Hazardous Areas and Medium Voltage Electric Motors

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AC Machines, Alrode

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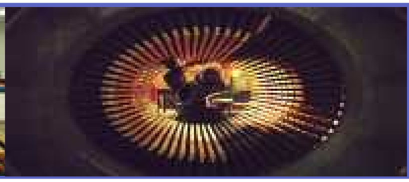

Agenda for Discussion

- Why the need for a presentation such as this
- Role players
- Applicable standards
- Classification of areas
- Basic principles of explosive atmospheres
- Types of protection with background and examples
  - Ex n – Non-Incendive
  - Ex e – Increased Safety
  - Ex p – Pressurization
- Responsibilities
- Summary

Why are we here?

- Subject matter is vast.
- Can re-visit certain areas later and drill down further
- Present customer base does not appear to be aware of implications and ramifications of an EX MV motor.
- Members of the Rotating Machines Working Group
- We are able to pass on the basics to others
- Increase awareness
- Customer and OEM/Repair Facility need to co-operate
- Select correct product for the correct environment
- Aim is to eliminate possibility of explosion that results in loss of life and damage to equipment

Role Players

- Customer
  - Very seldom direct
  - Intermediary / intermediaries
- OEM or Repair facility
- Technical committees who lay down the specifications
  - Objective is to facilitate international trade in electrical equipment for use in explosive atmospheres
- Statutory Authority
  - SABS, Explolabs
- Actual end users and operators

Scope of Discussion

- Base discussion on one internationally accepted standard
- Define basic principles of explosive atmospheres
- Two groups for electrical apparatus defined:
  - Group I – apparatus for mines susceptible to fire damp.
  - Group II – apparatus used in places other than mines.
    - Area of today's discussion
- Further limit discussion to gases and vapours
- Define Zones
- Define Types of Protection
- Look at realistic scenarios and examples

Specifications – International / Local

- European Standards
  - EN – European Norm
  - IEC – International Electrotechnical Commission
  - European Directive 94/9/EC – ATEX 100a (July 2003)
- North American Rules
  - NEC – National Electric Code
  - CEC – Canadian Electric Code
- South Africa
  - SABS IEC – Adopted IEC specifications
  - SANS – Will replace SABS IEC
- Today's discussion:
  - IEC 60079 – various parts

International Specifications – IEC 60079

SPECIFICATION		CURRENT ED.	PREVIOUS ED.
IEC 60079-0	General requirements	4.0, Jan 2004	3.1, June 2000 3.0, Amdt A1,2000 3.0, 1998 2.0, 1983
IEC 60079-1	Flameproof enclosures 'd'	5.0, Nov 2003	4.0, 2001
IEC 60079-2	Pressurised enclosures 'p'	4.0, Feb 2001	3.0, 1983
IEC 60079-7	Equipment protection by increased safety 'e'	4.0, July 2006	3.0, Nov 2001 2.0, Amdt 2, 1993 2.0, Amdt 1, 1991 2.0, 1990
IEC 60079-11	Equipment protection by intrinsic safety 'i'	5.0, July 2006	4.0, Feb 1999 3.0, 1991
IEC 60079-15	Construction, test and marking of type of protection 'n' electrical apparatus	3.0, March 2005	2.0, Feb 2001 1.0, 1987
IEC 60079-19	Equipment repair, overhaul and reclamation	2.0, Oct 2006	1.0, 1993

Comparison between IEC and SANS/SABS IEC

IEC SPECIFICATION		SANS/SABS IEC SPEC.	IEC EQUIV.	SANS RELEASE
IEC 60079-0	4.0, Jan 2004	SANS 60079-0 3.0, 2005	IEC 60079-0 4.0, Jan 2004	29-Apr-05
IEC 60079-2	4.0, Feb 2001	SANS 60079-2, 2.0, 2001	IEC 60079-2 4.0, Feb 2001	21-Sep-01
IEC 60079-7	4.0, July 2006	SANS 60079-7, 2.0, 2003	IEC 60079-7, 3.0, 2001	24-Jan-03
IEC 60079-11	5.0, July 2006	SANS 60079-11, 2.0, 1999	IEC 60079-11, 4.0, 1999	10-Sep-99
IEC 60079-15	3.0, Mar 2005	SANS 60079-15, 3.0, 2006	IEC 60079-15 3.0, Mar 2005	02-Jun-06
IEC 60079-19	2.0, Oct 2006	SANS 60079-19, 1.0, 1993	IEC 60079-19 1.0, 1993	05-Aug-96

