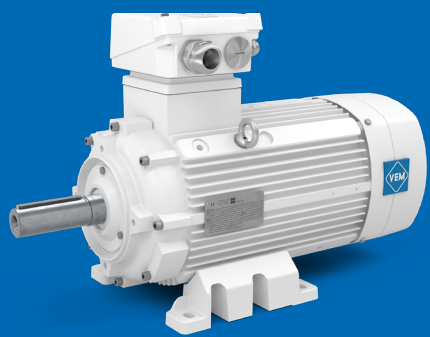
ELECTRIC DRIVES
FOR EVERY DEMAND

Explosion protection today

Electrical equipment for low-voltage applications, legal requirements, ATEX directives and ignition protection types, structural design of motors, VEM product range, repairs, maintenance and conversion



November 2025

Chemical, oil and gas industry

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Around 30 million electric machines worldwide operate under the VEM brand. They power ships, city and mainline railways, chemical plants and rolling mills. VEM generators produce electricity in water power stations and wind farms.

The VEM product range includes controlled electric drive systems, special motors and special machines with a power range from 0.06 kW to 42 MW, as well as components for drive systems and energy generation.

Published by VEM motors GmbH, 2025

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Acknowledgements

The creation of the VEM motors GmbH Ex Handbook was an extensive project made possible by the commitment and expertise of our team, together with strong partners. We would like to thank everyone involved for their tireless efforts and excellent cooperation.

Particular thanks go to the Physikalisch-Technische Bundesanstalt (PTB) and Dr. Christian Lehrmann, who provided us with active support on specific issues and thus made a significant contribution to the creation of this manual. Their expertise has helped us to meet the highest standards in the field of explosion protection.

We appreciate the excellent cooperation and would like to express our sincere thanks.

Yours, VEM motors GmbH

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Foreword

This handbook is based on the documentation for the explosion protection seminar „Planning and safe operation of explosion-proof electric drives" led by Dr.-Ing. Lehrmann/Dipl.-Phys. Seehase/Dipl. Ing. Sattler at the „HAUS DER TECHNIK" in Essen and internal training materials from VEM motors GmbH, taking into account the PTB test rules.

Explosive atmospheres are frequently formed in chemical and petrochemical plants as a result of process engineering procedures. They are caused, for example, by mixtures of gases, vapours or mists. However, mixtures with dust, such as those found in mills and silos, often prove to be explosive. This also requires attention in the food industry (flour dust explosion), for example. For these reasons, electrical equipment for potentially explosive areas is subject to special guidelines and national and international standards. Explosion protection specifies rules that aim to protect people and objects from possible explosion hazards.

Integrated explosion protection means that explosion protection measures have to be taken in a specific order. This basically means preventing explosive atmospheres from forming, avoiding the ignition of explosive atmospheres, and limiting the effects of an explosion to a safe level. Preventing the formation of explosive atmospheres, also known as primary explosion protection, is the responsibility of the facility designer and operator.

Which areas outdoors or indoors are to be considered potentially explosive within the meaning of the relevant regulations or provisions must be left entirely to the operator or, if there is any doubt about the definition of potentially explosive areas, to the competent supervisory authority. Directive 99/92/EC – ATEX 137 (formerly ATEX 118a), the Occupational Safety Directive, specifies the responsibilities of the operator of such installations. The basis for explosion-proof products is Directive 2014/34/EU – ATEX 114 (formerly 94/9/EC – ATEX 95 or 100a), (Quality Directive). This directive specifies the requirements for products intended for use in potentially explosive atmospheres.

Electrical machines for use in zones 1, 2 or 21, 22 can be designed with different types of ignition protection, the aim of each of these types of ignition protection being to reliably prevent ignition of any explosive atmosphere that may be present at the place of use of the electrical machine.

1 The explosion-proof drive – Introduction

An explosion-proof device is characterised by its ability to prevent the ignition of any explosive atmosphere that may be present at the place of use when operated within the permissible parameter limits for the gases present (e.g. ambient temperature, current, voltage, etc.). Since electrical machines always contain a potential ignition source, the aim of explosion protection measures is to prevent them from becoming an effective ignition source. Electrical machines can become an ignition source due to hot surfaces, electrical discharges and mechanically generated sparks (grinding).

The requirements for the effort required to prevent the ignition hazard depend on the location of use. Potentially explosive areas are divided into zones.

An explosive atmosphere may occur continuously or for long periods in Zone 0. Rotating electrical machines are not used here. Zone 0 usually occurs inside tanks and equipment.

In Zone 1, an explosive atmosphere may be present occasionally and for a short period of time. An example of this zone is the area around the ventilation opening of tank installations. Equipment used in Zone 1 must not become a source of ignition during normal operation or in the event of a fault.

In Zone 2, an explosive atmosphere is only to be expected for a short time in the event of operational faults, e.g. leaks. The equipment used must not constitute an ignition source during normal operation, but this is tolerated in the event of a fault. It is assumed that the probability of an explosive atmosphere and an operational fault occurring simultaneously is sufficiently low. In the event of an explosion hazard due to ignitable dust, zones 20/21/22 are classified in a similar manner.

The following types of ignition protection are considered to ensure explosion protection for rotating electrical machines: In gas explosion hazard areas of Zone 1 – increased safety "eb", flameproof enclosure "db/db eb" and pressurised enclosure "pxb" and for Zone 2 the type of protection increased safety "ec" and pzc. In areas at risk of dust explosion, "protection by enclosure" tb for use in Zone 21 and tc for use in Zone 22 are widely used types of protection for electrical machines.

With the type of protection known as pressure-resistant encapsulation „db", ignition is possible inside the enclosure, but the design prevents the explosion from spreading to the surrounding area. The enclosure must be able to withstand the explosion pressure, and flame propagation through feed-throughs must be prevented by using flame-proof gaps. A further condition is that the ignition temperatures of the gases occurring at the installation site must not be reached or exceeded on the surface of the enclosure. The implementation of this type of ignition protection is complex and expensive due to the need to comply with very small manufacturing tolerances.

With the „p" type of protection, the interior of the enclosure is flushed with an inert gas under pressure, preventing it from entering any flammable atmosphere. To ensure explosion protection, the pressure of the inert gas must be monitored and excessive surface temperatures must be prevented.

In the event of a failure of the ignition protection gas supply, it must be ensured that all internal ignition sources are eliminated before an ignitable mixture can form inside the enclosure due to the ingress of the external atmosphere. Due to the cost of the ignition protection gas supply, this type of ignition protection is only used for machines with a power rating above approximately 1 MW.

With the “eb” type of ignition protection, the surrounding atmosphere can penetrate the interior of the enclosure. To avoid the risk of ignition, no effective ignition sources can be present inside the enclosure with this type of ignition protection. This type of ignition protection can only be implemented with equipment that does not generate sparks during operation. To implement an asynchronous machine with this type of protection, the electrical inactive parts can essentially be based on the non-explosion-proof standard motor. For the active parts, the reduced permissible heating and requirements regarding partial discharges must be taken into account. The implementation of this type of protection in a frequency converter-fed drive is discussed later in this handbook.

The “ec” type of ignition protection is based on the “eb” type of ignition protection, but the requirements are less strict due to the lower probability of an ignitable atmosphere being present in Zone 2. For example, the machine can be used at higher temperatures because the “safety margin” of 10 K relative to the maximum permissible winding temperature according to the thermal class no longer applies. Furthermore, the fault condition “blocked state” does not have to be considered and, e.g. in operating mode S1, the start-up does not have to be monitored. Motors of this type of protection must not be put into operation if an ignitable mixture is present at the motor’s installation site.

In addition, standard EN 60079-14 also applies here, according to which the motor must be protected against overload and short circuit, i.e., a motor protection switch must be installed. These monitoring devices do not have to be functionally tested in accordance with directive 2014/34/EU for category 3 devices, e.g. ignition protection type “ec”, but the authors recommend using functionally tested monitoring devices in these applications as well. The standard IEC/EN 60079 Part 15 (or, for the type of protection “ec,” the standard EN 60079-7) provides detailed information on the relevant requirements. In accordance with Directive 2014/34/EU (formerly Directive 94/9/EC), the manufacturer carries out the test on its own responsibility and places the device on the market. Unlike the “eb” type of protection, type testing by a notified body is not required here.

The temperature class is a very important factor for the “eb” type of ignition protection. Depending on the composition of the potentially flammable atmosphere, a temperature class classification from T1 to T6 is used. The temperature classes indicate temperature ranges into which gases are classified according to their ignition temperature. In the case of mixtures, the component with the lowest ignition temperature is decisive for the classification. The maximum permissible surface temperatures for the temperature classes can be found in the IEC/EN 60079-0 standard.

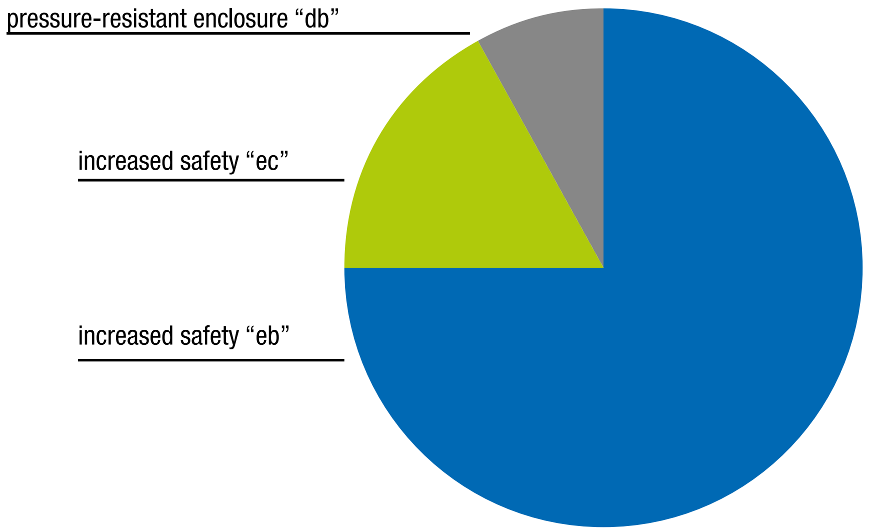


Image 1.1: Distribution of ignition protection types for mains-powered drives

The information is based on an estimate by the Explosion Protection Certification Authority of the PTB Brunswick.

For mains-powered drives, standard motors show an estimated distribution across the individual types of ignition protection as shown in the Image 1.1. For frequency converter-powered drives, the ratio between increased safety “eb” and flameproof enclosure “db/db eb” is reversed.

The reason for this is the fixed coupling of motor and frequency converter in the past, with the associated restrictions for the user and the high cost of testing. The total costs are lower for a drive with type of ignition protection “db” (flameproof enclosure), even though the costs for manufacturing the motors are significantly higher. Due to the extremely high potential damage in the event of an explosion, the corresponding protective measures must be given very high priority when designing a drive system in potentially explosive areas.

1.1 Overview of the legal basis for explosion protection

1.1.1 ATEX

	Procurement requirements	Operating requirements
European law	ATEX 114 2014/ 34/ EU	ATEX 137 1999/ 92/ EG
Laws	Product Safety Act (ProdSG)	ArbSchG Occupational Safety and Health Act
Regulations	11. ProdSV Explosion Protection Products Regulation	BetrSichV - Industrial Safety Regulation GefStoffV - Hazardous Substances Regulation
Technical rules, regulations, standards	IEC/EN 60079 ff.	Explosion protection rules BGR 104, TRBS

Device categories and zones

Device group	Device category	Zone	Device group	EPL	Definition according to BetrSichV	Mandatory certification
2014/ 34/ EU			according to IEC/ EN 60079-0			
for flammable gases, vapors and mists						
II	1G*	0	II	Ga	Zone 0 covers areas in which an explosive atmosphere consisting of a mixture of air and gases, vapors, or mists is present continuously, for long periods, or frequently.	yes
II	2G	1	II	Gb	Zone 1 covers areas where an explosive atmosphere consisting of gases, vapors, or mists is likely to occur occasionally.	yes
II	3G	2	II	Gc	Zone 2 covers areas where an explosive atmosphere of gases, mists, or vapors is not likely to occur, but if it does occur, it is likely to be only occasionally and for a short period of time.	no
for explosive dust atmospheres						
II	1D*	20	III	Da	Zone 20 covers areas in which an explosive atmosphere consisting of dust/air mixtures is present continuously, for long periods, or frequently.	yes
II	2D	21	III	Db	Zone 21 covers areas where explosive dust/air mixtures are likely to occur occasionally.	yes
II	3D	22	III	Dc	Zone 22 covers areas where an explosive atmosphere is not likely to occur due to airborne dust, but if it does occur, it is likely to be only very rarely and for a short period of time.	no

* Not common for electric motors

Worksite	Presence of an explosive dust atmosphere	occasionally	rarely or temporarily	
	Dust type	all kinds	electrically conductive	elektrisch nicht leitend
	Zone	21	22	
Operating resources	Device group according to RL2014/34/ EU			
	Device group n. EM 60079-0	IIIC	IIIC	IIIB
	Device category	2D	3D	3D
	EPL n. EN 60079-0	Db	Db, Dc	Db, Dc
	Protection class	IP 65	IP 65	IP 55
	Temperature	Maximum housing temperature 125°C		
	Certificate	EU type exam. certificate from the testing lab	EU Declaration of Conformity from the manufacturer	
	Labeling n. RL 2014/ 34/ EU	II 2D	II 3D	II 3D
	Labeling n. EN 60079-0/ EN60079-31	Ex tb IIIC T125°C Db (alt.: Ex tb IIIC T125°C)	Ex tc IIIC T125°C Dc (alt.: Ex tc IIIC T125°C)	Ex tc IIIB T125°C Dc (alt.: Ex tc IIIB T125°C)

1.1.2 United Kingdom – SI 2016 Nr. 1107

As part of Brexit, new approval regulations for explosion protection were introduced with the Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 2016: Great Britain (SI 2016/1107) for the territory of the United Kingdom of Great Britain. They are closely based on the ATEX Directive 2014/34/ EU.

The EU Exit Regulations 2019, SCHEDULE 25 (Amendment of the Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 2016) transposed the directive into UK law.

It applies to equipment and systems delivered to or within the UK from January 1, 2021.

1.1.3 IECEx - Scheme

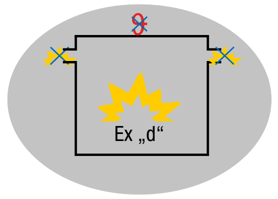
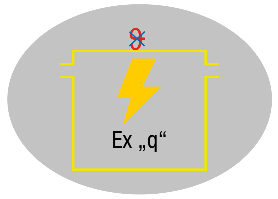
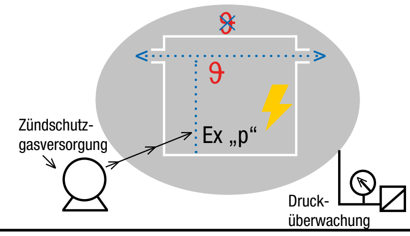
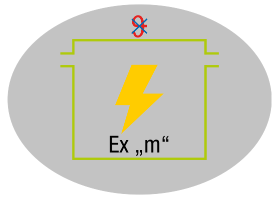
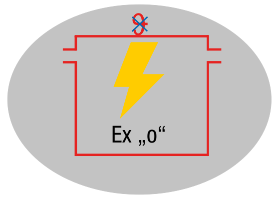
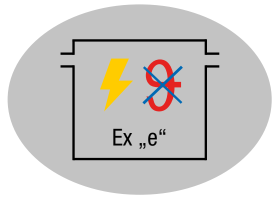
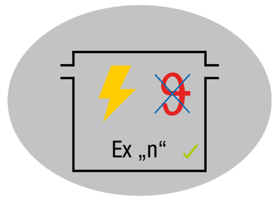
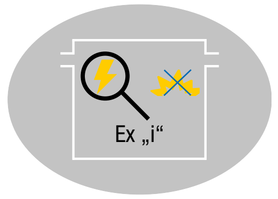
IECEx stands for: International Electrotechnical Commission System for Certification to Standards Relating to Equipment for Use in Explosive Atmospheres. Here, certification bodies (ExCB) issue certificates for electrical and non-electrical products (Certificate of Conformity (CoC)) in accordance with IECEx rules IECEx 01-S / IECEx 02. The aim is to achieve worldwide recognition of the certificates issued. However, this is currently only the case in Australia and New Zealand. In many other IECEx member countries (currently 32), though, the certificate can form the basis for a simplified approval procedure for the respective national certificate.

It is important to note that, in contrast to the ATEX directive, even Category 3 devices for use in Zones 2 or 22 must be certified by an "Ex CB, Certification Body." A declaration of conformity from the manufacturer is not sufficient in this case.

The ATEX regulations are implemented within the EU through national laws. Compliance with EU standards (series 60079) is not mandatory, but is usually applied by manufacturers. This automatically triggers the presumption of conformity; otherwise, this must be proven by the manufacturer. For IECEx, compliance with all applicable IEC standards is mandatory.

The EU type examination certificates required for the operation of protective systems and equipment in potentially explosive atmospheres within the EU are issued to accredited notified entities (Notified Bodies) after successful completion of the conformity assessment process. The IECEx Certificate of Conformity (IECEx COC) is issued and published by certification bodies (ExCB – Ex Certification Body) in an online procedure.

1.2 Overview of ignition protection types for gas explosion protection

General requirements (gas and dust)		IEC/EN 60079-0
Pressure-resistant enclosure "db"		IEC/EN 60079-1 Ignition protection type pressure-resistant enclosure "db"
Pressure-resistant enclosure "q"		IEC/EN 60079-5 Device protection through sand enclosure "q"
Overpressure enclosure "pxb, pvb, or pzc"		IEC/EN 60079-2 Ignition protection type overpressure enclosure "pcb, pvb, or pzc"
Moulding enclosure "m"		IEC/EN 60079-18 Ignition protection type moulding enclosure "m"
Oil enclosure "o"		IEC/EN 60079-6 Device protection through oil enclosure "o"
increased safety "eb"		IEC/EN 60079-7 Ignition protection type increased safety "eb"
increased safety "ec" (alt.: ignition protection type "n")		IEC/ EN 60079-7 (IEC/EN 60079-15) Ignition protection type increased safety "ec" (alt.: ignition protection type "n")
Intrinsic safety "ia/ ib"		IEC/EN 60079-11 Device protection through intrinsic safety "i"

1.3 Explanation of the general requirements of 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 between Group I (mining), II (gas), and III (dust)
- Requirements from dust areas transferred from EN 61241-0
- Classification of dusts into three categories (IIIA, IIIB, and IIIC)
- Explosion groups for Group II (IIA, IIB, and IIC)
- Introduction of equipment protection levels (EPL...Equipment Protection Level)
- Ambient temperature range -20 °C to +40 °C
- Max. operating temperature (max. ambient temperature + self-heating + external heat sources)
- Max. surface temperature (temperature classes T1 to T6)
- Mechanical strength
- Opening times (capacitors, hot components)
- Circulation currents
- Seal fastening
- Equipment with electromagnetic and ultrasonic energy
- Requirements for non-metallic enclosures and enclosure parts
- Operating instructions, marking
- Tests

Subdivision of equipment group II

Gases and vapors have previously been classified according to IEC/ EN 60079-0 based on their particular flammability in ignition protection types “d” and “i” into three explosion groups IIA, IIB, and IIC. The danger increases from explosion group IIA to IIC. (The higher explosion group, e.g., IIC, includes the lower groups IIB and IIA.) From IEC/ EN 60079-0 onwards, the designation II for all gas protection types is replaced by the designations IIA, IIB, and IIC (i.e., now also ...Ex eb IIC T3 or ... Ex ec IIC T3).

- IIA, typical gas is propane
- IIB, typical gas is ethylene
- IIC, typical gas is hydrogen

Temperature class

IEC/ EN 60079-0 Explosion group IIA; IIB; IIC		
Ignition temperature of the medium to the limit temperature	Temperature class	Permissible surface temperature of the operating equipment 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
from 100 - 135°C	T5	100°C
from 85 - 100°C	T6	85°C

Subdivision of equipment group III

Group III electrical equipment is further subdivided according to the characteristics of the explosive atmosphere for which it is intended. The potential danger posed by dust increases in connection with the operation of electrical equipment from IIIA to IIIC. Equipment marked IIIC is also suitable for groups IIIA and IIIB.

- IIIA, combustible lint
- IIIB, combustible, non-electrically conductive dust
- IIIC, combustible, electrically conductive dust

Device protection level

Equipment Protection Level (EPL), definition according to IEC/EN 60079-10-2

Subdivision of equipment group III

Gas explosion protection

EPL Ga	Device with a “very high” level of protection for use in gas explosion hazardous areas where there is no ignition hazard during normal operation, foreseeable or rare faults/ malfunctions.
EPL Gb	Device with a “high” level of protection for use in areas where there is a risk of gas explosion, but where there is no risk of ignition during normal operation or foreseeable faults/malfunctions.
EPL Gc	Device with “enhanced” protection level for use in gas explosion hazardous areas where there is no ignition hazard during normal operation and which have some additional protective measures to ensure that there is no ignition hazard during normally foreseeable malfunctions of the device.

Dust explosion protection

EPL Da	Device with a “very high” level of protection for use in combustible dust atmospheres where there is no risk of ignition during normal operation, foreseeable faults, or rare malfunctions.
EPL Db	Device with a “high” level of protection for use in combustible dust atmospheres where there is no risk of ignition during normal operation or foreseeable faults/malfunctions.
EPL Dc	Device with „enhanced“ protection for use in combustible dust atmospheres where there is no ignition hazard during normal operation and which has some additional protective measures to ensure that there is no ignition hazard during normally expected device malfunctions.

Potentially explosive atmosphere according to Directive 2014/34/EU	Device group and category according to Directive 2014/34/EU	Device group and Equipment Protection Level (EPL) according to 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
Tone 21	II 2D	III Db
Zone 20	II 1D	III Da
Mining (high level of safety)	I M2	I Mb
Mining (very high level of safety)	I M1	I Ma

Definition of the principles of protection

- Explosive mixtures can enter the device and be ignited. The explosion does not spread to the explosive atmosphere surrounding the device. (Ex db)
- The device has an enclosure that prevents explosive mixtures from entering and coming into contact with effective ignition sources. (Ex m, Ex o)
- Explosive mixtures can penetrate the device, but must not be ignited during normal operation of the device. Sparks and high temperatures above the ignition temperature of the respective gas must be prevented. (Ex ec)
- Explosive mixtures can penetrate the device, but must not be ignited even if a foreseeable fault occurs. Sparks and high temperatures above the ignition temperature of the respective gas must be prevented during normal operation and in the event of foreseeable device malfunctions. (Ex eb)
- Explosive mixtures may enter the equipment, but must not be ignited. The electrical circuits are limited in their energy. Sparks and high temperatures may occur to a limited extent, so that gases of the explosion group permitted for this device are not ignited. (Ex i)
- Explosive mixtures must not enter the device, or at least not in harmful quantities. The decisive factor is therefore only compliance with the maximum temperature of the outer surface. (Ex tb, Ex tc)

1.3.2 Types of ignition protection

1.3.2.1 Ignition protection type pressure-resistant enclosure "db"

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

Definition/Protection principles:
Ignition protection type in which the parts that can ignite an explosive atmosphere are enclosed in a housing that can withstand the pressure of an explosion of an explosive mixture inside and prevents the explosion from being transmitted to the explosive atmosphere surrounding the housing.

- Compliance with explosion group
- Pressure-resistant housing
- Compliance with the required gap widths and lengths
- Connection box Pressure-resistant enclosure "db" or increased safety "eb"
- The temperature of the outer surface must be lower than the ignition temperature of the gases present in the environment.
- An explosion may occur inside, but the enclosure must withstand this pressure and no flame or flammable hot gases may escape through gaps.

Testing
- Cover pressure, compressive strength
- Ignition flashover
- Leak test of bonded gap

Scope of application
Equipment Zone 1 and 2,
Category 2G and 3G (Gb, Gc)

1.3.2.2 Ignition protection type increased safety "eb"

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

Definition/Protection principles:
Ignition protection type in which additional measures are taken to prevent, with an increased degree of safety, the possibility of impermissibly high temperatures and the formation of sparks or arcs occurring during normal operation or under specified exceptional conditions.

- Prevention of sparks and other ignition sources
- Enclosure at least IP54 for bare, live parts in the interior
- Enclosure at least IP44 if all live parts inside are insulated
- Temperatures of the outer and <u>inner surfaces</u> must be lower than the ignition temperature both during normal operation and <u>in the event of a fault (motor blockage</u>)
- Observation of crawl and air distances
- Particular attention must be paid to insulation materials and seals.
- Protective devices (temperature monitoring and/or overcurrent switch with IA/IN-tE time characteristic curve) are required at the user's site.
- Frequency converter operation, see Chapter 3.

Testing
- Insulation test
- Temperature measurement for defined faults
- Additional tests for certain equipment (TMS full protection for electric motors)

Scope of application:
- Equipment Zone 1 and 2,
- Category 2G and 3G (Gb, Gc)

1.3.2.3 Ignition protection type increased safety "ec" (formerly: "nA")

Building regulations: IEC/EN 60079-7
(alt.: IEC/ EN 60079-15 (VDE 0170-16))

Definition/Protection principles:
Ignition protection type for electrical equipment in which, during normal operation, the equipment is incapable of igniting a surrounding explosive atmosphere. The design ensures that the risk of arcing or sparking, which could cause an ignition hazard during normal use, is minimized.

- Prevention of sparks and other ignition sources
- Enclosure at least IP54 for bare, live parts in the interior
- Enclosure at least IP44 if all live parts in the interior are insulated
- Observation of crawl and air distances
- Special attention to insulating materials and seals

Temperatures of the outer and <u>inner surfaces</u> must be lower than the ignition temperature during normal operation.

- For rated voltages up to 1 kV and a housing protection class of at least IP44, the terminal box may be open to the interior of the motor.

Temperatures of the outer and inner surfaces must be lower than the ignition temperature during normal operation.

Testing
- Insulation test
- Temperature measurement
- Additional tests for certain equipment (FU operation)

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

1.3.2.4 Ignition protection type overpressure enclosure "pxb, pyb, pzc"

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

Definition/Protection principles:
Ignition protection type for electrical equipment in which the ingress of the surrounding atmosphere into the enclosure is prevented by maintaining an ignition protection gas inside the enclosure at a pressure higher than that of the surrounding atmosphere. The overpressure is maintained with or without continuous ignition gas purging.
Minimum overpressure 50 Pa for protection levels pxb and pvb 25 Pa, for protection level pzc

- Enclosure at least IP4X
- Monitoring devices
- Gas leakage
- Containment system

Testing
- Pre-rinsing time
- Leakage losses
- Overpressure test (1.5 x P)
- Minimum flow rate

Scope of application:
Protection area pxb: Equipment Zone 1 and 2, Category 2G and 3G (Gb, Gc) and EPL Mb (mining)
Protection level pvb: Equipment Zone 1 and 2, Category 2G and 3G (Gb, Gc)
Protection level pzc: Equipment Zone 2, Category 3G (Gc)

Other types of gas ignition protection without detailed consideration, which are not relevant for electric motors:

1.3.2.5 Ignition protection type sand enclosure "q"

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

Definition/Protection principles:
Ignition protection type in which the parts of a piece of equipment that could become an effective ignition source are fixed in position and completely surrounded by the filling material to prevent ignition of an external explosive atmosphere.

- Filling material
- Closures
- Distances
- Housing at least IP54
- Energy storage

Testing
- Pressure test (50 kPa)
- Insulation capacity of filling material
- Flammability of plastics

Scope of application:
Category 2G (Gb)
Capacitors, primary elements, transformers, ballasts, and sensors

1.3.2.6 Ignition protection type oil enclosure "o"

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

Definition/Protection principles
Ignition protection type in which the electrical equipment or parts of the equipment are immersed in a liquid enclosure in such a way that a potentially explosive gas atmosphere above the liquid or outside the enclosure cannot be ignited.

- Protective liquid
- Minimum filling level
- Protection type IP66
- Fill level monitoring device
- Energy storage device

Testing

- Overpressure test
- Temperatures

Scope of application:
Category 2G (Gb),
Transformers, switching devices, starting resistors

1.3.2.7 Ignition protection type intrinsic safety "ia/ ib and ic"

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

Definition/Protection principles
An intrinsically safe circuit is a circuit in which no sparks or thermal effects occur that could cause ignition of a specific explosive atmosphere under the test conditions specified in this standard (which include normal operation and certain fault conditions).

