Latest news on explosion protection

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

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

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

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

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

Integrated explosion protection requires the implementation of explosion protection procedures in a specified sequence. In the first place, that means preventing the occurrence of explosive atmospheres, preventing the ignition of explosive atmospheres and limiting the effects of an explosion to an insignificant degree. Preventing the occurrence of explosive atmospheres, also known as primary explosion protection, is also a matter for the system designer and operator.

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

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

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

In Zone 2, only in the case of operational faults can the existence of a short-term explosive atmosphere be expected, e.g. in the case of leaks. The equipment used cannot be a source of ignition in normal operation but it is tolerated in the event of a fault. It is then assumed that there is a sufficiently low probability of an explosive atmosphere and an operational fault occurring at the same time. In the case of danger of explosion from ignitable dusts, there is a similar classification to Zone 1.

To ensure explosion protection in the case of rotating electrical machines, the following types of ignition protection are considered: In gas explosion hazard areas: Increased safety "eb", Flameproof enclosure "db" and Pressurized enclosure for "p", the interior of the housing is rinsed under pressure (from grinding).

Electrically-operated drives, the relation between Increased safety "ec" (old: "n") for Zone 2, in dust explosion hazard areas with electrical machines, "Protection by housing" is a common type of ignition protection.

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

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

In the case of the Increased safety "eb" type of ignition protection, the ignition gas pressure must be monitored and prohibited surface temperatures prevented.

Increasing the safety "eb" type of ignition protection is fundamentally possible to resort to the non-explosion-protected standard motor, in the case of the inactive electrical parts. In the case of the active parts, the reduced permitted temperature rise and requirements regarding the partial discharges must be taken into account. The implementation of this type of ignition protection with a frequency-converter-operated drive is carried out at a later stage of this manual.

Type of ignition protection "ec" (old: "n") is based on the Increased safety "eb" type of ignition protection. Because of the lower probability of the presence of ignitable atmospheres in Zone 2, the requirements are, however, lower. The machine may thus be used at a higher temperature, for example, as there is no necessity for the "safety reduction" of 10 K related to the maximum permissible winding temperature according to the thermal class. In addition, there is no need to heed the "locked state" fault or monitor the start-up.

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

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

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

VEM Ex-Manual 2017

Figure 1.1: Distribution of the types of ignition protection with mains-operated drives
1.1 Summary of the legal principles for explosion protection

<table>
<thead>
<tr>
<th>Quality requirements</th>
<th>Operating requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>European Law</td>
<td>ATEX 114/2014/EU</td>
</tr>
<tr>
<td>Standards</td>
<td>IEC/EN 60079-0</td>
</tr>
</tbody>
</table>

### Equipment group

<table>
<thead>
<tr>
<th>Equipment group</th>
<th>Equipment category</th>
<th>Zone</th>
<th>EPL</th>
<th>Certification obligation</th>
</tr>
</thead>
<tbody>
<tr>
<td>for combustible gases, vapours and mist</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>1G</td>
<td>0</td>
<td>Ga</td>
<td>yes</td>
</tr>
<tr>
<td>II</td>
<td>2G</td>
<td>1</td>
<td>Gb</td>
<td>yes</td>
</tr>
<tr>
<td>II</td>
<td>3G</td>
<td>2</td>
<td>Gc</td>
<td>no</td>
</tr>
</tbody>
</table>

*not normal for electric motors

| for explosive dust atmosphere |
| II                            | 1D                 | 20   | Da  | yes                      |
| II                            | 2D                 | 21   | Db  | yes                      |
| II                            | 3D                 | 22   | Dc  | no                       |

### Zone

- Zone 0 comprises areas in which an explosive atmosphere, consisting of a mixture of air and gases, vapours or mist, exists constantly, long-term or frequently.
- Zone 1 comprises areas in which it is expected that an explosive atmosphere consisting of gases, vapours or mist occasionally occurs.
- Zone 2 comprises areas in which it is not expected that an explosive atmosphere consisting of gases, vapours or mist occurs but when it does occur it is in all probability only very rarely and for a short period.
- Zone 20 comprises areas in which an explosive atmosphere consisting of dust exists constantly, long-term or frequently.
- Zone 21 comprises areas in which it is expected that an explosive atmosphere consisting of dust occasionally occurs.
- Zone 22 comprises areas in which it is not expected that an explosive atmosphere consisting of dust occurs but when it does occur it is in all probability only very rarely and for a short period.

### Equipment group

- Equipment group acc. to Directive 2014/34/EU: II
- Equipment group acc. to EN 60079-0: IIIC (IIIA, IIIB, IIIC)
- Equipment category: 2D, 3D
- EPL acc. to EN 60079-0: Db, Dc
- IP protection rating: IP 65
- Type of protection: Housing temperature max. 125 °C

### Price

- Marking acc. to Directive 2014/34/EU: II 2D (alternative: II 3D)
- Marking acc. to EN 60079-0: Ex tb IIIC T125 °C Db

1.2 General requirements (gas and dust)

<table>
<thead>
<tr>
<th>Type of protection</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flameproof enclosure “db”</td>
<td>Ex “d”</td>
</tr>
<tr>
<td>Powder filling “q”</td>
<td>Ex “q”</td>
</tr>
<tr>
<td>Pressurized enclosure “p”</td>
<td>Ex “p”</td>
</tr>
<tr>
<td>Encapsulation “m”</td>
<td>Ex “m”</td>
</tr>
<tr>
<td>Oil immersion “o”</td>
<td>Ex “o”</td>
</tr>
<tr>
<td>Increased safety “eb”</td>
<td>Ex “eb”</td>
</tr>
<tr>
<td>Increased safety “ec”</td>
<td>Ex “ec”</td>
</tr>
<tr>
<td>Intrinsic safety “ia”</td>
<td>Ex “i”</td>
</tr>
</tbody>
</table>

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

- Type of dust: all Types
- Zone: 21
- EPL acc. to EN 60079-0: Db, Dc
- IP protection rating: IP 65
- Type of protection: Housing temperature max. 125 °C

Certificate:
- EU-type examination certificate
- Manufacturer’s EU Declaration of Conformity certificate
1.3 Explanation of the general requirements, the types of ignition protection and areas of application

1.3.1 General requirements (gas and dust)

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

– Operating instructions and coding
– Tests

Subdivision of Equipment Group II

Complying with IEC/EN 60079-0, because of their particular ignitability in Flameproof enclosure "db" and intrinsic safety "i" types of ignition protection, gases and vapours have been divided into three explosion groups, IIA, IIB and IIC. The danger increases between Explosion-Groups IIA and IIC. (The higher explosion group, e.g. IIC includes the lower ones, IIB and IIA).

From IEC/EN 60079-0, Coding II is replaced for all gas protection types by the specifications IIA, IIB and IIC (so now also: … Ex e IIC T3 or … Ex iIa IIC T3)
– IIA, typical gas is propane
– IIB, typical gas is ethylene
– IIC, typical gas is hydrogen

Temperature categories

<table>
<thead>
<tr>
<th>IEC/EN 60079-0</th>
<th>Explosion Groups IIA, IIB, IIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium’s ignition temperature at limit temperature</td>
<td>Permitted equipment surface temperature including 4 °C ambient temperature (limit temperature)</td>
</tr>
<tr>
<td>Over 40 °C</td>
<td>11</td>
</tr>
<tr>
<td>Over 300 – 400 °C</td>
<td>12</td>
</tr>
<tr>
<td>Over 350 – 300 °C</td>
<td>13</td>
</tr>
<tr>
<td>Over 135 – 200 °C</td>
<td>14</td>
</tr>
<tr>
<td>100 – 135 °C</td>
<td>15</td>
</tr>
<tr>
<td>65 – 100 °C</td>
<td>16</td>
</tr>
</tbody>
</table>

Electrical equipment in Group III is further subdivided according to the properties of the explosive atmosphere for which it is intended. The potential danger of dust increases with the operation of electrical equipment between IIA and IIC. Group IIC equipment includes suitability for groups IIA and IIB.

– IIA: combustible lint
– IIB: combustible, electrically non-conductive dust
– IIC: combustible, electrically conductive dust

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

– Gas explosion hazard areas, in which there is no danger of ignition in normal operation and with foreseeable or rare faults/malfunctions.

EPL Ga: Device with “very high” level of protection for use in combustible dust atmospheres in which there is no danger of ignition in normal operation or with foreseeable or rare errors/malfunctions.

EPL Db: Device with “high” level of protection for use in combustible dust atmospheres, in which there is no danger of ignition in normal operation or with foreseeable errors/malfunctions.

EPL Gc: Device with “extended” protection level for use in gas explosion hazard areas, in which there is no danger of ignition in normal operation or with some additional safety measures which ensure that there is no danger of ignition in the case of normal foreseeable faults in the device.

Dust explosion protection:

EPL Dc: Device with “very high” level of protection for use in combustible dust atmospheres, in which there is no danger of ignition in normal operation or with foreseeable or rare errors/malfunctions.

EPL Dd: Device with “high” level of protection for use in combustible dust atmospheres, in which there is no danger of ignition in normal operation or with more additional safety measures which guarantee that there is no danger of ignition with faults in the device that are normally to be expected.

Definition of protection principles

– Explosive mixtures can penetrate the equipment and ignite. The explosion is not transferred to the explosive atmosphere surrounding the equipment. (Ex d)
– The equipment has an enclosure which prevents the explosive mixture from penetrating and coming into contact with an ignition source. (Ex m, Ex o)
– Explosive mixtures can penetrate the equipment, but must not ignite in normal operation. Sparks and high temperatures above the ignition temperature of the gas concerned must be prevented. (Ex ia)
– Explosive mixtures can penetrate the equipment, but must not ignite even in case of a foreseeable fault. Sparks and high temperatures above the ignition temperature of the gas concerned must be prevented in normal operation and in the case of a foreseeable equipment fault. (Ex ia)
– Explosive mixtures can penetrate the equipment in critical amounts. The only decisive factor is thus compliance with the maximum temperature on the outer surface (Zones 21, 22: Ex t)

1.3.2 Types of ignition protection

1.3.2.1 Type of ignition protection – Flameproof enclosure “db”

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

Definition/protection principle:

Type of protection with which the components capable of igniting an explosive atmosphere are arranged inside a housing, which sustains the pressure inside when an explosive mixture explodes and prevents the explosion from being transferred to the explosive atmosphere surrounding the housing.

