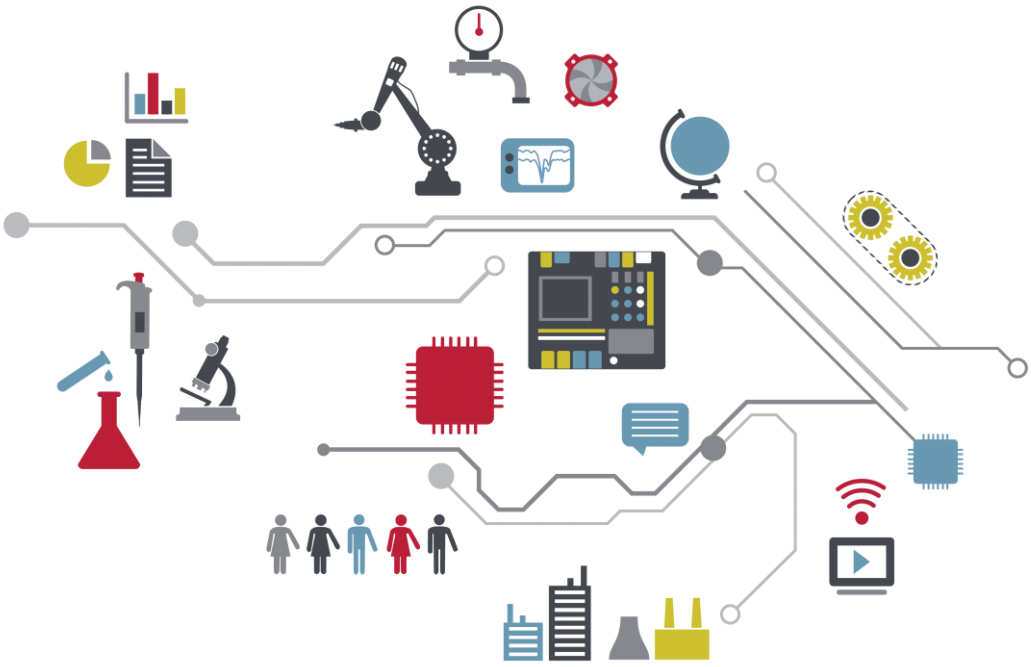
GAMBICA

Variable Speed Drives
Application of the ATEX Directives
to Power Drive Systems

A GAMBICA Technical Guide



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1. Introduction

This Guide has been produced to give guidance when connecting a variable speed drive (VSD) to a motor, where the motor is within a potentially explosive atmosphere and the VSD is outside the potentially explosive atmosphere (see Figure 1). Locations with potentially explosive atmospheres are sometimes also known as "hazardous areas".

This guide does not cover any instance where the VSD is fitted within the potentially explosive atmosphere.

This guide focusses on the requirements of the European Union ATEX directives, but the technical requirements are similar in other legislations, and most of the European standards referred to (EN xxxxx) have international equivalents (IEC xxxxx).

The ***ATEX Worker Protection Directive (Directive 1999/92/EC)*** lays down minimum requirements for the safety and health protection of workers potentially at risk from explosive atmospheres. The responsibility for site safety rests with the employer.

Essential information for electrical installations in potentially explosive atmospheres is contained in standard EN 60079-14, and it is strongly recommended that anyone responsible for the selection or installation of electrical equipment in potentially explosive atmospheres should refer to that standard. A list of some of the relevant clauses is given in *Appendix 1: Standards for equipment in potentially explosive* atmospheres of this guide. Products used must comply with the Product ATEX Directive (2014/34/EU).

2. European Directives

There are two European directives related to potentially explosive atmospheres.

Directive 2014/34/EU (the "product" ATEX directive):

- applies requirements to equipment intended to be used in potentially explosive atmospheres;
- defines equipment categories and lays down technical requirements and conformity assessment procedures for the equipment;
- places requirements on certain safety devices outside the potentially explosive atmosphere.

