What is considered of design for electrical apparatus in hazardous areas

Jörg Flötotto
Working Group 3.51 „Flameproof Enclosures“
Physikalisch-Technische Bundesanstalt
Overview

• Introduction
• Types of protections
• Marking system
• Example:
  – Flameproof motor with
  – increased safety terminal box
• The certificates

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Introduction

• Dipl.-Ing (FH) Jörg Flötotto
• Study of electrical engineering
• Since June 1999 member of the PTB laboratory “Flameproof Enclosures”

Key tasks at PTB:
* conformity assessment for motors and luminaries in type of protection flameproof enclosure
* since 2002: auditor for ATEX and IECEx Ex-Audits
* since 2006: member of the IEC Maintenance Team MT60079-1 (Flameproof Enclosure)
* since 2009: responsible for IECEx03 evaluation (service facilities / repairs shops)
Type of protections

General requirements are specified in the following standards:

• Electrical equipment
  IEC 60079-0:2007
  EN 60079-0:2009
  for gases, vapours and dusts

• Non-electrical equipment
  EN 13463-1:2009
  for non electrical devices
## Different types of protections

<table>
<thead>
<tr>
<th>Type of protection</th>
<th>Symbol</th>
<th>Gases/Vapours</th>
<th>Dusts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Electrical equipment</td>
<td>Non-electrical equipment</td>
</tr>
<tr>
<td>Flameproof enclosure</td>
<td>d</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Protection by enclosure</td>
<td>t</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Enclosed break device</td>
<td>nC</td>
<td>●</td>
<td>-</td>
</tr>
<tr>
<td>Non-incendive component</td>
<td>nC</td>
<td>●</td>
<td>-</td>
</tr>
<tr>
<td>Pressurized apparatus</td>
<td>p</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Powder filling</td>
<td>q</td>
<td>●</td>
<td>-</td>
</tr>
<tr>
<td>Oil immersion</td>
<td>o/k</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Increased safety</td>
<td>e</td>
<td>●</td>
<td>-</td>
</tr>
<tr>
<td>Non-sparking</td>
<td>nA</td>
<td>●</td>
<td>-</td>
</tr>
<tr>
<td>Constructive safety</td>
<td>c</td>
<td>-</td>
<td>●</td>
</tr>
<tr>
<td>Encapsulation</td>
<td>m</td>
<td>●</td>
<td>-</td>
</tr>
<tr>
<td>Hermetically sealed device</td>
<td>nC</td>
<td>●</td>
<td>-</td>
</tr>
<tr>
<td>Sealed/encapsulated device</td>
<td>nC</td>
<td>●</td>
<td>-</td>
</tr>
<tr>
<td>Intrinsic safety</td>
<td>i</td>
<td>●</td>
<td>-</td>
</tr>
<tr>
<td>Restricted breathing enclosure</td>
<td>nR/fr</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Protection by control of ignition sources</td>
<td>b</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Flameproof enclosure “d”

- **Electrical equipment “Ex d”**
  IEC 60079-1
  Group: I, II  EPL: Gb, Mb
  Non-electrical equipment “d”
  EN 13463-3

- **Principle:**
  An explosion inside of the enclosure withstand the explosion pressure. Gaps are designed that gas jets and outside surface temperatures will not ignite the surrounding atmosphere

- **Typical application:**
  Motors, brakes, terminal boxes, luminaries

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Protection by enclosure “t”

- Electrical equipment “Ex ta”
  IEC 60079-31
  “Ex tb”
  “Ex tc”
- Group III EPL Da, Db, Dc
- Principle:
  The enclosure is designed so tight that no (combustible) dust from the surrounding atmosphere can enter the enclosure. The outside surface temperature is limited.
- Typical application:
  Motors, brakes, terminal boxes, luminaries, control boxes
Enclosed break device “nC”

- Electrical equipment “Ex nC”
  IEC 60079-15
  Group: II   EPL: Gc
- Principle:
  Contacts potentially able to trigger an enclosure are closed in an enclosure withstand an internal explosion without transferring the explosion and without being damaged.
- Typical application:
  Contact systems, switches
- Limitation:
  20 cm³, 690 V and 16 A

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Non-incendive component “nC”

- Electrical equipment “Ex nC”
  IEC 60079-15
  Group: II   EPL: Gc
- Principle:
  The enclosure of contacts and/or the contact mechanism will prevent an explosion as long as defined.
- Typical application:
  contact systems
- Limitation:
  20 cm³, 254 V and 16 A
  L and C are part of the test
Pressurized apparatus “p”

- Electrical equipment
  “Ex p” IEC 60079-2 / IEC 61241-4
  “px”: Group: I, II, III  EPL: Gb, Mb, Db
  “py”: Group: II, III  EPL: Gb, Db
  “pz”: Group: II, III  EPL: Gc, Dc

- Non-electrical equipment
  “p” EN 13462-4

- Principle:
The ingress of surrounding explosive atmosphere is prevented by an internal overpressure realized by air, inert or other suitable gases. The overpressure and/or gas flow must be monitored.