– Heeding the explosion group
– Pressure-resistant housing
– Conforming to the required gap widths and lengths
– Pressure-resistant housing
– Terminal box Flameproof enclosure “db”
– Temperature of outer surface must be lower than the ignition temperature of the surrounding gasses

– An explosion may occur in the interior. The housing must resist this explosion and no flames or potentially ignitable gasses must reach the outside through the gap

Tests:
– Reference pressure and resistance to pressure
– Drop test
– Leak test for gas sealed in place

Areas of application: Equipment Zones 1 and 2, Categories 2G and 3G (Ex, Gc)
1.3.2.2 Type of ignition protection – Increased safety “eb”

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

**Definition/protection principle:**
Type of ignition protection, in which additional measures are taken in order to prevent the possibility of the occurrence of prohibited high temperatures and the production of sparks or arcs in use according to specifications or in specified unusual conditions:
- Prevention of sparks and other ignition sources
- Housing at least IP 54, if bare live parts are present in the interior
- Housing at least IP 44, if all live parts in the interior are insulated
- Temperatures of the exterior and interior surfaces must be lower than the ignition temperature both in normal operation and in the event of a fault (locking the motor)
- Taking creepage distances and clearances into account
- Paying particular attention to the insulating materials and seals

**Tests:**
- Protective equipment (temperature monitor and/or overcurrent switch with 1/3 N t time characteristic curve) essential for the user
- Frequency-converter operation – see Chapter III

**Areas of application:**
- Equipment Zones 1 and 2
- Categories 2G and 3G (Gb, Gc)
- Temperatures of the exterior and interior surfaces must be lower than the ignition temperature both in normal operation and in the event of a fault (locking the motor)
- Taking creepage distances and clearances into account
- Paying particular attention to the insulating materials and seals

1.3.2.3 Type of ignition protection – Increased safety “ec”

**Design regulations:** IEC/EN 60079-7

**Definition/protection principle:**
Type of ignition protection for electrical equipment which it is possible to prevent the equipment from being in a position to ignite a surrounding explosive atmosphere in normal operation. The design guarantees minimisation of the risk of occurrence of arcs or sparks which can cause a danger of ignition during normal use.
- Prevention of sparks and other ignition sources
- Housing at least IP 54, if bare live parts are present in the interior
- Housing at least IP 44, if all live parts in the interior are insulated
- Taking creepage distances and clearances into account
- Paying particular attention to the insulating materials and seals

**Tests:**
- In normal operation, exterior and interior surface temperatures must be lower than the ignition temperature
- At rated voltages up to 1 kV and with a degree of protection of at least IP 44, it is permissible for the terminal box to open to the inside of the motor

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

1.3.2.4 Type of ignition protection – Pressurized enclosure “p”

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

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

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

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

1.3.2.5 Type of ignition protection – Powder filling “q”

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

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

1.3.2.6 Type of ignition protection – Oil immersion “o”

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

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

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

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

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

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

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

1.3.2.8 Type of ignition protection – Encapsulation “m”

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

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

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

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

**Other types of gas ignition protection not relevant to electric motors, without detailed consideration:**
1.4 Summary of types of ignition protection for dust-explosion protection

General requirements

<table>
<thead>
<tr>
<th>Protection by housing “tx”</th>
<th>Design regulations</th>
<th>Protection principle:</th>
</tr>
</thead>
<tbody>
<tr>
<td>tx IIIY T --- °C Dx</td>
<td>IEC/EN 60079-31</td>
<td>Dangerous housings are enclosed by the housing which is not liable to malfunction. Evidence of the maximum surface temperature according to category.</td>
</tr>
</tbody>
</table>

New: Pressure test with an overpressure as follows:

- 4 kPa with devices with “ta” level of protection
- 2 kPa with devices with “tb” or “tc” level of protection

Limitation of the 10 kPa for EPL Da short-circuit current for acceptance

Temperature limitation depending on EPL

Determining the surface temperature for EPL Da, with a layer of dust of at least 500 mm on all accessible surfaces.

<table>
<thead>
<tr>
<th>Group</th>
<th>Level of protection</th>
<th>Level of protection/housing</th>
</tr>
</thead>
<tbody>
<tr>
<td>II A</td>
<td>a</td>
<td>IP EX</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>IP EX</td>
</tr>
<tr>
<td></td>
<td>c</td>
<td>IP EX</td>
</tr>
<tr>
<td>II B</td>
<td>a</td>
<td>IP EX</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>IP EX</td>
</tr>
<tr>
<td></td>
<td>c</td>
<td>IP EX</td>
</tr>
<tr>
<td>II C</td>
<td>a</td>
<td>IP EX</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>IP EX</td>
</tr>
</tbody>
</table>

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

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

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

Protection principle:

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

Subdivision of groups:

- II A, combustible lints
- II B, non-conductive dust
- II C, conductive dust

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

Tests:

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

Areas of application:

Switchgears, transformers, complete equipment and cabinets

1.4.2 Type of ignition protection – Pressurized enclosure “pD”

Design regulations: EN 61241-4

IEC/EN 60079-2 (p IIIY Dx)

Definition/protection principle:

Type of ignition protection for electrical equipment with which penetration of the housing by a surrounding atmosphere is prevented by an ignition protection gas being held under overpressure (> 50 Pa) in its interior against the surrounding atmosphere. The overpressure is maintained with or without ignition gas mixing.

- Housing at least IP 4X
- Monitoring equipment
- Gas outlet
- Containment system

Tests:

- Pre-flush time
- Tightness
- Impact test

Areas of application:

Switchgears, transformers, complete equipment and cabinets

1.4.3 Type of ignition protection – Intrinsic safety “iD”

Design regulations:

IEC/EN 60079-11 (VDE 0170-7) (ix IIIY Dx)

Definition/protection principle:

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

- Separation distances
- 2/3 capacity
- Non-susceptance to faults

Tests:

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

Areas of application:

MCr equipment, sensor, mobile measuring equipment

1.4.4 Type of ignition protection – Encapsulation “mD”

Design regulations:

IEC/EN 60079-18 (VDE 0170/0171-9) (mx IIIY Dx)

Definition/protection principle:

Type of ignition protection, with which the parts are embedded in sealing compound in such a way that the explosive atmosphere cannot be ignited under operating and installation conditions.

- Minimum requirements of sealing compound (T1 value)
- Minimum sealing compound thickness (5 mm “ma” and 1 mm “mb”)
- Faults analysis in sealing compound
- Level of protection
- Clearances and cavities
- Rated values

Tests:

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

Areas of application:

Switchgears for low output, command and signalling devices, solenoids, ultrasound sensors

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

1.4.2 Type of ignition protection – Pressurized enclosure “pD”

Design regulations: EN 61241-4

IEC/EN 60079-2 (p IIIY Dx)

Definition/protection principle:

Type of ignition protection for electrical equipment with which penetration of the housing by a surrounding atmosphere is prevented by an ignition protection gas being held under overpressure (> 50 Pa) in its interior against the surrounding atmosphere. The overpressure is maintained with or without ignition gas mixing.

- Housing at least IP 4X
- Monitoring equipment
- Gas outlet
- Containment system

Tests:

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

Areas of application:

Switchgears, transformers, complete equipment and cabinets

1.4.3 Type of ignition protection – Intrinsic safety “iD”

Design regulations:

IEC/EN 60079-11 (VDE 0170-7) (ix IIIY Dx)

Definition/protection principle:

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

- Separation distances
- 2/3 capacity
- Non-susceptance to faults

Tests:

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

Areas of application:

MCr equipment, sensor, mobile measuring equipment

1.4.4 Type of ignition protection – Encapsulation “mD”

Design regulations:

IEC/EN 60079-18 (VDE 0170/0171-9) (mx IIIY Dx)

Definition/protection principle:

Type of ignition protection, with which the parts are embedded in sealing compound in such a way that the explosive atmosphere cannot be ignited under operating and installation conditions.

- Minimum requirements of sealing compound (T1 value)
- Minimum sealing compound thickness (5 mm “ma” and 1 mm “mb”)
- Faults analysis in sealing compound
- Level of protection
- Clearances and cavities
- Rated values

Tests:

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

Areas of application:

Switchgears for low output, command and signalling devices, solenoids, ultrasound sensors

General requirements

<table>
<thead>
<tr>
<th>Protective gas</th>
<th>Supply</th>
<th>Pressure monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protective gas</td>
<td>Supply</td>
<td>Pressure monitoring</td>
</tr>
</tbody>
</table>

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

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

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

Protection principle:

Dangerous housings are enclosed by the housing which is not liable to malfunction. Evidence of the maximum surface temperature according to category.

Minimum type of protection IP SX/IX (EN 60529)

New: Pressure test with an overpressure as follows:

- 4 kPa with devices with “ta” level of protection
- 2 kPa with devices with “tb” or “tc” level of protection

Limitation of the 10 kPa for EPL Da short-circuit current for acceptance

Temperature limitation depending on EPL

Determining the surface temperature for EPL Da, with a layer of dust of at least 500 mm on all accessible surfaces.

Subdivision of groups:

- II A, combustible lints
- II B, non-conductive dust
- II C, conductive dust

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

Tests:

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

Areas of application:

Switchgears, transformers, complete equipment and cabinets

1.4.2 Type of ignition protection – Pressurized enclosure “pD”

Design regulations: EN 61241-4

IEC/EN 60079-2 (p IIIY Dx)

Definition/protection principle:

Type of ignition protection for electrical equipment with which penetration of the housing by a surrounding atmosphere is prevented by an ignition protection gas being held under overpressure (> 50 Pa) in its interior against the surrounding atmosphere. The overpressure is maintained with or without ignition gas mixing.