Directive 1999/92/EC (the "worker protection" ATEX directive):

- places obligations on employers;
- defines the various zones for gases, vapours or mists and/or dusts and states which equipment categories from directive 2014/34/EU (previously 94/9/EC) may be used in each of the zones (unless the explosion protection document based on a risk assessment states otherwise).

General guidance on these two directives is available from the European Commission's website and is not repeated here. This document concentrates on practical issues relating to the application of VSD-driven motors in potentially explosive atmospheres.

3. The Power Drive System

The concept of a power drive system (PDS) is used to describe an electric motor drive system within an overall installation. The terminology is used throughout IEC and EN standards relating to electrical variable speed drives to describe a combination of components, including a power converter (i.e. the VSD) and motor. The concept applies equally to a fixed speed drive, although this is not considered in this guide. The conventional illustration of a PDS and its component parts is shown in Figure 1, with an added indication of the location of a potentially explosive atmosphere within the scope of this guide.

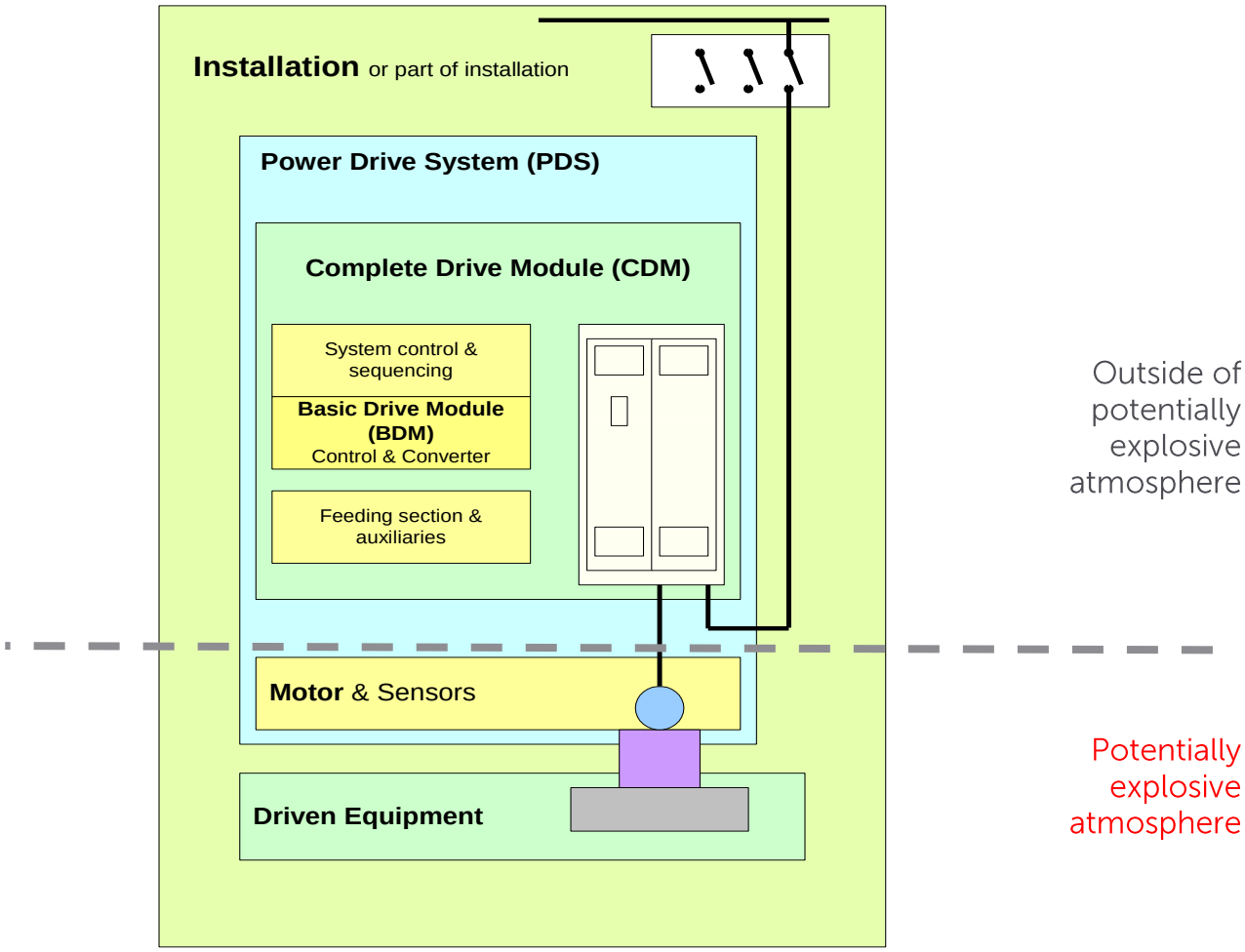


Figure 1: The Power Drive System indicating location of components within the hazardous and non-hazardous areas (adapted from EN 61800-5-1)

BDM Basic drive module consisting of power input, control and power output sections.

CDM Complete drive module consisting of BDM and auxiliary sections, but excluding the motor and motor-coupled sensors.

PDS Power Drive System, comprising CDM, motor and sensors, but excluding the driven equipment and sensors.

4. Motors

All electrical equipment for use in potentially explosive atmospheres must be installed with great care as potentially flammable or explosive conditions may arise. Depending on the nature of the

risk, different motor protection types can be used. The types, in accordance with the EN 60079 series of standards, which may be suitable for motors fed from VSD are:

Ex “d”	Flameproof
Ex “e”	Increased safety
Ex “de”	Flameproof with increased safety terminal box