- Separation distances
- Insulation
- Components

Testing

- Spark testing
- Insulation testing
- Ignition testing for small components
- Performance assessment

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

Protection level ia: EPL Ga, Gb, and Gc
Protection level ib: EPL Gb and Gc
Protection level ic: EPL Gc

1.3.2.8 Ignition protection type moulded enclosure "m"

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

Definition/Protection principles Ignition protection type in which the parts that could ignite an explosive atmosphere through sparks or heating are embedded in a casting compound in such a way that the explosive atmosphere cannot be ignited under operating and installation conditions.

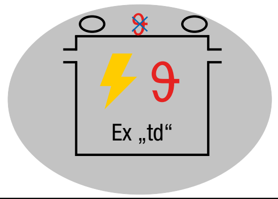
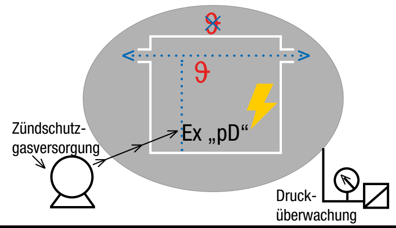
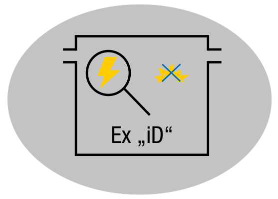
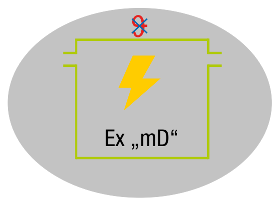
- Casting compound
- Protection level
- Distances and cavities

Testing

- Water absorption
- Heat and cold resistance
- Thermal cycle testing
- Insulation testing

Scope of application:
Category 1G (ma) and 2G (mb)
EPL Ga and Gb
Low-power switching devices, sensors, solenoid coils, signaling and control devices

1.4 Overview of ignition protection types for dust explosion protection

General requirements		IEC/EN 60079-0
Protection through housing (tx IIIY T --- °C Dx)		IEC/EN 60079-31 Equipment dust explosion protection through "t" enclosure
Overpressure enclosure "pxb, pyb, and pzc" („p IIIY Dx")		EN 61241-4 (IEC/EN 60079-2) Device protection through overpressure enclosure "p"
Intrinsic safety "ia, ib, and ic" („ix IIIY Dx")		IEC/EN 60079-11 Device protection through intrinsic safety "i"
Moulded enclosure "mD" („mx IIIY Dx")		IEC/EN 60079-18 Device protection through moulding enclosure "m"

x = EPL, Y = explosive group
Example labelling for protection by enclosure: Ex II 2D Ex tb IIIC T125 °C Db

1.4.1 Ignition protection type by enclosure „t“

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

Definition/Protection principles
- Devices with potential ignition sources for the surrounding dusty atmosphere are enclosed in a housing. This prevents contact with the external explosive atmosphere. Verification of the maximum surface temperature according to category. Minimum protection class IP5X/6X (EN 60529)

New: Pressure test before dust test with an overpressure of:
- 4 kPa for devices with protection level “ta”
- 2 kPa for devices with protection level “tb” or “tc”

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

Testing
- IP protection class testing
- Aging resistance of the plastics used in the device
- Impact testing
- Tightness
- Thermal testing with overload or fault conditions

Gruppeneinteilung:
- IIIA, combustible lint
- IIIB, non-conductive dust
- IIIC, conductive dust

Protection against dust penetration according to Table 1, IEC/EN 60079-31

Group	Level of protection	Enclosure protection rating
III A (Lint, 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 types of dust ignition protection that are not relevant for electric motors:

1.4.2 Ignition protection type overpressure capsule „pxb, pyb and pzc”

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

Definition/Protection principles
Ignition protection type for electrical equipment in which the ingress of the surrounding atmosphere into the enclosure is prevented by maintaining an ignition protection gas inside the enclosure at a pressure higher than the surrounding atmosphere (at least 50 Pa for protection level pxb or pyb and at least 25 Pa for protection level pzc). The overpressure is maintained with or without continuous ignition gas purging of the casting compound.
- Enclosure at least IP4X.
- Monitoring devices.
- Gas escape.
- Containment system.

Testing
- Pre-rinsing time
- Tightness
- Overpressure test (1.5 x P; > 200 Pa)
- Impact test

Scope of application:
Switchgear, transformers, complex equipment, cabinets

1.4.3 Ignition protection type intrinsic safety „ia, ib and ic”

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

Definition/Protection principles
Limitation of electrical energy (voltage, current, induction, capacity) and thus of the surface temperatures that occur, so that no ignition of a dust-air mixture occurs due to sparks or thermal effects in intrinsically safe devices during normal operation and under certain fault conditions in accordance with IEC/EN 60079-11.
- Separation distances
- 2/3 utilization
- Immunity to interference

Testing
- Spark test
- Insulation test
- Ignition test for small components
- Performance assessment
- No IP required

Scope of application:
MSR technology, sensor technology, mobile measurement technology

1.4.4 Ignition protection type moulded enclosure „mD”

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

Definition/Protection principles
Ignition protection type in which the parts are embedded in a casting compound in such a way that the explosive atmosphere cannot be ignited under operating and installation conditions.
- Minimum requirements for casting compound (TI value)
- Minimum casting thickness (3 mm “ma” and 1 mm “mb”)
- Fault analysis in the casting
- Protection level
- Distances, cavities
- Rated values

Testing
- Water absorption
- Verification of maximum surface temperature
- Heat and cold resistance
- Thermal cycle testing
- Insulation testing

Scope of application:
Low-power switching devices, control and signaling devices, solenoid coils, ultrasonic sensors

1.5 Labeling according to different editions of standards

Motors in category 3 are only marked with the CE mark on the rating plate. The identification number NB for QS n. 2014/34/EU (formerly: RL 94/9/EG) must not be indicated on this equipment. One of the changes in EN 60079-0:2009 (DIN EN 60079-0:2010) compared to previous editions was the introduction of the equipment protection level (EPL). In this context, the previous labeling of explosion-proof motors is changing with the addition of the Equipment Protection Level to the explosion protection labeling.

In addition to the information required by the ATEX directives (e.g., Ex II 2G for motors with increased safety “eb” ignition protection), the device protection level (Ex eb IIC T3 Gb) will also be indicated on the type plate in the future. Under certain conditions, the standard allows an alternative (abbreviated) marking in addition to the actual EPL marking. This is not used by VEM motors.

Labeling according to Directive 2014/34/EU			Old designation (invalid)	Designation according to(invalid)	Designation according to(invalid)	current designation according to
EU	Nr. NB	Group/Category G (Gas) o.D. (Dust/Fume)	EN 50014 ff.; EN 50281, ...	EN 60079-0:2006; EN61241-0:2004	EN60079-0:2009 with EPL	EN IEC 60079-0:2019
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)

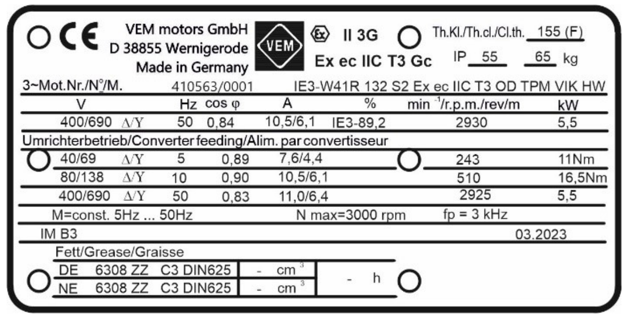
Combination of gas or dust					
CE 0102	II 2D II 2G	IP65 T 125°C EEX E II T2, T3 or T4	Ex tD A21 IP 65 T 125°C Ex e II T2, T3 or T4	Ex tb IIIC T 125°C Cb Ex e IIC T3 Gb	Ex tb IIIC T 125°C Ex eb IIC T3
CE	II 3D II 2G	IP55 T 125°C (IP 65 conductive dust) EEx e II T2, T3 or T4	Ex tD A22 IP 55 T 125°C (IP 65 conductive dust) Ex e II T2, T3 or T4	Ex tc IIIB T 125C 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	II 2D II 3G	IP65 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	II 3D II 3G	IP55 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 T, 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

[When specifying a maximum surface temperature: Zone 2 (gas): Entire surface including rotor and windings; for Zone 21, 22 (dust): external surface (housing, shaft)]

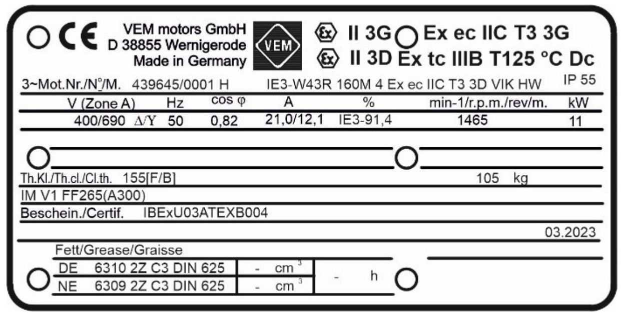
Notified body identification number
0102… Physical-Technical Federal Institute Braunschweig
0637… IBExU Institute for Safety Technology GmbH, Freiberg
0158… DEKRA EXAM GmbH

The identification number must be the number of the notified body that carried out the QS audit (production monitoring). This is not always the same as the EU type examination certificate.

Example of a type plate



Motor for use in Zone 22

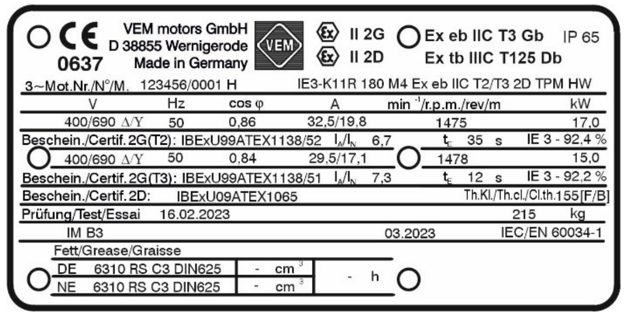


Motor with dual marking for use in Zone 2 and 22

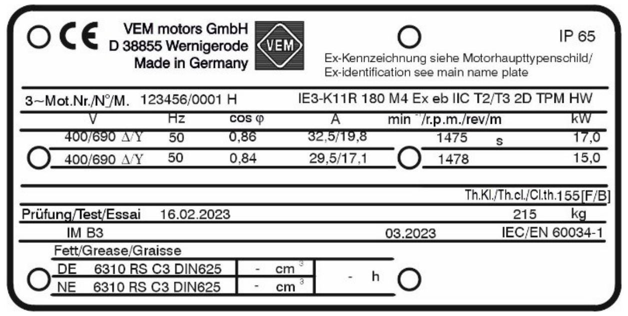
Some customers (and perhaps also manufacturers) believe that labeling has been mandatory under the new standards since June 1, 2012, the date on which the old standard expired. This view is incorrect. The only document that declares the conformity of our Ex motors with the ATEX regulations is the EU Declaration of Conformity. The explosion protection pages of the PTB Braunschweig contain documents that confirm this fact (commentary on the significance of the requirement of EU Directive 2014/34/EU (formerly: Directive 94/9/EC), Annex II, Part A, Effects of the replacement of existing standards by new harmonized standards, Notes on the issuance of EU declarations of conformity in accordance with EU Directive 2014/34/EU after the publication of a new edition of standards). Second type plate for Ex motors enclosed separately. In some cases, customers also request a separately enclosed type plate for Ex motors. This usually applies to machines or systems where the type plate attached to the motor is no longer legible when installed. However, current standards do not permit the delivery of a loose, complete type plate.
The labeling of Ex products is regulated in IEC/EN 60079-0 Chapter 29. The following principle applies: “It is essential that the labeling system described below is only applied to electrical equipment or Ex components that comply with the relevant standards listed in Section 1 for the respective type of protection.”

This means that no Ex marking in accordance with IEC/EN 60079-0 may be affixed to components or products that do not comply with the Ex-relevant standards and are therefore not certified by the manufacturer or a notified body.
Furthermore, IEC/EN 60079-0:2018, Chapter 29.1 regulates the marking location. “The electrical equipment must be clearly readable on the main component on the outside of the enclosure and must be readable before the equipment is installed.” This means that the component of a machine/system bearing an Ex marking is considered the main component of the ATEX-certified device.

It is therefore not permitted to supply a second nameplate with Ex marking and Ex information with the motor for attachment somewhere outside the motor housing.
As an alternative, e.g., if the main motor nameplate is difficult to read when installed, a second or additional motor information plate without Ex marking (see examples below, with motor number and all electrical information) can be supplied.



Motor for use in zones 1 and 21



Corresponding additional type plate without Ex labeling

1.6 Electric motors – mechanical structure and key design features for compliance with explosion protection requirements

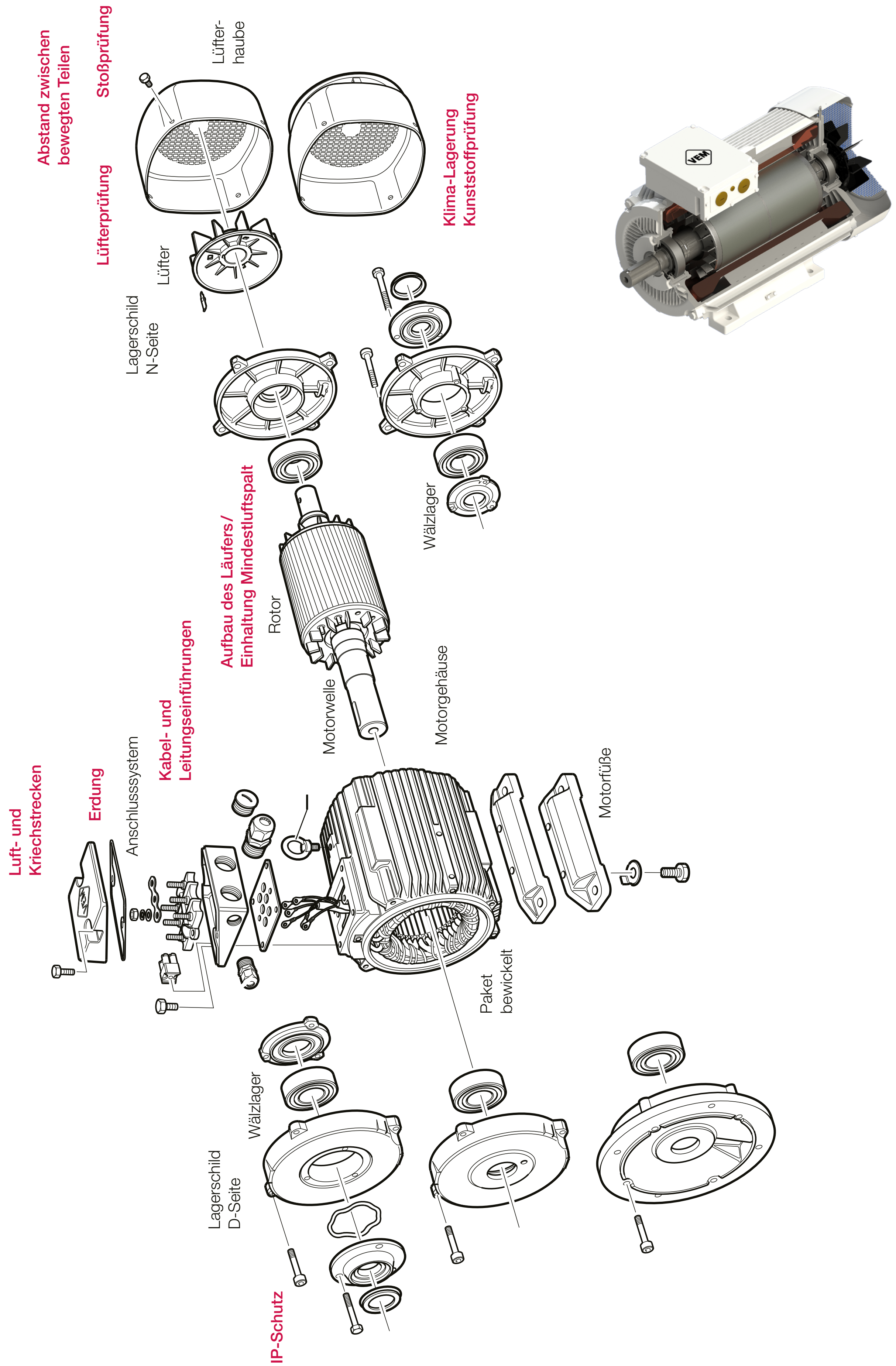


Figure 1.2: Exploded view

The IEC/EN 60079-0 standard forms the basis for the mechanical design of all electrical machines for use in potentially explosive atmospheres. For the “enhanced safety” (eb) ignition protection type (IEC/EN 60079-7), the focus is on the following areas, which must be subjected to the corresponding tests:

Cable and wire entry:
Conducting tensile tests, hardness increase of elastomers: IEC/EN 60079-0

Material combinations:
Prevention of friction and impact sparks

Air and crawl distances:
Compliance with air and crawl distances in accordance with IEC/EN 60079-7 to prevent ignitable electrical discharges and sparking

Distance between moving parts:
Prevention of mechanical wear during operation. In asynchronous machines, for example, the minimum air gap values between the stator and rotor specified in IEC/EN 60079-7 must be observed.

Impact testing:
Ensuring sufficient protection against mechanical damage

Fan testing:
Checking the mechanical stability of the fan

Plastics testing:
Verification of the heat and cold resistance of the materials used Plastics, checking the temperature resistance of seals. For plastic surfaces with a contiguous area larger than specified in IEC/EN 60079-0 depending on the explosion group, the issue of electrostatic charges must be considered.

IP protection:
Verification of the IP protection class of the equipment against solid foreign bodies and liquids. If the test confirms that the above points are fulfilled in accordance with the normative requirements, the testing center issues a mechanical test report, which forms the basis for the EU type examination certificate. This also includes a review of the operating instructions and documents describing the mechanical design of the series. Subsequent changes by the manufacturer are only permitted after consultation with the testing laboratory; under certain circumstances, addenda or new EU type examination certificates may be required.

Winding design and electrical-thermal testing:
No part of electrical equipment may reach a temperature higher than the temperature resistance of the materials used. In addition, no surface of any part of the equipment, including internal parts that may come into contact with the explosive atmosphere depending on the type of protection, may reach a temperature higher than the maximum surface temperatures specified in IEC/EN 60079-0..

The limit temperature of insulated windings in motors with increased safety “eb” type of protection must not exceed the values specified in IEC/EN-60079-7:2015 (Table 4), which are based on the thermal resistance of the insulating materials.

	Temperature measurement method	Heat class of insulating materials according to IEC 60085									
		105 (A)		120 (E)		130 (B)		155 (F)		180 (F)	
		„eb“	„ec“	„eb“	„ec“	„eb“	„ec“	„eb“	„ec“	„eb“	„ec“
Maximum operating temperature (°C) during normal operation Single-layer, insulated windings	Resistor or thermometer	95	105	110	120	120	130	130	150	155	174
Maximum operating temperature (°C) during normal operation other insulated windings	Resistor	90	100	105	115	110	120	130	145	155	165
	Thermometer	80	N/A	95	N/A	100	N/A	115	N/A	135	N/A
	Built-in sensor Output power > 5 MW or 5 MVA	95	105	110	120	120	125	135	150	160	170
	Built-in sensor > 200 kW or 200 kVA ≤Output power ≤ 5 MW or 5 MVA	95	105	110	120	120	130	135	155	160	175
Highest temperature of the motor winding (°C) a, end of time t_E or switch-off time via built-in sensor	Resistor	160	N/A	175	N/A	175	N/A	210	N/A	235	N/A

Table 4: Limit temperatures for insulated windings (according to IEC/EN 60079-7)

In addition to the mechanical design, the electrical-thermal design and testing is a very important step on the way to obtaining EU type examination certification for an explosion-proof electric machine. The data determined during the testing of the motors forms the basis of the data sheet for the EU type examination certificate and, if complied with, ensures safe operation of the motor. The electrical-thermal testing covers the following points:

- **Verification that the winding design meets the criteria for the "eb" type of protection**
- **Determination/verification of the machine's rated data**
- **Determination of continuous operating temperature rise**

When performing the heating measurement, the test specimen is loaded with the specified mechanical load and, during the test, the electrical power absorbed, the mechanical power output, as well as the current, voltage, speed, and torque are measured and automatically recorded. The measurement can be terminated when the temperatures measured on the housing during operation change by less than 2 K per hour (thermal steady state according to IEC/EN 60034). The temperature of the stator winding is calculated from the temperature-dependent resistance change from a winding resistance measurement when the machine is cold before the test and when the machine is at operating temperature after reaching thermal steady state. The rotor temperature is measured after the test using a sensor inserted through an opening in the bearing shield at the short-circuit ring.

Temperature measurement:
The temperature measurement on the housing is carried out using thermocouples, which are embedded in small drill holes to ensure the best possible heat transfer. In addition, the temperature is measured at elastomer seals, cable entries, and wire branches, as well as at any attachments that may be present. It must be ensured that both the limit temperature of the temperature class for which the motor is to be certified and the permissible continuous operating temperatures of the plastics and attachments used are not exceeded. Temperature measurement of the stator and rotor is required for the ignition protection types increased safety "eb" for Zone 1 and increased safety 'ec' (formerly "nA") for Zone 2. For the ignition protection types pressure-resistant enclosures "db" and protection by enclosure (dust), only the heating of the outer surfaces needs to be checked. Another important measurement is the determination of the heating in the blocked state (only ignition protection type increased safety "eb"). Figure 1.2 shows an example of the temperature curve determined on the enclosure during a heating measurement. The measurement is completed when the "thermal steady state" is reached, i.e., a temperature change rate of less than 2 K/h.
In order to evaluate the measurement in terms of the limit temperatures of the elastomers used, the highest temperature occurring after the engine has been switched off must be taken into account for each such measuring point (e.g., seal).

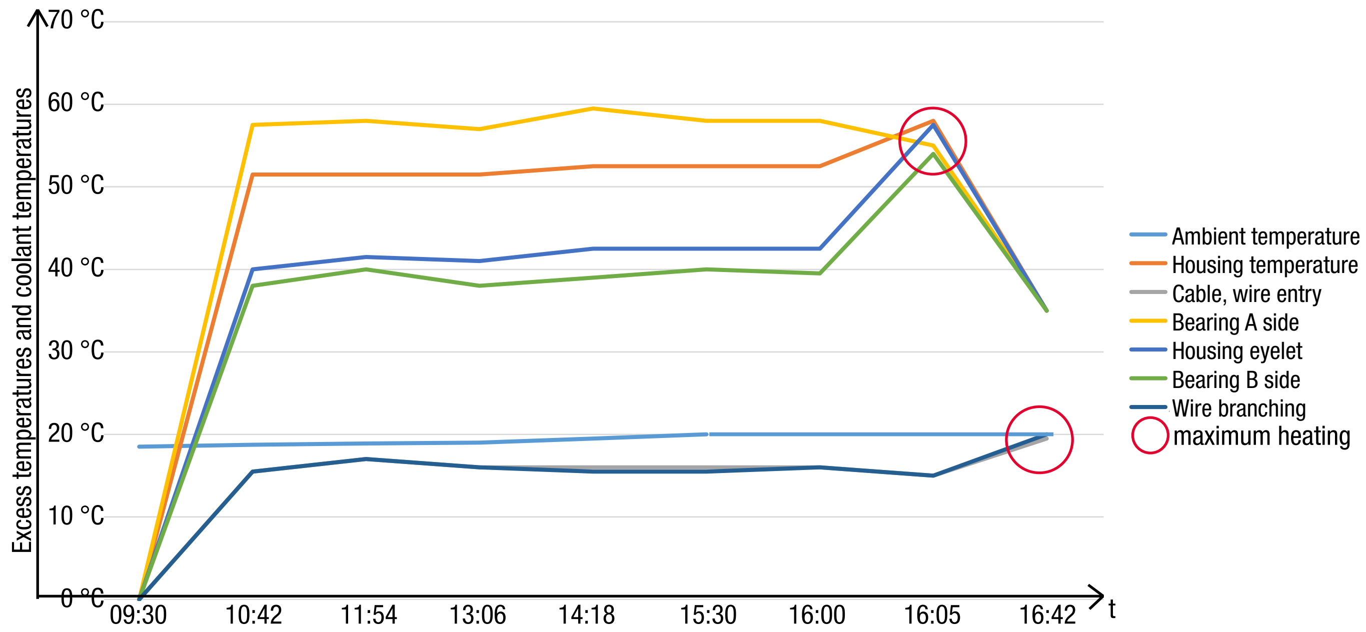


Chart 1.3: Example of the housing temperature curve during the test

Checking the machine protection/determining the time t_E and the ratio of starting current to rated current
This fault can occur, for example, if a working machine is blocked. A characteristic feature of this is that the motor current reaches a multiple of the rated current (e.g., seven times) and the machine heats up very quickly within a very short time. Without motor protection, the permissible temperature limits would be exceeded within a few seconds. Therefore, the machine must be protected against impermissible heating due to overload by means of a time-dependent overcurrent protection device (motor protection switch) or PTC thermistors embedded in the winding.
To measure the machine heating in a locked state, the rotor is equipped with thermocouples staggered along its length and the blocked motor is switched on for a defined time, e.g., 15 s. The temperature curve of the rotor is recorded by a temperature recorder, and the stator winding temperature is determined after shutdown based on the increase in winding resistance. The blocking test is performed with both directions of rotation, whereby measurable differences in heating occur in the rotor with skewed rotor bars. The rotating field with the highest heating is used for further evaluation.
For machines with type of protection "db" (pressure-resistant enclosures) there is no need to consider the possibility of jamming, as it is assumed that, with state-of-the-art motor protection, the high heat capacity of the stator laminations and the housing prevents any ignition-hazardous heating from occurring on the housing surface.

With the ignition protection type increased safety "ec" (formerly "nA") for Zone 2, the fault condition, i.e., the blocked state, also does not need to be considered.

Time t_E
The time t_E is a very important parameter in the data sheet of the EU type examination certificate for the ignition protection type increased safety "eb". This value specifies the maximum time after which the overcurrent protection device (motor protection switch) must switch off the motor in a blocked state.

To determine these values, the continuous operating temperature and the rate of temperature rise in the locked state are required for the stator and rotor. The calculation is based on the continuous operating temperature and the maximum permissible temperatures for the rotor and stator to determine the maximum permissible temperature rise in the locked state and, using the rate of temperature rise, to calculate the maximum duration of the locked state for both directions of rotation. The smaller of the two numerical values minus a safety margin of at least 5% gives the time t_E. If the machine is protected by a device for direct temperature monitoring, e.g., a PTC thermistor, an overload test and a shutdown test with the machine locked must be carried out to verify that no impermissible temperatures occur even in the event of a fault. The t_A time is then included in the EU type examination certificate instead of the t_E time; the I_A/I_N is not specified. The maximum permissible temperatures are specified in the standards IEC/EN 60079-0 (temperature classes) and IEC/EN 60034 (heat classes for winding insulation).

