
Smoke and heat control systems —

Part 3:

**Specifications 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*

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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 of 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 www.iso.org/iso/foreword.html.

This document 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*.

This second edition cancels and replaces the first edition (ISO 21927-3:2006), which has been technically revised.

The main changes compared to the previous edition are as follows:

- amendment of the test apparatus.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

A list of all parts in the ISO 21927 series can be found on the ISO website.

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 firefighting, reducing roof temperatures and delaying the lateral spread of fire is firmly established. For these benefits to be obtained, it is essential that smoke and heat exhaust ventilation systems be a scheme of safety equipment intended to perform a positive role in a fire emergency.

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Smoke and heat control systems —

Part 3: Specifications for powered smoke and heat exhaust ventilators

1 Scope

This document specifies the product characteristics of powered smoke and heat control ventilators (fans) intended to be used as part of a powered smoke and heat control ventilation system in construction works.

It provides test and assessment methods of the characteristics and the conformance criteria of the test assessment results.

This document applies to the following:

- a) fans for smoke and heat control ventilation;
- b) impulse/jet fans for smoke and heat control ventilation.

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 281, *Rolling bearings — Dynamic load ratings and rating life*

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 5801, *Fans — Performance testing using standardized airways*

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

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 60085, *Electrical insulation — Thermal evaluation and designation*

IEC 60584-1, *Thermocouples — Part 1: EMF specifications and tolerances*

EN 1363-1, *Fire resistance tests — Part 1: General Requirements*

EN 13501-4, *Fire classification of construction products and building elements — Part 4: Classification using data from fire resistance tests on components of smoke control systems*

3 Terms and definitions

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

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1 **powered smoke and heat control ventilator** **PSHC ventilator**

smoke-ventilating fan that is suitable for handling smoke and hot gases for a specified time/temperature profile

3.2 **smoke reservoir**

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

3.3 **powered roof ventilator**

fan designed for mounting on a roof and with exterior weather protection

3.4 **smoke reservoir ventilator**

ventilator suitable for operation fully immersed in a *smoke reservoir* (3.2)

3.5 **product family**

physically similar fans using the same form of construction and materials throughout, with the same methods of impeller construction, motor mounting and construction, and electrical connection in which the following may vary across the range:

- overall dimensions of the fans; and/or
- the impeller diameter and width, hub size, blade length and number of blades of the impeller; and/or
- the motor details, as per 3.7

3.6 **impulse/jet fans for smoke and heat control ventilation**

fan used for producing a jet of air in a space and unconnected to any ducting

Note 1 to entry: The air jet may be used, for example, for adding momentum to the air within a duct, a tunnel or other space, or for intensifying the heat transfer in a determined zone.

3.7 **motor rating**

maximum power that a motor delivers continuously without exceeding the allowable temperature rise

4 Requirements

4.1 Response delay (response time)

4.1.1 Opening under wind load within a given time

If the fan is designed to be installed at the atmospheric termination of a smoke control system (e.g. powered roof ventilator) and is fitted with a fan shutter flaps or louvers which project above the wind deflectors (cowl or wind shield), the shutter, flaps or louvers shall open in less than 30 s when tested in accordance with 5.2.1.

4.1.2 Opening under snow load within a given time

If the fan is designed to be installed at the atmospheric termination of a smoke control system (e.g. powered roof ventilator) and is fitted with a fan shutter flaps or louvers which project above the wind deflectors (cowl or wind shield), the shutter, flaps or louvers shall open in less than 30 s when tested in accordance with 5.2.2.

4.2 Operational reliability

4.2.1 General

Operational reliability of a PSHC ventilator (fan) shall be demonstrated by verification against application categories and by verification of motor ratings.

4.2.2 Application categories

To demonstrate its operational reliability, a PSHC ventilator (fan) shall be verified against categories.

[Table 1](#) shows the relevant method to allocate the results in the corresponding category.

Table 1 — Application categories

Clause of the test method	Application category	Compliance criteria
5.3.1	Thermally insulated	When tested in accordance with Annex C : <ul style="list-style-type: none"> — the outer surface temperature of a thermal insulated fan shall not increase by more than 180 K for any individual value; — the cooling air expelled from the unit shall not exhibit an increase of temperature of more than 180 K from the initial room temperature.
5.3.1	Thermally uninsulated	—
C.3.3	Installation inside the smoke reservoir	—
C.3.3	Installation outside the smoke reservoir	—
A.1 i)	Horizontal direction of motor shaft	—
A.1 i)	Vertical direction of motor shaft	—
A.1 n)	Converter feed (driven by frequency converter)	—
A.1 n)	Direct feed (no speed variation)	—
C.4.2.1	Dual purpose use	—
C.4.2.1, C.4.2.2	Emergency only use	—
C.3.3	Ducted cooling air required	—

4.2.3 Motor rating

Since the PSHC ventilator (fan) can be operated at different temperatures (current or emergency), motors shall be selected for operation at the power required for normal ambient temperature and not just for operation at high temperature.

Selection of the motors shall comply with the following requirements.

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

- Motor ratings shall be limited by the temperature rise for one class lower than the insulation class of the motor, as defined in IEC 60085.
- The fan tested in accordance with [5.3.2](#) shall comply with the stability requirement in [C.4.2.2](#).

4.3 Effectiveness of smoke/hot gas extraction

4.3.1 General

The effectiveness of smoke/hot gas extraction of the fan is the ability to continue to extract the required volume flow at high temperature.

4.3.2 Gas flow and pressure maintenance during smoke and heat extraction test

The effectiveness of smoke/hot gas extraction is demonstrated by conformance with the performance requirements in [C.5](#), when tested according to [5.4](#).

4.4 Resistance to fire

The fan is shown to be functioning satisfactorily by its continued ability to provide the initial volume or pressure within the defined limits in [C.5](#), when tested according to [5.5](#).

The test result shall be classified in accordance with EN 13501-4.

4.5 Ability to open under environmental conditions

4.5.1 Opening under wind load within a given time

When the fan is fitted with shutter, louvers or dampers, their ability to open under environmental conditions shall be demonstrated by fulfilling the requirements in [E.5](#) when tested in accordance with [5.6](#).

4.5.2 Opening under snow load within a given time

When the fan is fitted with shutter, louvers or dampers, their ability to open under environmental conditions shall be demonstrated by fulfilling the requirements in [E.5](#) when tested in accordance with [5.6](#).

4.6 Durability of operational reliability

Durability of operational reliability is demonstrated by motor rating according to [4.2.3](#) when tested according to [5.7](#).

5 Testing, assessment and sampling methods

5.1 General

PSHC ventilator (fan), tests shall be carried out in accordance with [Annexes A, B, C](#) and [E](#).

For each test, a test report shall be prepared in accordance with [Annex C](#).

A fan can be tested completely assembled with ancillaries, for example:

- flexible connection elements;
- anchors (fastenings for mounting to external structure);
- airflow operated dampers or external powered dampers;
- shock absorber (anti-vibration mount);

- sound absorber (silencer or acoustic attenuator);
- support construction (e.g. for powered roof or partition fans);
- thermal protection (e.g. PTC thermistor, Thermocouple, Pt100, etc.);
- ON-OFF switch and other electrical ancillaries (e.g. electrical safety box) which are directly mounted on the fan;
- guide vanes;
- flow deflectors;
- a jet fan shall be tested completely assembled and suspended from a supporting construction in accordance with the manufacturer's installation instruction.

For testing of motors alone, tests shall be carried out and test reports prepared in accordance with [Annex D](#).

5.2 Test of response delay (response time) opening under wind, snow load within a given time

5.2.1 Wind load

The fan shutter, flaps or louvers shall open in less than 30 s against a horizontally applied load of 200 Pa, simulated by means of an additional fan blowing on the flap at a suitable velocity, or by any suitable mechanical means when the fan is tested in accordance with [Annex E](#) and/or [Annex C](#).

WARNING — For fans which use the air pressure from the fan to open flaps or louvers:

Due to the temperature rise, the density of air decreases resulting in a corresponding decrease in the pressure developed. This pressure is needed to open the termination system (flaps or louvers).

In this case, the laboratory shall perform the wind load test also during the high temperature test.

If fans selected according to [Annex A](#) and tested according to [Annex C](#) are intended for use with external, air-pressure operated shutters, the combination shall also be tested with a wind load according to [Annex E](#).

The operating position can be considered as reached if the volume flow exhausted by the fan working under wind loads did not decrease by more than 10 % of that exhausted by the fan working without these loads.

If a fan intended for mounting on an external wall is fitted with external shutters, flaps or louvers and/or is not protected from wind force acting against it by a deflector or cowl, it shall be tested in accordance with this clause. Otherwise, the manufacture shall include a statement in his instructions that suitable wind guarding shall be fitted by the installer.

5.2.2 Snow load

The fan shutter, flaps or louvers shall open in less than 30 s against a vertically applied load shown in [Table 2](#), simulated by any suitable mechanical means, when the fan is tested in accordance with [Annex E](#), at ambient temperature only.

Table 2 — Snow load classes

Class	Load Pa
SL 0	0
SL 125	125
SL 250	250
SL 500	500
SL 1 000	1 000
SL A	A

The operating position can be considered as reached if the volume flow exhausted by the fan working under snow loads did not decrease by more than 10 % of that exhausted by the fan working without these loads.

Where the minimum angle of installation recommended by the supplier exceeds 45° from the horizontal, the fan takes the classification SL 1 000 without a test; except where snow is prevented from slipping from the fan, for example by wind deflectors. In this case, the fan shall be tested for a snow load classification which shall not be less than $SL = 2\,000 \cdot d$, where d is the depth of snow, in metres, which can be contained with the confines of the deflectors.

5.3 Operational reliability

5.3.1 Application categories

The relevant test methods are those indicated in [Table 1](#) in [4.2.2](#).

5.3.2 Motor rating

The test method to be applied is in [C.4.2](#).

5.4 Effectiveness of smoke/hot gas extraction: gas flow and pressure maintenance during smoke and heat extraction test

The test method is given in [Annex C](#).

5.5 Resistance to fire

The test method is given in [Annex C](#).

5.6 Ability to open under environmental conditions: opening under wind or snow load within a given time

The test method is given in [Annex E](#).

5.7 Durability of operational reliability

Durability of operational reliability is demonstrated by the test method given in [5.3.2](#).

6 Marking, labelling and packaging

The PSHC ventilator (fan) shall be marked with the following:

- the manufacturer's name or trademark;
- the resistance to fire classification;
- a reference to this document and its year of its publication (i.e. ISO 21927-3:2020), followed by the generic name of the product "powered smoke and heat control ventilator";
- the model/type;
- power requirements, e.g. power, current, voltage and rotational speed;
- the snow load class where applicable;
- the flow direction inside the fan (motor upstream, downstream or both);
- the direction of the motor shaft (vertical, horizontal or both);
- the minimum flow and maximum temperature of cooling air, where applicable;
- information about electrical connections of motor (e.g. Y or Δ);
- the following statement: "This powered smoke and heat control ventilator shall be installed as per the manufacturer's instruction.";
- the manufacturer's installation instructions or a reference to a document held by the manufacturer giving these instructions;
- the date of manufacture (month and year);

Annex A (normative)

Criteria to determine family of fans in order to select the sizes to be tested

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

It is not usually considered necessary to test every size of ventilator in a family of fans provided that the following are tested and the family conforms to the rules given in [A.3](#), [A.4](#) and [Annex B](#):

- a) the fan with the most highly stressed impeller, and the ventilators with impellers in which the individual stress in any component, weld or fastening is the highest, as appropriate, if not the same (see [A.4](#));
- b) for fans with motors mounted in an enclosure which restricts the cooling, the worst case shall be tested; this is the smallest free area of the motor enclosure or the smallest section of exit or entry airway for cooling air;
- c) at least two sizes of fans are tested at their highest rotational speed;
- d) the fan with the smallest motor frame size to be used, except for fans where the impeller is not mounted on the motor shaft and the motors are out of the airstream in ambient air and the cooling of the motor is not affected by heat transfer from the ventilator or the ventilator construction;
- e) if the highest impeller stress levels are determined by geometric similarity conditions from [A.4.1](#), sufficient sizes of fans to ensure that the impeller diameters of the range are from 0,8 to 1,27 of those tested;
- f) if the highest impeller stress levels are determined by the calculation methods in [A.4.2](#), sufficient sizes of fans to ensure that the impeller diameters of the range are from 0,63 to 1,27 of those tested;

NOTE The coefficients are taken from Renard Series R20 in accordance with several ISO standards. The aim of the coefficients 0,8 or 0,63 and 1,27 is to validate fans down to 2 or 4 sizes smaller and up to 2 sizes larger than the tested size. See [Annex F](#) for more information.

- g) for a direct drive axial fan where the blade profile is not symmetrical and the fan may be supplied with motor upstream or motor downstream, the fan shall be tested with motor downstream, which is the worst case;
- h) but if the fan range is intended to operate only with motor upstream, the tests can be performed in this configuration;
- i) if a fan or range of fans is intended for installation in either vertical or horizontal or intermediate positions, a minimum of one fan shall be tested in each of vertical (shaft down and motor downstream or shaft up and motor upstream if the fan range is intended to work only with the motor upstream) and horizontal orientation;
- j) if a family of axial fans is also intended to be used for jet fan application, a minimum of one size of fan shall be tested in the jet fan configuration;
- k) a fan for use as a jet fan shall be tested completely assembled, with its ancillaries as listed in [5.1](#) if supplied with the jet fan. A test of the fan with only the inlet side silencer is allowed to qualify a jet fan, unless the jet fan is suspended by the silencers;

- l) for a reversible fan or jet fan, equipped with a symmetrical impeller (symmetrical blade profile or impeller with alternate blades) the test shall be performed with motor downstream;
- m) a fan shall be tested with any electrical device used in combination with the motor which could have a negative impact on the motor (e.g. change electrical signal, overheating, etc.);
- n) fan driven by PWM frequency converter at ambient and at high temperature.

The currently well-known impacts of a PWM frequency converter driving on an electric three-phase motor are the following:

- creation of partial discharges through the air voids located inside motor insulation. These discharges are in proportion with the temperature;
- creation of voltage peaks higher than those obtained from direct online supply;
- damage in the windings due to these voltage peaks and voltage gradient (d_u/d_t);
- influence of the cable type/length;
- stray bearing currents.

In order to estimate the final impact of the combination of converter and cable on the motor, it is necessary to measure directly at the motor terminals by means of a suitable instrument (e.g. an oscilloscope), only at ambient temperature for 10 min before the warm up period of the test:

- the maximum peak voltage value, U_p , or peak to peak, $U_{pk/pk}$, as well as;
- the maximum rate of voltage rise, d_u/d_t , of the voltage fluctuations as indicated in [Figure A.1](#) and [Formula \(A.1\)](#):

$$d_u/d_t = (0,9 U_p - 0,1 U_p) / (t_{90} - t_{10}) \tag{A.1}$$

Refer to IEC 60034-18-41 for more details.