Ex “p”/ Ex “pD”	Pressurised enclosures
Ex “t”	Enclosure (dust proof)
Ex “nA”	Non-sparking

All designs seek to minimise the risk of sparking or of abnormally high temperatures being attained.

Regardless of the motor protection types, there is a requirement to keep external surface temperatures within a prescribed value according to the temperature classification, e.g. T4 (135°C). Although certification can be achieved with all types of motors, it is best left to the motor manufacturer to select the protection types suited to the user’s application.

5. Marking of motors

Motors intended for use in a potentially explosive atmosphere must be marked in accordance with the provisions of the ATEX product directive.

The motor manufacturer should consult the directive, the Commission Guidelines, and the relevant EN Standards for details of the actual markings that will be required. *Appendix 1: Standards for equipment in potentially explosive* atmospheres gives the relevant standards. **Error! Reference source not found.** and Figure 4**Error! Reference source not found.** in *Appendix 2: Some examples of motor marking for ATEX* show two examples of the types of marking that may be applied to a motor.

6. Effect of VSD on motors

The VSD affects motor operation and it is essential that this be taken into account when designing the installation.

A VSD supply can change the motor thermal performance in several ways:

a) Reduced speed operation reduces the cooling effect of the shaft-mounted cooling fan.
b) Motor power loss is increased due to a non-sinusoidal voltage waveform with increased harmonics, particularly if a lower Pulse Width Modulation (PWM) switching frequency is employed.

c) There is a possibility of running the motor with lower or higher voltage than that for which it was intended. This includes the possibility of operating above the motor base speed, usually in the "field weakening" and "constant power" region.
d) Changes to VSD settings from those initially tested can affect temperatures.
e) Combinations of all of the above.

The VSD can also cause side-effects resulting from the pulsed nature of the applied voltage, in the form of voltage overshoots at the motor terminals and stray currents in the shaft and bearings.