- Typical application:
  Large motors, control boxes, analytical apparatus

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Powder Filling “q”

• Electrical equipment “Ex q”
  IEC 60079-5
  Group: I, II  EPL: Gb, Mb
  Group: III    EPL: Db, Dc
• By filling the enclosure with finely grained powder (sand or glass balls) an arc within the enclosure is unable to ignite the outside atmosphere. No risk of ignition by flames or outside surface temperatures.
• Typical application: Capacitors, ballasts, transformers

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Oil immersion “o”, Liquid immersion “k”

• Electrical equipment “Ex o”
  IEC 60079-6
  Group: II  EPL: Gb
• Non-electrical equipment “k”
  EN 13463-8
• An potential ignition source is immersed in oil or other non-flammable insulating liquid. So gases and vapour above the oil level cannot be ignited.
• Typical application:
  Large transformers, switchgears, starting resistors
Increased safety “e”

- Electrical equipment “Ex e”
  IEC 60079-7
  Group: I, II   EPL: Gb, Mb
- Additional measures provide a higher level of protection. This ensure reliable prevention of high temperatures and sparks or electrical arcs inside and outside the enclosures.
- Typical application:
  Terminal boxes, cage motors, control boxes

Stator windings of high voltage rotating machines have to be type tested under explosive atmospheres.
Non-sparking device “nA”

- Electrical equipment “Ex nA”
  IEC 60079-15
  Group: II  EPL: Gc
- The construction ensures prevention of high temperatures, sparks or electrical arcs in normal operation. Overload and fault conditions are not considered.
- **Typical application:**
  Installation materials, rotating electrical machines, transformers low energy equipment.

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Constructive safety “c”

- Non-Electrical equipment “c” EN 13463-5 Group: I, II
- Equipment is constructed in a way which ensures that they cannot turn into an ignition source in normal operation and in cases of fault.
- Typical application: gripper units, cranes, pulley blocks

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Encapsulation “m”

• Electrical equipment “Ex m”  
  IEC 60079-18  
  “ma” Group: I, II, III  EPL: Ga, Ma, Da  
  “mb” Group: I, II, III  EPL: Gb, Mb, Db  
  “mc” Group: II, III  EPL: Gc, Dc

• Parts that could ignite an explosive atmosphere are potted to prevent an ignition of the atmosphere. The sealing compound have to be resistant to electrical, thermal and mechanical influences.

• Typical application:  
  Static coils, relays, PCB’s with electronic circuits
Hermetically sealed device “nC”

- Electrical equipment “Ex nC”
  IEC 60079-15
  Group I, II
- Any external atmosphere cannot gain access to the interior. The seal is made by fusion, for example by soldering, brazing, welding or the fusion of glass to metal
- **Typical application:**
  Spark generation equipments, igniters

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Sealed / Encapsulated device “nC”

- Electrical equipment “Ex nC”
  IEC 60079-15
  Group I, II
- The equipment may include cavities, which are fully enclosed similar to “m” type of protection. Device cannot be opened during normal service. The ingress of external atmosphere is prevented.
- **Typical application:**
  Spark generation equipments, igniters
Intrinsic safety “i”

- Electrical equipment “Ex ia”
  IEC 60079-11 “Ex ib”
  “Ex ic”

Group I  EPL: Ma, Mb
Group II  EPL: Ga, Gb, Gc
Group III EPL: Da, Db, Dc

- Intrinsically circuits are circuits in which no spark or thermal effects can ignite an explosive atmosphere. The test condition cover normal operation and certain fault conditions.

- **Typical application:**
  Measuring and monitoring equipment, electronic apparatus, actuators

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Restricted breathing enclosure “nR” or “fr”

- Electrical equipment “Ex nR”
  IEC 60079-15
  Group I, II and III
- Non-electrical equipment “fr”
  EN 13463-2
- The enclosure is constructed in such a way that the ingress of the surrounding atmosphere is restricted. Breathing effect shall be minimized and controlled.

