Derek Bryans – Business Development Manager, QLD

Shannon Bono – Applications Engineer

Selecting Motors for Hazardous Areas

Definition of an Atmosphere

Atmosphere can be classified as:

- Non-explosive atmosphere; the atmosphere does not contain explosive elements and all types of standard products can be used

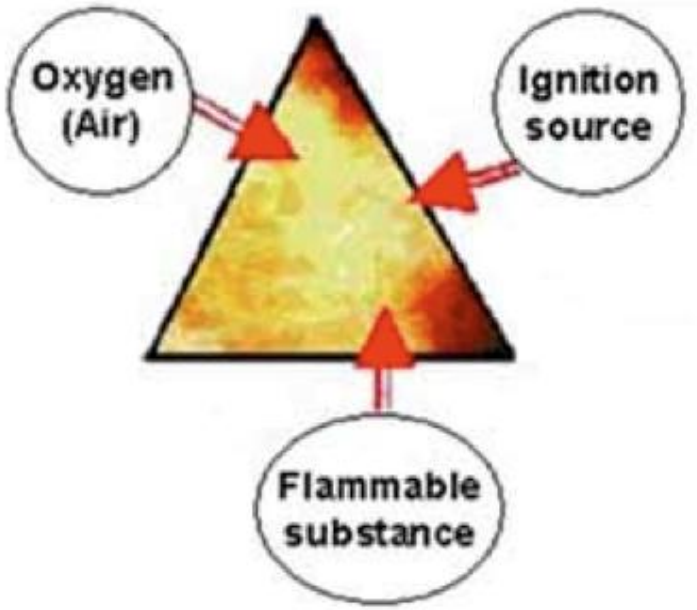
NON-HAZARDOUS AREA

- Explosive atmosphere; the atmosphere contains potentially explosive elements, either gas, vapor, mists or dust and only certified products can be used

HAZARDOUS AREA

The phenomenon of explosive atmosphere

- A potentially explosive atmosphere:
  - An explosion is defined as a sudden reaction involving rapid physical or chemical decay accompanied by an increase in temperature or pressure, or both.

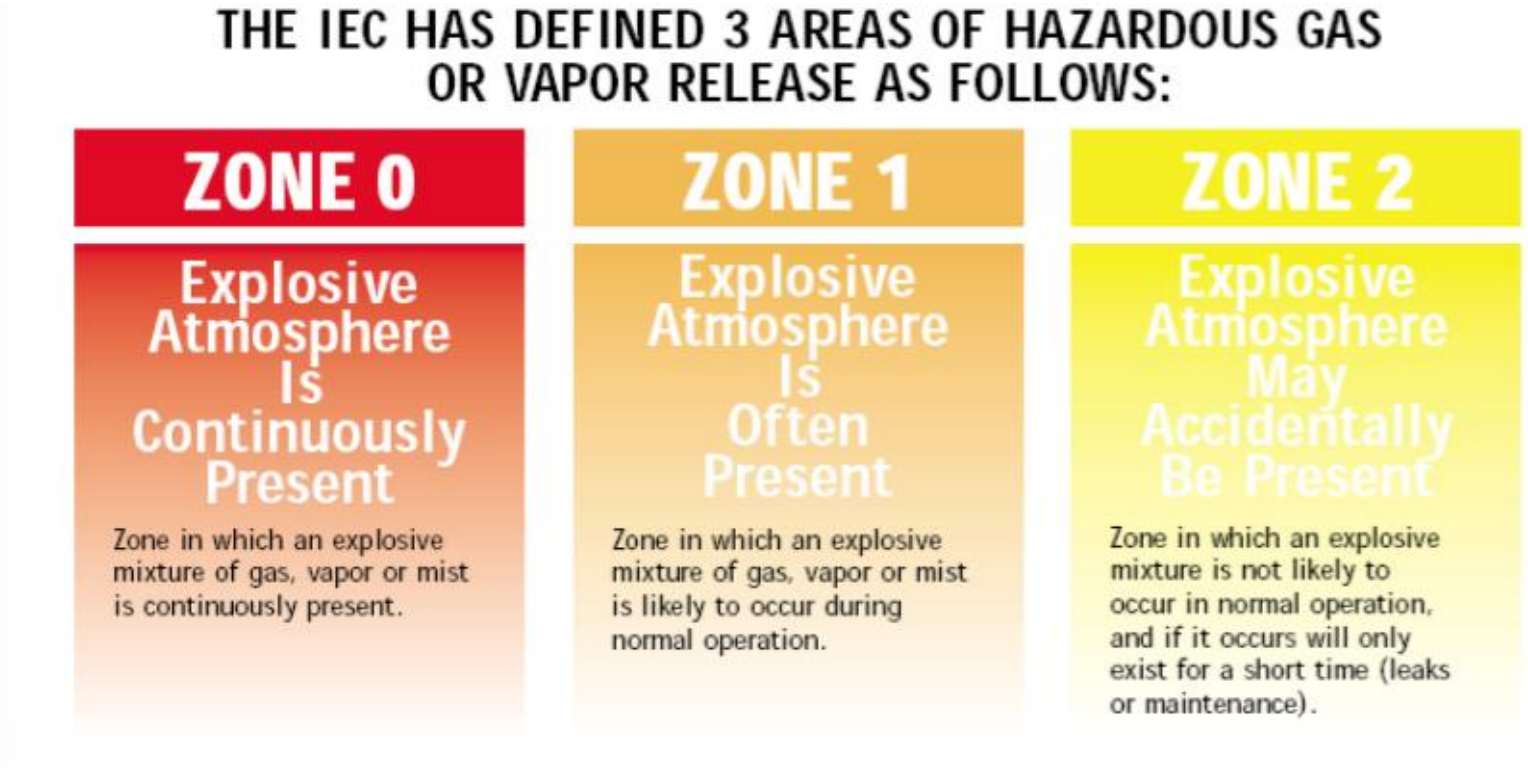


Potential ignition sources

- In industrial electrical equipment:
  - hot surfaces, electrical sparks, friction and impact sparks

- Other sources of ignition:
  - flames and hot gas
  - chemical reactions or biological processes
  - lightning
  - intense electromagnetic radiation
  - ionizing radiation

Hazardous environments - group II



GAS PRESENCE	> 1000 hours/year	10 - 1000 hours/year	< 10 hours/year

4 essential questions to determine a zone

1 What is emission level of gas/vapor?
(a) continuous, (b) first level emission, (released during normal operation)
(c) second level emission (released during abnormal operation)

2 What type of openings currently exist?
(a) continuously open, (b) normally closed,
(c) weatherproof, (d) emergency open only

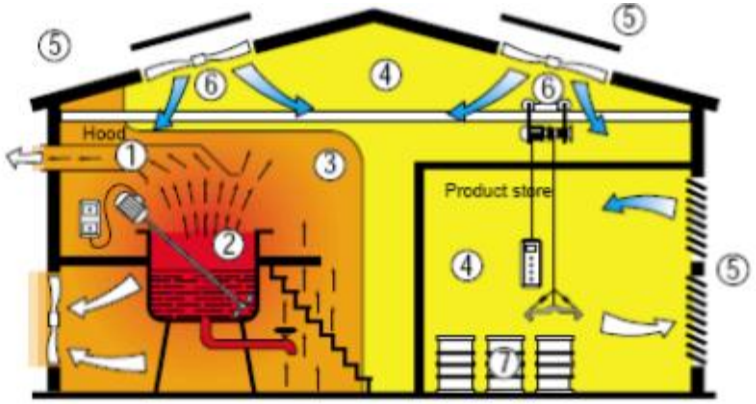
3 What is ventilation?
(a) very good, (b) good, (c) poor

4 What is level of ventilation?
(a) high, (b) average, (c) weak

- Basic approach: Reduce to an acceptable level the probability of coincidence of a flammable atmosphere and a source of ignition

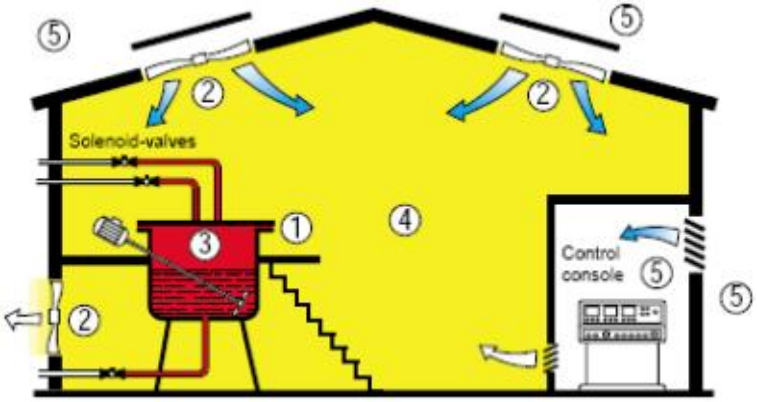
Example of different zones

ZONE 0 | ZONE 1 | ZONE 2 | NON HAZARDOUS ZONE



CONDITIONS:

1. Hood over tank
2. Zone 0 area
3. Zone 1 area
4. Zone 2 area
5. Non hazardous area
6. Mechanical ventilation
7. Stored products separated from work area

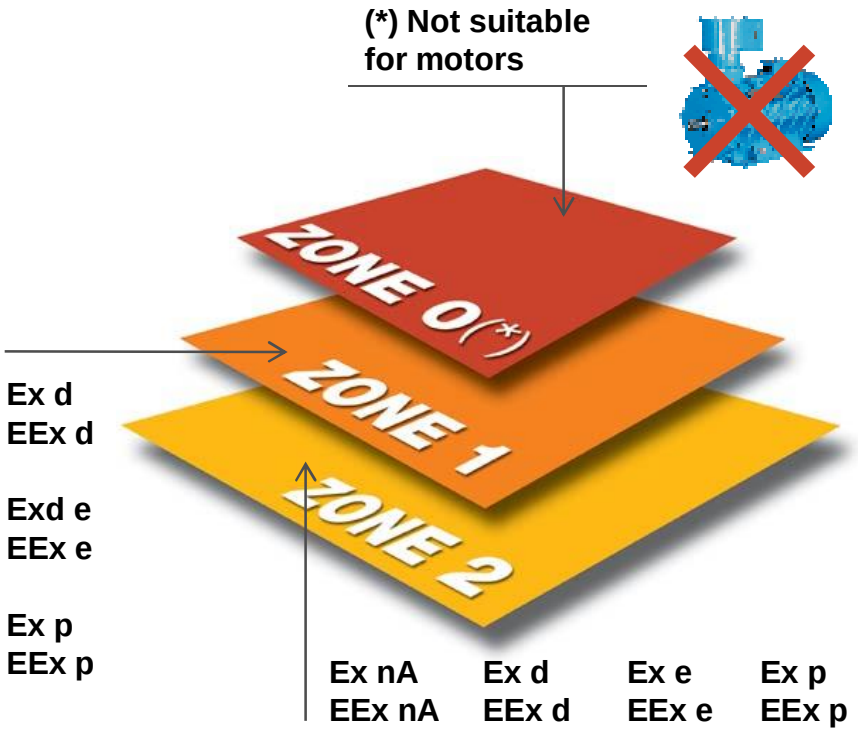


CONDITIONS:

1. Tank closed
2. Mechanical ventilation
3. Zone 0
4. Zone 2
5. Non hazardous area

- Operations control outside zones

IEC and EN standards



Apparatus groups

- Group I - Mines susceptible to fire damps (Methane)
- Group II - Other places

Gas groups

(needed only for Ex d and Ex e)

- IIA (e.g. Propane)
- IIB (e.g. Ethylene)
- IIC (e.g. Acetylene and Hydrogen)

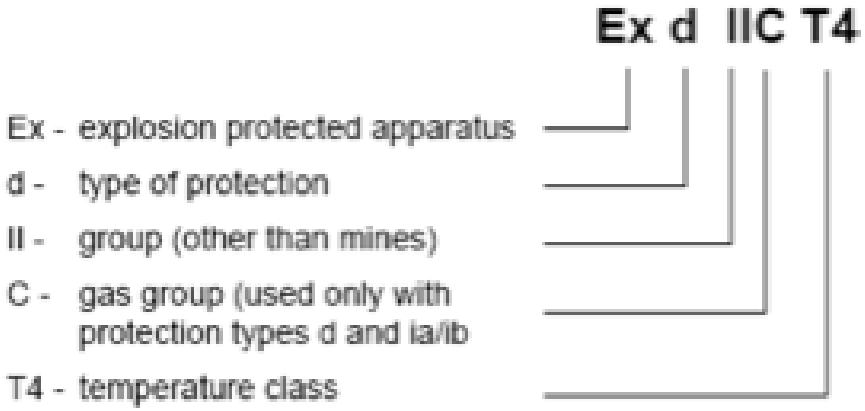
Zones

- Zone 0 - continuously
- Zone 1 - occasionally
- Zone 2 - in abnormal conditions

Temperature classes

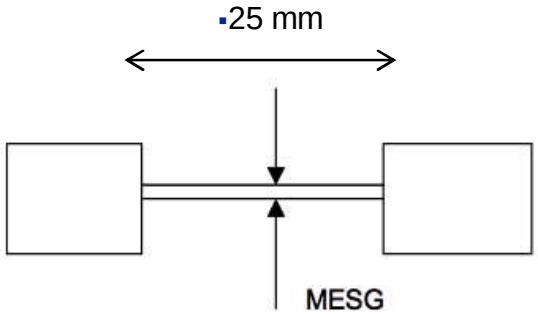
T1	T2	T3	T4	T5	T6
450 °C	300 °C	200 °C	135 °C	100 °C	85 °C

Gas and vapor subdivisions



- The group of gas according to the Maximum Experimental Safety Gap (MESG)

Group of gas (subdivisions)	MESG (Max. Experimental Safety Gap)	Combustible substance
A	> 0.9 mm	~120 gases and vapors: ethane-propane-butane, benzene-methanepetroleum, diesel, oil-ethanethiol
B	0.55 – 0.9 mm	~30 gases and vapors: ethylene-dimethyl, ether, coke oven gas
C	< 0.5 mm	3 gases: hydrogen H2-acetylenen C2H2, carbon disulphide CS2



- 10 tests to be done without any explosion transfer between box 1 and box 2

Comparison between division and zone system

Atmosphere	Zone	Definitions	Presence of explosive atmosphere per year
Gas	0	Explosive atmosphere is present continuously or for long periods or frequently	> 1000 h
Dust	20		
Gas	1	Explosive atmosphere is likely to occur in normal operation occasionally	10 h...100 h ...1000 h
Dust	21		
Gas	2	Explosive atmosphere is not likely to occur in normal operation, but if it does occur it will persist for a short period only	< 10 h
Dust	22		

Atmosphere	HAZLOC area NEC 500	Definitions
Gas or dust	Division 1	Explosive atmosphere is present continuously for long periods
Gas or dust	Division 2	Explosive atmosphere is unlikely to occur or, if it does occur, is likely to be of short duration and not in normal duty

ATEX & IEC standard

Standards

EN 60079-0 IEC 60079–0 General Rules for all Ex Motors			
EN 60079-2 IEC 60079–2 Pressurised “p”	EN 60079-1 IEC 60079–1 Flame Proof “d”	EN 60079-7 IEC 60079–7 Increased Safety “e”	EN 60079-15 IEC 60079–15 Non Sparking “n”

Zones

ZONE 1	ZONE 2

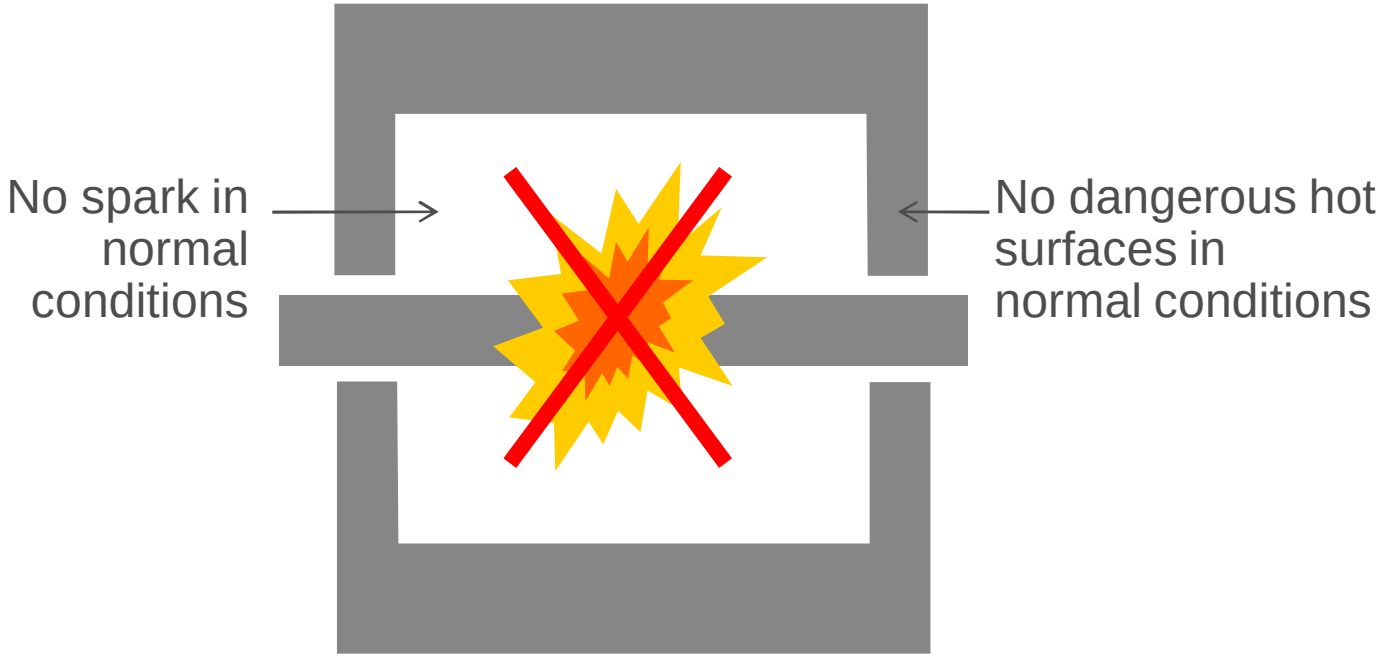
Motor category (ATEX only)

Category 2	Category 3

Non sparking motors (Zone 2)
Ex n

What does it mean Non Sparking enclosure ?

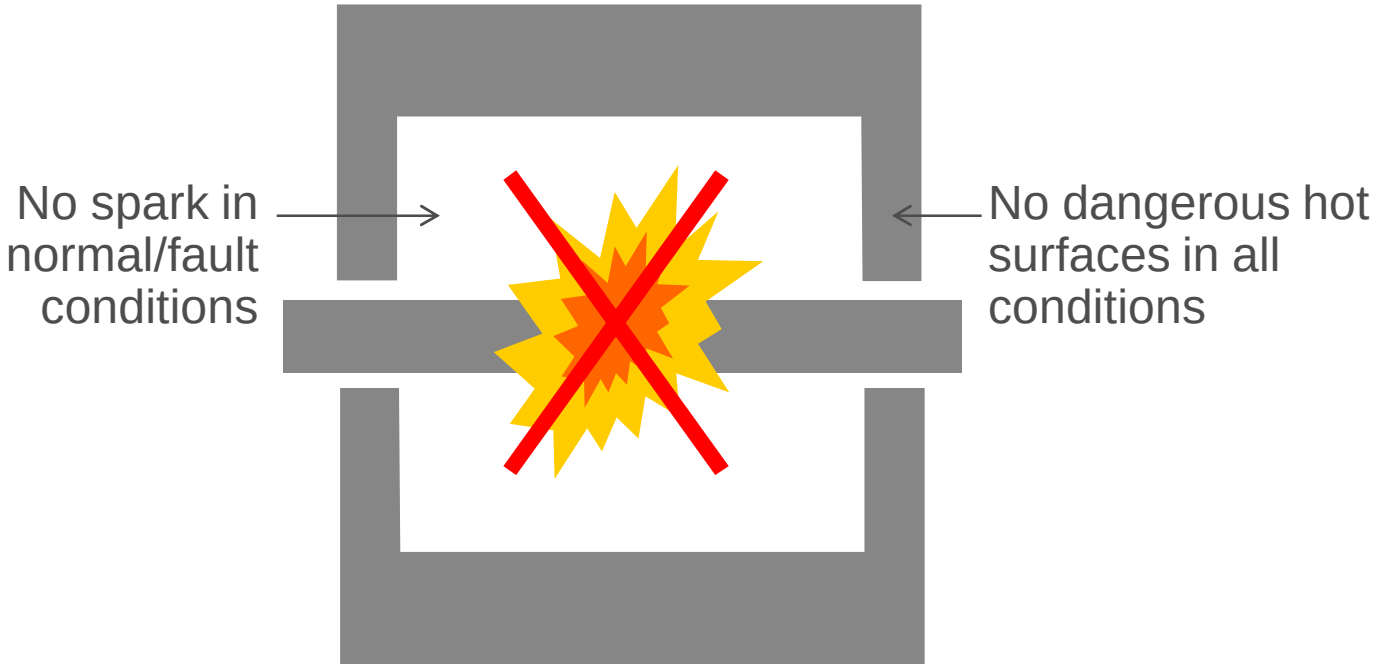
- Parts which could ignite an explosive gas are manufactured in such a way that to prevent ignition of flammable gas



Increased safety motors (Zone 1)
Ex e

What does it mean Increased Safety enclosure?