7. Selection of VSDs and motors

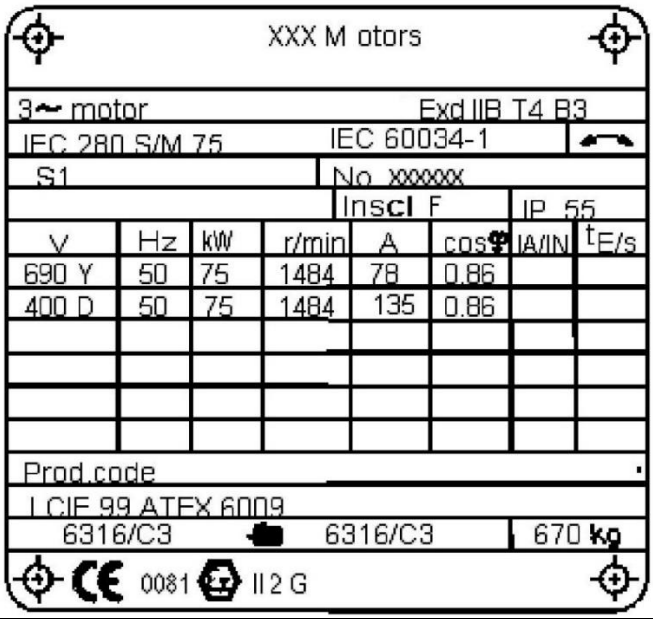
Compatibility of the motor and VSD is essential in order to meet the ATEX requirements. This might be achieved by using a motor and VSD which have been tested and approved as a defined combination, and in the case of an Ex "e" motor this is the most practicable procedure. For the other protection methods, it can also be achieved through the motor certification giving a specification for the necessary VSD characteristics. This information must be provided with the motor as additional marking and/or operating instructions.

The additional marking includes:

- relevant electrical characteristics of the converter:
    - these may include VSD type (typically PWM, CSI), switching frequency restrictions, d.c. bus voltage and peak rate of voltage change.
- maximum load torque corresponding to the speed range allowed according to the application:
    - in a centrifugal fan or pump application only the torque at maximum speed has normally to be considered.
    - for a constant torque application the exact value of the torque must be considered at the minimum and maximum speed corresponding to the application.
    - for intermittent duty applications the duty cycle must be detailed.

Figure 2 gives an example of marking for a motor intended for Converter (variable speed) duty. In this example the VSD is restricted to be of the voltage-source type, operating at a switching frequency exceeding 1 kHz, with field weakening commencing at 400 V and 50 Hz. The maximum power is specified at frequencies of 5 Hz, 50 Hz and 65 Hz.

The person responsible for selecting the VSD and motor must ensure that these requirements and restrictions are met. In this example, the requirements for the VSD are quite easy to meet since the torque is permitted to be constant down to a low speed, and most modern VSD designs use a voltage source inverter operating at 2 kHz or higher. If there had been stipulations regarding rates of change of voltage then it might have been necessary to use an output filter with the VSD. The user and installer are responsible for ensuring that the necessary VSD parameters are set to the required values to meet the specification, and that measures are in place to prevent inadvertent changes to these settings.



Complementary marking
Frame size and basic standard data

Sinusoidal supply data (if appropriate)

CE Conformity marking

XXX Motors						
3~ Motor E280SMA4 Exd IIB T4						
No						
CONVERTER SUPPLY						
Converter Type: VOLTAGE-SOURCE/PWM						
Switching Frequency: > 1 kHz						
Field Weakening Point: 400 VD 50 Hz						
V	**Hz**	**kW**	**r/min**	**A**	**cos φ**	**DUTY**
400	5	6	133	124		S9
400	50	60	1488	110		S9
400	65	60	1934	105		S9

Converter limitations

Converter supply data (Shows a constant torque load from 133 r/min to 1488 r/min, with constant power from 1488 r/min to 1934 r/min)

Figure 2: Typical Variable Speed Motor Marking

The user is advised when contacting the motor manufacturer or supplier to give full information of the application i.e. type of potentially explosive atmosphere, type of hazard (dust or gas), zone classification, temperature classification e.g. T4, application e.g. fan, conveyor, centrifuge, etc. and possibly to supply load curves for the driven equipment. When contacting the VSD manufacturer or supplier, the user should stipulate on any enquiry the restrictions on the VSD given by the motor manufacturer, and the offered VSD must meet these requirements.