  Typical application:
  Luminaries, switchgears, monitoring devices for Zone 2

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Protection by control of ignition sources “b”

- Non-electrical equipment “b” EN 13463-6
- Monitoring ignition sources during normal operation, which can become effective in abnormal situation (heating up/friction/impact sparking). The process shall be stopped in such situations.
- Typical application: Centrifugal governor which cut-off an apparatus in case of prohibited speed
## Equipment groups I, II

<table>
<thead>
<tr>
<th>Equipment group</th>
<th>Area</th>
<th>MESG</th>
<th>MIC ratio</th>
<th>MIE</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Methane Mining only</td>
<td>&gt; 1.0 mm</td>
<td>1.0</td>
<td>&gt; 0.25 mWs</td>
</tr>
<tr>
<td>IIA</td>
<td>≥ 0.9 mm</td>
<td>&gt; 0.8</td>
<td></td>
<td>&gt; 0.20 mWs</td>
</tr>
<tr>
<td>IIB</td>
<td>Surface Industries</td>
<td>&gt; 0.5 mm</td>
<td>≥ 0.45</td>
<td>&gt; 0.045 mWs</td>
</tr>
<tr>
<td></td>
<td>...</td>
<td></td>
<td>...</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt; 0.9 mm</td>
<td></td>
<td>≤ 0.8</td>
<td></td>
</tr>
<tr>
<td>IIC</td>
<td>≤ 0.5 mm</td>
<td>&lt; 0.45</td>
<td></td>
<td>≤ 0.045 mWs</td>
</tr>
</tbody>
</table>
## Temperature categories

<table>
<thead>
<tr>
<th>Temperature category</th>
<th>Ignition temperature</th>
<th>Maximum surface temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>&gt; 450 °C</td>
<td>&lt; 450 °C</td>
</tr>
<tr>
<td>T2</td>
<td>&gt; 300 °C</td>
<td>&lt; 300 °C</td>
</tr>
<tr>
<td>T3</td>
<td>&gt; 200 °C</td>
<td>&lt; 200 °C</td>
</tr>
<tr>
<td>T4</td>
<td>&gt; 135 °C</td>
<td>&lt; 135 °C</td>
</tr>
<tr>
<td>T5</td>
<td>&gt; 100 °C</td>
<td>&lt; 100 °C</td>
</tr>
<tr>
<td>T6</td>
<td>&gt; 85 °C</td>
<td>&lt; 85 °C</td>
</tr>
</tbody>
</table>
# Temperature category

<table>
<thead>
<tr>
<th>Explosion group</th>
<th>Temperature category (max. permissible surface temperature)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ignition temp.</td>
<td>T1 (450°C)  T2 (300°C)  T3 (200°C)  T4 (135°C)  T5 (100°C)  T6 (85°C)</td>
</tr>
<tr>
<td>&gt; 450°C</td>
<td>300–450°C</td>
</tr>
<tr>
<td>&gt; 842°F</td>
<td>572–842°F</td>
</tr>
<tr>
<td>I</td>
<td>methane</td>
</tr>
<tr>
<td></td>
<td>ammonia</td>
</tr>
<tr>
<td></td>
<td>benzene</td>
</tr>
<tr>
<td></td>
<td>ethyl acetate</td>
</tr>
<tr>
<td></td>
<td>methane</td>
</tr>
<tr>
<td></td>
<td>methanol</td>
</tr>
<tr>
<td></td>
<td>propane</td>
</tr>
<tr>
<td></td>
<td>toluene</td>
</tr>
<tr>
<td>IIA</td>
<td>acetone</td>
</tr>
<tr>
<td>Ignition energy</td>
<td>ammonia</td>
</tr>
<tr>
<td>more than 0.18 mJ</td>
<td>benzene</td>
</tr>
<tr>
<td></td>
<td>ethyl acetate</td>
</tr>
<tr>
<td></td>
<td>methane</td>
</tr>
<tr>
<td></td>
<td>methanol</td>
</tr>
<tr>
<td></td>
<td>propane</td>
</tr>
<tr>
<td></td>
<td>toluene</td>
</tr>
<tr>
<td>IIB</td>
<td>hydrogen</td>
</tr>
<tr>
<td>Ignition energy</td>
<td>cyanide</td>
</tr>
<tr>
<td>0.06 to 0.18 mJ</td>
<td>coal gas</td>
</tr>
<tr>
<td></td>
<td>ethylene</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>IIC</td>
<td>hydrogen</td>
</tr>
<tr>
<td>Ignition energy</td>
<td></td>
</tr>
<tr>
<td>less than 0.06 mJ</td>
<td></td>
</tr>
</tbody>
</table>