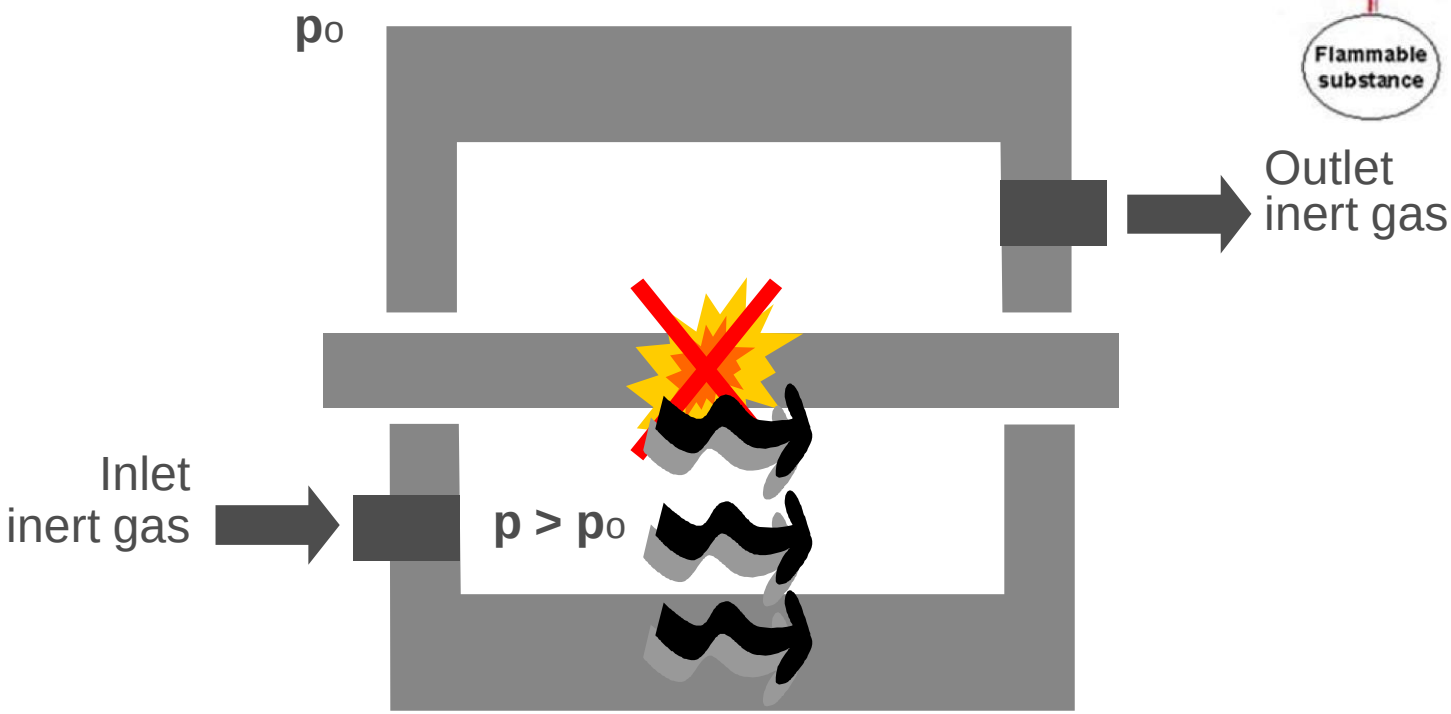
- Parts which could ignite an explosive gas are manufactured in such a way that to prevent ignition of flammable gas



Pressurized motors
Ex p

What does it mean Pressurized enclosure ?

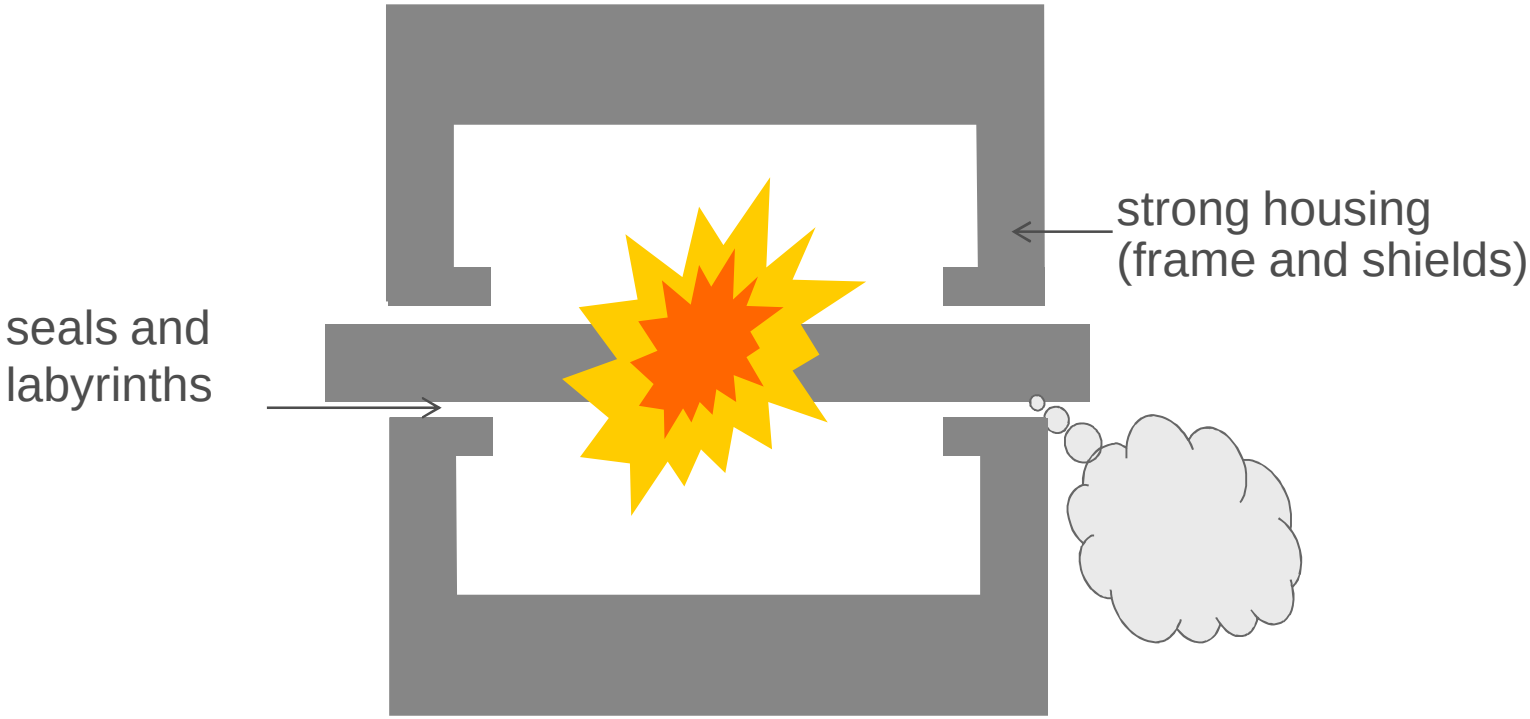
- Parts which could ignite an explosive gas mixture are housed in an enclosure which is flushed and pressurized by a protective gas, e.g. clean air



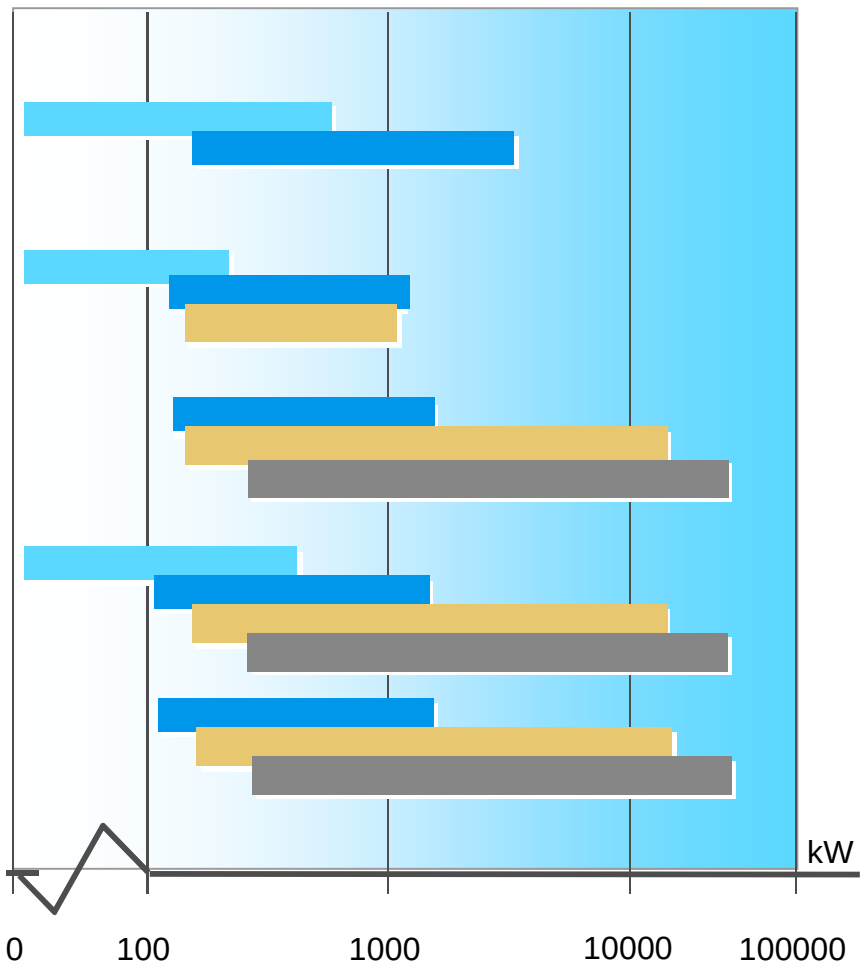
Flameproof motors
Ex d

What does it mean Flameproof enclosure ?

