ELECTRIC DRIVES
FOR EVERY DEMAND

Latest news on explosion protection

Electrical equipment for the low voltage area, legal principles, ATEX guidelines and types of ignition protection, modular design structure, VEM product range, repair, maintenance and conversion

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There are currently around 30 million electric machines bearing the VEM badge in use around the world. They are found aboard ships, in trains and trams, and in chemical plants and rolling mills. VEM generators produce electricity in hydropower plants and wind farms.

The VEM product range embraces variable-speed electric drive systems, special motors and special machines for outputs ranging from 0.06 kW to 42 MW, as well as a diversity of drive technology and power generation components.

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Contents

Preface

This manual is based on the Explosion Protection Seminar "Planning and Safe Operation of Explosion-protected Electrical Drives", Leader/Speakers Dr.-Ing. Lehrmann/ Dipl.-Phys. Seehase/Dipl. Ing. Sattler from "HAUS DER TECHNIK", Essen, as well as internal training documents of VEM motors GmbH, taking into account the relevant PTB testing instructions.

Technical processes continually produce explosive atmospheres in chemical and petrochemical systems. They are caused by mixtures of gases, vapours or mists, for example. Mixtures with dusts, however, such as occur in mills and silos, often also turn out to be explosive. For these reasons, electrical equipment for explosion hazard areas is subject to special directives and national and international standards. Explosion protection specifies regulations which have as their aim the protection of persons and materials from possible risks of explosion.

Integrated explosion protection requires the implementation of explosion protection procedures in a specified sequence. In the first place, that means preventing the occurrence of explosive atmospheres, preventing the ignition of explosive atmospheres and limiting the effects of an explosion to an insignificant degree. Preventing the occurrence of explosive atmospheres, also known as primary explosion protection, is also a matter for the system designer and operator. Which areas, outdoors or in enclosed spaces, are to be considered explosive in the sense of the relevant directives or regulations must be left to the operator to decide or, if doubts exist concerning the determination of explosive areas, to the supervisory authority responsible. In Directive 99/92/EC – ATEX 137 (formerly ATEX 118a), Health and Safety Directive, the responsibilities of the operator of such systems are specified. The basis for explosion-protected products is Directive 2014/34/EU – ATEX 114 (formerly 94/9/EC – ATEX 100a), (Quality Directive). The requirements of the products for use in explosive areas are defined here.

Electrical machines for use in Zones 1, 2 or 21, 22 may be designed as various types of ignition protection, whereby the aim of each of those types of ignition protection is to safely prevent ignition of any explosive atmosphere present where the electrical machine is in use.

1 The explosion-protected drive – Introduction

Explosion-protected equipment is distinguished by the characteristic of not igniting any explosive atmosphere in the place of use during operation within the permitted parameter limits for the gases occurring (e.g. ambient temperature, current, voltage etc.). Since electrical machines always contain a potential source of ignition, it is the aim of the explosion protection measures to prevent the latter from becoming an effective source of ignition. Electrical machines may become a source of ignition as a result of hot surfaces, electrical discharges and mechanically-produced sparks (from grinding).

The efforts required to prevent danger of ignition are in turn dependent on the place of use. Potential explosion areas are divided into zones.

In Zone 0, an explosive atmosphere can occur permanently or on a long-lasting basis. Rotating electrical machines are not used here. Zone 0 is usually inside tanks and systems.

In Zone 1, the explosive atmosphere may be present occasionally and short-term. An example of this zone is the surrounding area of the ventilation hole in tank systems. Equipment used in Zone 1 may be used neither in normal operation nor on the occurrence of a fault in the ignition source.

In Zone 2, only in the case of operational faults can the existence of a short-term explosive atmosphere be expected, e.g. in the case of leaks. The equipment used cannot be a source of ignition in normal operation but it is tolerated in the event of a fault. It is then assumed that there is a sufficiently low probability of an explosive atmosphere and an operational fault occurring at the same time. In the case of danger of explosion from ignitable dusts, there is a similar classification to Zones 20/21/22.

To ensure explosion protection in the case of rotating electrical machines, the following types of ignition protection are considered. In gas explosion hazard areas: Increased safety "eb", Flameproof enclosure and Pressurized enclosure for Zone 1 and Increased safety "ec" (old: "n") for Zone 2. In dust explosion hazard areas with electrical machines, "Protection by housing" is a common type of ignition protection.

With the Flameproof enclosure "db" type of protection, ignition inside the housing is possible but the design prevents the explosion from being transferred to the surrounding area. The housing must resist the pressure of the explosion and, with ducts, the flames must be prevented from penetrating by using a sparkover-prevention gap. As a further condition, the ignition temperatures of the gases occurring at the assembly site must not be reached or exceeded on the housing surface. The implementation of this type of ignition protection demands effort and expense because of the necessary compliance with very low manufacturing tolerances.

With the type of ignition protection Pressurized enclosure "p", the interior of the housing is rinsed under pressure with an ignition-protection gas below overpressure, preventing any ignitable atmosphere from penetrating it. To guarantee explosion protection, the ignition gas pressure must be monitored and prohibited surface temperatures prevented.

If the ignition protection gas supply fails, it must be guaranteed that all internal ignition sources are no longer present, until the invasion of an exterior atmosphere produces an ignitable mixture inside the encapsulation. Because of the costs of supplying ignition protection gas, this type of ignition gas protection is implemented only with machines which have an output of more than 1 MW.

In the case of the Increased safety "eb" type of ignition protection, the surrounding atmosphere may penetrate the housing interior. To avoid the danger of ignition, there must also be no effective ignition sources in the housing interior. This type of ignition protection can only be implemented with equipment which produces no sparks in operation. In order to design an asynchronous machine of this type of ignition protection, it is fundamentally possible to resort to the non-explosion-protected standard motor, in the case of the inactive electrical parts. In the case of the active parts, the reduced permitted temperature rise and requirements regarding the partial discharges must be taken into account. The implementation of this type of ignition protection with a frequency-converter-operated drive is carried out at a later stage of this manual.

Type of ignition protection "ec" (old: "n") is based on the Increased safety "eb" type of ignition protection. Because of the lower probability of the presence of ignitable atmosphere in Zone 2, the requirements are, however, lower. The machine may thus be used at a higher temperature, for example, as there is no necessity for the "safety reduction" of 10 K related to the maximum permissible winding temperature according to the thermal class. In addition, there is no need to heed the "locked state" fault or monitor the start-up. Motors of this type of ignition protection must not be started up if there is an ignitable mixture on the motor's installation site.

It is furthermore necessary to observe the Standard EN 60079-14, according to which a motor must be protected against overload and short-circuit, i.e. a motor circuit-breaker or the like must be provided.

Standard EN 60079 Part 15 provides detailed information on the relevant requirements. In the sense of Directive 94/9/EC, it is the manufacturer's responsibility to carry out the test and put the equipment into circulation. In contrast to the Increased safety "eb" type of ignition protection, type approval by a notified body is not necessary in this case.

In the case of Increased safety "eb" type of ignition protection, the temperature category is a very important factor. Depending on the composition of the possibly ignitable atmosphere there is a temperature category classification from T1–T6. The temperature categories delineate temperature ranges into which gases are divided according to their ignition temperature. In the case of mixtures, the component with the lowest ignition temperature is definitive for the classification. The maximum permissible surface temperatures for the temperature categories can be found in Standard IEC/EN 60079-0.

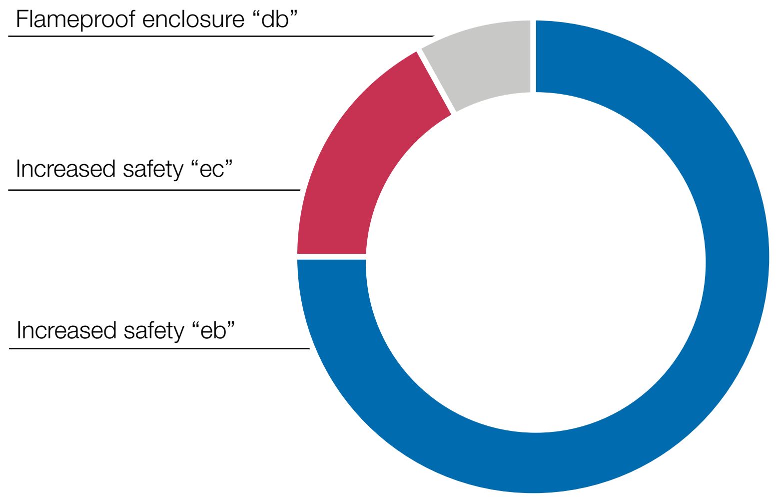


Figure 1.1: Distribution of the types of ignition protection with mains-operated drives

Electrical machines of the Increased safety "eb" type of ignition protection are usually designed only up to temperature category T4.

The specifications are based on an assessment by the Explosion Protection Certification Authority at PTB Braunschweig.

In the case of mains-operated drives, an estimated distribution is produced across the individual types of ignition protection according to Figure 1.1. With frequency-converter-operated drives, the relation between Increased safety "eb" and Flameproof enclosure "db" is reversed. The reason for this is the former firm link of motor and frequency converter with the associated restrictions on the user and the high cost of the test. The overall costs are lower for a drive of the Flameproof enclosure type of ignition protection, although distinctly higher costs apply to the motors' manufacture, in this case. Because of the extremely great potential damage in the event of an explosion, very high priority must be given to the respective safety procedures in the project planning of a drive system in explosive areas.

1.1 Summary of the legal principles for explosion protection

	Quality requirements	Operating requirements
European Law	ATEX 114 2014/34/EU	ATEX 137 1999/92/EG
Acts	Product Safety Act – GPSG	ArbSchG Health and Safety Act
Directives	11. ProdSV Explosion Protection Ordinance	BetrSichV Industrial Safety Ordinance GefStoffV 2013/2015 Hazardous Substances Ordinance
Technical regulations, regulations and standards	IEC/EN 60079 ff.	Explosion protection regulations BGR 104, TRBS …

Equipment categories and zones

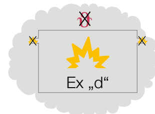
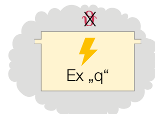
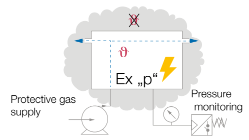
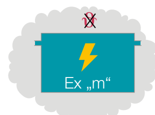
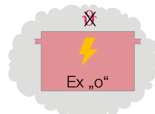
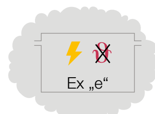
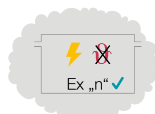
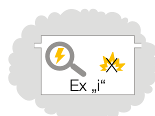
Equipment group	Equipment category	Zone	Equipment group	EPL	Definition based on BetrSichV	Certification obligation
2014/34/EU			complying with IEC/EN 60079-0			
for combustible gases, vapours and mist						
II	1G*	0	II	Ga	Zone 0 comprises areas in which an explosive atmosphere, consisting of a mixture of air and gases, vapours or mist, exists constantly, long-term or frequently.	yes
II	2G	1	II	Gb	Zone 1 comprises areas in which it can be expected that an explosive atmosphere consisting of gases, vapours or mist occasionally occurs.	yes
II	3G	2	II	Gc	Zone 2 comprises areas in which it is not expected that an explosive atmosphere consisting of gases, mist or vapours occurs but when it does occur it is in all probability only rarely and for a short period.	no
for explosive dust atmosphere						
II	1D*	20	III	Da	Zone 20 comprises areas in which an explosive atmosphere consisting of dust/air mixtures exists constantly, long-term or frequently.	yes
II	2D	21	III	Db	Zone 21 comprises areas in which it can be expected that an explosive atmosphere consisting of dust/air mixtures occasionally occurs.	yes
II	3D	22	III	Dc	Zone 22 comprises areas in which it is not expected that an no explosive atmosphere occurs as a result of whirled-up dust but when it does occur it is in all probability only very rarely and for a short period.	no

* not normal for electric motors

Dust explosion protection IEC/EN 60079-0 and IEC/EN 60079-31

Workplace	Existence of an explosive dust atmosphere	occasionally	rarely or short-term	
	Type of dust	all Types	electrically conductive	electrically non-conductive
	Zone	21	22	
Equipment	Equipment group acc. to Directive 2014/34/EU	II		
	Equipment group acc. to EN 60079-0	IIIC	IIIC	IIIB
	Equipment category	2D	3D	3D
	EPL acc. to EN 60079-0	Db	Db, Dc	Db, Dc
	IP protection rating	IP 65	IP 65	IP 55
	Type of protection	Housing temperature max. 125 °C		
	Certificate	EU type-examination certificate	Manufacturer's EU Declaration of Conformity certificate	
	Marking acc. to Directive 2014/34/EU	Ex II 2D	Ex II 3D	Ex II 3D
	Marking acc. to EN 60079-0/ EN 60079-31	Ex tb IIIC T125 °C Db (alternative: Ex tb IIIC T125 °C	Ex tc IIIC T125 °C Dc (alternative: Ex tc IIIC T125 °C)	Ex tc IIIB T125 °C Dc (alternative: Ex tc IIIB T125 °C)

1.2 Summary of the legal principles for explosion protection

General requirements (gas and dust)		IEC/EN 60079-0
Flameproof enclosure "db"		IEC/EN 60079-1 Type of ignition protection – Flameproof enclosure "db"
Powder filling "q"		IEC/EN 60079-5 Type of ignition protection – Powder filling "q"
Pressurized enclosure "p"		IEC/EN 60079-2 Type of ignition protection – Pressurized enclosure "p"
Encapsulation "m"		IEC/EN 60079-18 Type of ignition protection – Encapsulation "m"
Oil immersion "o"		IEC/EN 60079-6 Device of protection – Oil immersion "o"
Increased safety "eb"		IEC/EN 60079-7 Type of ignition protection – Increased safety "eb"
Increased safety "ec" (old: Type of ignition protection "n")		IEC/EN 60079-7 (IEC/EN 60079-15) Type of ignition protection – Increased safety „ec" (old: „n")
Intrinsic safety "ia/ib"		IEC/EN 60079-11 Device of protection – Intrinsic safety "i"

1.3 Explanation of the general requirements, the types of ignition protection and areas of application

1.3.1 General requirements (gas and dust)

IEC/EN 60079-0 (VDE 0170-1)
- Distinction Group I (mining), II (gas) and III (dust)
- Requirements transferred from dust areas EN 61241-0
- Newly-introduced groups for dust (IIIA, IIIB and IIIC)
- Explosion groups for Group II (IIA,IIB and IIC)
- Introduction of Equipment Protection Level (EPL)
- Ambient temperature range -20 °C to +40 °C
- Maximum operating temperature (maximum ambient temperature + intrinsic heating + external heat sources)
- Maximum surface temperature (temperature categories T1…T6)
- Mechanical stability
- Opening periods (capacitors and hot fitted parts)
- Circulating currents
- Seal attachment
- Equipment with electromagnetic and ultrasound energy
- Requirements of non-metallic housings and housing components
- Operating instructions and coding
- Tests

Subdivision of Equipment Group II
Complying with IEC/EN 60079-0, because of their particular ignitability in Flameproof enclosure “d” and Intrinsic safety “i” types of ignition protection, gases and vapours have been divided into three explosion groups, IIA, IIB and IIC. The danger increases between Explosion Groups IIA and IIC. (The higher explosion group, e. g. IIC includes the lower ones, IIB and IIA).
From IEC/EN 60079-0, Coding II is replaced for all gas protection types by the specifications IIA, IIB and IIC (so now also … Ex e IIC T3 or … Ex nA IIC T3)
– IIA, typical gas is propane
– IIB, typical gas is ethylene
– IIC, typical gas is hydrogen

Temperature categories

	IEC/EN 60079-0 Explosion Groups IIA; IIB; IIC	
Medium’s ignition temperature at limit temperature	Temperature categorie	Permitted equipment surface temperature including 40 °C ambient temperature (limit temperature)
Over 450 °C	T1	450 °C
Over 300 – 450 °C	T2	300 °C
Over 200 – 300 °C	T3	200 °C
Over 135 – 200 °C	T4	135 °C
100 – 135 °C	T5	100 °C
85 – 100 °C	T6	85 °C

Electrical equipment in Group III is further subdivided according to the properties of the explosive atmosphere for which it is intended. The potential danger of dust increases with the operation of electrical equipment between IIIA and IIIC. Group IIIC equipment includes suitability for groups IIIA and IIIB.
– IIIA, combustible lint
– IIIB, combustible, electrically non-conductive dust
– IIIC, combustible, electrically conductive dust

Equipment Protection Level
(EPL, definition complying with EN 60079-10-2)

Gas explosion protection:
EPL Ga: Device with “very high” protection level for use in gas explosion hazard areas, in which there is no danger of ignition in normal operation and with foreseeable or rare faults/malfunctions.
EPL Gb: Device with “high” level of protection for use in gas explosion hazard areas in which there is no danger of ignition in normal operation or in the case of foreseeable faults/malfunctions.
EPL Gc: Device with “extended” protection level for use in gas explosion hazard areas, in which there is no danger of ignition during normal operation and which have some additional safety measures which ensure that there is no danger of ignition in the case of normal foreseeable faults in the device.

Dust explosion protection:
EPL Da: Device with “very high” level of protection for use in combustible dust atmospheres in which there is no danger of ignition in normal operation or with foreseeable or rare errors/malfunctions.
EPL Db: Device with “high” level of protection for use in combustible dust atmospheres, in which there is no danger of ignition in normal operation or with foreseeable errors/malfunctions.
EPL Dc: Device with “extended” level of protection for use in combustible dust atmospheres, in which there is no danger of ignition in normal operation and which have some additional safety measures which guarantee that there is no danger of ignition with faults in the device that are normally to be expected.

Explosion hazard area complying with Directive 2014/34/EU	Equipment group and category complying with Directive 2014/34/EU	Equipment group and Equipment Protection Level (EPL) complying with IEC/EN 60079-0
Zone 2	II 3G	II Gc
Zone 1	II 2G	II Gb
Zone 0	II 1G	II Ga
Zone 22	II 3D	III Dc
Zone 21	II 2D	III Db
Zone 20	II 1D	III Da
Mining (high safety level)	I M2	I Mb
Mining (very high safety level)	I M1	I Ma

Definition of protection principles
- Explosive mixtures can penetrate the equipment and ignite. The explosion is not transferred to the explosive atmosphere surrounding the equipment. (Ex d)
- The equipment has an encasing which prevents the explosive mixture from penetrating and coming into contact with an ignition source. (Ex m, Ex o)
- Explosive mixtures can penetrate the equipment, but must not ignite in normal operation. Sparks and high temperatures above the ignition temperature of the gas concerned must be prevented. (Ex nA)
- Explosive mixtures can penetrate the equipment, but must not ignite even in case of a foreseeable fault. Sparks and high temperatures above the ignition temperature of the gas concerned must be prevented in normal operation and in case of a foreseeable equipment fault. (Ex e)
- Explosive mixtures can penetrate the equipment, but must not ignite. The energy in the circuits is limited. Sparks and high temperatures may occur to a limited degree, but without igniting gases of the explosion group for which the equipment is certified. (Ex i)
- Explosive mixtures must not penetrate the equipment in critical amounts. The only decisive factor is thus compliance with the maximum temperature on the outer surface (Zones 21, 22: Ex t)

1.3.2 Types of ignition protection

1.3.2.1 Type of ignition protection – Flameproof enclosure “db”

Design regulations: IEC/EN 60079-1 (VDE 0170-5)

Definition/protection principle:
Type of protection with which the components capable of igniting an explosive atmosphere are arranged inside a housing, which sustains the pressure inside when an explosive mixture explodes and prevents the explosion from being transferred to the explosive atmosphere surrounding the housing.
- Heeding the explosion group
- Pressure-resistant housing
- Conforming to the required gap widths and lengths
- Terminal box Flameproof enclosure “db” or in Increased safety “eb”
- Temperature of outer surface must be lower than the ignition temperature of the surrounding gasses
- An explosion may occur in the interior. The housing must resist this explosion and no flames or potentially ignitable gasses must reach the outside through the gap

Tests:
- Reference pressure and resistance to pressure
- Sparkover
- Leak test for gap sealed in place

Areas of application:
Equipment Zones 1 and 2,
Categories 2G and 3G (Gb, Gc)

1.3.2.2 Type of ignition protection – Increased safety “eb”

Design regulations: IEC/EN 60079-7 (VDE 0170-6)

Definition/protection principle:
Type of ignition protection, in which additional measures are taken in order to prevent the possibility of the occurrence of prohibited high temperatures and the production of sparks or arcs in use according to specifications or in specified unusual conditions.
- Prevention of sparks and other ignition sources
- Housing at least IP 54, if bare live parts are present in the interior
- Housing at least IP 44, if all live parts in the interior are insulated
- Temperatures of the exterior and interior surfaces must be lower than the ignition temperature both in normal operation and in the event of a fault (locking the motor).
- Taking creepage distances and clearances into account
- Paying particular attention to the insulating materials and seals
- Protective equipment (temperature monitor and/or overcurrent switch with I_A/I_N-t_E time characteristic curve) essential for the user
- Frequency-converter operation – see Chapter III

Tests:
- Insulation test
- Temperature measurement in the case of specific faults
- Additional tests for specific equipment (TMS full protection)

Areas of application:
Equipment Zones 1 and 2,
Categories 2G and 3G (Gb, Gc)

1.3.2.3 Type of ignition protection – Increased safety “ec”

Design regulations: IEC/EN 60079-7
(old: IEC/EN 60079-15 (VDE 0170-16))

Definition/protection principle:
Type of ignition protection for electrical equipment with which it is possible to prevent the equipment from being in a position to ignite a surrounding explosive atmosphere in normal operation. The design guarantees minimisation of the risk of occurrence of arcs or sparks which can cause a danger of ignition during normal use.
- Prevention of sparks and other ignition sources
- Housing at least IP 54, if bare live parts are present in the interior
- Housing at least IP 44, if all live parts in the interior are insulated
- Taking creepage distances and clearances into account
- Paying particular attention to the insulating materials and seals
- In normal operation, exterior and interior surface temperatures must be lower than the ignition temperature
- At rated voltages up to 1 kV and with a degree of protection of at least IP 44, it is permissible for the terminal box to open to the inside of the motor

Tests:
- Insulation test
- Temperature measurement
- Additional tests for specific equipment (converter-fed operation)

Areas of application:
Equipment Zone 2,
Category 3G (Gc)

1.3.2.4 Type of ignition protection – Pressurized enclosure “p”

Design regulations: IEC/EN 60079-2 (VDE 0170-3)

Definition/protection principle:
Type of ignition protection for electrical equipment with which penetration of the housing by a surrounding atmosphere is prevented by an ignition gas being held under primary pressure in its interior against the surrounding atmosphere. The overpressure is maintained with or without ignition gas rinsing.
- Housing at least IP 4X
- Monitoring equipment
- Gas outlet
- Containment system

Tests:
- Pre-flush time
- Leakage losses
- Overpressure test (1.5 x P)
- Minimum flow

Areas of application:
Equipment Zones 1 and 2,
Categories 2G and 3G (Gb, Gc)

Other types of gas ignition protection not relevant to electric motors, without detailed consideration:

1.3.2.5 Type of ignition protection – Powder filling “q“

Design regulations: IEC/EN 60079-5 (VDE 0170-4)

Definition/protection principle:
Type of ignition protection, with which the parts of a piece of equipment, which can become an active ignition source, are fixed in their position and completely surrounded by filling material, to prevent ignition of an external explosive atmosphere.
- Filling material
- Locks
- Clearances
- Housing at least IP 54
- Energy store

Tests:
- Pressure test (50 kPa)
- Filling material insulating property
- Inflammability of plastics

Areas of application:
Category 2G (Gb)
Capacitors, primary cells, transformers, ballast control gears and sensors

1.3.2.6 Type of ignition protection – Oil immersion “o”

Design regulations: IEC/EN 60079-6 (VDE 0170-2)

Definition/protection principle:
Type of ignition protection, with which the piece of electrical equipment or its parts is/are immersed in a fluid encapsulation, in such a way that an explosion hazard atmosphere which may be located above the liquid or outside the encapsulation cannot be ignited.
- Protective liquid
- Minimum fill level
- Type of protection IP 66
- Fill-level monitor
- Energy store

Tests:
- Overpressure test
- Temperatures

Areas of application:
Category 2G (Gb)
Transformers, switchgears and starting resistors

1.3.2.7 Type of ignition protection – Intrinsic safety “ia/ib”

Design regulations: IEC/EN 60079-11 (VDE 0170-7)

Definition/protection principle:
Intrinsically safe circuit – a circuit, in which no spark or no thermal effect occurs, which, under the test conditions specified in this standard (comprising normal operation and specific fault conditions), can cause ignition of a certain explosive atmosphere.
- Separation distances
- Insulations
- Structural components

Tests:
- Spark test
- Insulation test
- Spark test with small components
- Consideration of output

Areas of application:
Categories 1G, 2G and 3G, 1D, 2D and 3D
EPL Ga, Gb and Gc, measurement and control electronics, sensors and PC interfaces

1.3.2.8 Type of ignition protection – Encapsulation “m”

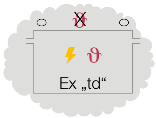
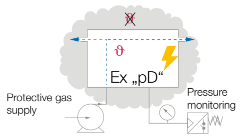
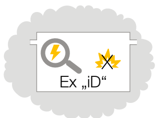
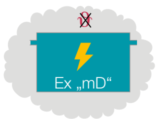
Design regulations: IEC/EN 60079-18 (VDE 0170/0171-9)

Definition/protection principle:
Type of ignition protection, with which the parts which can ignite an explosive atmosphere through sparking or heating up are embedded in a sealing compound in such a way that an explosive atmosphere cannot be ignited under operating and installation conditions.
- Sealing compound
- Level of protection
- Clearances and cavities

Test:
- Water intake
- Resistance to heat and cold
- Thermal cycle test
- Insulation test

Areas of application:
Categories 1G (ma) and 2G (mb)
EPL Ga and Gb
Switch gears for low output, sensors, solenoids, signalling and command devices

1.4 Summary of types of ignition protection for dust-explosion protection

General requirements		IEC/EN 60079-0
Protection by housing “tD” („tx IIIY T --- °C Dx“)		IEC/EN 60079-31
Pressurized enclosure “pD” („p IIIY Dx“)		EN 61241-4 (IEC/EN 60079-2)
Intrinsic safety “iD” („ix IIIY Dx“)		IEC/EN 60079-11
Encapsulation “mD” („mx IIIY Dx“)		IEC/EN 60079-18

x = EPL, Y = Explosion group

Example of labelling for protection by enclosure: Ex II 2D Ex tb IIIC T125 °C Db

1.4.1 Type of ignition protection – Protection by housing “tx IIIY Dx”

Design regulations: IEC/EN 60079-31 (VDE 0170-15-1)

Protection principle:
Dangerous housings are enclosed by the housing which is not liable to malfunction. Evidence of the maximum surface temperature according to category.
Minimum type of protection IP 5X/6X (EN 60529)
New: Pressure test with an overpressure as follows:
- 4 kPa with devices with “ta” level of protection
- 2 kPa with devices with “tb” or “tc” level of protection before the dust test

Limitation of the 10 kA for EPL Da short-circuit current for acceptance
Temperature limitation depending on EPL
Determining the surface temperature for EPL Da, with a layer of dust of at least 500 mm on all accessible surfaces.

