motor casing

**3.9**
**smoke- and heat-exhaust ventilator**
**SHEV**
device specially designed to move smoke and hot gases out of the construction work under conditions of fire

**3.10**
**dual purpose ventilator**
smoke- and heat-exhaust ventilator that has provision to allow its use for comfort (i.e. day-to-day) ventilation

**3.11**
**emergency ventilator**
smoke- and heat-exhaust ventilator that is not used for comfort (i. e. day-to-day) ventilation

**3.12**
**automatically initiated powered smoke- and heat-exhaust ventilator**
powered smoke- and heat-exhaust ventilator that operates automatically after the outbreak of fire if called upon to do so

**3.13**
**smoke reservoir**
region within a building limited or bordered by smoke curtains or structural elements and which, in the event of a fire, retains a thermally buoyant smoke layer

**3.14**
**hot-gas fan**
fan that is suitable for handling hot gases for a specified time/temperature profile

**3.15**
**powered smoke- and heat-exhaust ventilator**
hot-gas fan that is suitable for handling hot gases for a limited period only

**3.16**
**powered roof ventilator**
partition fan designed for mounting on a roof and having exterior weather protection

**3.17**
**insulated ventilator**
ventilator insulated to limit the external surface temperature to reduce the danger of injury to persons or damage to materials

**3.18**
**smoke-reservoir ventilator**
ventilator suitable for operation fully immersed in a smoke reservoir

**3.19**
**non-smoke-reservoir ventilator**
ventilator not suitable for operation fully immersed in a smoke reservoir

**3.20**
**powered ventilator product range**
physically similar ventilators using the same form of construction and materials throughout, with the same methods of impeller construction and motor mounting and construction, and electrical connection in which the following can vary across the range:

— overall dimensions of the units;

— impeller diameter and width, hub size, blade length and number of blades of the impeller;

— size of the motor

**3.21**
**powered ventilator motor range**
motors that are physically similar, using the same form of construction, i.e. same materials and manufacturing method for carcase, cooling impeller, when fitted, and end covers; same insulation specification that includes sheet insulation used for coil separation and slot insulation, winding-impregnation material (varnish or resin, etc.), lead insulation, terminal blocks and any other materials that can affect the integrity of the insulation; same bearing type, class of fit, lubricant and arrangement, with motor windings based on the same maximum winding temperature and class of insulation, in which the following can vary across the range:

— frame size;

— rotational speed;

— electrical windings, including multi-speed;

— form of mounting, e.g. foot, flange, pad, clamp, etc.

**3.22**
**motor rating**
maximum power that the motor delivers continuously without exceeding the allowable temperature rise

**3.23**
**fire position**
position of a component to be reached and maintained while venting smoke and heat

# 4 Design requirements

## 4.1 Application classes

A powered ventilator shall be classified into one or more of the following application classes:

— insulated or uninsulated;

— smoke reservoir or non-smoke reservoir;

— dual purpose or emergency only use;

— ducted cooling air required.

## 4.2 Motor rating

**4.2.1** The motors shall be selected for continuous operation at the power required for normal ambient temperature, not just for operation at high temperature.

**4.2.2** Motor ratings shall be limited either by the temperature rise for one class lower than the insulation class of the motor, as defined in IEC 60034-1 and as given in Table 1 of this part of ISO 21927, or for motors with class B or class F insulation to the motor rated output power being 15 % above the absorbed power at a density of 1,2 kg/m$^3$.

**Table 1 — Motor temperature ratings**

| Motor insulation | Temperature rise at ambient |
|---|---|
| Class H or C | Class F |
| Class F | Class B |
| Class B | Class E |

## 4.3 Motor specification

Motors shall comply with the requirements of IEC 60034-1.

## 4.4 Hot-gas fan

The time/temperature profile that a hot-gas fan is required to operate under, can be "continuous" or more specific to the application. Special materials may be incorporated in the fan that can have a direct or indirect drive. The motor may be in the air-stream on a direct-drive fan or separated from it by a bifurcation tunnel. Indirect drive fans may incorporate a means of cooling belts, bearings or other drive components.

# 5 General testing procedures

For type approval, tests shall be carried out in accordance with Annexes A, B, C, D and E. For each test, a test report shall be prepared in accordance with Annexes C and/or D.

For different directions of the motor axis, a separate test shall be done for either direction (horizontal and/or vertical).

NOTE A direct field of application for the direction of the motor axis (horizontal and/or vertical) is under consideration as of the date of publication of this part of ISO 21927.

# 6 Performance requirements and classification

## 6.1 Temperature/time classification

**6.1.1** A ventilator shall be classified (see Table 2) as

a) F200;

b) F300;

c) F400;

d) F600;

e) F842;

f) Not classified.

**6.1.2** For products intended to be installed within a building, there shall be no significant leakage of smoke from the furnace coming from the housing of the ventilator during the entire test period.

**6.1.3** At the appropriate temperature given in Table 2, a ventilator shall function for not less than the appropriate minimum time and shall re-start when tested in accordance with Annex C.

**Table 2 — Test temperature and functioning time according to classification**

| Class | Temperature<br>°C | Minimum functioning period<br>minutes |
|---|---|---|
| F200 | 200 | 120 |
| F300 | 300 | 60 |
| F400 | 400 | 120 |
| F600 | 600 | 60 |
| F842 | 842 | 30 |
| Not classified | as specified by sponsor | as specified by sponsor |

## 6.2 Flow and pressure

When tested in accordance with Annex C, at the appropriate temperature and for the appropriate time given in Table 2, the volume flow shall not change by more than 10 % or the static pressure shall not change by more than 20 % of that measured at the end of the warm-up period of the test.

## 6.3 Outer surface temperature and cooling air temperature of insulated ventilators

When the ventilator is tested in accordance with Annex C, at the temperature and for the time appropriate to the product temperature/time category:

— the outer surface temperature of an insulated ventilator shall not increase by more than 180 °C in accordance with ISO 834-1 for any individual value;

— the cooling air expelled from the unit shall not exhibit an increase of temperature of more than 180 °C from the initial room temperature.

NOTE Increases above the specified temperature can increase the fire risk.