8. Thermistor Protection

The effects of the VSD on motor thermal behaviour listed in section 6 above manifest themselves as increased temperatures within the motor and hence on the external surfaces. Unless it can be proven that the motor temperature will not exceed the required limit when using the VSD, in both normal and fault conditions, then some form of motor temperature protection must be provided. Thermistors embedded in the windings can be used to monitor internal temperatures that would eventually lead to excessive external temperatures, as determined by testing. Typically, a 140°C trip temperature thermistor is used for T4 certification. The temperatures attained in a motor must have a design margin to the temperature classification so that under

fault conditions, however they arise, the thermistor protection operates before a hazardous surface temperature can occur.

The PTC (Positive Temperature Coefficient) thermistor exhibits a rapidly increasing resistance at the trip temperature, which is used to operate the protective circuit. Typically to cover the risk of over temperature three thermistors are distributed around the winding with one embedded in each phase. They are connected in series so that if any one indicates a high temperature this results in a trip.

The relay or other equipment which is used to process the thermistor signal and initiate a trip must meet requirements for safety integrity, since a failure which resulted in it being ineffective might go unnoticed for a long time before the next proof test. Therefore, the relay or other equipment must comply with the requirements of the ATEX product directive for safety devices, even if they are placed outside the potentially explosive atmosphere. (See *Appendix 3: Safety devices outside the potentially explosive atmosphere*)

The European harmonised standard EN 50495, gives requirements for safety devices necessary for the safe functioning of equipment with respect to explosion risks. The standard specifies the required SIL (safety integrity level) of the complete thermal protection system as a function of the hardware fault tolerance of individual parts.

A VSD which is required for or contributes to the safe functioning of the motor (e.g. by providing a temperature trip function which complies with EN 50495) is considered to be a “safety device” according to the Product ATEX Directive and must meet the appropriate requirements. This must not be confused with certification permitting the use of the VSD itself within a potentially explosive atmosphere.

In a typical application of a motor with VSD that are not type tested together, the motor (EUC – equipment under control) would be considered to have a hardware fault tolerance (HFT) of 0 regarding over temperature faults, since readily achievable conditions within the VSD could allow overheating which is not protected against by the motor. This gives a requirement from EN 50495 for either SIL 1 or SIL 2 depending on the equipment group or zone.

In practice, EN 60079-14 would require a motor with embedded thermistors, a certified thermistor relay or device, and a suitable means of electrical disconnection of the motor from the VSD.

Generally, a VSD Safe Torque Off (STO) function according to EN 61800-5-2 will have SIL capability of 2 or more and is suitable for achieving the actual removal of power from the motor. The thermistor evaluation circuit must also achieve the required SIL – this might be available in the VSD or a separate relay unit might be required.

- Zone 0/20 or EPL Ga/Da requires SIL2, HFT 1 (see note)
- Zone 1/21 or EPL Gb/Db requires SIL 1, HFT 0
- Zone 2/22 or EPL Gc/Dc has no requirements for a safety device in EN 50495 – at this point the requirements of EN 60079-14 take precedence and good practice is to use the minimum SIL 1, HFT 0

A HFT of 0 means that the electrical disconnection system only requires a single channel. A HFT of 1 typically requires a dual channel design.

Note: It is prohibited for a motor to be installed in a Zone 0/20 as none of the above methods of protection that are used for motors are suitable on their own in a Zone 0 or Zone 20.

9. Commissioning and periodic proof test of over temperature protection devices

The over temperature protection loop must be proof tested when the drive system is commissioned, and also periodically on a minimum interval, often 1 to 3 years, as a condition of achieving the required SIL. This interval and a test log need to be included in the hazardous area verification dossier.