Tests:
- IP protection type test
- Ageing resistance of polymers used on the device
- Impact test
- Leak tightness
- Thermal test with overload or fault conditions

Subdivision of groups:
- IIIA, combustible lints
- IIIB, non-conductive dust
- IIIC, conductive dust

Protection against ingress of dust according to table 1, IEC/EN 60079-31

Group	Level of protection	Level of protection/housing
III A (fibers)	ta	IP 6X
	tb	IP 5X
	tc	IP 5X
III B (non-conductive dusts)	ta	IP 6X
	tb	IP 6X
	tc	IP 5X
III C (conductive dusts)	ta	IP 6X
	tb	IP 6X
	tc	IP 6X

The other dust types of ignition protection, which are not relevant to electric motors:

1.4.2 Type of ignition protection – Pressurized enclosure “pD”

Design regulations: EN 61241-4
IEC/EN 60079-2 („p IIIY Dx“)

Definition/protection principle:
Type of ignition protection for electrical equipment with which penetration of the housing by a surrounding atmosphere is prevented by an ignition protection gas being held under overpressure (> 50 Pa) in its interior against the surrounding atmosphere. The overpressure is maintained with or without ignition gas rinsing.
- Housing at least IP 4X
- Monitoring equipment
- Gas outlet
- Containment system

Tests:
- Pre-flush time
- Tightness
- Overpressure test (1.5 x P; > 200 Pa)
- Impact test

Areas of application:
Switchgears, transformers, complex equipment and cabinets

1.4.3 Type of ignition protection – Intrinsic safety “iD”

Design regulations:
IEC/EN 60079-11 (VDE 0170-7) („ix IIIY Dx“)

Definition/protection principle:
Limitation of the electric power (voltage, current, inductance and capacity), including the surface temperatures, so that no ignition occurs of a dust-air mixture as a result of sparks or thermal effects with intrinsically safe devices in normal operation and with specific fault conditions complying with EN 60079-11:2007.
- Separation distances
- 2/3 capacity
- Non-susceptance to faults

Tests:
- Spark test
- Insulation test
- Spark test with small components
- Consideration of output
- No IP required

Areas of application:
MCR equipment, sensor, mobile measuring equipment

1.4.4 Type of ignition protection – Encapsulation “mD”

Design regulations:
IEC/EN 60079-18 (VDE 0170/0171-9) („mx IIIY Dx“)

Definition/protection principle:
Type of ignition protection, with which the parts are embedded in sealing compound in such a way that the explosive atmosphere cannot be ignited under operating and installation conditions.
- Minimum requirements of sealing compound (TI value)
- Minimum sealing compound thickness (3 mm “ma” and 1 mm “mb”)
- Faults analysis in sealing compound
- Level of protection
- Clearances and cavities
- Rated values

Test:
- Water intake
- Evidence of maximum surface temperature
- Resistance to heat and cold
- Thermal cycle test
- Insulation test

Areas of application:
Switchgears for low output, command and signalling devices, solenoids, ultrasound sensors

1.5 Markings complying with different editions of the standard

Category 3 motors carry only the CE marking on their rating plate. The NB ID number for quality assurance in accordance with Directive 94/9 EC is not to be specified on such equipment.

One of the changes in EN 60079-0:2009 (DIN EN 60079-0:2010) compared to previous editions of the standard is the introduction of Equipment Protection Levels (EPL). In this connection, the previous marking of explosion-protected motors is also changed.

In addition to specifications in accordance with the ATEX directive (e.g. Ex II 2G for motors for increased safety - type of ignition protection “eb”), the rating plate will in future also indicate the equipment protection level (e.g. Exe IIC T3 Gb).

The standard also permits an alternative (abridged) marking alongside the actual EPL marking under certain circumstances. This alternative is not used by VEM motors.

Labelling complying with directive 2014/34/EU			Old designations (no longer valid)	Designation acc. to (no longer valid)	Designation acc. to (currently valid)	Future designation acc. to
EU	No. NB	Group/Category/ G (gas) o. D (dust)	(EN 50014 ff., and EN 50281,…)	EN 60079-0:2006 and EN 61241-0:2004	EN 60079-0:2009 with EPL	EN 60079-0:2012/A11:2013 with EPL
CE	0102	Ex II 2G	EN 50019 EEx e II T2, T3 or T4	EN 60079-7 Ex e II T2, T3 or T4	EN 60079-7 Ex e IIC T3 Gb	EN 60079-7 Ex eb IIC T3 Gb
CE		Ex II 3G	EN 50021, IEC 79-15 EEx nA II T2, T3 or T4	EN 60079-15 Ex nA II T2, T3 or T4	EN 60079-15 Ex nA IIC T3 Gc	EN 60079-7 Ex ec IIC T3 Gc
CE	0102	Ex II 2D	EN 50281-1-1 IP 65 T 125 °C	EN 61241-1 Ex tD A21 IP 65 T 125 °C	EN 60079-31 Ex tb IIIC T 125 °C Db	EN 60079-31 Ex tb IIIC T 125 °C
CE		Ex II 3D	EN 50281-1-1 IP 55 T 125 °C (IP 65 conductive dust)	EN 61241-1 Ex tD A22 IP 55 T 125 °C (IP 65 conductive dust)	EN 60079-31 Ex tc IIIB T 125 °C Dc (Ex tc IIIC T 125 °C Dc)	EN 60079-31 Ex tc IIIB T 125 °C (Ex tc IIIC T 125 °C)

Combination of gas or dust

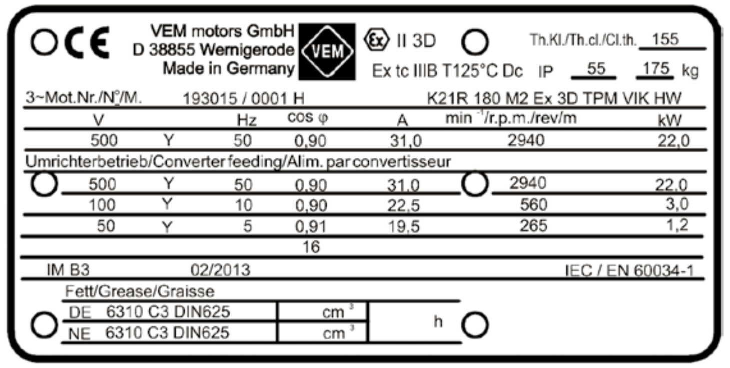
CE	0102	Ex II 2D Ex II 2G	IP 65 T 125 °C EEx e II T2, T3 or T4	Ex tD A21 IP 65 T 125 °C Ex e II T2, T3 or T4	Ex tb IIIC T 125 °C Db Ex e IIC T3 Gb	Ex tb IIIC T 125 °C Ex eb IIC T3
CE	0102	Ex II 3D Ex II 2G	IP 55 T 125 °C (IP 65 conductive dust) EEx e II T2, T3 or T4	Ex tD A22 IP 55 T 125 °C (IP 65 conductive dust) Ex e II T2, T3 or T4	Ex tc IIIB T 125 °C Dc (Ex tc IIIC T 125 °C Dc) Ex e IIC T3 Gb	Ex tc IIIB T 125 °C (Ex tc IIIC T 125 °C) Ex eb IIC T3 Gb
CE	0102	Ex II 2D Ex II 3G	IP 65 T 125 °C EEx nA II T2, T3 or T4	Ex tD A21 IP 65 T 125 °C Ex nA II T2, T3 or T4	Ex tb IIIC T 125 °C Db Ex nA IIC T3 Gc	Ex tb IIIC T 125 °C Ex ec IIC T3 Gc
CE		Ex II 3D Ex II 3G	IP 55 T 125 °C (IP 65 conductive dust) Ex nA II T2, T3 or T4	Ex tD A22 IP 55 T 125 °C (IP 65 conductive dust) Ex nA II T2, T3 or T4	Ex tc IIIB T 125 °C Dc (Ex tc IIIC T 125 °C Dc) Ex nA IIC T3 Gc	Ex tc IIIB T 125 °C (Ex tc IIIC T 125 °C) Ex ec IIC T3 Gc

[If a maximum surface temperature is specified: Zone 2 (gas): Total surface including rotors and windings; in the case of Zones 21 and 22 (dust): external surface (housing and shaft)]

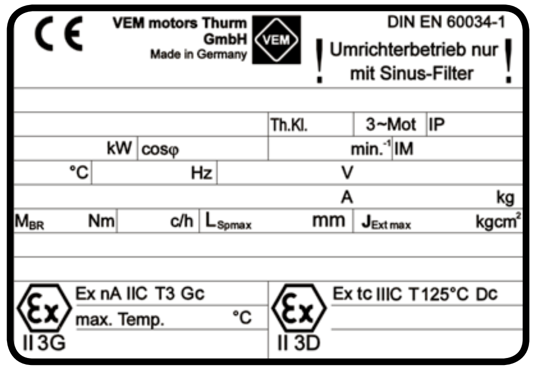
Notified body
ID number
0102… Physikalisch-Technische Bundesanstalt Braunschweig
0637… IBExU Institut für Sicherheitstechnik GmbH, Freiberg
0158… DEKRA EXAM GmbH

The number of the notified body which completed certification complying with directive 2014/34/EU must be quoted as the ID number. This is not always the same as in the EU type-examination certificate.

Examples of rating plates:



Motor for use in Zone 22



Motor with double marking for use in Zones 2 and 22

A number of customers (and perhaps also manufacturers) believe that an obligation to attach markings according to the new standard came into force already on 01/06/2012, the date on which the old standard expired. This interpretation, however, is incorrect. The only document which declares the conformity of our explosion-protected motors with ATEX regulations is the EC Declaration of Conformity. The explosion protection section of the PTB Braunschweig website also contains documents which address this situation **(Commentary on the meaning of the requirement of EU Directive 2014/34/EU, Annex II, Part A; Impact of the replacement of existing standards with new harmonised standards; Issuing of EU Declarations of Conformity in compliance with EU Directive 2014/34/EU after publication of a new edition of a standard).**

Second rating plate enclosed separately with explosion-protected motors
In some cases, customers may also request a second separate rating plate to be enclosed with explosion-protected motors. This is often the case where the rating plate attached to the motor is no longer visible after the motor is installed in a machine or plant. The current standards, however, do not permit a complete second rating plate to be enclosed separately with a delivery.

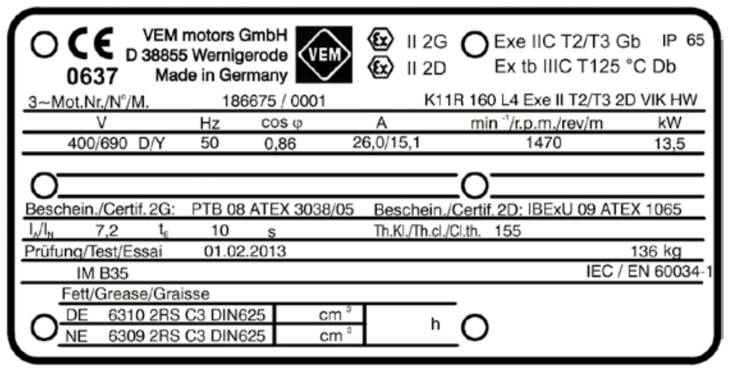
Rules for the marking of explosion-protected products are laid down in IEC/EN 60079-0, chapter 29.
The basic requirement reads: “It is imperative that the following system of markings only be used on electrical equipment or explosion-protected components which comply with the valid standards applicable for the type of ignition protection concerned as listed in Section 1.”

This means that it is not permissible to attach an explosion protection marking in accordance with IEC/EN 60079-0 to components or products which do not conform to the relevant standards and are thus also not certified accordingly by the manufacturer or notified body.

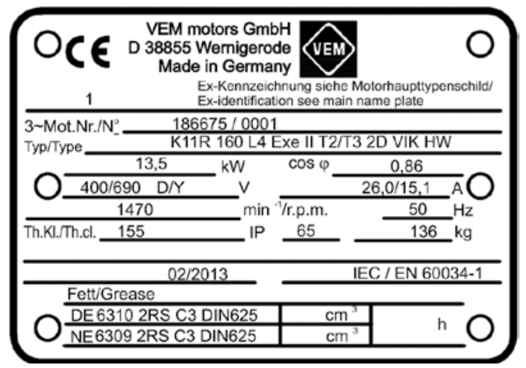
IEC/EN 60079-0, chapter 29.1 also contains stipulations with regard to the location of the marking:
“The electrical equipment must bear a clearly legible mark on the outside of the housing of the main component and this mark must be legible before installation of the equipment.”

This means that the component of a machine/plant which bears explosion protection marking is considered the main component of the ATEX-certified equipment.

It is consequently not permissible to supply a second rating plate with explosion protection marking and parameters for attachment at some other location separate from the motor. As an alternative, for example where the main motor rating plate is not clearly legible after installation, it is possible to provide a second or additional motor information plate without explosion protection marking (see examples below, with specification of the motor number and all electrical parameters).

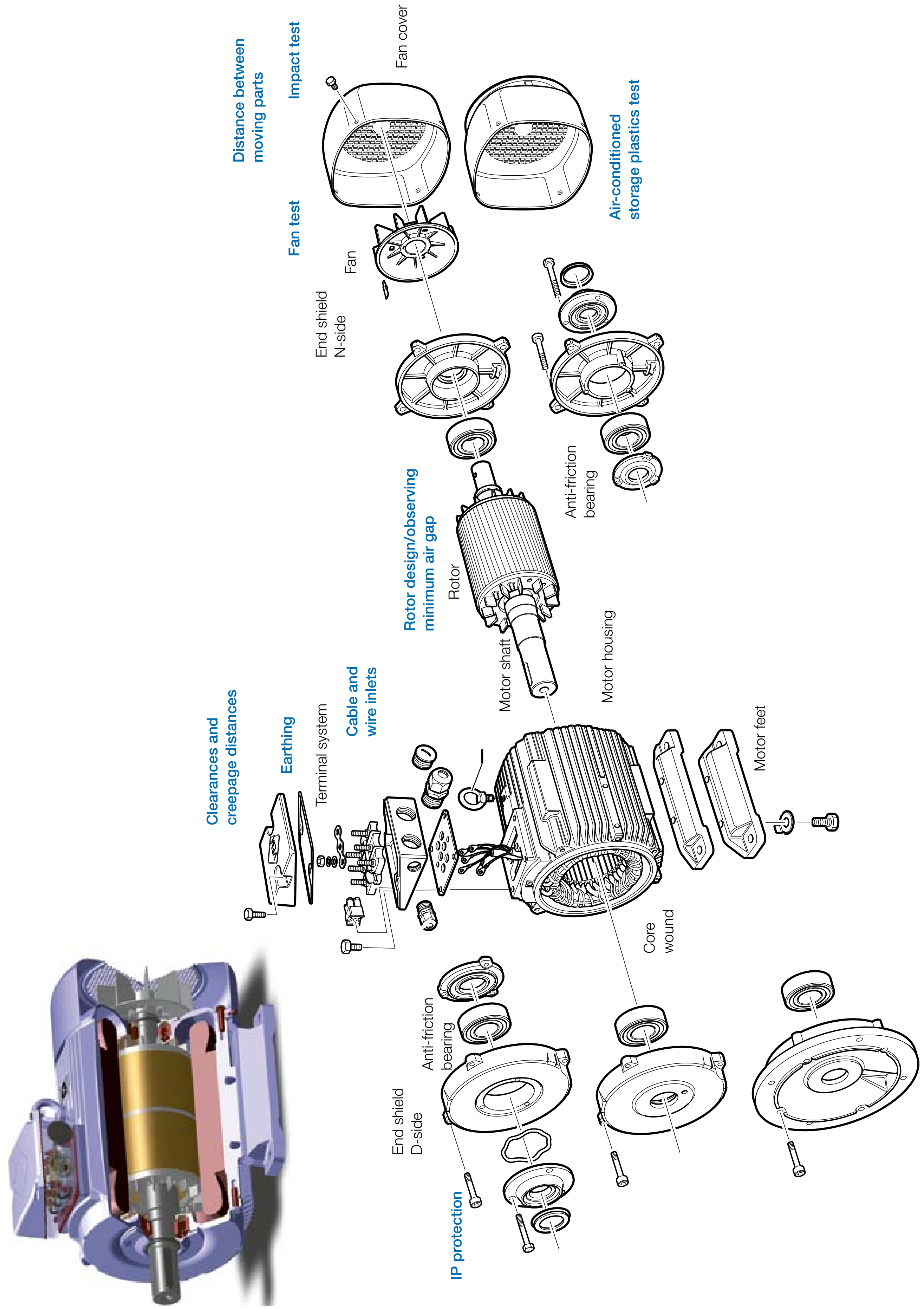


Motor for use in Zones 1 and 21



Corresponding additional rating plate without Ex marking

1.6 Electric motors – Mechanical structure and main focuses of design for conformity with explosion protection



Standard IEC/EN 60079-0 is the basis of the mechanical design of all electrical machines for use in explosion-protected areas. With the Increased safety “eb” (IEC/EN 60079-7) type of ignition protection, the main focuses are on the following areas, which have to be subjected to suitable tests:

Cable and wiring inlet:
Performance of tensile tests and increase in elastomer hardness: IEC/EN 60079-0

Material couplings:
Avoiding formation of abrasion and impact sparks

Clearance and creepage distances:
Observing the clearance and creepage distances complying with EN 60079-7 for avoiding ignitable electrical discharges and sparkovers

Distance between moving parts:
Avoiding mechanical grinding during operation. In the case of asynchronous machines, for example, the air gap minimum value between stator and rotor must be observed, complying with IEC/EN 60079-7.

Impact test:
Guaranteeing adequate protection against mechanical damage

Fan test:
Testing the fan’s mechanical stability

Plastics test:
Testing the heat and cold resistance of the plastics used and testing the seals’ heat resistance. In the case of plastic surfaces with a surface greater than that specified in IEC/EN 60079-0, depending on the explosion group, it is necessary to deal with the problem of electrostatic loads.

IP protection:
Testing the equipment’s type of IP protection against solid bodies and liquids. If it has been established that the above-mentioned points have been satisfied in the sense of the requirements of the standard, a mechanical test report is compiled by the test authority which forms the basis of the EU type-examination certificate. An inspection of the operating instructions is also part of that, as are documents which describe the series’ design. Later modifications by the manufacturer are permitted only after consultation with the test authority and amendments or new EU type-examination certificates may be necessary.

Winding design and electrothermal test:
No part of the electrical equipment must become warmer than the temperature resistance permitted by the materials used. In addition, no surface of a part of the equipment, including the interior parts, which could come into contact with the atmosphere depending on the type of ignition protection, must become warmer than the highest surface temperatures complying with IEC/EN 60079-0.

In the case of motors of the Increased safety “eb” type of ignition protection, the limit temperature of insulated windings must not exceed the values corresponding to IEC/EN-60079-7 (see table), on which the insulating materials’ thermal resistance is based.

Table 3 – Limit temperatures for insulated winding

		Temperature measurement process (see Note 1)	Heat category of insulations complying with IEC 60085 (see Note 2)				
			105 (A) °C	120 (E) °C	130 (B) °C	155 (F) °C	180 (H) °C
1	Limit temperature at rated operation						
	a) single-layer insulated windings	Resistance or temperature	95	110	120	130	155
	b) other insulated windings	Resistance temperature	90	105	110	130	155
			80	95	100	115	135
2	Limit temperature at end of tE time (See Note 3)	Resistance	160	175	185	210	235

Note 1: Measurement by thermometer is permitted only if the measurement is not possible by modifying the resistance. In this context thermometer” means the same as in IEC 60034-1 (for example, a bulb thermometer, a non-embedded thermocouple or a resistance temperature detector (RTD), which is used at the points which are accessible to a normal bulb thermometer).

Note 2: It is accepted as a provisional measurement until values have been stipulated; the higher insulating material heat categories designated in figures in IEC 60085 are regarded as applicable to the limit temperatures specified in Category 180 (H).

Note 3: These values are composed of the ambient temperature, the winding overtemperature in measurement mode and the temperature increase during the t_E time.

In addition to the mechanical design, the electrothermal design and test is a very important step on the way to EU type-examination certificate for an explosion-protected electrical machine. The data acquired during the motors' test form the basis of the data sheet for the EU type-examination certificate and guarantee safe operation of the motor if they are observed.
The electrothermal test comprises the following items:

- Inspection as to whether the winding design satisfies **the criteria of the Increased safety "eb" ignition protection type**
- **Determining/verifying the machine's measurement data**
- **Determining the continuous duty temperature rise**

During the performance of the temperature rise measurement, the DUT is given the prescribed mechanical load and the electrical power input, the mechanical force delivered, and current, voltage, speed and torque are measured and automatically logged during the experiment. The measurement may be terminated if the temperatures measured during operation on the housing change by less than 2 K per hour (thermal equilibrium complying with IEC/EN 60034). The stator winding temperature is calculated by the temperature-dependent resistance change from a winding resistance measurement before the experiment, in the case of a cold machine, and after the thermal equilibrium has been reached, in the case of a machine at operating temperature. The rotor temperature is measured after the experiment by a sensor on the end ring, introduced through a hole in the end shield.

Temperature measurement
The temperature on the housing is measured by thermocouples which are press-fitted in small holes to guarantee the best possible heat transfer. In addition, temperatures are measured on elastomer seals, on cable entry and lead intersections, as well as on existing add-on components. There must be a guarantee that both the temperature category's limit temperature, for which the motor is to be certified, and also the permitted continuous use temperatures for the plastics and add-on components used are not exceeded. With the types of ignition protection Increased safety "eb" for Zone 1 and Increased safety "ec" (old: "nA") for Zone 2, measurement of the stator and rotor temperatures is necessary. In the case of the Flameproof enclosure "d" and Protection by housing (dust) types of ignition protection, only the temperature rise of the exterior surfaces must be tested. A further important measurement is the determination of temperature rise in the locked state (Increased safety "eb" only).

As an example, Figure 1.2 shows the temperature characteristics determined during a temperature rise test on the housing. The measurement is terminated when a "thermal equilibrium" is reached, i.e. temperature rise less than 2 K/h.

To evaluate the measurement taking into account the limit temperatures of the elastomers used, the highest temperature occurring after the motor is switched off must be taken into account for each such measurement point (e. g. seal).

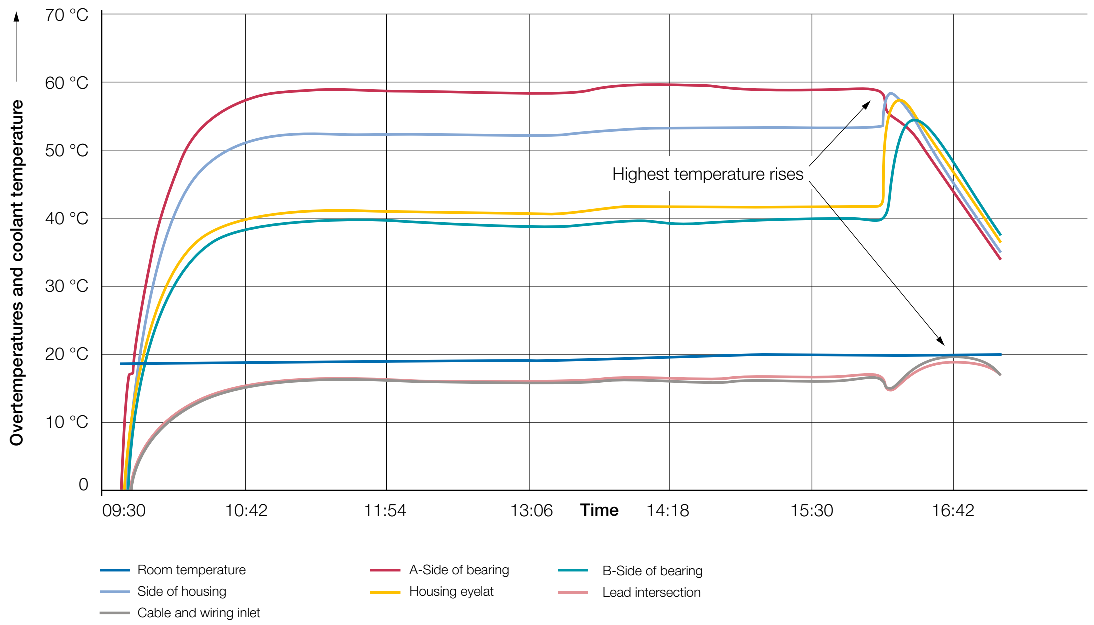


Figure 1.2: Example of housing temperature characteristics during the test

Inspecting the machine protection/determining the t_E time and the starting/rated current relation
This fault may, for example, occur if a machine is locked. Characteristic of this is the motor current reaching a multiple of the measured current (e. g., seven times) and the machine heating up intensely within the shortest possible period of time. Without motor protection, the permitted limit temperatures would have been exceeded within a few seconds. For that reason, the machine must be protected by a time-controlled overcurrent protection device (motor protection switch) or PTC thermistor located in the winding, against prohibited temperature rises as a result of overload.