- The enclosure is designed in such a way that an explosion inside the motor will not cause any permanent deformation and will prevent the flame propagation outside



Motors & generators for hazardous locations



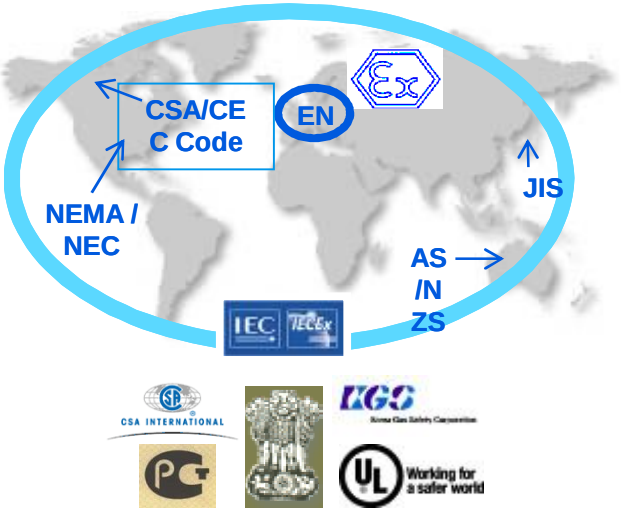
Hazardous areas

- Flameproof Ex d/Ex de
  IEC 80-710, up to 4500 kW
- Increased safety Ex e
  IEC 80-500, up to 1500 kW
- Pressurized Ex px/Ex pxe
  IEC 355-2500, up to 60 MW
- Non-sparking Ex nA
  IEC 71-2500, up to 60 MW
- Class I Div 2/Zone 2
  up to 60 MW, 80000 HP

(full data on the complete range available on request)

LV motors
HV Cast iron frame
HV Welded frame
Synchronous

Certification for hazardous area motors



Certifications used as global

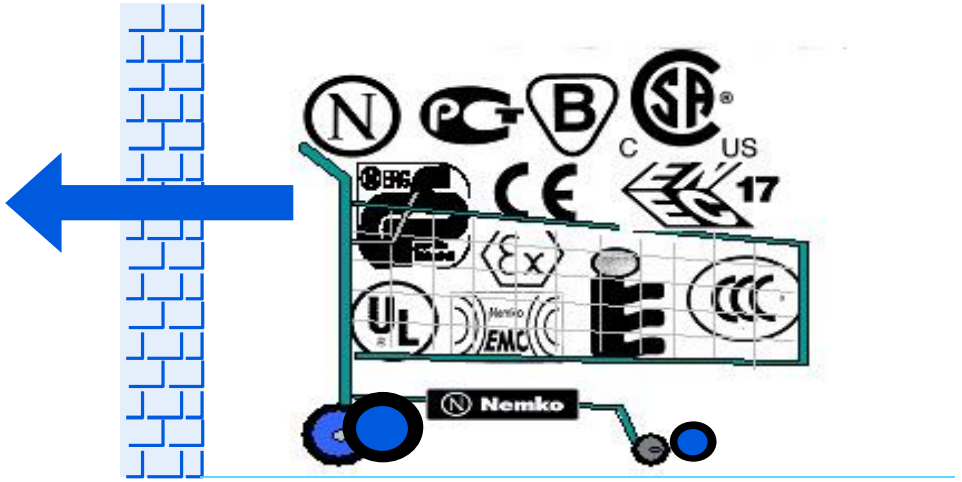
- IEC certificate
- IECEx Scheme certificate
- ATEX certification
- CSA and/or UL certification

Typical national certifications

- GOST to Russia
- Inmetro to Brazil
- CQST for China
- KOSHA for Korea
- CCE / DGFASLI for India

Local certifications
Based on IEC or ATEX

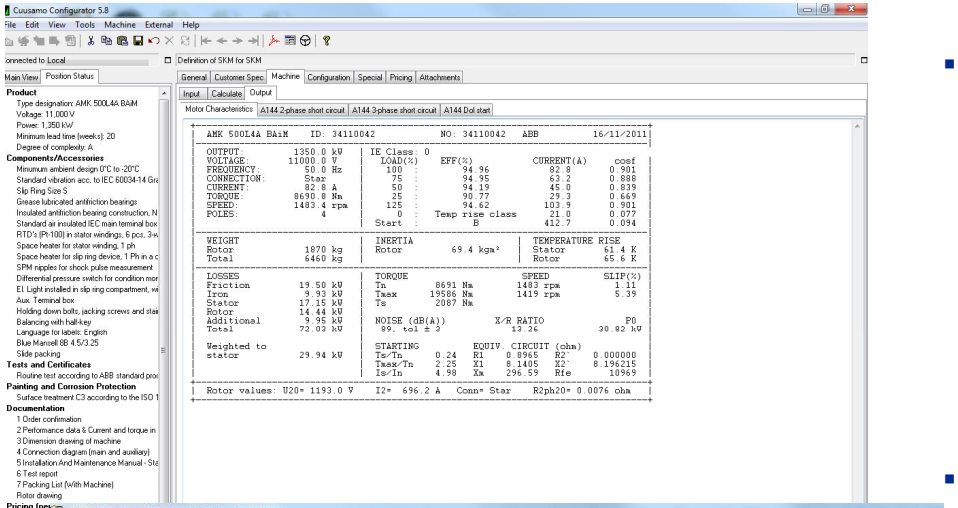
Local certifications are mainly obtained based on IEC or ATEX



Ex-standards
Approval process

Category 2	Category 3
Flameproof, increased safety, pressurised, dust ignition proof	Non-sparking, dust ignition proof
EC type examination	Internal control of production
Product quality assurance	Product quality assurance
CE Marking: CE Ex 0081 II 2 G – D **Complementary marking:** Ex d II C T4 - LCIE 98 ATEX 6015 EC declaration of conformity by ABB	**CE Marking:** CE Ex II 3 G – D **Complementary marking:** Ex nA II T3 EC declaration of conformity by ABB
Inspection by Notified Body with 3 years validity and yearly audit	Self declaration of conformity is accepted

Single source for all protection types



- When specifying motors or generators, correct protection type has to be selected acc. to the operating and ambient conditions. ABB have 2 x software packages we use for sizing Hazardous Area motors. One dedicated to catalogue L.V motors and the other is for L.V to H.V machines

- The ABB Library is an extensive data base of drawings, certificates, test reports etc

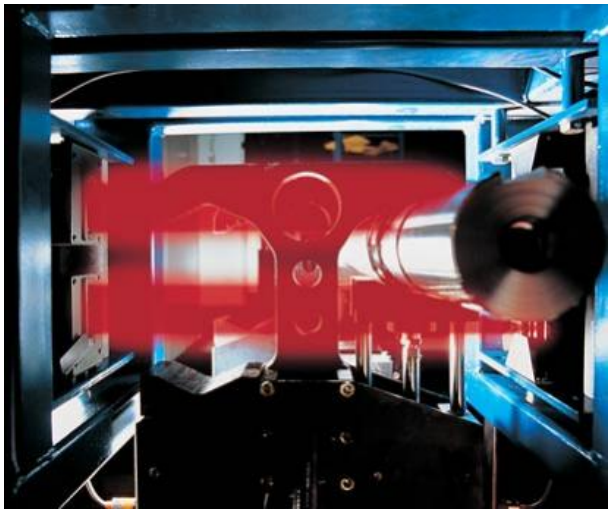
Full compliance with standards

- All protection types
  - Ex d(e) - flameproof
  - Ex nA – non-sparking
  - Ex e – increased safety
  - Ex p – pressurized
  - Class I Division 2
  - Class I Zone 2
  - Class I Zone 1
- Global and local certifications
  - All motors supplied by ABB are certified as meeting official requirements
  - ATEX certified
  - IECEx certified
  - Comply to US and Canadian standards
  - Complying also several national standards like Russia, Kazakhstan, Australia and China

Certified for use with drives

- ABB’s Ex motors are tested for safe use with drives and ABB offers tested/blanket certified drive and motor combinations.
- No need for earth brushing

Custom features in standard products



- Developed in close co-operation with customers in the oil, gas, petrochemical and chemical industries.
- Compliant to Shell DEP specifications
- Customized to provide enhanced reliability, safety and energy economy as standard. Factors taken into consideration when Shell signed 5 year EFA with ABB for motors up to 4MW (Aug, 2011)

Fin Fan Design – Ex Certified

Motors for air coolers in hazardous area applications

FACT FILE

PM310 EN Rev A 2004

Product Notes

Application principle

An air-cooled heat exchanger (ACHE) is a device for rejecting heat radiation from fluid directly to the ambient air.
An air-cooled heat exchanger does not require water. For this reason a plant that requires a high cooling capacity does not need to be located close to a cooling water supply.
Air-cooled heat exchangers are used as process coolers in gas processing (LNG plants), petroleum refining and similar applications within the chemical, oil and gas, and petrochemical industries.

There are mainly two types of air-cooled heat exchangers:

1. Induced draft unit
In the induced draft design, air is pulled across a finned tube surface, and the fan is located above the tube bundle.

2. Forced draft unit
The forced draft unit pushes air along the finned tube surface. The fans are located below the tube bundle.

Low voltage motor range

Motors of this application are positioned with their shaft upwards in very demanding site conditions such as high humidity, rain and dust. It is extremely important to prevent any damage caused by water entering the motors. This sets high requirements on sealing, especially with regard to bearings.
In order to ensure trouble-free operation of air-fin fan cooler drives or similar applications we have implemented a new design for our motors.

Range
Protection type: Low voltage non-sparking and flameproof motors
Frame sizes: IEC 160-250

www.abb.com/motors&drives

ABB

Specifications subject to change without notice.

FACT FILE

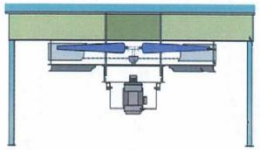
PM310 EN Rev A 2004

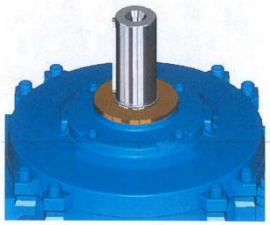
Product Notes

Design features

The motors are equipped with a specially designed end shield in order to achieve good drainage. The shaft sealing is a maintenance free, non-contacting labyrinth seal.

The design can be used for both foot- and flange-mounted motors, IM V3, V36 and V6.





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International IECEx Certification

Product note
International IECEx certification for hazardous area motors

IECEx Conformity Mark for low voltage motors

IECEx Conformity Mark for high voltage motors

What is the IECEx System?
The IECEx System is a certification system which verifies compliance with IEC international standards relating to safety in hazardous areas. It covers equipment, service facilities and the competency of personnel.

IECEx is a voluntary system which provides an internationally accepted means of proving compliance with IEC standards. It also means that the products can be supplied to the market without the need for additional tests. In the case of equipment, IECEx certification confirms that products have the appropriate protection for use in explosive atmospheres and that they have been manufactured under systems subject to ongoing surveillance by IECEx Certification Bodies (ExCBs). It is recognized in many countries around the world, including all the countries participating in the IECEx System, with the United Nations formally endorsing IECEx in November 2009.

The IECEx Conformity Mark (illustrated on this page) is used on Ex motors and other products which have been granted an IECEx Certificate of Conformity. It provides confidence for end-users that the equipment meets the requirements of the relevant standards.

The Mark includes the IEC logo and a code identifying both the Certification Body and license number.

How is the IECEx System organized?
IECEx has established comprehensive procedure to develop a single internationally standardized approach to Ex testing and certification. This approach includes a standardized evaluation process for bodies seeking to become IECEx Testing Laboratories and Certification Bodies and a standardized "IECEx way of Ex Testing and Certification". There is a single set of operational procedures, and Ex test procedures are always applied in the same way. A dedicated Technical and Operational Secretariat maintains the operations. Ex test procedures are evaluated and monitored on a centralized basis.

What does the certification process involve?
IECEx certification is a quality based system which involves – in addition to product tests – assessment of quality control procedures and testing plans, audits of manufacturing plants, and routine on-going surveillance and inspections. IECEx certification differs from the Certifier's own IEC certification, which is usually based on product type testing alone.

The table overleaf summarizes the main steps in a quality based certification system like IECEx. For comparison it also shows the activities involved in type test certification.