## 6.4 Wind load

If the ventilator is designed to be installed at the atmospheric termination of a system and is fitted with flaps or louvres and these project above the wind deflectors (cowl or wind shield), the flaps or louvres shall open in less than 30 s against of a load of 200 Pa, when the ventilator is tested in accordance with Annex E.

## 6.5 Snow load

**6.5.1** If the ventilator is designed to be installed at the atmospheric termination of a system, the ventilator shall be classified as one of the following:

— SL 0;

— SL 125;

— SL 250;

— SL 500;

— SL 1 000;

— SL $A$.

The designations 0, 125, 250, 500, 1 000 and "$A$" represent the test snow load, expressed in pascal, applied when the ventilator is tested in accordance with Annex E. The "$A$" in "SL $A$" will be replaced by the test snow load when this exceeds 1 000, or by the test load if one of the four defined values is not used.

Where the minimum angle of installation (combining roof pitch and ventilator pitch) recommended by the supplier exceeds 45°, the ventilator takes the classification SL 1 000 without a test; except where the snow is prevented from slipping from the ventilator, e.g. by wind deflectors.

If the ventilator is fitted with deflectors, the snow-load classification, SL, shall not be less than 2 000$d$, where $d$ is the depth of snow, in metres, that can be contained with the confines of the deflectors.

**6.5.2** The ventilator shall open to its fire-open position in not more than 30 s after actuation when tested under the snow load appropriate to its classification in accordance with Annex E.

The following types of ventilators can be suitable for use on heated buildings without a snow-load classification test:

a) vertical discharge units without flaps or dampers;

b) vertical discharge units with uninsulated metal flaps or dampers.

## 6.6 Operation at low temperature

A powered ventilator with a separate device for the operation of the dampers, flaps or louvres that does not use the air pressure from the fan shall conform to ISO 21927-2:2004, 8.3, when tested in accordance with ISO 21927-2:2004, Annex E.

## 6.7 Reliability

A powered ventilator with dampers, flaps or louvres or a separate device for the operation of the dampers, flaps or louvres that does not use the air pressure from the fan shall conform to ISO 21927-2:2004, 8.1, when tested in accordance with ISO 21927-2:2004, Annex C.

### 6.8 Performance data of ventilators

**6.8.1** The supplier shall provide a data sheet giving the aerodynamic and acoustic performance data of the ventilator assessed at ambient temperature in accordance with ISO 5801, taking into account the reduction in performance caused by the increased clearances required for high temperature.

It is permissible to convert these figures to determine the performance with hot gases and at other speeds of rotation using the scaling equations from ISO 5801, with due allowance for tip clearance effects.

**6.8.2** If a ventilator is designed to be fitted with a duct for cooling air, the data sheet shall include the volume pressure characteristic of the auxiliary system and the minimum cooling air flow required.

## 7 Marking

The ventilator shall be marked with the following:

a) name or trade mark of the supplier;

b) type and model;

c) application classes;

d) temperature/time category;

e) maximum exhaust temperature in °C;

f) functioning period in minutes;

g) year of manufacture;

h) technical data such as power, current, voltage, pressure, volume flow;

i) motor insulation class;

j) snow load class;

k) number and the year of this part of ISO 21927.

## 8 Evaluation of conformity

### 8.1 General

The compliance of powered smoke- and heat-exhaust ventilators with the requirements of this part of ISO 21927 shall be demonstrated by

— initial type testing,

— factory production control by the manufacturer.

### 8.2 Initial type testing

Initial type testing shall be performed on first application of this part of ISO 21927. Tests previously performed in accordance with the provisions of this part of ISO 21927 (e.g. same product, same characteristic(s), test method, sampling procedure, system of evaluation of conformity) may be taken into account. In addition, initial type testing shall be performed at the beginning of the production of a new product type or at the beginning of a new method of production (where these can affect the stated properties).

All characteristics given in Clause 5 and 6.1 to 6.7 shall be subject to initial type testing.

Annex F gives rules of possible changes to the originally classified product without the need of re-testing.

## 8.3 Factory production control

The manufacturer shall establish, document and maintain a factory production control (FPC) system to ensure that the products placed on the market conform with the stated performance characteristics. The FPC system shall consist of procedures, regular inspections and tests and/or assessments and the use of the results to control raw and other incoming materials or components, equipment, the production process and the product, and shall be sufficiently detailed to ensure that the conformity of the product is apparent.

An FPC system conforming with the requirements of the relevant part(s) of ISO 9001, and made specific to the requirements of this part of ISO 21927, shall be considered to satisfy the above requirements.

The results of inspections, tests or assessments requiring action shall be recorded, as shall any action taken. The action to be taken when control values or criteria are not met shall be recorded.

# Annex A
(normative)

# Type approval schedule for a range of ventilators

## A.1 Reduction of numbers of tests for ventilators forming a product range

For the purpose of type approval, it is not usually considered necessary to test every size of ventilator in a product range, provided that the following are tested and the range complies with the rules given in Clauses A.3 and A.4 and Annex B:

a) ventilator with the most highly stressed impeller or the ventilators with impellers in which the individual stress in any material weld or fastening is the highest as appropriate (see Clause A.4);

b) for ventilators with motors mounted in an enclosure that restricts the cooling, the worst case shall be tested, for example the ventilator with the highest ratio of motor cross-sectional area to cross-sectional area through which the cooling air flows;

c) at least two sizes are tested at their highest rotational speed;

d) ventilator with the smallest motor-frame size to be used;

e) if the highest impeller stress levels are determined by geometric similarity conditions from A.4.1, a sufficient number of sizes of ventilators to ensure that the impeller diameters of the range are from 0,8 to 1,26 of those tested;

f) if the highest impeller stress levels are determined by the calculation methods in A.4.2, a sufficient number of sizes of ventilators to ensure that the impeller diameters of the range are from 0,63 to 1,26 of those tested.

## A.2 Motors

A product range shall be approved only if the motors used in the range are also approved, except when the impeller is not mounted on the motor shaft and the motors are out of the air-stream in ambient air and the cooling of the motor is not affected by heat transfer from the ventilator or the ventilator construction. When the motor is out of the air-stream and the impeller is mounted on the motor shaft, motors from a different supplier to the one used in the ventilator test may be used, provided that the tested and alternative motors are of the same construction, i.e. same class of insulation and bearing type and class of fit and same synchronous speed and rating.