Conflicts between IEC and SANS/SABS IEC

- "Comparison" becomes "Conflict"

IEC vs SANS SPECIFICATION		
IEC 60079-0	General Requirements	~14 month delay
IEC 60079-2	EX p	~7 month delay
IEC 60079-7	EX e	Edition Behind
IEC 60079-11	EX i	Edition Behind
IEC 60079-15	EX n	~ 13 month delay
IEC 60079-19	Repairs	Edition Behind

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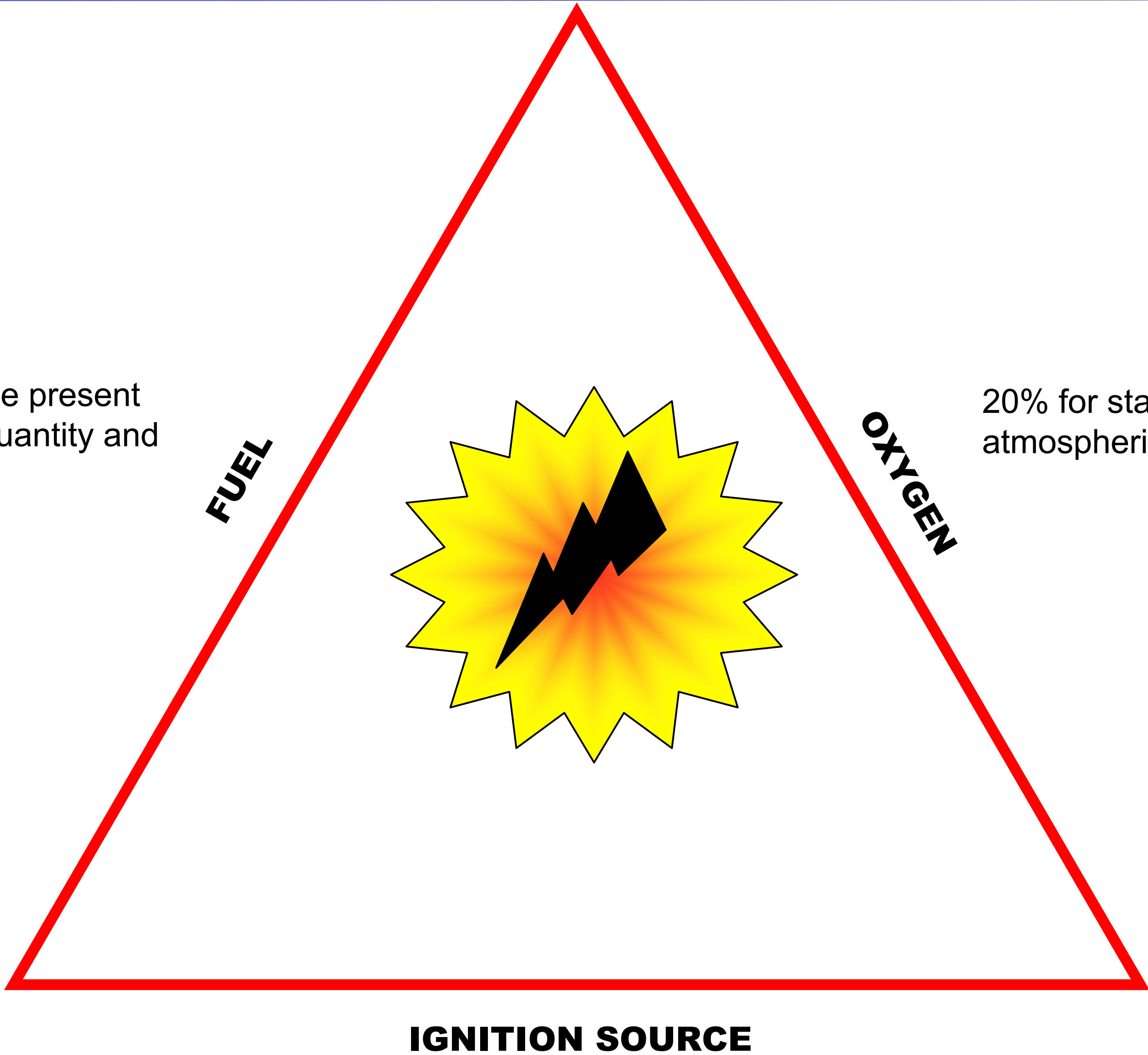
Basic Principle Of Explosive Atmospheres

- Mixture of air under atmospheric conditions and flammable substances in the form of gases, vapours, mists or dusts in which, after ignition has occurred, combustion spreads to the entire unburned mixture.
- Atmospheric conditions typically:
  - -20°C to +40°C
  - 0.8 to 1.1 bar
- Ignition sources:
  - Electric arcs and/or sparks
  - Flames
  - Electrostatic sparks
  - Mechanical sparks produced by grinding

Hazard Triangle

Fuel should be present in sufficient quantity and concentration



20% for standard atmospheric conditions.