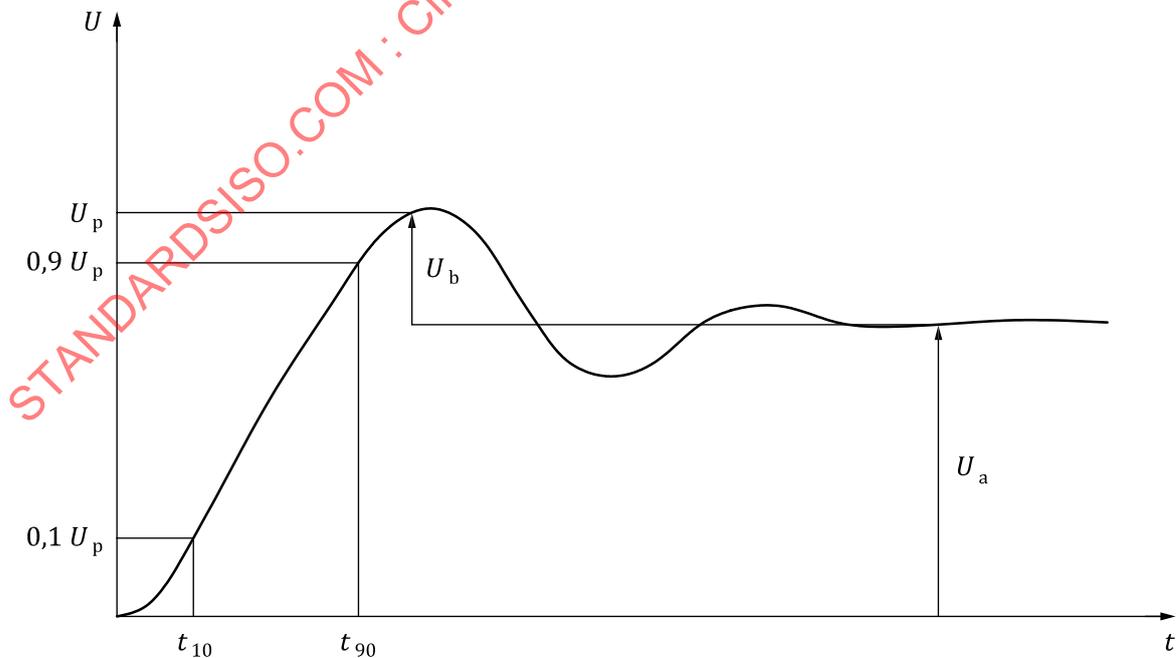


Figure A.1 — Voltage curve

Application of the test results:

The fan unit may be assumed to be able to withstand the same maximum peak to peak voltage values and rate of voltage rise at the motor terminals in an installation as during the test, independent of the pulse width modulation (PWM) frequency converter.

- a) Fan driven by PWM frequency converter only at ambient temperature.

Fan tested directly on line can be installed with a frequency converter, provided the converter is by-passed during smoke and heat exhausting operation, without additional testing.

- b) Fan driven by voltage converter (but switched off during smoke exhausting).

A motor which is supplied from a voltage converter may experience an increased temperature rise when run at a reduced voltage.

Because of this effect on the temperature rise inside the motor, the warm-up period of the test shall be performed with the output of the voltage converter set to run the motor at 70 % of nominal speed.

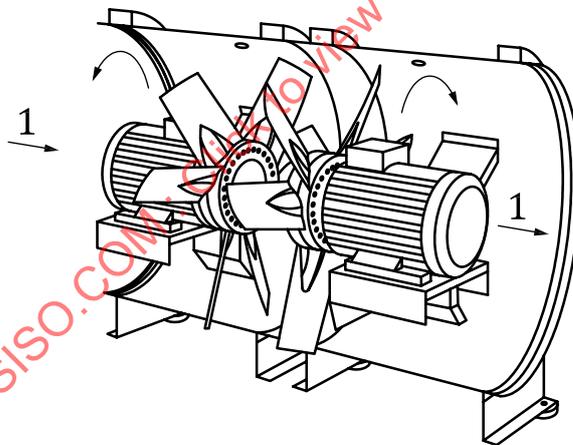
The temperature rise of the motor during this warm up period shall not be greater than one class lower than the insulation class of motor.

- c) Fan started by soft starter.

Since the soft starter is bypassed just after the motor starting, it is not obligatory to test it, especially if the fan manufacturer wants to get both applications (with and without soft starter).

- d) Contra-rotating installation.

Such installation does not require any additional test provided the fan range was tested individually with motor downstream (see [Figure A.2](#)).



Key
1 air flow

Figure A.2 — Contra-rotating installation

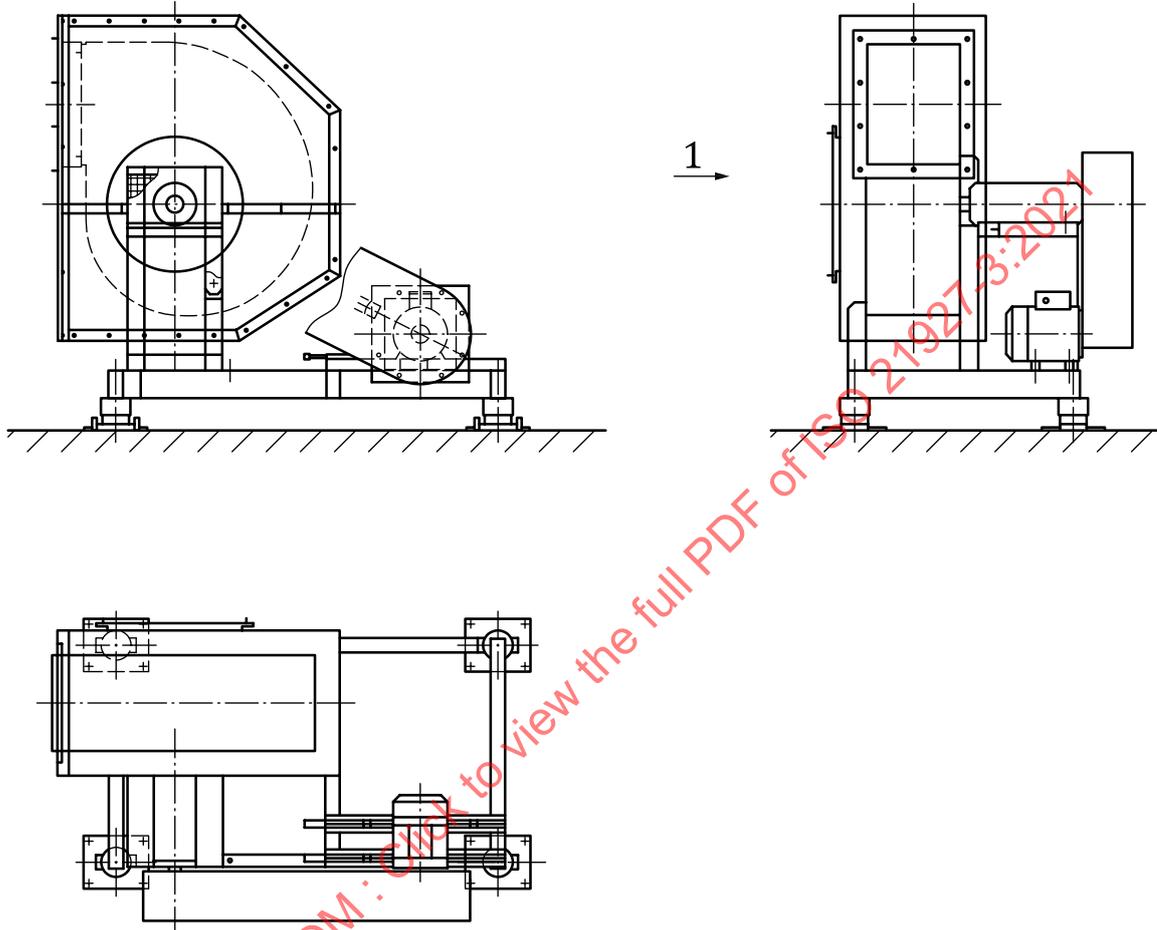
A.2 Motors

A.2.1 General

A family of motors shall only be assessed if the smallest and largest frame size motors used in the family are tested within the fans, at their highest ratings (voltage, power, rotational speed, etc.), 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 (type 1). When the motor is out of the air stream and the impeller is mounted on the

motor shaft (type 2), 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.2.2 Type 1 motor: Motor out of airstream and impeller not mounted on shaft



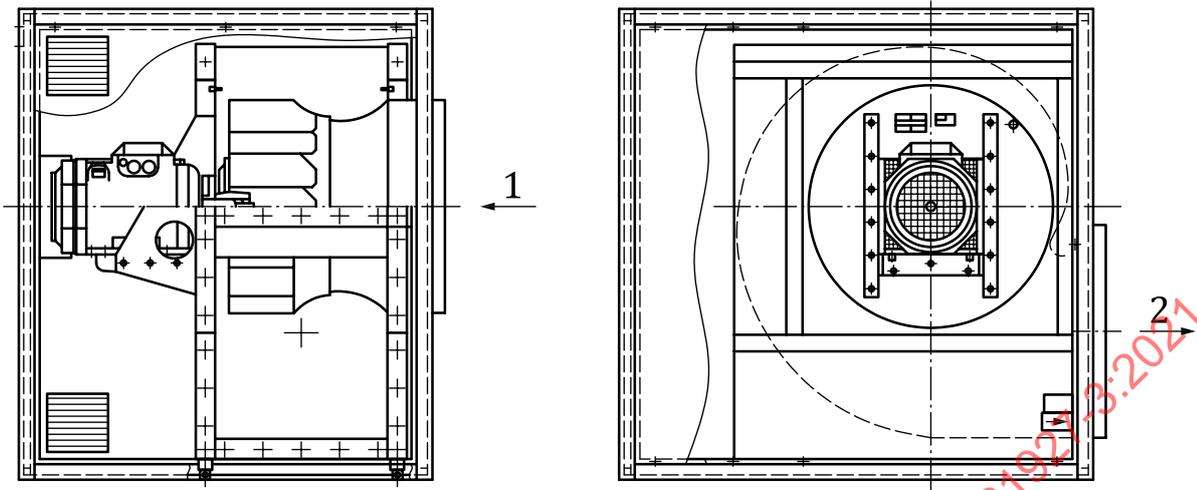
Key

1 air flow

Figure A.3 — Type 1 motor

In this case, Type 1 motors do not need to be approved and there are no requirements, except those described in [4.2.3](#).

A.2.3 Type 2 motor: Centrifugal fans with impeller mounted on the motor shaft



- Key**
- 1 air flow (inlet)
 - 2 air flow (outlet)

Figure A.4 — Type 2 motor

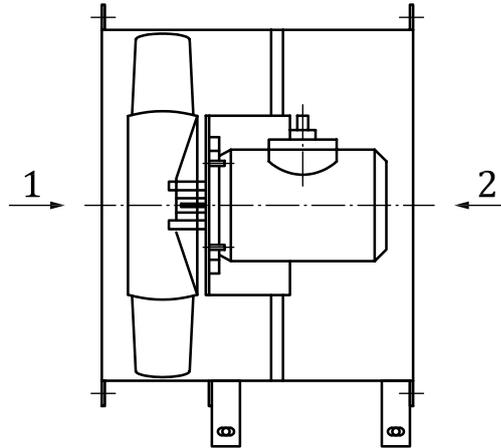
Type 2 motors shall be tested.

For interchangeability, the motor winding temperature shall be measured just after the test (according to the resistance measurement method of IEC 60034-19) to ensure that the temperature rise inside the motor is equal to or lower than that permitted for the insulation class. For example, with a standard class F motor, the motor winding temperature rise at the end of the high temperature test shall not exceed the class F requirement, i.e. 105 K.

Where single-phase motors were tested, the above rule for motor interchangeability applies, provided that the alternative capacitor is located at the same place (a plastic capacitor can be replaced by an aluminium capacitor but not vice-versa).

Otherwise, a motor cannot be changed without a new test. If new tests are required, see [A.3](#).

A.2.4 Type 3 motor: Fans with motor inside the airstream without cooling



Key

- 1 air 1
- 2 air 2

Figure A.5 — Motor Type 3

Type 3 motors shall be tested and interchangeability is only possible with other motors already tested under specific conditions, see [A.3](#).

A.2.5 Type 4 motor: Motors out of airstream but without fan casing

A.2.5.1 General

Type 4 motor: Fans with insulation class F (temperature rise B) or class H (temperature rise F) standard motors for F_{400} and lower temperature/times classes and motors affected by thermal transfer.

See examples in [A.2.5.2](#) and [A.2.5.3](#).