## A.3 Combined testing

The tests to approve ventilators and motors may be performed at the same time. The motor approval procedure is given in Annexes B and D. Motors tested independently of fans or in another range of ventilators may also be used, provided these tests have been undertaken with similar mechanical loads and cooling conditions as described in this annex and in Annex D.

## A.4 Determination of highest stresses in impellers

### A.4.1 Ventilators with geometrically similar impellers

For geometrically similar impellers, the impeller with the highest peripheral speed is the most highly stressed.

Impellers are geometrically similar if all dimensions, excluding thickness of materials, are within 5 % and the thickness of materials is within + 10 % of the values scaled by the ratio of the impeller diameters and the numbers of blades and fastenings are identical. The centre boss is excluded from the geometric similarity requirements.

### A.4.2 Ventilators with impellers that are not geometrically similar

#### A.4.2.1 General

The method given for calculating stresses is for comparative purposes only and is not suitable for design assessment. It takes into account only centrifugally induced stresses as aerodynamically induced stresses are of less importance.

#### A.4.2.2 Axial impellers

##### A.4.2.2.1 Centrifugal force

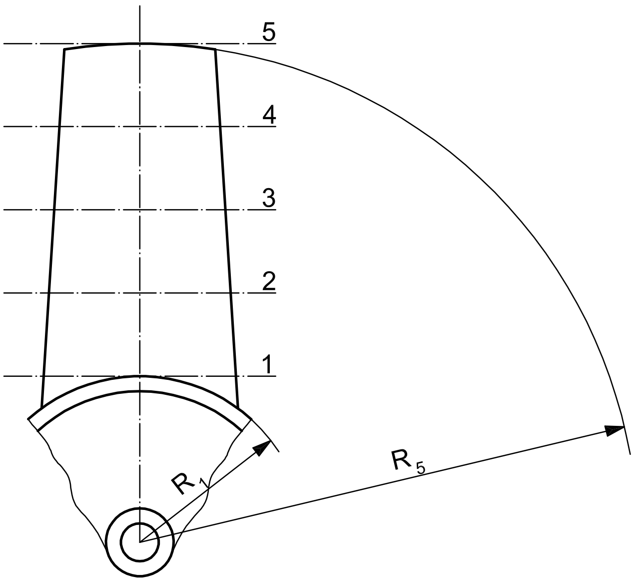
Divide the blade into four parts using five sections as shown in Figure A.1.

Calculate the centrifugal force, $F_{n,n+1}$, expressed in newtons, for that part of the blade between sections $n$ and $n + 1$, for each part as given in Equation (A.1)

$$F_{n,n+1} = \frac{\rho \times (A_n + A_{n+1})}{2} \times (R_{n+1} - R_n) \times \frac{(R_{n+1} + Rn)}{2} \times \omega^2 \tag{A.1}$$

where

- $\rho$ is the density, expressed in kilograms per cubic metre;
- $A_n$ is the area of section $n$, expressed in square metres;
- $R_n$ is the radius of section $n$;
- $\omega$ is the angular velocity, expressed in radians per second.




**Key**

$R_1$ inside radius of impeller

$R_5$ outside radius of impeller

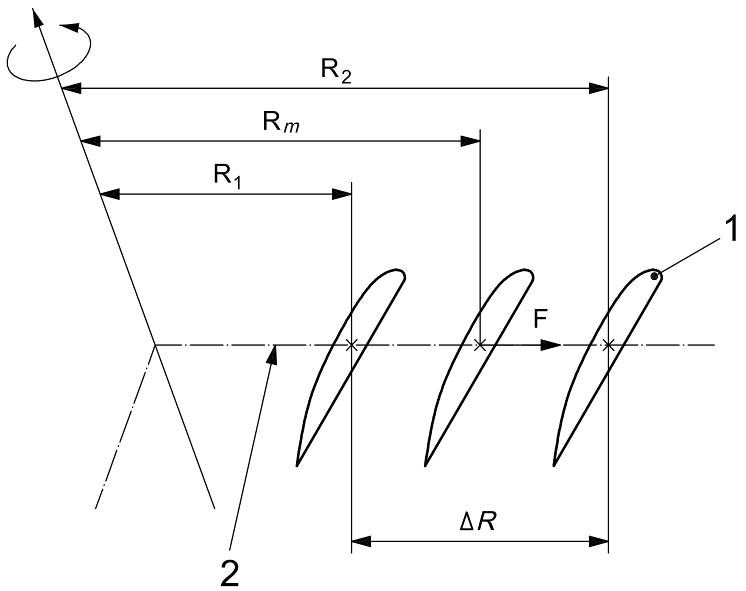
**Figure A.1 — Axial impeller, blade divided into four parts using five sections**

Calculate the tensile stress, $\sigma_{Tn}$, expressed in newtons per square millimetre, as given in Equation (A.2) using the centrifugal force, $F_n$, as given in Equation (A.3); see Figure A.2.

$$\sigma_{Tn} = F_n/(A_n \times 10^6) \quad (A.2)$$

$$F_n = F_{n,n+1} + \ldots\ldots\ldots + F_{4,5} \quad (A.3)$$

where $n$ is the number of the section.




**Key**

1 section area of blade

2 centrifugal force

$R_1$ radius 1

$R_2$ radius 2

$\Delta R = R_2 - R_1$

$R_m$ radius $m$

**Figure A.2 — Axial impeller, application of centrifugal force**

#### A.4.2.2.2 Fastenings or welds

Treat fastenings or welds as the inboard end of the blade section with the cross-section area calculated from the weld or fastener area.

#### A.4.2.2.3 Hub/backplate/shroud stresses

Consider only forces due to centrifugal effects. The stresses on the hub are a combination of the self-induced stress due to the rotation of the hub, the hoop stress due to the loads imposed by the blades and the bending stress due to the point loads of the blades. The self induced stress, $\sigma_{si}$, expressed in newtons per square millimetres is given in Equation (A.4):

$$\sigma_{si} = \frac{\rho \times R_h^2 \times \omega^2}{10^6} \quad \text{(A.4)}$$

where

$R_h$ is the maximum hub radius, expressed in metres;

$\omega$ is the angular velocity, expressed in radians per second;

$\rho$ is the density, expressed in kilograms per cubic metre.