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## Equipment group III

<table>
<thead>
<tr>
<th>Equipment group</th>
<th>Area</th>
<th>Type of dust</th>
</tr>
</thead>
<tbody>
<tr>
<td>IIIA</td>
<td></td>
<td>combustible flyings</td>
</tr>
<tr>
<td>IIIB</td>
<td>Dust</td>
<td>non-conductive dust</td>
</tr>
<tr>
<td>IIIC</td>
<td></td>
<td>conductive dust</td>
</tr>
</tbody>
</table>
## EPL / category / zone

<table>
<thead>
<tr>
<th>EPL</th>
<th>Group</th>
<th>Equipment Group</th>
<th>Equipment Category</th>
<th>Zones</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ma</td>
<td>I</td>
<td>I</td>
<td>M1</td>
<td>NA</td>
</tr>
<tr>
<td>Mb</td>
<td></td>
<td></td>
<td>M2</td>
<td></td>
</tr>
<tr>
<td>Ga</td>
<td>II</td>
<td></td>
<td>1G</td>
<td>0</td>
</tr>
<tr>
<td>Gb</td>
<td></td>
<td>II</td>
<td>2G</td>
<td>1</td>
</tr>
<tr>
<td>Gc</td>
<td></td>
<td></td>
<td>3G</td>
<td>2</td>
</tr>
<tr>
<td>Da</td>
<td>III</td>
<td></td>
<td>1D</td>
<td>20</td>
</tr>
<tr>
<td>Db</td>
<td></td>
<td></td>
<td>2D</td>
<td>21</td>
</tr>
<tr>
<td>Dc</td>
<td></td>
<td></td>
<td>3D</td>
<td>22</td>
</tr>
</tbody>
</table>
ATEX – Marking (1)

CE mark and number of the Notified body involved in the audit process

European Ex mark

II  Group I for Mining  Group II for Others

2 G  M1 (for zone 1)  1 G/D (for zone 0)
M2 (for zone 2)  2 G/D (for zone 1)

M for mining (methane)  G for gases and vapor

D for dusts

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ATEX Marking (2)

Ex  Symbol for explosion protected equipment

de  Symbol of the type of protection
d  - flameproof enclosure - for the main part
e  - increased safety - auxiliary part

IIIC  Group: I – Mining, II - Gas, III – Dust
subdivisions in A, B, C for several type of protections

T4  Temperature class
T4 – max. surface temperature is 135 °C

Gb  Equipment protection level-
G – Gas , M – Mining, D – Dust
a – Zone 0+1+2, b – Zone 1+2, c – Zone 2

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ATEX / IECEx Marking (3)

Name and address of manufacturer
ABC company LTD.
Main street 56, 65443
Dusan, South Korea

Serial number including year of manufacture
S.Nr.: D123456 2010

Certificate number
May end with U – Component cert.
May end with X – Special conditions for safe use

Additional certificate (optional)

Explosion protection marking (ATEX):
Equipment Group (I) and Category (2)
Type of explosive atmosphere
G – gas, vapor or mist / D – dust

Marking accd. IEC/CENELEC

Equipment name/type
CE marking and number of Notified Body responsible for the monitoring of the Quality System (0102 = PTB Germany)

Electrical parameters
Ambient temperature
-25°C to +55°C
(if -20°C to +40°C, marking is not required - Standard for all equipment)

Other essential information required by the used Standards

Made in Germany

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Example: Flameproof motor

Marking: II 2 G  Ex de IIC T3

Metal enclosure material
e.g. cast iron

self-ventilated

Operation mode: S1

Components (bushings, cable entries, terminals) are separate certified

Increased safety terminal box

One electrical design

Ambient temperature:
-20 °C to 40 °C

Flameproof motor enclosure

Technical description
Drawings of all details

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Constructive requirements (60079-0)

- Enclosure materials must be suitable for the scheduled application (e.g. temperature range, light resistance)
- Thermal endurance test to heat and cold in case of non-metallic enclosures / part of enclosures (e.g. sealant, O-rings)
- Electrostatic charges must be avoided
  Limitation of thickness of non-metallic layer (varnish)
- Impact test on the enclosure
  most critical point: cover of terminal box at -20 °C
- Temperature measurements
  surface temperature shall not be exceeded under one fault conditions
  service temperatures for all used material and components
Constructive requirements (60079-1)

• Enclosure must be constructed to withstand an overpressure of 1.5 times the explosion (reference) pressure (in case of plastic materials after the thermal endurance test).
• Flameproof joints must be constructed according to the requirements of the standard and the enclosure must withstand the non-transmission test.
• For joints of shafts the k and m values must be calculated taking all tolerances into account.
• Routine overpressure test with 1.5 times of the explosion pressure must be applied to every enclosure in production.