For measuring the temperature rise in the machine while the brake is fully applied, the rotor is prepared with thermocouples at intervals along its length and the locked motor switched on for a specified time, for example, 15 s.
The rotor's temperature characteristics are shown by a thermograph and the stator's winding temperature is determined by the increased winding resistance after shutdown. The locking attempt is carried out with both phase sequences, whereby measurable differences in the temperature rise are produced with bevelled rotor bars in the rotor. The rotating field with the highest rises in temperature is used for the rest of the evaluation.

In the case of machines of the Flameproof enclosure "db" protection type, locking does not have to be taken into account, as it is assumed that no incendive temperature rises occur with motor protection corresponding to the latest date of technology, because of the high thermal capacity of the stator core and the housing on its surface.

It is similarly not necessary to take the fault case, i.e. machine locked, into account with the Increased safety "ec" (old: "nA") type of ignition protection for Zone 2.

Time t_E
Time t_E is a very important value in the EU type-examination certificate data for the Increased safety "eb" type of ignition protection. This value states the latest time after which the overcurrent protection device (motor protection switch) must switch off the motor in the locked state.

In order to determine this, the continuous duty temperature rise and the temperature rise speed are required for stator and rotor in the locked state. On the basis of the continuous operating temperature and the maximum permitted temperatures for rotor and stator, the maximum permitted temperature increase is determined in the locked state and the maximum duration for the locked state is calculated by the temperature rise speed, for both rotating field directions. The smaller of the two numerical values produces the t_E time minus a safety deduction of at least 5%. If the ma-chine is protected by a device for direct temperature moni-toring, e. g. PTC thermistor, with the machine locked it must be proved, by means of an overload attempt and shutdown attempt, that no prohibited temperatures occur, also in the case of a fault. The t_A time is then part of the EU type-examination certificate instead of the t_E time and the I_A / I_N is not specified. The maximum permitted temperature rises are given in the standards IEC/EN 60079-0 (temperature categories) and IEC/EN 60034 (winding insulation thermal classes).

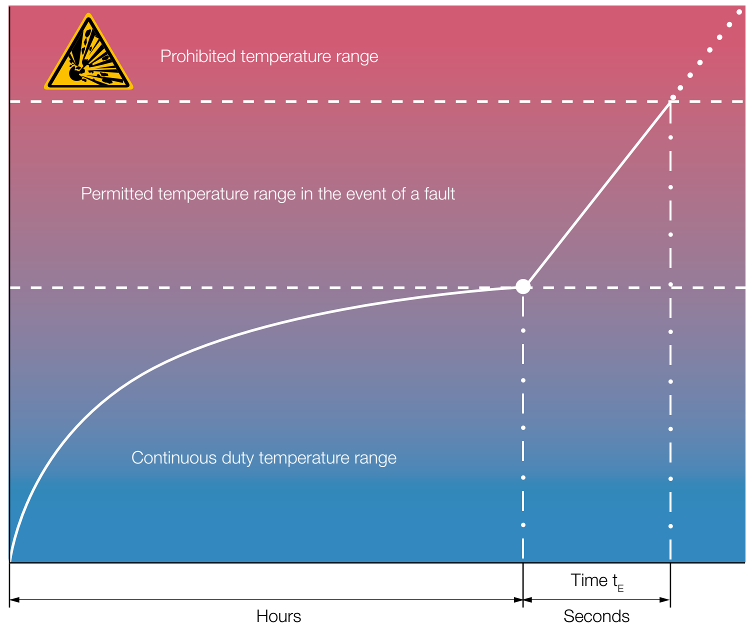


Figure 1.3: Definition of t_E time

1.7 High-voltage tests on windings under gas

These tests are necessary, if the following criteria apply:
- The machine is a high-voltage machine (rated voltage > 1 kV).
- An ignition danger assessment complying with EN 60079-7 Table G.1 has produced an ignition danger factor > 6.

The high-voltage test is made up of an AC test and an impulse voltage test. There the windings are individually tested, with the unused phases and the stator core being earthed. The DUT is in an explosive mixture. Hydrogen is used for Explosion Group IIC, ethylene for IIB and propane for IIA. The minimum ignition energies increase from Explosion Group IIC to IIA. The test is considered to be passed if there is no ignition in the test of two winding phases in the AC and impulse voltage tests.

Figure 1.4: Impulse voltage test on a winding model under gas (photo: PTB Braunschweig)

Risk assessment of possible discharges on stator windings – ignition risk factors according to IEC/EN 60079-7

Characteristic	Value	Factor
Rated voltage	> 6.6 kV to 11 kV	4
	> 3.3 kV to 6.6 kV	2
	> 1 kV to 3.3 kV	0
Average start frequency in operation	> 1/hour	3
	> 1/day	2
	> 1/week	1
	< 1/week	0
Interval between detailed inspections (see IEC 60079-17, Table 1, Type D)	> 10 years	3
	> 5 to 10 years	2
	> 2 to 5 years	1
	< 2 years	0
Type of protection (IP code)	< IP 44 [a]	3
	IP 44 and IP 54	2
	IP 55	1
	> IP 55	0
Environmental conditions	Very dirty and damp [b]	4
	Open-air coastal area	3
	Other open-air areas	2
	Clean open-air areas	1
	Clean, dry interior	0

a) Only in clean environments and with regular upkeep by trained personnel, see 5
b) "Very dirty and damp" includes areas exposed to flooding or includes open deck in the case of offshore applications.

1.8 Installation and electrical connection

The safety instructions supplied with the motor must be heeded for assembly and commissioning.
Assembly tasks must only be carried out by specialist personnel, who, on the basis of their specialist training, experience and instruction received, have adequate knowledge of the following:
- Safety instructions
- Accident prevention regulations
- Guidelines and generally-accepted regulations of technology (e. g. VDE regulations and standards).

The specialist personnel must be able to assess the tasks assigned to them and recognise and prevent possible dangers. It must be given the authority by the person responsible for the machine's safety to perform the required tasks and activities. In Germany, installing electrical machines in explosion hazard areas requires compliance with the following regulations:
- BetrSichV "Operating Safety Directive"
- TRBS "Technical Regulations for Operating Safety"
- GefStoffV "Hazardous Goods Directive"
- IEC/EN 60079 ff. "Explosive atmospheres"

Outside of Germany, the relevant national regulations must be observed.

Without labelling, the permitted cooling temperature (room temperature at installation site) complying with IEC/EN 60034-1 is 40 °C maximum and -20 °C minimum and the permitted installation height is up to 1000 m above sea level (different values are specified on the motor nameplate and certified separately if necessary).

Care must be taken to ensure that the cooling air can flow unimpeded up to the air inlet holes and can flow freely through the air outlet holes without being immediately drawn back again. Suction and exhaust holes must be protected from dirt and fairly coarse dust.

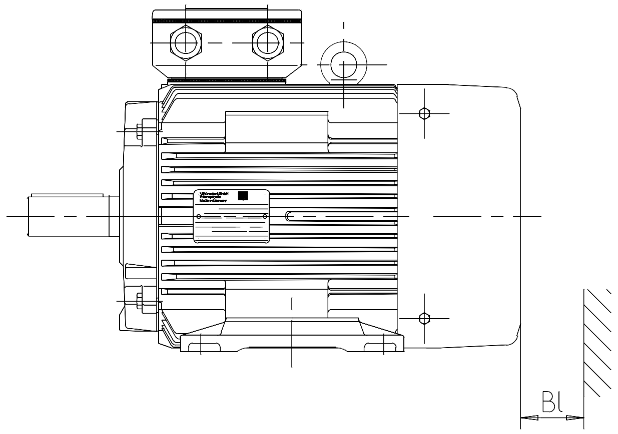


Figure 1.5: Minimum clearance at the air intake

The minimum distance between the fan cover's air intake and an obstacle (Bl measurement) must be observed at all costs.

With designs which have the shaft pointing upwards, the operator must prevent foreign bodies from falling vertically inside. The same applies to the "shaft pointing downwards" installation – in this case, a protective cover is necessary over the fan cover's air intake grid. While installing the surface-cooled motors, care must be taken to ensure that the condensate drain holes are at the lowest point.

In the case of closed condensate drain holes, the screws must be replaced using sealant, after the condensate has been drained off. In the case of open condensate holes, it is necessary to avoid using water jets or pressurised water. There must be an absolute guarantee that the motors are set up on a perfectly even base to avoid twisting during the tightening process. In the case of machines which are to be connected, precise alignment must be ensured. Flexible couplings must be used if at all possible.

Connecting the motor
Connection must be done by a specialist, complying with the currently applicable safety regulations. Outside of Germany, the relevant national regulations must be observed.

It is essential to observe specifications on nameplates.
- Compare current type, mains voltage and frequency.
- Pay attention to the circuit.
- Pay attention to rated current for safety switch setting.
- In the case of motors of the Increased safety "eb" type of ignition protection, you must pay attention to the t_E time.
- Connect motor in accordance with the connection diagram supplied in the terminal box.

For earthing, there is an earth terminal on the housing or flange end shield, depending on the model and design of each motor. All the motors also have a protective conductor terminal inside the terminal box. Unused cable glands in the terminal box must be closed to protect them against dust and humidity. The General Safety and Commissioning Instructions apply to the electrical connection. The cable glands or screw plugs must be certified for the Ex area. The installation torques, sealing areas and clamping ranges specified by the cable gland manufacturer must be observed at all costs.

Connection cables must be selected to comply with DIN VDE 0100, taking into account the rated current and machine-specific regulations (e. g. ambient temperature, type of cable-laying etc., complying with DIN VDE 0298 or IEC/EN 60204-1).
At room temperatures of above 40 °C, cables with an approved operating temperature of at least 90 °C must be used. This also applies to the motors in which reference is made by an X to special requirements for cable design on the supplementary sheet for EU type-examination certifcate.

In connecting the motors, particular care must be taken to set up the connections in the terminal box carefully. The connecting bolt nuts must be securely tightened without using force. In the case of motors which have a terminal board with slot terminal complying with Directive 2014/34/EU, only cable lugs complying with DIN 46295 may be used for connecting the motor. The cable lugs are fastened by nuts with integrated spring lock washers. As an alternative, a solid wire is permissible with a diameter which corresponds to the width of the slot in the connecting terminal.

When inserting the leads in the terminal box, care must be taken to ensure that the wires are not under tension. The interior of the terminal boxes must be kept clean. The seals must be undamaged and correctly positioned. The terminal box must always be locked during operation.

Safety measures against prohibited temperature rises
If no conflicting information regarding mode of operation and tolerances is provided in the test certificate or on the nameplate, electrical machines are designed for continuous duty (Mode of operation S1) and standard starting behav-

iour without frequently restarting so that no significant temperature rise is perceptible. The motors may only be used for the mode of operation specified on the nameplate.

IExplosion-protected motors are generally designed and certified for Range A of the voltage and frequency parameters specified in IEC/EN 60034-1 (DIN VDE 0530, Part 1): Voltage ± 5%, frequency ± 2%, characteristic curve, mains symmetry. To an increasing extent, explosion-protected motors are also being manufactured for greater supply voltage tolerances. This should be evident from the rating plate of the motor and, where appropriate, the EU type-examination certificate. There are thus numerous supplements to EU type-examination certificate for a voltage tolerance of ± 10% in accordance with Range B.
It is imperative to observe the specified tolerances, so that the temperature rise remains within the permissible limits. On start-up, it must be protected against prohibited temperature rises, e. g. with motor protection switch, i. e. prohibited rises in temperature in all phases must be prevented by a earth leakage circuit breaker complying with DIN VDE 0660 or an equivalent device. The protection device must be adjusted to the rated current. Delta-connected windings must be protected by connecting the tripping devices or relays in series to the winding phases. Basis for the selection and adjustment of the switch is the rated value of the phase current, i. e. the motor rating current multiplied by 0.58.
If such a connection is not possible, suitable protection switches, e. g. with phase failure monitoring, must be used. For pole-changing motors earth leakage circuit breakers must be equipped for each speed that can be locked against each other.
The start is also monitored in the case of Increased safety "eb" type of ignition protection. For this reason, the protective device must switch off when the rotor is locked, within the t_E time specified for the particular temperature category. The requirement is fulfilled if the tripping time (found in the tripping characteristic curve (start temperature 20 °C for the I_A/I_N factor) is no greater than the specified t_E time.

Electrical machines of the Increased safety "eb" type of ignition protection for starting with high inertia loads (ramp-up time > 1.7 x t_E time) must be protected by a start monitor in accordance with the specifications of the conformity certificate and must also be certified accordingly.

Thermal machine protection by direct temperature monitoring of the winding is permissible, if it is certified and the t_A time is specified on the nameplate. The explosion protection is guaranteed by temperature sensors complying with DIN 44081/44082, in conjunction with tripping devices with ⟨Ex⟩ II (2) G protection type identification.

Additional devices
As an option, explosion-protected motors may be provided with additional devices:

Additional thermal motor protection
For monitoring the stator winding temperature, temperature sensors (PTC thermistors, KTY or PT100) may be installed in the motor. To connect them, suitable auxiliary terminals for auxiliary circuits are available either in the main terminal box or in additional terminal boxes. The connection is made in accordance with the enclosed terminal connection diagram.

Thermal motor protection as full protection
The use of the thermal winding protection as full motor protection is only permissible if this mode is separately tested and certified by a notified body. In this case, identification is completed on the nameplate by provision of the t_A-time in place of the t_E-time and the text "Operation only with functionally-tested PTC tripping device with the protection Type identification ⟨Ex⟩ II (2) G". The I_A/I_N specification is not necessary.

Anti-condensation heating
The heating tapes must satisfy the requirements of Directive 2014/34/EU. The heat output and supply voltage are specified on the motor nameplate. To connect them, suitable terminals for auxiliary circuits are available either in the main terminal box or in additional terminal boxes. They are connected in accordance with the enclosed terminal connection diagram. The anti-condensation heating must be switched on only after the motor has been switched off. It must not be switched on during motor operation. This is guaranteed by locking the circuit.

External ventilation unit
The external fans must satisfy the requirements of Directive 2014/34/EU and must be suitable for the intended type of ignition protection. The external ventilation unit is responsible for removing the dissipated heat when the main motor is operating. While the main motor is operating, the external ventilation motor must be switched on. After the main motor has been switched off, the external fan must continue to work until the temperature is low enough. If there is a fault in the external fan, the main motor must be switched off.
In the case of motors with external fan units dependent on the direction of rotation, it is essential to pay attention to the direction of rotation (direction-of-rotation arrow). Only the external fan units supplied by the manufacturer may be used. The external ventilation unit must be connected according to the applicable terminal connection table supplied.

External heat and cold sources
In the case of existing external heat and cold sources, no additional measures are necessary if the permitted ambient temperatures are not exceeded at the installation point.
If they are, in fact, exceeded or effects on the operating temperatures or maximum surface temperatures can be expected, suitable measures for maintaining and certifying the explosion protection must be taken. If in doubt, consult the manufacturer.

General instructions for operation on the frequency converter
It is only permissible to operate explosion-protected three-phase motors in connection with frequency converters, if the motors are built, tested, approved and labelled separately for this mode. The separate manufacturer's instructions must be observed under all circumstances.
For the Increased safety "eb" type of ignition protection and for motors for use in Zone 21, separate EU type-examination certificates are necessary, in which operation in connection with frequency converters is explicitly approved and in which the binding conditions and parameter setting of the motor, frequency converter and protection device system are listed. For the Increased safety "ec" (old: "nA") type of ignition protection and for motors for use in Zone 22, motors operated on frequency converters at variable frequency and/or voltage must also be tested with the specified frequency converter or else a frequency converter similar in terms of its output voltage and current specifications. The necessary parameters and conditions can be found on the nameplate or the documentation of the motor.

In order to prevent prohibited temperatures, the motors are equipped as standard with thermal winding protection, which has to be evaluated by a suitable device. The motors must not be operated as a group drive.
The manufacturer's Notes and Operating Instructions for installation and commissioning of the frequency converter must observed under all circumstances.

1.9 Electrostatic hazards
1.9.1 Introduction

Over the past years, products with plastic elements – in particular plastic housings – and powder-coated metal parts have become increasingly widespread and are gradually replacing products with wood, glass and bare or painted metal surfaces. Unlike metal, wood, glass and most painted surfaces, plastics and powder-coated surfaces are usually subject to electrostatic charging through friction. High electrostatic charges can result from friction contact with clothing or when cleaning surfaces with a cloth. If an earthed counter-electrode, e.g. a person's finger, comes close to the charged surfaces, this may result in an electrostatic discharge capable of igniting solvent vapours.

The following describes how such ignition risks can be recognised and brought under control. To this end, various longstanding and proven standards and regulations exist; the individual regulations differ only in certain nuances. If the stipulations of these standards and regulations are observed, this triggers a "presumption of conformity", i.e. it is assumed that a level of protection conformant with all superordinate regulations is achieved.

1.9.2 Standards and regulations

- **IEC/EN 60079-0**
  A whole chapter of this standard is devoted to electrostatic requirements. It must be noted, however, that these requirements have been copied more or less verbatim from earlier regulations dealing with electrostatic hazards and have not been written specifically by electrostatic experts. There is thus corresponding scope for ambiguities and misunderstandings.
  For example, the standard demands that surfaces should be cleaned with a fluid before measuring the surface resistance. Typical fluid residues, however, may significantly affect the surface resistance. For this and many similar reasons, it is recommended to perform testing in accordance with IEC/TS 60079-32-1 Amendment 1, chapter 14, using the test method described by IEC 60079-32-2. In this way, such measuring errors will be avoided for the most part. The surface of a test object, for example, is cleaned only with a brush. Otherwise, both cases (-0 and -32) produce exactly the same result.
  The aforementioned weaknesses of IEC 60079-0 are known to the experts who perform testing and are usually taken into account. Special verification of the measured values obtained in accordance with -0 is thus not necessary.

- **TRGS 727:2016**
  The technical regulations TRGS 727:2016, formerly TRBS 2153:2009, and before that BGR 132:2003 and ZH1/200:1989, are the German-language source for regulatory information on the prevention of electrostatic charging. They constitute the latest regulations relating to electrostatic hazards, and were formerly the regulations which were copied into European and international standards. Even today, it can be safely assumed that the latest knowledge published here will be incorporated into international standards. TRGS 727, however, addresses the whole of industry and the entirety of everyday processes (e.g. fuelling of motor vehicles). For an outsider, it is thus often difficult to find the relevant chapter; there is no chapter which deals specifically with electrical equipment.

- **IEC/TS 60079-32-1 with Amendment 1, IEC 60079-32-2**
  IEC/TS 60079-32-1 is an international specification describing the prevention of electrostatic charging and was derived from TRBS 2153:2009. It currently embodies the highest internationally recognised state of the art with regard to the prevention of hazardous electrostatic charges in the form of a reference book. As numerous operating measures are prescribed by this specification, it cannot be published as a standard.
  The most important sections relating to electrical equipment are Chapter 14 in Amendment 1 and the process flowchart for electrostatic testing in the annex to IEC/TS 60079-32-1 (Figure 1.9). Detailed instructions on determination of the required parameters are to be found in IEC 60079-32-2.

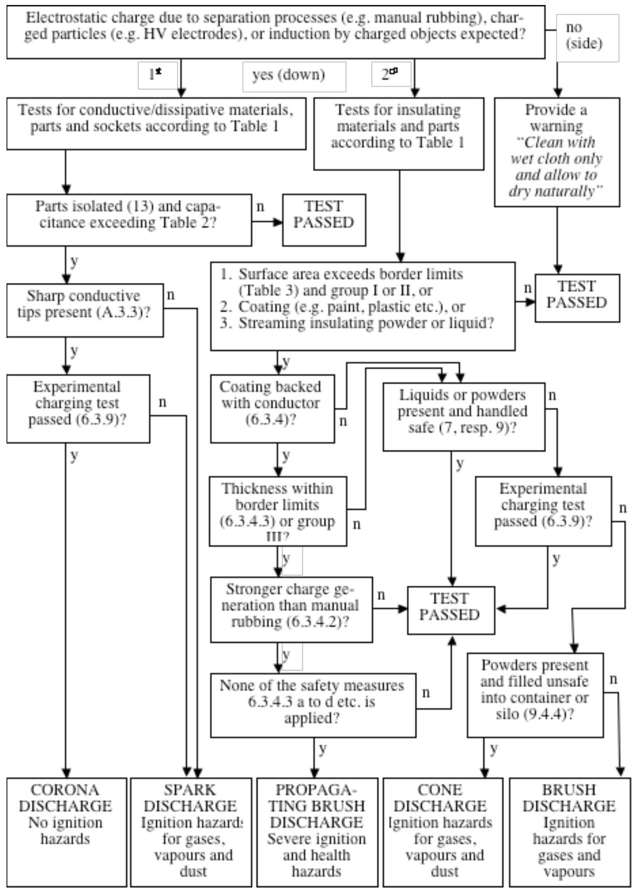


Bild 1.9: IEC/TS 60079-32-1, Figure F.1 – Flowchart for a systematic electrostatic evaluation with reference to the respective chapters

1.9.3 Test procedure

This chapter describes the typical process of electrostatic testing according to the flowchart presented in IEC/TS 60079-32-1 for the plastic housings of electrical equipment intended for use in a particular zone (in this example: Zone 1, group IIC) (Figure 1.9.). It must be taken into account here that the reference chapters specified in Figure 1.9 are summarised in Chapter 14 in the case of electrical equipment. The given sequence is especially important for the process, as the specified requirements are all connected with a logical "or" and contradictions may arise if they are considered in the wrong order.

1. Is the test object exposed to manual friction, e.g. contact with work clothing or cleaning using a cloth? Or exposed to streams of liquids or dusts? Or is it located in the proximity of high-voltage electrodes?
   Yes, the test object is subject to manual friction from work clothing, for example. Continue with 2.
2. Does the test object have any conductive/dissipative parts with an impermissibly high electrical capacitance?
   Yes, there is a screw terminal which is open to possible external contact. The capacitance measured according to IEC 60079-32-2, however, is only 2.5 pF. This capacitance is below the limit value for Zone 1 group IIC (less than or equal to 3 pF). Continue with 3.
3. Does the surface resistance of the test object, measured in accordance with IEC 60079-32-2, exceed the permissible limit value of 100 gigaohms, measured at a maximum of 30% relative humidity with a measuring voltage of at least 500 V (better: at least 1000 V)?
   Yes, continue with 4.
4. Does the maximum projected surface area of the test object which is open to friction exceed the specified maximum area (in our example max. 2000 mm² for Zone 1, group IIC)?
   Yes, the value is clearly exceeded. Continue with 5.
5. Has the interior of the housing been provided with a conductive coating?
   No, the interior of the housing has no conductive coating. Continue with 6.
6. Is the maximum possible charge which is transferred by a provoked discharge, measured according to the method defined by IEC 60079-32-2, less than or equal to 10 nC?
   Yes, no discharge whatsoever, and thus no electrostatic charging, was observed during the electrostatic testing. The housing is thus sufficiently antistatic and complies with the stipulations of all standards and regulations mentioned in chapter 1.9.2. Alternatively, with a measuring voltage of 10,000 V, it would already have been possible to determine at Step 3 that the surface resistance breaks down at higher voltages and that the test object thus cannot acquire a hazardous electrostatic charge under the high electrostatic voltages present.

The procedure in case of alternative answers at the individual steps can be taken from Figure 1.9.

1.9.4 Further notes

One problem which is frequently faced is: How can a test object which complies with the area criterion described under 1.9.3, Step 4, for IIB also be made safe for IIC? There are various possible approaches, examples of which are listed below:

1. Shrouding of the test object by way of a leather pouch or with paper/cardboard/antistatic film, or treatment with antistatic paint, etc.; antistatic sprays retain their effect for at least 1 year, but cannot be used in outdoor settings.
2. Conductive earthed coating of the inside surface of the test object (only possible in the absence of electrostatic charges greater than those caused by manual friction and only for a housing thickness of not more than around 0.2 mm).
3. Avoiding of electrostatic charges by using the test object in a cellar or in a ground hole with a permanent puddle of water (a relative humidity of constantly more than 60% means that no electrostatic charging is possible under these conditions), by mounting the test object on the ceiling (manual friction is then excluded, but a label "Clean only with a damp cloth" should still be attached), or by using the test object in an area in which overpressure prevents the ingress of a potentially explosive atmosphere.
4. **Use of liquid coatings/paints on a conductive primer or base (primers for electrostatic painting are typically conductive). Compared to powder coatings, liquid paints typically display a sufficiently low breakdown strength in order to avoid electrostatic charging, though they are at the same time less effective as corrosion inhibitors.**

2 Technologies for protecting induction machines from prohibited temperature rises as a result of overload – Summary complying with explosion protection

2.1 What legal/normative specifications exist regarding protection of electrical machines in explosion-hazard areas?

– **Directive 2014/34/EU:**
Directive 94/9/EC states the following regarding devices in Category 2 (Equipment Group II), which include electrical machines operated in Zone 1: "Category 2 comprises devices which are designed in such a way that they can be operated in accordance with the manufacturer-specified parameters and guarantee a high degree of safety". It is further stated as follows: "The machine-based explosion protection measures in this category guarantee the required degree of safety even in the case of frequent equipment faults or error situations which are normally to be expected." From this we can conclude that all equipment in Category 2 must not become an ignition source in the case of errors and faults which are frequent or to be expected. Furthermore, it is stated in article 1, paragraph 2: "Safety, control and regulation devices for use outside of explosion risk areas which, however, are essential for safe operation of equipment and protection systems or contribute to them, are also included in the area of application of this directive."
The terms of the directive require that all motors in Category 2 must be protected against prohibited temperature rises and that all equipment and devices for protecting the motor must be certified.