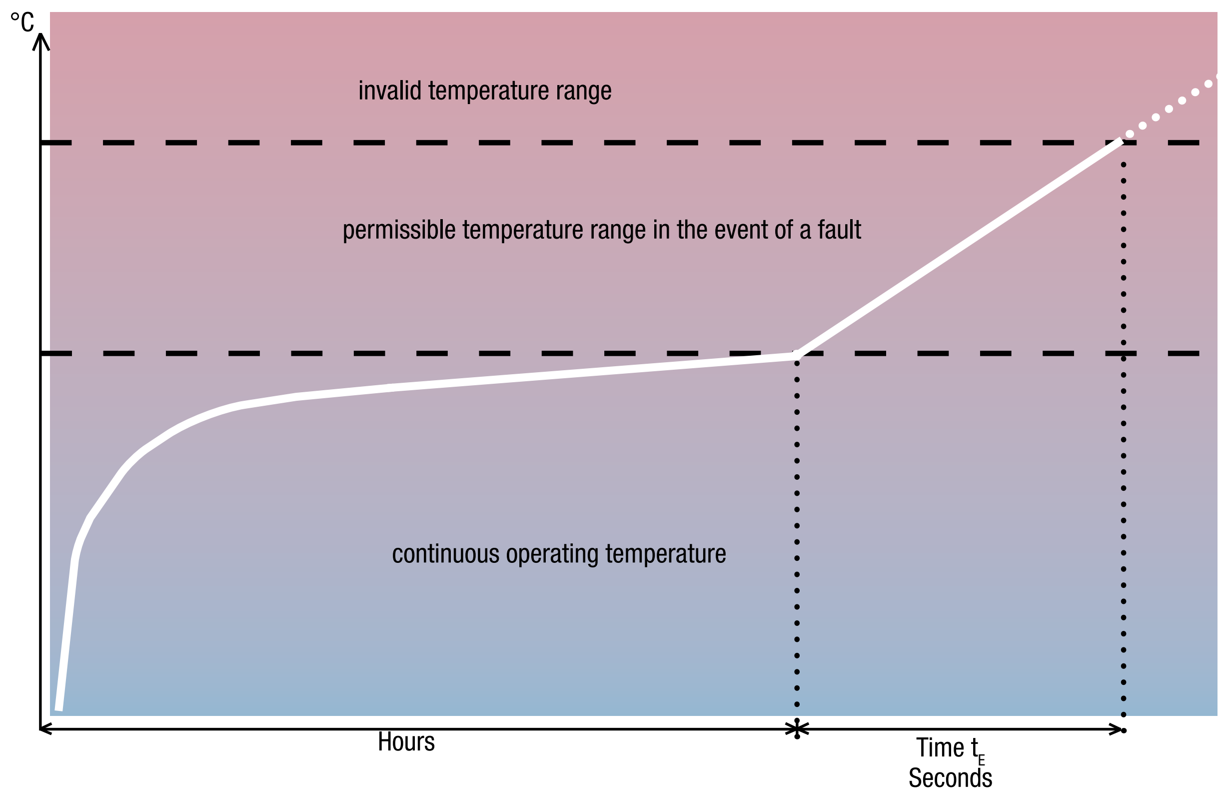


Chart 1.3: Definition of time t_E

1.7 High-voltage testing of windings using gas

These tests are required if the following criteria apply:

- The machine is a high-voltage machine (rated voltage > 1 kV).
- An ignition risk assessment in accordance with IEC/EN 60079-7 Table G.1 resulted in an ignition risk factor > 6.

The high-voltage test consists of an AC voltage test and an impulse voltage test. The windings are tested individually, with the unused strands and the stator laminations being grounded. The test specimen is located 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 passed if no ignition occurs during the AC voltage test and the surge voltage test when testing two winding strands.

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

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

Risk assessment regarding possible sparking in the air gap of cage runners - ignition risk factors		
Features	Value	Factor
Construction of the rotor cage	non-insulated dust runner cage	3
	Die casting with open slot ≥ 200 kW per pole	2
	Die casting with open slot ≤ 200 kW per pole	1
	Die casting with closed nut	0
	Die casting with insulated rods	0
Number of poles	2 poles	2
	4 to 8 poles	1
	> 8 poles	0
Rated power	> 500 kW per pole	2
	> 200 kW to 500 kW per pole	1
	≤ 200 kW per pole	0
Radial cooling slots in the rotor	yes : L < 200 mm (see a)	2
	yes: L ≥ 200 mm (see a)	1
	no	0
Runner or stand bevel	yes: > 200 kW je Pol	2
	yes: ≤ 200 kW je Pol	0
	no	0
Parts around the runner's winding head space	not fulfilled (see b)	2
	fulfilled (see b)	0
Limit temperature	> 200 °C	2
	135°C < T ≤ 200°C	1
	≤ 135 °C	0

a) L is the length of the end bundle of the core. Experimental investigations have shown that sparks occur preferentially in the cooling slots near the end of the bundle.

b) Parts in the winding head space of the runner must be arranged in such a way that intermittent contact is impossible and that they operate within the temperature class. If these conditions are met, the factor is 0; otherwise, it is 2.

1.8 Installation and electrical connection

Buring installation and commissioning, always observe the safety instructions supplied with the motor. Installation work may only be carried out by qualified personnel who, due to their professional training, experience, and instruction, have sufficient knowledge of

- safety regulations
- accident prevention regulations
- guidelines and recognized rules of technology (e.g., VDE regulations, standards).

Specialist personnel must be able to assess the work assigned to them and identify and avoid potential hazards. They must be authorized by the person responsible for the safety of the facility to carry out the necessary work and activities. The installation of electrical systems in potentially explosive atmospheres in Germany requires compliance with the following regulations:

- BetrSichV - "Industrial Safety Regulation"
- TRBS - "Technical Rules for Operational Safety"
- GefStoffV - "Hazardous Substances Ordinance"
- IEC/EN 60079 ff. "Explosive Atmospheres"

Outside Germany, the relevant national regulations must be followed!

The permissible coolant temperature (room temperature at the installation site) according to IEC/EN 60034-1 is a maximum of 40 °C and a minimum of -20 °C without labeling, and the permissible installation altitude is up to 1000 m above sea level (deviating values are indicated on the motor nameplate and, if necessary, certified separately).

It should be noted that the cooling air must be able to flow freely into the air inlet openings and out through the air outlet openings without obstruction and must not be sucked back in immediately. The intake and exhaust openings must be protected against contamination and rough dust.

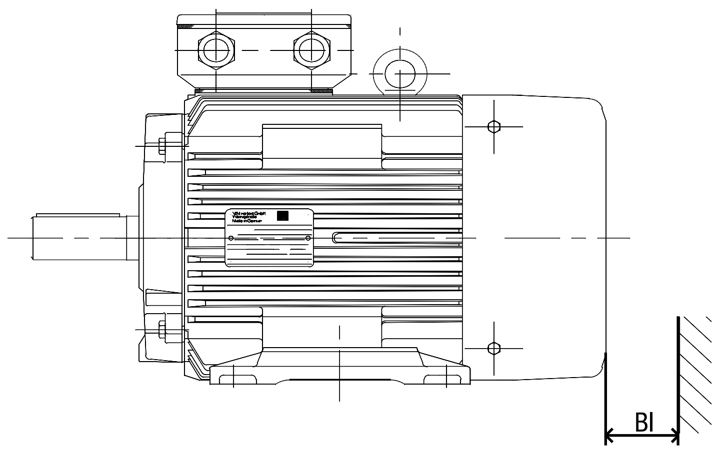


Image 1.5: Minimum distance at the air inlet

The minimum distance between the air inlet of the fan cover and any obstacle (dimension Bl) must be observed. For designs with the shaft facing upwards, the operator must prevent foreign objects from falling vertically into the fan. The same applies to the "shaft facing downwards" installation – in this case, a protective cover is required above the fan cover grille. When installing surface-cooled motors, ensure that the condensation drain holes are located at the lowest point. If the condensation drain holes are closed, the screws must be replaced with sealant after the condensation has been drained.

In the case of open condensation holes, direct exposure to water jets or splashing water must be avoided. Careful installation of the motors on a perfectly level surface is essential to prevent tension when tightening the screws. Machines that are to be coupled must be aligned precisely. Elastic couplings should be used wherever possible.

Motor connection

The connection must be made by a specialist in accordance with the applicable safety regulations. Outside Germany, the relevant national regulations must be applied.

The information on the type plate must be followed!

- Compare the type of current, mains voltage, and frequency!
- Check the circuit!
- Check the rated current for circuit breaker setting!
- For motors with increased safety "eb" ignition protection, observe the t_E time!
- Connect the motor according to the terminal diagram provided in the connection box!

Depending on the design and type of motor, there is an grounding terminal on the housing or flange bearing shield for grounding. All motors also have a protective conductor terminal inside the terminal box. Unused cable glands in the terminal box must be sealed to protect against dust and moisture. The general safety and commissioning instructions apply to the electrical connection. The cable glands or screw plugs must be certified for use in hazardous areas. The installation torques, sealing ranges, and clamping ranges of the strain relief specified by the gland manufacturer must be strictly observed. Connection cables must be selected in accordance with DIN VDE 0100, taking into account the rated current and the system-dependent conditions (e.g., ambient temperature, type of installation, etc., in accordance with DIN VDE 0298 or IEC/EN 60204-1).

At room temperatures above 40 °C, cables with a permissible operating temperature of at least 90 °C must be used. This also applies to motors in which the supplementary sheet to the EU type examination certificate refers to special requirements for cable design with an X.

When connecting the motors, particular care must be taken to ensure that the connections in the terminal box are made carefully. The nuts on the terminal screws must be tightened firmly without using force. For motors with a terminal board with slotted bolts in accordance with Directive 2014/34/EU, only cable lugs in accordance with DIN 46295 may be used for the motor connection. The cable lugs are fastened with pressure nuts with integrated spring washers. Alternatively, a solid round wire with a diameter corresponding to the slot width of the connection bolt may be used for the connection.
When inserting the supply cables into the connection box, ensure that the cables are strain-relieved. Keep the inside of the connection boxes clean. The seals must be intact and fit correctly. The connection box must always be closed during operation.

Protective measures against excessive heating

Unless otherwise specified in the EU type examination certificate data sheet or on the nameplate, electrical machines are designed for continuous operation (duty cycle S1) and normal, infrequent starts that do not cause significant start-up heating. The motors may only be used for the operating mode specified on the nameplate.

In general, Ex motors are designed and certified for voltage and frequency limits in accordance with IEC/EN 60034-1 (DIN VDE 0530, Part 1) – voltage ± 5%, frequency ± 2%, waveform, mains symmetry. Increasingly, Ex motors are also being manufactured for larger supply voltage tolerances. This should be indicated on the motor nameplate and, if necessary, on the EU type examination certificate. There are numerous data sheets and supplementary sheets for EU type examination certificates with a voltage tolerance of ±10% according to range B. The specified tolerances must be strictly adhered to in order to keep the heating within the permissible limits. Larger deviations from the rated values can increase the heating of the electric machine to an impermissible level. The motor must be protected against impermissible heating during start-up, e.g. with a motor protection switch, i.e. impermissible heating must be prevented in all phases by a current-dependent delayed circuit breaker in accordance with DIN VDE 0660 or an equivalent device. The protective device must be set to the rated current. Windings in delta connection must be protected in such a way that the triggers or relays are connected in series with the winding strands. The selection and setting of the triggers must be based on the nominal value of the phase current, i.e., 0.58 times the rated motor current. If such a circuit is not possible, suitable circuit breakers, e.g., with phase failure monitoring, must be used. For pole-changing motors, current-dependent delayed releases or relays must be provided for each speed stage, which must be interlocked with each other. With the "eb" type of protection, the start-up is also monitored. The protective device must therefore switch off within the t_E time specified for the respective temperature class when the rotor is blocked. The requirement is met if the tripping time (which can be taken from the tripping characteristic curve (initial temperature 20 °C) for the I_A/I_N ratio) is not greater than the specified t_E time.

Electrical machines with increased safety "eb" ignition protection for heavy starting (start-up time > 1.7 · t_E time) must be protected by start-up monitoring in accordance with the information in the certificate of conformity and must also be certified as such.

Thermal machine protection through direct temperature monitoring of the winding is permitted if this is certified and the t_A time is specified on the rating plate. Explosion protection is ensured by temperature sensors in accordance with DIN 44081/44082, in conjunction with triggering devices with protection class II (2) G.

Reactivation

If the overload switch is triggered, qualified personnel must determine the possible cause. Once this has been eliminated, the motor may be switched on again. One problem that is not clearly described in any standards or regulations is the time period after which this restart may take place. This time is determined by a variety of factors, such as the start-up time, the t_E time according to the nameplate, the heating of the motor, the current coolant temperature, and so on. If the motor is switched on too early, especially if it blocks again, the temperature could exceed the temperature permitted for the respective temperature class and ignite any explosive mixture that may be present.

With very short start-up times, the motor can be switched on repeatedly without risk until the total start-up time reaches the t_E time. If, for example, the t_E time specified in the EU type examination certificate is 15 seconds, but the start-up takes only 3 seconds, five consecutive starts could be performed before a sufficiently long pause is required.

In studies on this topic, which we conducted together with PTB Braunschweig, a rule of thumb for safe restarting was determined. Multiplying the ratio of ramp-up time to t_E time by 300 gives the minimum pause time in minutes. In the example above, this results in: 3s÷15s·300min=60min. This time is significantly longer than the 10 minutes often used in "practice."

Optional equipment

Explosion-proof motors can be equipped with optional additional features:

Additional thermal motor protection

Temperature sensors (PTC thermistors, KTY, PT1000, or PT100) may be installed in the motor to monitor the stator winding temperature. Appropriate auxiliary terminals for auxiliary circuits are available for connecting these sensors in either the main terminal box or in additional terminal boxes. Connect them according to the enclosed terminal diagram.

Thermal motor protection as full protection

The use of thermal winding protection as full motor protection is only permitted if this operation has been separately tested and certified by a notified body. In this case, the type plate is marked with the t_A time instead of the t_E time and the text "Operation only with functionally tested PTC release device with protection class marking II (2) G".

Standstill heating

The heating cables must comply with the requirements of Directive 2014/34/EU. The heating power and connection voltage are specified on the motor type plate. Appropriate terminals for auxiliary circuits are provided for connection either in the main connection box or in additional connection boxes. Connection is made to these terminals in accordance with the enclosed terminal diagram. The standstill heating must only be switched on after the motor has been switched off. It must not be switched on while the motor is running. This must be ensured by means of a locking mechanism in the circuit.

External ventilation unit

The forced ventilation fans must meet the requirements of Directive 2014/34/EU and be suitable for the intended type of ignition protection. The forced ventilation unit ensures that heat loss is dissipated when the main motor is in operation. The forced ventilation motor must be switched on during operation of the main motor. After switching off the main motor, a temperature-dependent overrun of the forced ventilation must be ensured. In the event of a malfunction of the forced ventilation fan, the main motor must be switched off.
For motors with external fan units that are dependent on the direction of rotation, the direction of rotation must be observed (direction of rotation arrow). Only external fan units supplied by the manufacturer may be used. The external ventilation unit must be connected in accordance with the valid terminal diagram supplied in the connection box.

External heat and cooling sources

No additional measures are necessary for existing external heat and cold sources if the permissible ambient temperatures at the installation site are not exceeded. If these are exceeded, or if effects on the operating temperature or maximum surface temperatures are to be expected, suitable measures must be taken to maintain and verify explosion protection. Information on this can be found in VDMA Standard Sheet 24263:2014-03, see also Section 2.4. In case of doubt, consult the manufacturer.

General information on operating the frequency converter

Explosion-proof three-phase motors may only be operated on frequency converters if they have been manufactured, tested, approved, and specially marked for this purpose. The manufacturer's specific instructions must be observed. For the ignition protection types increased safety "eb" and protection by enclosure "tb," EU type examination certificates are required in which operation with a frequency converter is explicitly approved and in which the conditions and parameter settings to be observed for the motor, frequency converter, and protective device are listed. For the types of protection increased safety "ec" and protection by enclosure "tc", motors that are supplied by converters with variable frequency and/or voltage must also be tested with the specified converter or a converter that is comparable in terms of output voltage and current specifications.

The necessary parameters and conditions can be found on the nameplate or in the motor documentation.
To prevent excessive temperatures, the motors are equipped with thermal winding protection, which must be evaluated using a suitable device. The motors must not be operated as a group drive. The manufacturer's instructions and operating manual must be strictly observed when installing and commissioning the frequency converter.

1.9 Electrostatic hazard

1.9.1 Introduction

In recent years, products with plastic parts, especially plastic housings, and powder-coated metal parts have become increasingly important and are gradually replacing products made of wood and glass or bare or liquid-coated metal. Unlike metal, wood, glass, and most liquid-painted surfaces, however, plastics and powder-coated surfaces can in most cases become electrostatically charged through friction. Such surfaces can become highly electrostatically charged through friction with clothing or when attempting to clean them with a cloth.

If a grounded counterelectrode, e.g., a person's finger, approaches these charged surfaces, electrostatic discharges that can ignite solvent vapors may occur.
The following section shows how such ignition hazards can be identified and controlled. There are numerous long-established sets of rules and regulations for this purpose, which differ only in minor details. Compliance with the provisions of these rules and regulations gives rise to a "presumption" that a sufficiently high level of protection is in place that complies with all higher-level rules and regulations.

1.9.2 Regulations

IEC/EN 60079-0
An entire chapter of this standard deals with electrostatic requirements. However, it should be noted that these requirements have been more or less copied from earlier electrostatic regulations and therefore do not represent a text written by electrostatic experts. As a result, there may be ambiguous or misleading wording.
For example, the standard requires surfaces to be cleaned with liquid before measuring surface resistance. However, this typically results in deposits from the liquid, which significantly affect the surface resistance. For this and other similar reasons, it is recommended that the test be carried out in accordance with IEC/TS 60079-32-1 Amendment 1, Section 14, using the test method specified in IEC 60079-32-2. This largely avoids such measurement inaccuracies. For example, the surface of the test sample is only cleaned with a brush. Otherwise, exactly the same result is obtained in both cases (-0 and -32).
The weaknesses of IEC 60079-0 mentioned above are known to the testing experts and are usually taken into account during testing. Therefore, it is not necessary to check the measured values obtained according to -0.

TRGS 727:2016
TRGS 727:2016, formerly TRBS 2153:2009, and before that BGR132:2003 and ZH1/200:1989, is the German-language set of rules for preventing electrostatic charges. It is currently the most up-to-date set of rules regarding electrostatics. It was previously the set of regulations from which European and international regulations were copied. Even today, you can be sure that the latest findings published here will be incorporated into international standards. However, TRGS 727 is a set of regulations for the entire industry and everyday life with all its everyday processes (e.g., refueling motor vehicles). It is therefore often difficult for external parties to find the right chapters, as there is no specific chapter for electrical equipment.

IEC/TS 60079-32-1 with Amendment 1, IEC 60079-32-2
IEC/TS 60079-32-1 is an international specification derived from TRBS 2153:2009 for the prevention of electrostatic charges. It represents the current best internationally recognized state of the art for the prevention of dangerous electrostatic charges in textbook form. Since this specification prescribes numerous operational measures, this set of rules cannot be published as a standard.
The most important chapters for electrical equipment are Section 14 in Amendment 1 and the flowchart for electrostatic testing in the appendix to IEC/TS60079-32-1 (Figure 1.9). Detailed test specifications for determining the required parameters can be found in IEC 60079-32-2.

1.9.3 Test procedure

The following describes the typical procedure for an electrostatic test in accordance with the flowchart in IEC/TS 60079-32-1 for a plastic enclosure of electrical equipment that is to be used in a specific zone (in the example, Zone 1, Group IIC) (Figure 1.9.). It should be noted that the reference chapters specified in Figure 1.9 are summarized in Section 14 in the case of electrical equipment. During the test procedure, particular attention must be paid to the specified sequence, as the requirements mentioned are all linked by "or" and contradictions may arise if the sequence is incorrect.

1. Is the test sample exposed to manual friction, e.g., through contact with work clothing or during cleaning processes with a cloth? Or to flowing particles (e.g., liquids or dust)? Or is it located near high-voltage electrodes? Yes, the test sample is exposed to manual friction, e.g., from work clothing. Continue with 2.
2. Are there any conductive or semi-conductive parts with an impermissibly high electrical capacity on the test sample? Yes, there is an electrical screw contact on the test sample that is accessible from the outside. However, its electrical capacitance measured in accordance with IEC 60079-32-2 is only 2.5 pF, which is below the required limit value for Zone 1 Group IIC of less than or equal to 3 pF. Continue with 3
3. Is the surface resistance of the test sample, measured in accordance with IEC 60079-32-2, greater than the permissible limit value of 100 gigaohms, measured at a maximum relative humidity of 30% and a minimum measuring voltage of 500 V (preferably at least 1000 V)? Yes, continue with 4.
4. Does the maximum possible friction-exposed projected area of the test sample exceed the specified maximum value (in our example, max. 2000 mm² for Zone 1 Group IIC)? Yes, the value is significantly exceeded. Continue with 5.
5. Is the interior of the housing coated with a conductive material? No, the interior of the housing is not coated with a conductive material. Continue with 6.
6. Is the maximum possible charge transferred by a provoked discharge, measured according to the method specified in IEC 60079-32-2, no more than 10 nC? Yes, during the discharge test, no discharge and therefore no transferred charge could be observed. The enclosure is therefore sufficiently antistatic and meets the requirements of all regulations mentioned in 1.9.2. Alternatively, it could have been determined at point 3 and a measurement voltage of 10,000 V that the surface resistance breaks down at higher voltages and that the test sample cannot be dangerously electrostatically charged at the high electrostatic voltages present.

The further procedure for alternative answers can be found in Figure 1.6.

1.9.4 Further information

Often, one is faced with the problem: How do I make a rechargeable test sample that meets the surface criterion in 1.9.3, point 4, for IIB, also safe for IIC? There are various options for this, which are listed below as examples:

1. Covering the test sample with a leather bag, paper/cardboard/ antistatic film, or antistatic paint, etc.; antistatic sprays last at least one year but cannot be used outdoors.
2. Conductive grounded coating of the test sample on the inside (only in the absence of electrostatic charges stronger than those possible through manual friction and with a housing thickness of no more than approximately 0.2 mm).
3. Prevent electrostatic charges by using the test sample in a basement or a hole in the ground with a permanent puddle of water (a relative humidity of more than 60% at all times means that electrostatic charges are not possible under these conditions), by mounting it on the ceiling (manual friction is not possible here, but a sticker stating "Clean only with a damp cloth" is provided) or use within an area where explosive atmospheres are prevented from entering by means of positive air pressure.
4. Use of liquid paints on conductive substrates (primers for electrostatic painting of top coats are typically conductive) - unlike powder coatings, liquid paints typically have a sufficiently low dielectric strength to prevent electrostatic charging, but are not as corrosion-resistant.

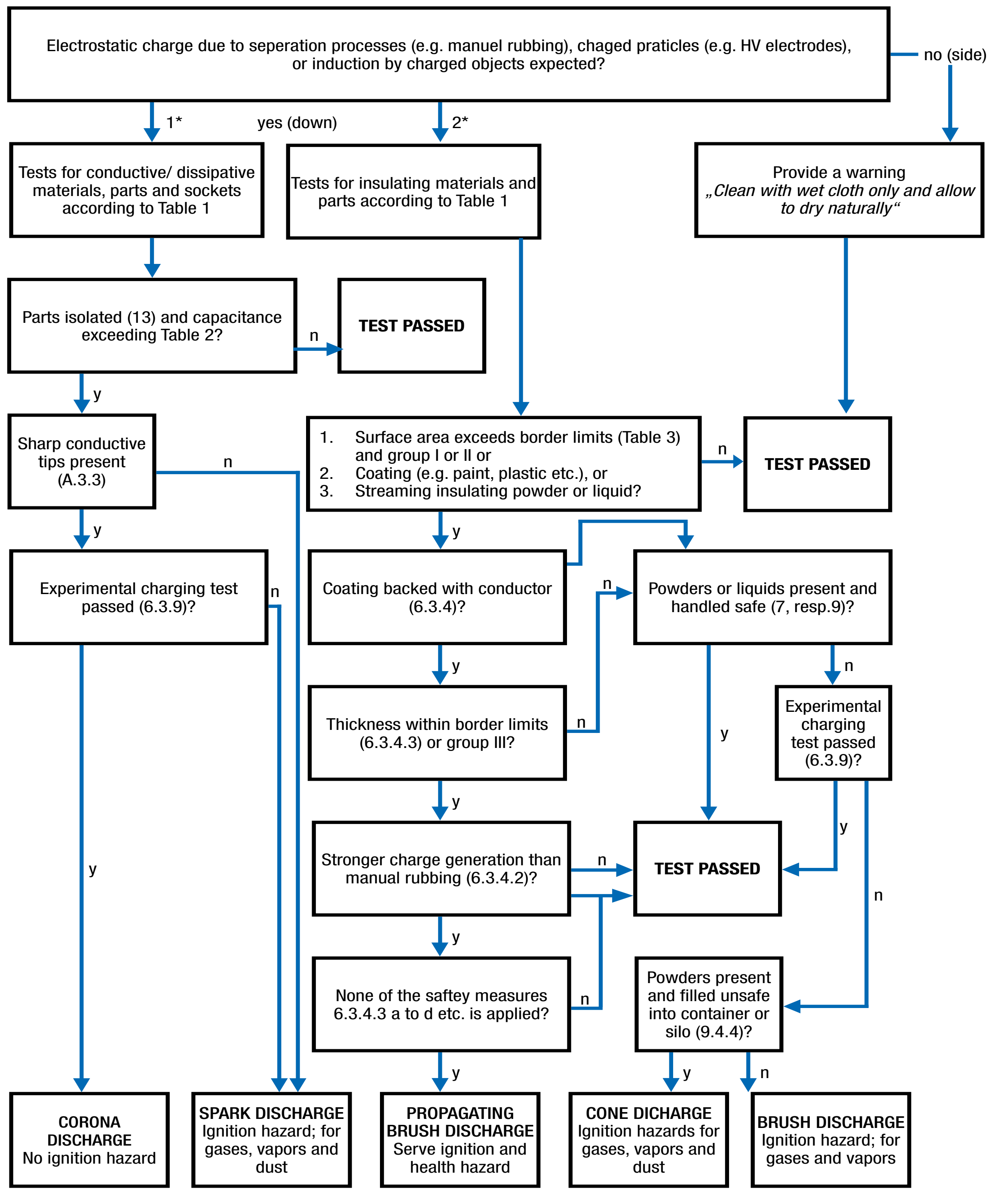


Figure 1.6: IEC/TS 60079-32-1, Figure F.1 – Flowchart for a systematic electrostatic evaluation with reference to the respective chapters

2 Technologies for protecting induction machines from unreliable heating due to overload – an overview from the perspective of explosion protection

2.1 What legal/regulatory requirements exist regarding the protection of electrical machinery in potentially explosive environments?

Directive 2014/34/EU:
Directive 2014/34/EU states the following about Category 2 equipment (Equipment Group II), which includes electrical machines operated in Zone 1: “Category 2 comprises equipment which is designed to be operated in accordance with the parameters specified by the manufacturer and which ensures a high level of safety.” It further states: “The equipment explosion protection measures in this category ensure the required level of safety even in the event of frequent equipment malfunctions or fault conditions that are normally to be expected.” It follows from this that all Category 2 equipment must not become a source of ignition in the event of frequent or expected faults and malfunctions. Furthermore, article 1, paragraph 2 states: “The scope of this directive also covers safety, control, and regulation devices for use outside potentially explosive areas, which are necessary or contribute to the safe operation of equipment and protective systems with regard to explosion hazards.” **The provisions of the directive require that all Category 2 engines must be protected against excessive heating and that all devices and equipment used to protect the engine must be certified.**

ATEX guidelines:
The ATEX guidelines specify the requirements of the directive and are drawn up by the Commission‘s standing committee on the directive. Chapter 3.10 states: “Safety, control, and regulation devices are subject to the Directive if they contribute to or are necessary for the safe operation of equipment or protective systems with regard to ignition hazards or the risk of an uncontrolled explosion.” It goes on to say: „These devices are also covered if they are intended to be used outside potentially explosive atmospheres. These devices are not classified into categories according to Article 1.“ It goes on to state: ”The essential requirements apply to these devices only insofar as they are necessary for the safe and reliable functioning and handling of these devices with regard to ignition hazards or the risk of an uncontrolled explosion.“ An explicit example is given: overload protection devices for electric motors with increased safety protection type “eb.” There is no statement regarding the protection of motors with ignition protection types “db,” “p,” and “ec.” **The guideline states that motors with increased safety “eb” ignition protection must be protected by a monitoring device certified in accordance with Directive 2014/34/EU..**

IEC/EN 60079-14:
The operation of electrical equipment for explosion protection is described in IEC/EN 60079-14. Application of the standard is not mandatory. Chapter 7.1 first states the following for all electrical equipment: “All electrical equipment shall be protected against the harmful effects of short circuits and earth faults.” It goes on to say: “Precautions must be taken to prevent the operation of multiphase electrical equipment (e.g., three-phase motors) if the failure of one or more mains phases could lead to overheating.”