A.2.5.2 Motor Type 4.1

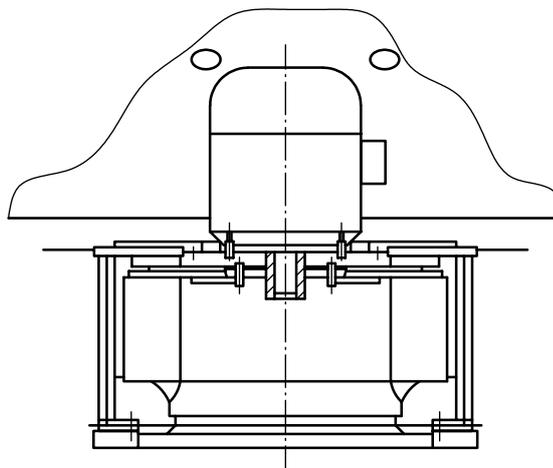


Figure A.6 — Motor Type 4.1

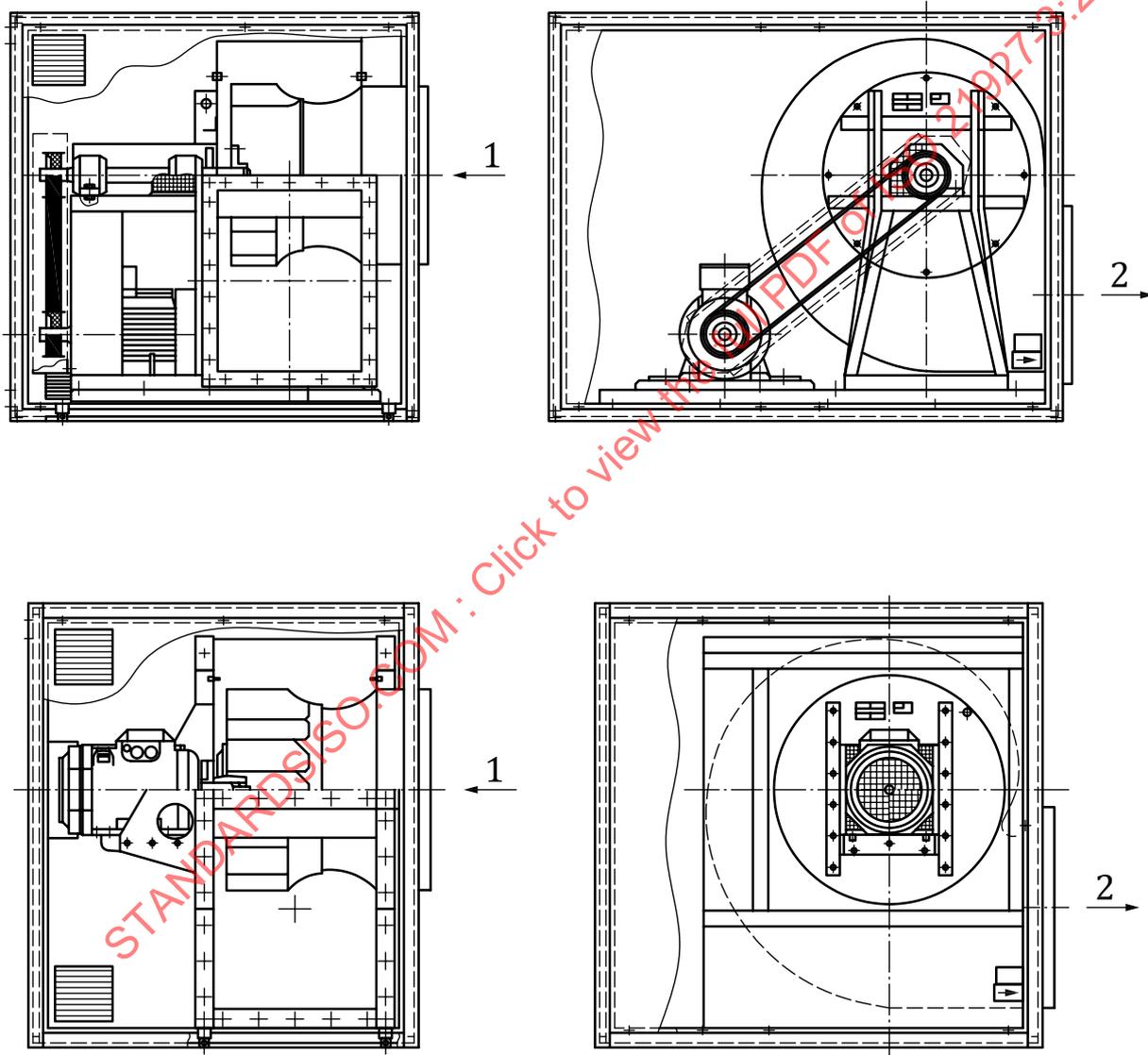
Motors of type 4.1 shall be tested.

For interchangeability, the motor winding temperature shall be measured just after the test (according to the resistance measurement method of IEC 60034-1) to ensure that temperature rise inside the motor is equal to or lower than that permitted for the insulation class. For example, with a standard class F motor, the motor winding temperature rise at the end of the high temperature test shall not exceed the class F requirement, i.e. 105 K.

Where single-phase motors were tested, the above rule for motor interchangeability applies, provided that the alternative capacitor is located at the same place (a plastic capacitor can be replaced by an aluminium capacitor but not vice-versa).

Otherwise the motor cannot be changed without a new test. If new tests are required, see [A.3](#).

A.2.5.3 Motor Type 4.2



Key

- 1 input
- 2 output

Figure A.7 — Motor Type 4.2

Motors of type 4.2 shall be tested.

For interchangeability, the motor winding temperature shall be measured just after the test (according to the resistance measurement method of EN 60034-1) to ensure that temperature rise inside the motor is equal to or lower than that permitted for the insulation class. For example, with a standard class F motor, the motor winding temperature rise at the end of the high temperature test shall not exceed the class F requirement, i.e. 105 K.

Where single-phase motors were tested, the above rule for motor interchangeability is the same, provided that the alternative capacitor is located at the same place (a plastic capacitor can be replaced by an aluminium capacitor but not vice-versa).

Otherwise, the motor cannot be changed without a new test. If new tests are required, see [A.3](#).

A.3 Combined testing

A.3.1 General rule

To allow the mounting of a new family of motors inside an already tested family of fans, test the smallest and largest frame motor sizes at their highest ratings within fans provided that the motors are part of the same homogeneous range.

A.3.2 Specific rule for an axial fan

When the family of fans is large, the motor family may consist of two or more homogeneous ranges. This means that for each homogeneous family, both the smallest and largest frame sizes shall be tested (i.e. 4 or more tests).

However, if the alternative motor family was already successfully tested according to [Annex D](#), or within another family of fans, in accordance with the same criteria listed in [A.1](#) and for the same temperature-time classification, only the smallest and largest frame size of the complete motor family shall be retested within the fans (only 2 tests).

EXAMPLE Fan family A tested with motor range X consisting of 2 homogeneous families:

- X1: Frame sizes 80 to 132;
- X2: Frame sizes 160 to 250.

According to [Annex B](#), the frame sizes 80, 132, 160 and 250 were tested during the initial assessment.

A fan manufacturer wants to mount motor family Y consisting of 2 homogeneous families:

- Y1: Frame sizes 90 to 112;
- Y2: Frame sizes 132 to 225.

If Y motors were never tested, tests of 90, 112, 132 and 225 frame sizes motors shall be carried out.

If Y motors (at least the 90 up to 225 frame sizes range) were successfully tested with a load (according to [Annex D](#)) or within a fan family B with the same criteria in accordance with [A.1](#) and for the same temperature-time classification, then retest only frame sizes 90 and 225.

A.4 Determination of highest stresses in impellers

A.4.1 PSHC 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 % 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.

Information regarding axial fans is shown in [Tables A.1](#) and [A.2](#).

Table A.1 — Axial fans

A fan family is geometrically similar if the fans of that family are manufactured according to standard series numbers R10, R20, R40 or according to self-defined design size increments (following a fixed size ratio), assuming similarity of the following component dimensions.

Geometrical parameters		Geometrical similarity	
Impeller diameter	D_i	e.g., R10, R20; R30 or self-defined design size increments	Dimensions according to drawing — check
Hub diameter	d	e.g., R10, R20; R30 or self-defined design size increments	Dimensions according to drawing — check
Number of blades	z	Testing is carried out with the maximum number of blades, i.e., max. load on the hub	The number of blades may be reduced after testing since the hub load is, thus, reduced.
Blade width at D (external diameter)	B_D		Dimensions according to drawing — check
Blade width at d (internal diameter)	B_d		Dimensions according to drawing — check
Blade length	l	$\frac{D-d}{2}$ maximum blade length is tested at maximum load	Dimensions according to drawing — check Blade length may be reduced, with simultaneous reduction in casing diameter, taking into account the load.
Blade profile shape		Linear form factor	Dimensions according to drawing — check
Hub width	w	e.g., R10, R20; R30 or self-defined design size increments	Dimensions according to drawing — check

Table A.2 — Design characteristics

If the fan and casing are built from sheet metal, geometrical incrementing of the sheet metal thickness is not necessary.

Design characteristics			
Fastening method		Geometrically uniform fastening method (welding, screws or riveting) across the entire series	Change of fastening method within the series is not possible without testing. Welding: Execution of welds shall be identical, i.e., continuous weld seams, weld shape (fillet weld, square/bevel groove weld), length of weld shall be geometrically similar Rivet and screw joining methods: If, for instance, 5 rivets are used on small impellers, at least 5 rivets shall likewise be used on all fans in the series according to the calculation method.
Material		Identical material, no mixing	Uniform materials and uniform material combinations to be used across the entire series.

Table A.2 (continued)

If the fan and casing are built from sheet metal, geometrical incrementing of the sheet metal thickness is not necessary.			
Design characteristics			
Hub section		1. Geometrical similarity 2. Hub supports (connection piece between hub and motor shaft) may differ as appropriate	2. With externally sourced hub supports, geometrical similarity cannot be maintained. Calculated proof of screw attachment is required.
Motor mounting type		Motor mounting type shall be the same for the entire series	
		Geometrically similar	For motor supports: δ_M = Material thickness G = Motor weight e.g., $\frac{\delta_M}{G}$ Least favourable conditions related to design size shall be tested
Centrifugal fans			
Blade outlet diameter	$D_{B,O}$	e.g., R10, R20; R30 or self-defined design size increments	Dimensions according to drawing — check
Blade inlet diameter	$D_{B,I}$	e.g., R10, R20; R30 or self-defined design size increments	Dimensions according to drawing — check
Blade radius	R_B	e.g., R10, R20; R30 or self-defined design size increments	Dimensions according to drawing — check

A.4.2 Fans with impellers that are not geometrically similar

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

A.4.2.1 Axial impellers

A.4.2.1.1 Centrifugal force

Divide the blade into four parts using five sections as shown in [Figure A.8](#).

Calculate the centrifugal force for each part using [Formula \(A.2\)](#):

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

where

$F_{n,n+1}$ is the centrifugal force of the part of the blade between sections n and $n+1$ in N;

ρ is the density of the blade material in kg/m^3 ;

A_n is the area of section n in m^2 ;

R_n is the radius of section n in m;

ω is the angular velocity of impeller in rad/s.

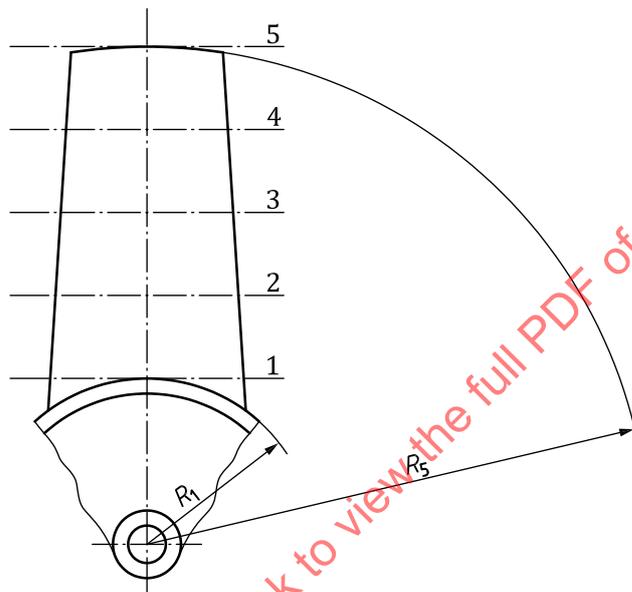


Figure A.8 — Axial impeller, blade divided into four parts using five sections

Calculate the tensile stress using [Formula \(A.3\)](#). See [Figure A.9](#).

$$\sigma_t = \frac{F_n}{A_n} \times 10^{-6} \quad (\text{A.3})$$

NOTE 10^{-6} is the calculation factor to convert A_n into mm^2 .

where

σ_t is the tensile stress in N/mm^2 ;

A_n is the area of section n in m^2 ;

F_n is the centrifugal force of the part of the blade in section n .

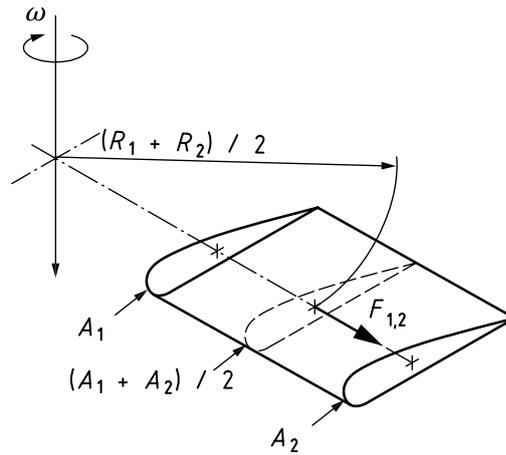


Figure A.9 — Axial impeller, application of centrifugal force $F_{1,2}$

A.4.2.1.2 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.

To simplify the calculation, the stress to be calculated shall be the force due to the blade divided by the cross-section of the studs, as shown in [Formula \(A.4\)](#):

Case of stud fixed blades

$$\sigma_f = \frac{F_1}{N' \times A} \quad (\text{A.4})$$

where

σ_f is the fastening stress in N/mm²;

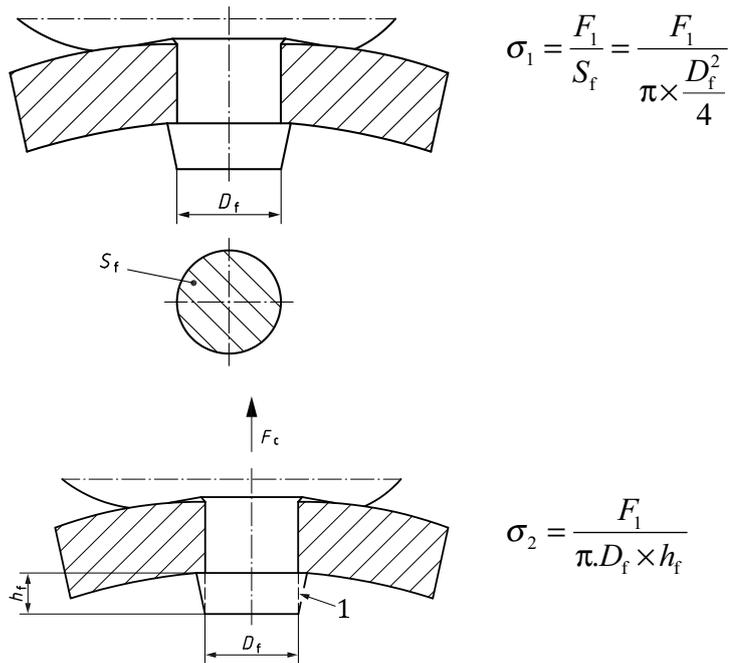
N' is the number of studs;

A is the resistant cross-section of a stud;

F_1 is the centrifugal force of the part of the blade in section 1, see [Figure A.9](#).

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. See [Figures A.10](#) and [A.11](#).



Key

- 1 shearing according to Fc

Figure A.10 — Blades with a shank

Then the fastening stress is $\sigma_f = \max(\sigma_1, \sigma_2)$

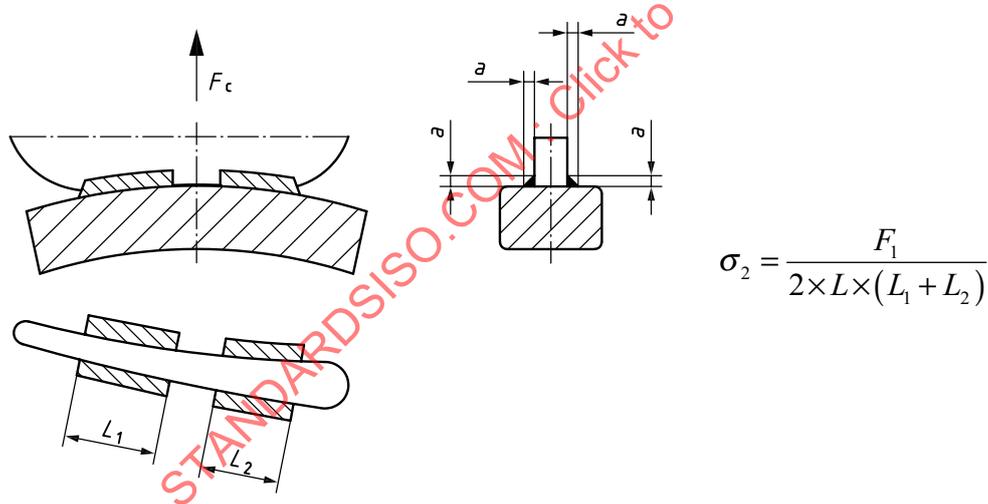


Figure A.11 — Welded blades

A.4.2.1.3 Hub/back-plate/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. See [Formula \(A.5\)](#):

$$\sigma_{si} = \frac{\rho \times R_h^2 \times \omega^2}{10^6} \quad (\text{A.5})$$

where

- σ_{si} is the self-induced stress in N/mm²;
- R_h is the maximum hub radius in m;
- ω is the angular velocity of impeller in rad/s.
- ρ is the density of the blade material in kg/m³.