– **ATEX guidelines:**
The ATEX guide specifies the Directive's requirements of the guideline and is itself produced by the Commission's Standing Committee as a guideline. It is stated in chapter 3.10: "Safety, control and regulation devices are subject to the directive, if they contribute to or are necessary for the safe operation of equipment or protection systems in terms of ignition dangers or the danger of an uncontrolled explosion." It is stated below: "These devices also come under it if they are to be used as intended outside of explosion risk areas. These devices are not allocated to categories complying with article 1." It is also stated as follows: "The fundamental requirements apply to these devices only to the extent that they are necessary for the safe, reliable mode of operation and handling of this device, with regard to dangers of ignition or the danger of an uncontrolled explosion." The following explicit example is given: Overload protection devices for electrical motors of the Increased safety "eb" type of protection. There is no statement regarding the protection of motors of the "db", "p" and "ec" types of ignition protection.
The guide also states that motors of the Increased safety "eb" type of ignition protection must be protected definitively by a certified monitoring device in accordance with Directive 2014/34/EU.

– **IEC/EN 60079-14**
The operation of electrical equipment for explosion protection is described by IEC/EN 60079-14. Application of the standard is not compulsory. In Chapter 7.1 a statement is made firstly on all electrical equipment: "All electrical equipment must be protected against harmful effects of short circuits and earth faults." Further on, it says: "Precautions must be taken to prevent the operation of multi-phase electrical equipment (e. g. three-phase motors) if the failure of one or more mains phases can result in overheating." There is also a statement on electrical machines at 7.2: "Rotating electrical machines must also be protected against overload, with the exception of motors which are continually capable of controlling the start-up current in the case of rated voltage and rating frequency or generators which are continually capable of controlling the short-circuit current without a prohibited temperature rise. The following must be used as overload protection devices: a current-dependent, time-delayed safety device for monitoring all three phases, not set any higher than to the machine's rated current which, at a setting current multiplied by 1.2, must respond within 2 h and at a setting current multiplied by 1.05 must not yet respond within 2 h or a device for direct temperature monitoring by embedded temperature sensors or an equivalent device." The following statement is also made at 11.3.1: "In order to satisfy the requirements of 7.2a), time-delayed overload protection devices must, depending on current, be designed in such a way that not only is the motor current monitored but also that the motor, with brake fully applied, is switched off within the t_E time specified on the nameplate. It is also stated regarding delta-connected machines: "For this reason, phase failure protection must be provided for machines with delta-connected windings, protection which recognises machine imbalances before they cause excessive temperature rises."
In summon it is recommended that all electrical machines in explosion hazard areas are protected against overload, short-circuit and phase failure and that the protection for the Increased safety "eb" type of ignition protection must be effective even when the motor is locked.

– **IEC/EN 60079-7**
The following statement is made on the t_E time in chapter 5.2.4.4.1 of the requirements of Increased safety "eb" type of ignition protection: "The t_E time must be long enough for the current-dependent safety device to switch off the locked machine within this period. This is usually possible if the specified minimum values for t_E specified in Figure 2 (the standard), depending on the I_A/I_N f initial starting current relation, are exceeded.
It follows from this that the area of the relation between initial starting current and rated current is restricted to the Increased safety "eb" ignition safety type and that the time t_E must conform to the minimum values shown in Figure 2.4.

– **EN 60079-1**
In the standard for the Flameproof enclosure "db" type of ignition protection, there is no statement on protection of rotating electrical machines. For calculating the maximum surface temperature, the test voltage of $U_A \pm 10\%$ is prescribed (or $U_A \pm 5\%$, if the area of application is specified on the equipment and is named in the operating instructions). No requirements are made of the overload or fault conditions.

– **EN 60079-2**
The standard governing Pressurized enclosure does not contain any statement on protection of rotating electrical machines.

– **IEC/EN 60079-15:**
IIn contrast to the above-mentioned types of ignition protection, equipment for the Increased safety "ec" (old: "n") type of ignition protection falls into Category 3 of Directive 2014/34/EU.
Equipment in this category must not have any ignition sources during normal operation. The following statement on the electrical machines standard appears in Section

17.8.1: “The temperature of each exterior or interior surface which may come into contact with an explosive atmosphere must not exceed the temperature category specified in Section 5, in normal operating conditions. The temperature rise during the start does not have to be considered for specifying the temperature category when S1 or S2 is given as mode of operation complying with IEC/EN 60034-1. It is further stated as follows: “Not taking the start conditions into account in specifying the temperature category is permissible for machines which do not start frequently and with which the statistical possibility of an explosive atmosphere existing during the start-up process is not considered to be highly feasible.“

The machine has to maintain the specified temperature category in normal operation only. The start does not have to be monitored. There is no direct statement on errors occurring.

2.2 Causes of prohibited high temperatures in an electrical machine

The most frequent cause of prohibited high temperatures in an electrical machine is overloading, i.e. loading at a higher torque than the machine’s rating torque. Reasons for this may be as follows: faulty design of the drive, sluggish working machine, damage after long-term storage, viscosity of medium too high in stirring devices etc. With an increased load, the currents in the stator winding and rotor squirrel cage increase, with the copper losses increasing quadratically with the current. Another cause of a prohibited temperature rise in the machine is operation outside of the machine’s rating parameters. Examples of this are as follows:

- **Undervoltage operation:** With operation at decreased voltage, the machine’s stator currents increase, in order to deliver its required output including motor losses. Because of the decreased voltage for the main inductance in the machine’s equivalent circuit diagram, a reduced magnetic flow density is produced in the air gap, which results in an increase in the machine slip rate even with constant load torque. Concerning the $P_{VCu2} = s \cdot P_\delta$ gives the relationship that explains the effect of significant increase in copper losses in the machine’s rotor. Ultimately the machine is “tilting”, whereby the speed drops steeply and the stator current increases to that of the initial starting current.
- **Overvoltage operation:** If the voltage is increased above the rated voltage range, a magnetic oversaturation of the machine occurs. As soon as the operating point in the sheet’s B-H characteristic curve moves into the linear range and the value of μ_r approaches 1, very high magnetisation currents flow and the core and stator winding losses increase sharply. The result may be a prohibited temperature rise in the machine. Figure 2.1 illustrates the situation.

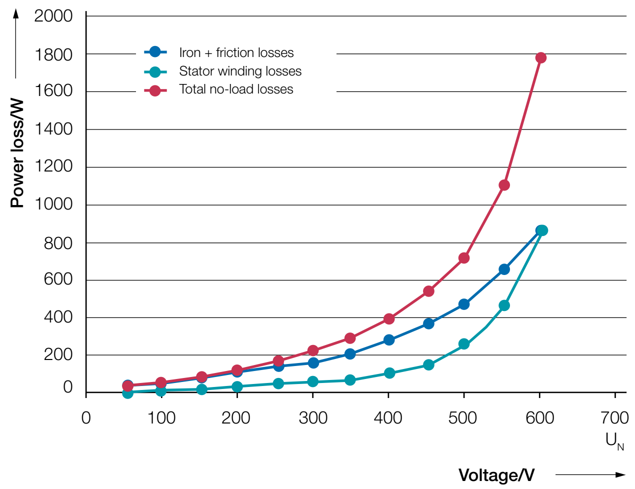


Figure 2.1: Voltage-dependent no-load loss curve

- **Voltage imbalances/phase failure:** Overvoltage imbalance and, in the extreme case, the failure of a phase do not necessarily cause the motor to stop. In the case of a low mechanical load, it results only in an increase in the slip rate. That is why there is a risk that this fault will remain undetected for a fairly long period. However, the motor no longer starts with only two remaining phases and corresponding load moment.

  If the motor is star-connected, an increase in current must be recorded in the remaining phases. If the current exceeds the machine’s rated current, prohibited temperature rises may occur. The motor protection switch must detect the overcurrent and switch the motor off.

  With a delta-connected motor, a phase failure (in accordance with Figure 2.2) results in the winding phase carrying to cease to carry the <$^1/\sqrt{3}$-times conductor current but the $^2/_3$-times conductor current instead of. A thermal overload of the winding phase is therefore possible without the protective device registering an overcurrent. It follows, however, from IEC/EN 60079-0 that the protective device must detect machine imbalances before prohibited temperature rises occur. This fault must, therefore, be detected by a certified motor protection device. The cause of the phase failure may be a tripped fuse or else a clamped connection which has worked loose.

  The interruption of a winding phase inside the motor, in the case of a delta connection, is to be regarded as especially critical. In this case, the uninterrupted winding phases are charged with the full conductor current. In order to accurately detect this fault, also, the motor protection switch must be switched on directly to the winding phases and be set to the $^1/\sqrt{3}$–times motor rated current, in order to regulate out ignitable temperature rises and thermal damage to the winding.
- **Inadequate cooling:** If the cooling air routes are blocked or the motor is operated at an excessive ambient temperature, there is a danger of prohibited temperatures, even without any overload. This fault can be detected only by direct temperature monitoring.
- **Converter mode:** Frequency-converter operated machines, as long as they are self-ventilated, are driven by a heat dissipation system, with speed varying according to the environment. At every point in time, the balance from the fundamental component losses including the harmonic losses as well as the heat dissipation to the environment and the machine’s heat-accumulation capability are safeguarded, in order to prevent a prohibited temperature rise.
- **Voltage drop at start:** If voltage drops should occur in the case of high network impedances during the start-up process, this results in an approximate linear reduction of the initial starting current by the voltage and in a quadratic reduction of the breakaway torque. Thus there is a risk that the machine will not start at the appropriate load moment. At the lower starting current according to figure 2.4, an extension of the motor protection switch’s switch-off time also results when the machine does not start. It is essential to ensure that the machine is not subjected to any prohibited temperatures within the extended switch-off time.

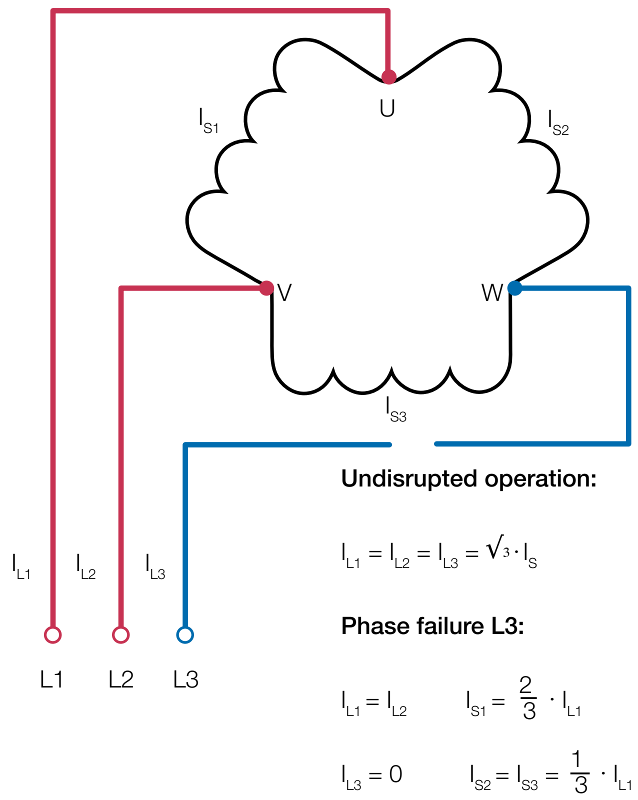


Figure 2.2: Delta connection in the case of phase failure

2.3 Protection principles for mains-operated machines and requirements of protection with explosion-protected drives

2.3.1 Type of ignition protection – Flameproof enclosure “db”

With this type of ignition protection, the principle is based on the fact that an explosion may occur in the interior of the motor and is allowed to do so but that the latter is not transferred to the surrounding explosive atmosphere because of the housing design. From an explosion protection point of view, the only thing that, therefore, must be required of these motors is that the exterior surfaces do not heat up beyond the certified temperature category in normal operation and in the case of faults, and that the seals, connection cable and other attachments are not thermally overloaded. These motors may be thermally protected by a time-based over-current trip and also by PTC thermistors embedded in the winding. It can be taken from Directive 2014/34/EU and Standard IEC/EN 60079-14 that motor protection is absolutely necessary. Locking, however, is not considered separately – something which also does not necessarily have to be essential because of the housing’s high heat capacities. In the case of locking, even if rotor and stator windings are supposed to have heated up above the ignition temperature when the motor protection responded, the housing will only reach distinctly reduced temperatures because of the distribution of the heat energy to a higher thermal capacity.

2.3.2 Type of ignition protection – Pressurized enclosure "p"

This type of ignition protection may be considered in the same way as the Flameproof enclosure. In this case also, only the external surface temperature is relevant to explosion protection. No combustible mixture can penetrate the motor's interior, as an explosion protection gas, for example, is maintained under overpressure here. As an additional condition, there must be a guarantee that internal parts are cooled down to values below the ignition temperature of the diffusing mixture when the mixture reaches them, if the ignition protection gas supply fails and the motor switches off.

2.3.3 Type of ignition protection – Increased safety "eb"

With this type of ignition protection, the ignitable mixture is allowed to penetrate the motor's interior but must not come into contact with any ignition sources. For that reason, special requirements are set of the motor protection in accordance with IEC/EN 60079-14, in order not to reach any prohibited stator or rotor temperatures at rated voltage, even in the case of locking. The direct temperature monitoring or a time-dependent overcurrent trip may be used as protection principles.

2.3.4 Type of ignition protection – "ec" (old: "n")

For this type of ignition protection, the machine only has to maintain the temperature category in "normal operating conditions", in accordance with IEC/EN 60079-15. It is stated explicitly in the standard that the case of locking does not have to be considered for operating modes S1 and S2. Overloading is not mentioned. In the case of operating conditions which cannot exclude overloading without protection and could remain undetected for a long time, they contradict the theory of this type of ignition protection. A type of overload protection similar to the Increased safety "eb" type of ignition protection is adequate.

2.3.5 Type of ignition protection – "t", dust explosion protection

For dust-explosion-protected machines in accordance with the standard IEC/EN 60079-31, a further core requirement – alongside the aforementioned verification of the enclosure protection – is observance of the maximum surface temperature specified in the EU type-examination certificate. The surface temperature is determined by way of electrical-thermal testing for rated-duty operation, for operation at the upper and lower limits of the rated voltage range and after overload testing with 120% rated current for two hours, starting from a state of thermal equilibrium after rated-duty operation. This is intended to simulate disconnection via the motor circuit-breaker in case of overload. For all tests, it is important to take into account the subsequent further warming of the housing after the end of the actual test duration.

2.3.6 Direct temperature monitoring

In the case of direct temperature monitoring as sole protection, PTC thermistors are embedded in all three of the winding head's three winding phases and impregnated along with the winding. This guarantees a strong thermal contact between winding and PTC thermistor, which is extremely important for the effectiveness of the protection principle. The individual PTC thermistors are connected in series and linked to a PTC thermistor tripping device, usually fitted outside the explosion hazard area, during motor installation. If the PTC thermistors are heated up past the nominal response temperature e.g. 130 °C, the resistance increases steeply and is registered by the evaluation unit. When the nominal switch-off temperature is reached, the motor is switched off. The unit must also detect resistance which is too low and beneath the PTC thermistor's "window of resistance". The reason for this may be a short circuit in the PTC thermistor's connecting wiring, which stops protection from being guaranteed. Protection by direct temperature monitor restricts the winding temperature to a fixed value.

By this means, it is possible to also detect prohibited temperatures which are attributable not to an overload but, for example, to blocked cooling air routes or to an excessive ambient temperature. From the point of view of pure current monitoring, this is a safety benefit.

In the design of the PTC thermistor for sole protection, care must, however, be taken to ensure that the rotor as well as the stator must be protected from prohibited temperatures (Increased safety "eb" type of ignition protection and type of ignition protection "ec"). This is a challenge for rotor-critical machines in particular and many machine designs do not permit sole protection via PTC thermistor.

In the case of a machine with sole thermal protection via PTC thermistor being tested, these cases must be considered and the "protection's equal quality to current monitoring" proved by calculation and experiment.

2.3.7 Current-dependent, time-delayed safety equipment

Motor protection via current monitoring is based on the approach of the motor protection relay representing a simplified thermal image of the motor and shutdown occurring in the case of a prohibited temperature rise registered by this thermal model. In addition, the motor protection switches contain another magnetic instantaneous trip for short-circuit protection. The simplest design of motor protection device is a motor protection switch with thermorelay. Here the bimetal is heated up by a heating winding with the motor current flowing through it. The bimetal may be regarded as a single-body equivalent motor circuit. Bimetals of this type exist for all three phases and different temperature rises in the bimetals and thus also a single phase overload and current imbalances are detected, by means of a mechanical link. In accordance with EN 60079-0, the protective device must not trip within 2 h, even when the rated current of the motor is 1.05. in the case of current multiplied by 1.2 it must respond within 2 h. The following consideration clarifies the motor's thermal behaviour:

For the single-body equivalent circuit, it is possible to write

$$P_V = \frac{\vartheta}{R_{th}} + c \cdot \frac{\Delta\vartheta}{dt}$$

P_V is the converted power loss in the machine, ϑ the overtemperature for the environment, R_{th} the heat transfer resistance for the environment and c the machine's heat capacity. The following may thus be written for the temperature:

$$\vartheta = \frac{P_V}{R_{th}} \cdot (1 - e^{-\frac{t}{R \cdot c}})$$

Alt follows from this equation that the rise in temperature, e.g. after the overloading has occurred in accordance with an e-function, approximates the new "steady state temperature" $\frac{P_V}{R_{th}}$.

For this reason, there must be a shutdown to safely protect the motor, before the overtemperature ϑ in the stator or rotor reaches prohibited values.

The motor's load-dependent losses may be seen as an initial approximation in quadratic dependency on the machine current, with the result that the integral must be evaluated by

$$\Delta\vartheta \sim \int I^2 \, dt$$

in the case of overload. In the most basic case, the evaluation may occur via the previously mentioned bimetal. Electronic protective devices, however, which guarantee a more precise response, respond with a freely-definable current imbalance factor, and are able to represent the machine better thermally by means of a more expensive thermal multi-body equivalent circuit, and are becoming increasingly widely distributed, particularly in the case of larger drives. As an alternative, there is also the possibility of monitoring the motor's active power input by an electronic protective device. This may be advisable with machines which have a very low current input in the case of overload or if, in the case of pump drives, for example, a drop in power must also be recognised as dry run prevention.

2.3.8 Protection selection and parameterisation with type of ignition protection – Increased safety "eb"

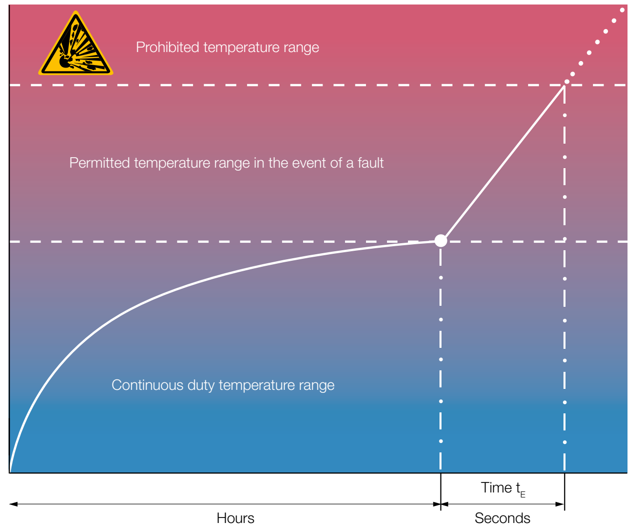


Figure 2.3: Definition of t_E time

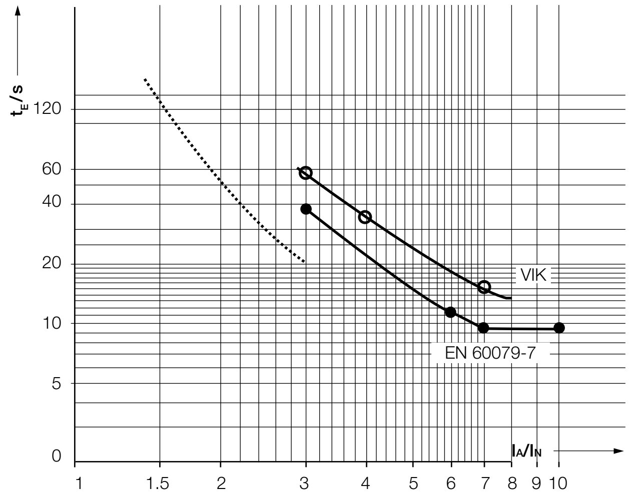


Figure 2.4: Tripping characteristic curve for current-dependent motor protection devices complying with EN 60079-7 and VIK Recommendation VE1-2011

In Figure 2.3 we see the worst fault in thermal terms for a machine, the motor locking at operating temperature. The motor protection must switch off the motor within the t_E heating period stated on the EC type-examination certificate.

In order to be able to guarantee that it is switched off at the right time, the motor protection device must firstly be correctly set to the motor's rated current. The other condition is that the t_E time calculated by measurement in the case of the motor's measured initial starting current relation should always be higher than the tripping characteristic curve for motor protection relay contained in Standard IEC/EN 60079-7, 5.2.4.4.1 (Figure 2.4). The permissible initial starting current/rated current relation is within the range of 3 – 10 for machines of the Increased safety "eb" type of ignition protection (for VIK motors, this range is limited). In addition to the shutdown of the machine in the cases of "Overload" and "Locking", the following more detailed requirements are made of the motor protection device, in order to guarantee safe operation of the motor:

- Protection against accidental adjustment
- No automatic restart after tripping
- Start monitor
- Short-circuit detection
- Detection of prohibited current imbalances
- Test possibilities
- Detection of safety-specific interior faults and transfer to safe state (shutdown)
- Minimum required: SIL Category 1
- Shutdown within 2 h in the case of overload at 1.2 times motor rated current
- "Thermal Memory" in the case of supply voltage interruptions

2.3.9 Current and temperature monitoring

For special instances of use, it is advisable to protect the motor by a direct temperature monitor in addition to the current monitor. Such a case occurs if, for example, operation results in having to deal with excessive ambient temperatures or blocking of the cooling air routes at the motor's installation site. In the case of this "hybrid protection" (Figure 2.5) the PTC thermistor does not have to be designed for sole protection, as overload and locking are detected by the current monitor.

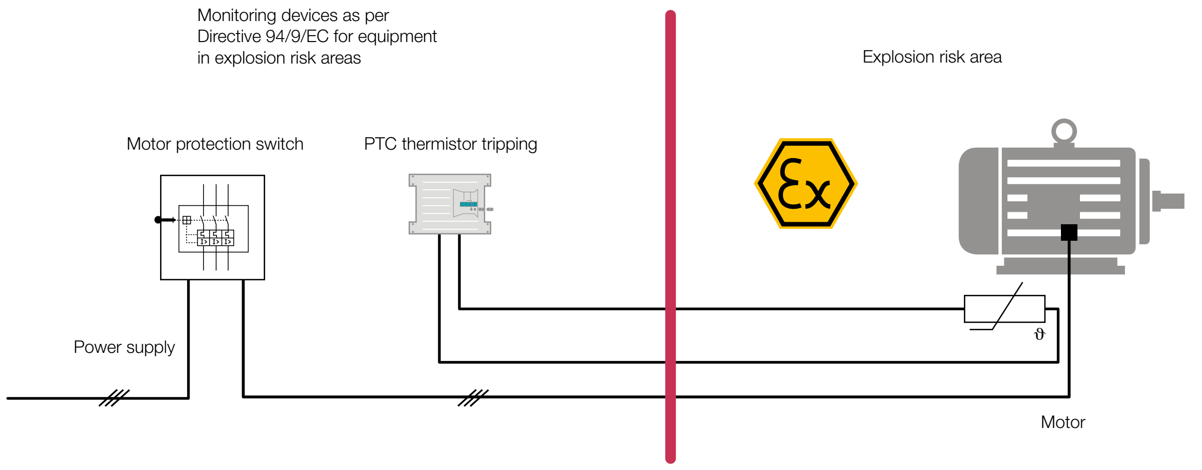


Figure 2.5: Motor protection by current and temperature monitoring

2.4 The motor in combination with other equipment

If the motor is directly connected to the machine, which happens very frequently in practice, it is no longer sufficient to consider the motor as detached from the environment, from a thermal point of view. This is particularly the case if the machine reaches a higher temperature than the motor and heat flows materialise towards the motor. In the case of a pump, this can occur when hot substances are being pumped. Figure 2.6 illustrates the situation.

When considering the combination of motor and pump, not only the temperature category of any gases has to be taken into account, but also the limit temperatures of the motor's components and attachments. In this case, the bearing in particular should receive the necessary attention, if heat flow caused by the shaft is expected. Excessive bearing temperatures may result in a premature failure of the bearing possibly combined with combustible conditions.