In addition to electrical machines, section 7.2 states: „Rotating electrical machines must also be protected against overload, with the exception of motors that can carry the starting current at rated voltage and rated frequency, or generators that can continuously carry the short-circuit current without excessive heating. The following overload protection devices must be used: a current-dependent, time-delayed protection device for monitoring all three phases, set no higher than the rated current of the machine, which must respond within 2 hours at 1.2 times the rated current and must not respond within 2 hours at 1.05 times the rated current, or a device for direct temperature monitoring. times the set current within 2 hours and must not respond at 1.05 times the set current within 2 hours, or a device for direct temperature monitoring by means of embedded temperature sensors or another equivalent device.“ Section 11.3.1 further states: “In order to comply with the requirements of 7.2a), current-dependent time-delayed overload protection devices must be designed in such a way that not only the motor current is monitored, but also the locked motor is switched off within the time t_E specified on the rating plate.” For machines with delta connection, it is additionally stated: “Therefore, machines with delta-connected windings must be equipped with phase failure protection that detects current imbalances before they lead to excessive heating effects.” **In summary, it is recommended that all electrical machines in potentially explosive atmospheres be protected against overload, short circuit, and phase failure, and that the protection for the “eb” type of protection must also be effective in the event of a blockage..**

IEC/EN 60079-7:
Section 5.2.4.4.1 of the requirements for the increased safety “eb” ignition protection type states the following about the time t_E: “The time t_E must be long enough for the current-dependent protective device to be able to switch off the locked machine within this time. This is generally possible if the minimum values for t_E specified in Figure 2 (of the standard) as a function of the starting current ratio I_A/I_N are exceeded.“ **It follows from this that the range of the ratio of starting current to rated current is limited for machines with the “eb” ignition protection type, and that the time t_E must comply with the minimum values shown in Figure 2.4..**

IEC/EN 60079-1:
The standard for the ignition protection type flameproof enclosure “db” does not contain any information on the protection of rotating electrical machines. To determine the maximum surface temperature (Table 5), a test voltage of UA ± 10% (or UA ± 5% if the area of application is specified on the equipment and mentioned in the operating instructions) is required. There are no requirements for overload or fault conditions.

IEC/EN 60079-2:
The standard on pressure-tight enclosures does not contain any statements regarding the protection of rotating electrical machines..

IEC/EN 60079-7 (Ex ec):
In contrast to the above-mentioned types of ignition protection, devices with increased safety “ec” ignition protection fall into category 3 of Directive 2014/34/EU. Devices in this category must not have any ignition sources during normal operation. The temperature of any external or internal surface that may come into contact with an explosive atmosphere must not exceed the limit temperature of the specified temperature class under normal operating conditions.

The temperature increase during start-up does not need to be taken into account when determining the temperature class if operating mode S1 or S2 is specified in accordance with IEC/EN 60034-1. It is permissible not to take the starting conditions into account when determining the temperature class for machines that do not start frequently and for which the statistical probability of an explosive atmosphere being present during the starting process is considered to be acceptably low.
The machine only has to maintain the specified temperature class during normal operation. The start-up does not have to be monitored. There is no direct statement regarding errors that may occur.

2.2 Causes of unreliably high temperatures in an electrical machine

The most common cause of impermissibly high temperatures in an electric machine is overload, i.e., loading with a torque higher than the rated torque of the machine. This can be caused by incorrect drive design, sluggishness of the working machine, bearing damage, excessive viscosity of the medium in agitators, etc. When the load increases, the currents in the stator winding and the rotor cage increase, with the current heat losses increasing quadratically with the current. Another cause of impermissible heating of the machine is operation outside the electrical design parameters of the machine. Examples of this are:

Operation at low voltage:
When operating at reduced voltage, the stator currents of the machine increase in order to provide the power required by the driven machine plus the motor losses. Due to the reduced voltage across the main inductance in the equivalent circuit diagram of the machine, there is also a reduction in the magnetic flux density in the air gap, which leads to an increase in machine slip even at constant load torque. The relationship $P_{VCu2} = s \cdot Pd$ also leads to a sharp increase in electrical heat losses in the machine‘s rotor. The extreme case is the “tipping” of the machine, whereby the speed drops sharply and the stator current rises to the order of magnitude of the starting current.

Operation during overvoltage:
If the voltage is increased beyond the rated voltage range, magnetic saturation of the machine occurs. As soon as the operating point in the B-H characteristic curve of the sheet metal moves into the linear range and the value of µr approaches 1, very high magnetizing currents flow and the iron losses and stator winding losses increase significantly. This can result in unacceptable heating of the machine. Chart 2.1 illustrates the situation.

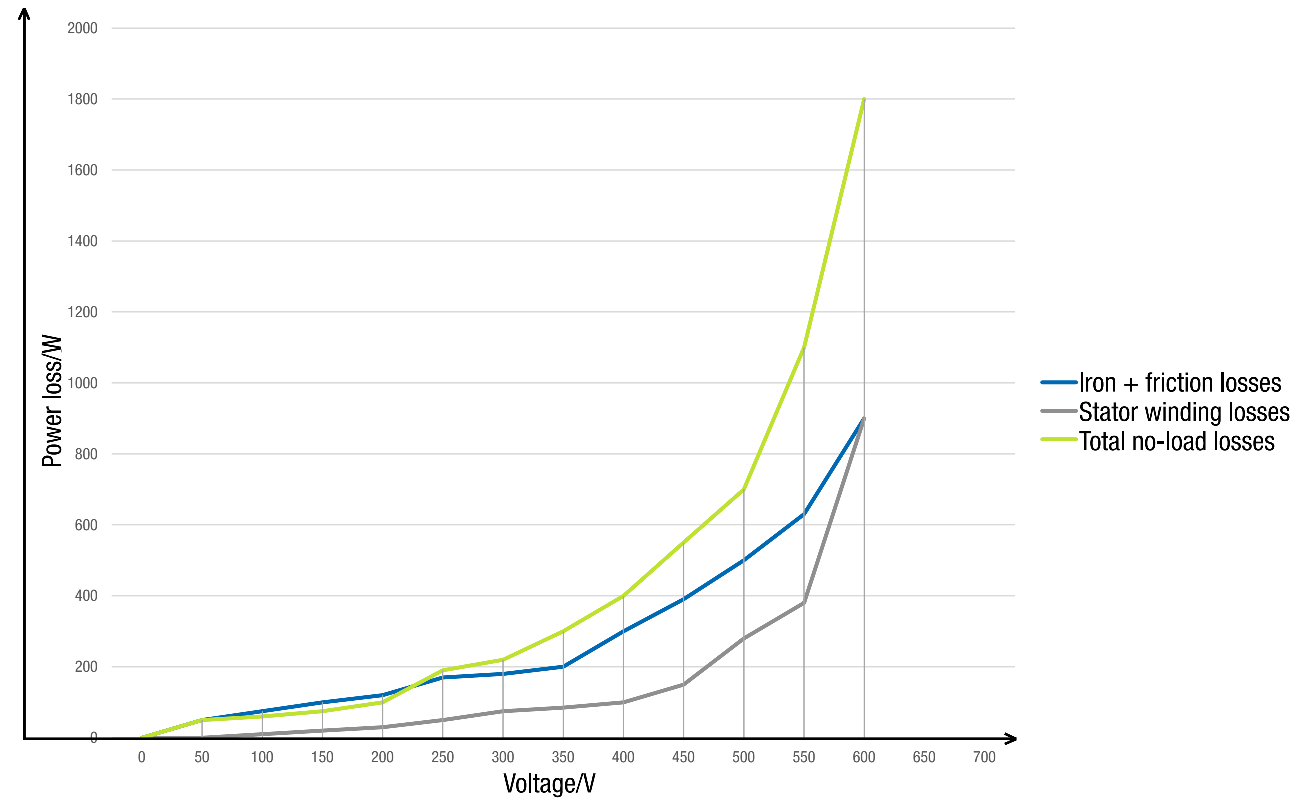


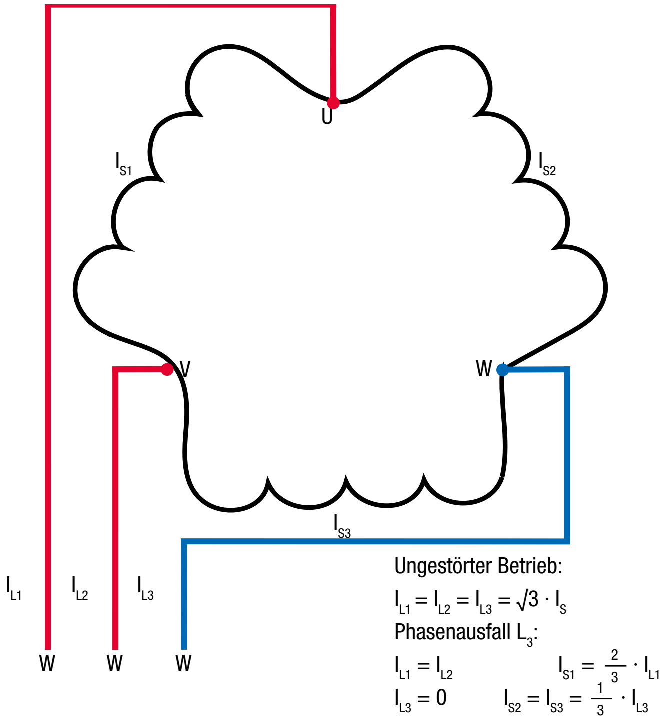
Chart 2.1: Curve of no-load losses as a function of voltage

Voltage imbalances/phase failure:
A voltage imbalance and, in extreme cases, the failure of one phase does not necessarily cause the motor to stop. With a low mechanical load, this merely results in increased slip. There is therefore a risk that this fault will remain undetected for a long time. However, with only two phases remaining and the corresponding counter-torque, the motor will no longer start.
If the motor is connected in star configuration, an increase in current will be recorded in the remaining phases. If the current exceeds the rated current of the machine, impermissible heating may occur. The motor protection switch must detect the overcurrent and switch off the motor.
In a delta-connected motor, a phase failure as shown in Scheme 2.2 means that a winding strand no longer carries $1/\sqrt{3}$ times the conductor current, but 2/3 times the conductor current. This means that thermal overload of this winding strand is possible without the protective device registering an overcurrent.
However, IEC/EN 60079-0 requires that the protective device must detect machine imbalances before impermissible heating occurs. This fault must therefore be detected by a certified motor protection device. The cause of the phase failure can be a tripped fuse or a loose terminal connection.
The interruption of a winding strand within the motor in a delta connection is particularly critical. In this case, the undisturbed winding strands are loaded with the full conductor current. To reliably detect this fault, the motor protection switch must be connected directly to the winding strands and set to $1/\sqrt{3}$ times the rated motor current in order to prevent ignitable heating and thermal damage to the winding.

Insufficient cooling:
If the cooling air passages are blocked or the motor is operated at too high an ambient temperature, there is a risk of impermissible temperatures even without overload. This fault can only be detected by means of direct temperature monitoring.

Converter operation:
Frequency converter-fed machines, if self-ventilated, are operated with variable speed heat dissipation to the environment. Here, the balance between fundamental vibration losses plus harmonic losses and heat dissipation to the environment and the heat storage capacity of the machine must be maintained at all times in order to prevent impermissible heating.

Voltage drop during start-up:
If voltage drops occur during the start-up process with high network impedances, this leads to an approximately linear reduction in the starting current with the voltage and to a quadratic reduction in the starting torque. There is therefore a risk that the machine will no longer start up if there is a corresponding counter-torque. Furthermore, the lower starting current shown in Chart 2.4 results in an extension of the shutdown time of the motor protection switch when the machine does not start. It must be ensured that the machine does not reach impermissible temperatures within the extended shutdown time.



Scheme 2.2: Delta connection in the event of a phase failure

2.3 Protection concepts for network-powered machines, protection requirements for explosion-proof drives

2.3.1 Ignition protection types pressure-resistant encapsulation „db“

With this type of ignition protection, the concept is based on the fact that an explosion can and may occur inside the motor, but due to the design of the housing, it is not transmitted to the surrounding explosive atmosphere. From an explosion protection perspective, the only requirement for these motors is that the outer surfaces do not exceed the certified temperature class during normal operation and in the event of malfunctions, and that the seals, connection cable, and other attachments are not thermally overloaded. These motors can be thermally protected both by a time-dependent overcurrent release and by PTC thermistors embedded in the winding. Directive 2014/34/EU and standard IEC/EN 60079-14 stipulate that motor protection is mandatory. However, the case of blockage is not considered separately, which is not necessarily required due to the large heat capacities of the housing. Even if the rotor and stator windings have heated up above the ignition temperature when the motor protection is triggered in the event of a blockage, the housing will only reach significantly lower temperatures due to the distribution of heat energy over a larger heat capacity.

2.3.2 Ignition protection types overpressure capsules „pxb, pyb and pzc”

This type of ignition protection can be considered similar to pressure-resistant enclosure. Here, too, only the external surface temperature is relevant for explosion protection. No ignitable mixture can penetrate the interior of the motor, as an ignition protection gas, e.g., air, is kept under positive pressure here. However, as an additional condition, it must be ensured that, in the event of failure of the ignition protection gas supply and shutdown of the engine, internal parts are cooled to values below the ignition temperature of the diffusing mixture when the mixture reaches this temperature.

2.3.3 Ignition protection types increased safety „eb“

With this type of ignition protection, the flammable mixture may penetrate the interior of the motor, but must not come into contact with any ignition sources. Therefore, in accordance with IEC/EN 60079-14, special requirements are imposed on the motor protection to ensure that no impermissible stator or rotor temperatures are reached even in the event of a blockage at rated voltage. Direct temperature monitoring or a time-dependent overcurrent release can be used as protection principles.

2.3.4 Ignition protection type increased safety „ec“

For the ignition protection type, according to IEC/EN 60079-7 (formerly IEC/EN 60079-15), the machine must only comply with the temperature class under “normal operating conditions.” The standard explicitly states that in operating modes S1 and S2, the blocking case does not need to be considered. Overload conditions are not mentioned. Operating conditions that cannot rule out overload conditions without protection and could remain undetected for a very long time are contrary to the philosophy of this type of ignition protection. Overload protection similar to the “eb” type of ignition protection is sufficient.

2.3.5 Ignition protection type by enclosure „tb“ and „tc“

For dust explosion-proof machines in accordance with the IEC/EN 60079-31 standard, in addition to the inspection of the enclosure protection type already described, compliance with the maximum surface temperature specified in the EU type examination certificate is a core requirement for ensuring explosion protection. The surface temperature is determined during the electrical-thermal test when operating with rated data, when operating at the upper and lower limits of the rated voltage range, and after an overload test with 1.2 times the rated current for 2 hours, starting from the thermal steady state after operating with rated data. This is intended to simulate the shutdown behavior of the motor protection switch in the event of an overload. It is important to take into account the after-heating of the enclosure after the end of the tests.

2.3.6 Direct temperature monitoring

In direct temperature monitoring as the sole form of protection, PTC thermistors are embedded in the winding of all three winding strands of the winding head and impregnated together with the winding. This ensures good thermal contact between the winding and the PTC thermistor, which is extremely important for the effectiveness of the protection principle. The individual PTC thermistors are connected in series and, when the motor is installed, are connected to a PTC thermistor trigger device, which is usually located outside the potentially explosive area. If the PTC thermistors are heated above the nominal response temperature, e.g., 130 °C, the resistance increases sharply, which is registered by the evaluation device. When the nominal cut-off temperature (NAT) is reached, the motor is switched off. The device must also detect a resistance that is too low, below the “resistance window” of the PTC thermistor. This can be caused by a short circuit in the PTC thermistor connection cable, which would mean that protection is no longer guaranteed. Protection through direct temperature monitoring limits the winding temperature to a fixed value. This also allows the detection of impermissible temperatures that are not caused by overload but, for example, by blocked cooling air paths or excessive ambient temperatures. Compared to pure current monitoring, this provides an additional safety benefit.
When designing the PTC thermistor for sole protection, however, it must be noted that in addition to the stator, the rotor must also be protected against impermissible temperatures (increased safety types of protection “eb” and “ec”). This is a challenge, especially for rotor-critical machines, and some machine designs do not allow sole protection via PTC thermistors.
When testing a machine with thermal sole protection via PTC thermistors, these cases must be considered and the “equivalence of the protective effect compared to current monitoring” must be proven mathematically and experimentally.

2.3.7 Current-dependent, time-delayed safety device

Motor protection via current monitoring is based on the approach that the motor protection relay maps a simplified thermal image of the motor and shuts down if this thermal model registers impermissible heating. In addition, the motor protection switches also include a magnetic quick-acting release for short-circuit protection. The simplest design of a motor protection device is the motor protection switch with a bimetal relay, whereby the bimetal is heated by a heating coil through which the motor current flows. The bimetal can be regarded as a single-body equivalent circuit diagram of the motor. Such bimetals are available for all 3 phases, and a mechanical link also detects different heating of the bimetals and therefore also single-phase overload and current imbalances. According to IEC/EN 60079-0, the protective device must not trip at 1.05 times the rated motor current within 2 hours, but must respond at 1.2 times the current within 2 hours.

The following consideration illustrates the thermal behavior of the motor: For the single-body equivalent circuit, the power loss balance can be written as follows

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

P_V is the power loss converted in the machine, ϑ the excess temperature relative to the environment, R_{th} is the heat transfer resistance to the environment, and c is the heat capacity of the machine. For the temperature, we can therefore write:

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

This equation shows that the heating, e.g. after an overload occurs, approaches the new "steady-state temperature" $\frac{P_V}{R_{th}}$ according to an e-function. ϑ

To ensure that the motor is protected, it must therefore be shut down before the overtemperature ϑ in the stator or rotor reaches impermissible values. The load-dependent losses of the motor can be viewed as a quadratic function of the machine current as a first approximation, meaning that the integral must be evaluated by the protective device in the event of an overload.

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

In the simplest case, the evaluation can be carried out using the aforementioned bimetal. However, electronic protection devices are becoming increasingly popular, especially for larger drives. These devices ensure a more precise response, respond to a freely definable degree of current imbalance, and can better map the machine thermally thanks to a more complex thermal multi-body equivalent circuit diagram. As an alternative, it is also possible to monitor the active power consumption of the motor using an electronic protection device. This can be useful for machines where the increase in current is very low in the event of an overload, or if, for example, a drop in power must also be detected as dry-running protection in pump drives.

2.3.8 Selection and configuration of protection for the ignition protection type increased safety „eb"

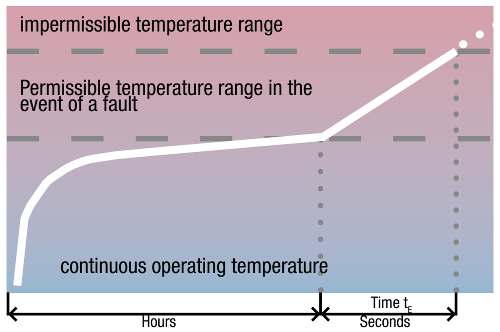


Chart 2.3: Definition of time t_E

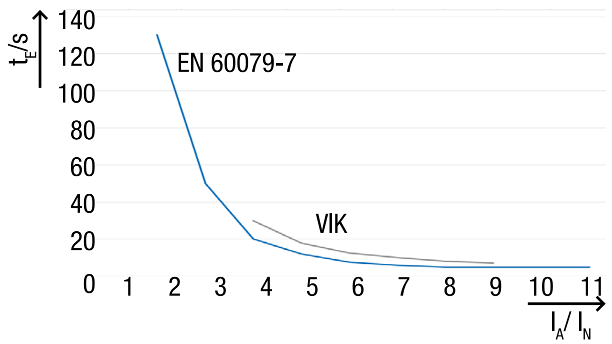


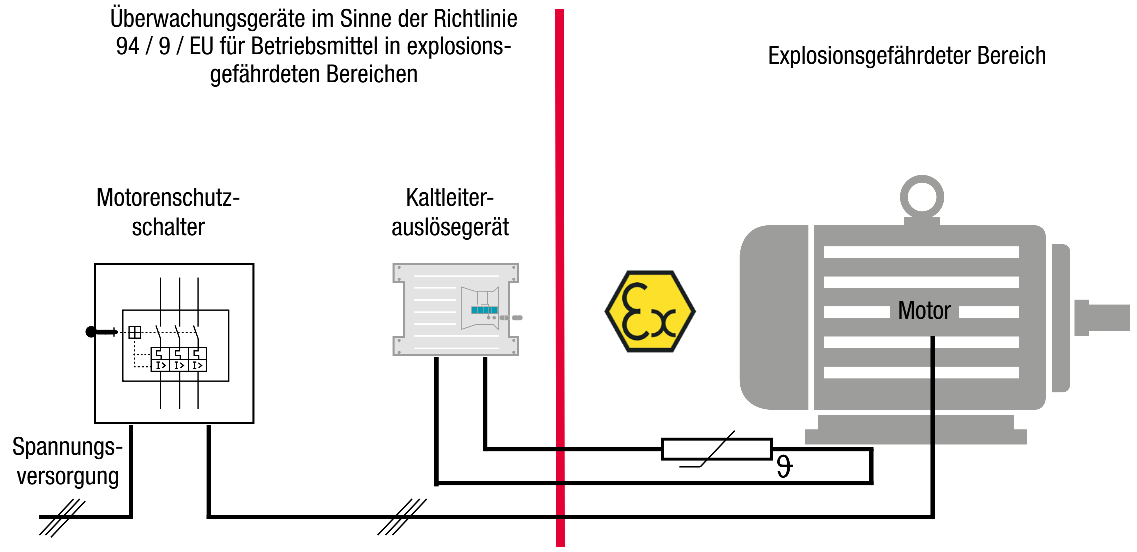
Chart 2.4: Tripping characteristic curve for current-dependent motor protection devices according to EN 60079-7 and VIK recommendation

is the most thermally unfavorable fault condition for a machine, namely the blocking of the motor at operating temperature. In this case, the motor protection must switch off the motor within the heating time t_E specified in the EU type examination certificate for the motor. In order to ensure timely shutdown, the motor protection device must be correctly set to the rated current of the motor. The other condition is that the measured time t_E at the measured starting current ratio of the motor must always be above the trip characteristic curve for motor protection relays contained in the IEC/EN 60079-7 standard, section 5.2.4.4.1 (Chart 2.4). The permissible starting current/rated current ratio for machines with increased safety "eb" ignition protection is in the range of 3–10 (this range is limited for VIK motors). In addition to switching off the machine in the event of 'overload' and "blockage," further requirements are placed on the motor protection device to ensure safe operation of the motor:

- Protection against accidental adjustment
- No automatic restart after tripping
- Start-up monitoring
- Short-circuit detection
- Detection of impermissible current imbalances
- Test options
- Detection of safety-relevant internal faults and transition to safe state (shutdown)
- Minimum requirement: SIL category 1
- Shutdown within 2 hours in case of overload with 1.2 times the rated motor current
- "Thermal memory" in case of supply voltage interruptions

2.3.9 Current and temperature monitoring

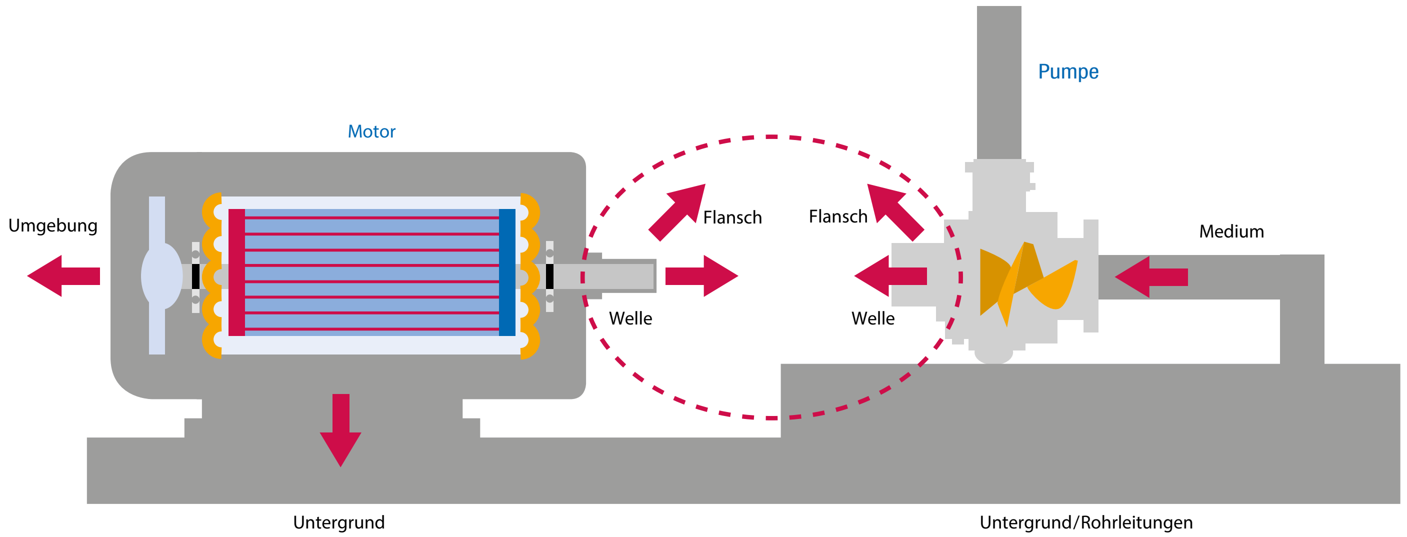
For special applications, it makes sense to protect the motor with direct temperature monitoring in addition to current monitoring. This is the case, for example, if high ambient temperatures or blockages in the cooling air paths at the motor installation site are to be expected due to operating conditions. With this "hybrid protection" (Scheme 2.5), the PTC thermistor does not have to be designed for sole protection, as overload and blockage cases are detected by current monitoring.



Scheme 2.5: Protection of the motor through current and temperature monitoring

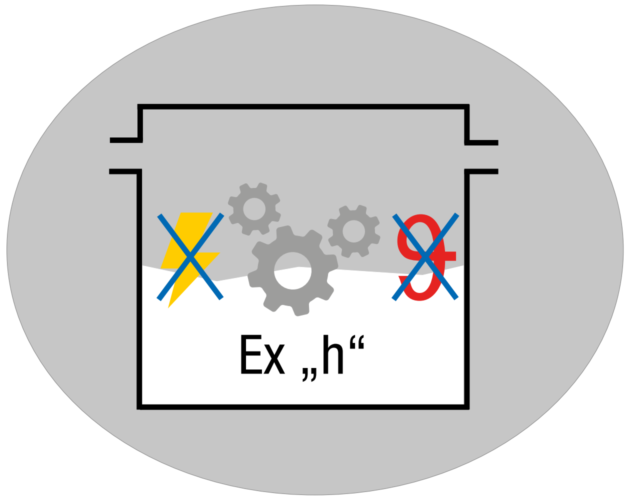
2.4 The motor in combination with other devices

If the motor is directly coupled to the driven machine, which is very often the case in practice, it is no longer sufficient to consider the motor in isolation from its surroundings in terms of thermal aspects, especially if the driven machine reaches a higher temperature than the motor and heat flows toward the motor. In the case of a pump, this can occur when pumping hot liquids. Scheme 2.6 illustrates this situation. When considering the combination of motor and pump, not only must the temperature class of any gases that may occur be taken into account, but also the limit temperatures of the components and attachments of the motor. Here, particular attention should be paid to the bearing if heat flow via the shaft is to be expected. Excessively high bearing temperatures can lead to premature and possibly flammable failure of the bearing.



Scheme 2.6: Assembly of motor pump

Another very common combination is the motor with a coupled gearbox. In this case, too, gearbox heating must be taken into account when selecting and designing the drive. This does not apply if the motor and gearbox were purchased as a single unit from the manufacturer. As shown in Scheme 2.7, the gearbox is often designed with a combination of the ignition protection types “structural safety” and “liquid enclosure”.



Scheme 2.7: Combination of ignition protection types “c” and “k” in a gearbox (“c” and “k” ... mechanical explosion protection)

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

1. The motor and pump cannot be assessed separately: the combination is subject to the conformity assessment procedure for electrical equipment.
2. The motor and pump can be assessed separately: if there are no further ignition hazards, the unit does not fall within the scope of the directive; the result is a unit consisting of two individual devices, each with a separate declaration of conformity.
   The manufacturer of the assembly wishes to issue a summary declaration of conformity: Obligation to carry out an ignition hazard assessment; -> Preparation of documentation, CE marking, declaration of conformity; Manufacturer bears full responsibility, third-party certification not necessary
3. Additional ignition hazards due to combination or a component not fully compliant with the directive: **The combination must undergo the full conformity assessment procedure.**

In addition to the thermal influences already described, all other factors affecting explosion protection must also be taken into account. Here, the pitfalls often lie in the details. For example, when installing a plastic soundproofing hood, not only the impact on engine cooling but also the issue of “electrostatics” must be considered.

2.4.1 Recommended maximum joint temperature for flange motors

When connected to work machines, flange-mounted motors can reach temperatures higher than 40 °C at both the flange and the shaft end.

Motors with Ex d and Ex e types of protection in accordance with VE 1/NE 47 are assumed to still comply with the explosion protection requirements as long as the interface temperatures specified below are not exceeded.

Note 1:
The specified limit values are published in coordination between VDMA and ZVEI as a VDMA standard data sheet for pumps in block design.

Note 2:
Up to the specified interface temperatures, no significant heat input from the shaft end and flange into the active parts of the machine is expected.