Assume that only the section of the hub/back-plate/shroud approximately symmetrical about the plane of rotation through the centre of the blade fixing is supporting the blades, see [Figure A.12](#), then calculate the hoop stress using [Formula \(A.6\)](#):

$$\sigma_h = \frac{N \times F_1}{(2 \times \pi \times A_{csm})} \quad (\text{A.6})$$

where

- σ_h is the hoop stress in N/mm²;
- N is the number of blades;
- F_1 is the total blade centrifugal force in N;
- A_{csm} is the cross-sectional area of the hub in mm².

Calculate the section modulus I_x/v about an axis through the section centre of area, parallel to the axis of rotation, where v is the distance from this axis to the outside of the hub/back-plate/shroud supporting the blade. Then calculate the bending stress using [Formula \(A.7\)](#):

$$\sigma_b = \frac{F_1 \times 2\pi \times R_h \times 10^3}{\left(N \times 12 \times \frac{I_x}{v} \right)} \quad (\text{A.7})$$

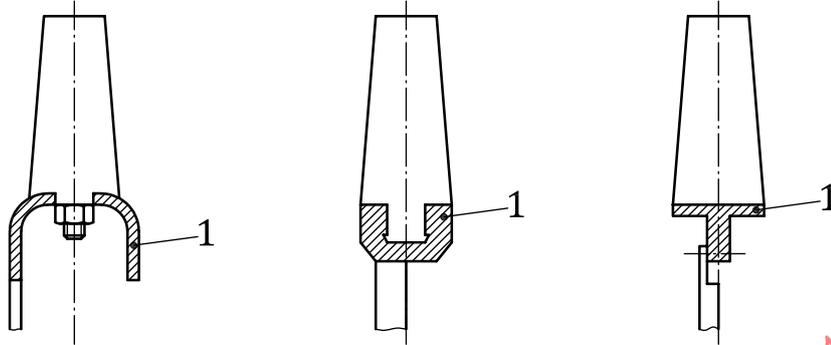
where

- σ_b is the bending stress in N/mm²;
- F_1 is the total blade centrifugal force in N;
- R_h is the maximum hub radius in m;
- I_x/v is the section modulus of A_{csm} section in mm³;
- N is the number of blades.

Then using linear hypothesis, see [Formula \(A.8\)](#):

$$\sigma_{tot} = \sigma_{si} + \sigma_h + \sigma_b \tag{A.8}$$

where σ_{tot} is the total stress.



Key

1 cross-sectional area of the hub in mm² (A_{csm})

Figure A.12 — Portion of hub to be used for calculation

NOTE Shaded parts in [Figure A.12](#) show portion to be used for calculation.

A.4.2.2 Centrifugal impellers

A.4.2.2.1 Centrifugal force

The centrifugal force is calculated by treating the blade as one piece, using [Formula \(A.9\)](#) (see [Figure A.13](#)):

$$F = \rho \times A_b \times L \times R \times \omega^2 \tag{A.9}$$

where

- F is the centrifugal force in N;
- ρ is the density of blade material, in kg/m³;
- A_b is the cross-section area of the blade at the centre of gravity, perpendicular to the axis of rotation in m²;
- L is the distance between the back-plate and shroud, through the centre of gravity, parallel to the axis of rotation, in m;
- R is the radius of blade centre of gravity about the axis of rotation, in m;
- ω is the angular velocity of impeller in rad/s.

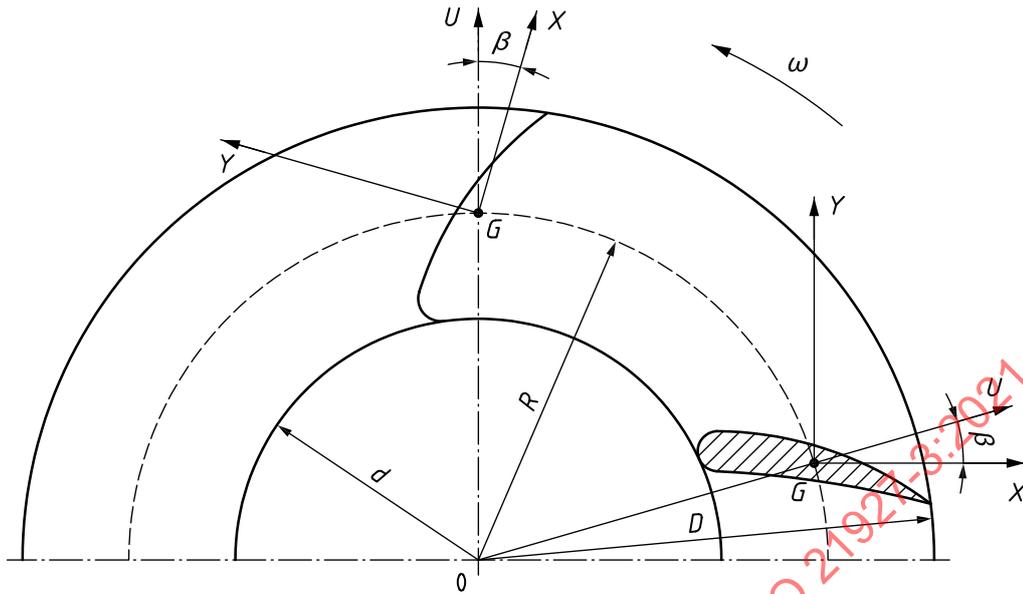


Figure A.13 — Centrifugal impeller, calculation of centrifugal forces about a principal axis

A.4.2.2.2 Blade bending moment

See [Formula \(A.10\)](#):

$$M = F \times L / k \quad (\text{A.10})$$

where

F is the centrifugal force defined in [A.4.2.2.1](#);

L is defined in [A.4.2.2.1](#);

M is the bending moment in Nm;

k is a constant depending on the type of impeller construction (for comparative purposes use, it may be assumed that $k = 1$).

A.4.2.2.3 Comparative blade stresses

To calculate comparative blade stresses resolve the bending moment about the principal axis and the stress calculated using [Formula \(A.11\)](#) and [Formula A.12](#)) (see [Figure A.14](#) and [Figure A.15](#)):

$$\sigma_{z1} = \frac{F \times \sin \beta \times L / k}{Z_{x_{\min}}} \quad \text{or} \quad \sigma_{z1} = 1000 \times M \times \sin \beta / Z_{x_{\min}} \quad \text{with } M = F \times L / k \quad (\text{A.11})$$

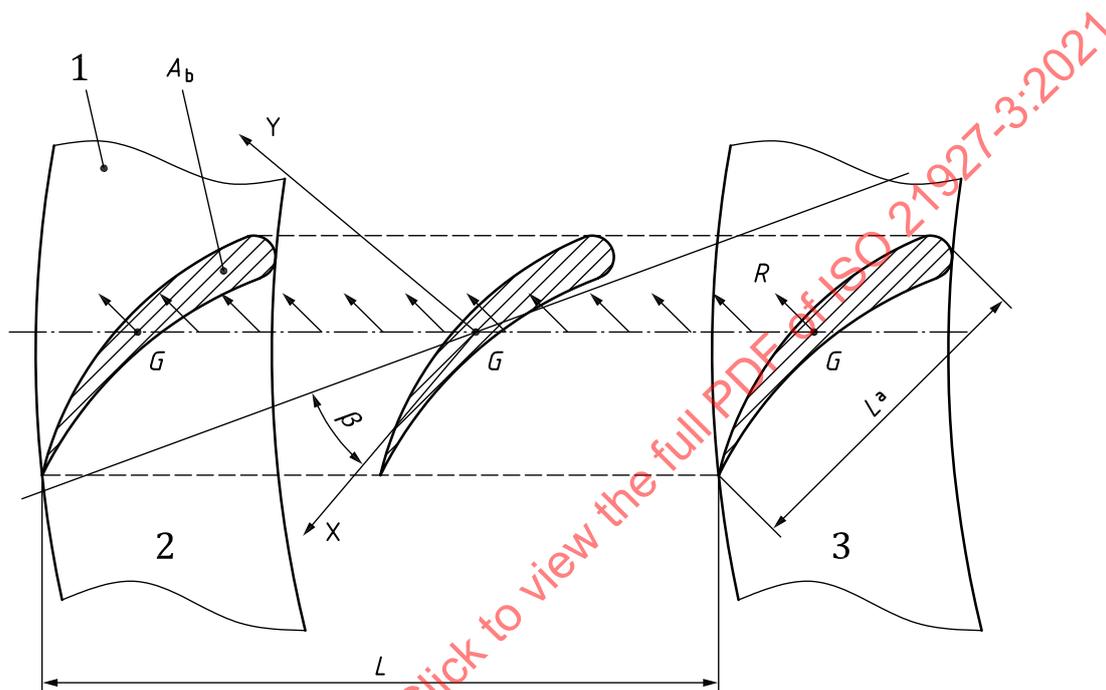
$$\sigma_{z2} = \frac{F \times \cos \beta \times L / k}{Z_{y_{\min}}} \quad \text{or} \quad \sigma_{z2} = 1000 \times M \times \cos \beta / Z_{y_{\min}} \quad \text{with } M = F \times L / k \quad (\text{A.12})$$

where

σ_{z1} and σ_{z2} are the bending stresses about principal axis X and Y in N/mm² (most of the time, $\sigma_{z2} < \sigma_{z1}$);

β is the angle between principle axis and the radial line of impeller;

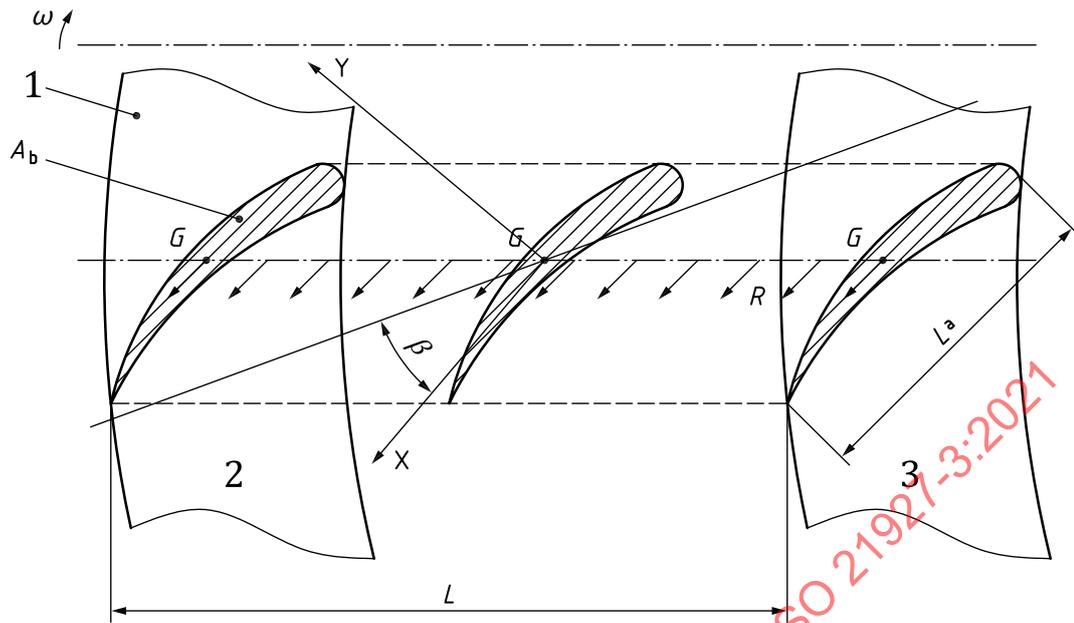
$Z_{x\min}$ and $Z_{y\min}$ are the section modulus about principal axis X and Y in mm³.



Key

- 1 centrifugal impeller
- 2 back-plate
- 3 shroud

Figure A.14 — Centrifugal impeller, calculation of σ_{z1}



Key

- 1 centrifugal impeller
- 2 back-plate
- 3 shroud

Figure A.15 — Centrifugal impeller, calculation of σ_{Z2}

A.4.2.2.4 Blade joint stress

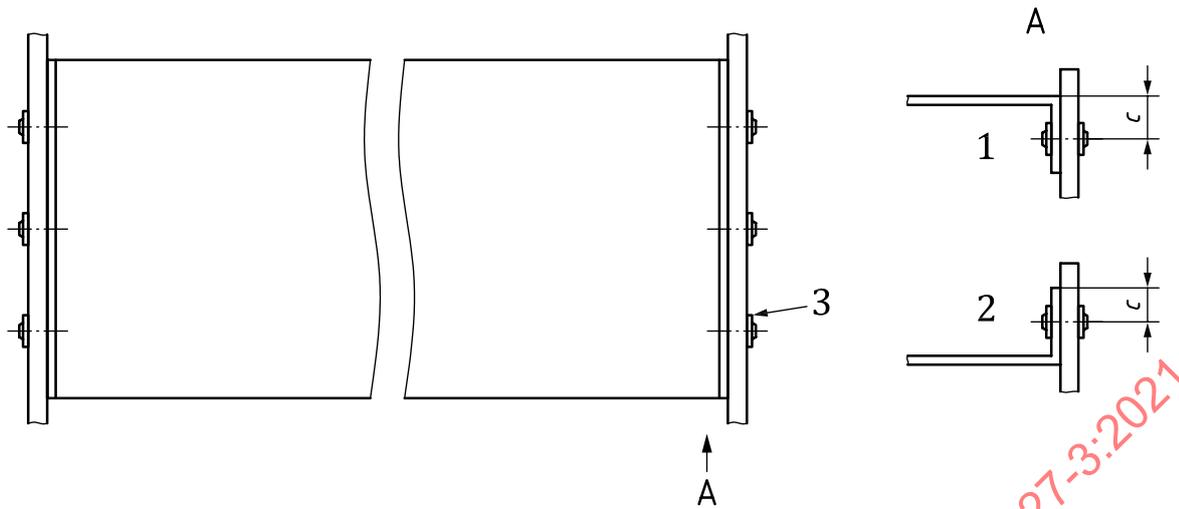
Calculate the relative shear stresses at each blade joint using [Formula \(A.13\)](#):

$$\sigma_s = F / A \tag{A.13}$$

where

- σ_s is a shear stress in N/mm²;
- F is the centrifugal force in N;
- A is the area of cross-section of fastening at joint in mm².