Definition of Zones

- Zone 0
  - A place in which an explosive atmosphere is present continuously, for long periods or frequently.
  - No electric motors can be installed in Zone 0.
- Zone 1
  - A place in which an explosive atmosphere is likely to occur in normal operation, occasionally.
- Zone 2
  - A place in which an explosive atmosphere is not likely to occur in normal operation but, if it does occur, will persist for a short period only

Gases and Vapours

- Gases for Group II apparatus further divided into sub divisions:
  - IIA
  - IIB
  - IIC
- All gases and vapours require oxygen to make them flammable.
- Too much or too little oxygen and there will not be an ignition
- Only exception is acetylene
- Upper and lower concentration is known as explosive limit

Explosive range of some gases

GAS	LEL - UEL			INGITION ENERGY (µJ)	GAS GROUP
Acetylene	1.50%	to	100%	19	IIC
Hydrogen	4.00%	to	75%	85	IIC
Ethylene	2.70%	to	34%	19	IIB
Methanol	6.70%	to	36%	290	IIA
Propane	2.00%	to	9.50%	260	IIA

GAS GROUP OF AREA	ACCEPTED GAS GROUP FOR DEVICE
II A	II A, II B, II C
II B	II B, II C
II C	II C

Temperature Classification

- The maximum surface temperature of an electrical or mechanical apparatus must always be lower than the ignition temperature of surrounding gases/vapours mixed with air at normal pressure.

TEMPERATURE CLASS	MAXIMUM SURFACE TEMP. OF APPARATUS (°C)	IGNITION TEMPERATURE OF FLAMMABLE SUBSTANCE (°C)
T1	450	> 450
T2	300	> 300 <= 450
T3	200	> 200 <= 300
T4	135	> 135 <= 200
T5	100	> 100 <= 135
T6	85	> 85 <= 100

Types of Protection

- Protection types for each zone
  - Basic standard requirement is IEC 60079-0
  - "Electrical apparatus for explosive gas atmospheres – Part 0: General requirements

TYPE OF PROTECTION	STANDARD	PERMITTED IN ZONE
Ex nA - Non-Incendive	IEC 60079-15	2
Ex e - Increased safety	IEC 60079-7	1 and 2
Ex d - Flameproof enclosure	IEC 60079-1	1 and 2
Ex p - Pressurisation	IEC 60079-2	1 and 2

- Additional protection types for accessories

TYPE OF PROTECTION	STANDARD	PERMITTED IN ZONE
Ex ia - Intrinsic safety	IEC 60079-11	0, 1 and 2
Ex ib - Intrinsic safety	IEC 60079-11	1 and 2
Ex q - powder filling	IEC 60079-5	1 and 2
Ex m - encapsulation	IEC 60079-18	1 and 2
Ex o - oil immersion	IEC 60079-6	2

Ex nA Machines

- The protection of an Ex nA machine is to prevent sparks and hot surfaces inside and outside of the machine enclosure in normal operation.
- Normal operation
  - Situation when machine is operating within its design parameters,
  - Does NOT include start and stall conditions.
- IP protection for enclosures containing bare live parts shall be a minimum of IP54.
- Present IEC specification is IEC 60079 -15, Third ed., March 2005.
- Superceded IEC 60079 -15, Second ed., Feb 2001.

Ex nA Machines (cont.)

- Significant changes between second and third editions:
  - Risk assessment tables for motors > 1 kV and >100 kW added,
  - Requirements changed with regards motors operating with frequency converters,
  - Ignition tests for large or high-voltage machines added s33.14,
  - Assumed working voltage of neutral points,
  - Two notes were included after s4.6 in 2nd edition whereby:
    - Note 1: It is **not** the responsibility of the certifying body or testing station to check compliance.
    - Note 2: Under adverse conditions it **not** the responsibility of the certifying body or testing station to confirm suitability for the adverse conditions.
    - These notes have been removed from the 3rd edition.

Ex nA Machines (cont.)

Table 7 – Potential stator winding discharge risk assessment – Ignition risk factors

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.

Ex nA Machines (cont.)

Table 6 – Potential air gap sparking risk assessment for cage rotor ignition risk factors

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.