Assume that only the section of the hub/backplate/shroud approximately symmetrical about the plane of rotation through the centre of the blade-fixing is supporting the blades (see Figure A.3), then calculate the hoop stress, $\sigma_h$, expressed in newtons per square millimetre, as given in Equation (A.5):

$$\sigma_h = N \times F_{1-5} / (2 \times \pi \times A_h) \quad \text{(A.5)}$$

where

$N$ is the number of blades;

$F_{1-5}$ is the total blade centrifugal force, expressed in newtons;

$A_h$ is the cross-sectional area of the hub, expressed in square millimetres.

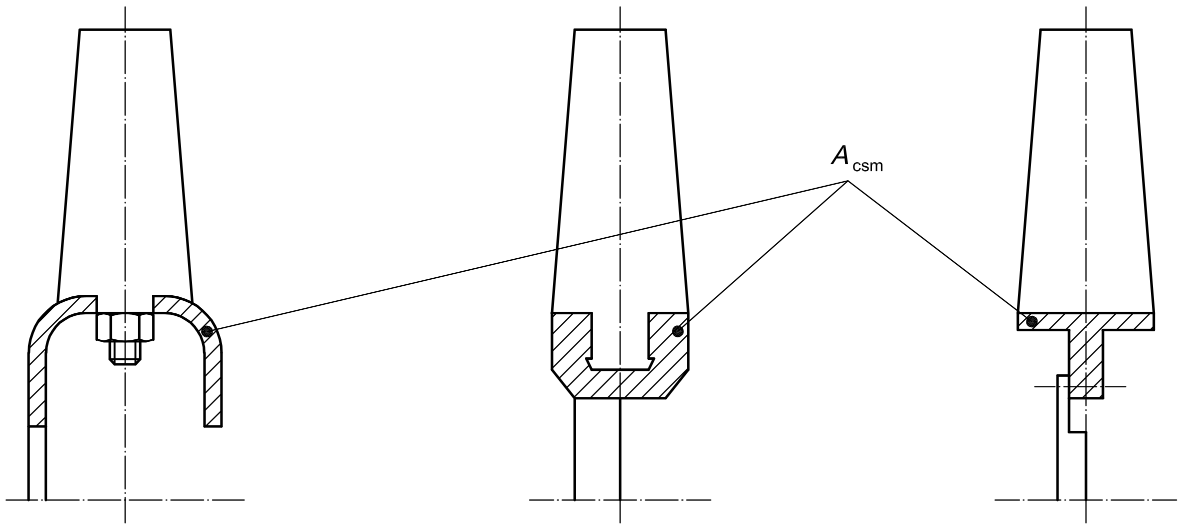
Calculate the section modulus about an axis through the section centre of area, parallel to the axis of rotation, using the distance to the outside of the hub/backplate/shroud supporting the blade. Then calculate the bending stress, $\sigma_b$, expressed in newtons per square millimetre, as given in Equation (A.6):

$$\sigma_b = F_{1-5} \times \pi \times R_h / (6N \times Z) \quad \text{(A.6)}$$

where $Z$ is the section modulus, expressed in cubic millimetres.

Then using linear hypothesis, the total stress, $\sigma_T$, expressed in newtons per square millimetre, is given by Equation (A.7):

$$\sigma_T = \sigma_{si} + \sigma_h + \sigma_b \quad \text{(A.7)}$$




**Key**

$A_{csm}$ is the section area of blade

NOTE The shaded parts show the portion for the calculation.

**Figure A.3 — Portion of hub to be used for calculation**

### A.4.2.3 Centrifugal impellers

#### A.4.2.3.1 Centrifugal force

The centrifugal force, $F$, expressed in newtons, is calculated by treating the blade as one piece, as given in Equation (A.8):

$$F = \rho \times A_b \times b_s \times R \times \omega^2 \quad \text{(A.8)}$$

where

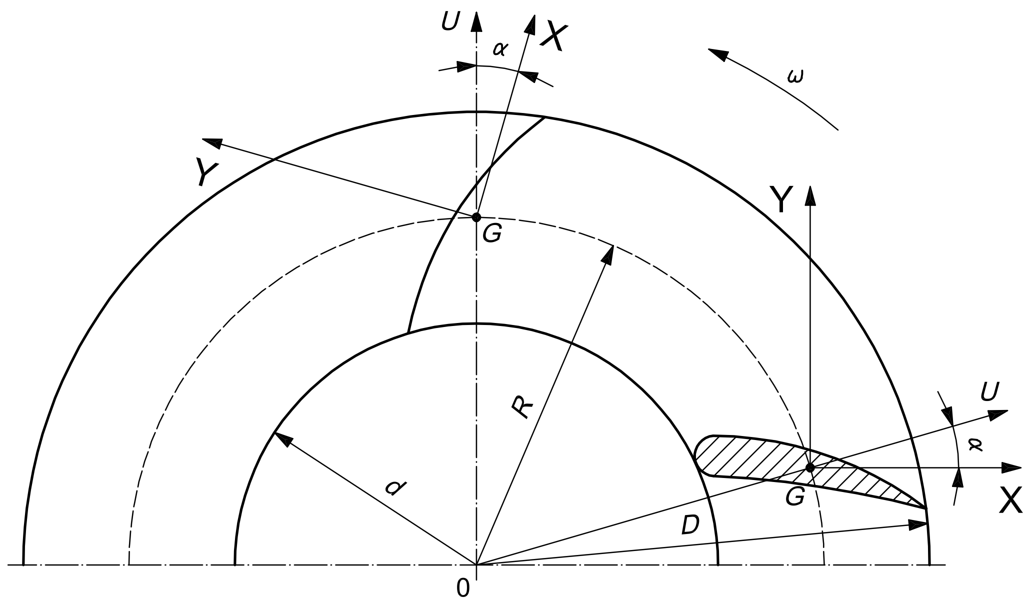
$\rho$ is the density of blade material, expressed in kilograms per cubic metre;

$A_b$ is the cross-section area of the blade at the centre of gravity, perpendicular to the axis of rotation, expressed in square metres;

$b_s$ is the distance between the backplate and shroud, through the centre of gravity, parallel to the axis of rotation, expressed in metres;

$R$ is the radius of blade centre of gravity about the axis of rotation, expressed in metres;

$\omega$ is the angular velocity of impeller, expressed in radians per second.