In specific cases, the fastenings experience tensile stress and not shear stress, see for example [Figure A.16](#):



Key

- 1 view X
- 2 inner fastening
- 3 outer fastening
- 4 rivets or spot welding
- c a distance in mm.

Figure A.16 — Centrifugal impeller, calculation of blade joint stress

Calculate also the relative tensile stresses at each blade joint using [Formula \(A.14\)](#):

$$\sigma_t = F \times L / (A \times c) \tag{A.14}$$

where

- σ_t is the tensile stress in N/mm²;
- A is the area of cross-section of fastening at joint in mm²;
- c is a distance in mm, see [Figure A.16](#).

A.5 Assessment of changes in a fan family

A.5.1 Assessment of motor change

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 [A.2](#).

A.5.2 Assessment of fan component change

The changes made to the fan family that has been tested shall be re-assessed as follows.

After the initial assessment of a fan family including blades made of material alloy A, the way to replace material A by material B (of the same main component) is as follows.

First option

Retest the fan including the most highly stressed impeller with material alloy B. The test duration of alternative impeller material shall be at least the duration of the initial assessment.

Second option

Comparison mechanical tests shall be performed on 5 blade samples (finished worked component in order to take into account the manufacturing process) made of both alloys.

This comparison tests shall be performed at the aimed classification temperature and during the whole test period (same heat up period time and temperature time period as in [Annex C](#)).

If:

- 1) $(R_{p02})_2 \geq (R_{p02})_1$;
- 2) $(\text{Creep})_2 \geq (\text{Creep})_1$ (for the classification time, the classification temperature and the force applied to the blade in the fan) and the material has the same geometry, and the same or better surface roughness and the same or better grain size;
- 3) $\rho_2 \leq \rho_1$;
- 4) $\alpha_2 \leq \alpha_1$; and
- 5) $E_2 \geq E_1$;

then the new material is OK.

If:

- 1) $\alpha_2 > \alpha_1$; or
- 2) $E_2 < E_1$;

then the material is OK, but the new clearance shall be checked.

If $\rho_2 > \rho_1$, then it shall be checked that $(R_{p02}/\sigma_{cal})_2 \geq (R_{p02}/\sigma_{cal})_1$.

See [Annex F](#) for more explanation.

Annex B (normative)

Criteria to determine a family of motors in order to select the sizes to be tested

B.1 Reduction of numbers of tests for a motor family

It is not usually considered necessary to test every size and speed of motor to be used in a family of fans. Provided tests are carried out on the largest and smallest motor frame size at the highest ratings (i.e. highest voltage rotational speed and power), it is assumed that all the motors in a range comply with this document.

If the difference between two frame sizes is only the height of feet (e.g. the frame size between sizes 80 and 90), a test performed on the 90 frame size is also valid for the 80 frame size, provided the active parts are strictly the same.

When motors are direct on line (DOL) tested at 50 Hz, the application at 60 Hz (DOL) with the suitable voltage (keeping the voltage/frequency ratio) is also covered for motors of the same family including the same bearings and lubrication and having a higher pole number than the tested pole number, provided the rated power at 60 Hz, corresponding to maximum 1,15 times the power rated at 50 Hz, is covered by the family tested at 50 Hz.

EXAMPLE A test of 2 pole motors (frame size 80 at 1,1 kW + frame size 250 at 55 kW) tested direct on line on 400 V/50 Hz network is valid for 4 poles motors supplied by DOL network 440 V–480 V/60 Hz for frame sizes with a rated power corresponding to maximum 1,15 times the power rated at 50 Hz (frame sizes 80 to 225 in this case).

[Tables B.1](#), [B.2](#) and [B.3](#) give the parameters to be taken into account to check if the motors are part of the same family. This list of motor components shall be delivered by the motor manufacturer to the laboratory **before** selecting the specimen to be tested according to [A.1](#).

The preferred method to prove the resistance to temperature of electric motors for use in powered ventilators (fans) is to test the motor at elevated temperature in a powered ventilator (fan). The motor is shown to be functioning satisfactorily if the fan continues to provide the required volume flow for the duration of the test, see [C.5](#).

B.2 Assessment of changes in a motor family

B.2.1 Assessment for changing a family of motors in a family of fans

The assessment for changing a family of motors in a family of fans shall be in accordance with [A.2](#).

B.2.2 Assessment for changing components in a family of motors

The assessment for changing components in a family of motors shall be done in order to check if the changes do not worsen the performance of the family of fans. In that case, further specific tests are necessary to verify performance.

If more than one material of the insulation system within the production life time of the motor (line "wiring insulation" up to "winding impregnation") is changed, it shall be considered as a new family of motors and both smallest and largest frame sizes shall be retested.

[Tables B.1](#), [B.2](#), [B.3](#) and [B.4](#) specify the relevant components and the way to change them.

Table B.1 — Mechanical critical components in a motor

Elements	Security level	How to change
Housing (carcase) material	Critical	<p>Test performed with cast iron/steel frames is not valid for aluminium frames.</p> <p>The smallest (thermally critical) and largest frame (mechanically critical) sizes of the whole range shall be re-tested. If the whole range consists of several previously evaluated smaller homogeneous ranges, the intermediate sizes need not be re-tested.</p> <p>Test performed with aluminium frames is not valid for cast iron/steel frames, except if additional technical evidence is available (e.g. calculations, temperature rise consideration, etc.).</p> <p>A successful re-test of the smallest motor frame size is sufficient to demonstrate.</p>
Housing (carcase) design (e.g. ribs size, spacing and distribution but not method of mounting)	Critical	<p>The design is directly linked to the rate of thermal exchange, so the change is not possible, except if additional technical evidence is available (e.g. calculations, ...etc.).</p> <p>Successful comparison tests according to B.2.3 between original and alternative design performed on a representative sample is sufficient to cover the change.</p>
End shields (drive end and non-drive end) material	Critical	<p>Tests performed with aluminium frames are valid for cast iron/steel frames but not vice versa.</p>
Cooling impeller material	Critical	<p>“No impeller” is considered as more critical than a plastic impeller, itself more critical than an aluminium impeller, itself more critical than a cast iron/steel impeller.</p> <p>This component is not critical for axial fans where the motor is in the airstream.</p>
Fan cover	Critical	<p>“No impeller casing” is considered as more critical than a plastic casing, itself more critical than an aluminium casing, itself more critical than a cast iron/steel casing.</p> <p>This component is not critical for axial fans where the motor is in the airstream.</p>
Bearing type (ball, rollers...)	Critical	<p>In order to replace a ball bearing by an angular contact bearing for vertical application (including the same grease), then retest the smallest motor equipped with an angular contact bearing. The motor shall be tested with the highest axial load consistent with the specified expected bearing life for the motor range.</p> <p>This configuration is reached by weighting, if necessary, the hub of the impeller to increase the axial force.</p> <p>For a motor range approval made according to Annex D, the test for changing the ball bearing into an angular contact bearing shall be made with a test bench in vertical position, applying the highest permitted load on the bearing.</p>
Class of fit/Bearing Clearance	Critical	<p>C0 is considered as more critical than CN, itself more critical than C3, itself more critical than C4.</p>
Arrangement (locked/floating)	Informative	<p>Changes are allowed, provided that the axial clearance between end shield and bearing is the same or higher than tested. If test was performed on motor where both bearings are floating, it is not possible to mount any motor with one locked bearing.</p>

Table B.1 (continued)

Elements	Security level	How to change
Lubricant/grease	Critical	<p>Only the tested grease can be used.</p> <p>A new test is required for a new grease.</p> <p>Test only the motor or the fan with the motor including the bearing which has the highest peripheral speed (i.e. rotation speed × medium diameter of the bearing). If several bearings sizes have the same highest peripheral speed, select from these the bearing which has the highest rotation speed.</p>

Table B.2 — Electrical and insulation critical components in a motor

Elements	Security level	How to change
Rotor (material of bars, end rings)	Critical	A range tested with copper bars is valid only for copper cage. A range tested with aluminium cage is valid for both, provided the full load power and temperature rise are not increased.
Lamination steel grade	Informative	This grade is usually changed to increase the efficiency. No extra test is required, provided the core length is not reduced.
Stator	Informative	Manufacturing and assembling method, motor outline range drawing showing the main dimensions of motor and a table with the dimensions for each size are required.
Internal cooling impeller	Critical	If at least one motor was tested with an internal cooling impeller, an impeller made of the same material can be mounted in other motor sizes if required to meet requirement of temperature rise.
Wiring insulation*	Critical	If the wire insulation change comes from a change of its material, there is a doubt concerning its association with other insulation materials of the stator. Retest the smallest motor/ the fan with the smallest motor, because it includes the highest windings density and because it has the smallest thermal inertia.
Slot insulation*	Critical	<p>Suppliers' data sheets that show that the new insulation material is identical to the tested insulation material are acceptable (identical means exactly the same material and not only the same thermal classification). Otherwise, retest the smallest motor frame.</p> <p>An increase in the thickness of identical material is allowed without retesting.</p>
Interlayer insulation (between windings inside a same slot)*	Critical	Idem
Slot wedge*	Critical	Idem
Phase insulation*	Critical	Idem
Lacing ribbon*	critical	Idem
Winding impregnation*	Critical	Only the resin tested or exactly the same material as tested is accepted. Otherwise, retest the smallest frame size which is the most critical regarding the penetration of impregnation varnish.
Method of impregnation*	Critical	If the method of impregnation is changed, retest the smallest motor frame size manufactured with the alternative method, except if the initial method was one dipping and the manufacturer decides to use two dipping.

Table B.2 (continued)

Elements	Security level	How to change
Terminal box or flying leads	Critical	Test performed on a motor equipped with a terminal box is only valid to cover motors equipped with terminal boxes. Test performed on a motor equipped with flying leads only covers motors equipped with flying leads. A test of one example of the alternative configuration is sufficient to allow the change. Where the same type (insulation, manufacturer) of cables is used for both applications (same cable as flying leads is used to connect winding heads to the terminal board and also from terminal box to outside), the test with terminal box covers the flying leads application.
Terminal board	Critical	Change of this element can be carried out if it is separately tested in its terminal box at equivalent voltage and at the specified classification temperature +50 °C inside the terminal box, using the same cables and way of fixing them. The change is acceptable if no short-circuit occurs during the specified classification time.
Terminal leads	Critical	These leads are an internal part of the motor and shall be tested with the smallest motor frame.
Gland and gland sealing, if fitted	Critical	No gland (and no protection during the test) is considered as more critical than a plastic gland, itself more critical than metal gland.
Insulation and type of connection between terminal leads and stator winding	Critical	The method of connection (e. g. clamping or welding) and the material of the insulation sleeve protecting this connection are both critical. If one or other of these parameters is changed, retest the smallest motor frame size.

Table B.3 – Variant acceptability

Elements	Security level	How to change
Application (direct on line, frequency converter)	Critical	Tests made with a frequency converter are valid for DOL operation at the same voltage and frequency. When the initial assessment is performed direct on line (DOL), no further test is required for use with converter provided that: <ul style="list-style-type: none"> — any of the four filters described in Table B.4 is used with the converter; and — the power of the motor is de-rated by 20 %^a or by a factor that results in the DOL or lower temperature rise. If the initial assessment is performed in DOL application and the fan family needs to be installed with frequency converters without filters or de-rates, then retest both the smallest and largest frame motors at their highest powers and voltage, supplied from frequency converters in accordance with A.1 n).
Forms of running (horizontal, vertical)	Critical	If a motor or family of motors is intended for installation in either vertical or horizontal or intermediate positions, a minimum of one motor shall be tested in each of vertical (shaft down and motor downstream or shaft up and motor upstream) and horizontal orientation.
Air direction (motor upstream, motor downstream or both)	Critical	Worst case valid for both. See A.1 g) and i).
Mounting feet or flange or foot and flange.	Informative	

^a Based on IEC 60034-17.

Table B.3 (continued)

Elements	Security level	How to change
Second end shaft	Informative	
Protection IP56 and IP65	Informative	
Use grease nipples	Critical	Tests done with grease nipples are valid with permanent grease bearings.
Reinforced bearing series 63	Critical	62 series is considered as more critical than 63 series.
Options		
Sensors	Critical	It is only possible to use sensors PTC, Pt100 or bimetallic detectors if they are disconnected in case of a fire emergency, and if they were present during the tests. It is possible to install only one of these options for initial assessment, provided they are all installed inside the motor in the same way (same insulation sleeve).
Heating elements	Critical	It is allowed to fit anti-condensation heating elements, but they shall not be in service during the normal motor operation or the emergency and should have been present during the test.
Supplying cable to motor (between terminal box and outside) or flying leads	Critical	The cables can be replaced by other cables tested in the same conditions of temperature/time and connection on evaluation of the test laboratory.
Capacitor	Critical	The alternative capacitor shall be placed at the same location as for the tested one. Plastic capacitor may be replaced by aluminium capacitor but not vice-versa.
^a Based on IEC 60034-17.		

Table B.4 — Filters for frequency converters

Ordered by best protection provided for motor (insulation and bearings)	Voltage drop	Losses to be added
Variable speed drive (VSD) + sinusoidal filter	10 %	0 %
d_u/d_t filter	Negligible	0,1 % to 1,5 % due to filter +8 %–14 % due to VSD (PWM)
Motor termination unit	Negligible	0,1 % to 1,5 % due to filter +8 %–14 % due to VSD (PWM)
Output reactor	Negligible	0,1 % to 1,5% +8 %–14 % due to VSD (PWM)

B.2.3 Assessment of changes using Annex D

Annex D gives the possibility of performing the test of motor independently of fan hazard and is helpful for controlling electrical, thermal and aerodynamic conditions on the motor.

A test of the initial version of the motor and a test of the alternative version are performed in the same conditions by recording the following parameters by means of type K thermocouples:

- temperature in the winding heads;
- temperature in the bearings.

If the test of the initial version fails, no conclusion can be issued.

If the required temperature data from a test of the original motor is already available, only a test of the alternative version of motor is required.

If both tests are successful **and** the temperatures measured in the alternative version are equal to or lower than the ones measured in the initial version of the motor **during the whole test period**, (which can be up to 25 K higher to allow for tolerance in the measured furnace temperature), then the change is allowed without the need for any extra testing.

If the alternative version fails or if the above temperature comparison criterion is not matched, then there are doubts regarding the effect of the change on the emergency high temperature performance and:

- the change cannot be accepted; or
- if the motor manufacturer believes that the test failed due to the high stressing conditions of the test according to [Annex D](#), he/she can retest the alternative motor version in all fan ranges for which he/she wants to supply the alternative version of motor.

B.2.4 List of motor components

This subclause indicates the list of information required by the test laboratory to evaluate changes and select motors that can be tested:

[Figures B.1](#) and [B.2](#) show the location of some of the referenced components.