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k/m calculation

Taking in account:
• Bearings clearance
• Tolerances
• Deflection of the shaft in the area of the gap

$k$ minimum radial clearance min. 50 µm
$m$ maximal radial clearance max. 2/3 of constructive allowed gap

Flameproof joint
Reference pressure test

Explosive atmosphere

Gas adaptation

Pressure sensor

Igniter

Pressure

Reference pressure

K3  K2  K1
10  10  10

Point of ignition

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Flame transmission test (1)

Special preparation:

- Max tolerances at all gaps
- Without gaskets and grease

Explosive gas mixture

Igniter/
Gas adaptor
Flame transmission test (2)
Overpressure test

1.5 times reference pressure
→ routine test with 1.5 time reference pressure

4 times reference pressure
→ no routine required (only allowed if not welded)
Overpressure test
Constructive requirements (60079-7)

- Degree of protection provided by the enclosure min. IP 54 (IP test will be done after thermal endurance tests, open and re-close of the enclosure).
- Temperature measurements
  Relevant for the temperature class is the max. temperature inside of the enclosure (terminals / bushings).
- Only separate certified components inside of the e-terminal box are allowed.
- Clearances and creepage distances must be fulfilled and checked.
Thermal endurance test / IP-Test

2 weeks
95 °C / 90 % rel. humidity

2 weeks max. service temperature + 20 K

48 h
- 25 °C

Impact test (7J)

Open and re-close

IP 54 test on the “e” terminal box according IEC 60529

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In the end…. The Certificate

Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin

EC-TYPE-EXAMINATION CERTIFICATE
(Translation)

PTB 11 ATEX 1234

Manufacture: ABC company Ltd.

Address: Main street 58, 05443 Bussan, South Korea

This equipment and any acceptable variation thereon are specified in the schedule to this certificate and the documents therein referred to.

The Physikalisch-Technische Bundesanstalt, certified body No. 0152 in accordance with Article 8 of the Council Directive 94/9EC of 23 March 1994, certifies that this equipment has been found to comply with the Essential Health and Safety Requirements relating to the design and construction of equipment and protective systems intended for use in potentially explosive atmospheres, given in Annex II to the Directive. The examination and test results are recorded in the confidential assessment and test report PTB Ex E13545.

Compliance with the Essential Health and Safety Requirements has been assured by compliance with:
EN 60079-0:2009

The sign “X” is placed after the certificate number, it indicates that the equipment is subject to special conditions for safe use specified in the schedule to this certificate.

This EC-type-examination certificate relates only to the design, examination and test of the specified equipment in accordance to the Directive 94/9EC. Further requirements of the Directive apply to the manufacturing process and supply of the equipment. This certificate does not cover these.

The marking of the equipment shall include the following:

Zertifi zierungskonsortium Explosionsschutz
On behalf of PTB:

Dr. Ing. U. Johannsmeyer
Direktor und Professor

Dr. Ing. U. Johannsmeyer
Direktor und Professor

IECEx Certificate of Conformity
INTERNATIONAL ELECTROTECHNICAL COMMISSION
IEC Certification Scheme for Explosive Atmospheres
for rules and details of the IECEx Scheme visit www.iecex.com

Certificate No.: IECEx PTB 09-00211X
Issue No. 0
Certificate Holder: Issue No. 0 (2006-0-20)

Status: Current

Date of issue: 2010-10-22 Page 1 of 4

Applicant: ABC company Ltd.
Main street 58
05443 Bussan
Korea, Republic of

Electrical Apparatus: Three phase asynchron motor type KOM 132-L4

Type of Protection: Flameproof Enclosures “d”, Increased Safety “e”

Marking: Ex de IEC TX Gb

Approved for issue on behalf of the IECEx Certification Body: Dr.-Ing. Uwe Klausmeyer

Position: Head of Section “Flameproof Enclosures”

Signature (for proof version): 

Date: 

1. This certificate and schedule may only be reproduced in full.
2. This certificate is not transferable and remains the property of the issuing body.
3. The status and authenticity of this certificate may be verified by visiting the official IECEx Website.

Certificate issued by:
Physikalisch-Technische Bundesanstalt (PTB)
Bundesallee 105
38116 Braunschweig
Germany

www. atexegitim.com
Thank you for your attention!

Your questions please…….