**Key**

$R$ central radius

$d$ inside radius

$D$ outside radius

**Figure A.4 — Centrifugal impeller, calculation of centrifugal forces about a principal axis**

### A.4.2.3.2 Blade bending moment

The bending moment, $M$, expressed in newton-metres, is calculated as given in Equation (A.9):

$$M = F \times b_s / k \tag{A.9}$$

where $k$ is a constant depending on the type of impeller construction (for comparative purposes use $k = 1$).

### A.4.2.3.3 Comparative blade stresses

To calculate comparative blade stresses, resolve the bending stresses, $\sigma_{b,max.}$ and $\sigma_{b,min.}$, expressed in newtons per square millimetre, about the maximum and minimum principal axes, respectively as given in Equations (A.10) and (A.11):

$$\sigma_{b,max.} = 1\,000 \times M \times \cos\alpha / Z_{max.} \tag{A.10}$$

$$\sigma_{b,min.} = 1\,000 \times M \times \sin\alpha / Z_{min.} \tag{A.11}$$

where

$\alpha$ is the angle between maximum principal axis and a radial line, expressed in degrees;

$Z$ is the section modulus about principal axis, expressed in cubic millimetres.

#### A.4.2.3.4 Blade joint stress

Calculate the relative shear stress, $\sigma_S$, expressed in newtons per square millimetre, at each blade joint as given in Equation (A.12):

$$\sigma_S = F/A \tag{A.12}$$

where $A$ is the area of cross section of fastening at joint, expressed in square millimetres.

## A.5 Assessment of changes after testing

### A.5.1 Assessment of motor changes

If motors of a different construction or from a different supplier to the one that has been tested are used, the assessment shall be made in accordance with Clause A.2 by the body responsible for testing the product range.

### A.5.2 Assessment of detail changes

If detail changes are made to the product range that has been tested, the body responsible for testing the product range shall assess either that the changes do not impair the performance of the product range or that further specific tests are necessary to verify performance.

# Annex B
(normative)

# Type approval schedule for a product range of motors

## B.1 Reduction of numbers of tests for motors forming part of a range

For the purpose of type approval it is not usually considered necessary to test every size and speed of motor to be used in a range of powered ventilators. Provided tests are carried out on the largest and smallest motor frame size at the highest ratings, it may be assumed that all the motors in a range comply with this part of ISO 21927.

## B.2 Assessment of changes after testing

### B.2.1 Assessment of motor changes

If the sponsor wishes to use motors of a construction different from the one that was tested, the assessment shall be made in accordance with Annex A.2, by the body responsible for testing the product range.

### B.2.2 Assessment of detail changes

If detail changes are made to the product range that has been tested, the body responsible for testing the product range shall assess either that the changes do not impede the performance of the product range or that further specific tests are necessary to verify performance.

# Annex C
(normative)

# Test method for performance of powered ventilators at high temperature

## C.1 Principle

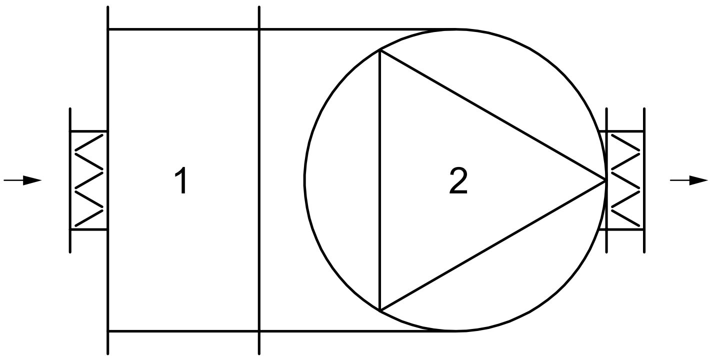
Determine the performance of powered ventilators by testing the ventilator so that at normal ambient pressure and temperature (i.e. a density of 1,2 kg/m$^3$) the power output input is 80 % to 100 % of the maximum absorbed input power of the ventilator motor and it is operating anywhere on its volume-pressure curve, provided that the volume and pressure readings are stable.

## C.2 Apparatus

**C.2.1 Furnace**, capable of heating the required quantity of air and raising the temperature of the system to the specified level in the specified time within the specified tolerances, either connected directly or through a system of ducting, either to re-circulate the hot gases or to discharge to atmosphere.

NOTE 1 See Figures C.1, C.2 and C.3.

NOTE 2 Some test furnaces are specified in ISO 834-1 and ISO 6944.