— **General information:**

Motor manufacturer	
--------------------	--

— **General data:**

Motors reference Lowest and highest frame sizes with their highest rated power Highest voltage Highest frequency Highest and lowest poles number Insulation class Rise temperature class	
--	--

— **Mechanical data:**

Elements	Reference	Material and characteristics
Frame material		
End shields (DE and NDE) material		
Cooling impeller material		
Fan cover		
Bearing type (ball, rollers...)		
Class of fit (C3, C4)		
Bearing clearance		

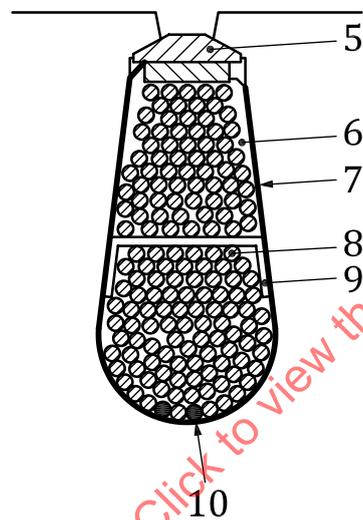
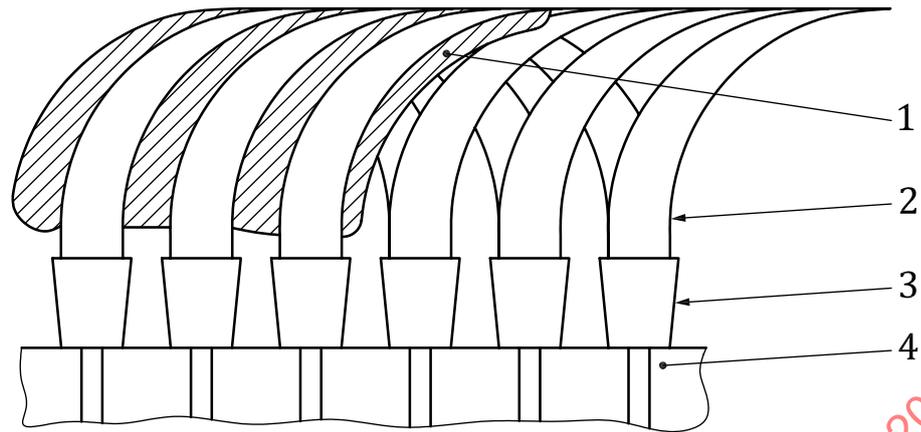
Arrangement (locked/floating)		
Lubricant/grease		

— **Electrical and insulation data:**

Elements	Reference	Material and characteristics
Rotor (material of bars...)		
Stator core		
Wiring insulation		
Slot insulation		
Interlayer insulation (between windings inside a same slot, if used)		
Slot wedge		
Phase insulation		
Lacing ribbon, if used		
Winding impregnation		
Terminal board		
Terminal leads, if used		
Gland and gland sealing, if fitted		
Insulation and type of connection between windings heads and terminal leads		

The variants through the range concern:

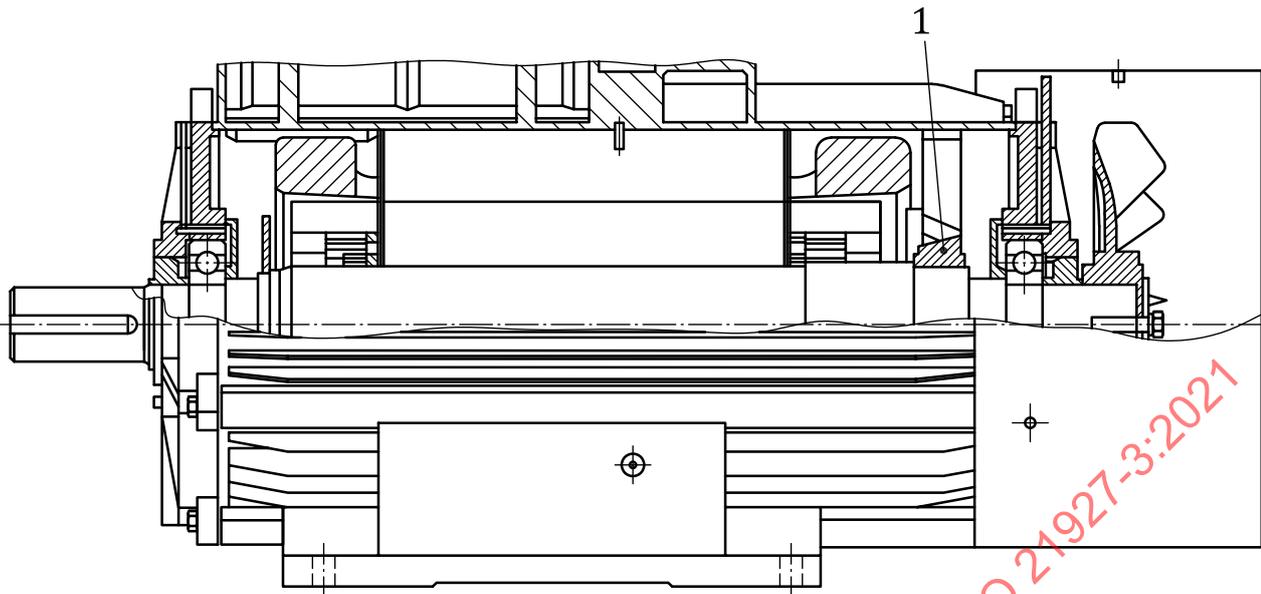
- cooling arrangements (IC 40, IC 41, IC 48, etc.);
- electrical connection (terminal box, or flying leads, etc.);
- the application (direct on line, frequency converter);
- forms of running (horizontal, vertical);
- air direction (motor upstream, motor downstream or both).



Key

- | | |
|----------------------------------|---------------------------------|
| 1 phase insulation | 6 varnish |
| 2 coil | 7 slot insulation |
| 3 slot insulation and slot wedge | 8 copper wires |
| 4 stator core | 9 layer insulation |
| 5 slot wedge | 10 leads of sensors and heaters |

Figure B.1 — Details of stator



Key

1 internal impeller

Figure B.2 — Example of motor with external and internal cooling impeller

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Annex C (normative)

Test method for the determination of fire resistance of powered smoke and heat control ventilators (fans)

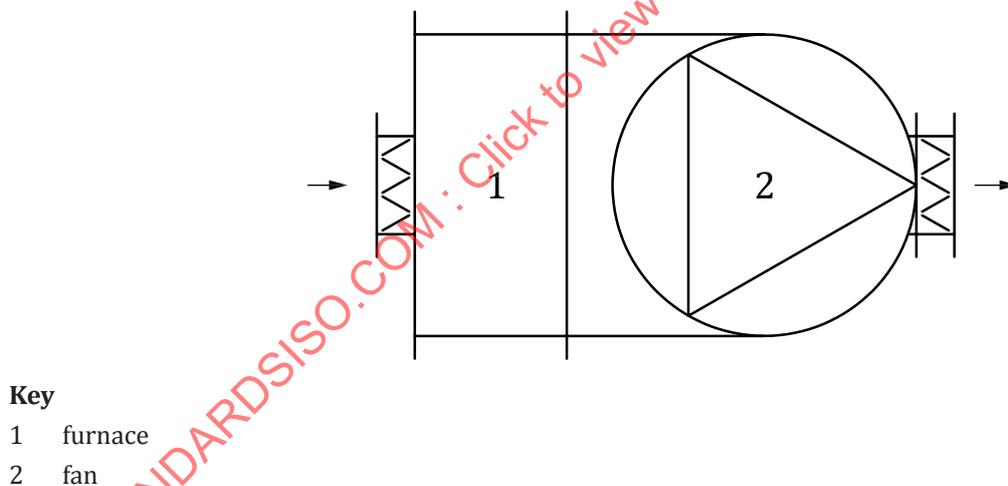
C.1 Principle

Fire resistance of powered smoke and heat ventilators (fans) is assessed with the fan set up in order to have, at normal ambient pressure and temperature (i.e. density $1,2 \text{ kg/m}^3$):

- the power output from the motor from 80 % to 100 % of the rated power of the motor;
- the fan operating anywhere on a stable part of its volume pressure curve.

C.2 Apparatus

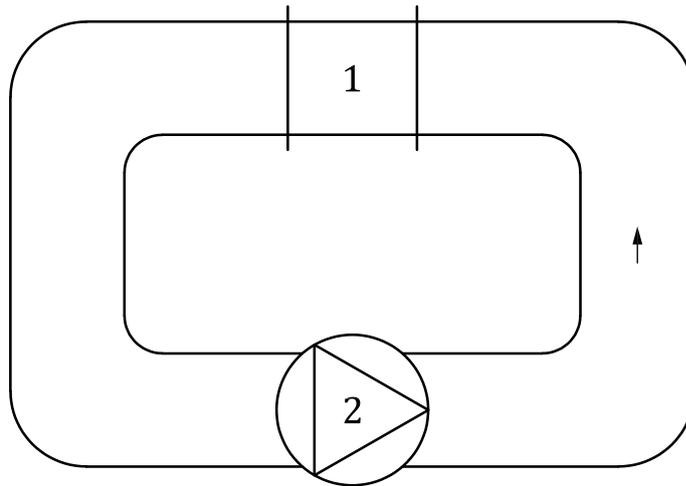
C.2.1 Furnace, capable of heating the required air flow and raising the temperature of the system to the specified level in the specified time within the specified tolerances, either connected directly or through a system of ducting either to recirculate the hot gases or to discharge to atmosphere, see [Figures C.1](#), [C.2](#) and [C.3](#).



Key

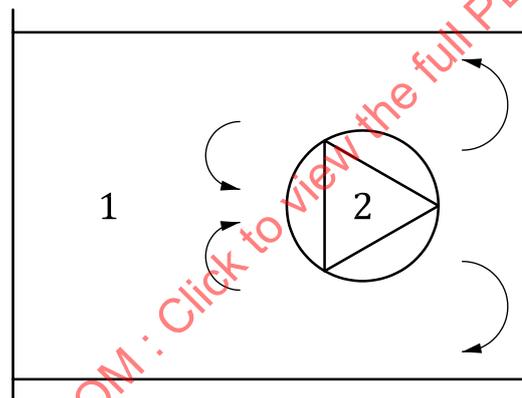
- 1 furnace
- 2 fan

Figure C.1 — Fan connected directly to furnace



- Key**
- 1 furnace
 - 2 fan

Figure C.2 — Fan connected to furnace by recirculating duct system



- Key**
- 1 furnace
 - 2 fan

Figure C.3 — Fan mounted inside furnace

C.2.2 Flow and/or pressure measuring equipment, in accordance with ISO 5801, ISO 5167 (all parts).

C.2.3 Thermo-elements and thermocouples, in accordance with EN 1363-1. Plate thermometers (according to EN 1363-1) shall not be used; type K thermocouples shall be used to measure furnace temperature at 100 mm upstream of the fan, in accordance with EN 60584-1.

It is allowed to use shielded thermocouples for stability reasons.

C.3 Preparation

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

C.3.1 Axial Fan running (tip) clearance

A fan that is intended for installation outside of the smoke reservoir may be tested inside the furnace or outside the furnace with applied insulation. In these cases, the test fan shall be provided with a tip clearance reduced in accordance with [Formula \(C.1\)](#):

Reduced clearance = normal clearance – reduction of clearance

$$\text{Reduction of clearance} = (D_{\text{mn,cl}} / 2) \times C \times \Delta T \quad (\text{C.1})$$

where

$D_{\text{mn,cl}}$ is the diameter at minimum clearance in mm;

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

ΔT is half the difference between the hot gas temperature and the ambient temperature, in mm.

NOTE 1 For this calculation, the casing temperature is assumed to be the average between the hot gas temperature inside the fan and ambient temperature outside the fan.

Measure the minimum clearance between the impeller and the casing.

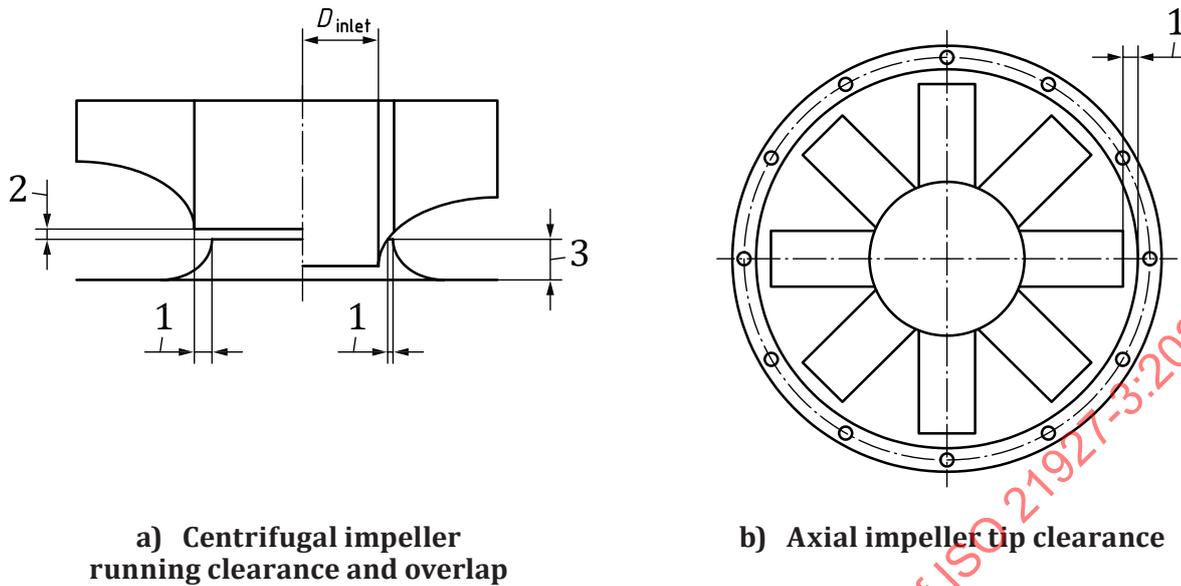
An example of procedure to measure the clearance is given in [C.3.2](#).

NOTE 2 A ventilator tested with insulation has a higher casing temperature than one without insulation and consequently under test has a larger tip clearance.

C.3.2 Measuring of running clearance

For an axial fan, the running clearance is the gap between the blade end and the fan case (tip clearance). For a centrifugal impeller, it is the clearance between the inlet nozzle and the impeller. Additionally, there may be an overlap between the impeller and the inlet nozzle. The running clearance shall be measured before the test and may be measured for information when the fan has cooled after the high temperature test. See Figure C.4.

NOTE A measurement of the running clearance after the high temperature test can provide information on the elongation of an impeller blade and/or hub as a result of centrifugal force.



a) Centrifugal impeller running clearance and overlap

b) Axial impeller tip clearance

Key

- 1 running clearance
- 2 running clearance
- 3 overlap
- D_{inlet} inlet nozzle

Figure C.4 — Tip clearance

Example of measurement procedure:

Step 1: Fix a suitable measurement device, e.g. displacement transducer, to the impeller and rotate to find the minimum position of the casing/of the nozzle.

Step 2: On the minimum position place a pin, e.g. drill bit, and rotate the impeller. If no impeller blades make contact with the pin, take the next largest size of pin. When an impeller blade is rubbing the pin, the tip clearance has been established.