Power and productivity for a better world™ ABB

Activity	IECEx (quality based product certification)	IEC (type test product certification)
Select suitable standard	x	x
Develop plan for testing representative samples	x	x
Test samples	x	x
Issue Test Report	x	x
Perform technical review of Test Report	x	x
Assess manufacturer's quality control procedures and testing plans	x	
Conduct audit to verify quality control systems are appropriate and correctly implemented	x	
Issue certificate	x	x
Perform full re-testing to re-issue certificate		x
Issue online certificate via central website	x	
Ensure all Certifiers use single set of Operational Procedures	x	
Operate centralized assessment process for Test Laboratories and Certifiers	x	
Conduct routine, on-going surveillance and audits of manufacturers	x	
Maintain central process for independent sample surveillance of Certifiers' certificates and reports	x	

PM009 EN REVB 2010

IECEx certification is particularly useful in certain markets. In Australia, New Zealand, and Singapore, for example, IECEx certificates are accepted, but not all Certifiers' own IEC certificates are accepted. Certain other countries, including Korea and China, accept IECEx Test Reports (ExTRs) as a basis for their own national certificates. There are also many countries that are willing to accept products covered by current IECEx certificates, even though the countries in question are not members of the IECEx Management Framework.

Who is responsible for the certification work?
A manufacturer needing to have equipment IECEx certified can apply to an ExCB in any member country. The ExCB performs or coordinates the activities shown in the table above.

Samples of the products are tested at the ExCB's test laboratory and a factory inspection is organized. Periodic audits ensure that stringent standards are maintained by the manufacturer.

The IECEx Scheme provides an IECEx Test Report (ExTR), Quality Assessment Report (QAR) and Certificate of Conformity (CoC). These documents are available on the IECEx website, providing verification that the certification procedures have been undertaken for the product and manufacturer in question. Approved Certification Bodies can issue IECEx Conformity Mark Licenses, allowing manufacturers to display the IECEx Conformity Mark on products covered by an IECEx Certificate of Conformity.

How do I know if a motor is IECEx certified ?
The IECEx Conformity Mark clearly shows which products are covered by an IECEx Certificate of Conformity.

In addition, IECEx certificates are publicly available on the IECEx website, which is kept permanently updated. They can therefore be viewed and printed by anyone with access to the Internet. See 'Online Certificates' at www.iecex.com.

IECEx Conformity Mark for ABB motors
ABB is the first motor manufacturer in the world to be granted a License to use the IECEx Conformity Mark. ABB can display the IECEx Conformity Mark on products covered by an IECEx Certificate of Conformity, and on packaging and promotional materials. The IECEx Conformity Mark License considerably enhances ABB's ability to market its products globally. It complements ABB's existing ATEX approval, which is based on two EU Directives governing the use of equipment in potentially explosive atmospheres.

Which ABB motors and generators are IECEx certified?
Certificate includes both DOL and VSD-applications for motors for hazardous areas in low voltage motor types M3GP, M3JP, M3KP and in high voltage motor types M3GM, AMA, AMI and HXR.

For more information please contact:

www.abb.com/motors&generators

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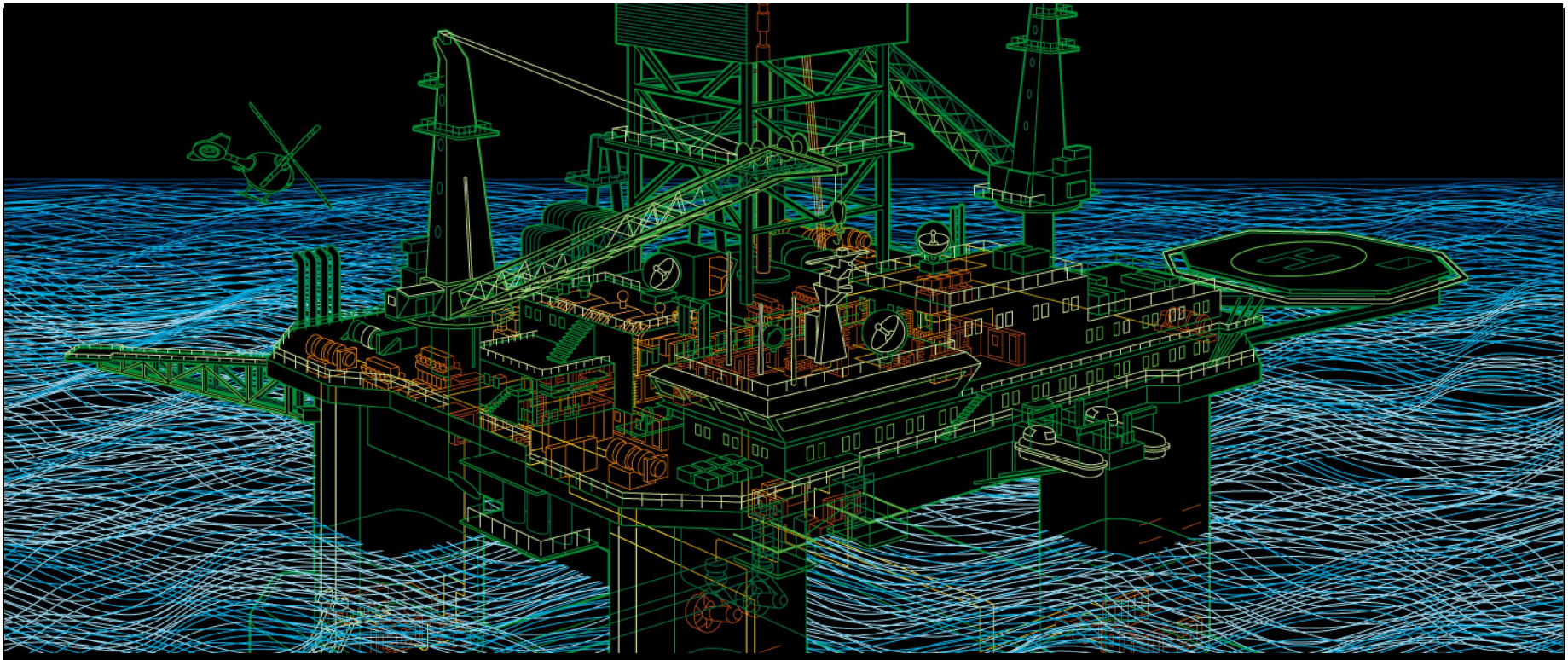
ABB

Maintenance by authorized local partners

- Inspection and maintenance of Ex motors can be carried out only by authorized service shops.
- Authorized servicing available on a local basis thanks to ABB’s worldwide organisation and network.
- ABB Service workshop at Eagle Farm for all motor and generator service, including field service, for LV & MV/HV requirements.



Safety Improvements of Non-Sparking and Increased Safety motors

Power and productivity
for a better world™

Background

- During 1984-1992 there were 6 incidents reported involving HV motors in UK
- Root cause identified as sparking between motor parts and electrical discharges in stator windings

Year	Description	Voltage	Duty
1984	Sparking was observed between a terminal box and side plate during starting. No explosion occurred and the motor continued to operate.	13.8 kV	Crude oil pump
1985	Inspection of an 'in-service' motor suggested that an internal explosion had occurred. The motor continued to operate. The source of ignition was not satisfactorily explained.	11 kV	Gas compressor
1988	A motor exploded during a start up procedure. There was evidence of electrical faults within the stator winding. Most of these faults were thought to have occurred as the motor exploded.	11 kV	Gas compressor with combined lube oil system
1989	A motor exploded on start up. Bonding straps had been fitted. Initial conclusions suggested that ignition was due to an electrical fault in the motor, but the possibility of ignition due to sparking, owing to interruption of circulating currents in the motor enclosure or constructional parts, could not be excluded. Nor could the possibility of some other electrical discharge mechanism.	13.8 kV	Gas compressor with combined lube oil system
1991	A motor exploded during start up. There was evidence of motor faults which could have resulted in sparking.	N/a	N/a
1992	On start up a small explosion from the motor was heard and a flash observed. The motor started successfully and was left running. Subsequent investigation revealed slight distortion of the motor cooler.	11 kV	Gas compressor with common oil/lube seal system

N/a = information not available

History of accidents involving electric motors in the UK

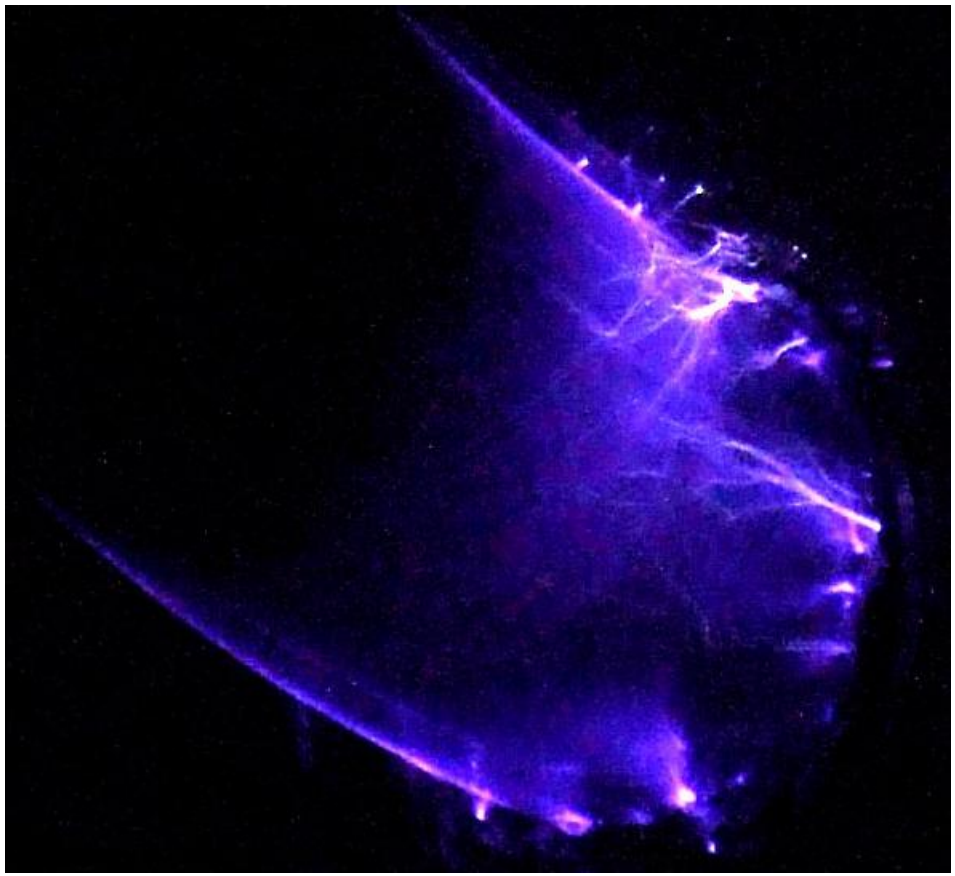
- Further investigations revealed:
  - discharges likely to occur at > 3 kV
  - bar-to-bar currents during start ups
  - contamination of HV insulation

  ► Result: Priorities of risk assessment have been defined
- Immediate responses by End Users:
  - high risk areas identified (compressors in hydrocarbon service)
  - need for equipotential bonding is identified and applied
  - no Ex e for Zone 1 areas, only Ex d and Ex p
  - pre purging of old motors
  - winding contamination checks scheduled (ABB's L.E.A.P tests)
  - EEMUA guide for risk assessment

Where does sparking occur in motors?