- Housing at least IP 4X
- Monitoring equipment
- Gas outlet
- Containment system

Tests:

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

Areas of application:

Switchgears, transformers, complete equipment and cabinets

1.4.3 Type of ignition protection – Intrinsic safety “iD”

Design regulations:

IEC/EN 60079-11 (VDE 0170-7) (ix IIIY Dx)

Definition/protection principle:

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

- Separation distances
- 2/3 capacity
- Non-susceptance to faults

Tests:

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

Areas of application:

MCr equipment, sensor, mobile measuring equipment

1.4.4 Type of ignition protection – Encapsulation “mD”

Design regulations:

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Definition/protection principle:

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- Minimum requirements of sealing compound (T1 value)
- Minimum sealing compound thickness (5 mm “ma” and 1 mm “mb”)
- Faults analysis in sealing compound
- Level of protection
- Clearances and cavities
- Rated values

Tests:

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

Areas of application:

Switchgears for low output, command and signalling devices, solenoids, ultrasound sensors
1.5 Markings complying with different editions of the standard

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

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

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

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

Examples of rating plates:

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

The electrical equipment must bear a clearly legible mark with regard to the location of the marking: “The electrical equipment must bear a clearly legible mark on the outside of the housing of the main component and this mark must be legible before installation of the equipment.”

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

| Labeling complying with directive 2014/34/EU | Old designations (no longer valid) | Designation acc. to EN 50281-1-1 (no longer valid) | Designation acc. to EN 50281-1-1 (no longer valid) | Future designation acc. to EN 61241-1-1
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>EU No. NB</td>
<td>Category/Group</td>
<td>Designation acc. to EN 50281-1-1</td>
<td>Designation acc. to EN 50281-1-1</td>
<td>Future designation acc. to EN 50281-1-1</td>
</tr>
<tr>
<td>0102</td>
<td>2 G 4 G</td>
<td>EN 50281-1-1</td>
<td>EN 50281-1-1</td>
<td>EN 50281-1-1</td>
</tr>
<tr>
<td>0102</td>
<td>3 G 6 G</td>
<td>EN 50281-1-1</td>
<td>EN 50281-1-1</td>
<td>EN 50281-1-1</td>
</tr>
<tr>
<td>0102</td>
<td>8 G 10 G</td>
<td>EN 50281-1-1</td>
<td>EN 50281-1-1</td>
<td>EN 50281-1-1</td>
</tr>
</tbody>
</table>

Examples of marking categories and additional details for types of explosion protection marking:

**Gas**

1. **Zone 1 (gas):** Total surface including rotors and windings; the nB ID number for quality assurance in accordance with directive 2014/34/EU must be quoted as the ID number. This is not always the same as the EU type-examination certificate.

2. **Zone 2 (gas):** Total surface including rotors and windings; the nB ID number for quality assurance in accordance with directive 2014/34/EU must be quoted as the ID number. This is not always the same as the EU type-examination certificate.

**Dust**

1. **Zone 1 (dust):** IP 55 T 125 °C
2. **Zone 2 (dust):** IP 55 T 125 °C

[Image of rating plates]

**Examples of labeling compliant with different editions of the standard**

<table>
<thead>
<tr>
<th>Motor for use in Zone 22</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor with double marking for use in Zones 2 and 22</td>
</tr>
<tr>
<td>Motor for use in Zones 1 and 21</td>
</tr>
</tbody>
</table>

[Image of additional marking]

**Corresponding additional rating plate without Ex marking**

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

The electrical equipment must bear a clearly legible mark with regard to the location of the marking: “The electrical equipment must bear a clearly legible mark on the outside of the housing of the main component and this mark must be legible before installation of the equipment.”

This means that the component of a machine/plant which bears explosion protection marking is considered the main component of the ATEX-certified equipment. It is consequently not permissible to supply a second rating plate with explosion protection marking and parameters for attachment at some other location separate from the motor. As an alternative, for example where the main motor rating plate is not clearly legible after installation, it is possible to provide a second or additional motor information plate without explosion protection marking (see examples below, with specification of the motor number and all electrical parameters).
1.6 Electric motors – Mechanical structure and main focuses of design for conformity with explosion protection

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

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

**Material couplings:**
Avoiding formation of abrasion and impact sparks

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

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

**Impact test:**
Guaranteeing adequate protection against mechanical damage

**Fan test:**
Testing the fan’s mechanical stability

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

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

### Technical explanation

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

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

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

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

### Table 3 – Limit temperatures for insulated winding

<table>
<thead>
<tr>
<th>Temperature measurement procedure (see note 1)</th>
<th>115 (A)</th>
<th>120 (B)</th>
<th>130 (C)</th>
<th>155 (F)</th>
<th>180 (H)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Limit temperature at rated operation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Single-layer insulated windings</td>
<td>Resistance or temperature</td>
<td>90</td>
<td>110</td>
<td>120</td>
<td>130</td>
</tr>
<tr>
<td>b) Other insulated windings</td>
<td>Resistance temperature</td>
<td>90</td>
<td>105</td>
<td>110</td>
<td>130</td>
</tr>
<tr>
<td>2 Limit temperature at end of tE time (see note 3)</td>
<td>Resistance</td>
<td>180</td>
<td>175</td>
<td>185</td>
<td>210</td>
</tr>
</tbody>
</table>

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

**Note 2:** It is accepted as a provisional measurement until values have been established that the thermal resistances designated in figures in IEC 60085 are regarded as applicable to the limit temperatures specified in Category 180 (H).

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

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

The electrothermal test comprises the following items:
- Determining/verifying the machine’s measurement data
- Determining the continuous duty temperature rise

During the performance of the temperature rise measurement, the DUT is given the prescribed mechanical load and the electrical power input, the mechanical force delivered, and current, voltage, speed and torque are measured and automatically logged during the experiment. The measurement may be terminated if the temperatures measured during operation on the housing change by less than 2 K per hour (thermal equilibrium complying with IEC/EN 60034). The stator winding temperature is calculated by the temperature-dependent resistance change from a winding resistance measurement before the experiment, in the case of a current interruption, as example, figure 1.2 shows the temperature characteristic during a temperature rise test on the core.

The measurement is terminated when a “thermal equilibrium” is reached, i.e. temperature rise less than 2 K/h. To evaluate the measurement taking into account the limit temperatures of the elastomers used, the highest temperature occurring after the motor is switched off must be taken into account for each such measurement point (e. g. seal).

Temperature measurement

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

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

Inspecting the machine protection/determining the \( t_e \) time and the starting rated current relation

This fault may, for example, occur if a machine is locked. Characteristic of this is the machine current reaching a multiple of the measured current (e. g., seven times) and the machine heating up intensely within the shortest possible period of time. Without motor protection, the permitted limit temperatures would have been exceeded within a few seconds. For that reason, the machine must be protected by a time-controlled overcurrent protection device (motor protection switch) or PTC thermistor located in the winding, against prohibited temperature rises as a result of overload. For measuring the temperature rise in the machine while the brake is fully applied, the rotor is prepared with thermocouples at intervals along its length and the locked motor switched on for a specified time, for example, 15 s. The rotor’s temperature characteristics are shown by a thermograph and the stator’s winding temperature is determined by the increased winding resistance after shutdown. The locking attempt is carried out with both phase sequences, whereby measurable differences in the temperature rise are produced with bevelled rotor bars in the rotor. The rotating field with the highest rises in temperature is used for the rest of the evaluation.

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

Time \( t_e \)

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

In order to determine this, the continuous duty temperature rise and the temperature rise speed are required for stator and rotor in the locked state. On the basis of the continuous operating temperature and the maximum permitted temperatures for rotor and stator, the maximum permitted temperature increase is determined in the locked state and the maximum duration for the locked state is calculated by the temperature rise speed, for both rotating field directions. The smaller of the two numerical values produces the \( t_e \) time minus a safety deduction of at least 5%. If the machine is protected by a device for direct temperature monitoring, e. g. PTC thermistor, with the machine locked it must be proved, by means of an overload attempt and shutdown attempt, that no prohibited temperatures occur, also in the case of a fault. The \( t_e \) time is then part of the EU type-examination certificate instead of the \( t_e \) time and the \( L_{210/3} \) is not specified. The maximum permitted temperature rises are given in the standards IEC/EN 60079-0 (temperature categories) and IEC/EN 60034 (winding insulation thermal classes).
1.7 High-voltage tests on windings under gas

These tests are necessary, if the following criteria apply:
- The machine is a high-voltage machine rated voltage > 1 kV.
- An ignition danger assessment complying with EN 60079-7 Table 5.1 has produced an ignition danger factor > 6.

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

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

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated voltage</td>
<td>&gt; 5.5 kV to 11 kV</td>
<td>4</td>
</tr>
<tr>
<td>&gt; 10 kV to 33 kV</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Average start frequency in operation</td>
<td>&gt; 1/week</td>
<td>5</td>
</tr>
<tr>
<td>Internal between detailed inspections (see IEC 60079-7, Table 1, Type DI)</td>
<td>&gt; 5 to 10 years</td>
<td>2</td>
</tr>
<tr>
<td>&lt; 2 years</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Type of protection (IP code)</td>
<td>IP 44 and IP 54</td>
<td>2</td>
</tr>
<tr>
<td>IP 55</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>&gt; IP 56</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Environmental conditions</td>
<td>Very dry and damp*1</td>
<td>4</td>
</tr>
<tr>
<td>Open-air coastal area</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Outdoor open-air areas</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Overhead, dry interior</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

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

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

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

1.8 Installation and electrical connection

The safety instructions supplied with the motor must be heeded for assembly and commissioning.