Step 3: If required, mark the impeller blade and the minimum position.

For accuracy, drills bits with diameter step of 0,1 mm may be used.

C.3.3 Installation in furnace depending on the intended application categories

Set up the fan, 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 fan by a method appropriate to the application category(ies) determined according to 4.2.2. Set up a smoke reservoir ventilator either surrounded by hot gases as indicated in Figure C.3, or, if the motor is inside the fan, totally surrounded by the high temperature gas flow and not cooled by ambient air. Set up the insulated ventilator 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 may be necessary to make special duct connections when hot gas recirculation test systems are used. Install the duct connection so that it does not prevent heat recirculation to the motor if this could happen in practice. For the case of the roof fan, such a connection duct cannot be used to measure air flow rate, but the temperature of the incoming air can be measured for information.

A fan for use as a jet fan shall be tested completely assembled.

A jet fan can be tested according to [Figure C.3](#) or mounted completely inside a recirculating duct (i.e. fan surrounded by hot gases) provided its working point is stable. If the ventilator discharges motor cooling air into the main airstream, set up the ventilator so that the flow of cooling air is the minimum that is achieved in practice.

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 fan.

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.

Fit at least three furnace thermo-elements at 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. Position the temperature sensors centrally at the inlet and outlet cross-sections.

For insulated fans, install thermocouples at the critical position (e.g. thermal bridge, over a joint between two insulation boards), observing the following rules:

- thermocouples 50 mm away from the corner if applicable and at the centre of each face;
- thermocouples 15 mm away from the joint between faces;
- thermocouples 25 mm away from critical point (e.g. penetrating screws where the diameter is less than 25 mm);
- at least three surface temperature thermocouples for 1 m² side.

Fit electrical devices for the measurement of frequency, voltage, current, power and speed in accordance with IEC 60034-2-1. A frequency measurement is not required if the main supply is of known frequency.

NOTE 3 It is possible to measure temperature rise by means of a thermocouple affixed into the winding head (but in no case inside the slot) and bearings at ambient and high temperature for information.

Additional precautions are needed when the power to the motor is being supplied from a frequency converter: if the output from the frequency converter is fed to the motor via sinusoidal filters, the voltage, current and electrical power may be measured with conventional instrumentation. However, it shall be taken into consideration that the use of sinusoidal filters can result in a voltage drop of 10 % from that of the fundamental wave root mean square (r.m.s) voltage at output of the frequency converter. Where sinusoidal filters are not used, conventional and wideband power analysers and digital voltmeters shall measure the total r.m.s values including all harmonics generated by the Frequency Converter and may register voltages between 20 % and 30 % higher voltages than the fundamental wave r.m.s values. It is therefore necessary to use power analysers or voltmeters either able to get the complete spectrum in order to identify the fundamental wave or equipped with low pass line filters that attenuate harmonics of the variable speed drive (VSD) output and enable accurate measurements to be recorded.

Care shall be taken with the test set-up to ensure that other instrumentation, transducers and sensors are not affected by electromagnetic interference. It may be necessary to use screened power cables and/or shielded sensor leads to guarantee the reliability of all other recorded measurements.

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 all fan classes different from F₈₄₂, test in accordance with [C.4.2](#), [C.4.3](#) and [C.4.4](#). For fan Class F₈₄₂, test in accordance with [C.4.2](#) and [C.4.5](#).

If a fan is tested at a higher temperature than that which is specified for a lower class or classes, and for a time which is equal to or longer than that which is specified for a lower class or classes, then the fan shall also be approved for the lower class or classes.

C.4.2 Warm up period

C.4.2.1 Operate a dual purpose use fan at ambient temperature, at the maximum speed, for a warm up period until the motor frame or winding temperature increase is less than 2 °C in 10 min, but for a minimum period of 60 min. Record voltage, current, power, flow or pressure and temperature measurements at intervals not exceeding 1 min. Ensure that the measurements are stable.

Do not operate a fan for emergency only use prior to test.

When a large fan is tested in a recirculating duct or inside a furnace, it can be difficult to achieve stabilization of the motor temperature. When the temperature rise for the insulation class of the fan motor is reached, the heat up period can start provided that the fan volume flow or pressure is stabilized.

If bearing temperature measurements are required for information, monitor temperatures by means of thermocouples fitted as near as possible to the outer rings of both bearings.

C.4.2.2 Operate an emergency only use fan, at ambient temperature until the volume flow or pressure readings are stable.

A variation of $\pm 2,5$ % in volume flow or ± 5 % 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 fan to the appropriate value in 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 so that the average temperature upstream of the impeller is not less than the specified temperature and not more than the specified temperature +25 °C, maintained for the appropriate period of time. Record electrical, flow or pressure and temperature measurements at intervals not exceeding 1 min. Correct pressure measurements for the effects of density change due to temperature.

After 15 min, switch off the fan for 2 min, and then restart the fan. During this period, the temperature variation may exceed the specified limits.

If the motor is driven by a frequency converter, the motor shall be stopped (power switched off) without any decelerating ramp set by the converter and then restarted after two minutes via the converter which is programmed with the shortest practical starting ramp (acceleration time).

Add the time the ventilator is switched off or is working below its target frequency to the specified 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 average temperature to a tolerance of 0 °C to +25 °C. Test the ventilator for a period of 30 min. Record electrical, flow and/or pressure and temperature measurements at intervals not exceeding 1 min. Correct pressure measurements for the effects of density change due to temperature.

During this period the temperature variation may exceed the specified limits.

C.5 Compliance criteria

The volume flow shall not decrease by more than 10 % and not increase by more than 25 %, or the static pressure difference (corrected for the effects of density due to temperature change) shall not decrease by more than 20 % and not increase by more than 50 % of that measured at the end of the warm up period of the test.

C.6 Test report

C.6.1 Prepare a test report after completion of each test including the following information:

- a) the name of the test laboratory;
- b) the name of the sponsor;
- c) the date of test;
- d) the name of the supplier and trade name of the product;
- e) a reference to the test methods;
- f) the catalogue description, size and speed of the ventilator tested;
- g) the ancillaries tested including electric cables (type, size, supplier);
- h) the temperature/time class (see [4.4](#));
- i) the application categories (see [4.2.2](#));
- j) the snow load class;
- k) details of the test arrangement including all equipment used for measurement of temperature, flow, pressure, current, voltage, electrical power and wind and snow load;
- l) observations, measurements and calculated results made before, during and after the tests in accordance with [Annexes C](#) and [E](#) or [D](#);
- m) when the test is performed to assess the fan for installation with a frequency converter: record the model reference and type of converter (e.g. pulse width modulation [PWM]), type, section and length of cable between converter and motor, switching frequency, start ramp time, type of filter if used and the frequency supplied by the converter. If the fan is intended for installation with different models or brands of frequency converter, record the maximum voltage peak, peak to peak value and the maximum rate of voltage rise (d_u/d_t) at which the motor has been tested.

C.6.2 Prepare an additional test report providing details of a complete product family that may be covered by a number of tests including:

- a) the fan model reference or catalogue code;
- b) the product range covered by the tests in accordance with [Annex A](#);

- c) the fan speed;
- d) the impeller and hub diameter, tip clearance (see C.3) length and number of blades;
- e) the approximate blade cross-sectional area;
- f) the approximate hub cross-sectional area;
- g) the motor speed if different from c);
- h) the motor model reference or catalogue code;
- i) the motor rating;
- j) the bearing type, class of fit, lubricant and arrangement for motor, and for fan if fan is indirectly driven;
- k) the carcass, end cover and cooling impeller (if fitted) material;
- l) the insulation specification and class;
- m) which ancillaries are covered;
- n) when the tests have been performed to allow use with frequency converters: type of converter (e.g. PWM), switching frequency, starting time ramp, filter to be used (if any) and allowed highest frequency for the converter application. If the fans are intended for installation with different models or brands of frequency converter, include information on maximum voltage peak, peak to peak value and the maximum rate of voltage rise (d_u/d_t) at which a motor has been tested. (when many motors are tested to cover a range, the reference values for voltage peak and rate of voltage rise are the lowest values recorded among the different tests);
- o) a recommendation about the supplying electric cable: "the fan shall be supplied by an electric cable which is suitable for smoke exhausting application and for the relevant temperature-time and installation classes";
- p) the following statement: "The tip/running clearances can have a large influence on the aerodynamic performance.";
- q) all information indicated in 6.3.2.6.

C.6.3 Evaluation of the minimum tip clearances for serial production of axial fans.

The fan manufacturer shall submit to the lab data regarding the minimum tip clearances (taken into consideration manufacturing tolerances) for the serial family of fans that he intends to produce.

- a) For each submitted test specimen measure the actual minimum tip clearance for the impeller (see C.4).
- b) Calculate for each test specimen the clearance safety factor.

The definition of a safety factor, C , is calculated using [Formula \(C.2\)](#):

$$C = J / J_{th} \tag{C.2}$$

where

J_{th} is the minimum tip clearance declared by the manufacturer;

J is the minimum tip clearance measured by the lab.

C shall be greater than or equal to 1.

The safety factor to apply to the declared minimum tip clearances for non-tested fan sizes shall be:

- the safety factor of the smallest tested size for fans smaller than that which was tested;
- the safety factor of the largest tested size for fans larger than that which was tested;
- the highest safety factor of any two tested fans for sizes in between the two tested sizes,

EXAMPLE If, in order to cover a family of fans, it is necessary to test 400, 710 and 1 250 fan sizes, 3 safety factors, C_{400} , C_{710} and C_{1250} , are derived.

For fan sizes smaller than 400, the accepted tip clearance is the declared minimum tip clearance (supplied by manufacturer) multiplied by the C_{400} safety factor.

For fan sizes larger than 1 250, the accepted tip clearance is the declared minimum tip clearance (supplied by manufacturer) multiplied by the C_{1250} safety factor.

For fan sizes between 400 and 710, the accepted tip clearance is the declared minimum tip clearance (supplied by manufacturer) multiplied by the maximum (C_{400} or C_{710}) safety factor.

For fan sizes in between 710 and 1 250, the accepted tip clearance is the declared minimum tip clearance (supplied by manufacturer) multiplied by the maximum (C_{710} or C_{1250}) safety factor.

- a) Depending on the test configuration (within the furnace, with or without insulation, etc.) and the intended applications (smoke or non-smoke reservoir, insulated fan) the above clearances can have to be corrected in accordance with [C.3.1](#).
- b) Two tables shall be supplied in the range report:
 - one table providing the minimal tip clearance for installation outside the smoke reservoir without insulation;
 - one table providing the minimal tip clearance for installation inside the smoke reservoir or with insulation.

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Annex D (normative)

Test methods for electric motors to determine the impact of the changes on the product characteristics

D.1 Principle

Another method to prove the resistance to temperature of electric motors for use in powered ventilators is by testing the motor at elevated temperature 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 corresponding to the desired temperature/time category.

D.2 Tests in association with a generator or another load

D.2.1 Modulated frequency method (MFM)

Within the EN 60034 series, different methods for loading a motor are approved as being equivalent and are well used by motor manufacturers. Either:

- loading motors with a generator; or
- “electrically” loading the motor by using the Modulated Frequency Method, described in EN 60034-29:2008, 6.2.2, which gives the same temperature rise in any active motor as it has if loaded mechanically by a generator as described in [Figure D.1](#).

IEC 60034-29:2008, 6.2.2, describes the way to electrically load the motor by using a modulated frequency, which means the motor is accelerating and de-accelerating within a short time, resulting in the heat up of the motor with a temperature rise, stabilized by the setting of the current value during that period.

The modulated frequency is generated with a frequency converter.

Concerning the MFM (IEC 60034-29:2008, 6.2.2), the input power cannot be easily measured, but normally it is possible to obtain values for the voltage, the current and power between motor and converter which represents the losses of the motor tested.

Some preliminary tests shall be performed at ambient temperature by the motor manufacturer in order to establish the same temperature rise as the rise measured with DOL or inverter running.

The settings of the converter to apply the MFM shall be adjusted so that:

- the current within the motor is at least the same as the current when the motor is loaded by a generator on a test bench;
- the temperature rise within the motor is the same or higher than the rise when the motor is loaded by a generator through an inverter on a test bench;
- the average frequency shall be the highest frequency required for the approval.

Since the measurement of power is not relevant, the lab shall measure the current and the average frequency.

D.2.2 Apparatus for testing with a generator

D.2.2.1 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.

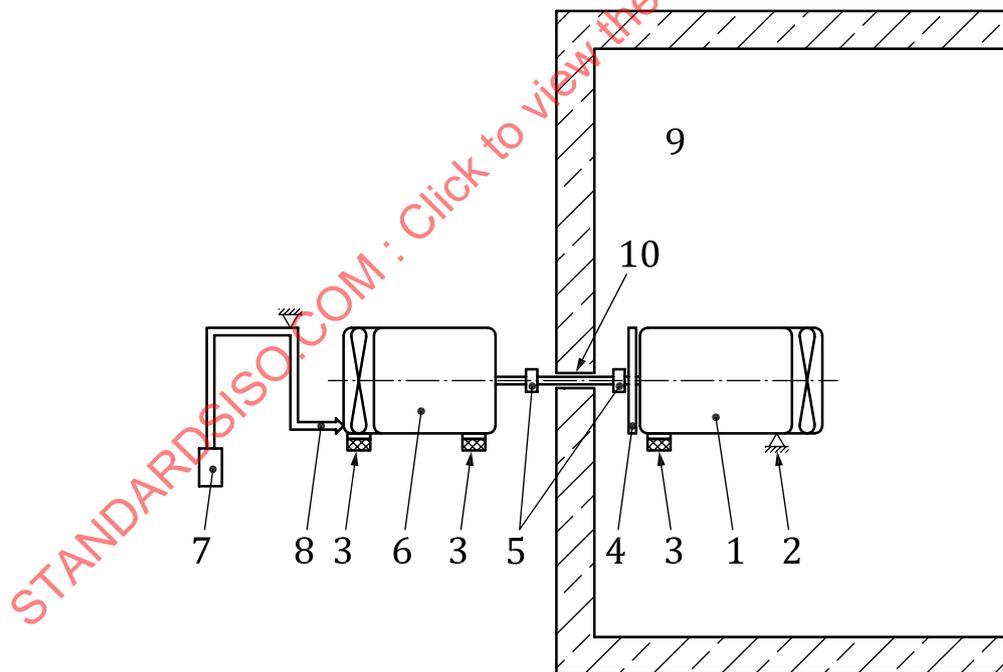
To circulate the hot gas past the carcass at the rated velocity, fit either the normal integral cooling impeller or an external impeller if the motor is mounted within the fan airstream. Mount the external impeller either directly on the motor shaft or on the transmission shaft.

Air speed and air flow may be measured along the motor frame at ambient temperature for information.

D.2.2.2 Specifications for bearing load

Provide means of applying axial and/or radial load to the motor shaft corresponding to a certain capacity of bearing defined according to the rules stated in applicable standards (ISO 281) and corresponding to a life time, L_{10h} , as defined in the motor manufacturer documentation. For example, apply either a radial load and/or an axial load.