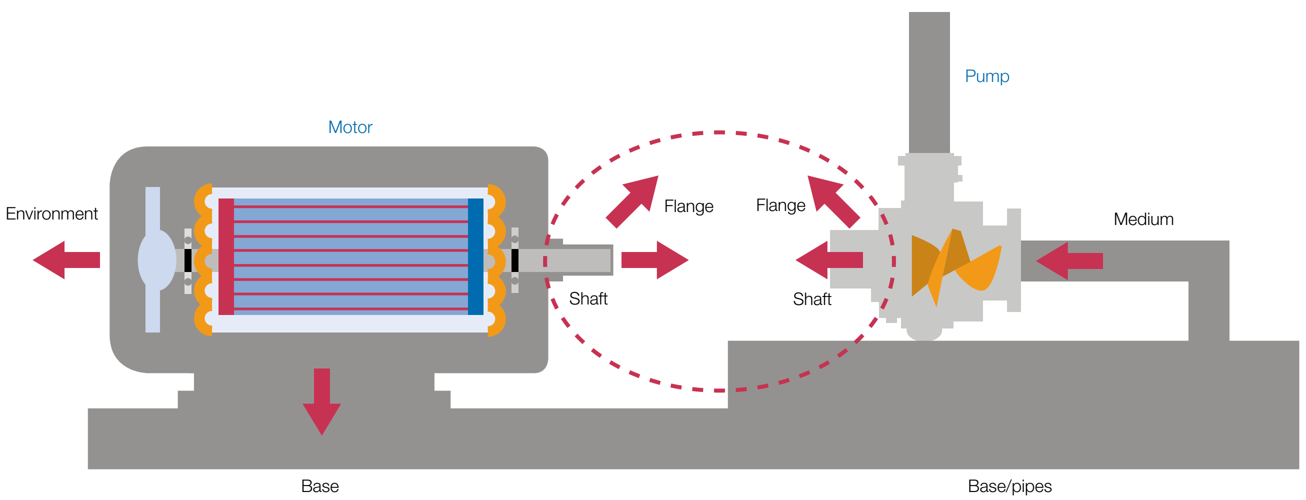


Figure 2.6: Motor-pump assembly

The motor with gearbox connected is another very common combination. In this case also, the gearbox temperature rise must be taken into account in the selection and design of the drive. This does not apply if motor and gearbox have been obtained from the manufacturer as one unit.

In accordance with Figure 2.7 the gearbox is frequently designed as a combination of "Structural Safety" and "Fluid encapsulation" types of ignition protection.

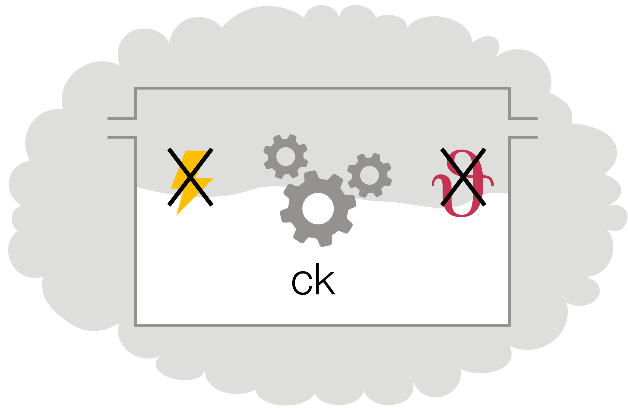


Figure 2.7: Combination of the "c" and "k" types of ignition protection with a gearbox ("c" and "k"… mechanical explosion protection)

Directive 2014/34/EU details the following possibilities for assembling two devices (e. g. motor and pump):

1. Motor and pump cannot be assessed separately: the combination is subjected to the conformity evaluation process for electrical equipment.
2. Motor and pump may be assessed separately: If no other ignition dangers occur, the unit does not come under the directive's area of application; a unit is produced which consists of two individual devices which each have a separate declaration of conformity.
3. The assembly's manufacturer wishes to submit a comprehensive declaration of conformity: obligation to carry out an ignition risk evaluation; creation of documentation; CE label and declaration of conformity; manufacturer bears full responsibility; third-party certification not necessary
4. Additional ignition hazards resulting from a combination or a component is not in full compliance with the directive: **The combination must be subjected to the complete conformity evaluation process.**

In addition to the thermal influences already described, all other values affecting explosion protection must be taken into account. Here the devil is often in the detail. Thus, for example, the topic of "Electrostatics" must be subjected to consideration besides the effects on motor cooling when attaching a plastic noise protection cover.

2.4.1 Recommended maximum interface temperatures for flange motors

As a result of connection to machines, temperatures above 40 °C may occur in flange motors, both on the flange and on the shaft end. It is required of motors of Ex d and Ex e type of ignition protections in accordance with VE 1/NE 47 that they still adhere to the conditions of explosion protection, as long as the interface temperatures specified below are not exceeded.

Note 1: The specified limit values are published in agreement between VDMA and ZVEI as a VDMA standard sheet for pumps built as a block assembly.

Note 2: With the exception of the specified interface temperature, no other real heat input to the machine's active parts from shaft end and flange is expected.

2.4.1.1 Machines of type of ignition protection – Flameproof enclosure "db" in mains operation

Temperature category	T3	T4	T5	T6
max. shaft temperature	100 °C	100 °C	85 °C	70 °C
max. flange temperature	100 °C	100 °C	85 °C	70 °C

General conditions:
- Maximum permissible temperatures on shaft end and motor flange
- No converter mode
- Self-ventilated
- Size from 63 to 200, motors in accordance with EN 50347
- Applies to ambient temperatures from -20 °C to +40 °C
- 2 and 4 pole motors

2.4.1.2 Machines of type of ignition protection – Flameproof enclosure "db" in converter mode

Temperature category	T3	T4	T5	T6
max. shaft temperature	100 °C	100 °C	- *)	- *)
max. flange temperature	100 °C	100 °C	- *)	- *)

*) still under discussion

General conditions:
- Maximum permissible temperatures on shaft end and motor flange
- Adjustment range from 10 Hz to f_N (≦ 60 Hz)
- Self-ventilated
- Size from 63 to 200, motors in accordance with EN 50347
- Applies to ambient temperatures from -20 °C to +40 °C
- 2 and 4 pole motors
- Individual test necessary

2.4.1.3 Machines of type of ignition protection – Increased safety “eb”, temperature category T3

Pole number	2-pole	4-pole
max. shaft temperature	60 °C	75 °C
max. flange temperature	60 °C	75 °C

General conditions:
- Maximum permissible temperatures on shaft end and motor flange
- No converter mode
- Self-ventilated
- Size from 63 to 200
- Motors in accordance with EN 50347 and DIN V 42673-2 (formerly DIN 42677-2)
- Applies to ambient temperatures from -20 °C to +40 °C

3 Frequency-converter operated explosion-protected drives and safety measures

In the case of Flameproof enclosure “d” and Pressurized enclosure “p”, the explosion protection principle is based on the fact that either an explosion occurring in the housing interior is not transferred to the surrounding atmosphere (Flameproof enclosure “d” type of ignition protection) or else the explosive atmosphere cannot penetrate the housing interior during operation (Pressurized enclosure “p” type of ignition protection). With these types of ignition protection, the temperature of the exterior surfaces, which must not exceed the temperature category’s limit temperature, is the decisive criterion. In the case of the Pressurized enclosure “p” type of ignition protection, there is the addition of the limiting condition for the maximum temperatures in the housing interior that the residual heat stored cannot ignite diffusing gas if there is a failure of the ignition protection gas supply and the motor is switched off. In the case of the Flameproof enclosure “db” type of ignition protection, suitability for operation on the frequency converter is certified across-the-board in the EU type-examination certificate by the notified body. The same applies to the Pressurized enclosure “p” type of ignition protection.

The interior temperatures are otherwise not relevant to explosion protection. There must, however, be a guarantee in terms of operating safety and availability that the permitted operating temperatures of the insulation materials and other installed components are not exceeded. These motors are protected by PTC thermistors in a similar way to the mains-operated motor, with evaluation unit embedded in the winding. Slot resistance thermometers may be used as an alternative.

With the Increased safety “eb” type of ignition protection, the equipment’s explosion protection is based on the prevention of an explosive atmosphere igniting, whereby the explosive atmosphere can also penetrate the equipment’s interior. With an asynchronous motor, the possible ignition sources are hot surfaces, mechanically-produced abrasion and impact sparks and electrical discharges. In order to eliminate them, increased requirements of the mechanical structure and design of the electrical insulation system, as well as protection from prohibited high temperatures, are necessary in the case of explosion-protected motors. With frequency converter operated machines, there are additional dangers of ignition due to “Electrical Discharges” and “Hot Surfaces” ignition sources compared with mains operation, ignition dangers which must be taken into consideration for the machine’s design and for certification.

3.1 Electrical discharges

Caused by the power transistors’ fast switching operations and thus high voltage increase speeds, travelling wave processes form on the motor wiring, whereby the motor’s and converter input’s impedances, effective for the high-frequency processes, differ from the wiring’s wave impedance. $Z_{motor} >> Z_{wiring}$ generally applies, so that a reflection factor of approximately 1 is produced for the voltage wave running in the direction of the motor and the wave is reflected. In the case of electrically long wires compared to the frequency of these travelling wave processes, transient voltage peaks occur as far as the double intermediate circuit voltage on the motor terminals (Figure 3.1). The clearances in the machine’s terminal box would have to be sized to the transient overvoltages, whereas the creepage distances in accordance with IEC/EN 60079-7 must be designed only for the converter output voltage’s RMS value. In accordance with IEC/EN 60079-7, short-term voltage peaks do not result in the formation of erosions caused by leakage currents on the surface.

With low voltage machines, it has proved effective in practice to design the terminal box’s rated voltage according to the frequency converter input voltage, as long as no transient overvoltages occur at an amplitude higher than the double intermediate circuit voltage. If multiple reflections and thus higher voltages are to be expected, the next highest rated voltage step must be chosen for the terminal box. This procedure is recommended by the PTB.

It is also very important, however, for the winding insulation to be designed for these high, steep-flank voltage pulses. The winding insulation in the winding input zone is also severely stressed, as a major proportion of the voltage is cleared here. If partial discharges occur here, that results in destruction of the organic enamelled wire insulation over sustained periods and finally in an ignitable flashover and failure of the motor. If the motor manufacturer cannot guarantee absence of partial discharge, a filter must be connected upstream, in order to reduce the winding’s voltage stress.

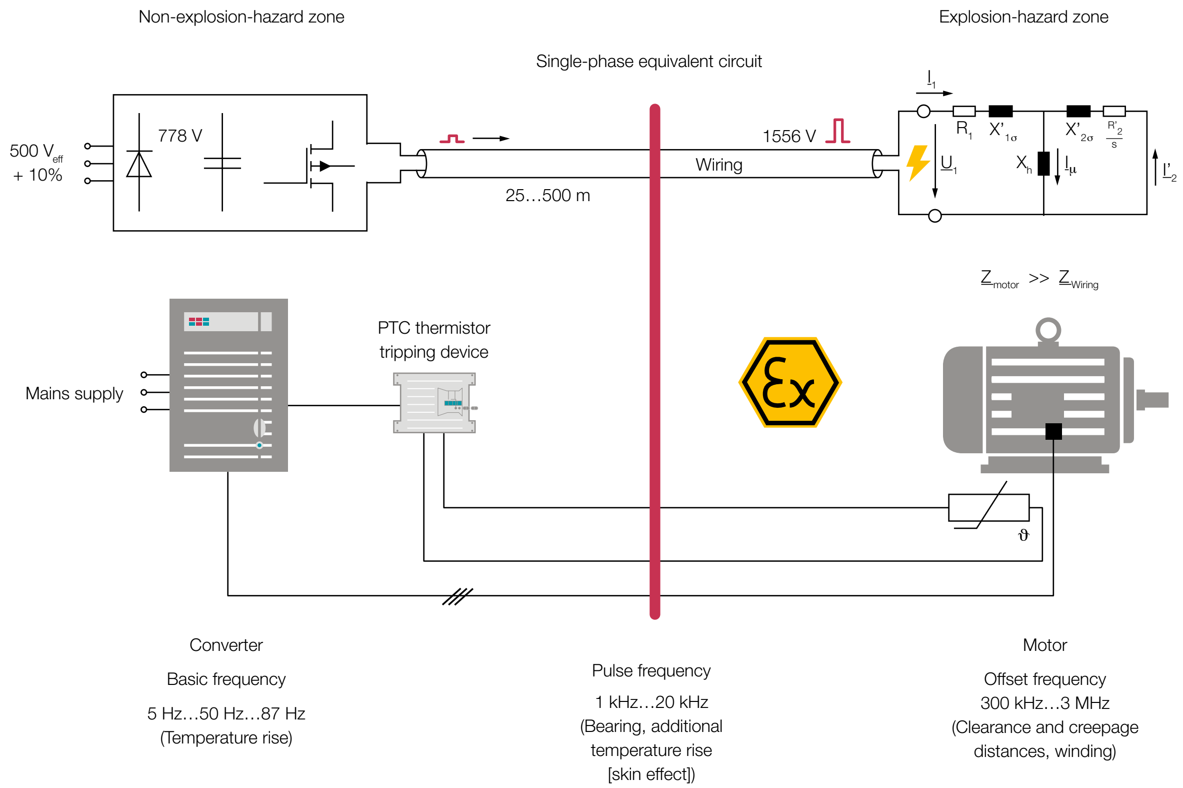


Figure 3.1: Development of transient overvoltages on a frequency-converter operated drive

3.2 Hot surfaces

If an electrical machine takes on a prohibited temperature, the reasons are either an excessive heat loss inside the machine, for example, as a result of overload, or insufficient cooling. Reason for a prohibited overload, especially in the machine’s rotor, may also be expected beyond the motor’s specifications, for example, at undervoltage.
These effects must be overcome by technical protection devices and operating parameter limits specified in the EU type-examination certificate and dangers of ignition must be eliminated. In addition to the the limitation imposed by the temperature category, the continuous duty temperatures of the winding insulation, seals and other attachments must not be exceeded, in order to prevent premature ageing, along with possible ignitable failure. With the indirect voltage link converter normally used today, additional temperature rises in the motor caused by the harmonics are very rare, even without sine wave output filter, and are less than 10 K in most cases in the PTB-inspected motors complying with the permitted operating parameter limits. In the design of the converter in accordance with the specifications of the EU type-examination certificate for the motor, the “locked motor” fault does not have to be considered. For that reason, the temperature reserve maintained for it may be distinctly reduced. On the other hand, a very important point is the increase in the thermal resistance to the environment with a reduction in speed in the case of self-ventilated machines. In Figure 3.2, this relation is applied to two machines of sizes 180 and 132.

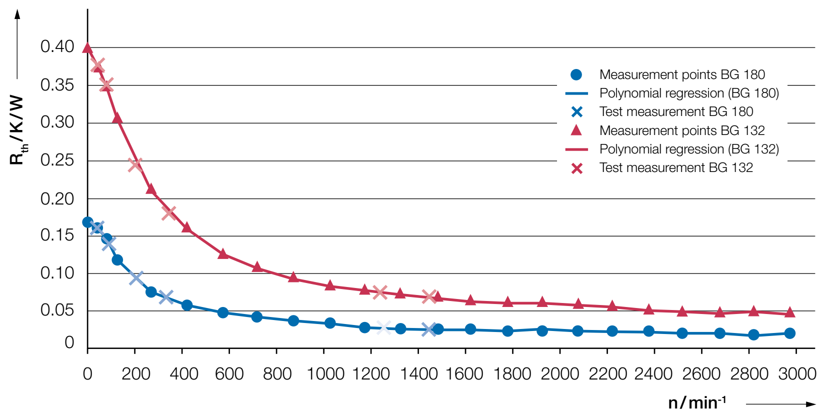


Figure 3.2: Characteristics of thermal resistance to the environment depending on speed

This effect is considered in the new testing and certification concept for frequency converter operated drives, of the Increased safety "eb" type of ignition protection, by a variable speed current limit in the frequency converter. In Figure 3.3, the maximum machine current related to the rated current of a machine of size 132 is shown as an example. All the operating points below the curve are permanently permissible but those above the line are only permissible for a limited time, which is calculated in dependence on the overload. With a machine current greater than the 1.5-times rated current, an immediate shutdown occurs.

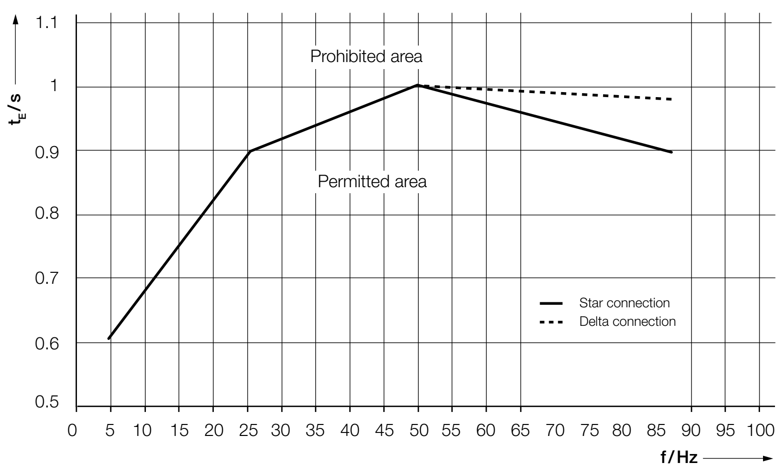


Figure 3.3: Variable speed current limitation, from the EC type-examination certificate

The nodes in the curves have been detected by measurements in the PTB. In addition to this protection by means of frequency-dependent current monitor, a second protective device is required, certified as a monitoring device in accordance with Directive 2014/34/EU, as the frequency converter is not certified and that is also not desired by the manufacturers. This protective device amounts in most cases to direct temperature monitoring via triple PTC thermistor with tested PTC thermistor evaluation device. The direct temperature monitoring has a further advantage in that other faults, such as a blocked fan grid or excessive ambient temperatures, are detected.

Also very important for safe operation is compliance with the motor's operating parameters specified in the data sheet, whereby the fundamental oscillating voltage on the motor terminals is given particular significance. If, for example, the voltage drop on the converter and the motor connection cables is not adequately taken into account, the motor slip increases in the case of unmodified torque and the rotor, in particular, heats up very intensively.

The voltage drop must also be taken into account in any case if a sine output filter to reduce overvoltages is connected between motor and frequency converter.

Figure 3.4 illustrates the situation. The motor has to be authorised for the expected motor terminal voltage or the edge frequency adapted accordingly.

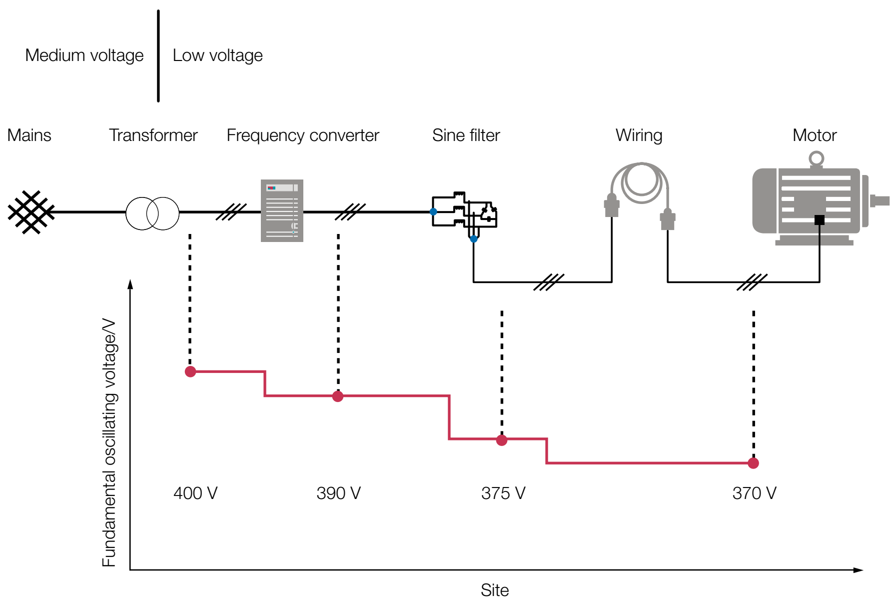


Figure 3.4: Voltage drops between mains and motor

3.3 Harmonic losses

A further source of losses and thus of temperature rises with a frequency converter operated drive are the harmonic losses caused by the frequency converter input. This is caused by the voltage harmonics contained in the motor's supply voltage which contribute nothing to the motor's torque but, however, result in current flowing through the motor and thus in losses both in the iron (eddy losses) and in the stator winding and the rotor cage (ohmic losses). Graphically presented, the machine may be subdivided into the "fundamental mode motor" formed by the torque and multiple "Harmonic motors" arranged on the shaft, whereby the superposition principle is applicable because of the different frequencies. It can be seen very clearly from this graphic presentation that the harmonics losses increase both with the number of harmonic occurring and with their amplitude. Here it becomes clear that the frequency converter input voltage or the difference between the RMS value and the motor voltage's fundamental oscillation value have a direct effect on the harmonic losses, as shown by the measurement in Figure 3.5.

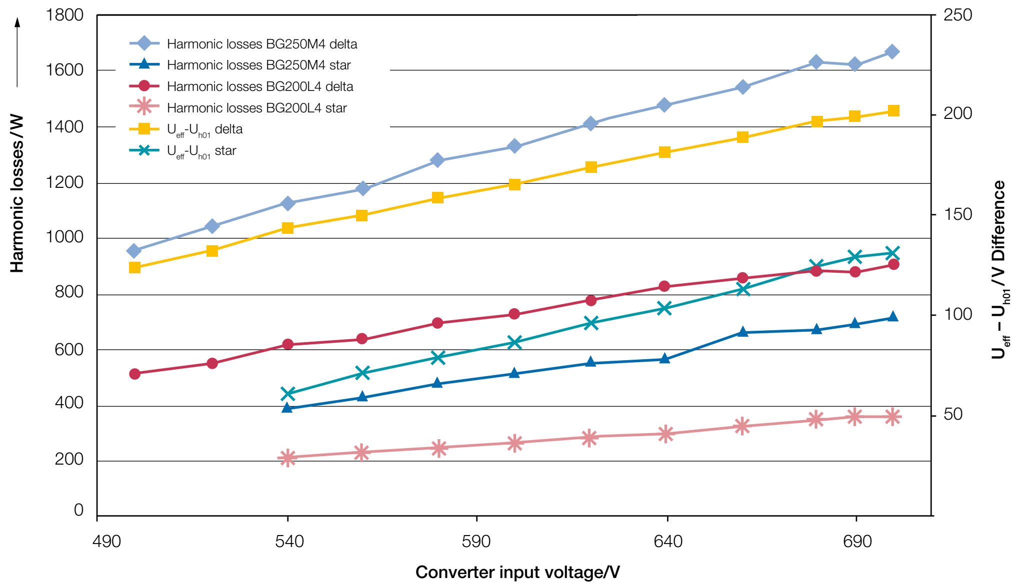


Figure 3.5: How the harmonic losses depend on the converter input voltage

To limit the harmonic losses it is, therefore, necessary to limit the converter's supply voltage. This value is thus also listed in the EU type-examination certificate. If these specifications are observed, the harmonic losses are slight compared with the fundamental mode losses (below 10%) and do not result in prohibited temperature rises.

3.4 Increase in energy efficiency

This new approach will also contribute to an increase in the proportion of frequency converter operator drives in the chemical industry, as a result of which extremely high energy-saving potential is produced, particularly in the case of the drive for fluid flow machines. The result of a comparison of the energy efficiency of the flow rate adjustment by bypass or reducing valve and the pump's direct speed adjustment by means of frequency converter is shown in Figure 3.6. The general conditions adopted were the pump's rated output of 50 m³/h at a pressure of 7 bar. A flow rate of 30 m³/h required by the process was applied for the consideration in Figure 3.6. At assumed 5,000 part load annual operating hours and a motor rated output of 18 kW, the amortisation period for the frequency converter is often less than one year, at today's energy prices.

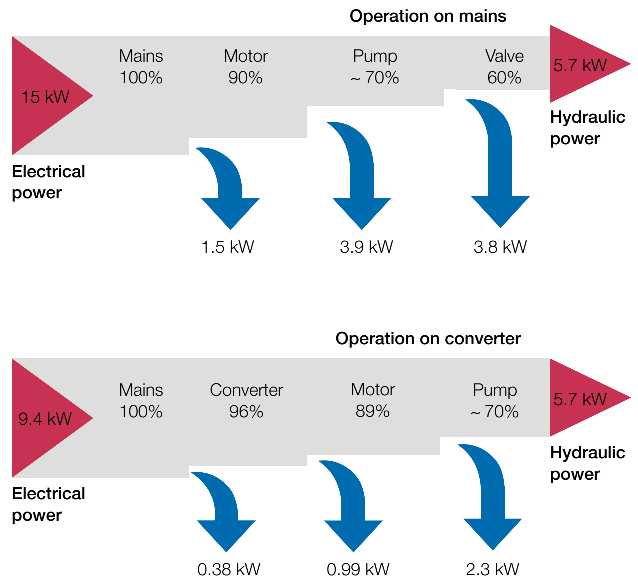


Figure 3.6: From electrical to hydraulic power

All in all, the energy-saving compared to the flow rate adjustment by means of valves with increasing pump throttling, i. e. reduced flow rate, increases. If the pump is operated in the unthrottled state, the other hand, insignificantly higher losses compared to direct mains operation are produced because of the converter's losses and the motor's harmonic losses.

If, because of the process, the pump is constantly driven at its rated flow rate, retrofitting of a frequency converter is not advisable.
Figure 3.7 shows the estimated amortisation period for a frequency converter (purchase price 2000 €) depending on the flow rate (motor output 18 kW and kWh price 0.19 €/kWh).

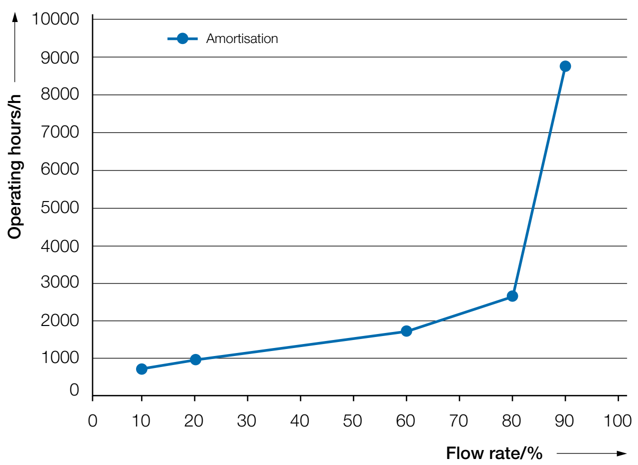


Figure 3.7: Frequency converter amortisation period (purchase price 2000 €) depending on relation of flow rate to rated flow rate.