Copyright IEC 60079-15:2005 page 67

Ex nA Machines (cont.)

Table 5 – Assumed working voltage of neutral points

Working voltage U a.c. r.m.s or d.c. V	Assumed working voltage of neutral point V
$\leq$ 1 100	U
1 100 $< U \leq$ 3 300	1 100
3 300 $< U \leq$ 6 600	3 300
6 600 $< U \leq$ 11 000	6 600
11 000 $< U \leq$ 15 000	11 000

Ex e Machines

- The protection of an Ex e machine is to prevent sparks and hot surfaces inside and outside of the machine enclosure in normal operations INCLUDING starts and also in typical fault conditions, such as stalling.
- Present IEC specification is IEC 60079 -7, Fourth ed., July 2006.
- Superceded IEC 60079 -7, Third ed., November 2001.
- Start and Stall Requirements:
  - Limiting T-Class not to be exceeded during starting with maximum temperature 300 °C.
  - Overheating protection based on the t_E time.
  - This defines the maximum safe stall time

Ex e Machines (cont.)

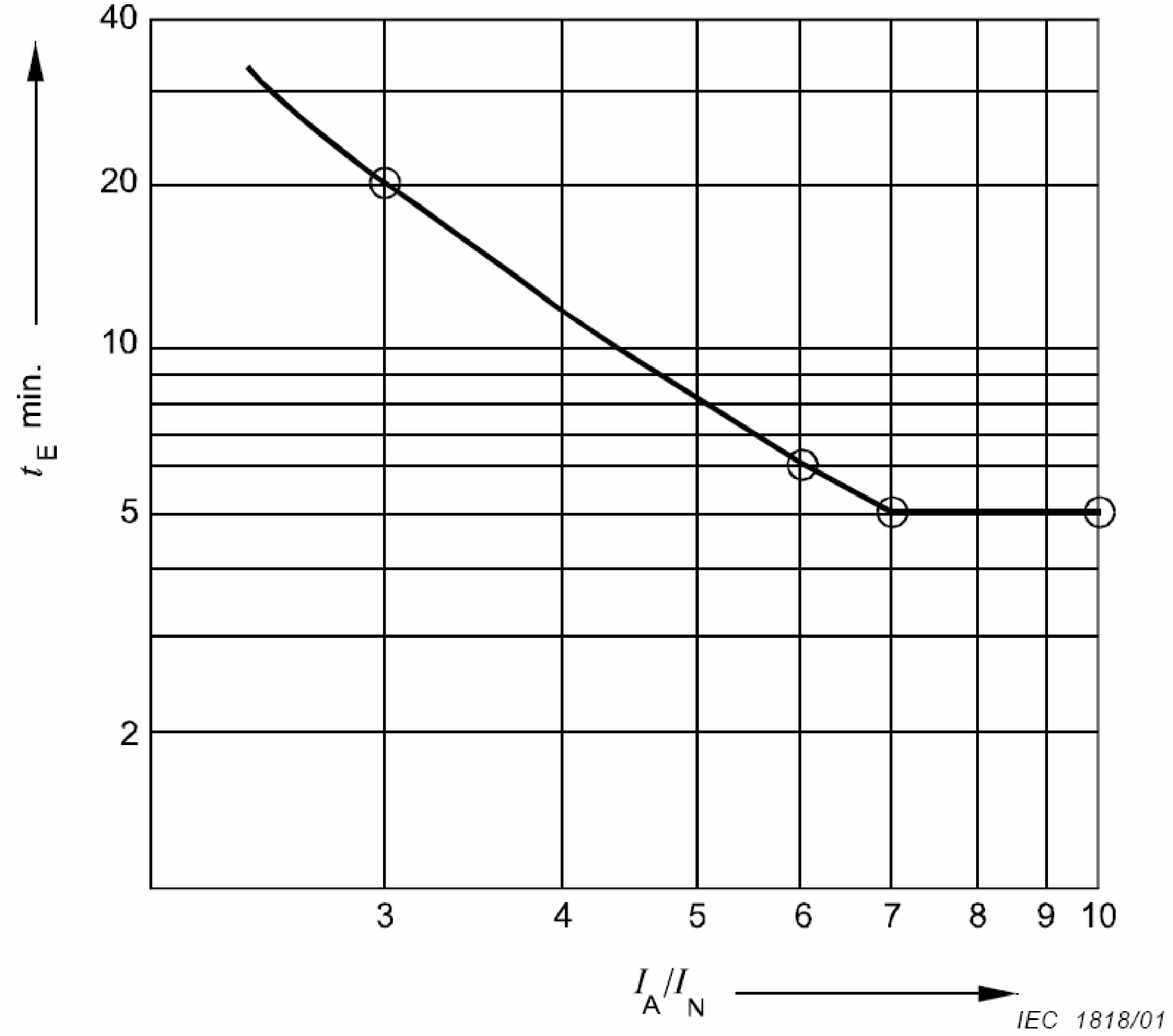


Figure 2 – Minimum values of the time t_E of motors in relation to the starting current ratio I_A/I_N

Ex e Machines (cont.)