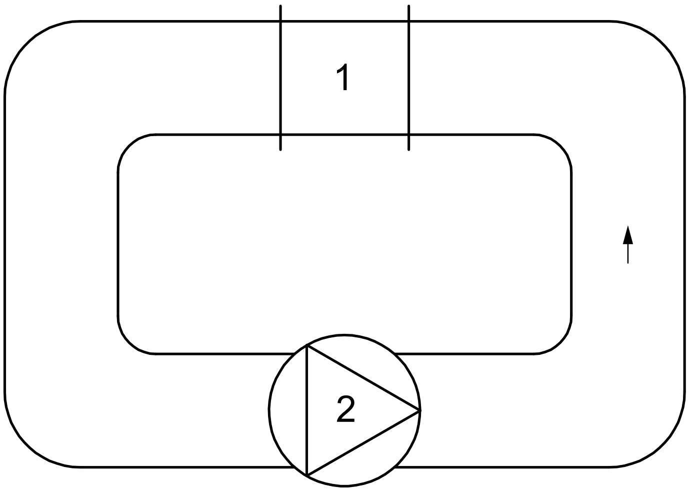



**Key**

1 furnace

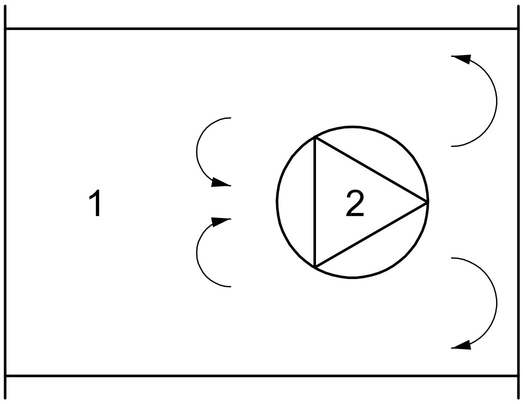
2 ventilator

**Figure C.1 — Ventilator connected directly to furnace**




**Key**
1 furnace
2 ventilator

**Figure C.2 — Ventilator connected to furnace by re-circulating duct system**




**Key**
1 furnace
2 ventilator

**Figure C.3 — Ventilator mounted inside furnace**

**C.2.2 Flow- and/or pressure-measuring equipment**, in accordance with ISO 5801, ISO 5167 or ISO 5221 or **static pressure taps**, in accordance with ISO 5221, either side of the impeller.

**C.2.3 Thermoelements** and **thermocouples**. in accordance with ISO 10294-1 and ISO 834-1.

## C.3 Preparation

Set up the ventilator, following the supplier's instructions, with its air-intake side connected to the furnace so that it represents as near as possible the conditions to which it will be exposed in service.

Test the ventilator by a method appropriate to the application class or classes (stated by the manufacturer). Set up a smoke-reservoir ventilator, either surrounded by hot gases as indicated in Figure C.3, or totally surrounded by the high temperature gas flow and not cooled by ambient air if the motor is inside the fan, or insulated so that the effect is the same as being surrounded by hot gases. Install a non-smoke-reservoir ventilator connected to the hot gases, either by partial insertion, e.g. for a roof-extract unit, or in a ducted system surrounded by ambient air; see Figures C.1 to C.3. It can be necessary to make special duct connections when hot gas re-circulation test systems are used. Install the duct connection so that it does not prevent heat re-circulation to the motor if this can happen in practice.

When the motor requires cooling air, the flow of the cooling air shall be a minimum in terms of the design of the fan and shall relate to the test. The manufacturer shall supply the laboratory with that minimum value of the cooling air.

NOTE 1 The flow rate is affected by the operating point and the upstream and downstream loading.

Set up a flow- or pressure-measuring device in the system to measure the volume flow or pressure of the ventilator.

NOTE 2 The installation of flow-measuring devices or pressure taps is not critical, as the readings are for comparative purposes only and cannot be used to indicate actual performance.

Test an insulated axial fan for use as an uninsulated fan as well as an insulated fan with a smaller than normal tip clearance. The reduced clearance, $l_{\mathrm{RC}}$, expressed in millimetres, is as given in Equation (C.1).

Reduction in tip clearance, $l_{\mathrm{RTC}}$, expressed in millimetres, shall be calculated as follows:

$$l_{\mathrm{RC}} = l_{\mathrm{NC}} - \Delta l_{\mathrm{TC}} \quad \text{(C.1)}$$

where

$l_{\mathrm{NC}}$ is the normal clearance;

$\Delta l_{\mathrm{TC}}$ is the reduction of clearance.

The reduction in tip clearance, $\Delta l_{\mathrm{NT}}$, expressed in millimetres, shall be calculated as given in Equation (C.2):

$$\Delta l_{\mathrm{TC}} = \left(D/2\right) \times C \times \Delta T \quad \text{(C.2)}$$

where

$D$ is the diameter at minimum clearance, expressed in millimetres;

$C$ is the coefficient of expansion for the material of the casing;

$\Delta T$ is half the difference between the hot gas temperature and the ambient temperature.

Measure the minimum clearance between the impeller and the casing. Check that

a) it is not less than the minimum specified by the supplier;

b) it is not greater than the minimum plus 25 %.

NOTE 3 A ventilator tested with insulation has a higher casing temperature than one without insulation and consequently under test has a larger tip clearance.

Fit at least three furnace thermoelements approximately 100 mm upstream of the intake plate of the ventilator, positioned uniformly, to measure the temperature of the incoming gases.

Where the motor is mounted within the fan casing and is cooled by ambient air, fit flow-measuring equipment, taking care that it does not affect the flow rate of cooling air. Also, fit thermocouples in the centre of the inlet and exit airways.

Fit electrical devices for the measurement of frequency, voltage, current, power and speed in accordance with IEC 34-2. A frequency measurement is not required if the main supply is of known frequency.

## C.4 Procedure

### C.4.1 General conditions

Carry out the following tests, continuously in the order indicated, at an ambient temperature between 15 °C and 40 °C and in a location not affected by varying ambient conditions such as rain, snow or wind. Test insulated fans inside a building. Check that any cooling air is not below 15 °C. Start test measurements prior to the test period. For ventilator classes F200, F300, F400 and F600, test in accordance with C.4.2, C.4.3 and C.4.4. For ventilator class F842, test in accordance with C.4.2 and C.4.5.

If a ventilator is tested at a higher temperature and for a longer period than a lower class or classes, then the ventilator shall also be approved for that class or classes.

During the entire period of the test (for products intended to be installed within a building), observe the emissions of any smoke from the furnace coming from the housing of the ventilator due to distortion/leakage of the housing.

### C.4.2 Warm-up period

**C.4.2.1** Do not operate an emergency ventilator prior to test. Operate a dual-purpose ventilator at ambient temperature, at the maximum speed, for a warm-up period until the motor-carcase temperature increase is less than 2 °C per 10 min, but for a minimum period of 60 min. Record voltage, current, power, flow and/or pressure and temperature measurements at intervals not exceeding 2 min. Ensure measurements are stable.

**C.4.2.2** Operate an emergency ventilator at ambient temperature until the volume flow or pressure readings are stable.

A variation of ± 1 % in volume flow or ± 2 % in pressure, averaged over consecutive 2 min periods, may be considered stable.

### C.4.3 Heat-up period

Increase the gas temperature at the intake plane of the powered ventilator to the appropriate value specified in Table 1 during a period of not more than 10 min and not less than 5 min. Record voltage, current, power, temperature and flow and/or pressure measurements.