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

The specialist personnel must be able to assess the tasks assigned to them and recognise and prevent possible dangers. It must be given the authority by the person responsible for the machine’s safety to perform the required tasks and activities. In Germany, installing electrical machines in explosion hazard areas requires compliance with the following regulations:
- BGIeV “Operating Safety Directive”
- TRBS “Technical Regulations for Operating Safety”
- IEC/EN 60079-7 “Explosive atmospheres”

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

Connection cables must be selected to comply with DIN VDE 0100, taking into account the rated current and machine-specific regulations (e.g. ambient temperature, type of cable-laying etc., complying with DIN VDE 0298 or IEC/EN 60332-1).

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

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

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

Safety measures against prohibited temperature rises

If no conflicting information regarding mode of operation and tolerances is provided in the test certificate or on the nameplate, electrical machines are designed for continuous duty (Mode of operation S1) and standard starting behav-
VEM Ex-Manual 2017

Technical explanation

1.9 Electrostatic hazards

1.9.1 Introduction

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

The following describes how such ignition risks can be recognised and brought under control. To this end, various longstanding and proven standards and regulations exist. In many countries, the individual regulations differ only in certain nuances. If the stipulations of these standards and regulations are observed, this triggers a “presumption of conformity”, i.e. the device or machine is presumed to be safe. If in doubt, consult the manufacturer.

The most important sections relating to electrical equipment are Chapter 14 in Amendment 1 and the process flowchart for electrostatic testing in the annex to IEC 60079-32-1 (Figure 1.8). Detailed instructions on the test parameters and required parameters are found in IEC 60079-32-2.

IEC/EN 60079-0

A whole chapter of this standard is devoted to electrostatic hazards. It must be noted, however, that these requirements have been copied more or less verbatim from earlier regulations dealing with electrostatic hazards and have not been written specifically by electrostatic experts. There is thus corresponding scope for ambiguities and misunderstandings.

For example, the standard demands that surfaces should be cleaned with a fluid before measuring the surface resistance. Typical fluid residues, however, may significantly affect such measurements. For these and many similar reasons, it is recommended to perform testing in accordance with IEC 60079-0-1 Amendment 1, figure 14, using the test method described by IEC 60079-32-2. In this way, such measuring errors will be avoided for the most part. The surface of a test object, for example, is cleaned only with a brush. Otherwise, both cases (1 and 2) produce exactly the same result.

The aforementioned weaknesses of IEC 60079-0 are known to the experts who perform testing and are usually taken into account. Special verification of the measured values is obtained in accordance with -0 only if necessary.

TRQS 727:2016

The technical regulations TRQS 727:2016, formerly TRBS 2153:2009, and before that BGR 132:1993, are the German language source for regulatory information on the prevention of electrostatic charging. They constitute the latest regulations relating to electrostatic hazards, and were formerly the regulations which were copied into European and international standards. Even very recently, it was assumed that the latest knowledge published here will be incorporated into international standards. TRQS 727, however, addresses the whole of industry and the entirety of everyday processes (e.g. fuelling of motor vehicles). For an outsider, it is often too difficult to find the relevant chapter; there is no chapter which deals specifically with electrical equipment.

An electrostatic charge due to separation processes (e.g. manual handling, skin friction) or electrical friction between charged objects requires a test according to EN 60664-1. The standard is based on the concentration of charges on the test object, for example, is cleaned only with a brush. Otherwise, both cases (1 and 2) produce exactly the same result.

The aforementioned weaknesses of IEC 60079-0 are known to the experts who perform testing and are usually taken into account. Special verification of the measured values is obtained in accordance with -0 only if necessary.

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

1. Is the test object exposed to manual friction, e.g. contact with work clothing or cleaning with a cloth? Or exposed to streams of liquids or dusts? Or is it located in the proximity of high-voltage electrodes?
Yes, the test object is subject to manual friction from work clothing, for example. Continue with 2.

2. Does the test object have any conductive/dissipative parts with an impermissibly high electrical capacitance?
Yes, there is a screw terminal which is open to possible external contact. The capacitance measured according to IEC 60079-32-2, however, is only 2.5 pF. This capacitance is below the limit value for Zone 1 group IIC (less than or equal to 3 pF). Continue with 3.

3. Does the surface resistance of the test object, measured in accordance with IEC 60079-32-2, exceed the permissible limit value of 100 gigaohms, measured at a maximum of 30% relative humidity with a measuring voltage of at least 500 V better at 1000 V?
Yes, continue with 4.

4. Does the maximum projected surface area of the test object which is open to friction exceed the specified maximum area (in our example max. 2000 mm² for Zone I group IIC)?
Yes, the value is clearly exceeded. Continue with 5.

5. Has the interior of the housing been provided with a conductive coating?
No, the interior of the housing has no conductive coating. Continue with 6.

6. Is the maximum possible charge which is transferred by a provoked discharge, measured according to the method defined by IEC 60079-32-2, less than or equal to 10 nC?
No, discharge whatever, and thus no electrostatic charging, was observed during the electrostatic testing. The housing is thus sufficiently antistatic and complies with the stipulations of all standards and regulations mentioned in chapter 1.9.2. Alternatively, with a measuring voltage of 10,000 V, it would already have been possible to determine at Step 3 that the surface resistance breaks down at higher voltages and that the test object thus cannot acquire a hazardous electrostatic charge under the high electrostatic voltages present.

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

1.9.4 Further notes
One problem which is frequently faced is: How can a test object which is not accessible in a normal test be handled?

4. Use of liquid coatings/paints on a conductive primer or base (primers for electrostatic painting are typically conductive). Compared to powder coatings, liquids have a significantly lower flash-off and breakdown strength in order to avoid electrostatic charging, thus they are at the same time less effective as corrosion inhibitors.

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

- Directive 2014/34/EU:
Directive 94/9/ECE states the following regarding devices in Category 2, which include electrostatic machines operated in Zone 1: “Category 2 comprises devices which are designed in such a way that they can be treated in accordance with the manufacturer-specified parameters and guarantee a high degree of safety”. It is further stated as follows: “The machine-based explosion protection measures in this category guarantee the required degree of safety even in the case of frequent equipment failures or errors which are normally to be expected.” From this we can conclude that all equipment in Category 2 must become an ignition source when the case of faults and faults which are frequent or to be expected. Furthermore, it is stated in article 1, paragraph 2: “Safety, control and regulation devices for use outside of explosion risk areas which, however, are essential for safe operation of equipment and protection systems or contribute to them, are also included in the area of application of this directive.”

The terms of the directive require that all motors in Category 2 must be protected against inhibited temperature rises and that all equipment and devices for motors which must be certified.

- ATEX guidelines:
The ATEX guide specifies the Directive’s requirements of the guideline and is itself produced by the Commission’s Standing Committee as a guideline. It is stated in chapter 3.10: “Safety, control and regulation devices are subject to the directive, if they contribute to or are necessary for the safe operation of equipment or protection systems, in terms of ignition dangers or the danger of an uncontrollable combustion. It is stated below: “These devices also come under if they are to be used intended outside of explosion risk areas. These devices are not allocated to categories complying with article 1.” It is also stated as follows: “The fundamental requirements apply to these devices only to the extent that they are necessary for the safety, reliable mode of operation and handling of this device, with regard to dangers of ignition or the danger of an uncontrollable explosion.” The following example is given: Overload protection devices for electrical motors of the increased safety “eb” type of protection must be effective even when the motor is locked.

- IEC/EN 60079-7
The following statement is made on the tE time in chapter 5.2.4.1.4.1 of the requirements of increased safety “eb” type of ignition protection: “The tE time must be long enough for the current-dependent safety device to switch off the locked motor.” The following statement is made: “The motor current monitored but also that the motor, with brake on current, be designed in such a way that not only is the expected frequency or generators which are continually capable of being operated in accordance with the manufacturer’s specifications, but also that the tE time specified is always longer than the time specified in the nameplate. It is also stated regarding delta-connected machines: “For this reason, phase failure protection must be provided for motors with delta-connected wiring, protection which recognises machine imbalances before they cause excessive temperature rises.”

In summary it is recommended that all electrical machines in explosion hazard areas are protected against overload, short-circuit and phase failure and that the protection for the Increased safety “eb” type of ignition protection must be effective even when the motor is locked.

- IEC/EN 60079-7

The following statement is made on the tE time in chapter 5.2.4.1.4.1 of the requirements of increased safety “eb” type of ignition protection: “The tE time must be long enough for the current-dependent safety device to switch off the locked motor.” The following statement is made: “The motor current monitored but also that the motor, with brake on current, be designed in such a way that not only is the expected frequency or generators which are continually capable of being operated in accordance with the manufacturer’s specifications, but also that the tE time specified is always longer than the time specified in the nameplate. It is also stated regarding delta-connected machines: “For this reason, phase failure protection must be provided for motors with delta-connected wiring, protection which recognises machine imbalances before they cause excessive temperature rises.”

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- IEC/EN 60079-7
Because of the decreased voltage for the main in-
2.3.2 Type of ignition protection – Pressurized enclosure “p”

This type of ignition protection may be considered in the same way as the Flameproof enclosure. In this case also, only the external side of the motor’s interior but not must come into contact with any ignition sources. For that reason, special requirements are set of the motor protection in accordance with IEC/EN 60079-14, in order not to reach any prohibited stator or rotor temperatures at rated voltage, even in the case of locking. The direct temperature monitoring or a time-dependent overload trip may be used as protection principles.

2.3.3 Type of ignition protection – Increased safety “eb”

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

2.3.4 Type of ignition protection – “ec” (old: “in”)

For this type of ignition protection, the machine only has to maintain the temperature category in “normal operating conditions”, in accordance with IEC/EN 60079-15. It is stated explicitly in the standard that the case of locking does not have to be considered for operating modes S1 and S2. Overloading is not mentioned. In the case of

2.3.5 Type of ignition protection – “t”, dust explosion protection

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

2.3.6 Direct temperature monitoring

In the case of direct temperature monitoring as sole protection, PTC thermistors are embedded in all three of the windings head’s three winding phases and impregnated along with the winding. This guarantees a strong thermal contact between winding and PTC thermistor, which is extremely important for the effectiveness of the protection principle. The individual PTC thermistors are connected in series and linked to a PTC thermistor tripping device, usually fitted outside the explosion hazard area, during motor installation. If the PTC thermistors are heated up past the nominal response temperature (e.g. 150°C), the resistance increases steeply and is registered by the evaluation unit. When the nominal switch-off temperature is reached, the motor is switched off. The unit must also detect resistance which is too low and beneath the PTC thermistor’s “window of resistance”. The reason for this may be a short circuit in the PTC thermistor’s connecting wiring, which stops protection from being guaranteed. Protection by direct temperature monitor restricts the winding temperature to a fixed value.