In actual use, it is highly improbable that the pump is constantly operated at the same hydraulic capacity over the period. It is much closer to practice to adopt various load profiles for an estimation of the energy-saving potential, with each expressing the dividing-up of various capacities over the total operating period of one year.

For the assessments carried out in this case, the three load profiles shown in Figure 3.8 were adopted. In that case a pump period of use of 5000 hours in total within one year was assumed. The bars show the time proportion of the hydraulic capacities (50, 30, 10, 5 m^3/h) with the rated flow rate amounting to 50 m^3/h.

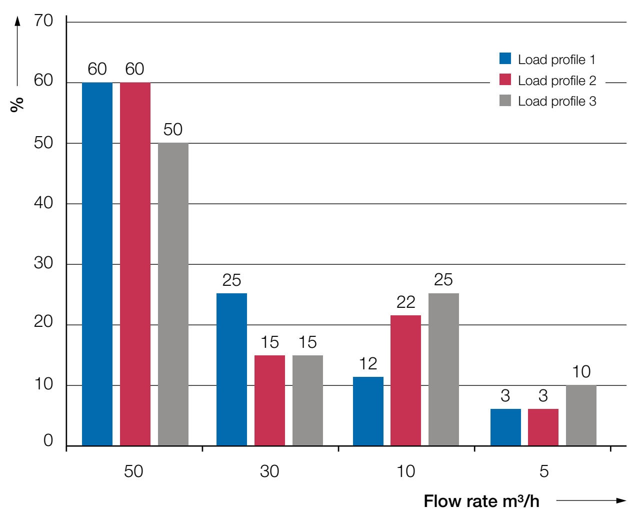


Figure 3.8: Classification of the hydraulic capacity by time

If the costs occurring over the period for the mains operation and for the operation on the frequency converter are calculated adopting the load profiles shown in Figure 3.8, then because of the simplified adoption of constant motor output for mains operation (flow rate adjustment by a bypass valve), a straight line is produced running through the coordinate origin, with the energy costs per time unit as the incline (mains operation costs).

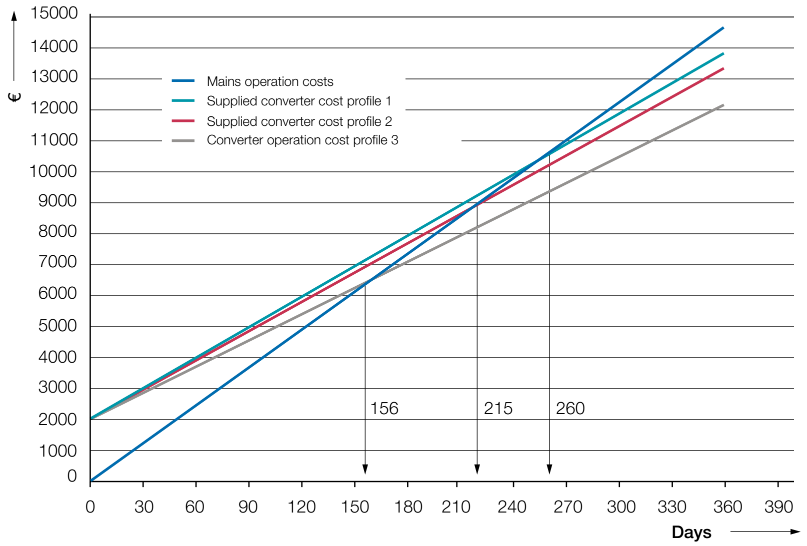


Figure 3.9: Energy cost characteristics over the period for mains operation and for frequency converter operation. Frequency converter purchase cost: 2000 €

The costs in the amount of 2000 € for the converter-operated drives, already generated at t = 0 time, correspond to the accepted purchase costs of the frequency converter. As indicated by the dotted lines, the amortisation period in days is produced from the points of intersection of the straight lines for converter operation and mains operation.
By means of the relation shown in Figure 3.9, the amortisation periods for any investment costs (parallel move of the "converter curves") and for other, possibly more favourable methods (in terms of energy) for conventional flow rate adjustment (flattening of the "mains curve") may be determined.

But even with a considerable extension of the amortisation periods, the use of frequency converters for driving fluid flow machines is associated in most cases with major financial savings and other advantages, for example, optimisation of process management and prevention of voltage drops on starting high-output pumps.

3.5 Summary and outlook

Experience to date with the new testing and certification concept for frequency-converter operated drives of the Increased safety "eb" type of ignition protection is extremely promising and it is apparent that certification for operation on the converter up to Temperature Category T3 is easily possible. A requirement of safe operation, however, is that the motor's operating parameters specified in the data sheet are observed and the winding is suitable for the voltage pulses which occur.

A motor protection device for converter operated drives is currently being developed in collaboration with a certain company. When the device is in use, frequency converters without variable speed current limitation can also be used and the PTC thermistor is also no longer necessarily required. Figure 3.10 shows the protective device's possible use.

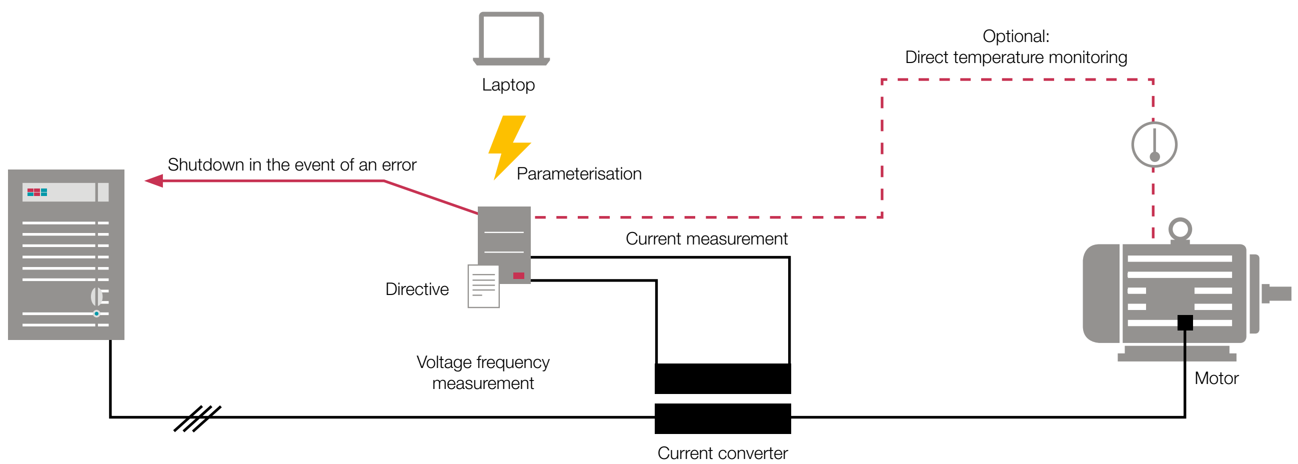


Figure 3.10: Monitoring the motor in converter mode

The following may be stated in summary:

3.6 Operation on frequency converter with use in Zone 2 (Ex II 3G) or Zone 22 (Ex II 3D)

Operation on the frequency converter is only possible within the operating points specified on the nameplate. It is permitted to exceed the machine rated current up to 1.5 times the rated current for a maximum of 1 min with a time interval of 10 min. By no means can the specified maximum speed or frequency be exceeded. By selecting a suitable converter and/or using filters, it can be guaranteed that the maximum permitted pulse voltage on the motor terminals is not exceeded.

It is necessary to ensure that the operating voltage at the motor terminals complies with the specifications on the nameplate (watch out for voltage drop because of filter!). Thermal winding protection must be assessed either by a separate tripping device or by the converter.

3.7 Operation on frequency converter with use in Zone 21 (Ex II 2D)

It is mandatory that motors for use in Zone 21 be certified by a notified body for operation on the frequency converter. It is imperative that the limit values specified on the nameplate and on the EU type-examination certificate are observed. This also means, in particular, monitoring the motor current depending on the frequency. Only frequency converters which meet the requirements stated in the EU type-examination certificate may be used.

3.8 Operation on frequency converter with use in Zone 1 (Ex II 2G)

It is mandatory that motors of the Increased safety "eb" type of ignition protection for use in Zone 1 are certified by a notified body for operation on the frequency converter. It is essential that the limit values specified on the nameplate and on the EU type-examination certificate are observed. In particular, this means monitoring the continuous current depending on the frequency. Only frequency converters which meet the requirements stated on the EU type-examination certificate may be used. The thermal winding protection installed must be evaluated by a tripping unit meeting the requirements of Directive 2014/34/EU, using the Ex labelling II (2) G. By no means can the specified maximum speed or frequency be exceeded. The maximum permitted pulse voltage of 1560 V must be limited on the motor terminals by selecting a suitable converter and/or using filters. It is necessary to ensure that the operating voltage at the motor terminals complies with the specifications on the nameplate (watch out for voltage drop because of filter!). If the terminal voltage on the motor is less than the rated voltage specified on the nameplate, because of voltage drops caused by the frequency converter, wiring and possible throttles or filters, the edge frequency must be set to a lower value corresponding to a linear voltage/frequency allocation. This produces a lower possible speed range.

Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin

Datenblatt 03 zur EG-Baumusterprüfbescheinigung PTB 07 ATEX 3143 X

der Firma VEM Motors GmbH,
Carl-Friedrich-Gauß-Str. 1, 38855 Wernigerode, Deutschland

für Drehstrom-Asynchronmotor Typ K11R 180 L6 ExeII

Bemessungsgrößen und Daten

Diese Bescheinigung gilt unter der Voraussetzung, dass sich die Motoren dieses Typs hinsichtlich der elektrischen und thermischen Beanspruchung nur unwesentlich von dem geprüften Muster unterscheiden, für die folgenden Ausführungen:

Sternschaltung

Drehmoment:	80	130	150	90	Nm
Leistung:	0,68	6,5	15	15,8	kW
Spannung: *)	40	200	400	400	V
Strom:	18,5	26	29,2	31,9	A
Frequenz:	5	25	50	87	Hz
Drehzahl:	81	475	972	1672	min^{-1}
Betriebsart:		S1			
Wärmeklasse:		F			

Dreieckschaltung

Drehmoment:	80	130	150	140	Nm
Leistung:	0,68	6,5	15	25,2	kW
Spannung: *)	23	115	230	400	V
Strom:	32	45	50,6	48,5	A
Frequenz:	5	25	50	87	Hz
Drehzahl:	81	475	972	1712	min^{-1}
Betriebsart:		S1			
Wärmeklasse:		F			

*) Grundschwingung, an den Motorklemmen gemessen.
Die Spannung ist von der Umrichtereingangsspannung, dem Spannungsabfall am Filter und über der Motoranschlussleitung abhängig und darf den Bemessungswert auch bei minimaler Umrichtereingangsspannung um nicht mehr als 5 % entsprechend IEC 60034 – 1 Bereich „A" unterschreiten. Dies ist bei der Motorauslegung, der Umrichterparametrierung (z. B. U/f – Anpassung) und bei der minimalen Umrichtereingangsspannung zu berücksichtigen. Die maximale Eingangsspannung des Umrichters beträgt 500 V.

Eine Anpassung der Bemessungsspannung des Motors ist über die Windungszahl der Wicklung zulässig. Der Bemessungsstrom ändert sich im reziproken Verhältnis zur Bemessungsspannung.

Blatt 1/3

Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin
Datenblatt 03 zur EG-Baumusterprüfbescheinigung PTB 07 ATEX 3143 X

Überwachungseinrichtung

Gegen unzulässige Erwärmung infolge Überlastung werden die Motoren durch eine Einrichtung zur direkten Temperaturüberwachung verbunden mit festgelegten Einstelldaten des Umrichters überwacht.

Wegen der Besonderheiten der Motoren mit Umrichterspeisung und der angepassten Überwachungseinrichtung entfallen für die Motoren mit dem Umrichterbetrieb die Angaben über das Verhältnis I_A/I_N und die Erwärmungszeit t_E.

Die Einrichtung zur direkten Temperaturüberwachung ist von der Physikalisch-Technischen Bundesanstalt typengeprüft und besteht aus drei in die Wicklung eingebauten Kaltleitern DIN 44082 Typ S 130 sowie einem nach der Richtlinie 94/9/EG hierfür funktionsgeprüften Auslösegerät.

Bei einem Strangstrom von 174 A und blockierter Welle muss der Kaltleiter nach 42,4 s (± 20 %) ausgehend vom kalten Zustand (20 °C) ansprechen.

Durch die Temperaturüberwachungseinrichtung wird gemäß EN 60079-7 die Temperaturklasse **T3** eingehalten.

Umrichtereinstelldaten

In Verbindung mit der vorgenannten Überwachungseinrichtung sind folgende Umrichterdaten einzustellen und im Betrieb einzuhalten:

Minimale Taktfrequenz:	3	kHz
Stromgrenze kurzzeitig:	$1{,}5 \cdot I_N$	
Maximale Überlastzeit:	60	s
Minimalfrequenz f_{min}:	5	Hz
Maximalfrequenz f_{max}:	87	Hz
Zulässige Dauer für den Betrieb unter f_{min}:	60	s

Die maximale Überlastzeit und die zulässige Dauer für den Betrieb unter f_{min} beziehen sich auf ein Zeitintervall von 10 min.

Das Drehmoment in Abhängigkeit der Frequenz ergibt sich aus der zulässigen Dauerstromgrenze.

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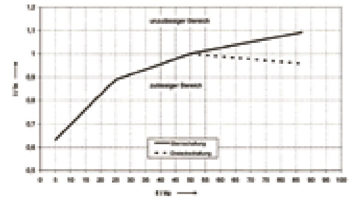
Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin

Datenblatt 03 zur EG-Baumusterprüfbescheinigung PTB 07 ATEX 3143 X

Die Dauerstromgrenze des Frequenzumrichters muss gemäß dem folgenden Diagramm in Abhängigkeit der Frequenz eingestellt werden:



Einstellparameter für die Dauerstromgrenze des Frequenzumrichters zwischen 5 Hz und 87 Hz

Alle übrigen Einstelldaten sind den Erfordernissen des Antriebs entsprechend zu wählen.

Besondere Bedingungen

Ein Gruppenbetrieb der Motoren ist nicht zulässig.

Die Motoren dieses Typs dürfen nur an Umrichtern betrieben werden, die die oben unter "Umrichtereinstelldaten" genannten Anforderungen erfüllen.

Der Bemessungsstrom des Frequenzumrichters darf maximal dem zweifachen Motorbemessungsstrom entsprechen.

Die Stromüberwachung des Frequenzumrichters muss den Effektivwert des Maschinenstromes mit einer Toleranz von ± 5 % bezogen auf den Motorbemessungsstrom erfassen

Vor der Inbetriebnahme ist sicherzustellen, dass an den Klemmen der elektrischen Maschine keine umrichterbedingten Überspannungen mit einem Scheitelwert von mehr als 1556 V ($2 \cdot \sqrt{2} \cdot 550V$) auftreten.

Bewertungs- und Prüfbericht PTB Ex 09-39060

Zertifizierungsstelle Explosionsschutz
Im Auftrag

Dr.-Ing. F. Lienesch
Regierungsdirektor

Braunschweig, 23. Juli 2009

Blatt 3/3

Figure 3.11: Example of an EC type-examination certificate of Increased safety "eb" type of ignition protection for operation on the frequency converter.

3.9 Permanent-magnet synchronous machines/reluctance machines

Synchronous machines as such have been known since the beginnings of electrical drive engineering as a machine type which is used for high-power motors in the form of an externally excited synchronous motor. All high-power generators in thermal power stations and hydropower stations are likewise based on this function principle. The normative demands placed on this machine type are described in the standard IEC/EN 60034-1.
In a permanent-magnet synchronous machine, the DC rotor winding required to excite the magnetic field is replaced with permanent magnets. In the field of positioning drives (e.g. robot arms in the automotive industry), permanent-magnet synchronous machines have already represented the state of the art for several years.

It is generally possible to use permanent-magnet synchronous machines and reluctance machines in areas subject to explosion hazards, but each individual case must be analysed separately with regard to machine design and the potential ignition sources, in order to determine the scope of testing to be performed by the notified body.

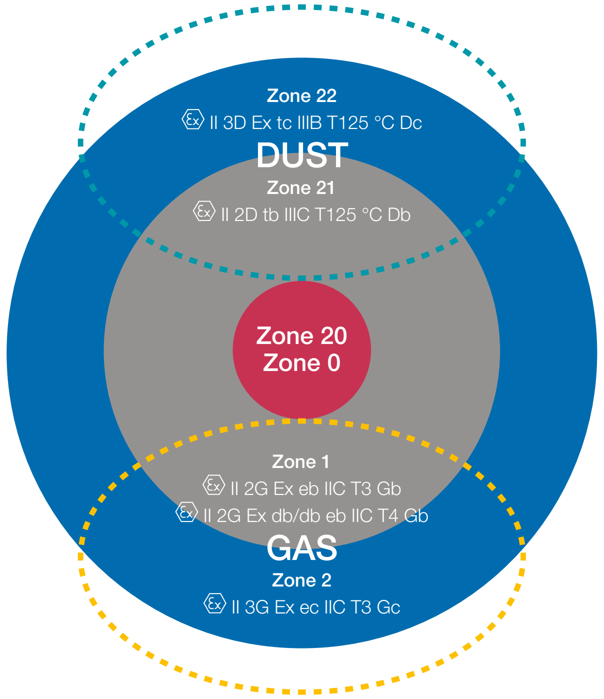
The current harmonised standards IEC/EN 60079-7 and IEC/EN 60079-0 do not address the special requirements of these machines in respect of increased safety – type of ignition protection "eb". At IEC level, too, no normative specifications exist with regard to the testing of permanent-magnet synchronous machines.

Explosion-protected permanent-magnet synchronous machines and their testing are the subject of a current PTB research project.

4 The VEM product range of explosion-protected equipment

4.1 Overview

The extensive range of VEM low voltage motors provides the chemical industry with a wide selection of explosion-protected motors of the various types of ignition protection for gas and dust explosion-protected areas. The following type of ignition protections are included in the range:



Explosion-protected three-phase asynchronous motors with squirrel-cage rotor for low voltage
- Increased safety "eb" type of ignition protection Ex e II complying with IEC/EN 60079-0 / IEC/EN 60079-7
- Flameproof enclosure "db/db eb" Ex d/de complying with IEC/EN 60079-0 / IEC/EN 60079-1
- Increased safety "ec" (old: "n") type of ignition protection complying with IEC/EN 60079-0 / IEC/EN 60079-7 (old: IEC/EN 60079-15)
- Motors for use in areas with combustible dusts Ex II 2D, Ex II 3D complying with IEC/EN 60079-0 / IEC/EN 60079-31, IEC/EN 61241-1, EN 60079-0/EN 60079-31
- Motors for optional use in gas and dust explosion protection 2G or 2D, 3G or 2D and 3G or 3D

VEM has been supplying these drives for decades. They are tested and certified by the following bodies:
- **Physikalisch-Technische Bundesanstalt Braunschweig (Notified body No. 102),**
- **IBExU Freiberg (Notified body No. 0637)** or
- **DMT Gesellschaft für Forschung und Prüfung mbH (Notified body No. 0158), now DEKRA EXAM GmbH.**

These test certificates are recognised by all European Union member states. The members of CENELEC who do not belong to the EU also accept them. In the case of special designs which affect explosion protection (other frequency, output, coolant temperature, use on the frequency converter, etc.), an additional or new certificate may be necessary.

4.2 Energy efficiency and explosion protection

While the questions of classification of energy-saving motors in Europe used to be settled on a voluntary basis by the Voluntary Agreement (Degree of Efficiency Categories EFF1, EFF2 and EFF3), the latter has now been replaced by IEC/EN 60034-30-1: "Degree of Efficiency Classification of Three-Phase Motors with Squirrel-Cage Rotors, with the Exception of Pole-Changing Motors (IE Code)". For 2-, 4- and 6-pole motors in the 0.75 kW–375 kW output range, this standard specifies the minimum efficiency factors for Degree of Efficiency Category IE1 (standard degree of efficiency), IE2 (higher degree of efficiency) and IE3 (premium degree of efficiency). It should be noted that the measurement procedures for determining the degree of efficiency have changed with the switch to this standard. Where EN 60034-2, with which the additional losses were calculated across-the-board at 0.5% of input power, used to be applied, the new rules provide for IEC/EN 60034-2-1 to serve as the basis for determining the degree of efficiency; the additional losses are calculated by testing, in this case.

Motors for operation in explosive atmospheres (IEC/EN 60079) are also addressed by the efficiency classifications defined in IEC/EN 60034-30-1 (IE1...IE4). This includes all types of ignition protection relevant to electrical equipment, such as Flameproof enclosure "db", Increased safety "eb", Increased safety "ec" (old: "n") and protection by housing "tb" and "tc". It is true that no minimum degrees of efficiency are applicable to such equipment under Regulation (EC) No. 640/2009 and Regulation (EU) No. 4/2014, but energy efficiency is nevertheless also a topic in this product segment, not least due to the demands of the chemical industry. From the design point of view, motors for the Ex d/d, Ex ec and dust explosion protection types are not complicated. There is no separate size/output allocation compared with the standard motors; the electrical design is identical. That means that EN 50347 can be applied in full to these motors. With these types of ignition protection, the explosion protection concentrates primarily on special design measures such as the use of certified components, special connection systems, increased clearance and creepage distances, questions of electrostatic charges with fans, compliance with certain minimum degrees of IP protection and questions of materials (especially ageing and the temperature resistance of seals). The temperature limitation measures at the surfaces of the motors and in the interiors also do not contradict high degrees of efficiency. For this reason, it has already previously been possible to find motors with enhanced degrees of efficiency in the market for these types of ignition protection.

VEM motors from the WE.R energy-saving series with types of ignition protection Increased safety "ec" (old: "n") and Protection by housing "tb" and "tc" have been available for a long time. These motors can be supplied as IE2-W..R/IE2-KPR/KPER and as IE3-W4.R. Motors in Flameproof enclosure "db" in series K82R can also be supplied in classes IE2 (K82R...Y2) and IE3 (K82R...Y3).

The situation is different for the Increased safety "eb" type of ignition protection. Here we have temperature limitation in the case of error, in addition to the measures already mentioned. That means special requirements of the starting current and a guarantee of t_E times that are as long as possible. Further to that, the size/output allocation is governed in Germany by the DIN 42673 and DIN 42677 standards. The active materials in the Increased safety "eb" series will be the same as those in the standard IE2 series in the future. This produces the basic prerequisites for observing the new degree of efficiency categories. Motors of the series K1.R 112-355 could already be supplied for efficiency class IE1 when the stipulations of IEC/EN 60034-30 came into force. In the meantime, motors for efficiency classes IE2 and IE3 are available as the series IE2-K11R.../ IE2-K41R.../ IE2-KPR/KPER... Exe IIC T3 and IE3-K11R.../ IE3-K4.R.../IE3-KPR/KPER... Exe IIC T3. Motors for the Increased safety "eb" type of ignition protection can also be supplied in an IE4 version upon request.

4.3 Gas-explosion protected motors

4.3.1 Motors with squirrel-cage rotor, type of ignition protection – Flameproof enclosure "db/db eb"

Type	K82R and B82R (-Y2, -Y3) (Y2 corresponds to IE2 design and Y3 corresponds to IE3 design)
Sizes	63 – 450
Types of protection	IP 55, IP 56, IP 65 complying with IEC/EN 60034-5
Cooling type	IC 411 complying with EN 60034-6
Designs	IM B3, IM B35, IM B5, IM B14, IM B34 and derived designs complying with IEC/EN 60034-7
Ambient temperatures	-55 °C to +60 °C
Temperature category	T3 to T6

Explosion-protected design in accordance with Equipment Group II, Category 2 Ex db(eb)
IEC/EN 60079-0 General Conditions
IEC/EN 60079-1 Flameproof enclosure "db"

Mounting dimensions and power allocation complying with DIN 42673 page 3 or DIN 42677 page 3

Summary of approvals:

Series and shaft centres	Ex II 2G Ex d(e) IIC T3 – T6	Ex II 2G Ex d(e) IIB+H2 T3 – T6
K82. 63 – 71	PTB09ATEX1017 X	PTB09ATEX1032 X
K82. 80 – 160	PTB09ATEX1018 X	PTB09ATEX1033 X
K82. 180	PTB09ATEX1019 X	PTB09ATEX1034 X
K82. 200	PTB09ATEX1020 X	PTB09ATEX1035 X
K82. 225 – 315	PTB09ATEX1018 X	PTB09ATEX1033 X
K82. 355	PTB09ATEX1021 X	PTB09ATEX1036 X
K82. 400	PTB09ATEX1022 X	PTB09ATEX1037 X
K82. 450	PTB09ATEX1023 X	PTB09ATEX1038 X
B82. 80 - 132		PTB09ATEX1039 X

Example of labelling:
Ex d IIC T4 Gb or: Ex db IIC T4

4.3.2 Motors with squirrel-cage rotor, type of ignition protection – Increased safety "eb"

Type KPR/KPER/IE1-KPR/KPER/IE2-KPR/KPER
K1.R/IE1-K1.R/IE2-K1.R/IE3-K1.R
Size 56 – 355
Types of protection IP 54, IP 55 and IP 65 complying with IEC/EN 60034-5
Cooling type IC 411 complying with EN 60034-6
Designs IM B3, IM B35, IM B5, IM B14, IM B34 and derived designs complying with IEC/EN 60034-7
For assembling motors in designs with vertical shaft position, it is necessary to prevent foreign bodies from falling into the ventilation holes (protective cover).
Explosion-protected design in accordance with Equipment Group II, Category 2 complying with
IEC/EN 60079-0 General Conditions
IEC/EN 60079-7 Increased safety "eb"
Temperature categories T1 and T2, T3 or T4

Mounting dimensions and power allocation complying with EN 50347 (DIN 42673 page 2 or DIN 42677 page 2)

Ambient temperatures -40 °C to +40 °C, with sizes 56 to 112: -20 °C to +40 °C, other values in accordance with amendments and appropriate data sheets or supplementary sheets

The motors' design is tested by the PTB and by the IBExU Institut für Sicherheitstechnik GmbH and certified as follows:

Motor's mechanical components:
EG type-examination certificate IBExU02ATEX1108 U
EG type-examination certificate IBExU00ATEX1083 U
including Supplements 1 to 11

Terminal boxes:
EG type-examination certificate IBExU00ATEX1051 U
including Supplements 1 to 6

The EG type-examination certificates listed below are also available with supplementary sheets on the documentation, for use as intended in explosion areas.