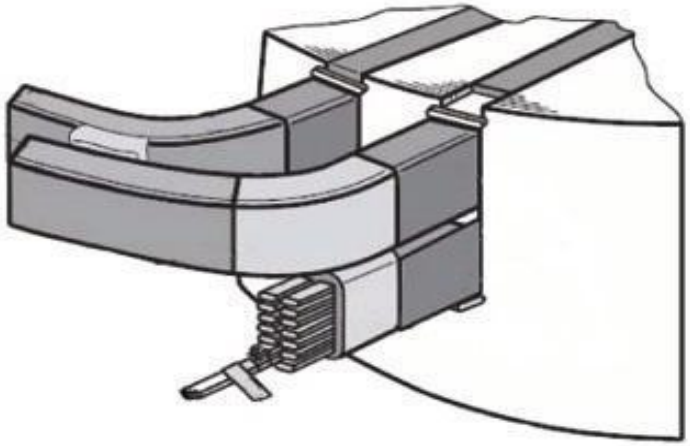
- Extensive studies by manufacturers revealed that sparking can occur at stator windings, at rotor bars and between parts of enclosure.
- **Stator Winding**
- Partial Discharges (PD) – ionization of air inside or on the surface of HV insulation
- Inception voltage can be low subject to structure of insulation
- When? All the time when motor is energised
- Why? Electrical stress distribution is inversely proportional with material permittivity
    - improper stress grading
    - inadequate clearances
    - aging of insulation
    - network voltage transients
    - dirty surfaces
- How to avoid PD?
    - Corona protection by correct stress grading (avoid electrical field differentials)
    - Correct clearances to winding components (RTD wiring)
    - Correct routing of winding leads

Where does sparking occur in motors? - Stator



Intense sparking observed at the edge of lamination (sharp corners intensify electric field)

Photograph courtesy of PTB test laboratory



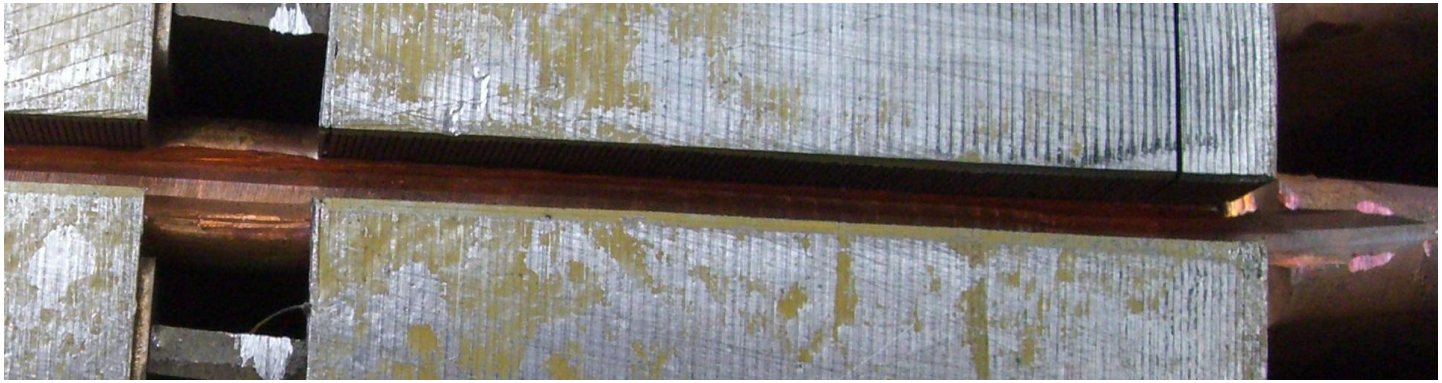
Conductors, turn insulation, phase insulation

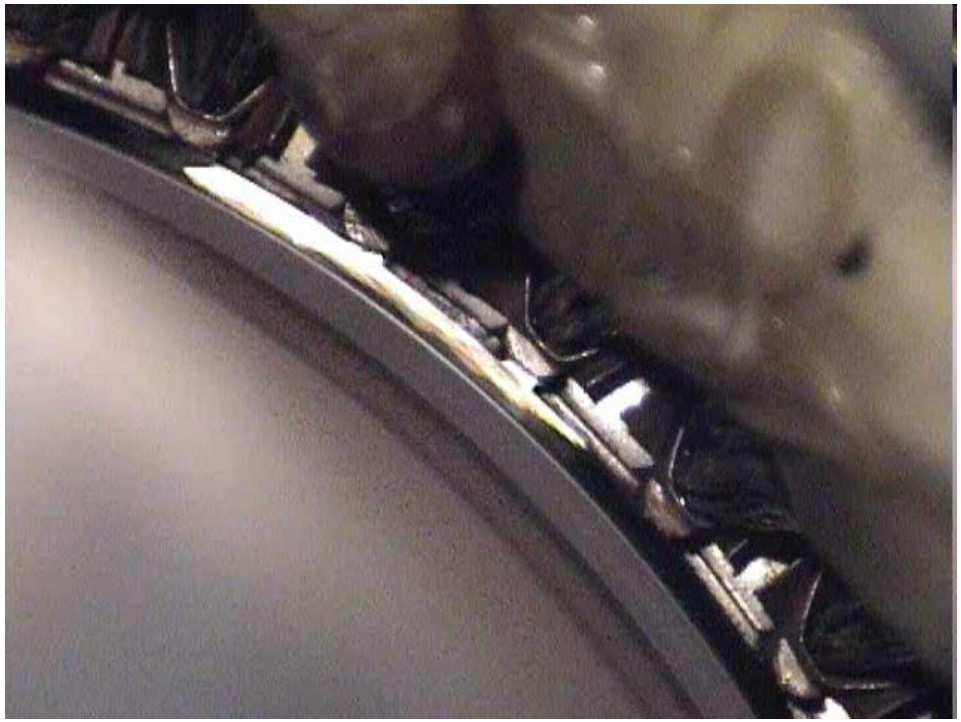
Effective stress grading plays crucial role in prevention of PD’s

Where does sparking occur in motors? Rotor

- Stray current switching (current flows between bars through lamination)
- When? During start ups
- Where? Between bars and lamination at each ends of core
- Why? Stray current interrupted by relative bar movements due to start up stresses and vibration
- How to avoid it?
    - Specific know-how applied for bar fixation
    - Reduce start up stresses by keeping Is/In low or use VSD's
- Note: Sparking does not take place between stator and rotor, i.e. across the air gap!

Where does sparking occur in motors? - Rotor





Rotor bars can be swaged for a tight fit in the slot.
Photograph courtesy of Notified Body

Sparking on the rotor surface.
Photograph courtesy of PTB test laboratory

Where does sparking occur in motors? - Circulating currents

Where and When:

- Between separate parts of enclosures
- When motor magnetized and running
- Over-voltages

Why:

- Parts get unequal charges from the magnetic flux created by the stator
- If parts are not equipotential bonded, they are ‘floating’ on own potential
- Improper grounding
- If equipotential cables are disconnected

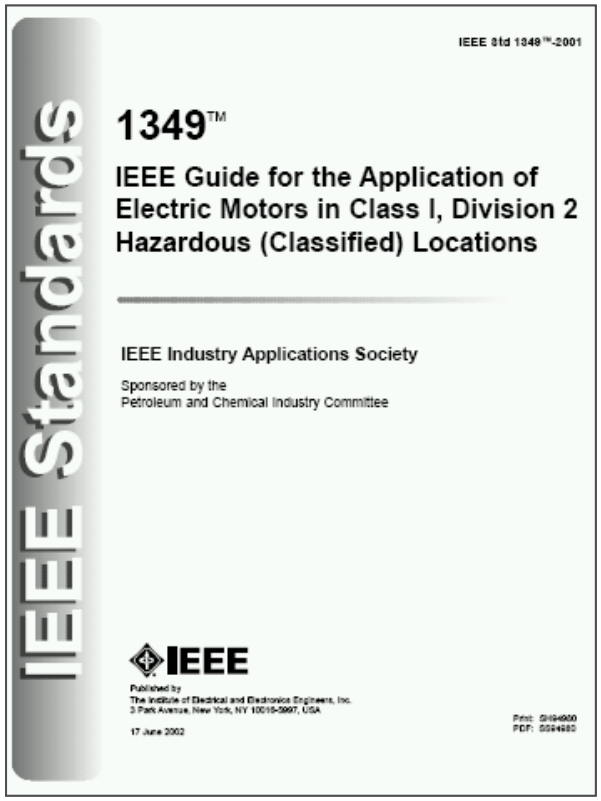
Evolution of Standards

Directive 94/9/EC (ATEX)

"State of the art" principle: manufacturers must go beyond requirements of standards to maximise safety

ENV50269:1997

Risk identification, equipotential bonding, principles of risk assessment even gas environment testing formulated



This guide addresses two Fine Print Notes (FPNs): Section 501-8(b) FPN No. 1 was added to the *NEC* in 1984 as follows: "It is important to consider the temperature of internal and external surfaces that may be exposed to the flammable atmosphere."[3] Section 501-8(b) FPN No. 2 was added to the *NEC* in 1993 as follows: "It is important to consider the risk of ignition due to currents arcing across discontinuities and overheating of parts in multisection enclosures of large motors and generators. Such motors and generators may need equipotential bonding jumpers across joints in the enclosure and from enclosure to ground. Where the presence of ignitable gases or vapors is suspected, clean-air purging may be needed immediately prior to and during start-up periods."[3]

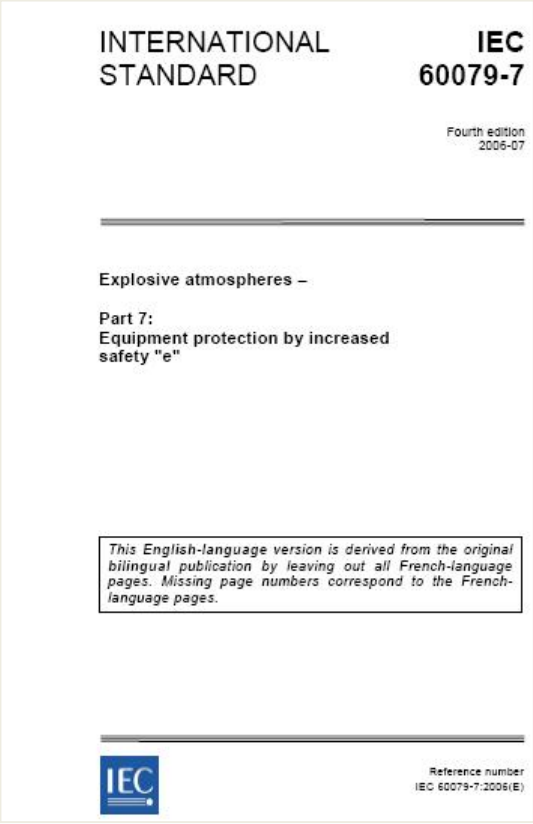
Since the mid-1980s, at least five events involving motors were documented (see Annex J). The extent of these events ranged from internal explosions causing enclosure failure to visible sparking across enclosure panels. In all cases, where the information is known, the motor sizes were over 5 MW or the motor voltage ratings were over 5.5 kV.