2.3.7 Current-dependent, time-delayed safety equipment

Motor protection via current monitoring is based on the operating core of the motor protection relay representing a simplified thermal model of the machine. If a short circuit occurs, occurring in the case of a prohibited temperature rise registered by this thermal model, in addition, the motor protection switches contain another comparator for short-circuit protection. The simplest design of motor protection device is a motor protection switch with thermorelay. Here the

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

1.05. in the case of current multiplied by 1.2 it must respond within 2 h. The following consideration clarifies the motor’s thermal behaviour:

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

\[ P_v = \frac{1}{1 + c} \]

\[ c = 1 - R \]

\[ P_v = \frac{P}{1 + c} \]

\[ P_v = P - (1 - e^{-t/\theta}) \]

All follows from this equation that the rise in temperature, e.g. after the overload has occurred in accordance with an e-function, approximates the new “steady state temperature”

\[ \theta \]

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

In the design of the PTC thermistor for sole protection, care must, however, be taken to ensure that the rotor as well as the stator must be protected from prohibited temperatures “Increased safety “eb” type of ignition protection and type of ignition protection for the environment, R, the heat transfer resistance for the environment and c the machine’s heat capacity. This is a challenge for rotor-critical machines in particular and many machine designs do not permit sole protection via PTC thermistor.

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

2.3.8.1 Motor protection: thermal protection

Motor protection via current monitoring is based on the operating core of the motor protection relay representing a simplified thermal model of the machine. If a short circuit occurs, occurring in the case of a prohibited temperature rise registered by this thermal model, in addition, the motor protection switches contain another comparator for short-circuit protection. The simplest design of motor protection device is a motor protection switch with thermorelay. Here the

&. The extended circuit of figure 2.3: Definition of \( t_e \) time

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

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

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

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

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

\[ \Delta I \frac{dt}{dt} \]

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

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

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

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

<table>
<thead>
<tr>
<th>Temperature category</th>
<th>T3</th>
<th>T4</th>
<th>T5</th>
<th>T6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. shaft temperature</td>
<td>100 °C</td>
<td>100 °C</td>
<td>85 °C</td>
<td>70 °C</td>
</tr>
<tr>
<td>Max. flange temperature</td>
<td>100 °C</td>
<td>100 °C</td>
<td>85 °C</td>
<td>70 °C</td>
</tr>
</tbody>
</table>

2.4 The motor in combination with other equipment

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

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

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

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

2.4.1 Recommended maximum interface temperatures for flange motors

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

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

<table>
<thead>
<tr>
<th>Temperature category</th>
<th>T3</th>
<th>T4</th>
<th>T5</th>
<th>T6</th>
</tr>
</thead>
<tbody>
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<td>Max. shaft temperature</td>
<td>100 °C</td>
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<td>70 °C</td>
</tr>
<tr>
<td>Max. flange temperature</td>
<td>100 °C</td>
<td>100 °C</td>
<td>85 °C</td>
<td>70 °C</td>
</tr>
</tbody>
</table>

General conditions:
- Maximum permissible temperatures on shaft end and motor flange
- No converter mode
- Self-ventilated
- Size from 63 to 200, motors in accordance with EN 50034
- Applies to ambient temperatures from -20 °C to +40 °C
- 2 and 4 pole motors

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

<table>
<thead>
<tr>
<th>Temperature category</th>
<th>T3</th>
<th>T4</th>
<th>T5</th>
<th>T6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. shaft temperature</td>
<td>100 °C</td>
<td>100 °C</td>
<td>- °C</td>
<td>- °C</td>
</tr>
<tr>
<td>Max. flange temperature</td>
<td>100 °C</td>
<td>100 °C</td>
<td>- °C</td>
<td>- °C</td>
</tr>
</tbody>
</table>

* still under discussion

General conditions:
- Maximum permissible temperatures on shaft end and motor flange
- Adjustment range from 10 Hz to 100 Hz
- Self-ventilated
- Size from 63 to 200, motors in accordance with EN 50034
- Applies to ambient temperatures from -20 °C to +40 °C
- 2 and 4 pole motors
- Individual test necessary
2.4.1.3 Machines of type of ignition protection – Increased safety “eb”,
temperature category T3

<table>
<thead>
<tr>
<th>Pole number</th>
<th>2-pole</th>
<th>4-pole</th>
</tr>
</thead>
<tbody>
<tr>
<td>max. shaft temperature</td>
<td>80 °C</td>
<td>75 °C</td>
</tr>
<tr>
<td>max. flange temperature</td>
<td>80 °C</td>
<td>75 °C</td>
</tr>
</tbody>
</table>

General conditions:
- Maximum permissible temperatures on shaft end and motor flange
- No converter mode
- Self-ventilated

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

In the case of Flameproof enclosure “d” and Pressurized enclosure “p”, the explosion protection principle is based on the fact that either an explosion occurring in the housing interior is not transferred to the surrounding atmosphere (Flameproof enclosure “d” type of ignition protection) or else the explosive atmosphere cannot penetrate the housing interior during operation (Pressurized enclosure “p” type of ignition protection). With these types of ignition protection, the temperature of the exterior surfaces, which must not exceed the temperature category’s limit temperature, is decisive for the prevention of an explosive atmosphere igniting, whereby the explosive atmosphere can also penetrate the equipment’s interior. With an asynchronous motor, the possible ignition sources are hot surfaces, mechanically-produced abrasion and impact sparks and electrical discharges. In order to eliminate these, increased requirements of the mechanical structure and design of the electrical insulation system, as well as protection from prohibited high temperatures, are necessary in the case of explosion-protected motors. With frequency converter operated machines, there are additional dangers of ignition due to “Electrical Discharges” and “Hot Surfaces” ignition sources compared with mains operation, ignition dangers which must be taken into consideration for the machine’s design and for certification.

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

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

3.1 Electrical discharges

Caused by the power transistors’ fast switching operations and thus high voltage increase speeds, travelling wave processes form on the motor wiring, whereby the motor’s and converter input’s impedances, effective for the high-frequency processes, differ from the wiring’s wave impedance. $Z_{wiring}$ > $Z_{motor}$ generally applies, so that a reflection factor of approximately 1 is produced for the voltage wave running in the direction of the motor and the wave is reflected. In the case of electrically long wires compared to the frequency of these travelling wave processes, transient voltage peaks occur as far as the double intermediate circuit voltage on the motor terminals (Figure 3.1). The clearances in the machine’s terminal box would have to be sized to the transient overvoltages, whereas the creepage distances in accordance with IEC/EN 60799-7 must be designed only for the converter output voltage’s rMS value. In accordance with EC/EN 60799-7, short-term voltage peaks do not result in the formation of erosions caused by leakage currents on the surface.

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

It is also very important, however, for the winding insulation to be designed for these high, steep-flank voltage pulses. The winding insulation in the winding input zone is also severely stressed, as a major proportion of the voltage is transferred to the environment depending on speed.

3.2 Hot surfaces

If an electrical machine takes on a prohibited temperature, the reasons are either an excessive heat loss inside the machine, for example, as a result of overload, or insufficient cooling. Reason for a prohibited overload, especially in the machine’s rotor, may also be operation beyond the motor’s permitted operating parameter limits. In the design of the converter in accordance with the specifications of the EU type-examination certificate for the motor, the “locked-motor” fault does not have to be considered. For that reason, the temperature reserve maintained for it may be distinctly reduced. On the other hand, a very important point is the increase in the thermal resistance to the environment with a reduction in speed in the case of self-ventilated machines. In Figure 3.2, this relation is applied to two machines of sizes 180 and 132.

![Figure 3.1: Development of transient overvoltages on a frequency-converter operated drive](image)

![Figure 3.2: Characteristics of thermal resistance to the environment depending on speed](image)
This effect is considered in the new testing and certification concept for frequency converter operated drives, of the increased safety “eH” type of ignition protection, by a variable speed current limit in the frequency converter. In figure 3.3, the maximum machine current related to the rated current of a machine of size 132 is shown as an example. All the operating points below the curve are permanently permissible but those above the line are only permissible for a limited time, which is calculated in dependence on the overload. With a machine current greater than the 1.5-times rated current, an immediate shutdown occurs.

The nodes in the curves have been detected by measurements in the PTB. In addition to this protection by means of frequency-dependent current monitor, a second protective device is required, certified as a monitoring device in accordance with Directive 2014/34/EU, as the frequency converter is not certified and that is also not desired by the manufacturers. This protective device amounts in most cases to a direct temperature monitoring via triple PTC thermistor with fault indication, from the EC type-examination certificate. If these specifications are observed, the harmonic losses are slight compared with the fundamental mode losses (below 10%) and do not result in prohibited temperature rises.

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

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

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

3.3 Harmonic losses

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

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

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

3.4 Increase in energy efficiency

This new approach will also contribute to an increase in the proportion of frequency converter operator drives in the chemical industry, as a result of which extremely high energy-saving potential is produced, particularly in the case of the drive for fluid flow machines. The result of a comparison of the energy efficiency of the flow rate adjustment by bypass or reducing valve and the pump’s direct speed adjustment by means of frequency converter is shown in Figure 3.4. The general conditions adopted were the pump’s rated output of 50 m³/h at a pressure of 7 bar. A flow rate of 30 m³/h required by the process was applied for the consideration in Figure 3.4. At assumed 5,000 part load annual operating hours and a motor rated output of 18 kW, the amortisation period for the frequency converter is often less than one year, at today’s energy prices.