Provide 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	6	generator
2	fixed support	7	mass
3	sliding support	8	axial load, induced by mass (7)
4	radial load (e.g. steel disc)	9	furnace
5	flexible couplings, torsionally rigid	10	penetration point

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

D.2.2.3 Temperature measurements

Fit one or more furnace thermocouples at a distance of approximately 100 mm from the motor frame to measure the temperature of the surrounding gases. Fit devices between the ribs of the motor for surface temperature measurement.

Fit also equipment in the windings to check temperature rise of motor.

No plate thermometer (according to EN 1363-1) can be used; type K shielded thermocouples with at least a 3 mm diameter lead shall be used around the motor to control furnace temperature.

D.2.2.4 Electrical measurements

Measure frequency, voltage, current, power and speed in accordance with IEC 60034-2-1.

Additional precautions are needed when the power to the motor is being supplied from a frequency converter: if the output from the frequency converter is fed to the motor via sinusoidal filters, the voltage, current and electrical power may be measured with conventional instrumentation. However, it shall be taken into consideration that the use of sinusoidal filters can result in a voltage drop of 10 % from that of the fundamental wave r.m.s voltage at output of the frequency converter.

Where sinusoidal filters are not used, conventional and wideband power analysers and digital voltmeters shall measure the total r.m.s values including all harmonics generated by the frequency converter and may register voltages between 20 % and 30 % higher than the fundamental wave r.m.s values. It is therefore necessary to use power analysers or voltmeters able to record the complete spectrum in order to identify the fundamental wave to enable accurate measurements of voltage, current and r.m.s. input power to be recorded.

Care shall be taken with the test set-up to ensure that other instrumentation, transducers and sensors are not affected by electromagnetic interference. It may be necessary to use screened power cables and/or shielded sensor leads to guarantee the reliability of all other recorded measurements.

D.2.3 Test specimens

Select test specimens in accordance with [Annexes A](#) and [B](#).

D.2.4 Test procedure

D.2.4.1 General conditions

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

D.2.4.2 Warm up period

Operate the motor at ambient temperature at its rated frequency and voltage and at 100 % of the rated power.

Operate the motor at ambient temperature until the motor frame or winding temperature increase is less than 2 °C in 10 min but for a minimum period of 60 min.

Record electrical and temperature measurements.

If the temperature rise of the motor exceeds one class below the insulation class of the motor, the motor shall not be used for smoke vent application.

Measure the temperature of bearings by means of thermocouples fitted as nearer as possible to the outer rings of both bearings.

Increase the temperature at the air intake of or around the motor to that specified in [Table D.1](#) within a period of not more than 10 min or not less than 5 min.

Table D.1 — Test temperature and functioning time according to classification

Class	Temperature °C	Minimum functioning period min
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

Record electrical and temperature measurements during this period. Adjust the load applied to the motor so that the motor output power is F times the rated power at a density of $1,2 \text{ kg/m}^3$, where F is as follows:

- 0,88 at a temperature of 200 °C;
- 0,84 at a temperature of 250 °C;
- 0,80 at a temperature of 300 °C;
- 0,76 at a temperature of 400 °C;
- 0,60 at a temperature of 600 °C.

D.2.4.3 High temperature test

Carry out the test at not less than the specified temperature and not more than the specified temperature +25 °C and for the appropriate period of time. Record electrical and temperature measurements at intervals not exceeding 1 min.

After 15 min, switch off the motor for 2 min, and then restart the motor. During this period, the temperature variation may exceed the specified limits.

If the motor is driven by a frequency converter, the motor shall be stopped (power switched off) without any decelerating ramp set by the converter and then restarted after two minutes via the converter which is programmed with the shortest practical starting ramp (acceleration time).

Add the time the motor is switched off or is working below its target frequency to the specified period of the test.

D.3 Test report

D.3.1 Prepare a test report after completion of the tests including the following information:

- a) the name of the test laboratory;
- b) the name of the sponsor;
- c) the date of test;
- d) the name of supplier and trade name of the product;
- e) a reference to the test method/s;
- f) the catalogue description, frame size, class of insulation and speed of the motor tested;

- g) the temperature time class (see 4.5);
- h) the application classes (see 4.2.2);
- i) the product range approved by the tests in accordance with Annex B;
- j) details of the test arrangement including all equipment used for measurement of temperature, current, voltage, electrical power and (if required for information) air speed and air flow at ambient temperature;
- k) observations, measurements and calculated results made before, during and after the tests in accordance with Annex D;
- l) when the test is required to qualify the fan for installation with a frequency converter: record the model reference and type of converter (e.g. PWM), type, section and length of cable between converter and motor, switching frequency, start ramp time, type of filter if used and the frequency supplied by the converter. If the fan is intended for installation with different models or brands of frequency converter, record the maximum voltage peak, peak to peak value and the maximum rate of voltage rise (d_u/d_t) at which the motor has been tested.

D.3.2 Prepare an additional report providing details of the complete product range approved including:

- a) the motor speed;
- b) the motor model number or catalogue code;
- c) the motor rating;
- d) the bearing type, class of fit, lubricant and arrangement;
- e) the carcass, end cover and cooling impeller (if fitted) material;
- f) the insulation specification and class;
- g) when the tests have been performed to approve use with frequency converters: type of converter (e.g. PWM), switching frequency, starting time ramp, filter to be used (if any) and allowed highest frequency for the converter application. If the fans are intended for installation with different models or brands of frequency converter, include information on maximum voltage peak, peak to peak value and the maximum rate of voltage rise (d_u/d_t) at which a motor has been tested. When many motors are tested to approve a range, the reference values for voltage peak and rate of voltage rise are the lowest values recorded among the different tests.

Annex E (normative)

Test method for assessing the response delay and ability to open under environmental conditions

E.1 Objective of test

The objective of this test is to assess the response delay and ability to open under environmental conditions.

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. 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

See [5.2.1](#) for the wind load test.

For the snow load test, the largest fan of the family shall be considered representative of all the fans in that family.

A test on the largest fan of the family shall be considered representative of all the fans in that family.

E.4 Test procedure

Mount the fan on the test rig in accordance with the supplier's recommendations. Apply the load using one of the methods given in [E.2](#), increasing the load to the upper appropriate limit given in [5.2.1](#) and [5.2.2](#) and maintain the load for (10 ± 1) min.

Remove the load, actuate the ventilator and check that the dampers, flaps or louvers 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 [4.1](#) 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 the family of fans.

The operating position can be considered as reached if the volume flow exhausted by the fan working under snow and wind loads did not decrease by more than 10 % of that exhausted by the fan working without these loads.

Annex F (informative)

Explanatory notes

F.1 Explanation for A.4.4.3

To calculate comparative blade stresses resolve the bending moment about the principal axis and the stress calculated using [Formula \(F.1\)](#) and [Formula \(F.2\)](#):

$$\sigma_{Z1} = \frac{F \times \sin \beta \times L / k}{Z_{Xmin}} \text{ or } \sigma_{Z1} = 1\,000 \times M \times \sin \beta / Z_{Xmin} \text{ with } M = F \times L / k \quad (\text{F.1})$$

$$\sigma_{Z2} = \frac{F \times \cos \beta \times L / k}{Z_{Ymin}} \text{ or } \sigma_{Z2} = 1\,000 \times M \times \cos \beta / Z_{Ymin} \text{ [with } M = F \times L / k \text{]} \quad (\text{F.2})$$

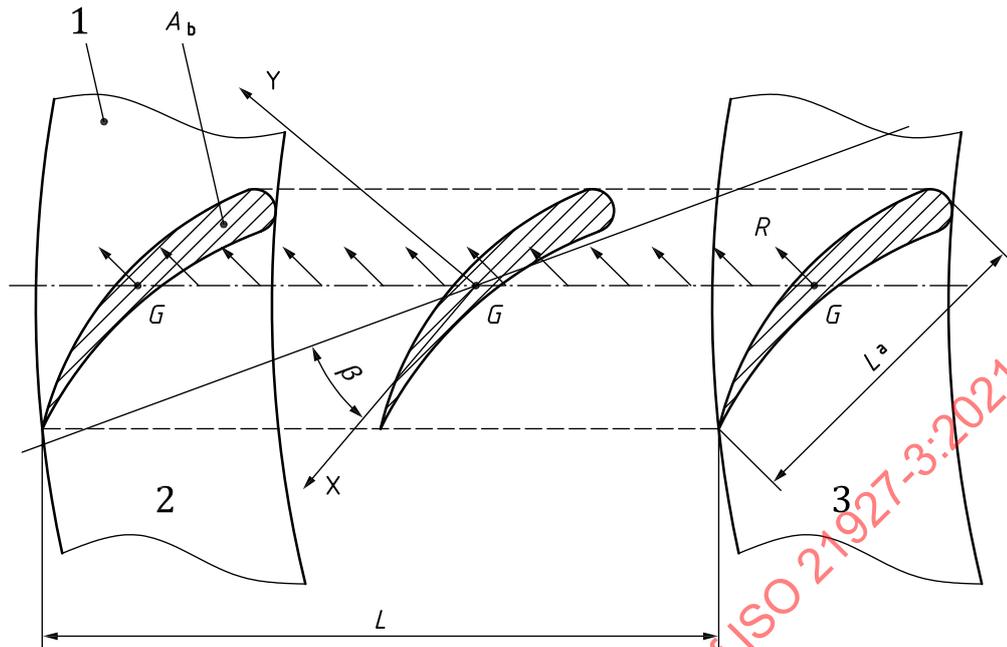
where

F and L are defined in [A.4.2.2.1](#);

σ_{Z1} and σ_{Z2} are the bending stresses about principal axis X and Y in N/mm² (most of the time, $\sigma_{Z2} < \sigma_{Z1}$);

β is the angle between principal axis and the radial line of impeller:

Z_{Xmin} and Z_{Ymin} is the section modulus about principal axis X and Y in mm³.



Key

- 1 centrifugal impeller
- 2 back plate
- 3 shroud

Figure F.1 — Centrifugal impeller, calculation of σ_{z1}

- The centrifugal force about the principal axis GY is $F \times \sin\beta$ where F is the centrifugal force calculated as in [A.4.2.2.1](#);
- the blade bending moment is $M_1 = F \times \sin\beta \times L / k$ ($k = 12$ if the blade is considered as fully embedded in back plate and shroud);
- the maximum blade stress is $\sigma_{z1} = \frac{M_1}{Z_{Xmin}}$.

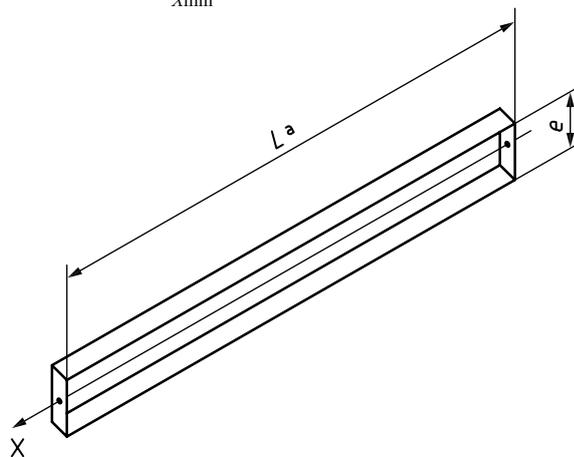


Figure F.2 — Example of calculation of Z_{Xmin} with a rectangular cross-section of blade

According to [Formula \(F.3\)](#):

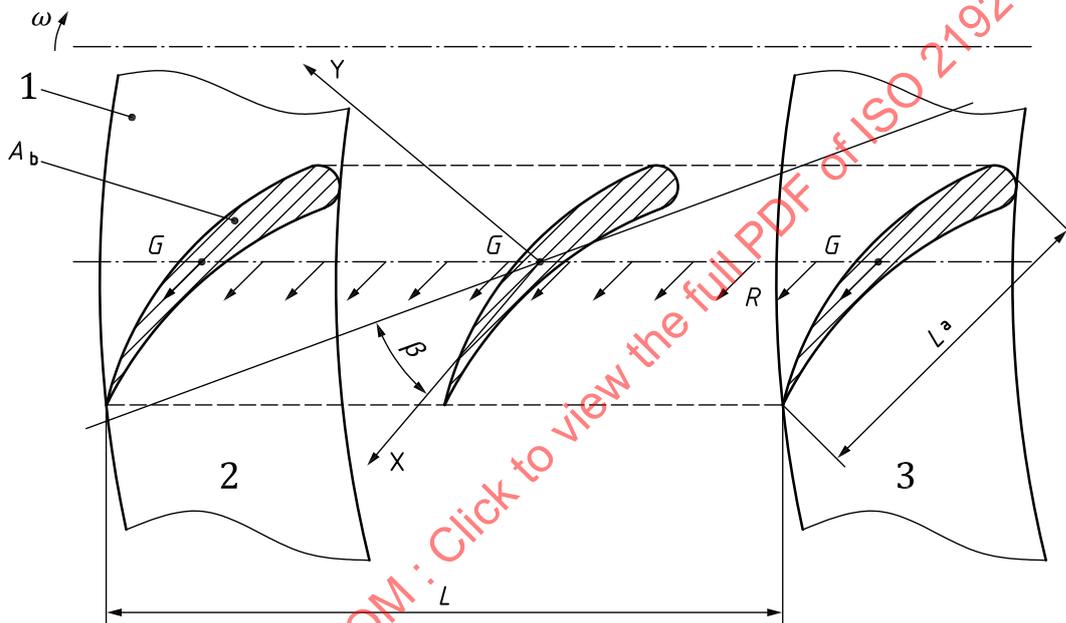
$$Z_{Xmin} = \frac{L(cord) \times e^3}{\frac{12}{e}} \text{ or } Z_{Xmin} = \frac{L(cord) \times e^2}{6} \tag{F.3}$$

and [Formula \(F.4\)](#):

$$\sigma_{z1} = \frac{M1}{Z_{Xmin}} \text{ with } \sigma_{z1} = \frac{F \times \sin\beta \times L / k}{Z_{Xmin}} \tag{F.4}$$

EXAMPLE 1 Blade with $L(\text{cord}) = 100 \text{ mm}$, $e = 2 \text{ mm}$, $\beta = 25^\circ$. See [Formula \(F.5\)](#):

$$\sigma_{z1} = F \times L / k \times 6,35 \times 10^6 \tag{F.5}$$



Key

- 1 centrifugal impeller
- 2 back plate
- 3 shroud

Figure F.3 — Centrifugal impeller, calculation of σ_{z2}

- The centrifugal force about the principal axis GX is $F \times \cos\beta$ where F is the centrifugal force calculated as in A.4.4.1;
- the blade bending moment is $M_2 = F \times \cos\beta \times L / k$ ($k = 12$ if the blade is considered as fully embedded in back plate and shroud).

The maximum blade stress is calculated using [Formula \(F.6\)](#):

$$\sigma_{z2} = M_2 / Z_{ymin} \tag{F.6}$$