2.4.1.1 Machines with ignition protection type pressure-resistant enclosure “db” in mains operation

Temperature class	T3	T4	T5	T6
max. wave 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 at the shaft end and motor flange!
- no converter operation
- Self-ventilated
- Sizes 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 with type of protection pressure-resistant enclosure “db” in converter operation

Temperature class	T3	T4	T5	T6
max. wave temperature	100°C	100°C	-*	-*
max. flange temperature	100°C	100°C	-*	-*

* still under discussion

General conditions:

- Maximum permissible temperatures at the shaft end and motor flange!
- Adjustment range from 10 Hz to fN (≤ 60 Hz)
- self-ventilated
- Sizes 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 testing required

2.4.1.3 Machines with ignition protection type pressure-resistant enclosure “eb” temperature class T3

Number of poles	2 poles	4 poles
max. wave temperature	60°C	75°C
max. flange temperature	0°C	75°C

General conditions:

- Maximum permissible temperatures at the shaft end and motor flange!
- no converter operation
- self-ventilated
- Sizes 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

With the types of protection pressure-resistant enclosure "d" and pressurized enclosure "p," the explosion protection principle is based on either an explosion occurring inside the enclosure not being transmitted to the surrounding atmosphere (type of protection pressure-resistant enclosure "d") or that the explosive atmosphere cannot penetrate the interior of the enclosure during operation of the device (type of protection: pressurized enclosure "p"). With these types of protection, the temperature of the outer surfaces is therefore the decisive criterion, which must not exceed the limit temperature of the temperature class. In the case of type of protection "p", an additional restrictive condition for the maximum temperatures inside the enclosure is that, in the event of a failure of the ignition protection gas supply and with the motor switched off, the stored residual heat cannot ignite diffusing gas. For type of protection "db," suitability for operation on a frequency converter is certified by the notified body in the EU type examination certificate. The same applies to type of protection "p."

The internal temperatures are otherwise not relevant for explosion protection, but for operational safety and availability, it must be ensured that the permissible operating temperatures of the insulation materials and other components are not exceeded.

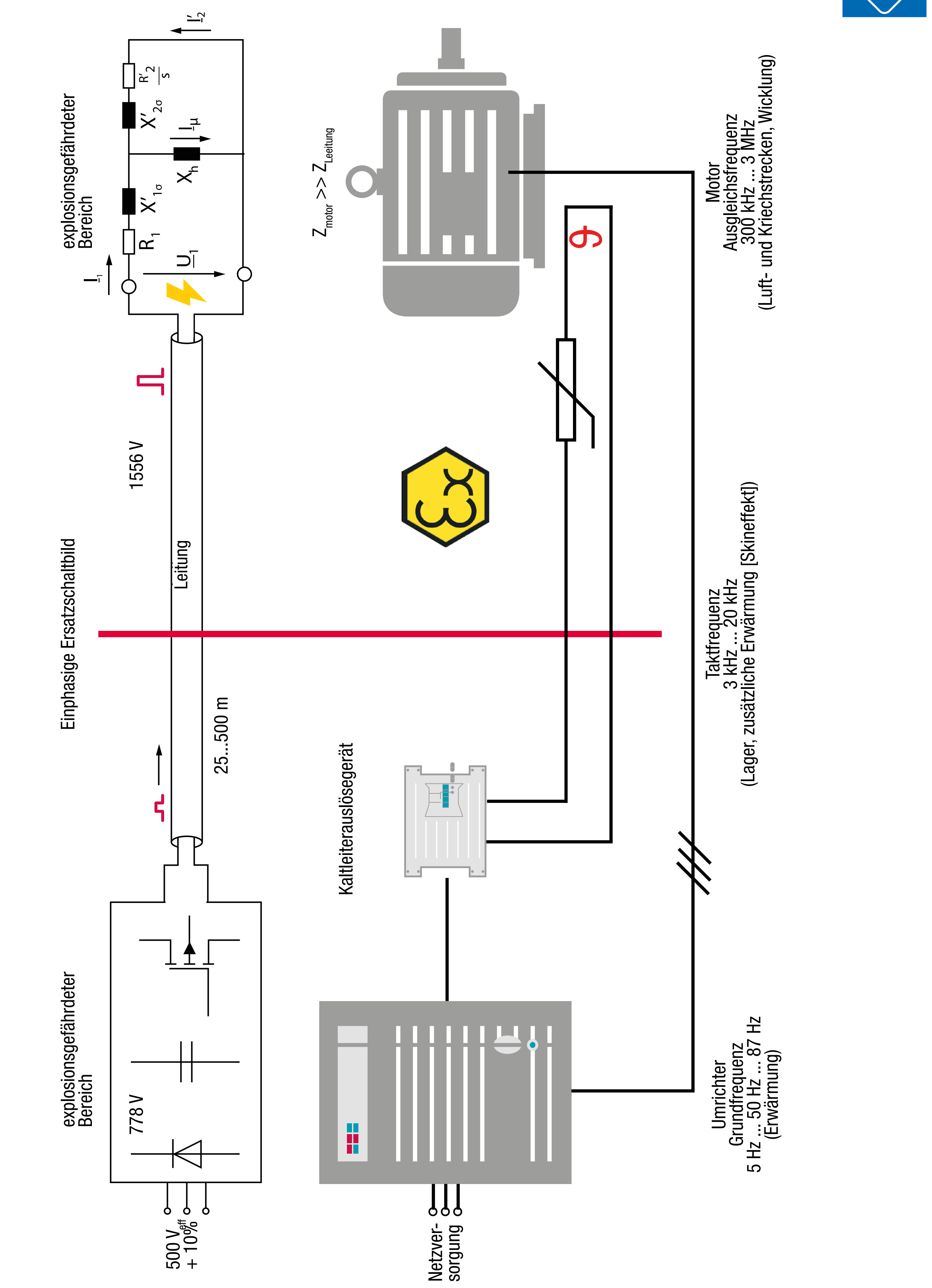
These motors are protected by PTC thermistors embedded in the winding with an evaluation device, similar to mains-powered motors. Alternatively, slot resistance thermometers can also be used.

With the "eb" type of protection, the explosion protection of the equipment is based on preventing the ignition of explosive atmospheres, whereby the explosive atmosphere can also penetrate the interior of the equipment. The possible ignition sources in an asynchronous motor are hot surfaces, mechanically generated friction and impact sparks, and electrical discharges. To prevent these, explosion-proof motors are subject to increased requirements in terms of mechanical construction and design, the electrical insulation system, and protection against impermissible heating. In machines powered by frequency converters, the ignition sources "electrical discharges" and "hot surfaces" pose additional ignition hazards compared to operation on the mains, which must be taken into account in the design of the machine and its certification.

3.1 Electrical discharge

Due to the fast switching operations of the power transistors and the resulting high voltage rise rates, traveling waves are formed on the line to the motor, whereby the input impedances of the motor and the converter output, which are effective for the high-frequency processes, differ from the characteristic impedance of the line. In general, $Z_{Motor} >> Z_{Line}$, so that the voltage wave traveling in the direction of the motor has a reflection factor close to 1, and the wave is reflected. In the case of electrically long lines in relation to the frequency of these traveling wave processes, transient voltage peaks of up to twice the DC link voltage can occur at the motor terminals (Scheme 3.1) . The air gaps in the machine's terminal box must be dimensioned for the transient overvoltages, whereas the creepage distances according to IEC/EN 60079-7 only need to be designed for the effective value of the inverter output voltage. According to IEC/EN 60079-7, short-term voltage peaks do not lead to erosion due to leakage currents on the surface.

In practice, it has proven effective for low-voltage machines to design the rated voltage of the terminal box for the frequency converter input voltage, provided that no transient overvoltages with an amplitude greater than twice the DC link voltage occur. If multiple reflections and thus higher voltages are to be expected, the next higher rated voltage level should be selected for the terminal box. This procedure is recommended by the PTB.
However, it is also very important that the insulation of the winding is designed for these high, steep-flanked voltage pulses. The winding insulation in the input area of the winding is also heavily loaded, as this is where most of the voltage is dissipated. If partial discharges occur here, this will lead to the destruction of the organic enameled wire insulation over longer periods of time and ultimately to an ignitable breakdown and failure of the motor. If the motor manufacturer cannot guarantee that there will be no partial discharges, a filter must be connected upstream to reduce the voltage load on the winding.



Scheme 3.1: Generation of transient overvoltages on a frequency converter-fed drive

3.2 Hot surfaces

If an electric machine reaches an impermissible temperature, the causes are either excessive power loss within the machine, e.g. due to overload, or insufficient cooling. Operation outside the motor specifications, e.g. with undervoltage, can also cause impermissibly high power loss, particularly in the machine‘s rotor.

These effects must be controlled by technical protective devices and operating parameter limits specified in the EU type examination certificate, and ignition hazards must be ruled out. In addition to the limitation specified by the temperature class, the continuous operating temperatures of the winding insulation, seals, and other attachments must not be exceeded in order to prevent premature aging with potentially ignitable failure.

With the DC link converters commonly used today, even without a sinus output filter, the additional heating of the motor due to harmonics is very low. In most cases, the motors tested by the PTB show a temperature increase of less than 10 K when the permissible operating parameter limits are observed. If the converter is designed in accordance with the specifications of the EU type examination certificate for the motor, the fault condition “blocked motor” does not need to be taken into account. This means that the temperature reserve provided for this purpose can also be significantly reduced. On the other hand, a very important point is the increase in thermal resistance to the environment with decreasing speed in self-ventilated machines. Chart 3.2 shows this relationship for two machines of sizes 180 and 132.

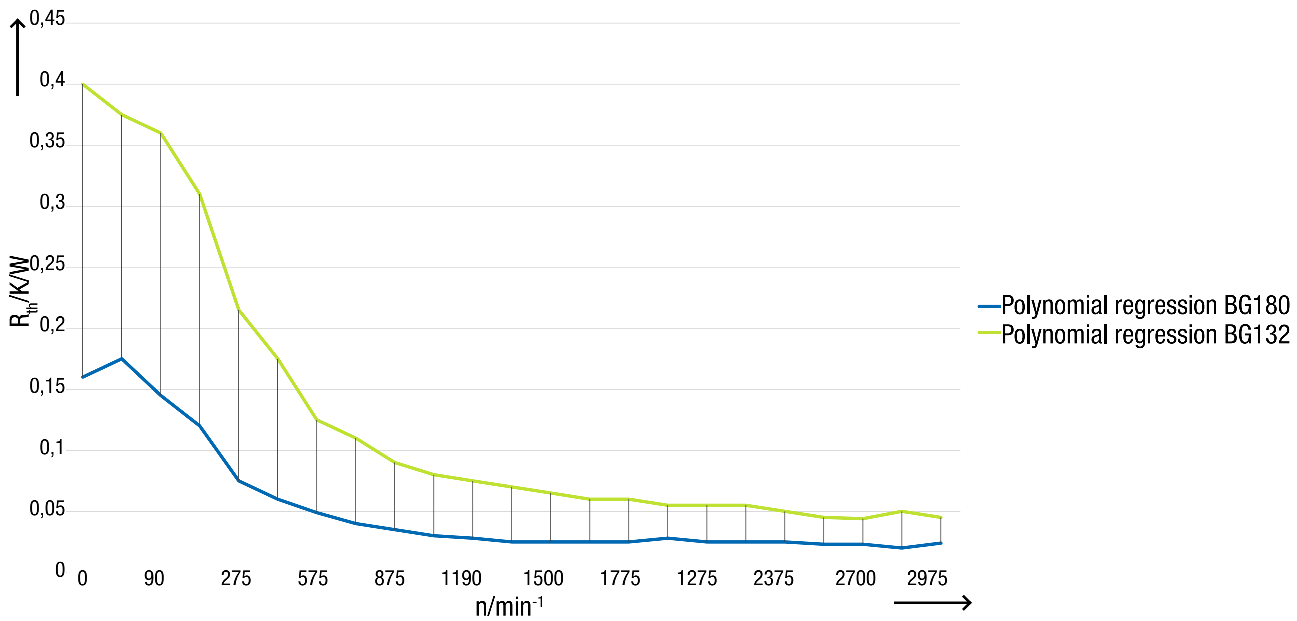


Chart 3.2: Thermal resistance to the environment in relation to speed

This effect is taken into account in the new testing and certification concept for frequency converter-fed drives with increased safety “eb” protection by means of variable speed current limitation of the frequency converter. Chart 3.3 shows an example of the maximum machine current in relation to the rated current for a machine of size 132. All operating points below the curve are permanently permissible, but those above the line are only permissible for a limited time calculated on the basis of the overload. If the machine current exceeds 1.5 times the rated current, the system is immediately shut down.

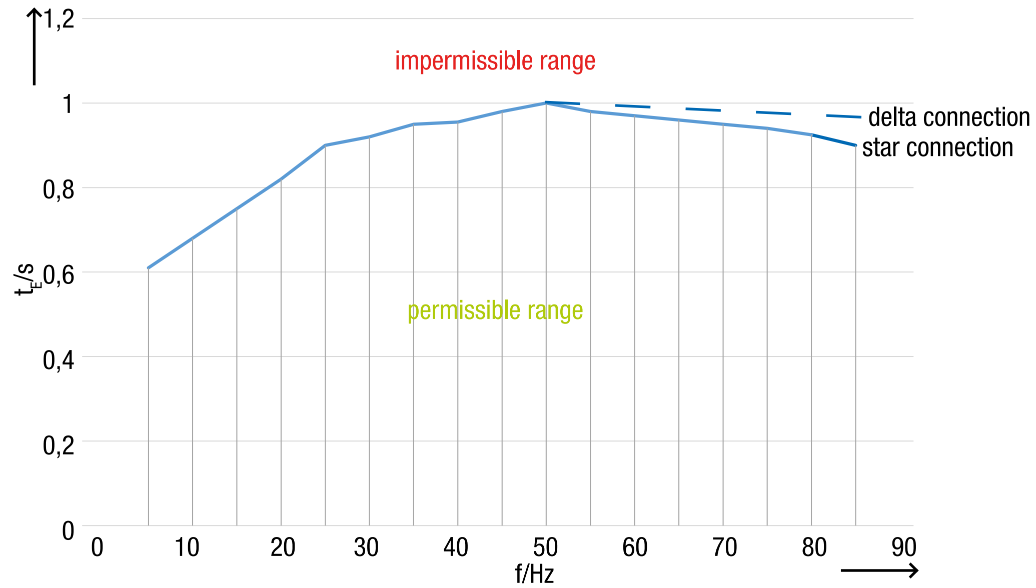


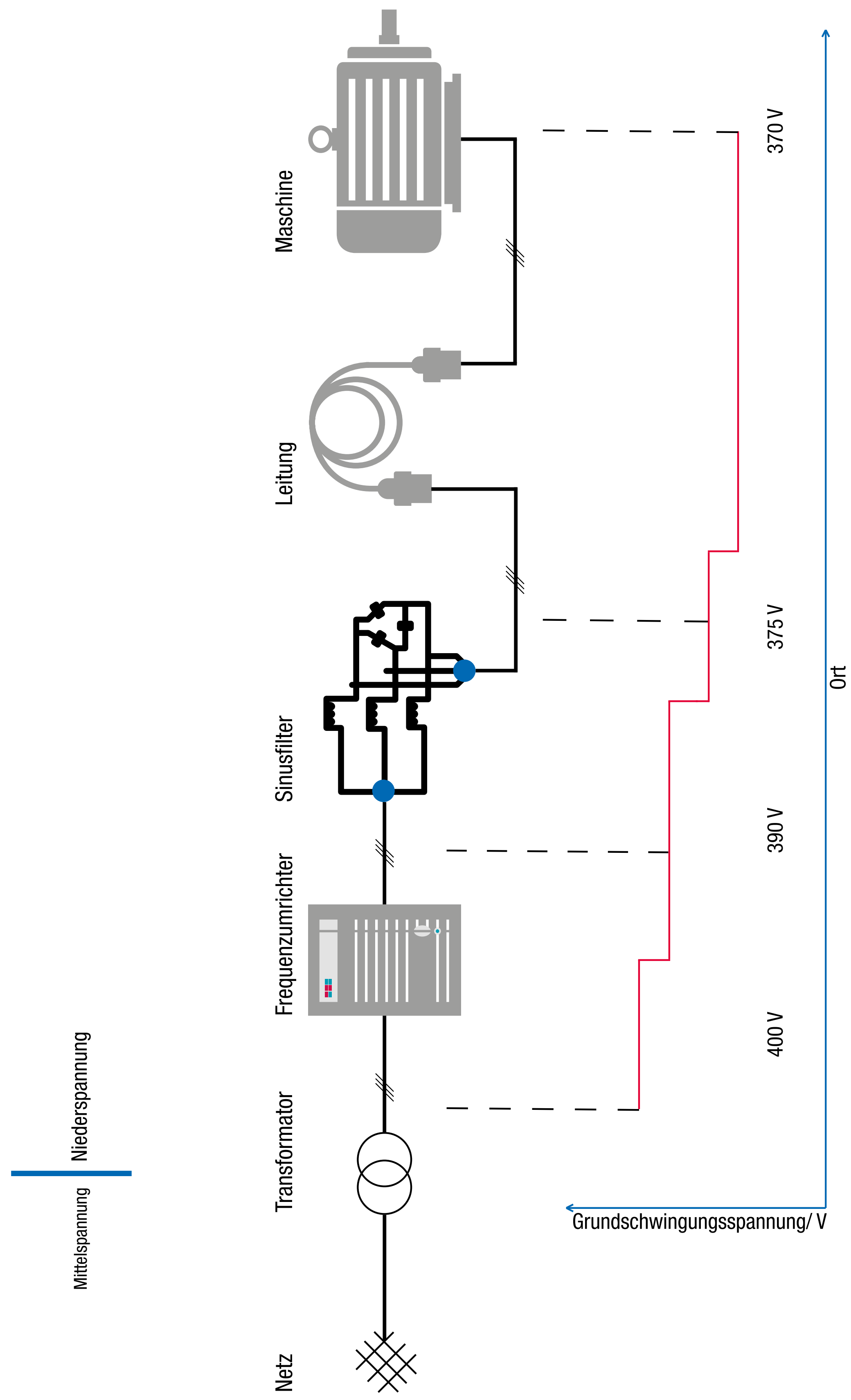
Chart 3.3: Variable speed current limitation, from EC type examination certificate

The support points of the curves were determined by measurements at the PTB. In addition to this protection via frequency-dependent current monitoring, a second protective device certified as a monitoring device in accordance with Directive 2014/34/EU is required, as the frequency converter is not certified and this is not desired by the manufacturers. In most cases, this protective device is a direct temperature monitoring system using triple thermistors with a tested thermistor evaluation device. Direct temperature monitoring has the additional advantage that other faults, such as a blocked fan grille or excessive ambient temperatures, can also be detected.

It is also very important for safe operation to comply with the operating parameters specified in the motor data sheet, with particular attention being paid to the fundamental frequency voltage at the motor terminals. If, for example, the voltage drop at the inverter and the motor connection cables is not taken into account sufficiently, the slip of the motor increases while the torque remains unchanged, and the rotor in particular heats up very strongly.

The voltage drop must also be taken into account in all cases if a sinus output filter is connected between the motor and the converter to reduce overvoltages.

Scheme 3.4 illustrates the situation. The motor must be ordered for the expected motor terminal voltage, or the corner frequency must be adjusted accordingly.



Scheme 3.4 Voltage drops between the mains and the machine

3.3 Harmonic loss

Another source of losses and thus heating in a frequency converter-fed drive are the harmonic losses caused by the frequency converter feed. This is caused by voltage harmonics contained in the motor supply voltage, which do not contribute to the torque generation of the motor, but nevertheless lead to a current flow through the motor and thus to losses both in the iron (eddie current losses) and in the stator winding and the rotor cage (ohmic losses). Figuratively speaking, the machine can be divided into a "fundamental vibration machine" that generates torque and several "harmonic machines" arranged on the shaft. Due to the different frequencies, the superposition principle can be applied. This visual representation clearly shows that harmonic losses increase with both the number of harmonics occurring and their amplitude. It is clear that the frequency converter input voltage or the difference between the effective value and the fundamental of the motor voltage have a direct influence on the harmonic losses, as clearly shown by the measurement of the harmonic losses converted in the machine as a function of the difference between the measured effective voltage value and the metrologically determined fundamental component of the motor voltage, as shown in Chart 3.5.

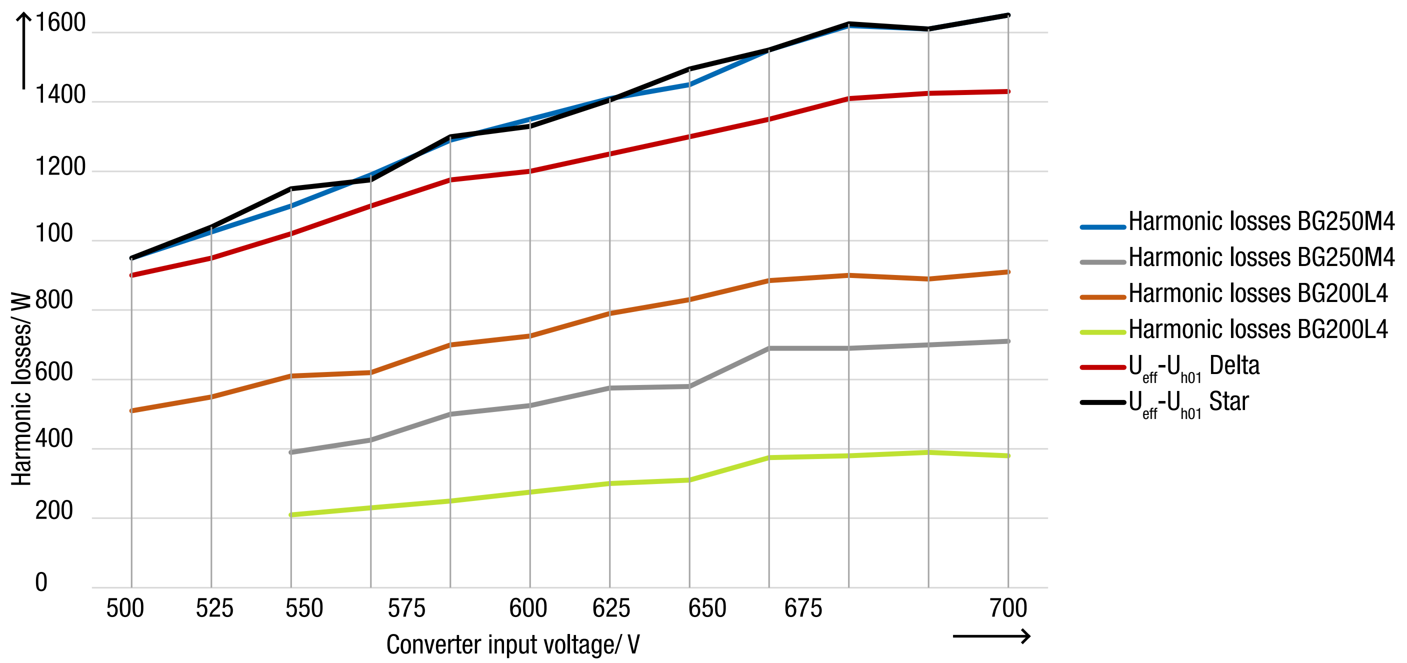
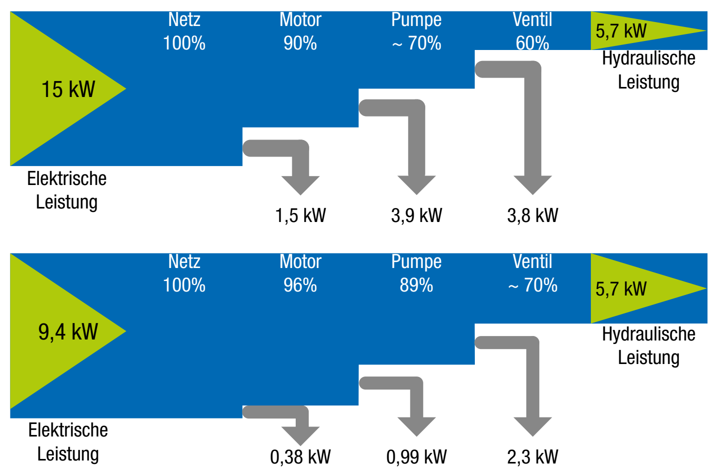


Chart 3.5 Dependence of harmonic losses on converter input voltage

To limit harmonic losses, it is therefore necessary to limit the supply voltage of the converter. This value is therefore also listed in the EU type examination certificate. If these specifications are complied with, the harmonic losses are small compared to the fundamental losses (less than 10%) and do not lead to impermissible heating. m³/h

3.4 Increasing energy efficiency

This new approach will help to further increase the proportion of frequency converter-fed drives in the chemical industry. This results in very large energy saving potentials, especially in the drive of flow machines. The results of a comparison of the energy efficiency of flow rate adjustment via bypass or reduction valves and direct speed adjustment of the pump using frequency converters are shown in Figure 3.6. The assumed boundary conditions were a rated flow rate of the pump of 50 m³/h at a pressure of 7 bar. For the analysis in Scheme 3.6, a flow rate of 30 m³/h required by the process was assumed. Assuming 5000 partial load operating hours per year and a rated motor power of 18 kW, the payback period for the frequency converter is often less than one year at today's energy prices.



Scheme 3.6: From electrical to hydraulic power

In summary, energy savings increase as the pump throttling increases, i.e., as the delivery rate decreases, compared to adjusting the pump delivery rate using valves. If the pump is operated without throttling, however, there are slightly higher losses compared to direct operation on the mains due to the losses of the converter and the harmonic losses of the motor.

If the pump is constantly operated at its rated delivery rate due to process requirements, retrofitting a frequency converter is not advisable.
Chart 3.7 shows the estimated payback period for a frequency converter (purchase price €2,000) depending on the delivery rate (motor power 18 kW, working price €0.19/kWh).

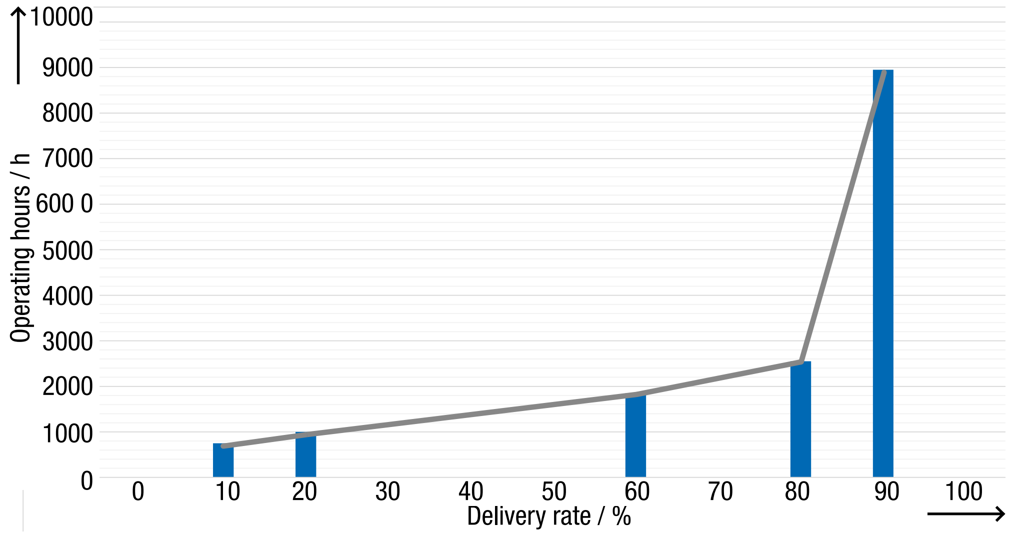


Chart 3.7:
Payback period for the frequency converter (purchase price €2,000) as a function of the ratio of the delivery rate to the rated delivery rate

In real-world applications, it is highly unlikely that the pump will operate continuously at the same hydraulic load over time. It is much more realistic to assume different load profiles for estimating energy savings potential, with each profile expressing the distribution of different loads over the entire operating time of a year. For the considerations carried out here, the three load profiles shown in Chart 3.8 were assumed. This assumes a total operating time of the pump of 5000 hours within a year. The bars represent the proportion of time spent at each hydraulic load (50, 30, 10, 5 m³/h), with a rated flow rate of 50 m³/h.