Figure 3.6: From electrical to hydraulic power
All in all, the energy-saving compared to the flow rate adjustment by means of valves with increasing pump throttling, i.e. reduced flow rate, increases. If the pump is operated in the unthrottled state, the other hand, insignificantly higher losses compared to direct mains operation are produced because of the converter’s losses and the motor’s harmonic losses.

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

For the assessments carried out in this case, the three load profiles shown in Figure 3.8 were adopted. In that case a pump period of use of 5000 hours in total within one year was assumed. The bars show the time proportion of the hydraulic capacities (50, 30, 10, 5 m³/h) with the rated flow rate amounting to 50 m³/h.

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

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

3.5 Summary and outlook

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

A motor protection device for converter operated drives is currently being developed in collaboration with a certain company. When the device is in use, frequency converters without variable speed current limitation can also be used and the PTC thermistor is also no longer necessarily required. Figure 3.10 shows the protective device’s possible use.
3.6 Operation on frequency converter with use in Zone 2 (Ex II 3G) or Zone 22 (Ex II 3D)

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

It is necessary to ensure that the operating voltage at the motor terminals complies with the specifications on the nameplate. Thermal winding protection must be assessed either by a separate tripping device or by the converter.

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

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

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

It is mandatory that motors of the Increased safety “eb” type of ignition protection for use in Zone 1 are certified by a notified body for operation on the frequency converter. It is essential that the limit values specified on the nameplate and on the EU type-examination certificate are observed. This means monitoring the continuous current depending on the frequency. Operation converters which meet the requirements stated in the EU type-examination certificate may be used. The thermal winding protection installed must be evaluated by a tripping unit meeting the requirements of Directive 2014/34/EU, using the Ex labelling II (2) G.

3.9 Permanent-magnet synchronous machines/reluctance machines

Synchronous machines as such have been known since the beginnings of electrical drive engineering as a machine type which is used for high-power motors in the form of an externally excited synchronous motor. All high-power generators in thermal power stations and hydropower stations are likewise based on this function principle. The normative demands placed on this machine type are described in the standard IEC/En 60034-1.

In a permanent-magnet synchronous machine, the DC rotor winding required to excite the magnetic field is replaced with permanent magnets. In the field of positioning drives (e.g., robot arms in the automotive industry), permanent-magnet synchronous machines have already represented the state of the art for several years.

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

The current harmonised standards IEC/EN 60079-7 and IEC/EN 60079-0 do not address the special requirements of these machines in respect of increased safety – type of ignition protection “eb”. At IEC level, too, no normative specifications exist with regard to the testing of permanent-magnet synchronous machines. Explosion-protected permanent-magnet synchronous machines and their testing are the subject of a current PTB research project.
4 The VEM product range of explosion-protected equipment

4.1 Overview

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

Explosion-protected three-phase asynchronous motors with squirrel-cage rotor for low voltage – Increased safety “eb” type of ignition protection Ex e II complying with IEC/EN 60079-0 / IEC/EN 60079-7
Flameproof enclosure “db/db eb”
Ex d/e complying with IEC/EN 60079-0 / IEC/EN 60079-1
Increased safety “ec” (old: “n”) type of ignition protection complying with IEC/EN 60079-0 / IEC/EN 60079-7 (old: IEC/EN 60079-15)
Motors for use in areas with combustible dust (II 2D, II 3D complying with 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 are tested and certified by the following bodies:

- Physikalisch-Technische Bundesanstalt Braunschweig (Notified body no. 102), now DEKRA EXAM GmbH.
- BIEU Freiberg (Notified body No. 0637) or
- DMT Gesellschaft für Forschung und Prüfung mbH (Notified body no. 0158), now DEKRA EXAM GmbH.

These test certificates are recognised by all European Union member states. The members of CENELEC who do not belong to the EU also accept them. In the case of special requirements in Germany by the DIN 42673 and DIN 42677 standards. The active materials in the increased safety “eb” series will be the same as those in the standard IIEx series in the future. This produces the basic prerequisites for observing the new degree of efficiency categories. Motors of the series K1.R 112-355 could already be supplied for efficiency class IE1 when the stipulations of IEC/EN 60034-30 came into force. In the meantime, motors for efficiency classes IE2 and IE3 are available as the series IE2-K11R... / IE2-K14R... / IE2-KPR/KPER... Exe IIC T3 and IE3-K11R... / IE3-K4... / IE3-KPR/KPER... Exe IIC T3.

4.2 Energy efficiency and explosion protection

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

Motors for operation in explosive atmospheres (IEC/EN 60079) are also addressed by the efficiency classifications defined in IEC/EN 60034-30-1 (IE.../IE3). This includes all types of ignition protection relevant to electrical equipment, such as Flameproof enclosure “db”, Increased safety “eb”, Increased safety “ec” (old: “n”) and Protection by housing “tb” and “tc”. It is to be noted that no minimum degrees of efficiency are applicable to such equipment under Regulation (EC) No. 640/2009 and Regulation (EU) No. 4/2014, but energy efficiency is nevertheless also a topic in this product segment, not least due to the demands of the chemical industry. From the design point of view, motors for the Ex d/e, Ex ec and dust explosion protection types are not complicated. There is no separate size/output allocation compared with the standard motors, the electrical design is identical. That means that EN 50347 can be applied in full to these motors. With these types of ignition protection, the explosion protection concentrates primarily on special design measures such as the use of certified components, special connection systems, increased clearance and creepage distances, questions of electrostatic charges with fans, compliance with certain minimum degrees of IP protection and questions of materials (especially ageing and the temperature resistance of seals). The temperature limitation measures at the surfaces of the motors and in the interiors also do not contradict high degrees of efficiency. For this reason, it has already previously been possible to find motors with enhanced degrees of efficiency in the market for these types of ignition protection.

VEM motors from the WE.R energy-saving series with types of ignition protection increased safety “ec” (old: “n”) and Protection by housing “tb” and “tc” have been available for a long time. These motors can be supplied as IEC/EN 60034-2:1 and with efficiency classes IE2 and IE3. Motors of Flameproof enclosure “db” in series K1.BR can also be supplied in classes IE2 (K1.BR...Y2) and IE3 (K1.BR...Y3).

The situation is different for the increased safety “eb” type of ignition protection. Here we have temperature limitation in the case of error, in addition to the measures already mentioned. That means special requirements of the starting current and a guarantee of tE times that are as long as possible. Further to that, the size/output allocation is
4.3.2 Motors with squirrel-cage rotor, type of ignition protection – Increased safety “eb”

**Type**
- KPR/KPER/E1-KPR/KPER/E2-KPR/KPER

**Size**
- 56 – 355

**Types of protection**
- IP 54, IP 55 and IP 65 complying with IEC/EN 60034-5

**Cooling type**
- IC 411 complying with EN 60034-6

**Designs**
- IM B3, IM B35, IM B5, IM B14, IM B34 and derived designs complying with IEC/EN 60034-7

For assembling motors in designs with vertical shaft position, it is necessary to prevent foreign bodies from falling into the ventilation holes (protective cover).

**Temperature categories**
- T1 and T2, T3 or T4

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

 Terminal boxes:
- EG type-examination certificate IBEU00ATEX1051 U
- Including Supplements 1 to 6

**Ambient temperatures**
- -40 °C to +40 °C, other values in accordance with amendments and appropriate data sheets or supplementary sheets.

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

**Motor’s mechanical components:**
EG type-examination certificate IBEU03ATEX1108 U
EG type-examination certificate IBEU03ATEX1083 U
- Including Supplements 1 to 11

**Terminal boxes:**
- The EG type-examination certificates listed below are also available with Supplementary sheets on the documentation, for use as intended in the approval summary.

**Series and shaft centres**

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<tr>
<th>Series and shaft centres</th>
<th>EG type-examination certificate</th>
<th>EG type-examination certificate</th>
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<td>IBExU06ATEX3314</td>
<td>IBExU02ATEX1114</td>
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<td>(IE-1) KPER 63</td>
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<td>IBExU02ATEX1100</td>
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<td>IBExU04ATEX1118</td>
<td>IBExU02ATEX1118</td>
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<td>(IE-2) W.1R 132</td>
<td>IBExU04ATEX1117</td>
<td>IBExU02ATEX1117</td>
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<td>(IE-2) W.1R 152</td>
<td>IBExU04ATEX1116</td>
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**Example of labelling:**
- Ex e IIC T3 Gb (alternatively: Ex eIC T3 Gb)
  - New complying with IEC/EN 60079-7: Ex eIC T3 Gb (alternatively: Ex eb IIC T3)

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

**Type**
- KPER/KPER/E1-KPR/KPER/E2-KPR/KPER

**Size**
- 56 – 400

**Types of protection**
- IP 54, IP 55, IP 65 and IP 65 complying with IEC/EN 60034-5

**Cooling type**
- IC 411 complying with IEC/EN 60034-6

**Mounting dimensions and power allocation complying with EN 50347**

**Designs**
- IM B3, IM B35 and IM B5 and derived designs complying with IEC/EN 60034-7.

For assembling motors in designs with vertical shaft position, it is necessary to prevent foreign bodies from falling into the ventilation holes (protective cover).

**Temperature categories**
- T2, T3 or T4

**Ambient temperatures**
- -40 °C to +55 °C

For the motors’ design, there are the following type-examination certificates:
- Series KPR 56 – 112: IBExU06ATEX1401
- Series KPR 63 – 132T: IBExU06ATEX1402
- Series (IE1-) K1.R 112 – 355: IBExU09ATEX1403
- Series (IE2-) W.1R 112 – 355: IBExU03ATEX1404

**Example of labelling:**
- ExIIC T3 Gb (alternatively: Ex IIC T3)

4.4 Dust-explosion protected motors

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

**Type**
- KPR/KPER/E1-KPR/KPER/E2-KPR/KPER

**Size**
- 56 – 355

**Types of protection**
- IP 65 complying with IEC/EN 60034-5

**Cooling type**
- IC 411 complying with IEC/EN 60034-6

**Temperature**
- 125 °C, other surface temperatures on request

**Designs**
- IM B3, IM B35 and IM B5 and derived designs complying with IEC/EN 60034-7

For assembling motors in designs with vertical shaft position, it is necessary to prevent foreign bodies from falling into the ventilation holes (protective cover).