Starting in the early 1990s a number of independent engineering groups conducted tests on open-type and TEFC motors in flammable atmospheres. To date, most testing has involved manually filling a motor enclosure with a flammable mixture and measuring the resulting atmospheric and motor

[1] *National Electrical Code*® are registered trademarks of the National Fire Protection Association, Quincy, MA.
[2] The numbers in brackets correspond to those of the bibliography in Annex A.
[3] Reprinted with permission from NFPA 70 *National Electrical Code*® Copyright © 1999, National Fire Protection Association. This reprinted material is not the complete and official position of the NFPA on the reference subject which is represented only by the standard in its entirety.

Recent developments: IEC/AS/NZS60079-15:2005 (Ex n) and IEC/AS/NZS60079-7:2001 then 2006 (Ex e)

Standard with verification requirements



INTERNATIONAL STANDARD

IEC 60079-7

Fourth edition 2006-07

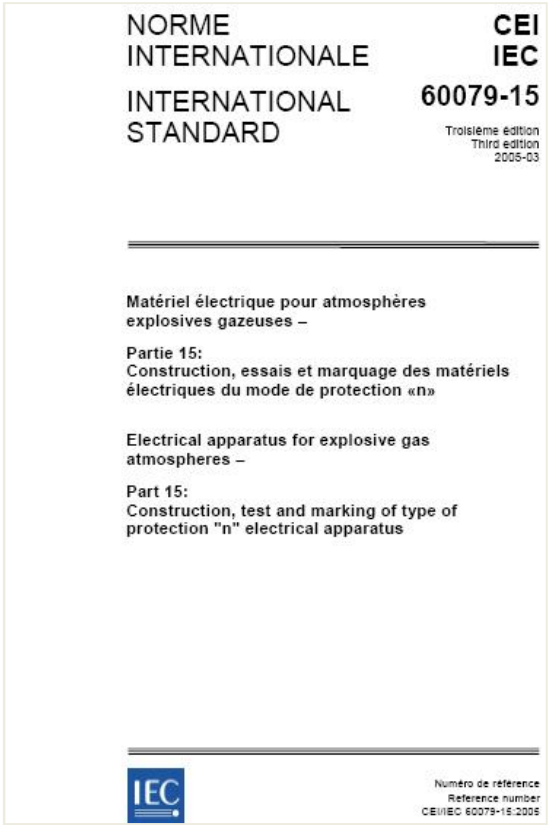
Explosive atmospheres –

Part 7: Equipment protection by increased safety "e"

This English-language version is derived from the original bilingual publication by leaving out all French-language pages. Missing page numbers correspond to the French-language pages.

IEC

Reference number IEC 60079-7:2006(E)



NORME INTERNATIONALE

CEI IEC 60079-15

INTERNATIONAL STANDARD

Troisième édition Third edition 2005-03

Matériel électrique pour atmosphères explosives gazeuses –

Partie 15: Construction, essais et marquage des matériels électriques du mode de protection «n»

Electrical apparatus for explosive gas atmospheres –

Part 15: Construction, test and marking of type of protection "n" electrical apparatus

IEC

Numéro de référence Reference number CEI/IEC 60079-15:2005

- Risk assessment tables appear
- Manufacturer's and end user responsibilities
- "Product standards" and "installation standards" (Part 14)
- Complex, hard to follow requirements
- General conditions standard (Part 0)
- Problem: product standard include end-user activity
- Problem: rapidly changing standards
- Positive: definite safety improvements with risk reduction achieved
- Negative: inconsistencies

Stator risk assessment – Ex e increased safety motors

Risk Assessment Table

Table 5 – Potential stator winding discharge risk assessment – Ignition risk factors

Characteristic	Value	Factor
Rated voltage	> 6,6 kV to 11 kV	4
	> 3,3 kV to 6,6 kV	2
	> 1 kV to 3,3 kV	1
Average starting frequency in service	> 1 / hour	3
	> 1 / day	2
	> 1 / week	1
	< 1 / week	0
Time between detailed inspections (see IEC 60079-17, table 1, type D)	> 10 years	3
	> 5 to 10 years	2
	> 2 to 5 years	1
	2 years	0
Degree of protection (IP Code)	< IP44 [a]	3
	IP44 and IP54	2
	IP5[illegible]	1
	IP55	0
Environmental conditions	Very dirty and wet [b]	4
	Coastal outdoor	3
	Other outdoor	2
	Clean outdoor	1
	Clean and dry indoor	0

Only in clean environments and regularly serviced by trained personnel, see 5.2.1.

"Very dirty and wet" locations include those that may be subjected to deluge systems or comprise open deck on offshore locations.

- Risk assessment must be carried out for **practically all motors at > 1kV**
- If factor numbers are higher than 5 or 6 special measures must be applied
- Special or further measures include pre purging, continuos purging or gas testing
- Assessment is difficult as manufacturer has no control over user practices as conditions, application, ownership may change
- End users confused with construction details
- Requirements differ for various gas groups, voltage / power levels and frequency of start ups

Stator risk assessment – Ex n non-sparking motors

Characteristics	Value	Factor
Rated voltage	> 11 kV	6
	> 6,6 kV to 11 kV	4
	> 3,3 kV to 6,6 kV	2
	> 1 kV to 3,3 kV	0
Average starting frequency in service	> 1 / hour	3
	> 1 / day	2
	> 1 / week	1
	≤ 1 / week	0
Time between detailed inspections (see IEC 60079-17)	> 10 years	3
	> 5 to 10 years	2
	> 2 to 5 years	1
	< 2 years	0
Degree of protection (IP Code)	< IP44 [a]	3
	IP44 and IP54	2
	IP55	1
	> IP55	0
Environmental conditions	Very dirty and wet [b]	4
	Coastal outdoor [c]	3
	Outdoor	1
	Clean and dry indoor	0

[a] Only in clean environments and regularly serviced by trained personnel, see 6.6.1.

[b] "Very dirty and wet" locations include those that may be subjected to deluge systems or comprise open deck on offshore locations.

[c] Exposed to atmospheres containing salt.

Further measures to be applied if the sum of risk factors is greater than 6:

- Stator design shall pass the required gas environment non-sparking tests (para 33.14.2.3), **or**
- Motor shall be equipped with a provision pre-start ventilation (**Note!** operator needs to make decision whether to use it or not, affected by their possibility accept the risk)

Note, the table will be moved to IEC 60079-14 in the future, and the stator gas testing will be compulsory for all random-wound high-voltage stators and all high-voltage form-wound stators in gas groups IIC and IIB, as well as in gas group IIA if the nominal voltage is greater than 6.6kV

Rotor risk assessment

Non-sparking motors (IEC 60079-15:2005)

Characteristic	Value	Factor
Rotor cage construction	Fabricated rotor cage	2
	Cast aluminium rotor cage ≥ 200 kW per pole	1
	Cast aluminium rotor cage < 200 kW per pole	0
Number of poles	2-pole	2
	4-pole to 8-pole	1
	> 8-pole	0
Rated output	> 500 kW per pole	2
	> 200 kW to 500 kW per pole	1
	≤ 200 kW per pole	0
Radial cooling ducts in rotor	Yes: L < 200 mm (Note 1)	2
	Yes: L ≥ 200 mm (Note 1)	1
	No	0
Rotor or stator skew	Yes: > 200 kW per pole	2
	Yes: ≤ 200 kW per pole	0
	No	0
Rotor overhang parts	Non-compliant (Note 2)	2
	Compliant (Note 2)	0
Temperature class	T1 / T2	2
	T3	1
	≥ T4	0

NOTE 1 L is the length of end packet of core. Experimental tests have shown that sparking occurs predominantly in ducts near the ends of the core.

NOTE 2 Rotor overhang parts should be designed to eliminate intermittent contact and to operate within the temperature classification. Compliance with this ruling gives a factor of 0, otherwise it is 2.

Special measures shall be applied if the sum of risk factors is greater than 5

Increased safety motors (IEC 60079-7:2006)

Characteristic	Value	Factor
Rotor cage construction	Uninsulated bar fabricated rotor cage	3
	Open slot cast rotor cage ≥ 200 kW per pole	2
	Open slot cast rotor cage < 200 kW per pole	1
	Closed slot cast rotor cage	0
	Insulated bar rotor cage	0
Number of poles	2-pole	2
	4- to 8-pole	1
	> 8-pole	0
Rated output	> 500 kW per pole	2
	> 200 kW to 500 kW per pole	1
	≤ 200 kW per pole	0
Radial cooling ducts in rotor	Yes: L <200 mm (see Note 1)	2
	Yes: L ≥200 mm (see Note 1)	1
	No	0
Rotor or stator skew	Yes: > 200 kW per pole	2
	Yes: ≤ 200 kW per pole	0
	No	0
Rotor overhang parts	Non-compliant (see Note 2)	2
	Compliant (see Note 2)	0
Limiting temperature	>200 °C	2
	135 °C < T ≤ 200 °C	1
	≤ 135 °C	0

NOTE 1 L is the length of end packet of core. Experimental tests have shown that sparking occurs predominantly in ducts near the ends of the core.

NOTE 2 Rotor overhang parts should be designed to eliminate intermittent contact and to operate within the temperature classification. Compliance with this ruling gives a factor of 0, otherwise it is 2.