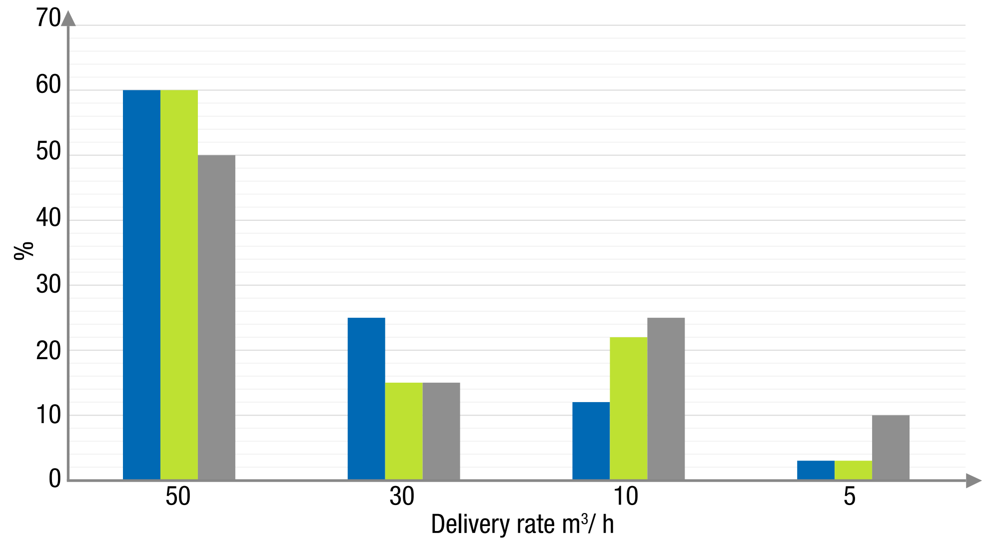


Chart 3.8: Temporal distribution of hydraulic utilization

If the costs incurred over time for operation on the grid and for operation on the frequency converter are now calculated assuming the load profiles shown in Chart 3.8, under the simplified assumption of constant motor power for grid operation (delivery rate adjustment via a bypass valve), this results in a straight line passing through the origin of the coordinates with the energy costs per unit of time as the slope (grid operation costs).

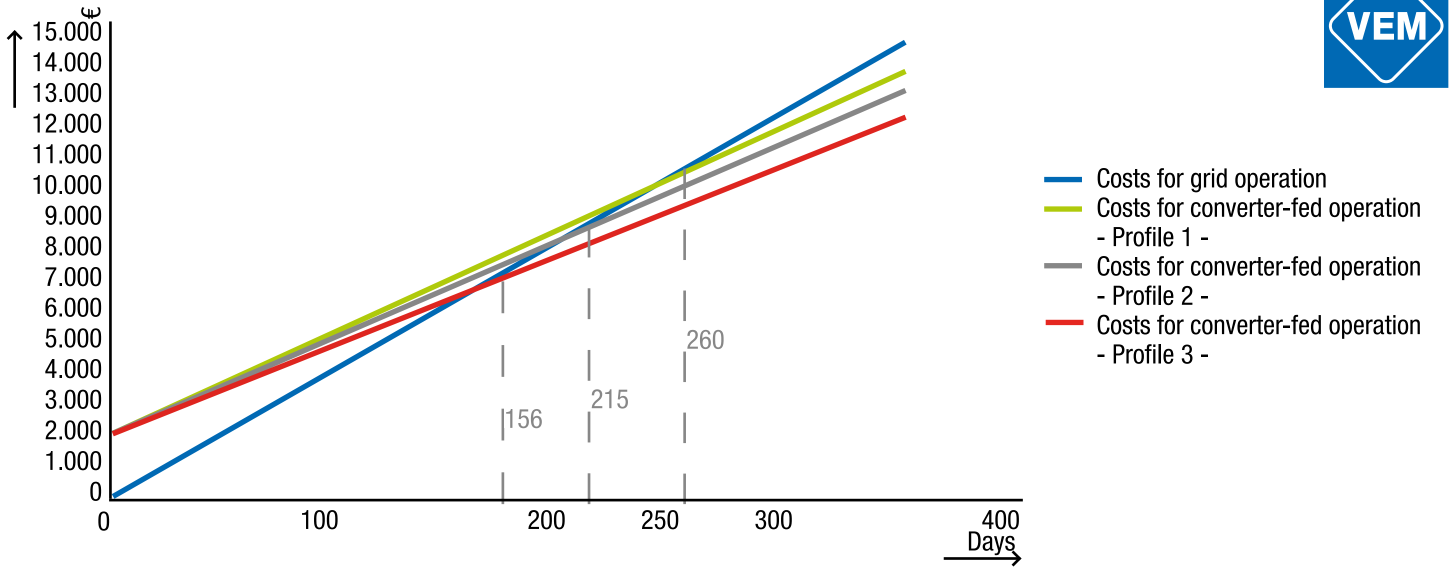


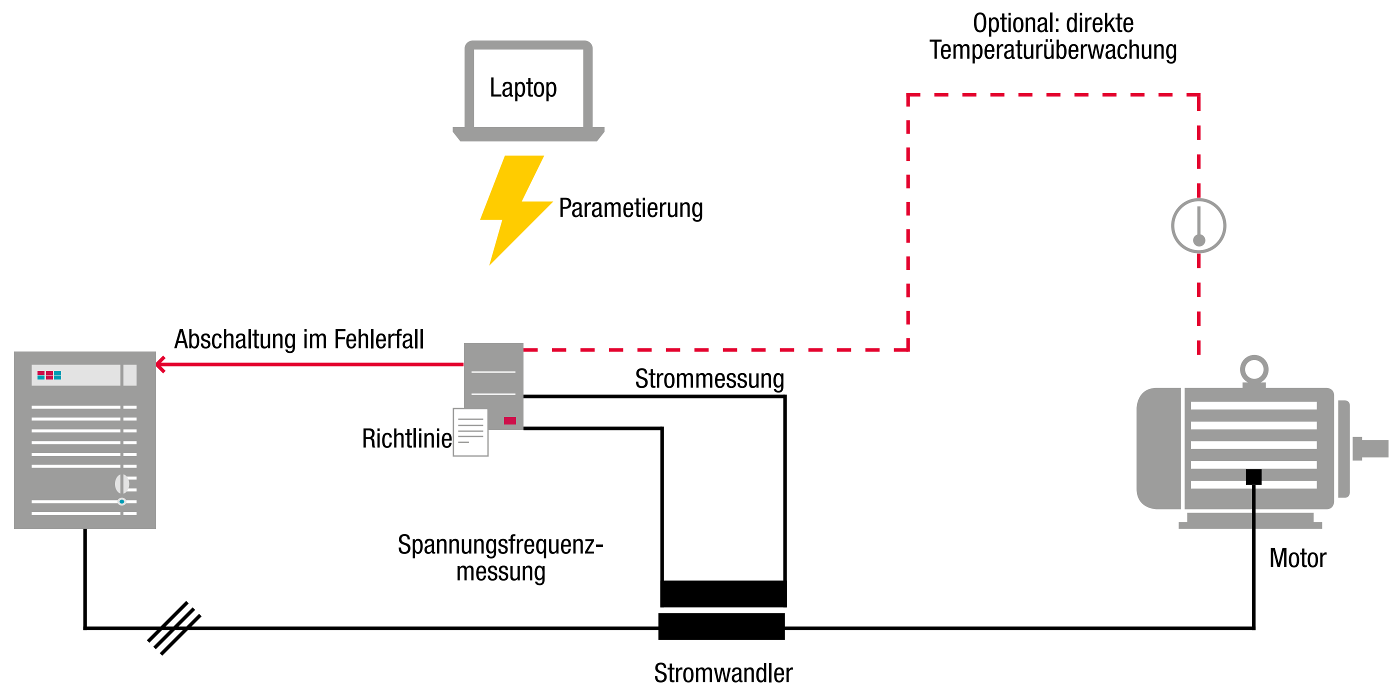
Chart 3.9: Energy costs over time for grid operation and frequency converter operation. Purchase cost of the frequency converter: €2,000.00

The costs of €2,000 incurred for the converter-fed drives at time t = 0 correspond to the assumed acquisition costs of the frequency converter. The intersection points of the straight lines for converter operation and grid operation directly indicate the payback periods in days, as indicated by the dashed lines. The relationship shown in Chart 3.9 can be used to determine the payback periods for any investment costs (parallel shift of the "converter curves") as well as for other, possibly more energy-efficient methods of conventional conveyor output adjustment (flattening of the "mains curve").

However, even with a significant extension of the payback periods, the use of frequency converters for driving flow machines is in most cases associated with significant financial savings and other advantages, such as optimization of process control and avoidance of voltage dips when starting high-power pumps, over the service life of the device.

3.5 Summary and outlook

Experience to date with the new testing and certification concept for frequency converter-fed drives with increased safety "eb" ignition protection has been extremely promising, and it has been shown that certification for operation on the converter is possible without any problems up to temperature class T3. However, safe operation requires that the motor operating parameters specified in the data sheet are adhered to and that the winding is suitable for the voltage pulses that occur. A motor protection device for converter-fed drives is currently being developed in collaboration with a partner company. When using this device, frequency converters without variable speed current limitation can also be used. The thermistor is also no longer absolutely necessary. Scheme 3.10 shows the possible use of the protection device.



Scheme 3.10: Monitoring the motor during inverter operation

In summary, the following can be stated:

3.6 Operation with frequency converter when used in Zone 2 (EX II 3G) or Zone 22 (EX II 3D)

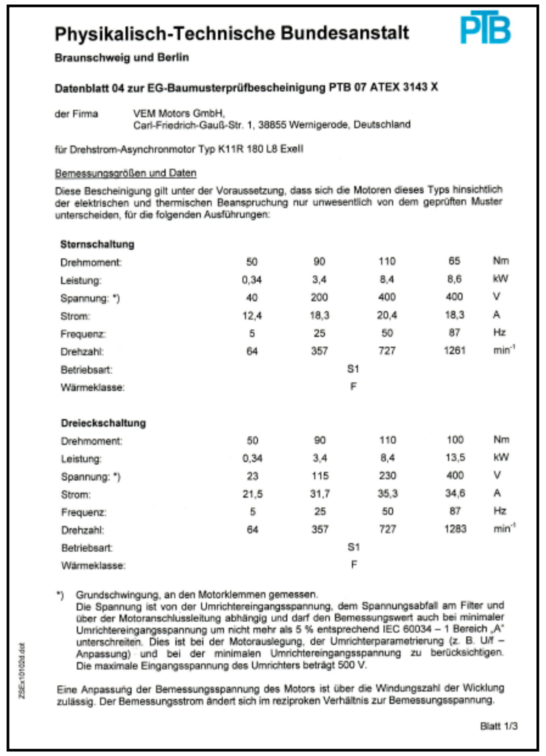
Operation with a frequency converter is only permitted within the operating points specified on the type plate. A brief exceeding of the machine's rated current up to 1.5 times the rated current is permitted for a maximum of 1 minute within a time interval of 10 minutes. The specified maximum speed or frequency must not be exceeded under any circumstances. The appropriate inverter selection and/or the use of filters must ensure that the maximum permissible pulse voltage at the motor terminals is not exceeded.
Ensure that the operating voltage applied to the motor terminals always corresponds to the specification on the nameplate (note voltage drop across filters!). The thermal winding protection must be evaluated either via a separate trigger device or via the inverter.

3.7 Operation with frequency converter when used in Zone 21 (EX II 2D)

Motors for use in Zone 21 must always be certified by a notified body for operation with a frequency converter. The limit values specified on the type plate and in the EU type examination certificate must be strictly observed. This means, in particular, monitoring the motor current as a function of frequency. Only frequency converters that meet the requirements specified in the EU type examination certificate may be used.

3.8 Operation with frequency converter when used in Zone 1 (EX II 2G)

Motors with increased safety "eb" ignition protection for use in Zone 1 must always be certified by a notified body for operation with a frequency converter. The limit values specified on the type plate and in the EU type examination certificate must be strictly complied with. This means, in particular, monitoring the continuous current as a function of frequency. Only frequency converters that meet the requirements specified in the EU type examination certificate may be used. The built-in thermal winding protection must be evaluated using a trigger unit with Ex marking II (2) G that complies with the requirements of Directive 2014/34/EU. The specified maximum speed or frequency must not be exceeded under any circumstances. The maximum permissible pulse voltage of 1560 V at the motor terminals must be limited by selecting a suitable converter and/or using filters. It must be ensured that the operating voltage applied to the motor terminals always corresponds to the specification on the nameplate (note voltage drop across filters!). If, due to voltage drops across the frequency converter, the cables, and any chokes or filters, the terminal voltage at the motor is lower than the rated voltage specified on the nameplate, the corner frequency must be set to a lower value corresponding to a linear voltage/frequency assignment.


Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin

Datenblatt 04 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 L8 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:	50	90	110	65	Nm
Leistung:	0,34	3,4	8,4	8,6	kW
Spannung: *)	40	200	400	400	V
Strom:	12,4	18,3	20,4	18,3	A
Frequenz:	5	25	50	87	Hz
Drehzahl:	64	357	727	1261	min^{-1}
Betriebsart:		S1			
Wärmeklasse:		F			

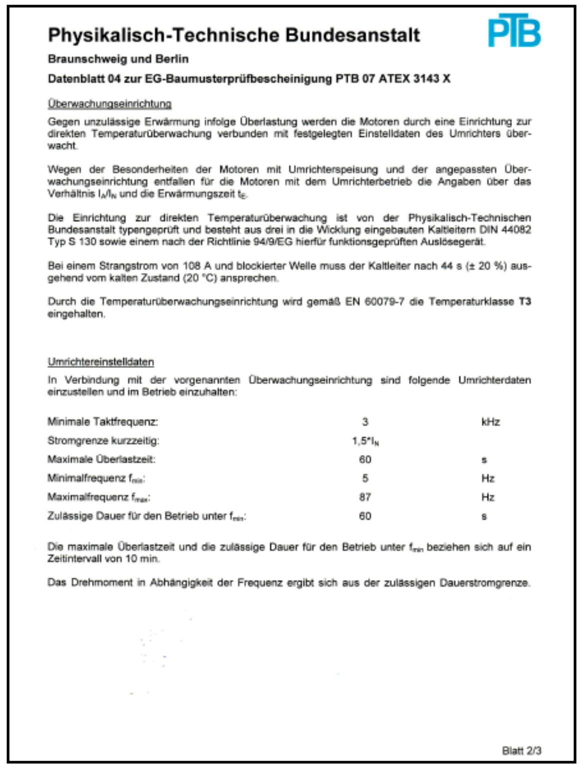
Dreieckschaltung					
Drehmoment:	50	90	110	100	Nm
Leistung:	0,34	3,4	8,4	13,5	kW
Spannung: *)	23	115	230	400	V
Strom:	21,5	31,7	35,3	34,6	A
Frequenz:	5	25	50	87	Hz
Drehzahl:	64	357	727	1283	min^{-1}
Betriebsart:		S1			
Wärmeklasse:		F			

*) 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.

ZSEx10102d.dot

Blatt 1/3


Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin
Datenblatt 04 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 108 A und blockierter Welle muss der Kaltleiter nach 44 s (± 20 %) ausgehend vom kalten Zustand (20 °C) ansprechen.

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

Umrichtereinstelldaten

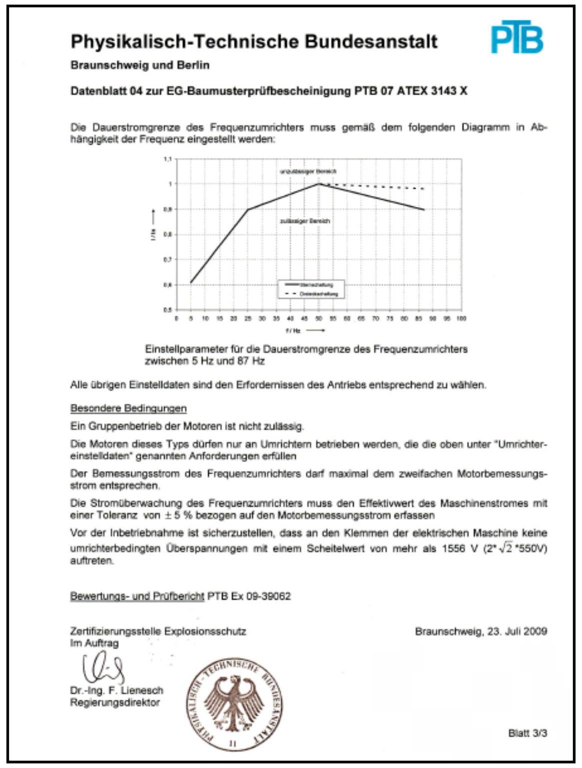
In Verbindung mit der vorgenannten Überwachungseinrichtung sind folgende Umrichterdaten einzustellen und im Betrieb einzuhalten:

Minimale Taktfrequenz:	3	kHz
Stromgrenze kurzzeitig:	$1,5*I_N$	
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.

Blatt 2/3


Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin

Datenblatt 04 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 ($2*\sqrt{2}*550V$) auftreten.

Bewertungs- und Prüfbericht PTB Ex 09-39062

Zertifizierungsstelle Explosionsschutz
Im Auftrag

Dr.-Ing. F. Lienesch
Regierungsdirektor

Braunschweig, 23. Juli 2009

Blatt 3/3

Image 3.11:
Example of an EC type examination certificate for ignition protection type increased safety "eb" for operation on a frequency converter

3.9 Permanent magnet synchronous machines/reluctance machines

The synchronous machine as such is a type of machine that has been known since the early days of electric drive technology and is used for very high-power motors as a separately excited synchronous motor. All high-power generators in thermal power plants and hydroelectric power plants are also based on this operating principle. This type of machine is described in the DIN EN 60034-1 standard with regard to requirements. In permanently magnet-excited synchronous machines, the DC winding of the rotor required to excite the rotor magnetic field is replaced by permanent magnets. In the field of positioning drives (e.g., robot arms in the automotive industry), permanent magnet-excited synchronous machines have been considered state of the technology for several years.

The use of permanent magnet synchronous machines and reluctance machines in potentially explosive atmospheres is possible in principle, but requires certification by a notified body for use in zones 1 and 21, as with asynchronous machines, certification by a notified body, which determines the necessary testing requirements based on the design of the machine and the potential ignition sources present, and carries out the tests. In permanently magnet-excited synchronous machines, especially in designs with magnets bonded to the rotor surface, the bonding of the magnets is a critical detail for explosion protection, as magnets that come loose are ground down in the air gap, forming ignitable sparks.
The current 2016 edition of DIN EN 60079-7 therefore requires a test at 1.2 times the highest rated speed of the motor after testing the thermal resistance in accordance with DIN EN IEC 60079-0:2019. No magnets may come loose or shift during this test. If an overspeed test is not possible, the standard also allows for testing the adhesive force as an alternative.

The explosion-proof, permanently magnetized synchronous machine, as well as the reluctance machine and their testing, are the subject of a current research project at PTB.

4 The VEM supply programme of explosion-proof equipment

4.1 Overview

The comprehensive range of VEM low-voltage motors offers the chemical industry a wide selection of explosion-proof motors in various types of protection for gas and dust explosion-proof areas. The range includes the following types of protection:

Explosion-proof three-phase asynchronous motors with cage rotor for low and high voltage
- Ignition protection type increased safety "eb" Ex eb II according to IEC/EN 60079-0/IEC/EN 60079-7
- Ignition protection type pressure-resistant enclosure "db/db eb" Ex d/de according to IEC/EN 60079-0/EC/EN 60079-1
- Ignition protection type increased safety "ec" according to IEC/EN 60079-0/EC/EN 60079-7
- Ignition protection type pressurized enclosure "pxb/pzc" according to IEC/EN 60079-0/IEC/EN 60079-2
- Motors for use in areas with combustible dusts Ex II 2D, Ex II 3D IEC/EN 60079-0/IEC/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 have been tested and certified by the following notified bodies:
- Physical-Technical Federal Institute Braunschweig (notified body no. 0102),
- IBExU Freiberg (notified body no. 0637)
- DEKRA (notified body no. 0158) – formerly DMT Society for Research and Testing mbH CNEX-GLOBAL Arnhem (notified body no. 2614)

These test certificates are recognized by all member states of the European Union. Non-EU members of CENELEC also accept them. In the case of special designs that affect explosion protection (different frequency, power, coolant temperature, use with a frequency converter, etc.), additional or new certification may be required.

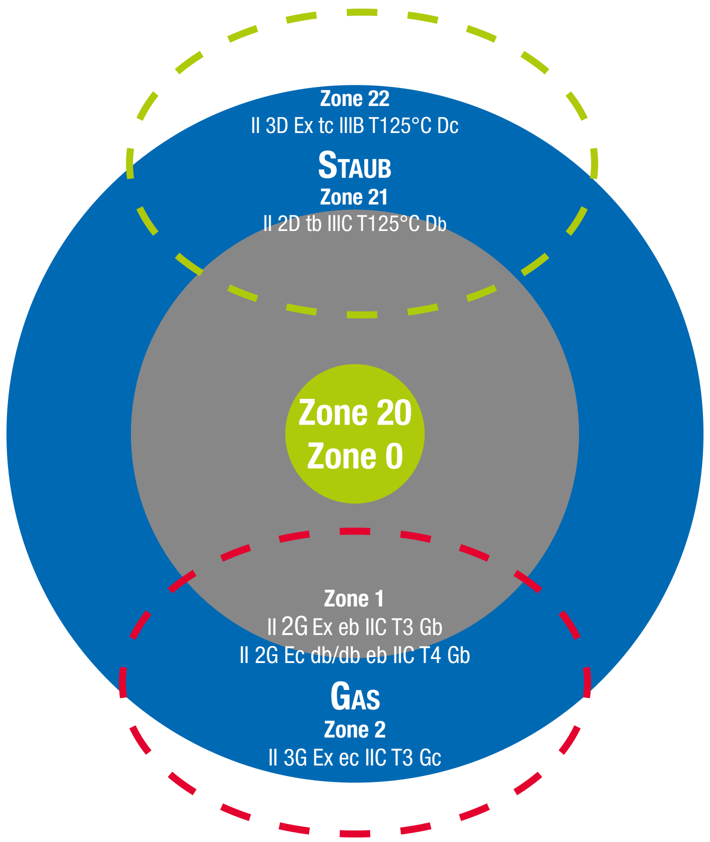


Figure 4.1. Own representation of Ex zones based on DIN EN 60079-0

4.2 Energy efficiency and explosion protection

The European Union's plan is to achieve energy efficiency and CO2 emission targets in order to reduce greenhouse gas emissions and thus limit the average global temperature increase to 1.5 °C. Regulation 640/2009, which is valid until June 30, 2021, has resulted in savings of approximately 57 TWh per year by 2020. An increase in energy efficiency is possible if additional motors that were not previously covered by Regulation (EU) 640/2009, as well as speed controls, were included in new regulations. Whereas the classification of energy-saving motors in Europe was previously regulated on a voluntary basis by the Voluntary Agreement (efficiency classes EFF1, EFF2, and EFF3), this has now been replaced by IEC/EN 60034-30-1: "Efficiency classification of three-phase cage rotor motors, excluding pole-changing motors (IE code)". This standard specifies the minimum efficiencies for 2- to 8-pole motors in the power range 0.12 kW – 1,000 kW for efficiency classes IE1 (standard efficiency), IE2 (high efficiency), IE3 (premium efficiency), and IE4 (super premium efficiency). It should be noted that the transition to this standard has also changed the measurement methods used to determine efficiency. Whereas IEC/EN 60034-2 was previously applied, in which additional losses were assessed at a flat rate of 0.5% of the input power, the new regulation uses IEC/EN 60034-2-1 as the basis for determining efficiency; here, additional losses are determined by testing.

Motors for operation in explosive atmospheres (IEC/EN 60079) are also included in the efficiency classification according to 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" and "ec", and protection by enclosure 'tb' and "tc".
For this reason, the new Regulation (EU) 2019/1781 has adapted the ecodesign requirements for motors and established new ones for speed control systems. The new Regulation (EU) 2019/1781 will take effect in two stages starting on July 1, 2021.

Since January 1, 2017, the following has applied:
Three-phase motors with a power rating of 0.75 kW ≤ Pn ≤ 375 kW; 2-, 4-, or 6-pole, must meet the efficiency requirements of class IE3 or IE2 with mandatory operation on a frequency converter (hereinafter referred to as "FC").
The following motors were excluded:
I) Explosion-proof motors
II) Brake motors
III) Motors that are completely operated in liquid
IV) Motors that are completely integrated into a product (independent determination of efficiency not possible)
V) Motors with multiple windings or pole-changing

Once the new Regulation (EU) 2019/1781 and Regulation (EU) 2021/341 (Amendment) come into force: effective from July 1, 2021:	Minimum efficiency class
Three-phase motors 0,75 to 1.000 kW, 2-, 8- poles (including brake motors where the efficiency can be determined without a brake)	IE 3
Three-phase motors, < 0,75 kW	IE 2
Explosion-proof three-phase motors 0.75 to 1,000 kW, 2 to 8 poles Ignition protection type: pressure-resistant enclosure "Ex db eb" Ignition protection type: increased safety "Ex ec" Protection by enclosure "tb" and "tc"	IE 3
Explosion-proof three-phase motors 0.12 to < 0.75 kW 2-, 4-, 6-, and 8-pole (does not apply to increased safety "Ex eb")	IE 2
Speed-controlled drives 0.12 to 1,000 kW	IE 2

Three-phase motors with a power rating of 0.12 kW ≤ Pn < 0.75 kW; 2, 4, 6, or 8 poles must meet the efficiency requirements of class IE2. Three-phase motors with a power rating of 0.75 kW ≤ Pn ≤ 1000 kW; 2, 4, 6, or 8 poles must meet the efficiency requirements of class IE3 (IE2 with operation on the frequency converter is no longer possible!).

Motors that are now subject to these requirements:
1. Motors with attached brakes
2. All Ex motors, except Ex eb motors (increased safety) and Group I (flameproof/underground)
3. Motors that are fully integrated into a product but can be tested with a temporary bearing shield/drive bearing

In addition, the following motors are excluded:
1. Motors without fans
2. Replacement motors that serve as replacements for motors purchased for the original version until July 1, 2022 (valid until June 30, 2029).

effective from 1 July 2023:	Minimum efficiency class
Three-phase motors ≥ 75.0 to 200 kW; 2-, 4-, and 6-pole (does not apply to explosion-proof motors, brake motors, 8-pole motors)	IE 4
Explosion-proof three-phase motors Increased safety ignition protection type "eb eb" 0.12 to 1,000 kW 2-, 4-, 6-, and 8-pole	IE2
Single-phase motors ≥ 0.12 kW	IE 2

Ex eb motors (increased safety) and single-phase motors with a power rating of 0.12 kW ≤ Pn ≤ 1000 kW; 2, 4, 6, or 8 poles must meet the efficiency requirements of class IE2.
Three-phase motors with a power rating of 75 kW ≤ Pn ≤ 200 kW; 2, 4, or 6 poles must meet the efficiency requirements of class IE4. Ex motors and brake motors may continue to be supplied in IE3.
In terms of design, motors in Ex db/db eb, Ex ec, and dust ignition protection types are relatively unproblematic. There is no separate size/power assignment here compared to standard motors; the electrical design is identical. This means that EN 50347 is fully valid for these motors. Explosion protection for these types of ignition protection focuses primarily on special design measures, such as the use of certified components, special connection systems, increased air and creep distances, issues of electrostatic charging in fans, compliance with certain minimum IP protection ratings, and material issues (in particular, the aging and temperature resistance of sealing elements). The temperature limitation measures on the surface of the motors or inside them are also not contrary to high efficiency levels.

For this reason, motors with increased efficiency levels in these types of ignition protection have already been available on the market in the past. The situation is different for the increased safety "eb" type of protection. Here, in addition to the measures already mentioned, temperature limitation in the event of a fault is also required. This means special requirements for the starting current and ensuring the longest possible t_E times. Furthermore, the size/power allocation in Germany is regulated by the DIN 42673 and DIN 42677 standards. Since these motors are Category 2 devices (use in Zone 1), separate EU type examination certificates are required for motors of this type of ignition protection. VEM motors in the ignition protection types increased safety "eb" and "ec", flameproof enclosure "db", and protection by enclosure 'tb' and "tc" have been available in energy efficiency classes IE1 to IE3 since IEC/EN 60034-30 came into force. All Ex motors are also available in IE4 versions on request.