**Mounting dimensions and power allocations complying with EN 50347**

**Ambient temperatures**
- -30 °C to +40 °C (+55 °C)

**Exposure-protected design in accordance with Equipment Group II, Category 2**

**Types of protection**
- IP 54, IP 55, IP 56 and IP 65 complying with IEC/EN 60034-5

**Cooling type**
- IC 411 complying with IEC/EN 60034-6

**Size**
- 56 – 400

**Types of protection**
- IP 65 complying with IEC/EN 60034-5

**Cooling type**
- IC 411 complying with IEC/EN 60034-6

**Temperature**
- 125 °C, other surface temperatures on request

**Designs**
- IM B3, IM B35 and IM B5 and derived designs complying with IEC/EN 60034-7

For the motors’ design, there are the following type-examination certificates:
- Series KPR 56 – 112: IBExU06ATEX1401
- Series KPR 63 – 132T: IBExU06ATEX1402
- Series (IE1-) K1.R 112 – 355: IBExU09ATEX1403
- Series (IE2-) W.1R 112 – 355: IBExU03ATEX1404

**Example of labelling:**
- Ex IIC T3 Gb (alternatively: Ex IIC T3)

4.4 Dust-explosion protected motors

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

**Type**
- KPR/KPER/E1-KPR/KPER/E2-KPR/KPER

**Size**
- 56 – 355

**Types of protection**
- IP 65 complying with IEC/EN 60034-5

**Cooling type**
- IC 411 complying with IEC/EN 60034-6

**Temperature**
- 125 °C, other surface temperatures on request

**Designs**
- IM B3, IM B35 and IM B5 and derived designs complying with IEC/EN 60034-7

For the motors’ design, there are the following type-examination certificates:
- Series KPER 56 to 132T: DTM00ATEX120X
- Series (IE1-) K2.Q 112 – 315: IBExU02ATEX1101
- Series (IE1-) K1.R 112 – 355: IBExU09ATEX1105
- Series (IE2-) W.1R 112 – 355: IBExU03ATEX1118

**Example of labelling:**
- Ex tb IIIb T125 °C Db (alternatively: Ex tb IIIb T125 °C)
4.4.2 Motors with squirrel-cage rotor for use in the presence of combustible dusts, Zone 22

Depending on the design, the following combinations are possible:

<table>
<thead>
<tr>
<th>Type</th>
<th>Design</th>
<th>Operating conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>2G or 2D</td>
<td>Ex db(e) IIC 2G or Zone 21 II 2D</td>
<td>-40 °C to +40 °C, for sizes 56 to 132T: -35 °C to +40 °C</td>
</tr>
<tr>
<td>2G or 2D</td>
<td>Ex ec IIC 2G or Zone 21 II 2D</td>
<td>-35 °C to +40 °C</td>
</tr>
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<td>3G or 2D</td>
<td>Ex ec IG 3G or Zone 21 II 2D</td>
<td>-35 °C to +40 °C</td>
</tr>
<tr>
<td>3G or 2D</td>
<td>Ex ec IIC 3G or Zone 21 II 3D</td>
<td>-35 °C to +40 °C</td>
</tr>
</tbody>
</table>

For the combinations 2G/2D and 3G/2D, the ambient temperature is limited to -40 °C to +60 °C for the K12 series, -20 °C to +40 °C for the KPER/KPR series and -30 °C to +40 °C for the K1.R series.

There are also the following certificats:

- Design of motors 2G oder 2D
  - Series K22, 63 – 450: according to the Flameproof enclosure “db” certification summary
  - Series KPER/KPR 56 – 112: IBEuX03ATEX1108 U and IBEuX03ATEX1109 to 1115
  - Series K1.R 112 – 355: according to the increased safety “ed” certification summary with additional certificate IBEuX09ATEX1005

- Design of motors 3G oder 2D
  - Series (IE1-K)R 112 – 355: IBEuX09ATEX8006 in addition to IBEuX09ATEX1005
  - Series (IE1-1)R 112 – 315: IBEuX03ATEX8004 in addition to IBEuX04ATEX1118

5 Maintenance and repair

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

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

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

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

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

Further instructions for testing and upkeep of electrical systems or the repair and repair of electrical equipment are given in IEC/EN 60079-17 and IEC/EN 60079-19. Tasks affecting explosion protection are considered as such, for example:
- Repairs to the stator winding and the terminals
- Repairs to the ventilation system
- Repairs to the bearings and the seals in the case of dust-explosion protected motors (Ex 2D, 3D) may be carried out only by the manufacturer's service personnel or buyers/in authorised workshops by qualified personnel which has the necessary knowledge acquired from training, experience and instruction.

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

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

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

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

Careful, regular maintenance, inspections and checks are essential in order to detect any faults in time and to remedy them before consequential damage occurs. Since the operating conditions cannot be precisely defined, only general deadlines, with the prerequisite of fault-free operation, can be given. They must always be adapted to the local conditions (pollution, stress etc.).
The necessary lubrication times for anti-friction bearings must be observed according to manufacturer’s specifications.

Maintenance tasks (except for lubrication tasks) must be performed only when the machine is shut down. It must always be ensured that the machine is safeguarded against being switched on and labelled with a suitable warning sign. Also, the particular manufacturers’ safety instructions and accident prevention regulations must be observed. This also includes the repair of equipment and protective systems. Abrad, the relevant national regulations must be observed.

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

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

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

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

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

6 Repair and modification of electrical equipment
6.1 General

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

Previously applicable guidelines such as the “Guidelines for the Expensive in Explosion Hazard Areas (EleExV)“ have thus lost their validity.

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

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

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

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

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

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

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

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

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

6.2 Repair tasks not affecting the explosion protection

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

Cleaning:
- Sealing surfaces
- Seals

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

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

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

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

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

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

In the event that the certification documents are not available or available to an inadequate extent, the repair must be carried out on the basis of IEC/EN 60079-19 or the corresponding relevant standard (IEC/EN 60079...). If more detailed types of repair or modification are applied, which do not conform to standards, it must be decided on the part of the manufacturer or the certifying authority (notified body) whether this equipment is suited to continued use in explosion hazard areas.
6.5 Repair tasks on Ex db motors (modifications) which require a new type approval (e.g. by a notified body according to directive 2014/34/EU)

- Installing additional components in the machine
- Reconditioning sparkover-prevention gap
- Reconditioning rotor and stator
- Regenerating components which are not part of the Flameproof enclosure
- Renewing ventilation system parts (e.g. fan wheel)
- Regenerated components must pass the appropriate overpressure test

- Rewinding for a different speed or voltage
- Changing the gap size
- Modifications to the ventilation system

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

6.6 Summary

Scheduling the tasks to be performed

<table>
<thead>
<tr>
<th>Task Description</th>
<th>With use of standard part</th>
<th>Genuine spare part</th>
<th>Trained experts</th>
<th>Manufacturing factory</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.5 Repair tasks</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.6 Summary</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7 Testing the motors after repairs, maintenance or modifications

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

7.1 Visual check

7.1.1 Visual check of winding – main points

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

7.1.2 Visual check of complete motor – main points

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

7.2 Winding test

7.2.1 Winding resistance

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

7.2.2 High-voltage test

The winding’s insulation resistance is tested by the high-voltage test. IEC-EN 60034-1 or VDE 0530 Part 1 prescribes the following procedure for testing machines with a rated voltage ≤ 1 kV. The voltage test must be performed between the windings for testing and the motor housing. The stator core is connected to the windings or phases (e.g. V1 and W1) which are not provided for testing and the test voltage is applied between housing and U phase. The motor is thus tested simultaneously for short-circuit to the exposed conductive part and for inter-phase short-circuit with one measurement.

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

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

The full test voltage must be maintained for 1 minute. A repeat test may be performed only at 80% of the maximum test voltage. Windings already in use are tested for an inspection, for example, at a minimum of 1000 V.
7.2.3 Insulation value (insulation resistance)

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

<table>
<thead>
<tr>
<th>Rated power ( P_e ) kW</th>
<th>Insulation resistance ( R_{A/2} ) V</th>
<th>Illustrated values of insulation resistance ( R_{A/2} ) V/kV</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1 ≤ ( P_e ) ≤ 10</td>
<td>0.3</td>
<td>0.3 A/2 V/kV (at 100 V)</td>
</tr>
<tr>
<td>10 &lt; ( P_e ) ≤ 100</td>
<td>4</td>
<td>4 A/2 V/kV (at 100 V)</td>
</tr>
<tr>
<td>( P_e ) &gt; 100</td>
<td>2.5</td>
<td>2.5 A/2 V/kV (at 100 V)</td>
</tr>
</tbody>
</table>

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

7.3 Test run

7.3.1 Rotating field (direction of rotation check)

The direction of rotation check ensures that the direction of rotation is to the right, looking towards the drive side, when the mains wiring is connected to \( U_1 \), \( L_2 \) to \( V \) and \( L_3 \) to \( W \).

7.3.2 No-load test, detection of no-load current \( I_0 \)

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

7.3.3 Evidence of phase symmetry

7.3.3.1 Short-circuit tests with \( I_k \)

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

7.3.3.2 Kurzschlussprüfung nach IEC/EN 60034-1

The short-circuit test is used to determine the relation \( I_{A/2} \) in the case of reduced test voltage with locked rotor. The no load test is used for checking the winding number, the circuit and evaluating the running properties. It is performed when the engine is cold, at a rated voltage of +1%. The machine is completely unloaded (disconnected from the load machine). During the measurement, voltage, currents and outputs are recorded.