### C.4.4 High-temperature test

Carry out the test at not less than the temperature specified and not more than the temperature specified plus 25 °C and for the appropriate period of time specified in Table 2. Record electrical, flow and/or pressure and temperature measurements at intervals not exceeding 2 min. Correct the static-pressure measurements for the effects of density change due to temperature.

After 15 min, switch off the ventilator for 2 min, then restart the ventilator. During this period, the temperature variation may exceed the specified limits. Add the time the ventilator is switched off to the period of the test.

### C.4.5 High-temperature test in accordance with temperature time curve

Increase the gas temperature at the intake plane of the ventilator in accordance with the standard time/temperature curve defined in ISO 834-1. Control the temperature to a tolerance of $^{+25}_{0}$ °C . Test the ventilator for a period of 30 min. Record electrical, flow and/or pressure and temperature measurements at intervals not exceeding 2 min. Correct the static pressure measurements for the effects of density change due to temperature. At the end of this period, switch off the ventilator for 2 min and then re-start the ventilator. During this period, the temperature variation may exceed the specified limits. The test is completed once the fan has re-started and meets the requirements of Clause C.1.

During the entire period of the test (for products intended to be installed within a building), observe the emissions of any smoke from the furnace coming from the housing of the ventilator due to distortion/leakage of the housing.

## C.5 Test report

**C.5.1** Prepare a test report after completion of the tests, including the following information:

a) name of the test laboratory;

b) name of the sponsor;

c) date of tests;

d) name of supplier and trade name of the product;

e) engineering plans of the ventilator including any technical details;

f) reference to the test methods;

g) catalogue description, size and speed of the ventilator tested;

h) ancillaries tested;

i) temperature/time class (see 6.1);

j) application classes (see 4.1);

k) product range approved by the tests in accordance with Annex A;

l) snow load class;

m) details of the test arrangement, including all equipment used for measurement of temperature, flow, pressure, current, voltage, electrical power and wind and snow load;

n) observations, measurements and calculated results made before, during and after the tests, in accordance with this annex and Annexes D or E;

o) minimum volume of cooling air (see Clause C.3).

**C.5.2** Prepare an additional report providing details of the complete product range approved, including:

a) fan model number or catalogue code;

b) engineering plans of the ventilators, including any technical details;

c) fan speed;

d) impeller and hub diameter, tip clearance, length and number of blades;

e) approximate blade cross-sectional area;

f) approximate hub cross-sectional area;

g) motor speed;

h) motor model number or catalogue code;

i) motor rating;

j) bearing type, class of fit, lubricant and arrangement for motor and fan, if fan is indirectly driven;

k) carcase, end cover and cooling impeller material;

l) class of insulation and specification;

m) ancillaries have been approved;

n) minimum volume of cooling air (see Clause C.3).

# Annex D
(normative)

# Test method for resistance to temperature of electric motors for use in powered ventilators

## D.1 Principle

The resistance to temperature of electric motors for use in powered ventilators is proved by testing the motor at elevated temperature, either in a powered ventilator or in conjunction with a generator or other method of providing the load. The motor is shown to be functioning satisfactorily by continuing to give the required output power and meeting the requirements of 4.2 and 6.1.2.

## D.2 General

Test motors mounted within the air-stream for ventilator classes F200, F300, F400 and F600 to this procedure. Test motors that are mounted outside the air-stream with the impeller mounted on the motor shaft and motors for ventilator class F842 as a unit with the ventilator.

## D.3 Tests in association with a powered ventilator

Test the motor in a powered smoke ventilator in accordance with Annex C.

## D.4 Tests in association with a load

### D.4.1 Apparatus

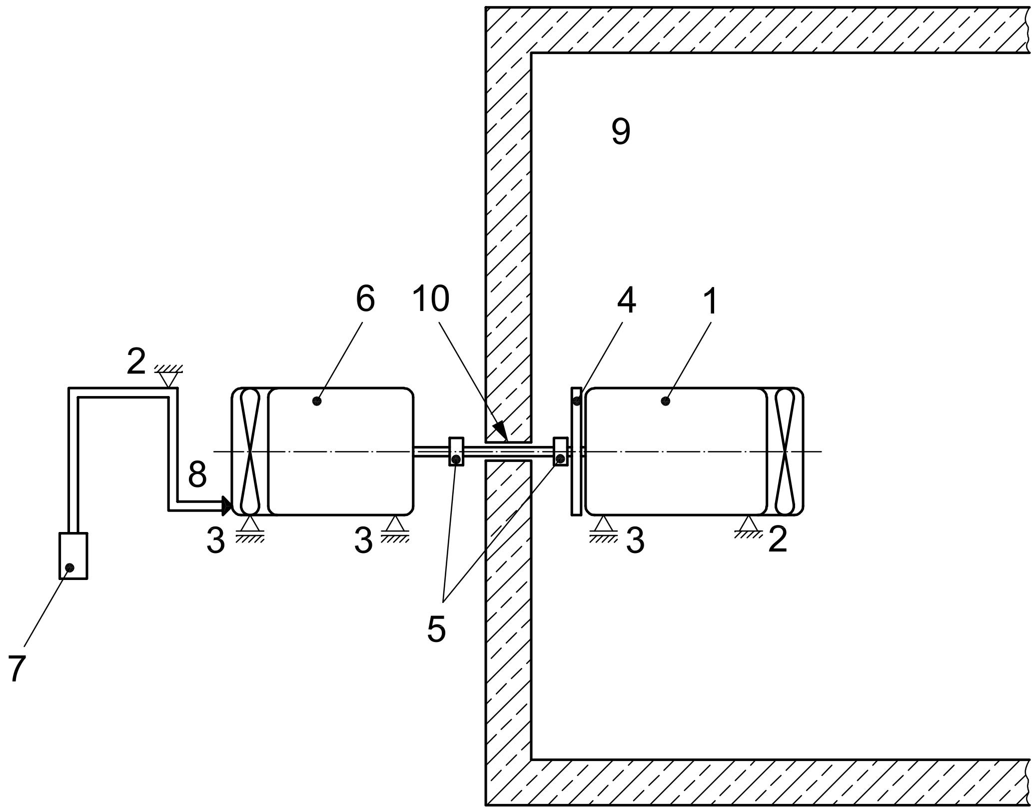
#### D.4.1.1 Test installation

Mount the motor on a stable support in an enclosure that has a minimum radial dimension twice the maximum motor dimension.