Special measures shall be applied if the sum of risk factors is greater than 6

Tests to verify that the designs are non-sparking per IEC 60079 standards:
1. Stator test / Sinusoidal voltage test

- Insulation systems and connection cables shall be tested in an explosive gas mixture comprised of (21 ± 5) % hydrogen-in-air or (7,8 ± 1) % ethylene-in-air, v/v
- U = Sinusoidal voltage of **1.5 times** the rated RMS line voltage for 3 min
- The maximum rate of voltage rise shall be 0.5 kV/s
- No explosion shall occur
- In this test, insulation will be tested between
  - Phase to earth
  - Phase to phase

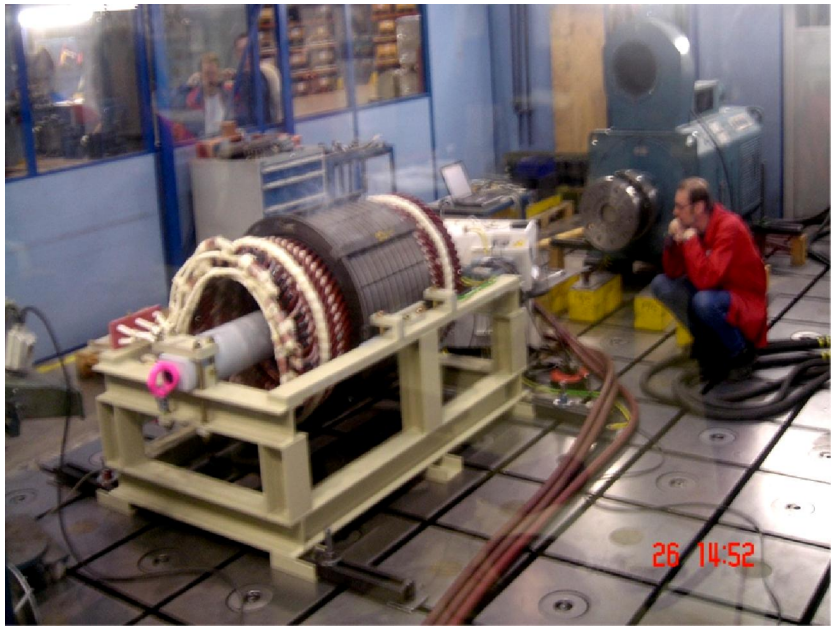
2. Stator test / Voltage impulses test

- Insulation systems and connection cables shall be tested in an explosive gas mixture comprised of (21 ± 5) % hydrogen-in-air or (7,8 ± 1) % ethylene-in-air, v/v
- U = 10 voltage impulses of three times peak phase voltage with tolerance of ±3 %
- Voltage rise time between 0,2 µs and 0,5 µs
- Time to half value which is at least 20 µs but normally not exceeding 30 µs
- Electrical connection same as a sinusoidal voltage test
- No explosion shall occur
- In this test, insulation will be tested between
  - Phase to earth
  - Phase to phase

3. Rotor test

Aging before tests

- The rotor cage shall be subject to an ageing process comprising a minimum of five locked rotor tests
- The maximum temperature of the cage shall cycle between the maximum design temperature and less than 70°C
- The applied voltage >/= 50 % of the rated voltage



Tests

- The same gas mixtures as for stator testing
- Motors shall be subjected to 10 direct-on-line uncoupled starts or 10 locked rotor tests. Duration of at least 1 s
- No explosion shall occur
- Terminal voltage >/= 90 % of the rated voltage. The concentration of hydrogen or ethylene shall be confirmed after each test

Options available under IEC/AS/NZS60079-15:2005 (Ex n) and IEC/AS/NZS60079-7:2001 then 2006 (Ex e) :

1. To perform Risk Assessment for each case together with Manufacturer and keep fingers crossed, or

2. To have a Provision for pre-purging if risk factors limits are exceeded, or

3. To require manufacturers to carry out gas testing and provide certification based on that

Scenario 1 – To perform Risk Assessment for each case

Easiest and most attractive procedure for Manufacturer, but in practice it brings some issues:

- In most of the cases, the risk factor limits are exceeded, and special measures are needed.
- Lack of information flow
  - Effective co-operation is needed between End User and Manufacturer during the motor design phase (through OEM and EPC contractor)
  - All information is not typically available at that time
- Changing specification
  - Risk assessment results might change many times during tendering
- Varying conditions during the machine's life time
- Easy for manufacturers, just advises the relevant items of the list

Scenario 2 – Provision for Pre-Purging when Risk Factor Limits Exceeded

Another easy and economical solution for manufacturers

- Manufacturer provides flanges and End User / Operator takes the responsibility to decide to use them or not
- Safety engineers typically require purging if the risks are indicated
- If pre-purging is selected by end user
  - Does NOT protect against stator partial discharges, which can still occur all the time. That's the reason why IEC 60079-7:2006 requires stator gas environment testing for all Ex e motors above 1kV
  - 10 to 60min delay before each start
  - Additional investments to purge control device, piping and air compressor
  - Additional cost for operator to run air compressor
  - Overall reliability is reduced due to additional components

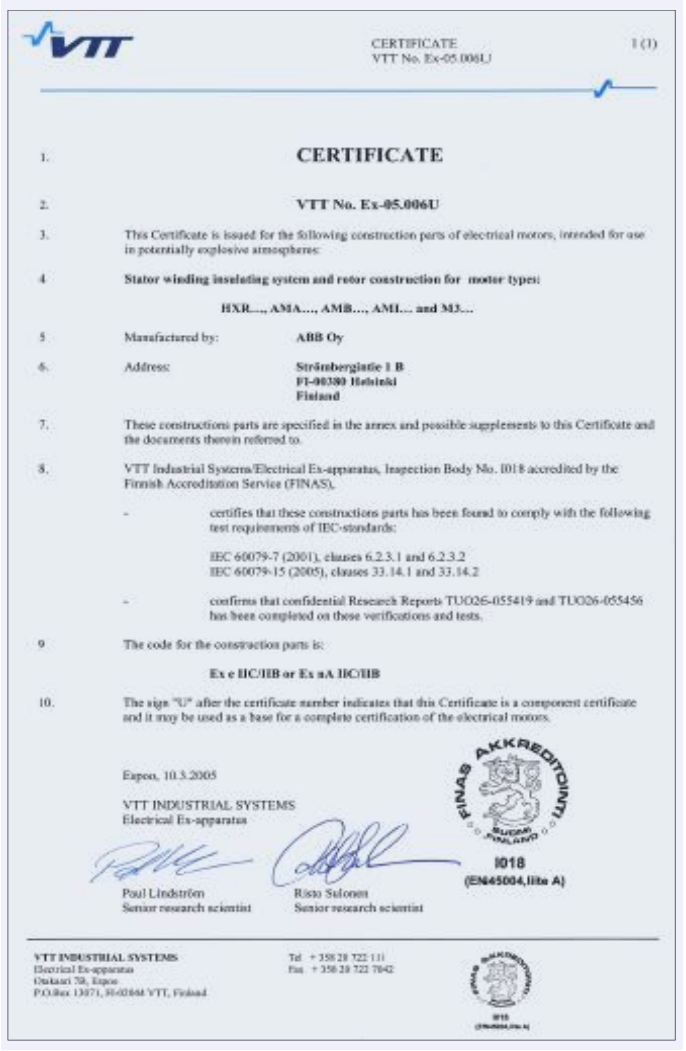
Scenario 3 – Gas testing and Certification

Most difficult and demanding exercise for manufacturers: Gas environment testing for Rotor & Stator is probably the best and safest way for End Users & Operators

- No onus of responsibility on end user for motor safety
- Verified confirmation that motor design is non-sparking as per international standards
- No start up limitations in motor use
- No need to consider risk assessment factor sums as motors are already tested to worst outcome
- No need to review risk assessment, if user conditions are changing e.g. starting frequency or maintenance strategy
- Longer life-time for stator insulation due to no surface discharges (PD's)

ABB's approach: The required gas tests are performed for most of HV motors

- The gas test covers:
- LV Motors < 1kV (rotor test is applicable)
- Induction Machines produced in Helsinki or Shanghai (stator & rotor test passed)
- Synchronous Machines produced in Helsinki (stator test passed)
- Results of the test
  - All rotor test passed (LV & HV)
- Stator test passed (HV)
  - 13.2 kV with IIC gases
  - 15 kV with IIA and IIB gases
- Motors not covered by these tests are equipped with a provision for pre-start purging.



VTT

CERTIFICATE
VTT No. Ex-05.006U

1 (1)

1. **CERTIFICATE**

2. **VTT No. Ex-05.006U**

3. This Certificate is issued for the following construction parts of electrical motors, intended for use in potentially explosive atmospheres:

4. **Stator winding insulating system and rotor construction for motor types:**

HXR..., AMA..., AMB..., AMI... and M3...

5. Manufactured by: **ABB Oy**

6. Address: **Strömbergintie 1 B**
FI-00380 Helsinki
Finland

7. These constructions parts are specified in the annex and possible supplements to this Certificate and the documents therein referred to.

8. VTT Industrial Systems/Electrical Ex-apparatus, Inspection Body No. 1018 accredited by the Finnish Accreditation Service (FINAS),

- certifies that these constructions parts has been found to comply with the following test requirements of IEC-standards:

IEC 60079-7 (2001), clauses 6.2.3.1 and 6.2.3.2
IEC 60079-15 (2005), clauses 33.14.1 and 33.14.2

- confirms that confidential Research Reports TUO26-055419 and TUO26-055456 has been completed on these verifications and tests.

9 The code for the construction parts is:

Ex e IIC/IIB or Ex nA IIC/IIB

10. The sign "U" after the certificate number indicates that this Certificate is a component certificate and it may be used as a base for a complete certification of the electrical motors.

Espoo, 10.3.2005

VTT INDUSTRIAL SYSTEMS
Electrical Ex-apparatus

FINAS AKKREDITOINTI

1018
(EN45004, liite A)

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Benefits of gas tested motor for Operators / End Users

- Streamlining the risk assessment process (no need of risk factor calculations)
- Reinforce the insulation system to increase the life time of products (lack of PD's)
- The alternative to gas testing and certification involves preparing motor with provision for pre-purging
  - Investment in a higher capacity air compressor, piping, and a purge control unit
  - Represent time delay during purging, every time the motor is started

Risk assessment and gas tests for non-sparking and increased safety motors

FACT FILE

PM315 EN RevA Dec 2005

Product notes

Non-sparking (EEx nA / Ex nA) and increased safety (EEx e / Ex e) motors now have to meet tough requirements with regard to sparking. The latest IEC and EN standards specify criteria for risk assessment and gas environment tests for rotor and stator designs to show that the motors are spark-free in all operational conditions.

What are the causes of sparking?

Stator sparking consists of partial discharges at the winding surface due to high potential differences, and it tends to occur continuously while the motor is running. Typical causes are high voltages or inappropriate stress grading, degradation of the insulation due to ageing, voltage transients, or dirt in the windings.

Rotor sparking takes place during starting and occurs between the rotor bars and rotor core, especially in the vicinity of the first radial cooling ducts. It is generally caused by 'shaking' of the rotor bars in the slots, which interrupts current flow between the bars and core. The shaking is the result of angular and radial forces which act on the rotor during starting.

What do the latest standards require?

The tables on next page summarize the main requirements contained in the standards. The requirements depend on a duty type, the voltage and power rating of the motor, and are specified separately for rotors and stators.

Where a risk assessment is required, this is performed using risk factor tables provided in the standards. Depending on the risk factors identified in the assessment, the motor may have to be equipped with a space heater, and / or special measures may be required. Special measures typically involve the provision of pre start ventilation.

ABB

ABB

Benefits of gas tested motor for Operators / End Users

- Benefits of the ABB approach: Reduced
  - …initial capital expenditure
  - …lower operating costs
  - Faster, no delay starting
  - Reliability is improved as no additional components are required
- Most importantly, ABB's certified motors offer proven safety, as testing represents the only way to verify that equipment is really safe