The supplementary sheets on the EG type-examination certificate applicable to the individual models can be found in the approval summary.

Series and shaft centres	EG type-examination certificate	EG(EU) type-examination certificate
(IE.-) KPER 56	PTB99ATEX3308	IBExU02ATEX1109
(IE.-) KPER 63	PTB99ATEX3309	IBExU02ATEX1110
(IE.-) KPER 71	PTB99ATEX3310	IBExU02ATEX1111
(IE.-) KPER 80	PTB99ATEX3311	IBExU02ATEX1112
(IE.-) KPER 90	PTB99ATEX3312	IBExU02ATEX1113
(IE.-) KPER 100	PTB99ATEX3313	IBExU02ATEX1114
(IE.-) KPER 112	PTB99ATEX3314	IBExU02ATEX1115
(IE.-) K1.R 112	PTB09ATEX3004/PTB08ATEX3026X	IBExU02ATEX1153
(IE.-) K1.R 132	PTB08ATEX3037/PTB08ATEX3001X	IBExU99ATEX1142
(IE.-) K1.R 160	PTB08ATEX3038/PTB07ATEX3142X	IBExU99ATEX1105
(IE.-) K1.R 180	PTB08ATEX3039/PTB07ATEX3143X	IBExU99ATEX1138
(IE.-) K1.R 200	PTB08ATEX3040/PTB08ATEX3027X	IBExU99ATEX1143
(IE.-) K1.R 225	PTB08ATEX3041/PTB08ATEX3028X	IBExU99ATEX1144
(IE.-) K1.R 250	PTB08ATEX3042/PTB08ATEX3029X	IBExU99ATEX1131
(IE.-) K1.R 280	PTB08ATEX3043/PTB08ATEX3030X	IBExU99ATEX1030
(IE.-) K1.R 315	PTB08ATEX3044/PTB08ATEX3031X	IBExU99ATEX1137
(IE.-) K1.R 355	PTB08ATEX3032X	IBExU01ATEX1009
(IE.-) K4.R 355		IBExU15ATEX1146
(IE.-) K4.R 400		IBExU15ATEX1075
W52R 355		IBExU15ATEX1179 *)
W52R 400		IBExU15ATEX1180 *)

*) EU type-examination certificate

Example of labelling:
Ex e IIC T3 Gb (alternatively: Ex eb IIC T3)
new complying with IEC/EN 60079-7: Ex eb IIC T3 Gb (alternatively: Ex eb IIC T3)

4.3.3 Motors with squirrel-cage rotor, type of ignition protection – "ec" (old: „n")

Type KPER/KPR/IE1-KPR/KPER/IE2-KPR/KPER
K1.R/W.1R/IE1-K1.R/IE2-W..R/IE3-W4.R
Size 56 – 400
Types of protection IP 54, IP 55, IP 56 and IP 65 complying with IEC/EN 60034-5
Cooling type IC 411 complying with IEC/EN 60034-6
Mounting dimensions and power allocation complying with EN 50347
Designs IM B3, IM B35 and IM B5 and derived designs complying with IEC/EN 60034-7.
For assembling motors in designs with vertical shaft position, it is necessary to prevent foreign bodies from falling into the ventilation holes (protective cover).
Temperature category T2, T3 or T4
Ambient temperatures -40 °C to +55 °C
(for sizes 56 – 112: -20 °C to +55 °C)
Explosion-protected design in accordance with Equipment Group II, Category 3
IEC/EN 60079-0 General Conditions
IEC/EN 60079-15 type of ignition protection "n"

For the motors' design, there are the following type-examination certificates:
Series KPR 56 – 112: IBExU06ATEXB001
Series KPR 63 – 132T: IBExU06ATEXB002
Series (IE1-)K1.R 112 – 355: IBExU09ATEXB006
Series (IE2-)W.1R 112 – 315: IBExU03ATEXB004

Example of labelling:
Ex nA IIC T3 Gc (alternatively: Ex nAc IIC T3)

4.4 Dust-explosion protected motors

4.4.1 Motors with squirrel-cage rotor for use in the presence of combustible dusts, Zone 21

Type KPR/KPER/IE1-KPR/KPER/IE2- KPR/KPER
K2.Q/IE1-K2.Q/K1.R/IE1-K1.R/IE2-W.1R/IE3-W.4R
Size 56 – 355
Type of protection IP 65 complying with IEC/EN 60034-5
Cooling type IC 411 complying with IEC/EN 60034-6
Temperature 125 °C, other surface temperatures on request
Designs IM B3, IM B35 and IM B5 and derived designs complying with IEC/EN 60034-7
For assembling motors in designs with vertical shaft position, it is necessary to prevent foreign bodies from falling into the ventilation holes (protective cover).
Mounting dimensions and power allocations complying with EN 50347
Ambient temperatures -30 °C to +40 °C (+55 °C),
for sizes 56 to 132T: -20 °C to +40 °C (+55 °C)
Explosion-protected design in accordance with Equipment Group II, Category 2
IEC/EN 60079-0 IEC/EN 60079-31, EN 61241-0 General Conditions
IEC/EN 61241-1 protection by housing "tD"

For the motors' design, there are the following EG type-examination certificates:
Series KPER 56 to 132T: DTM00ATEXE012X
Series (IE1-)K2.Q 112 – 315: IBExU02ATEX1019
Series (IE1-)K1.R 112 – 355: IBExU09ATEX1065
Series (IE2-)W.1R 112 – 315: IBExU04ATEX1118

Example of labelling:
Ex tb IIIC T125 °C Db (alternatively: Ex tb IIIC T125 °C)

4.4.2 Motors with squirrel-cage rotor for use in the presence of combustible dusts, Zone 22

Type	KPR/KPER/IE1-KPR/KPER/IE2- KPR/KPER K1.R/K2.R/IE1-K2.R/IE2-W.1R/IE3-W.4R
Size	56 – 400
Type of protection	IP 55 complying with IEC/EN 60034-5 (for combustible dusts IP 65)
Cooling type	IC 411 complying with IEC/EN 60034-6
Maximum surface Temperature	125 °C, other surface temperatures on request
Designs	IM B3, IM B35 and IM B5 and derived designs complying with IEC/EN 60034-7, for assembling the motors in designs with vertical shaft position, foreign bodies must be prevented from falling into the ventilation holes (protective cover)

Mounting dimensions and power allocations complying with EN 50347

Ambient temperatures	-40 °C to +40 °C, for sizes 56 to 132T: -35 °C to +40 °C

Explosion-protected design in accordance with Equipment Group II, Category 3
IEC/EN 60079-0 and EN 61241-0 General Conditions
IEC/EN 60079-31 protection by enclosure “t”

The motors’ design is certified by an EC Declaration of Conformity.

Example of labelling:
Ex tc IIIC T125 °C Dc (alternatively: Ex tc IIIC T125 °C)

4.5 Combinations of gas-explosion protection or dust-explosion protection

Depending on the design, the following combinations are possible:

2G or 2D	**Ex db(eb) IIC 2G or Zone 21 II 2D**
2G or 2D	**Ex ec IIC 2G or Zone 21 II 2D**
3G or 2D	**Ex ec IIC 3G or Zone 21 II 2D**
3G or 3D	**Ex ec IIC 3G or Zone 22 II 3D**

For the combinations 2G/2D and 3G/2D, the ambient temperature is limited to -40 °C to +60 °C for the K82. series, -20 °C to +40 °C for the KPER/KPR series and -30 °C to +40 °C for the K1.R series.

There are also the following certificates:

Design of motors 2G oder 2D

Series K82. 63 – 450:	according to the Flameproof enclosure “db” certification summary
Series KPER/KPR 56 – 112:	IBExU02ATEX1108 U and IBExU02ATEX1109 to 1115
Series K1.R 112 – 355	according to the Increased safety “eb” certification summary with additional certificate IBExU09ATEX1065

Design of motors 3G oder 2D

Series (IE1-)K1.R 112 – 355: IBExU09ATEXB006 in addition to IBExU09ATEX1065
Series (IE.-)W.1R 112 – 315: IBExU03ATEXB004 in addition to IBExU04ATEX1118

Design of motors 3G oder 3D

Series (IE1-)K1.R 112 – 355: IBExU09ATEXB006 in addition to manufacturer’s declaration Zone 22
Series (IE.-)W.1R 112 – 315: IBExU03ATEXB004 in addition to manufacturer’s declaration Zone 22

5 Maintenance and repair

In Germany, all maintenance, repairs and modifications in connection with explosion-protected machines must be carried out in accordance with the Industrial Safety Ordinance (BetrSichV) and ProdSV (Ordinance to the Product Safety Act/Explosion Protection Ordinance).

In order to guarantee the safe operation of the system, consisting of the drives and the matching monitoring devices, through the total period of use of the technical system, a regular inspection of the equipment and, if necessary repair/replacement must be carried out. In this case it is in the operator’s responsibility to ensure the equipment’s proper maintenance and upkeep. As regulations for this purpose, the Operating Safety Guidelines and Standard IEC/EN 60079-17 must be named.

With the increasing testing intensity in the tests, the distinction is drawn between visual inspection, close inspection and detailed examination. A visual inspection can be carried out while the machine is running and often just in passing, during a walk through the plant. A visual inspection means looking over the equipment without using any aids to access it. By this means it is possible to detect a missing or damaged terminal box lid on the machine but also to recognise noticeable bearing noises. In the case of a close inspection, the housing is subjected to a detailed inspection, e.g. with the help of a ladder, or the bearing temperature is measured with an infrared thermometer. Generally speaking, taking the machine out of service is not necessary.

For the detailed inspection, the machine is shut down and subjected to tests such as measurement of insulation resistance. The various tests can be clearly displayed in the ”Testing Pyramid”.

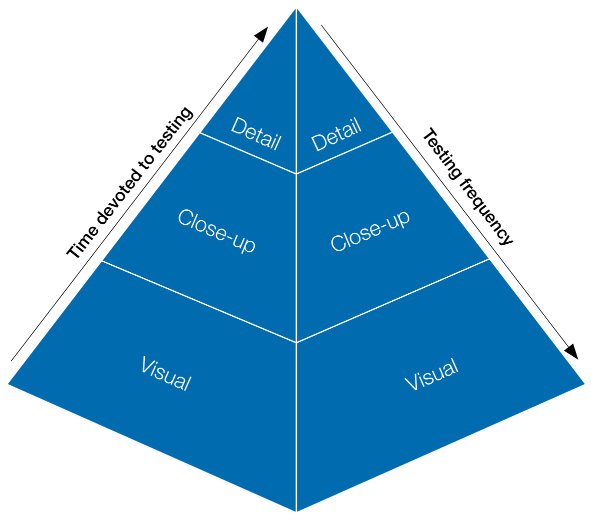


Figure 5.1: Testing Pyramid

Recommended values, manufacturer-dependent

What is to be done?	Time interval	Recommended deadlines
Initial inspection	After approx. 500 operating hours	After six months at the latest
Checking motor’s air supply and surface	Depending on degree of local pollution	
Lubrication (optional)	See nameplate or lubrication plate	
Main inspection	Approx. 10000 operating hours	Once annually
Drain condensate	Depending on climatic conditions	

Outside of Germany, the relevant national regulations must be observed.

Further instructions for testing and upkeep of electrical systems or the repair and repair of electrical equipment are given in IEC/EN 60079-17 and IEC/EN 60079-19. Tasks affecting explosion protection are considered as such, for example:

– Repairs to the stator winding and the terminals
– Repairs to the ventilation system
– Repairs to the bearings and the seals in the case of dust-explosion protected motors (Ex 2D, 3D) may be carried out only by the manufacturer’s service personnel or buyers/in authorised workshops by qualified personnel which has the necessary knowledge acquired from training, experience and instruction.

In the case of dust-explosion protected motors, dust-explosion protection depends very heavily on local conditions. For this reason, the motors in these areas must be regularly tested and serviced.

Because of thermal insulation, thick layers of dust result in a rise in temperature on the motor’s surface. Dust deposits on motors or indeed the motors being covered completely must thus be prevented by suitable fittings and ongoing maintenance.

The specified motor surface temperature is only valid if the dust deposits on the motor do not exceed a thickness of 5 mm. There must be a guarantee that these initial conditions (type of dust, maximum layer thickness etc.) are assured. The motor must not be opened before a sufficiently long time has passed, to allow the internal temperatures to die down to values which are no longer combustible. If the motors have to be opened for maintenance or repairs, these tasks must be completed wherever possible in a dust free-environment. If this is not possible, suitable measures must be taken to prevent dust from entering the housing. In the case of dismantling, particular care must be taken to ensure that the components necessary for imperviousness of the structure, such as seals, end faces etc. are not damaged.

Careful, regular maintenance, inspections and checks are essential in order to detect any faults in time and to remedy them before consequential damage occurs. Since the operating conditions cannot be precisely defined, only general deadlines, with the prerequisite of fault-free operation, can be given. They must always be adapted to the local conditions (pollution, stress etc.).

The necessary lubrication times for anti-friction bearings must be observed according to manufacturer's specifications.

Maintenance tasks (except for lubrication tasks) must be performed only when the machine is shut down. It must always be ensured that the machine is safeguarded against being switched on and labelled with a suitable warning sign. Also, the particular manufacturers' safety instructions and accident prevention regulations must be heeded for the use of oils, lubricants and cleaning agents! Adjacent components which are live must be covered!

It must be ensured that the auxiliary circuits, e. g. shutdown heaters, are dead. In the case of the design with condensate drain hole, the drain plug must be smeared with suitable sealant (e. g. Epple 28) before it is closed again!

If the tasks are not performed by the manufacturer, they must be performed by suitably-qualified personnel and tested by a "Qualified, Officially-Recognised Person" (in the case of the repair's relevance to explosion protection). That person must issue a written confirmation or attach a test mark to the machine. Tests undertaken in accordance with Section 14, paragraph 6 of the Operating Safety Guidelines must be documented in accordance with Section 19 of the Operating Safety Guidelines. The documentation must show that the device, protection system and safety, control or regulation devices correspond to the requirements of the Operating Safety Guidelines after the repair. It is recommended to retain the documentation beyond the device's period of use and to clearly label the device for the sake of traceability.

Important: The operator is responsible for operating a system requiring monitoring. This also includes the repair of equipment and protective systems. Abroad, the relevant national regulations must be observed.

Spare parts
With the exception of standardised, commercially available and similar standard components (e. g., anti-friction bearings) only genuine spare parts (see manufacturer-specific spare part lists) may be used; this particularly applies also to seals and connection parts.

The following details are essential for ordering spare parts:
- Spare part designation
- Motor model
- Motor number

6 Repair and modification of electrical equipment

6.1 General

The legal basis for operation of explosion-protected electrical equipment in explosion hazard areas is the 11th Ordinance to the Product Safety Act (Explosion Protection Ordinance) – **11. ProdSV**, in conjunction with the Operating Safety Guidelines (BetrSichV).

Previously applicable guidelines such as the "Guidelines on Electrical Systems in Explosion Hazard Areas (ElexV)" have thus lost their validity.

Further requirements are contained in the **Standard IEC/EN 60079-14** and in the **Explosion Protection Regulations BGR 104**. A modification to a system requiring monitoring, in the sense of the Operating Safety Guidelines, is considered to be any procedure which affects the system's safety. A modification is also considered to be any repair which affects the system's safety. A **considerable** modification to a system requiring monitoring in the sense of the Operating Safety Guidelines is considered to be any modification which changes the system requiring monitoring to the extent that it corresponds to a new system, where safety features are concerned. Under the designation of Maintenance and Repairs comes a combination of all the tasks which are performed to maintain an object in a certain state or to restore it to that state which meets the requirements of the object in question and guarantees the performance of the required functions.

The following form the basis of this:
- IEC/EN 60079-17, Testing and upkeep of electrical systems and
- TRBS 1201 "Testing of work equipment and systems requiring monitoring"
- TRBS 1201 Part 3 "Repairs to equipment, protection systems etc."

They are provided for operators and deal with the points of view which are directly related to testing and upkeep of electrical systems in explosion risk areas. The operator may have explosion-protected equipment repaired in any workshop of his choice. If parts on which explosion protection depends are replaced or repaired, there must be a test by an officially recognised qualified person before recommissioning.

(A qualified person in the sense of the Operating Safety Guidelines is a person who has the necessary specialist knowledge to test the work equipment on the basis of their professional training, their professional experience and their recent professional activities.

The requirements of the qualified person are explained in the guide to the Operating Safety Guidelines and in TRBS 1203. In accordance with Section 14, paragraph 6 of the Operating Safety Guidelines, qualified persons can be officially recognised by the appropriate ministry – this varies from state to state.

Recognition as a qualified person is company-related and applies only to tests of such equipment, protection systems and safety, control and regulation devices which this company has repaired. Recognition does not apply to all tests on equipment, protection systems and safety, control and regulation devices which have been repaired within the company regarding a part on which explosion protection depends but only to tests complying with repair procedures for which the recognition application has been made and which are listed in detail in the approval document).

The technical regulations for repair and maintenance of equipment in explosion hazard areas are defined in Standard IEC/EN 60079-19. It constitutes a guideline which provides instructions of a technical nature on repair and the repair, regeneration and modification of certified equipment and which has been designed for use in explosion hazard areas.

The objective is instruction on practical measures for maintaining the safety of the equipment, the definition of the requirements which must be set of the function of equipment that has been repaired and the description of procedures necessary for that, so that the equipment also continues to satisfy all relevant regulations after a repair. In the case of the various ignition types, examples are given on repair, maintenance and overhaul as well as possible modifications to explosion-protected electrical equipment and the necessary tests for them are described.

After repair the equipment is accepted as complying with the EU type-examination certificate if manufacturer-prescribed components have been used.

In the event that the certification documents are not available or available to an inadequate extent, the repair must be carried out on the basis of IEC/EN 60079-19 or the corresponding relevant standard (IEC/EN 60079...). If more detailed types of repair or modification are applied, which do not conform to standards, it must be decided on the part of the manufacturer or the certifying authority (notified body) whether this equipment is suited to continued use in explosion hazard areas.

6.2 Repair tasks not affecting the explosion protection

Replacement of the following:
- Bearings
- Motor feet (if possible)
- Terminal box (parts)
- Replacement of the seals by genuine parts
- Inlet part
- Terminal board
- Fan/fan cover
- End shields

Design conversions from:
- IM B3 to IM B35 and IM B34
- IM B3 to IM B5 and IM B14
- Terminal box (parts)
- IM B35 to IM B5 and IM B14
- Attaching and removing feet (if possible)

Cleaning:
- Sealing surfaces
- Seals

Generally speaking, genuine spare parts must be used. The use of non-genuine, but Ex-tested parts is legally permissible but automatically voids the manufacturer's guarantee.

6.3 Repair tasks requiring inspection by an officially recognized person qualified to perform such testing

- Repairing or renewing winding (winding information according to manufacturer)
- Reworking size and number of inlet holes
- Renewal of parts in ventilation system
- Replacement of the seals by parts that are not genuine but with Ex-test results
- Reconditioning motor and stator without significantly increasing the air gap

Repairing or renewing the winding must only be done according to manufacturer's information (winding data/materials). In the case of insulating material parts being replaced by parts from another insulating material and/or of different dimensions, the guarantee is automatically voided.

6.4 Repair tasks on Ex eb motors (modifications) which require a new type approval (e. g. by a notified body according to Directive 2014/34/EU)

- Installation of different/additional parts in the device (main terminals, auxiliary terminals or additional equipment)
- Reconditioning rotor and stator
- Winding for a different voltage
- Renewing ventilation system parts (e. g. fan wheel)
- Rewinding for a different speed
- Changing gap sizes

These tasks may be performed under the above-mentioned condition. VEM, however, allows these tasks only in the manufacturing factories. If they are performed in a workshop, warranty is automatically voided!

6.5 Repair tasks on Ex db motors (modifications) which require a new type approval (e.g. by a notified body according to directive 2014/34/EU)

- Installing additional components in the machine
- Reconditioning sparkover-prevention gap
- Reconditioning rotor and stator
- Regenerating components which are not part of the Flameproof enclosure
- Renewing ventilation system parts (e.g. fan wheel)
- Regenerated components must pass the appropriate overpressure test
- Rewinding for a different speed or voltage
- Changing the gap size
- Modifications to the ventilation system

These tasks may be performed under the above-mentioned condition. VEM, however, allows these tasks **only in the manufacturing factories**. If they are performed in a workshop, the guarantee is automatically voided!

6.6 Summary

Scheduling the tasks to be performed	With use of		By and under the responsibility of	
	Standard part	Genuine spare part	Trained experts	Manufacturing factory
Replacement of the following				
– Bearings	X	X	X	X
– Motor feet (if possible)	-	X	X	X
– Terminal box (parts)	-	X	X	X
– Terminal board [1]	X	X	X	X
– Inlet part [1]	-	X	X	X
– Fan/fan cover	-	X	X	X
– End shields	-	X	X	X
– Rotor	-	X	X [2]	X
Conversion of				
– IM B3 to IM B35, IM B34	-	X	X	X
– IM B3 to IM B5, IM B14	-	X	X	X
– IM B35 to IM B5, IM B14	-	X	X	X
– Attaching and removing feet (if possible)	-	X	X	X
Cleaning of				
– Sealing surfaces	-	X	X	X
– Seals	-	X	X	X
Reconditioning and revising of				
– Air gap	-	-	0	X
– Number and/or size of inlet holes	-	-	X [2]	X
Fitting other/additional				
– Main terminals	0	0	0	X
– Auxiliary terminals	-	X	X	X
Replacement winding				
– Stator	-	-	X [2]	X
– TMS	-	-	X [2]	X
– Stator together with wound core	-	X	X	X
Winding according to manufacturer's specifications	-	-	X [2]	X
Winding for				
– different number of poles/frequencies	-	-	0	X

[1] With component certificate or certificate of conformity
[2] Only with test certificate of a recognised workshop inspector
- Not applicable / not required
0 Not permissible
X Permissible / required

7 Testing the motors after repairs, maintenance or modifications

After repairs, maintenance or modifications the motors must undergo a test in accordance with Section 10 of the Operating Safety Guidelines (BetrSichV) dated 3rd October 2002. This test may be performed only by persons qualified to do so. The test must satisfy the requirements in accordance with IEC/EN 60079-19.

The tests below must be performed and documented:

Visual check of winding and of the complete motor, taking the increased safety requirements particularly into account.

7.1 Visual check

7.1.1 Visual check of winding – main points

- Check of winding overhang
- Bandages
- Slot and phase insulation
- Slot wedges
- Wire insulation

7.1.2 Visual check of complete motor – main points

- Terminal marking
- Terminal connectors properly connected
- Cable glands
- Seals
- Fan assembly
- Fan cover fastening

7.2 Winding test

7.2.1 Winding resistance

The ohmic DC resistances are supplied by supplying the motor winding with a constant current via two terminals in each case and the voltage drop is measured on the motor terminals. The resistance between the U-V, V-W and U-W terminals is calculated on this basis. In addition, the winding temperature is measured.

On the test certificates, the winding's winding resistance is shown at 20 °C. For this purpose, the measurements must be converted at temperatures deviating from 20 °C.

7.2.2 High-voltage test

The winding's insulation resistance is tested by the high-voltage test.

IEC/EN 60034-1 or VDE 0530 Part 1 prescribes the following procedure for testing machines with a rated voltage ≤ 1 kV:

The voltage test must be performed between the windings for testing and the motor housing. The stator core is connected to the windings or phases (e.g. V1 and W1) which are not provided for testing and the test voltage is applied between housing and U phase. The motor is thus tested simultaneously for short-circuit to the exposed conductive part and for inter-phase short-circuit with one measurement.

The high-voltage test is performed on the impregnated and fully-assembled motor by a mains-frequency and, as much as possible, sinusoidal test voltage, with an RMS value of $2 \cdot U_N + 1000$ V complying with IEC/EN 60034-2. The test should be started at a maximum voltage of half of the full test voltage and then increased, within at least 10 seconds, constantly or in maximum steps of 5% of the final value.

The full test voltage must be maintained for 1 minute.

A repeat test may be performed only at 80% of the maximum test voltage. Windings already in use are tested for an inspection, for example, at a minimum of 1000 V.

7.2.3 Insulation value (insulation resistance)

On initial commissioning and especially after fairly lengthy storage, the winding's insulation resistance must be measured for earthing and between the phases. The test must be performed at rated voltage and at least at 500 V. Dangerous voltages occur on the terminals during and immediately after measurement. On no account touch terminals and carefully heed operating instructions for insulation measuring unit! Depending on the rated voltage U_N, the following minimum values must be observed at a winding temperature of 25 °C:

Rated power P_B kW	Insulation resistance related to rated voltage kΩ/V
$1 < P_B \leq 10$	6.3
$10 < P_B \leq 100$	4
$100 < P_B$	2.5

If the minimum values are not reached, the winding must be properly dried until the insulation resistance corresponds to the required value.

7.3 Test run
7.3.1 Rotating field (direction of rotation check)

The direction of rotation check ensures that the direction of rotation is to the right, looking towards the drive side, when the mains wiring is connected to U, L2 to V and L3 to W.