10. Responsibilities

The safety of an installation in a potentially explosive atmosphere is the result of a co-operation between the equipment manufacturers, the installer and the end user.

The employer / end user is responsible for the zone classification and, in conjunction with the installer, is also responsible for the specification, installation and maintenance of the equipment, for ensuring that both the motor and the VSD are suitable for the application, and that the VSD meets the requirements of the certificate provided by the motor manufacturer.

The manufacturers of the motor and VSD are responsible for ensuring that their specifications and instructions are complete and correct so that the end user can meet their obligation to ensure the safety of the installation.

11. Appendix 1: Standards for equipment in potentially explosive atmospheres

The main general standard for electrical equipment in explosive atmospheres is EN 60079-14 (IEC 60079-14).

The following clauses in that standard (edition of 2014) are particularly relevant:

4.1	General requirements
4.2	Documentation
4.4	Assurance of conformity of equipment
4.5	Qualifications of personnel
5.11	Rotating electrical machines
5.11.4	Motors fed from a converter supply
7	Electrical protection
11	Rotating electrical machines
11.2.1	Motors with converter supply – protection type “d”
11.3.4	Motors with converter supply – protection type “e”
11.4.1	Motors with converter supply – protection type “p” and “pD”
11.5.1	Motors with converter supply – protection type “t”
11.6.1	Motors with converter supply – protection type “nA”

Other parts of the EN 60079 series cover specific protection techniques:

Ex “d”	EN 60079-1
Ex “e”	EN 60079-7
Ex “t”	EN 60079-31
Ex “nA”	EN 60079-15
Ex “p”/ Ex “pD”	EN 60079-2

The European EN 60079 series have corresponding international IEC equivalents with the same numbers; dates may differ.

EN 50495 applies to “Safety devices required for the safe functioning of equipment with respect to explosion risks”. At the time of writing, a future corresponding IEC standard which will be IEC 60079-42 is in draft.

12. Appendix 2: Some examples of motor marking for ATEX

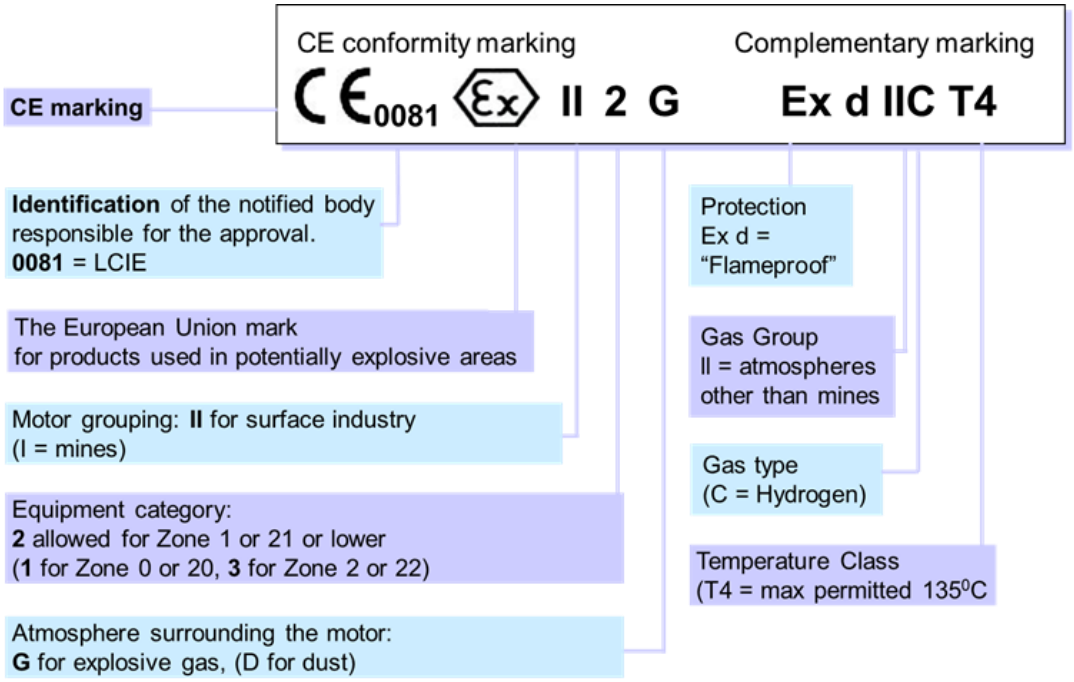


Figure 3: Example of ATEX Labelling (Gas Hazard)