7.3.4 Vibration test

To evaluate the quiet running a vibration test according to IEC/EN 60079-7. Copying the winding is not permitted until the \( I_k \) time has been checked against Equipment Standard IEC/EN 60079-7.

7.4 Painting and impregnation after repair work

The repainting of an explosion-protected motor or the impregnation of a complete stator after re-winding may result in thicker paint or resin layers on the machine surface. This could lead to electrostatic charging, with a corresponding risk of explosion in case of discharge. Charging processes in the immediate surroundings could similarly produce an electrostatic charge on the surface or parts of the surface, and likewise bring a risk of explosion in case of discharge. It is thus imperative to observe the stipulations of IEC/EN 60079-7: “Equipment – General requirements”, section 7.4, and TRBS 2153, e.g. by:

- limiting the total paint or resin layer thickness in accordance with the explosion group
  - IIA, IIB: Total layer thickness \( \leq 2 \) mm
  - IIC: Total layer thickness \( \leq 0.2 \) mm

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

The test results must be documented in a test report.

VEM motors GmbH sample certificate

below:

Alternative: ZVEH test certificate

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

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

8 Summary of standards and regulations
8.1 General standards

<table>
<thead>
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<th>Standard</th>
<th>International</th>
<th>Europe</th>
<th>Germany</th>
</tr>
</thead>
<tbody>
<tr>
<td>Device testing procedures for alternating current rotating electric machines</td>
<td>EN 60034-1</td>
<td>EN 60034-1</td>
<td>DIN EN 60034-1</td>
</tr>
<tr>
<td>Method for determining losses and efficiency from tests for rotating electric machines</td>
<td>EN 60034-2-1</td>
<td>DIN EN 60034-2-1</td>
<td></td>
</tr>
<tr>
<td>Efficiency classes of single-speed cage-induction motors</td>
<td>EN 60034-30-1</td>
<td>DIN EN 60034-30-1</td>
<td></td>
</tr>
<tr>
<td>Degrees of protection provided by the integral design of rotating electric machines (IP Code) - introduction</td>
<td>EN 60034-5</td>
<td>DIN EN 60034-5</td>
<td></td>
</tr>
<tr>
<td>Methods of cooling (IC Code)</td>
<td>EN 60034-6</td>
<td>DIN EN 60034-6</td>
<td></td>
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<tr>
<td>Classification of types of construction, mounting arrangements and terminal box position (IM Code)</td>
<td>EN 60034-7</td>
<td>DIN EN 60034-7</td>
<td></td>
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<tr>
<td>Terminal markings and direction of rotation</td>
<td>EN 60034-8</td>
<td>DIN EN 60034-8</td>
<td></td>
</tr>
<tr>
<td>Noise limits</td>
<td>EN 60034-9</td>
<td>DIN EN 60034-9</td>
<td></td>
</tr>
<tr>
<td>Starting performance of single-speed three-phase cage-induction motors</td>
<td>EN 60034-12</td>
<td>DIN EN 60034-12</td>
<td></td>
</tr>
<tr>
<td>Mechanical vibrations of certain machines with shaft heights 56 mm and higher; measurement, evaluation and limits of vibration severity</td>
<td>EN 60034-14</td>
<td>DIN EN 60034-14</td>
<td></td>
</tr>
<tr>
<td>Balance quality</td>
<td>ED 1940</td>
<td>DIN ISO 19403</td>
<td></td>
</tr>
<tr>
<td>EC standard voltages</td>
<td>EN 60038</td>
<td>DIN EN 60038</td>
<td></td>
</tr>
<tr>
<td>Electrical insulation - Thermal evaluation and designation</td>
<td>EN 60085</td>
<td>DIN EN 60085</td>
<td></td>
</tr>
<tr>
<td>Dimensions and output series for rotating electric machines</td>
<td>EN 60072-1</td>
<td>DIN 50347</td>
<td></td>
</tr>
</tbody>
</table>
### 8.2 Explosion protection standards

<table>
<thead>
<tr>
<th>Type</th>
<th>IEC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fundamentals</strong></td>
<td>Explosive atmospheres – Explosion prevention and protection Part 1: Basic concepts and methodology Explosive atmospheres – Explosion prevention and protection Part 2: Basic concepts and methodology for mining Potentially explosive atmospheres – Terms and definitions for equipment and protective systems intended for use in potentially explosive atmospheres</td>
</tr>
<tr>
<td><strong>Characteristics of flammable gases and vapours</strong></td>
<td>Determination of minimum explosion pressures and the maximum rate of pressure rise of gases and vapours Flammable atmospheres – Method of fault diagnosis for equipment with enclosure “e” Flammable atmospheres – Method of determination of maximum experimental safe gap Testing of residual air inflow - Determination of ignition temperature</td>
</tr>
<tr>
<td><strong>Characteristics of flammable dusts</strong></td>
<td>Explosive atmospheres – Part 20 – 1: Material characteristics for gas and vapour classification – test methods and data Explosive atmospheres – Part 20 – 2: Material characteristics – Combustible dust test methods</td>
</tr>
<tr>
<td><strong>Classification of hazardous areas</strong></td>
<td>Explosive atmospheres – Part 10 – 1: Classification of areas – Flammable gas atmospheres Explosive atmospheres – Part 10 – 2: Classification of areas – Explosion dust atmospheres</td>
</tr>
<tr>
<td><strong>Equipment, design, installation, maintenance and repairs</strong></td>
<td>Explosive atmospheres – Part 4: Electrical installations design, selection and erection Explosive atmospheres – Part 7: Electrical installations inspection and maintenance Explosive atmospheres – Part 8: Equipment repair, overhaul and reclamation Explosive atmospheres – Part 19: Equipment repair, overhaul and reclamation</td>
</tr>
<tr>
<td><strong>DA</strong></td>
<td>Explosive atmospheres – Part 34: Application of quality systems for equipment manufacture</td>
</tr>
</tbody>
</table>
### 9 Tolerances

#### 9.1 Electrical parameters

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

**Efficiency**  
\[-0.15 \text{ (up to } P_e = 100 \text{ kW})\]  
\[-0.1 \text{ (up to } P_e = 150 \text{ kW})\]

**Power factor**  
\[p_f = 0.85 \text{ (minimum) } 0.92 \text{ (maximum)}\]

**Slip (at rated load and operating temperature)**  
\[\pm 20\% \text{ at } P_e = 1 \text{ kW}\]  
\[\pm 35\% \text{ at } P_e = 1 \text{ kW}\]

**Initial starting current (in the starting circuit provided)**  
without de-energization in traction

**Starting torque**  
\[-15\% \text{ and } +25\%\]

**Pull-up torque**  
\[-10\%\]

**Breakdown torque**  
\[-12\% \text{ (after applying this tolerance M} / \text{MN still at least } 1.5\%]\]

**Inertia torque**  
\[\pm 10\%\]

**Noise intensity (best surface sound pressure level)**  
\[\pm 2 \text{ dB (A)}\]

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

1. A guarantee of all or any of the values in the table is not the guaranteed values. In the standard, the following notes are especially. The permitted deviations must correspond to the table.

2. Your attention is drawn to the differences in interpretation of the term “guarantee”. In some countries a distinction is made between typical or declared values.

3. If the permitted deviation applies only in one direction, the value in the other direction is not restricted.

#### 9.2 Mechanical parameters – normal tolerances

<table>
<thead>
<tr>
<th>Measurement abbreviation</th>
<th>Fit or tolerance</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>Clearance of the housing height attachment holes in axial direction</td>
<td>± 1 mm</td>
</tr>
<tr>
<td>a, b</td>
<td>Flange diameter or width</td>
<td>± 1 mm</td>
</tr>
<tr>
<td>b</td>
<td>Clearance of housing height attachment holes at right angle to the axial direction</td>
<td>± 1 mm</td>
</tr>
<tr>
<td>b0</td>
<td>Diameter of flange's setting flange</td>
<td>up to diameter 230 mm ± 0.05</td>
</tr>
<tr>
<td>d, d1</td>
<td>Diameter cylindrical shaft end</td>
<td>up to diameter 40 mm end from shaft diameter 55 mm end</td>
</tr>
<tr>
<td>e1, e2</td>
<td>Flange's hole circle diameter</td>
<td>± 0.8 mm</td>
</tr>
<tr>
<td>e, f</td>
<td>Motor's overall width (without terminal box)</td>
<td>± 2%</td>
</tr>
<tr>
<td>f</td>
<td>Shaft centre (lower edge of foot to centre of shaft end)</td>
<td>12 250 mm +0.5 over 250 mm –1</td>
</tr>
<tr>
<td>k, k1</td>
<td>Motor's total length</td>
<td>± 1%</td>
</tr>
<tr>
<td>k</td>
<td>Motor's total length (lower edge of foot, housing in flange to motor's highest point)</td>
<td>± 2%</td>
</tr>
<tr>
<td>k0, k1</td>
<td>Diameter of attachment holes in foot or flange</td>
<td>± 3%</td>
</tr>
<tr>
<td>l, l1</td>
<td>Lower edge of shaft end to upper edge of parallel key</td>
<td>± 0.2 mm</td>
</tr>
<tr>
<td>m</td>
<td>Predelivery length</td>
<td>± 0.5 mm</td>
</tr>
<tr>
<td>m0, m1</td>
<td>Distance between center of foot attachment hole and shaft collar or flange surface</td>
<td>± 3.5 mm</td>
</tr>
<tr>
<td>m</td>
<td>Distance from shaft collar to flange surface with D-side fixed bearing</td>
<td>± 0.5 mm</td>
</tr>
<tr>
<td>n</td>
<td>Distance from shaft collar to flange surface</td>
<td>± 3.5 mm</td>
</tr>
<tr>
<td>n0, n1</td>
<td>Motor dimensions</td>
<td>± 0.5 mm ± 1%</td>
</tr>
</tbody>
</table>

### List of source material

**Abstract**

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- Diverse weitere Normen und Normenentwürfe