Link it via a coupling and transmission shaft to an adjustable external load, such as a generator, which absorbs the power output of the motor.

To circulate the hot gas past the carcase at the rated velocity, fit either the normal integral cooling impeller if the motor is not normally mounted in the fan air-stream, or an external impeller if the motor is mounted within the fan air-stream. Mount the external impeller either directly on the motor shaft or on the transmission shaft.

Provide a means of applying axial and radial loads to the motor shaft. For example, apply the axial load by rigidly connecting the motor to an external load generator that is free to move axially and so can be used to convert a stationary axial load to one that rotates; see Figure D.1.




**Key**

1 motor to be tested
2 fixed support
3 sliding support
4 radial load (e.g. steel disc)
5 flexible couplings, torsionally rigid
6 generator
7 mass
8 axial load, induced by the mass (key item 7)
9 furnace
10 penetration point

**Figure D.1 — Typical method of applying radial and axial load to a motor**

#### D.4.1.2 Temperature measurements

Fit a furnace thermocouple approximately 100 mm upstream of the motor on the motor axis of rotation to measure the temperature of the incoming gases. Fit a single device at the fins of the motor for surface temperature measurement.

#### D.4.1.3 Electrical measurements

Fit equipment to measure frequency, voltage, current, power and speed in accordance with IEC 34-2 and ISO 5801.

### D.4.2 Test specimens

Select test specimens in accordance with Annexes A and B.

### D.4.3 Test procedure

#### D.4.3.1 General conditions

Carry out the tests at an ambient temperature between 15 °C and 40 °C.

#### D.4.3.2 Warm-up period

Operate the motor at ambient temperature at its rated frequency and voltage at 80 % to 100 % of the maximum rated power, at the maximum speed or, if the motor is a two-speed motor designed for continuous operation at low speed only, at the lower speed. Monitor the surface temperature of the motor until the rate of temperature increase is less than 2 °C per 10 min. Record electrical and temperature measurements.

Increase the temperature at the air intake of the motor to that specified in Table 2 within a period of not more than 10 min and not less than 5 min. Record electrical and temperature measurements during this period. Adjust the motor input power to $\Phi$ times the rated power at a density of 1,2 kg/m$^3$, where $\Phi$ is as follows:

— 0,88 at 200 °C;

— 0,80 at 300 °C;

— 0,76 at 400 °C;

— 0,60 at 600 °C.

These factors do not apply to motors approved in the fans in which they are used, as the change of temperature causes all the effects that change the power. However, the factors established for one range of fans cannot be used for another.

#### D.4.3.3 High temperature test

Carry out the test at not less than the specified temperature, and not more than the specified temperature plus 25 °C and for the appropriate period of time specified in Table 2. Record electrical, flow and/or pressure and temperature measurements at intervals not exceeding 2 min.

## D.5 Test report

**D.5.1** Prepare a test report after completion of the tests including the following information:

a) name of the test laboratory;

b) name of the sponsor;

c) date of tests;

d) name of supplier and trade name of the product;

e) reference to the test method/s;

f) catalogue description, frame size, class of insulation and speed of the motor tested;

g) temperature/time class (see 6.1);

h) application classes (see 4.1);

i) product range approved by the tests in accordance with Annex A;

j) details of the test arrangement, including all equipment used for measurement of temperature, flow, pressure, current, voltage and electrical power;

k) observations, measurements and calculated results made before, during and after the tests in accordance with Annex C or D.4.3.

**D.5.2** Prepare an additional report providing details of the complete product range approved including the following:

a) motor speed;

b) motor model number or catalogue code;

c) motor rating;

d) bearing type, class of fit, lubricant and arrangement;

e) carcase, end cover and cooling impeller material;

f) class of insulation and specification.

# Annex E
(normative)

# Test method for operation under load

## E.1 Objective of test

The objective of this test is to establish the ability of the installed ventilator to operate at the critical operation condition, i.e. against an applied wind and snow load.

## E.2 Test apparatus

Use a suitable test rig onto which the ventilator can be mounted and subjected to a test load equivalent to a wind pressure of 200 Pa, when required as defined in 6.4, and a snow load as defined in 6.5. Apply the test load by one of the following methods:

a) plates;

b) bags containing up to 5 kg of solid particles or liquid.

Spread the loads over the whole of the external surface of the individual elements of the opening parts of the ventilator to produce a uniformly distributed load.

## E.3 Test specimen

A test on the largest ventilator of a range shall be considered representative of all ventilators in a particular range.

## E.4 Test procedure

Mount the ventilator on the test rig in accordance with the supplier's recommendations. Apply the load using one of the methods given in Clause E.2, increasing the load to the upper appropriate limit given in 6.4 and 6.5 and maintain the load for 10 ± 1 min.

Remove the load, actuate the ventilator and check that the dampers, flaps or louvres open to the design position.

Operate the ventilator against the design load three times, using the energy source as specified by the supplier and its fire activating mechanism. Determine if the fire operating position is reached each time.

## E.5 Evaluation of test results

The ventilator meets the requirement of 6.4 and 6.5 if the test specimen achieves the operating position in each of the tests in less than 30 s. The test results may be applied to all ventilators of the same range.

# Annex F
(normative)

# Direct field of application for powered smoke- and heat-exhaust ventilators

## F.1 General

This annex gives general rules for acceptable changes of the powered smoke- and heat-exhaust ventilator from its initial type tests without affecting the test results negatively.

## F.2 Change of motor

The motor may be changed to one different from the one tested in the initial type test if all of the following remain the same:

— type and size of the motor;

— type of bearings, including the lubrication.

In addition, the new motor shall be tested at the same rating and at the same or higher temperature for at least as long as the one tested at the initial type test. The resulting axial and radial loads on the new motor shall not exceed the ones tested in the initial type test.

# Bibliography

[1] ISO 14520-1, *Gaseous fire-extinguishing systems — Physical properties and system design — Part 1: General requirements*

[2] ISO 6944, *Fire resistance tests — Ventilation ducts*

[3] ISO 9001, *Quality management systems — Requirements*

ICS 13.220.20

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