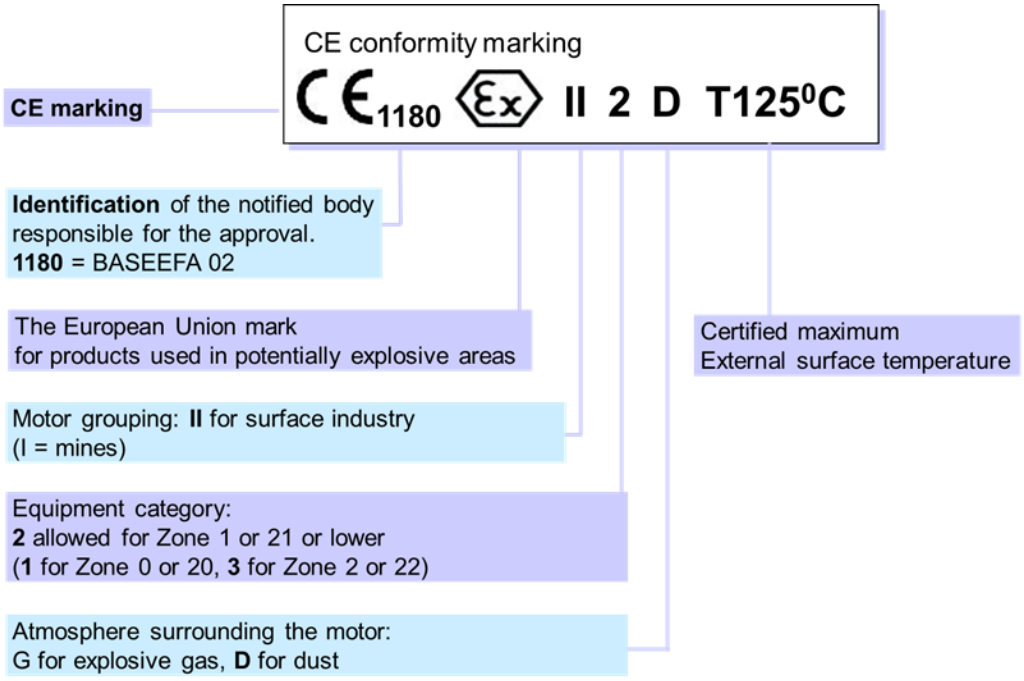


Figure 4: Example of ATEX Labelling (Dust Hazard)

13. Appendix 3: Safety devices outside the potentially explosive atmosphere

The product ATEX directive 2014/34/EU applies to certain equipment in the safe area in addition to equipment in the potentially explosive atmosphere. The legal basis is given in article 1(1) of directive 2014/34/EU, which states that this directive applies to the following products:

(a) equipment and protective systems intended for use in potentially explosive atmospheres;

(b) safety devices, controlling devices and regulating devices intended for use outside potentially explosive atmospheres but required for or contributing to the safe functioning of equipment and protective systems with respect to the risks of explosion;

(c) components intended to be incorporated into equipment and protective systems referred to in point (a).

The technical requirements that the directive places on the devices in the safe area identified in point (b) above are generally functional safety requirements.

The GAMBICA Association Ltd

Rotherwick House
3 Thomas More Street
London E1W 1YZ

T +44 (0) 20 7642 8080
E info@gambica.org.uk
W gambica.org.uk