4.3 Gas explosion-proof motors

4.3.1 Cage rotor motors, ignition protection type pressure-resistant encapsulation „db/db eb“

Series	• K82R, B82R (-Y2, -Y3) (Y2 corresponds to IE2 version, Y3 corresponds to IE3 version) • IE3 -(IE4) W..R • DKCF, DKCJ (medium voltage)
Dimensions	63 - 450 350 - 560 (medium voltage)
Types of protection	IP 55, IP 56, IP 65 according to IEC/ EN 60034-5
Cooling method	IC 411 according to EN 60034-6
Designs	IM B3, IM B35, IM B5, IM B14, IM B34 und abgeleitete Bauformen n. IEC/ EN 60034-7
Ambient temperature	-55°C TO +60°C
Temperature class	T3 TO T6
Explosion-proof design in accordance with equipment group II, category 2 Ex db(eb)	IEC/EN 60079-0 General requirements IEC/EN 60079-1 Pressure-resistant enclosure “db”

Mounting dimensions and power ratings according to DIN 42673 Sheet 3 and DIN 42677 Sheet 3

Approval overview

Series and axle heights	Ex II 2G Ex d(e) IIC T3 - T6	Ex II 2G 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

Series and axle heights	Ex II 2G Ex d(e) IIC or IIB up to T3-T6
IE.-W4..63	IBExU23ATEX1074X
IE.-W4..71	IBExU23ATEX1073X
IE.-W4..80	IBExU23ATEX1067X
IE.-W4..90	IBExU23ATEX1013X
IE.-W4..100	IBExU23ATEX1030X
IE.-W4..112	IBExU24ATEX1017X
IE.-W4..132	IBExU21ATEX1021X
IE.-W4..160	IBExU20ATEX1142X
IE.-W4..180	IBExU22ATEX1029X
IE.-W4..200	IBEXU24ATEX1045X
IE.-W4..225	IBEXU24ATEX1046X

Labelling example:
Ex d IIC T4 Gb or Ex db IIC T4

4.3.2 Cage rotor motors, ignition protection type increased safety „eb“

Type	KPR / KPER / IE1-KPR/KPER / IE2- KPR/KPER K1.R / IE1-K1.R / IE2-K1.R / IE3-K1.R / IE4-K1.R / K4.R / W52R / W72R
Dimensions	56 - 450
Types of protection	IP 54, IP 55, IP 56, IP 65 according to IEC/EN 60034-5
Cooling method	IC 411 according to IEC/EN 60034-6
Designs	IM B3, IM B35, IM B5, IM B14, IM B34, and derived designs in accordance with IEC/EN 60034-7. When installing motors in designs with vertical shaft position, foreign objects must be prevented from falling into the ventilation openings (protective cover).
Temperature class	T1 and T2, T3 or T4
Explosion-proof design in accordance with equipment group II, category 2 Ex db(eb)	IEC/EN 60079-0 General requirements IEC/EN 60079-7 Increased safety “eb”

Mounting dimensions and power ratings according to EN 50347 (DIN 42673 Sheet 2 or DIN 42677 Sheet 2)

Ambient temperatures -40 °C to +40 °C, for shaft heights 56 to 112: -20 °C to +40 °C, other values according to supplements and associated data sheets or supplementary sheets

The design of the motors has been tested by the PTB and IBExU Institute for Safety Technology GmbH and approved as follows:

Mechanical motor:
EC type examination certificate IBExU02ATEX1108 U
EU type examination certificate IBExU00ATEX1083 U

Motor terminal boards Ex eb:
EC type examination certificate IBExU13ATEX1089 U

Connection boxes Ex eb:
EU type examination certificate IBExU00ATEX1051 U

Connection boxes Ex db:
EU type examination certificate IBExU21ATEX1025 U

Furthermore, the EC type examination certificates listed below, with corresponding supplementary sheets for documentation of intended use in potentially explosive atmospheres, are available.

The supplementary sheets for the EC type examination certificates that are valid for the individual types can be found in the approval overview.

Series and axle heights	EC type examination certificate	EC (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 *)

continue to next page

Series and axle heights	EC type examination certificate	EC (EU) type examination certificate
W52R 450		IBExU15ATEX1181
W72R 450		IBExU23ATEX1025X *)

*) EU-currently still in progress: completion planned for 01/2024

Custom-made motors with larger axle heights and other cooling types can be supplied. These receive an EU declaration of conformity after individual testing.

Labeling example:
Ex e IIC T3 Gb (alternative: Ex eb IIC T3)
New according to IEC/EN 60079-7: Ex eb IIC T3 Gb (alternative Ex eb IIC T3)

4.3.3 Cage rotor motors, ignition protection type increased safety „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 / IE4-W6.R / W52R/ W72R
Dimensions	56 - 450
Types of protection	IP 54, IP 55, IP 56, IP 65 according to IEC/EN 60034-5
Cooling method	IC 411 according to IEC/EN 60034-6
Mounting dimensions and power allocation	according to EN 50347
Designs	IM B3, IM B35, IM B5, and derived designs in accordance with IEC/ EN 60034-7. When installing motors in designs with vertical shaft position, foreign objects must be prevented from falling into the ventilation openings (protective cover).
Temperature class	T2, T3 oder T4
Ambient temperature	-40°C to +55°C (for axle height 56 - 112: -20°C to +55°C)
Explosion-proof design in accordance with equipment group II, category 3	IEC/EN 60079-0 General requirements IEC/EN 60079-7 Increased safety “ec”
The following type examination certificates are available for the design of the motors:	Series KPR 56 – 112: IBExU06ATEXB001 Series KPR 63 – 132 T: IBExU06ATEXB002 Series (IE1-)K1.R 112 – 355: IBExU09ATEXB006 Series (IE.-)W.1R 112 – 315: IBExU03ATEXB004

Customized motors with larger axle heights and other cooling types can be supplied. After testing, these receive an EU declaration of conformity and, on request, a type examination certificate.

Labelling example:
Ex nA IIC T3 Gc (alternatively: Ex nAc IIC T3)

4.3.4 Engines, ignition protection type: vacuum encapsulation „pcb/ pzc“

Customized motors in asynchronous and synchronous designs can be supplied. After testing, these receive an EU certificate of conformity for Zone 1 or an EU declaration of conformity for Zone 2, and a type examination certificate on request.

Labelling example:
Ex pxb IIC T3 Gb

4.4 Dust explosion-proof motors

4.4.1 Cage rotor motors 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 / IE.-W..R
Dimensions	56 - 355
Types of protection	IP 65 according to IEC/EN 60034-5
Cooling method	IC 411 according to IEC/EN 60034-6
Mounting dimensions and power allocation	according to EN 50347
Designs	IM B3, IM B35, IM B5, and derived designs according to IEC/EN 60034-7: when installing motors in designs with vertical shaft position, foreign objects must be prevented from falling into the ventilation openings (protective cover).
Ambient temperature	–30 °C to +40 °C (+55 °C), for axle heights 56 to 132 T: -20 °C to +40 °C (+55 °C)
Maximum surface temperature	125 °C, other surface temperatures on request
Explosion-proof design in accordance with equipment group II, category 2	EC/EN 60079-0, IEC/EN 60079-31, EN 61241-0 General provisions EN 61241-1 Protection provided by enclosures “t_D”
The following EC type examination certificates are available for the design of the motors:	Series KPER 56 to 132 T: DTM00ATEXE012X Series (IE1-)K2.Q 112 – 315: IBExU02ATEX1019 Series (IE1-)K1.R 112 – 355: IBExU09ATEX1065 Series (IE.-)W.1R 112 – 315: IBExU04ATEX1118

Customer-specific motors, including slip ring motors, with larger shaft heights and other cooling types can be supplied. These receive an EU declaration of conformity after individual testing.

4.4.2 Cage rotor motors for use in the presence of combustible dusts, Zone 11

Type	KPR/KPER / IE1-KPR/KPER / IE2-KPR/KPER / IE3-KPR/KPER K1.R / K2.R / IE1-K2.R / IE2-W.1R / IE3-W.4R / IE4-W6.R / W52R
Dimensions	56 – 400
Types of protection	IP 55 according to IEC/EN 60034-5 (bei leitfähigen Stäuben IP 65)
Cooling method	IC 411 according to IEC/EN 60034-6
Mounting dimensions and power allocation	according to EN 50347
Designs	IM B3, IM B35, IM B5, and derived designs according to IEC/EN 60034-7; when installing motors in designs with vertical shaft position, foreign objects must be prevented from falling into the ventilation openings (protective cover).
Ambient temperature	–40 °C to +40 °C, for axle heights 56 to 132 T: -35 °C to +40 °C
Maximum surface temperature	125 °C, other surface temperatures on request
Explosion-proof design in accordance with equipment group II, category 3	IEC/EN 60079-0 General requirements IEC/EN 60079-31 Protection provided by enclosures “t”

The design of the motors is certified with an EU declaration of conformity.

Customer-specific motors, including slip ring motors, with larger shaft heights and other cooling types can be supplied. These come with a declaration of conformity and, on request, a type examination certificate.

Labelling example:
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 eb 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

- The ambient temperature for the combined motors 2G or 2D and 3G or 2D is -40 °C
- to +60 °C, KPER / KPR from -20 °C to +40 °C, and for the K1.R series from -30 °C to +40 °C (+55 °C).

The following certificates are available for this:

Versions of the 2G or 2D motors	
Series K82. 63 - 450 / W4.. 63-250	According to the certification overview, pressure-resistant motors “db”
Series KPER/KPR 56 – 112:	IBExU02ATEX1108 U and IBExU02ATEX1109 to 1115
Series K1.R 112 – 355	According to the certification overview, increased safety “eb” with additional certification IBExU09ATEX1065
Versions of the 3G or 2D motors	
Series (IE1-)K1.R 112 – 355:	IBExU09ATEXB006 additionally with IBExU09ATEX1065
Series (IE.-)W.1R 112 – 315:	IBExU03ATEXB004 additionally with IBExU04ATEX1118
Versions of the 3G or 3D motors	IBExU09ATEXB006 additionally with manufacturer‘s declaration Zone 22
Series (IE1-)K1.R 112 – 355:	IBExU03ATEXB004 additionally with manufacturer‘s declaration Zone 22
Series (IE.-)W.1R 112 – 315:	

5 Maintenance and repair

Maintenance, repairs, and modifications to explosion-proof machines must be carried out in Germany in compliance with the BetrSichV (Industrial Safety Regulation) and ProdSV (Product Safety Act/Explosion Protection Regulation).

In order to ensure the safe operation of the system, consisting of the drives and the associated monitoring devices, throughout the entire service life of the process engineering system, regular inspection of the operating equipment and, if necessary, repair/replacement must be carried out. It is the operator‘s responsibility to ensure the proper maintenance and servicing of the operating equipment. The relevant regulations are the Industrial Safety Regulation and the IEC/EN 60079-17 standard.

During inspections, a distinction is made between visual inspection, close inspection, and detailed inspection, with increasing depth of inspection. A visual inspection can be carried out during operation and often also incidentally while walking through the facility. A visual inspection means an inspection of the operating equipment without the use of access aids. This can reveal, for example, a missing or damaged terminal box cover on a machine, but also noticeable bearing noises. In a close inspection, the housing is subjected to a thorough examination, e.g., with the aid of a ladder, or the bearing temperature is determined with an infrared thermometer. Decommissioning is generally not necessary.

During the detailed inspection, the machine is shut down and subjected to tests such as measuring the insulation resistance. The various tests can be clearly illustrated in the “testing pyramid”:

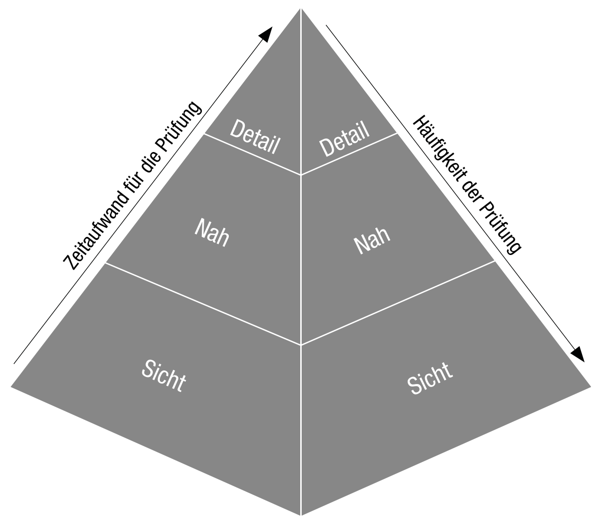


Figure 5.1: Pyramid of testing

Guideline values, depending on manufacturer

What should be done?	Time interval	Recommended timeframes
Initial inspection	After approximately 500 operating hours	after six months at the latest
Checking the airways and surface of the motor	depending on the local level of contamination	
Relubrication (optional)	See type plate or lubrication plate	
Main inspection	Approximately 8,000 operating hours	once a year
Drain condensation water	depending on climatic conditions	

Outside Germany, the relevant national regulations must be complied with!

Further information on testing and maintaining electrical systems and repairing and overhauling electrical equipment is provided in IEC/EN 60079-17 and IEC/EN 60079-19. Work that affects explosion protection includes, for example:

- Repairs to the stator winding and terminals
- Repairs to the ventilation system
- Repairs to the bearings and seals on dust explosion-proof motors (Ex 2D, 3D) may only be carried out by the manufacturer‘s service personnel or by qualified personnel from/in authorized workshops who have the necessary knowledge based on professional training, experience, and instruction.

In dust explosion-proof motors, dust explosion protection depends heavily on local conditions. For this reason, motors in these areas must be inspected and maintained regularly.

Thick layers of dust cause the temperature on the surface of the motor to rise due to thermal insulation. Dust deposits on motors or even their complete filling must therefore be avoided as far as possible through appropriate installation and ongoing maintenance.

The specified surface temperature of the motor is only valid if the dust deposits on the motor do not exceed a thickness of 5 mm. These initial conditions (type of dust, maximum layer thickness, etc.) must be ensured. The motor must not be opened until sufficient time has elapsed for the internal temperatures to drop to non-flammable levels. If the motors need to be opened for maintenance or repair, this work should be carried out in a dust-free room if possible. If this is not possible, suitable measures must be taken to prevent dust from entering the housing. During disassembly, particular care must be taken to ensure that the parts necessary for the tightness of the construction, such as seals, flat surfaces, etc., are not damaged.

Careful and regular maintenance, inspections, and revisions are necessary in order to detect and eliminate any malfunctions in good time before consequential damage can occur. Since operating conditions cannot be precisely defined, only general intervals can be specified, assuming trouble-free operation. These must always be adapted to local conditions (contamination, load, etc.).

The necessary lubrication intervals for roller bearings must be observed in accordance with the manufacturer's specifications.

Maintenance work (except for relubrication) may only be carried out when the machine is at a standstill. Always ensure that the machine is secured against being switched on and marked with an appropriate warning sign. Furthermore, safety instructions and accident prevention regulations for the use of oils, lubricants, and cleaning agents from the respective manufacturers must be complied with! Neighbouring parts that are under voltage must be covered!

Ensure that the auxiliary circuits, e.g., standstill heating, are disconnected from the power supply. For models with a condensation drain hole, coat the drain screw with a suitable sealant (e.g., Epple 28) before closing it again!

If the work is not carried out by the manufacturer, it must be carried out by suitably qualified personnel and checked by a person who is qualified to do so and officially recognized (if the repair is relevant to explosion protection). This person must issue a written confirmation or affix their test mark to the machine.

Inspections carried out in accordance with §14 (6) BetrSichV must be documented in accordance with § 19 BetrSichV. The documentation must show that the device, protective system, safety, control, or regulating device complies with the requirements of BetrSichV after repair. It is recommended that the documentation be kept for the entire service life of the device and that the device be clearly marked for traceability. Important: The operator is responsible for the operation of a system that requires monitoring. This also includes the repair of devices and protective systems. When operating abroad, the relevant national regulations must be complied with.

Spare parts
With the exception of standardized, commercially available, and equivalent parts (e.g., roller bearings), only original spare parts (see manufacturer-specific spare parts lists) may be used; this applies in particular to seals and connecting parts.

The following information is required when ordering spare parts:
- Spare part designation
- Motor type
- Motor number

6 Repair and modification of electrical equipment

6.1 General information

The legal basis for the operation of explosion-proof electrical equipment in potentially explosive atmospheres is the **11th ProdSV** Ordinance to the Product Safety Act (Explosion Protection Products Ordinance) in conjunction with the Industrial Safety Ordinance (Betr SichV).

Previously applicable regulations such as the "Regulation on Electrical Installations in Potentially Explosive Atmospheres (ElexV)" were thereby repealed.

Further requirements are contained in the **IEC/EN 60079-14 standard** and in the **BGR 104 explosion protection regulations**. A change to a system requiring monitoring within the meaning of the BetrSichV is any measure that affects the safety of the system. Any repair work that affects the safety of the system is also considered a modification. A **significant** modification to a system requiring monitoring within the meaning of the BetrSichV is any modification that changes the system requiring monitoring to such an extent that it corresponds to the safety features of a new system. Maintenance and repair refers to a combination of all activities carried out to maintain an object in a condition or to restore it to a condition that meets the relevant requirements and ensures that the required functions are performed.

The basis for this is:
- IEC/EN 60079-17, "Inspection and maintenance of electrical installations" and
- TRBS 1201 "Inspection of work equipment and installations requiring monitoring"
- TRBS 1201 Part 3 "Repair of equipment, protective systems..."

They are intended for operators and deal with aspects directly related to the testing and maintenance of electrical equipment in potentially explosive atmospheres. The operator can have explosion-proof equipment repaired at any workshop. If parts on which explosion protection depends are replaced or repaired, the equipment must be inspected by an officially recognized person qualified to perform such inspections before it is put back into service.

(A "person qualified to perform inspections" within the meaning of the BetrSichV is a person who, due to their professional training, professional experience, and recent professional activity, has the necessary expertise to inspect work equipment.

The guidelines for the Industrial Safety Regulation and TRBS 1203 explain the requirements for a qualified person. Persons qualified to perform inspections can be officially recognized by the relevant ministry in accordance with the Industrial Safety Regulation – this varies from state to state.

Recognition as a person qualified to perform inspections is company-specific and applies only to inspections of equipment, protective systems, safety, control, and regulation devices that have been repaired by that company. The recognition does not apply to all inspections of equipment, protective systems, safety, control, and regulation devices that have been repaired by the company with regard to a part on which explosion protection depends, but only to inspections after repair measures for which the application for recognition has been submitted and which are listed in detail in the notice of recognition.

The technical rules for the repair and overhaul of equipment in potentially explosive atmospheres are defined in the IEC/EN 60079-19 standard. It provides guidelines that give technical instructions for the repair, overhaul, regeneration, and modification of certified equipment designed for use in potentially explosive atmospheres.

The objectives are to provide guidance on practical measures for maintaining the safety of equipment; to define the requirements that must be met by repaired equipment; and to describe the procedures necessary to ensure that the equipment continues to comply with all relevant regulations after repair. For the various types of ignition protection, examples are given for the repair, overhaul, and refurbishment of explosion-proof electrical equipment, as well as possible modifications, and the necessary tests are described.

After repair and overhaul, the equipment is accepted as complying with the EU type examination certificate if parts specified by the manufacturer have been used.

In the event that the certification documents are not available or are insufficient, the repair or overhaul must be carried out in accordance with IEC/EN 60079-19 or the corresponding relevant standard (IEC/EN 60079...). If (more extensive) types of repair or modifications are used that do not comply with the standards, the manufacturer or certification body (notified body) must determine whether this equipment is suitable for further use in potentially explosive atmospheres.

6.2 Repair work that does not affect explosion protection

Replacement of:
- Bearings
- Motor mounting feet (if possible)
- Terminal box (parts)
- Replacement of seals with original parts
- Insertion parts
- Terminal box tray
- Fan/fan cover
- Bearing shield
- IM B3 in IM B35, IM B34

Design modifications of:
- IM B3 in IM B5, IM B14
- Terminal box (parts)
- IM B35 in IM B5, IM B14
- Installation and removal of feet (if possible)

Cleaning of:
- Sealing surfaces
- Seals

Original spare parts should generally be used.
The use of non-original, but ex-tested parts is legally permissible. However, this automatically voids the manufacturer's warranty.

6.3 Repair work that requires inspection by an officially recognised person qualified to carry out such inspections

- Repair or replacement of the winding (winding data according to manufacturer)
- Reworking of the number and/or size of the feed-through openings
- Replacement of parts of the ventilation system
- Replacement of the seal with non-original but explosion-proof parts
- Reconditioning of rotor and stator without significantly increasing the air gap

The winding may only be repaired or replaced in accordance with the manufacturer's specifications (winding data/materials). If insulating material parts are replaced with parts made of a different insulating material and/or with different dimensions, the warranty shall automatically expire.

6.4 Repair work on Ex e motors (modifications) that require a new type examination (e.g. by a notified authority in accordance with Directive 2014/34/EU)

- Installation of other/additional parts in the device (main terminals, auxiliary terminals, or additional devices)
- Reconditioning of rotor and stator
- Winding for a different voltage
- Renewal of parts of the ventilation system (e.g., fan wheel)
- Rewinding for a different speed
- Change of gap dimensions

This work can be carried out under the above conditions. However, VEM only permits this work to be carried out at the manufacturer's facilities. If the work is carried out at a workshop, the warranty will automatically expire!

6.5 Repair work on Ex d motors (modifications) that require a new type examination (e.g. by a notified authority in accordance with Directive 2014/34/EU)

- Installation of additional parts in the device
- Refurbishment of spark-proof gaps
- Refurbishment of rotors and stators
- Regeneration of components that are not part of the pressure-resistant enclosure
- Renewal of parts of the ventilation system (e.g., fan wheel)
- Regenerated components must be ordered with the appropriate overpressure test
- Rewinding for a different speed or voltage
- Changing the gap dimensions
- Changes to the ventilation system

This work may be carried out under the above conditions. However, VEM only permits this work to be carried out at the manufacturer's facilities. If the work is carried out at a workshop, the warranty will automatically expire!

6.6 Summary

Permissible work on motors with ignition protection type "db" "db

List of work to be carried out Motors with "db" and "db eb" type of protection	Production area: VEM motors GmbH facilities in Zwickau and Wernigerode				
	when using		by and under the responsibility of		
	Standard part [3]	Original spare part	Qualified specialist	qualified person with official recognition	Manufacturer
Replacement of					
• Bearings	X	X	X[2]	X	X
• Motor feet	-	X	X	-	X
• Terminal box (parts) "eb"	-	X	X	-	X
• Terminal tray „eb"[1]	X	X	X	-	X
• Insert section „eb"[1]	X	X	X	-	X
• Fan/fan cover	-	X	X	-	X
• Bearing shields	-	X	X[2]	X	X
• Shaft	-	X	X[2]	X	X
• Terminal box (parts) „db"	-	X	X[2]	X	X
• Terminal tray „db"	X	X	X[2]	X	X
• Insert section „db" [1]	X	X	X	-	X
• Seals	-	X	X[2]	X	X
Refurbishment of:					
• Grooves (DIN 625) on cylindrical roller bearings (DIN 5412) and back	0	0	0	0	X
• IM B3 in IM B5, IM B14	-	X	X	-	X
• IM B35 in IM B5, B14	-	X	X	-	X
• Attaching and removing feet	-	X	X	-	X
• Terminal box position and foot disassembly (FX version only) Specifications from BuW	-	X	X	-	X
Cleaning of					
• Sealing surfaces	-	X	X[2]	X	X
• Seals	-	X	X[2]	X	X
Follow-up work of					
• Air gap	-	-	0	0	X
• Number and/or size of the insertion opening „eb"	-	X	X[2]	X	X
• Number and/or size of the insertion opening „db"	-	-	0	0	X
• Split surfaces	-	-	X[2]	X	X
Installation of additional					
• Main terminals	0	0	0	0	X
• Auxiliary terminals	0	0	0	0	X
Replacement winding					
• Stator (unwound)	-	-	X[2]	X	X
• TPM as additional protection	-	-	0	0	X
• Housing with stator package (wound)	-	X	X[2]	X	X

[1] with partial or conformity certificate
[2] only with a test certificate from a recognized workshop specialist
- Not applicable/not required
0 not allowed
X permissible/ required

Permissible work on motors with ignition protection type “db” “db

List of work to be carried out Motors with “db” and “db eb” type of protection	Production area: VEM motors GmbH facilities in Zwickau and Wernigerode				
	when using		by and under the responsibility of		
	Standard part [3]	Original spare part	Qualified specialist	qualified person with official recognition	Manufacturer
Rewinding according to					
• Manufacturer‘s specification	-	-	0	0	X
Winding for					
• different number of poles/frequency	-	-	0	0	X
• TPM as sole protection	-	-	0	0	X

[1] with partial or conformity certificate
[2] only with a test certificate from a recognized workshop specialist
- not applicable/not required
0 not permitted
X permissible/ required

Permissible work on motors with ignition protection type „eb“, „ec“, „tb“

List of work to be carried out Motors with „eb“, „ec“, „tb“ and „tc“	Production area: VEM motors GmbH facilities in Zwickau				
	when using		by and under the responsibility of		
	Standard part [3]	Original spare part	Qualified specialist	qualified person with official recognition	Manufacturer
Replacement of					
• Bearings	X	X	X	-	X
• Motor feet	-	-	0	0	X
• Terminal box (parts)	-	X	X	-	X
• Terminal tray [1]	X	X	X	-	X
• Insert section [1]	X	X	X	-	X
• Fan/fan cover	-	X	X	-	X
• Bearing shields	-	X	X	-	X
• Shaft	-	x	x[2]	X	X
• Seals	-	X	x	-	X
Refurbishment of:					
Grooves (DIN 625) on cylindrical roller bearings (DIN 5412) and back	0	0	0	0	X
IM B3 in IM B35, IM B34	-	X	X	-	X
IM B3 in IM B5, B14		X	X	-	X
IM B35 IN IM B5, IM B14		X	X	-	X
Removing feet (Attaching and removing in EMW)	-	-	X	-	X
Cleaning of					
• Sealing surfaces	-	X	X	-	X
• Seals	-	X	X	-	X
Follow-up work of					
• Air gap	-	-	0	0	X
• Number and/or size of the insertion opening	-	X	X[2]	X	X
Installation of additional					
• Main terminals	0	0	0	0	X
• Auxiliary terminals	0	0	0	0	X
Replacement winding					
• Stator (unwound)	-	-	0	0	X
• TPM as additional protection	-	-	0	0	X
• Housing with stator package (wound)	-	X	X[2]	X	X
Rewinding according to					
• Manufacturer‘s specification	-	-	0	0	X
Winding for					
• different number of poles/frequency	-	-	0	0	X
• TPM as sole protection	-	-	0	0	X

[1] with partial or conformity certificate
[2] Only with a test certificate from a qualified person with official recognition
[3] Standard parts equivalent to original spare parts in terms of dimensions and certification; consult with manufacturer if necessary
- not applicable/not required
0 not permitted
X permissible/ required

Permissible work on motors with ignition protection type „eb“, „ec“, „tb“ and „tc“

List of work to be carried out Motors with „eb“, „ec“, „tb“ and „tc“	Production area: VEM motors GmbH facilities in **Wernigerode**				
	when using		by and under the responsibility of		
	Standard part [3]	Original spare part	Qualified specialist	qualified person with official re-cognition	Manufac-turer
Replacement of					
• Bearings	X	X	X	-	X
• Motor feet	-	X	X	-	X
• Terminal box (parts)	-	X	X	-	X
• Terminal tray [1]	X	X	X	-	X
• Insert section [1]	X	X	X	-	X
• Fan/fan cover	-	X	X	-	X
• Bearing shields	-	X	X	-	X
• Shaft	-	X	X[2]	X	X
• Seals	-	X	X	-	X
Refurbishment of:					
Grooves (DIN 625) on cylindrical roller bearings (DIN 5412) and back	0	0	0	0	X
IM B3 in IM B35, IM B34	-	X	X	-	X
IM B3 in IM B5, B14	-	X	X	-	X
IM B35 IN IM B5, IM B14	-	X	X	-	X
Removing feet (Attaching and removing in EMW)	-	X	X	-	X
Cleaning of					
• Sealing surfaces	-	X	X	-	X
• Seals	-	X	X	-	X
Follow-up work of					
• Air gap	-	-	0	0	X
• Number and/or size of the insertion opening	-	-	X[2]	X	X
Installation of additional					
• Main terminals	0	0	0	0	X
• Auxiliary terminals	0	0	0	0	X
Replacement winding					
• Stator (unwound)	-	-	X[2]	X	X
• TPM as additional protection	-	-	0	0	X
• Housing with stator package (wound)	-	X	X[2]	X	X
Rewinding according to					
• Manufacturer‘s specification	-	-	X[2]	X	X
Winding for					
• different number of poles/frequency	-	-	0	0	X
• TPM as sole protection	-	-	0	0	X

[1] with partial or conformity certificate
[2] Only with a test certificate from a qualified person with official recognition
[3] Standard parts equivalent to original spare parts in terms of dimensions and certification; consult with manufacturer if necessary
- not applicable/not required
0 not permitted
X permissible/ required

7 Inspection of motors after repairs, maintenance or conversion

After repairs, maintenance, or modifications have been carried out, the motors must be inspected in accordance with §15 of the German Industrial Safety Regulation (BetrSichV) of February 3, 2015. This inspection may only be carried out by qualified personnel.