7.3.2 No-load test, detection of no-load current I_0

The no load test is used for checking the winding number, the circuit and evaluating the running properties. It is performed when the engine is cold, at a rated voltage of ±1%. The machine is completely unloaded (disconnected from the load machine). During the measurement, voltage, currents and outputs are recorded.

The power consumption is measured in all the phases and compared with the **manufacturer's specifications**.
The permitted tolerance – related to the manufacturer's specification – is ± 15%. Furthermore, the no load currents in the three phases may also differ from one another only by a maximum of 15%.

7.3.3 Evidence of phase symmetry
7.3.3.1 Short-circuit tests with I_B

The stator winding of motors with squirrel-cage rotor must be supplied by an accordingly reduced voltage, when the rotor is locked, in order to reach the full load rated current and to guarantee the balance of all the phases.

The test is applied as an alternative to the full load test, in order to prove the undamaged nature of the winding and the air gap and in order to detect damage on the rotor. Imbalances deviating by less than 5% from the mean value are permitted.

7.3.3.2 Kurzschlussprüfung nach IEC/EN 60034-1

The short-circuit test is used to determine the relation $\mathbf{I_A/I_N}$.
The rotor is braked, the stator winding is connected to the voltage and the power consumption measured. If this test is not performed at rated voltage, the initial starting current $\mathbf{I_A}$ must be converted in the ratio of the rated voltage to the test voltage.

In addition to that, a saturation factor of the iron must be taken into account in the case of reduced test voltage. The ratio $\mathbf{I_A/I_N}$ calculated in this way may differ from the nameplate specification by up to 20%.

Initial starting current I_A (only with Increased safety "eb" type of ignition protection) saturation factor f_s for conversions in the case of reduced test voltage with locked rotor
(1) Rotor with slots completely or almost closed
(2) Rotor with open slots

Target value for initial starting current $I_A = I_N \cdot I_A/I_N$
a) Test voltage = rated voltage U_N
Test current's permitted deviation: ± 20% from I_A
(essential to observe minus tolerance for stator and rotor winding test)
b) Test voltage U_x
Test voltage I_x
Reduction ratio $R = U_x/U_N$
Saturation factor f_S
Test current converted to rated voltage

$I_{KN} = I_x \cdot f_S/R$
Permitted deviation for the converted test current:
I_{KN}: ± 10% of I_A

If the original insulation system and/or paint system is/are not available, the t_E time must be checked according to IEC/EN 60079-7. Copying the winding is not permitted until the t_E time has been checked against Equipment Standard IEC/EN 60079-7.

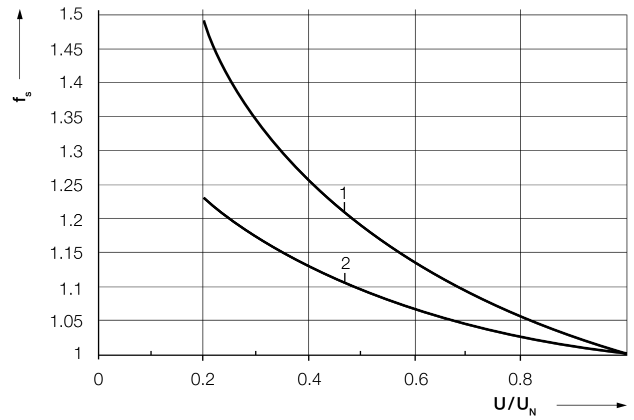


Figure 7.1: Saturation factors as dependent on the ratio of test voltage to rated voltage

7.3.4 Vibration test

To evaluate the quiet running a vibration test according to IEC/EN 60034-14 (VDE 0530 part 14):2004 has to be done. The limit values of class A or B must be kept in accordance with the requirements.

Step A
(for motors without special vibration requirements)
Step B
(for motors with special vibration requirements)

7.4 Painting and impregnation after repair work

The repainting of an explosion-protected motor or the impregnation of a complete stator after re-winding may result in thicker paint or resin layers on the machine surface. This could lead to electrostatic charging, with a corresponding risk of explosion in case of discharge. Charging processes in the immediate surroundings could similarly produce an electrostatic charge on the surface or parts of the surface, and likewise bring a risk of explosion in case of discharge. It is thus imperative to observe the stipulations of IEC/EN 60079-0: "Equipment – General requirements", section 7.4, and TRBS 2153, e.g. by:

limiting the total paint or resin layer thickness in accordance with the explosion group
– IIA, IIB: Total layer thickness ≤ 2 mm
– IIC: Total layer thickness ≤ 0.2 mm

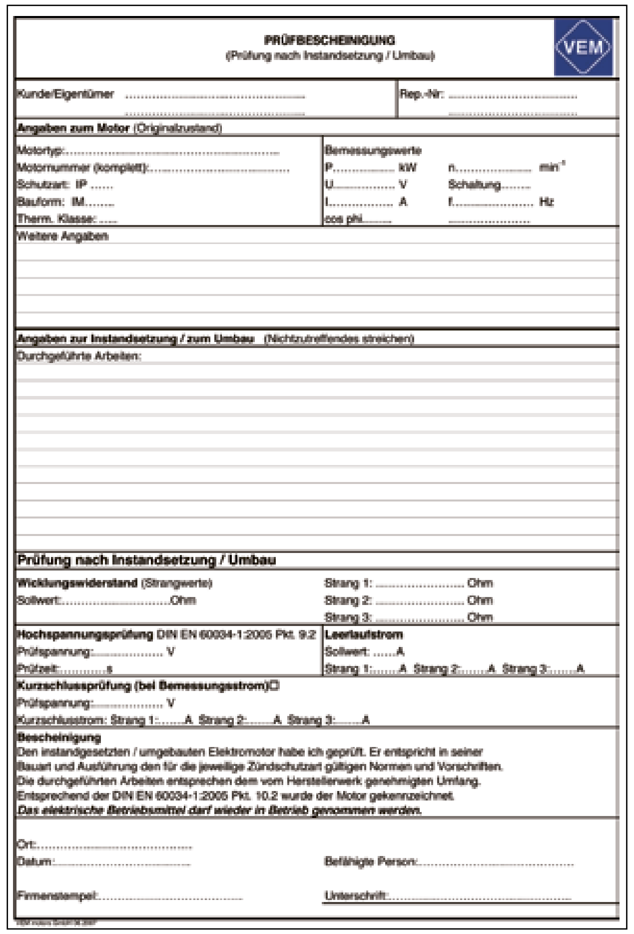
limiting the surface resistance of the paint or resin used
– IIA, IIB, IIC, III Surface resistance ≤ 1GΩ for motors of groups II and III

Breakdown voltage ≤ 4 kV for explosion group III (dust only, measured according to the thickness of the insulation material using the method described in IEC 60243-1).

In addition, due attention should be given to the contents of IEC/EN 60079-32: "Electrostatic hazards", in particular
Annex A: "Basics of static electricity",
Annex B: "Electrostatic discharges in special situations" and
Annex C: "Combustibility of materials".

7.5 Test Documentation

The test results must be documented in a test report.



PRÜFBESCHEINIGUNG
(Prüfung nach Instandsetzung / Umbau)

Kunde/Eigentümer .... Rep.-Nr: ....

Angaben zum Motor (Originalzustand)

Motortyp: ....
Motornummer (komplett): ....
Schutzart: IP ......
Bauform: IM.......
Therm. Klasse: .....

Bemessungswerte
P.............. kW n.................. min⁻¹
U.............. V Schaltung.......
I.............. A f.................. Hz
cos phi.......

Weitere Angaben

Angaben zur Instandsetzung / zum Umbau (Nichtzutreffendes streichen)
Durchgeführte Arbeiten:

Prüfung nach Instandsetzung / Umbau

Wicklungswiderstand (Strangwerte)
Sollwert:..........................Ohm
Strang 1: .... Ohm
Strang 2: .... Ohm
Strang 3: .... Ohm

Hochspannungsprüfung DIN EN 60034-1:2005 Pkt. 9.2
Prüfspannung:.................. V
Prüfzeit:...........s

Leerlaufstrom
Sollwert: ......A
Strang 1:.......A Strang 2:.......A Strang 3:.......A

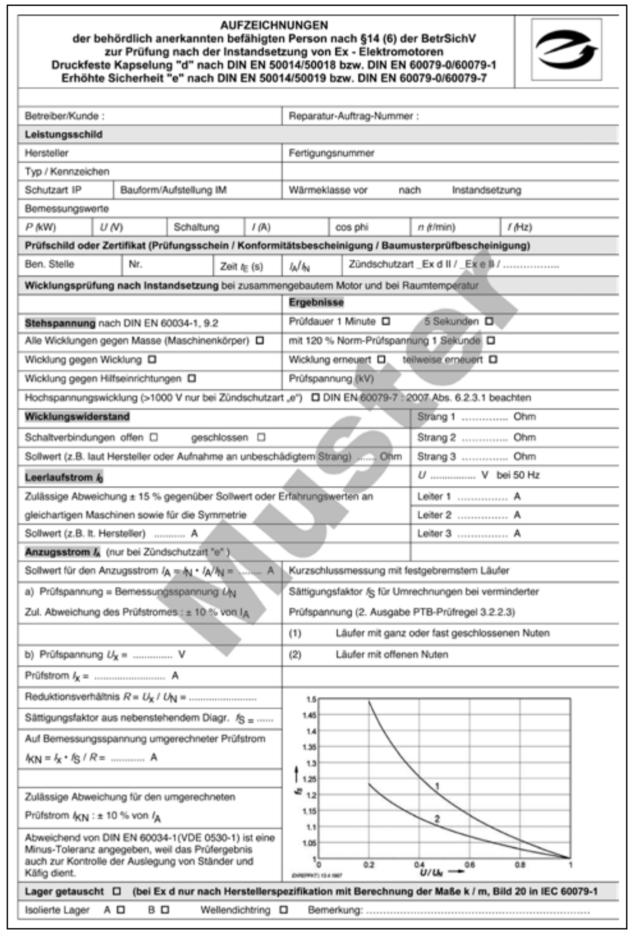
Kurzschlussprüfung (bei Bemessungsstrom)☐
Prüfspannung:.................. V
Kurzschlusstrom: Strang 1:.......A Strang 2:.......A Strang 3:.......A

Bescheinigung
Den instandgesetzten / umgebauten Elektromotor habe ich geprüft. Er entspricht in seiner Bauart und Ausführung den für die jeweilige Zündschutzart gültigen Normen und Vorschriften. Die durchgeführten Arbeiten entsprechen dem vom Herstellerwerk genehmigten Umfang. Entsprechend der DIN EN 60034-1:2005 Pkt. 10.2 wurde der Motor gekennzeichnet.
Das elektrische Betriebsmittel darf wieder in Betrieb genommen werden.

Ort:....................
Datum:.................... Befähigte Person:....................
Firmenstempel:.................... Unterschrift:....................

VEM motors GmbH sample certificate

below:
Alternative: ZVEH test certificate



AUFZEICHNUNGEN
der behördlich anerkannten befähigten Person nach §14 (6) der BetrSichV
zur Prüfung nach der Instandsetzung von Ex - Elektromotoren
Druckfeste Kapselung "d" nach DIN EN 50014/50018 bzw. DIN EN 60079-0/60079-1
Erhöhte Sicherheit "e" nach DIN EN 50014/50019 bzw. DIN EN 60079-0/60079-7

Betreiber/Kunde : Reparatur-Auftrag-Nummer :
Leistungsschild
Prüfschild oder Zertifikat (Prüfungsschein / Konformitätsbescheinigung / Baumusterprüfbescheinigung)
Wicklungsprüfung nach Instandsetzung bei zusammengebautem Motor und bei Raumtemperatur
Lager getauscht ☐ (bei Ex d nur nach Herstellerspezifikation mit Berechnung der Maße k / m, Bild 20 in IEC 60079-1)

Muster

Befund der Teile für die druckfeste Kapselung
Anschlusskasten Erhöhte Sicherheit ☐
Thermistoren als Alleinschutz
Anbauten
Durchgeführte Arbeiten
Bemerkungen
Bestätigung des Instandsetzers
Prüfung nach Instandsetzung durch die behördlich anerkannte befähigte Person

Dieses Formular für die Aufzeichnungen nach der Instandsetzung eines explosionsgeschützten Elektromotors stimmt überein mit den Anforderungen der TRBS 1201-3.

Muster

The test reports' archiving period is 10 years. The report's conformity to regulations is checked by an officially recognized, qualified person.

Published by:
Zentralverband der Deutschen Elektro- und Informationstechnischen Handwerke (ZVEH)

8 Summary of standards and regulations

8.1 General standards

Heading	International IEC – International Electrotechnical Commission	Europa EN – CENELEC European Commitee for Electrical Standardisation	Germany DIN/VDE German Industrial Standard/Association of German Electricians
Rotating electrical machines Measurement and operating performance	IEC 60034-1	EN 60034-1	DIN EN 60034-1/ VDE 0530-1
Method for determining losses and efficiency from tests for rotating electrical machines	IEC 60034-2-1	EN 60034-2-1	DIN EN 60034-2-1/
	IEC 60034-2	EN 60034-2	VDE 0530-2-1 DIN EN 60034-2/ VDE 0530-2
Efficiency classes of single-speed, cage-induction motors	IEC 60034-30-1	EN 60034-30-1	DIN EN 60034-30-1 VDE 0530-30-1
Degree of protection provided by the integral design of rotating electrical machines (IP Code) – Introduction	IEC 60034-5	EN 60034-5	DIN EN 60034-5/ VDE 0530-5
Methods of cooling (IC Code)	IEC 60034-6	EN 60034-6	DIN EN 60034-6/ VDE 0530-6
Classification of types of construction, mounting arrangements and terminal box position (IM Code)	IEC 60034-7	EN 60034-7	DIN EN 60034-7/ VDE 0530-7
Terminal markings and direction of rotation	IEC 60034-8	EN 60034-8	DIN EN 60034-8/ VDE 0530 Part 8
Noise limits	IEC 60034-9	EN 60034-9	DIN EN 60034-9/ VDE 0530-9
Starting performance of single-speed three-phase cage-induction motors	IEC 60034-12	EN 60034-12	DIN EN 60034-12/ VDE 0530 Part 12
Mechanical vibrations of certain machines with shaft heights 56 mm and higher; measurement, evaluation and limits of vibration severity	IEC 60034-14	EN 60034-14	DIN EN 60034-14/ VDE 0530-14
Balance quality	ISO 1940	-	DIN ISO 1940/ VDE 0175
IEC standard voltages	IEC 60038	-	DIN IEC 60038
Electrical insulation – Thermal evaluation and designation	IEC 60085	-	DIN IEC 60085/ VDE 0301-1
Dimensions and output series for rotating electrical machines	IEC 60072-1	EN 50347	DIN EN 50347

VEM

8.2 Explosion protection standards

	Titel	IEC	CEN/CENELEC	DIN/VDE	Reference of replaced standard	Last date of acceptance of declarations of conformity for the replaced standard
Fundamentals	Explosive atmospheres – Explosion prevention and protection Part 1: Basic concepts and methodology		EN 1127-1:2011	DIN EN 1127-1:2011-10		
	Explosive atmospheres – Explosion prevention and protection Part 2: Basic concepts and methodology for mining		EN 1127-2:2014	DIN EN 1127-2:2014-09		
	Potentially explosive atmospheres – Terms and definitions for equipment and protective systems intended for use in potentially explosive atmospheres		EN 13237:2012	DIN EN 13237:2013-01		
Characteristics of flammable gases and vapours	Determination of maximum explosion pressure and the maximum rate of pressure rise of gases and vapours		EN 15967:2011	DIN EN 15967:2011-10		
	Flameproof enclosures “d” – Method of test for ascertainment of maximum experimental safe gap	IEC 60079-1-1:2002				
	Testing of mineral oil hydrocarbons - Determination of ignition temperature			DIN 51794:2003-05		
Characteristics of flammable dusts	Explosive atmospheres – Part 20 – 1: Material characteristics for gas and vapour classification – test methods and data	ISO/IEC DIS 80079-20-1:2015	ISO/IEC DIS 80079-20-1:2015	DIN EN ISO/IEC 80079-20-1:2016-02 – Draft		
	Explosive atmospheres – Part 20 – 2: Material characteristics – Combustible dusts test methods	ISO/IEC 80079-20-2:2016				
Classification of hazardous areas	Explosive atmospheres – Part 10 – 1: Classification of areas – Explosive gas atmospheres	IEC 60079-10-1:2015	FprEN 60079:2014	DIN EN 60079-10-1:2014-10; VDE 0165-101:2014-10 – Draft		
	Explosive atmospheres – Part 10 – 2: Classification of areas – Explosive dust atmospheres	IEC 60079-10-2:2015	EN 60079-10-2:2015	DIN EN 60079-10-2:2015-10;		
Equipment, design, installation, maintenance and repairs	Explosive atmospheres – Part 14: Electrical installations design, selection and erection	IEC 60079-14:2013	EN 60079-14:2014	DIN EN 60079-14:2014-10; VDE 0165-1:2014-10		
	Explosive atmospheres – Part 17: Electrical installations inspection and maintenance	IEC 60079-17:2013	EN 60079-17:2014	DIN EN 60079-17; VDE 0165-10-1:2014-10		
	Explosive atmospheres – Part 19: Equipment repair, overhaul and reclamation	IEC 60079-19:2010 + A1:2015	EN 60079-19:2011 + A1:2015	DIN EN 60079-19:2015-09; VDE 0165-20-1:2015-09		
Types of protection for explosion-protected equipment	Explosive atmospheres – Part 0: Equipment - General requirements	IEC 60079-0:2011, modified + Cor.:2012+Cor.:2013	EN 60079-0:2012/A11:2013	DIN EN 60079-0; VDE 0170-1:2014-06	DIN EN 60079-0:2013	7.10.2016
	Explosive atmospheres – Part 1: Equipment protection by flameproof enclosures “d”	IEC 60079-1:2014	EN 60079-1:2014	DIN EN 60079-1:2015-04; VDE 0170-5:2015-04	EN 60079-1:2007	1.8.2017
	Explosive atmospheres – Part 2: Equipment protection by pressurized enclosure “p”	IEC 60079-2:2014:2014 + Cor.:2015	EN 60079-2:2014/AC:2015	DIN EN 60079-2:2015-05; VDE 0170-3:2015-05 + Corrigendum 1:2016-01	EN 61241-4:2006 EN 60079-2:2007	25.8.2017
	Explosive atmospheres – Part 5: Equipment protection by powder filling “q”	IEC 60079-5:2015	EN 60079-5:2015	DIN EN 60079-5:2015-12; VDE 0170-4:2015-12		
	Explosive atmospheres – Part 6: Equipment protection by liquid immersion “o”	IEC 60079-6:2015	EN 60079-6:2015	DIN EN 60079-6:2016-06; VDE 0170-2:2016-06	EN 60079-6:2007	27.3.2018
	Explosive atmospheres – Part 7: Equipment protection by increased safety “e”	IEC 60079-7:2015	EN 60079-7:2015	DIN EN 60079-7:2016	EN 60079-7:2007	31.7.2018
	Explosive atmospheres – Part 11: Equipment protection by intrinsic safety “i”	IEC 60079-11:2011	EN 60079-11:2012	DIN EN 60079-11:2012-06; VDE 0170-7:2012-06		
	Explosive atmospheres – Part 15: Equipment protection by type of protection “n”	IEC 60079-15:2010	EN 60079-15:2010	DIN EN 60079-15:2011-02; VDE 0170-16:2011-02		
	Explosive atmospheres – Part 18: Equipment protection by encapsulation “m”	IEC 60079-18:2014	EN 60079-18:2015		EN 60079-18:2009	16.1.2018
	Explosive atmospheres – Part 25: Intrinsically safe electrical systems	IEC 60079-25:2010	EN 60079-25:2010	DIN EN 60079-25:2011-06; VDE 0170-10-1:2011-06		
	Explosive atmospheres – Part 26: Equipment with Equipment Protection Level (EPL) Ga	IEC 60079-26:2014	EN 60079-26:2015		EN 60079-26:2007	2.12.2017
	Explosive atmospheres – Part 27: Fieldbus intrinsically safe concept (FISCO)	IEC 60079-27:2008	EN 60079-27:2008			
	Explosive atmospheres – Part 28: Protection of equipment and transmission systems using optical radiation	IEC 60079-28:2015	EN 60079-28:2015		EN 60079-28:2007	1.7.2018
	Explosive atmospheres – Part 29-1: Gas detectors – Performance requirements of detectors for flammable gases	IEC 60079-29-1:2007 (modified)	EN 60079-29-1:2007	DIN EN 60079-29-1:2008-07; VDE 0400-1:2008-07		
	Explosive atmospheres – Part 29-4: Gas detectors – Performance requirements of open path detectors for flammable gases	IEC 60079-29-4:2009 (modified)	EN 60079-29-4:2010	DIN EN 60079-29-4:2011-02; VDE 0400-40:2011-02		
	Explosive atmospheres – Part 30 – 1: Electrical resistance trace heating – General, type testing and design requirements	IEC 60079-30-1:2007	EN 60079-30-1:2007	DIN EN 60079-30-1:2007-12; VDE 0170-60-1:2007-12		
	Explosive atmospheres – Part 31: Equipment dust ignition protection by enclosure “t”	IEC 60079-31:2013	EN 60079-31:2014	DIN EN 60079-31:2014-12; VDE 0170-15-1:2014-12	EN 60079-31:2009	1.1.2017
	Explosive atmospheres – Part 35 – 1: Caplights for use in mines susceptible to firedamp – General requirements - Construction and testing in relation to the risk of explosion	IEC 60079-35-1:2011	EN 60079-35-1:2011 + Cor.:2011	DIN EN 60079-35-1:2012-01; VDE 0170-14-1:2012-01		
QA	Explosive atmospheres – Part 34: Application of quality systems for equipment manufacture	ISO/IEC 80079- 34:2011	EN ISO/IEC 80079-34:2011			

9 Tolerances
9.1 Electrical parameters

In accordance with DIN EN 60034-1 the following tolerances are permitted:

Efficiency	$-0.15\ (1-\eta)$ at $P_N \leq 150$ kW $-0.1\ (1-\eta)$ at $P_N > 150$ kW
Power factor	$\frac{1-\cos\varphi}{6}$ minimum 0.02, maximum 0.07
Slip (with rated load at operating temperature)	± 20% at $P_N \geq 1$ kW ± 30% at $P_N < 1$ kW
Initial starting current (in the starting circuit provided)	+ 20% without downward limitation
Starting torque	- 15% and + 25%
Pull-up torque	- 15%
Breakdown torque	- 10% (after applying this tolerance MK/MN still at least 1.6)
Inertia torque	± 10%
Noise intensity (test surface sound pressure level)	+ 3 dB (A)

These tolerances are approved for three-phase asynchronous motors, taking into account necessary manufacturing tolerances and material deviations in the materials used for the guaranteed values. In the standard, the following notes are provided on this:

1. A guarantee of all or any of the values in the table is not necessarily provided. In quotes, guaranteed values to which permitted deviations should apply must be named specifically. The permitted deviations must correspond to the table.
2. Your attention is drawn to the differences in interpretation of the term "guarantee". In some countries a distinction is made between typical or declared values.
3. If the permitted deviation applies only in one direction, the value in the other direction is not restricted.

9.2 Mechanical parameters – normal tolerances

Measurement abbreviation according to DIN 42939	Fit or tolerance	Meaning
a	Clearance of the housing foot attachment holes in axial direction	± 1 mm
a_1	Flange diameter or width	- 1 mm
b	Clearance of housing foot attachment holes at right angles to the axial direction	± 1 mm
b_1	Diameter of flange's centring spigot	up to diameter 230 mm j6 up to diameter 250 mm h6
d, d_1	Diameter of cylindrical shaft end	up to diameter 48 mm k6 from Durchmesser 55 mm m6
e_1	Flange's hole circle diameter	± 0.8 mm
f, g	Motor's greatest width (without terminal box)	+ 2%
h	Shaft centre (lower edge of foot to centre of shaft end)	to 250 mm -0.5 over 250 mm -1
k, k_1	Motor's total length	+ 1%
p	Motor's total length (lower edge of foot, housing or flange to motor's highest point)	+ 2%
s, s_1	Diameter of attachment holes in foot or flange	+ 3%
t, t_1	Lower edge of shaft end to upper edge of parallel key	+ 0.2 mm
u, u_1	Parallel key width	h9
w_1, w_2	Distance between centre of first foot attachment hole and shaft collar or flange surface	± 3.0 mm ϕ
	Distance from shaft collar to flange surface with D-side fixed bearing Distance from shaft collar to flange surface	± 0.5 mm ± 3.0 mm
m	Motor dimensions	-5 bis +10%

Normal shaft end fits

Shaft ends	up ∅ 48	k6
	from ∅ 55	m6
Mating components		H7

RICHTLINIE 2014/34/EU DES EUROPÄISCHEN PARLAMENTS UND DES RATES
vom 26. Februar 2014
Harmonisierung der Rechtsvorschriften der Mitgliedstaaten für Geräte und Schutzsysteme zur bestimmungsgemäßen Verwendung in explosionsgefährdeten Bereichen (Neufassung)

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vom 16. Dezember 1999
über Mindestvorschriften zur Verbesserung des Gesundheitsschutzes und der Sicherheit der Arbeitnehmer, die durch explosionsfähige Atmosphären gefährdet werden können (Fünfzehnte Einzelrichtlinie im Sinne von Artikel 16 Absatz 1 der Richtlinie 89/391/EWG)

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Ausfertigungsdatum: 03.02.2015
(Zuletzt geändert durch Art. 15 V v. 2.6.2016 I1257)

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Rechtliche Grundlagen des Explosionsschutzes
Dr.-Ing Andreas Pärnt

Diverse weitere Normen und Normenentwürfe

VMUK_NS02-101-EN-02/17 Printed in Germany. Subject to change.

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