The test must meet the requirements of IEC/EN 60079-19. The following tests must be performed and documented:
Visual inspection of the winding and the entire motor, paying particular attention to the increased safety requirements.

7.1 Visual inspection

7.1.1 Visual inspection of the winding

- Checking the winding projection
- Bandages
- Groove and phase insulation
- Groove closure element
- Wire insulation

7.1.2 Visual inspection of the entire engine, focusing on

- Terminal designation
- Proper connection of terminal connectors
- Cable screw connections
- Seals
- Fan assembly
- Fan cover mounting

7.2 Winding test

7.2.1 Winding resistance

The ohmic DC resistors are fed with a constant current via two terminals each by supplying the motor winding, and the voltage drop at the machine terminals is measured. This is used to determine the resistance between the terminals U-V, V-W, and U-W. In addition, the temperature of the winding is measured.

The test certificates show the winding resistance of the winding at 20 °C. To this end, the measured values must be converted for temperatures deviating from 20 °C.

7.2.2 High-voltage testing

The high-voltage test is used to check the insulation strength of the winding.

IEC/EN 60034-1 and VDE 0530 Part 1 specify the following procedure for testing machines with a rated voltage < 1 kV:

The voltage test must be carried out between the windings to be tested and the machine housing. The laminated core is connected to the windings or strands not intended for testing (e.g., V1 and W1) and the test voltage is applied between the housing and the U string. A single measurement is used to test the machine for ground faults and phase faults at the same time.

The high-voltage test is performed on the impregnated and fully assembled machine with a test voltage at mains frequency and as sinusoidal as possible with an effective value of $2 \cdot U_{Nenn}$+1000V in accordance with IEC/EN 60034-2. The test should be started with a voltage of no more than half the full test voltage and then increased continuously or in steps of no more than 5% of the final value within at least 10 seconds.

The full test voltage must be maintained for 1 minute.

A repeat test may only be performed at 80% of the maximum test voltage. Windings already in use are tested at a minimum of 1000V, e.g., during an overhaul.

7.2.3 Insulation values (insulation resistance)

During initial commissioning and especially after prolonged storage, the insulation resistance of the winding to ground and between phases must be measured. The test must be carried out at rated voltage, but at least at 500 V. Dangerous voltages occur at the terminals during and immediately after the measurement. Do not touch the terminals under any circumstances; follow the operating instructions for the insulation measuring device exactly! Depending on the rated voltage UN, the following minimum values must be observed at a winding temperature of 25 °C:

Rated power P_B & kW	Insulation resistance relative 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 values fall below the minimum values, the winding must be dried properly until the insulation resistance corresponds to the required value.

7.3 Test run

7.3.1 Rotating field (rotation direction control)

The direction of rotation check ensures that when the power cable is connected to the machine terminals L1 to U, L2 to V, and L3 to W, the direction of rotation is clockwise when viewed from the drive side.

7.3.2 Idle test, determination of idle current I_0

The idle test is used to check the number of windings, the circuitry, and to assess the running characteristics. It is performed at rated voltage ± 1% when the machine is cold. The machine is completely unloaded (disconnected from the load machine). The voltage, currents, and power are recorded during the measurement.

The current consumption is measured in all phases and compared with the manufacturer's specifications. The permissible tolerance – based on the manufacturer's specifications – is ± 15%. Furthermore, the no-load currents of the three phases may only differ by a maximum of 15% from each other.

7.3.3 Proof of phase symmetry

7.3.3.1 Short circuit test at I_B

The stator winding of cage motor machines must be supplied with an appropriately reduced voltage when the rotor is locked in order to achieve the full-load rated current and to ensure the symmetry of all phases.

The test is used as an alternative to the full load test to verify the integrity of the winding and air gap and to detect damage to the rotor. Asymmetries of less than 5% of the mean value are permissible.

7.3.3.2 Short circuit test according to IEC/ EN 60043-1

The short-circuit test is used to determine the I_A/I_N ratio. The rotor is braked firmly, voltage is applied to the stator winding, and the current consumption is measured. If this test is not performed at rated voltage, the starting current I_A must be converted in proportion to the ratio of the rated voltage to the test voltage.

In addition, a saturation factor of the iron must be taken into account when the test voltage is reduced. The I_A/I_N ratio calculated in this way may deviate by up to 20% from the rating plate specification.

Starting current I_A Starting current I_A (only for ignition protection type increased safety "eb") Saturation factor f_S for conversions at reduced test voltage with fixed-braked rotor

- Rotor with completely or almost completely closed slots
- Rotor with open slots

Setpoint for the acceleration current $I_A = I_N \cdot I_A/I_N$

1. Test voltage = rated voltage U_N Permissible deviation of the test current: ± 20% of I_A (compliance with the negative tolerance for testing the stator and rotor windings is required)
2. Test voltage U_X
   Test current I_X
   Reduction ratio $R = U_X/U_N$
   Saturation factor f_S
   Test current converted to rated voltage

$I_{KN} = I_X \cdot f_S / R$
Permissible deviation for the converted
Test current
I_{KN}: ±10 % von I_A

If the original insulation system and/or coating system is/are not available, the t_E time must be rechecked in accordance with IEC/EN 60079-7. Copying the winding is not permitted until the t_E time has been rechecked in accordance with the equipment standard IEC/EN 60079-7.

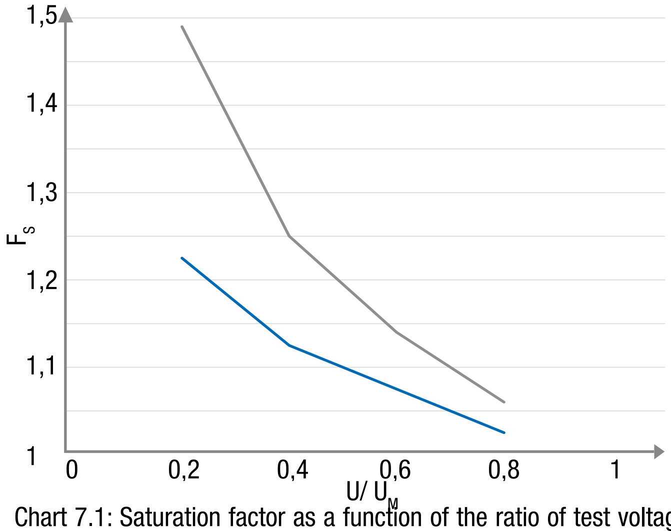


Chart 7.1: Saturation factor as a function of the ratio of test voltage to rated voltage

7.3.4 Oscillation test

To assess smoothness of operation, a vibration test must be carried out in accordance with IEC/EN 60034-14 (VDE 0530 Part 14):2004. The limit values for level A or B must be complied with in accordance with the specifications.

Level A
(for machines without special oscillation requirements)
Level B
(for machines with special oscillation requirements)

7.4 Painting and impregnation after repair or maintenance work

When repainting explosion-proof motors or impregnating a complete stator after rewinding, thicker layers of paint or resin may form on the machine surface. These can lead to electrostatic charges, resulting in a risk of explosion when discharged. Charging processes in the vicinity can also lead to electrostatic charging of the surface or parts of the surface, and there may be a risk of explosion due to discharge. The requirements of IEC/EN 60079-0: "Equipment – General requirements," section 7.4, and TRBS 2153 must therefore be strictly observed, including by:

Limitation of the total paint or resin layer thickness according to the explosion group to

- IIA, IIB: total layer thickness ≤ 2 mm
- IIC: total layer thickness ≤ 0.2 mm

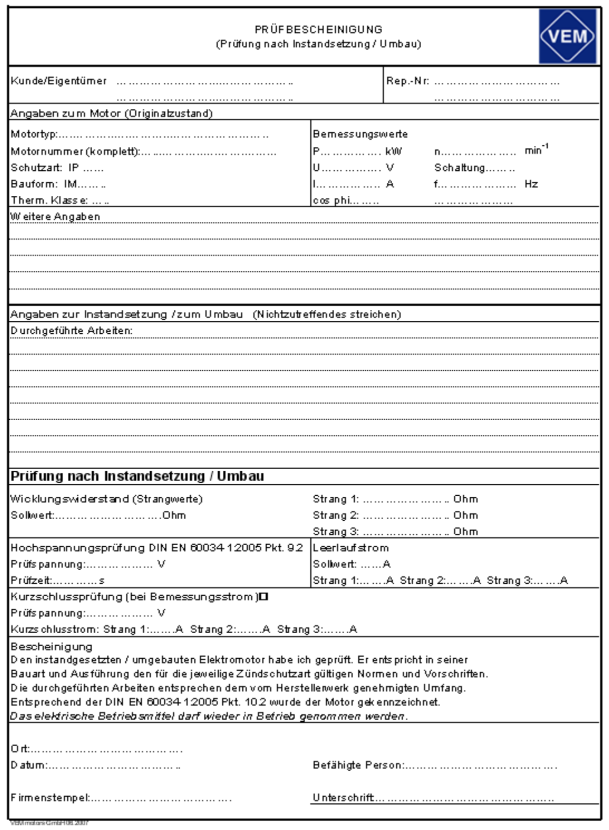
Limitation of the surface resistance of the paint or resin used to

- IIA, IIB, IIC, III Surface resistance ≤ 1GΩ for motors in groups II and III

Breakdown voltage ≤ 4 kV for explosion group III (dust only, measured through the thickness of the insulating material according to the method described in IEC 60243-1).
The provisions of IEC/EN 60079-32: "Electrostatic hazards" should also be observed, in particular Annex A: "Fundamentals of static electricity," Annex B: "Electrostatic discharges in special situations," and Annex C: "Flammability of substances."

7.5 Test documentation

The results of the test must be documented in a test report.



PRÜFBESCHEINIGUNG
(Prüfung nach Instandsetzung / Umbau)

Kunde/Eigentümer .... Rep.-Nr. ....

Angaben zum Motor (Originalzustand)

Motortyp: .... Bemessungswerte
Motornummer (komplett): .... P .... kW n .... min⁻¹
Schutzart: IP ...... U .... V Schaltung ....
Bauform: IM ...... I .... A f .... Hz
Therm. Klasse: ...... cos phi ....

Weitere Angaben

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

Prüfung nach Instandsetzung / Umbau

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

Hochspannungsprüfung DIN EN 60034-1:2005 Pkt. 9.2 Leerlaufstrom
Prüfspannung: .... V Sollwert: ...... A
Prüfzeit: .... s Strang 1: ...... A Strang 2: ...... A Strang 3: ...... A

Kurzschlussprüfung (bei Bemessungsstrom) ☐
Prüfspannung: V
Kurzschlussstrom: 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.

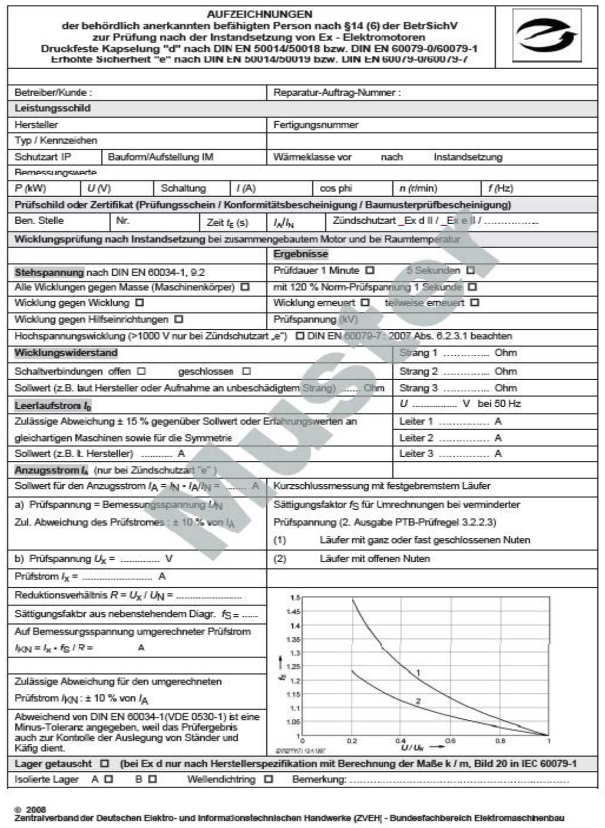
Ort: ....
Datum: .... Befähigte Person: ....
Firmenstempel: .... Unterschrift: ....

Sample report VEM motors GmbH

below:
Alternatively: ZVEH test certificate

The retention period for test reports is 10 years. Compliance checks are carried out by an officially recognized “person qualified to perform tests.”

Publisher:
German Electrical and Information Technology Contractors‘ Association (ZVEH)



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

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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.

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8 Overview of standards and regulations

8.1 General standards

Title	International IEC - International Electro-technical Commission	Europe EN - CENELEC European Committee for Electrotechnical Standardization	Germany DIN/ DE German Institute Standard/ Association of German Electrical Engineers
Rotating electrical machines Rating and operating behavior	IEC 60034-1	EN 60034-1	DIN EN 60034-1 VDE 0530-1
Method for determining the losses and efficiency of rotating electrical machines from tests	IEC 60034-2-1 IEC 60034-2	EN 60034-2-1 EN 600342	DIN EN 60034-2-1 VDE 0530-2-1 DIN/ EN 60034-2 VDE 0530-2
Efficiency classification of three-phase motors with cage rotors	IEC 60034-30-1	EN 6003430-1	DIN EN 60034-30-1 VDE 0530-30-1
Degrees of protection based on the overall construction of rotating electrical machines (IP code) Introduction	IEC 60034-5	EN 60034-5	DIN EN 60034-5 VDE 0530-5
Classification of cooling methods (IC code)	IEC 60034-6	EN 60034-6	DIN EN 60034-6 VDE 0530-6
Classification of types of construction, types of installation, and terminal box position (IM code)	IEC 60034-7	EN 60034-7	DIN EN 60034-7 VDE 0530-7
Connection designations and direction of rotation	IEC 60034-8	EN 60034-8	DIN/ EN 60034-8 VDE 0530 Teil 8
Noise limiters	IEC 60034-9	EN 60034-9	DIN EN 60034-9 VDE 0530-9
Starting behavior of three-phase motors with cage rotors, except for pole-changing motors	IEC 60034-12	EN 60034-12	DIN/ EN 60034-12 VDE 0530 Teil 12
Mechanical vibrations of certain machines with an axis height of 56 mm and higher; measurement, evaluation, and limit values of oscillation amplitude	IEC 60034-14	EN 60034-14	DIN/ EN 60034-14 VDE 0530-14
Balancing quality	ISO 1940	-	DIN ISO 1940 VDE 0175
IEC standard voltage	IEC 60038	-	DIN IEC 60038
Evaluation and classification of electrical insulation according to its thermal behavior	IEC 60085	-	DIN IEC 60085 VDE 0301-1
Three-phase asynchronous motors for general use with standardized dimensions and power ratings	IEC 60072-1	EN 50347	DIN EN 50347

	Title	IEC	CEN/ CENELEC	DIN/ VDE	Reference of the replaced standard	Date of cessation of presumption of conformity of the replaced standard
Fundamentals	Explosive atmospheres – Explosion protection Part 1: Fundamentals and methodology		EN 1127-1:2019	DIN EN 1127-1:2019-10	EN 1127-1:2011	
	Explosive atmospheres – Explosion protection Part 2: Fundamentals and methodology in mines		EN 1127-2:2014	DIN EN 1127-2:2014-09		
	Explosive atmospheres – Explosion protection Part 1: Terms for equipment, protective systems, and components intended for use in explosive atmospheres		EN 13237:2012	DIN EN 13237:2013-01		
Key figures for combustible gases and vapors	Method for determining the maximum explosion pressure and the maximum pressure rise over time for gases and vapors		EN 15967:2022	DIN EN 15967:2022-03	EN 15967:2011	
	Flameproof enclosures "d" – Method of test for ascertainment of maximum experimental safe gap (test method for determining the maximum safe gap width)	IEC 60079-1-1:2002			withdrawn	
	Testing of mineral oil hydrocarbons – Determination of the ignition temperature			DIN 51794:2003-05		
Key figures for combustible dusts	Explosive atmospheres – Part 20 – 1: Material characteristics for the classification of gases and vapors – Test methods and data	ISO/IEC 80079-20-1:2017+Cor1:2018	EN ISO/IEC 80079-20-1:2019	DIN EN ISO/IEC 80079-20-1:2020-09		
	Explosive atmospheres – Part 20 – 2: Material characteristics – Combustible dusts test methods	ISO/IEC 80079-20-2:2016	EN ISO/IEC 80079-20-2:2016	DIN EN ISO/IEC 80079-20-2:201-12		
Classification of hazardous areas	Electrical equipment for potentially explosive gas atmospheres Part 10: Classification of potentially explosive gas atmospheres	IEC 60079-10-1:2020+ Cor1:2021	EN IEC 60079-10-1:2021	DIN EN IEC 60079-10-1:2022-02	DIN EN 60079-10-1:2016	22.01.2024
	Explosive atmospheres – Part 10-2: Classification of areas – Areas with a risk of dust explosion	ISO/IEC 80079-20-2:2016	EN 60079-10-2:2015	DIN EN 60079-10-2:2015-10; VDE 0165-102:2015-10	DIN EN 60079-10-2:2010	20.02.2018
Systems, design, installation, maintenance and repair	Explosive atmospheres – Part 14: Design, selection, and installation of electrical equipment	IEC 60079-14:2013 (IEC 31J/301/CD:2019)	EN 60079-14:2014	DIN EN 60079-14:2014-10; VDE 0165-1:2014-10 E DIN EN IEC 60019-14 VDE 0165-1:2021-05		
	Explosive atmospheres – Part 17: Testing and maintenance of electrical installations	IEC 60079-17:2013 (IEC 31J/287/CD:2019)	EN 60079-19:2019	DIN EN 60079-17:2014-10 VDE 0165-10-1:2014-10 (DIN EN IEC 60079-17:2020-06-draft)	DIN EN 60079-17:2008-10	24.12.2016
	Explosive atmospheres – Part 19: Equipment repair, overhaul and refurbishment	IEC 60079-19:2019	EN 60079-19:2011+ A1:2015	DIN EN IEC 60079-19:2021-07; VDE 0165-20-1:2021-07	DIN EN 60079-19:2015	22.11.2022
Protection classes for explosion-proof equipment	Explosive atmospheres – Part 0: Equipment – General requirements	IEC 60079-0:2017	EN IEC 60079-0:2018	DIN EN IEC 60079-0:2019-09 VDE 0170-1:2019-09	DIN EN 60079-0:2014-06	06.07.2021
	Explosive atmospheres – Part 1: Equipment protection by flameproof enclosure "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 + correction 1:2016-01	EN 61241-4:2006 EN 60079-2:2007	25.8.2017
	Explosive atmospheres – Part 5: Equipment protection by sand encapsulation "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/ A1:2017	EN IEC 60079-7:2015/A1:2018	DIN EN IEC 60079-7:2016-08/A1:2018-07 VDE 0170-6/A1:2018-07	DIN EN 60079-7:2007-08	31.7.2018
	Explosive atmospheres – Part 11: Equipment protection by intrinsic safety "i"	IEC 60079-11:2011 (IEC 31G/327/CDV:2020)	EN 60079-11:2012 (prEN 60079-11:2020)	DIN EN 60079-11:2012-06; VDE 0170-7:2012-06 E DIN EN 60079-11:2021-10)		
	Explosive atmospheres – Part 15: Equipment protection by type of protection "n"	IEC 60079-15:2017	EN IEC 60079-15:2019	DIN EN IEC 60079-15:2020-03 VDE 0170-16:2020-03	EN 60079-15:2010	

	Title	IEC	CEN/ CENELEC	DIN/ VDE	Reference of the replaced standard	Date of cessation of presumption of conformity of the replaced standard
Protection classes for explosion-proof equipment	Explosive atmospheres – Part 18: Equipment protection by encapsulation “m”	IEC 60079-18:2014	EN 60079-18:2015	DIN EN 60079-18:2015-10 VDE 0170-9:2015-10	EN 60079-18:2009	16.1.2018
	Explosive atmospheres – Part 25: Intrinsically safe systems	IEC 60079-25:2010 (IEC 31G/318/FDIS:2020)	EN 60079-25:2010 (FprEN IEC 60079-25:2020)	DIN EN 60079-25:2011-06; VDE 0170-10-1:2011-06 (E DIN EN IEC 60079-25:2021-06)		
	Explosive atmospheres – Part 26: Equipment with equipment protection level (EPL) Ga	IEC 60079-26:2014	EN 60079-26:2015	DIN EN 60079-26:2015-05 VDE 0170-12-1:2015-05	EN 60079-26:2007	2.12.2017
	Explosive atmospheres – Part 27: Concept for intrinsically safe fieldbus systems (FISCO)	IEC 60079-27:2008	EN 60079-27:2008	DIN EN 60079-27:2008-12 VDE 0170-27:2008-12		withdrawn
	Explosive atmospheres – Part 28: Protection of equipment and transmission systems operating with optical radiation	IEC 60079-28:2015	EN 60079-28:2015	DIN EN 60079-28:2016-04 VDE 0170-28:2016-04	EN 60079-28:2007	1.7.2018
	Explosive atmospheres – Part 28: Protection of equipment and transmission systems operating with optical emissions	IEC 60079-29-1:2016 (modifiziert)	EN 60079-29-1:2016	DIN EN 60079-29-1:2017-09; VDE 0400-1:2017-09	EN 60079-29-1:2007	
	Explosive atmospheres – Part 29-4: Gas detectors – Requirements for the performance of open-path detectors for the detection of combustible gases	IEC 60079-29-4:2009 (modifiziert) + Cor.:2010	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 systems – General requirements and test requirements	IEC/IEEE 60079-30-1:2015	EN 60079-30-1:2017	DIN EN 60079-30-1:2018-04; VDE 0170-60-1:2018-04	EN 60079-30-1:2007	
	Explosive atmospheres – Part 31: Equipment – Dust explosion 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
	Headlamps for use in mines where firedamp is likely to occur – Part 35-1: General requirements – Construction and testing in relation to explosion risk	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		
QS	Explosive atmospheres – Part 34: Application of quality management systems for the manufacture of equipment	ISO/IEC 80079-34:2018	EN ISO/IEC 80079-34:2020	DIN EN ISO/IEC 80079-34:2020-06	EN ISO/IEC 80079-34:2011	

9 Tolerances

9.1 Electrical parameters

According to IEC/EC 60034-1, the following tolerances are permitted:

Efficiency	-0,15 (1-η) for $P_N \leq 150$ kW -0,1 (1-η) for $P_N > 150$ kW
Power factor	$\frac{1-\cos \Phi}{6}$ at least 0,02 at most 0,07
Slip (at rated load in operating temperature)	±20% for $P_N \geq 1$ KW ±30% for $P_N < 1$ KW
Starting current (in the designated starting circuit)	+20% no lower limit
Tightening torque	-15% and 25% M_K
Saddle moment	-15%
Tilting moment	-10% (after applying this tolerance, M_K/M is still at least 1.6)
Moment of inertia	±10%
Noise level (measured surface sound pressure level)	+3 dB (A)

These tolerances are permitted for three-phase asynchronous motors, taking into account necessary manufacturing tolerances and material deviations in the raw materials used for the guaranteed values. The standard provides the following comments on this:

1. A guarantee of all or any of the values in the table is not mandatory. Offers must explicitly state the guaranteed values for which permissible deviations are to apply. The permissible deviations must correspond to the table.
2. Attention is drawn to the differences in the interpretation of the term “warranty.” In some countries, a distinction is made between typical or declared values.
3. If a permissible deviation applies in only one direction, the value in the other direction is not limited.

9.2 Mechanical parameters - standard tolerances

Dimension symbols according to DIN 42939	Meaning of the measurements	Tolerance fit
a	Distance between the mounting holes of the housing base in the axial direction	± 1 mm
a_1	Diameter or corner dimension of the flange	- 1 mm
b	Distance between the mounting holes of the housing base perpendicular to the axial direction	± 1 mm
b_1	Diameter of the centering wheel of the mounting flange	up to diameter 230 mm j6 from diameter 250 mm h6
d, d_1	Diameter of the cylindrical shaft end	up to diameter 48 mm k6 from diameter 55 mm m 6
e_1	Hole circle diameter of the mounting flange	± 0,8 mm
f, g	Maximum width of the motor (without terminal box)	+ 2 %
h	Axle height (lower edge of foot to center of shaft end)	up to 250 mm -0,5 from 250 mm -1
k, k_1	Overall length of the motor	+ 1 %
p	Total height of the motor (lower edge of base, housing, or flange to the highest point of the motor)	+ 2 %
s, s_1	Diameter of the mounting holes of the foot or flange	+ 3 %
t, t_1	Lower edge of shaft end to upper edge of key	+ 0,2 mm
u, u_1	Width of the key	h9
w_1, w_2	Distance between the center of the first foot mounting hole and the shaft collar or flange mounting surface	± 3 mm
	Distance from shaft collar to flange contact surface for fixed bearing on D side Distance from shaft collar to flange contact surface	± 5,0 mm ± 3,0 mm
m	Motor weight	-5 to -10 %

Standard fits - shaft end

ATEX-Guidelines - 4st Edition 11/2022 (only in English so far)	**PTB Notes**, http://www.explosionsschutz.ptb.de
ATEX-Leitlinien, 3rd edition, 05/2020 (German version of Directive 2014/34/EU)	**PTB information sheet on the protection of asynchronous machines during start-up with reduced voltage, ensuring explosion protection**, AG 3.72, April 2009
Various other standards and draft standards	**PTB test standard –** Explosion-proof machines with increased safety protection type "e" Ex e, Volume 3, second edition 2007
Explosion-proof three-phase motors and the new standard voltages by U. Engel and H. Wickboldt, PTB Braunschweig	**DIRECTIVE 1999/92/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL** of December 16, 1999: on minimum requirements for improving the health and safety protection of workers potentially at risk from explosive atmospheres (fifteenth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC)
Explosion protection regulations (Ex-RL) DGUV Regulation 113-001 Collection of technical regulations for the prevention of hazards caused by explosive atmospheres, with examples of the classification of potentially explosive areas into zones; December 2022 edition	**DIRECTIVE 2014/34/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL** of February 26, 2014: Harmonization of the laws of Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres (revised version)
Friedl, W.J.; **Ecological and economic significance of fire and explosion protection;** Kohlhammer Publishing, 1998	**TRBS 1201** (January 2018) Part 3 Repair of equipment, protective systems, safety, control, and regulation devices within the meaning of Directive 2014/34/EU GMBI 2018, p. 67 [No. 5] (March 7, 2018); Change: GMBI 2022, p. 5 [No. 1] (January 14, 2022)
Lehrmann, C.: **On an approval procedure for explosion-proof, converter-fed squirrel-cage motors with increased safety "e" ignition protection;** dissertation, Leibniz University Hannover, 2006; published by Shaker-Verlag, Aachen.	**TRBS 1201** (March 2019) Part 1 Inspection of equipment in potentially explosive atmospheres Correction: GMBI 2022, p. 4 [No. 1] (January 14, 2022); Correction: GMBI 2022 p. 530 [23] (July 18, 2022)
Lehrmann, C., Pape, H., Dreger, U., Lienesch, F.: **Converter-fed drives – a new protection concept for drives in potentially explosive areas**; Ex magazine, R. Stahl Schaltgeräte GmbH, edition 38/2006, pp. 36–47	**TRBS 1203** (March 2019) Persons qualified to conduct examinations GMBI 2019 p. 262 [No. 13-16] (May 23, 2019); Change: GMBI 2021, p. 1002 [No. 46] (August 23, 2021); Correction: GMBI 2022, p. 16 [No. 1] (January 14, 2022)
Guidelines on the Industrial Safety Regulation (LV 35), 1st revised edition, October 2020	**VDMA Standard Sheet** 24263; Date of issue 2014-03
Standards for explosion-proof electrical equipment in transition, presentation at the 7th Technical Day of the VEM Group 2008 Dr.-Ing. F. Lienesch, PTB Braunschweig	**Regulation on safety and health protection when using work equipment (Industrial Safety Regulation - BetrSichV)**; Date of issue: February 3, 2015 (Last amended by Art. 7 G of July 27, 2021 I 3146)
	Ordinance on Protection against Hazardous Substances (Hazardous Substances Ordinance - GefStoffV); date of issue: November 26, 2010 (last amended by Art. 2 V of July 21, 2021 I 3115)

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