Table G.1 – 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	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, 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
	IP55	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

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

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

Ex e Machines (cont.)

Table 4 – Potential air gap sparking risk assessment for cage rotor ignition risk factors

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.

Ex e Machines (cont.)

POTENTIAL STATOR WINDING DISCHARGE RISK ASSESSMENT (TABLE 5)

Characteristics	Value	Factor
Rated voltage	2) > 3,3 kV to 6,6 kV	2
Average Starting Frequency in service	2) > 1 / day	2
Time between detailed inspections	3) > 2 to 5 years	1
Degree of protection (IP Code)	3) IP55	1
Environmental Conditions	2) Coastal outdoor	3
	TOTAL	**9**

Stator ignition test to be performed, anti-condsentaion heaters needed and purging necessary

POTENTIAL AIR GAP SPARKING RISK ASSESSMENT (TABLE 4)

Characteristics	Value	Factor
Rotor cage construction	1) Fabricated rotor cage	2
Number of poles	3) > 8-pole	0
Rated ouput	3) ? 200 kW per pole	0
Radial cooling ducts in rotor	2) Yes: L ?200 mm (see note 1)	1
Rotor or stator skew	3) No	0
Rotor overhang parts	2) Compliant	0
Temperature class	2) T3	1
	TOTAL	**4**

Ex e Machines – Outcome btw. 2nd & 3rd eds.

POTENTIAL STATOR WINDING DISCHARGE RISK ASSESSMENT (TABLE 5)

Characteristics	Value	Factor (2nd ed.)	Factor (3rd ed.)
Rated voltage	2) > 3,3 kV to 6,6 kV	2	2
Average Starting Frequency in service	2) > 1 / day	2	2
Time between detailed inspections	3) > 2 to 5 years	1	1
Degree of protection (IP Code)	3) IP55	1	1
Environmental Conditions	2) Coastal outdoor	3	3
	TOTAL	**9**	**9**

Stator ignition test to be performed, anti-condsentaion heaters needed and purging necessary

POTENTIAL AIR GAP SPARKING RISK ASSESSMENT (TABLE 4)

Characteristics	Value	Factor (2nd ed.)	Factor (3rd ed.)
Rotor cage construction	1) Fabricated rotor cage	2	3
Number of poles	3) > 8-pole	0	0
Rated ouput	3) ? 200 kW per pole	0	0
Radial cooling ducts in rotor	2) Yes: L ?200 mm (see note 1)	1	1
Rotor or stator skew	3) No	0	0
Rotor overhang parts	2) Compliant	0	0
Temperature class	2) T3	1	2
	TOTAL	**4**	**6**

Rotor ignition test and purging required

Ex e Machines (cont.)

- Stator ignition test
  - Coil motorette in accordance with IEC 60079-7 constructed
  - Relevant clauses:
    - 6.2.3.1.2 – representative model of motor
    - 6.2.3.1.3
      - Sinusoidal voltage of 1.5 rated rms line voltage for 3 minutes
      - Maximum rate of voltage rise is 0.5 kV/s
      - Voltage to be applied between one phase and earth
    - 6.2.3.1.4
      - 10 voltage impulses, 3 times peak phase voltage (±3% tol.)
      - Rise time between 0.2 and 0.5 micro seconds
      - Voltage to be applied between phases, and
      - Voltage to be applied between one phase and earth
  - Mixture is 21±5% hydrogen in air
  - No explosion shall occur

Ex p Machines

- Within the Ex p protection system there are 3 further sub divisions:
  - Px pressurization
    - Pressurization that reduces the classification within the pressurized enclosure from Zone 1 to non-hazardous.
  - Py pressurization
    - Pressurization that reduces the classification within the pressurized enclosure from Zone 1 to Zone 2
  - Pz pressurization
    - Pressurization that reduces the classification within the pressurized enclosure from Zone 2 to non hazardous
- Present IEC specification is IEC 60079 -2, Fourth ed., February 2001.

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Ex p Machines (cont.)

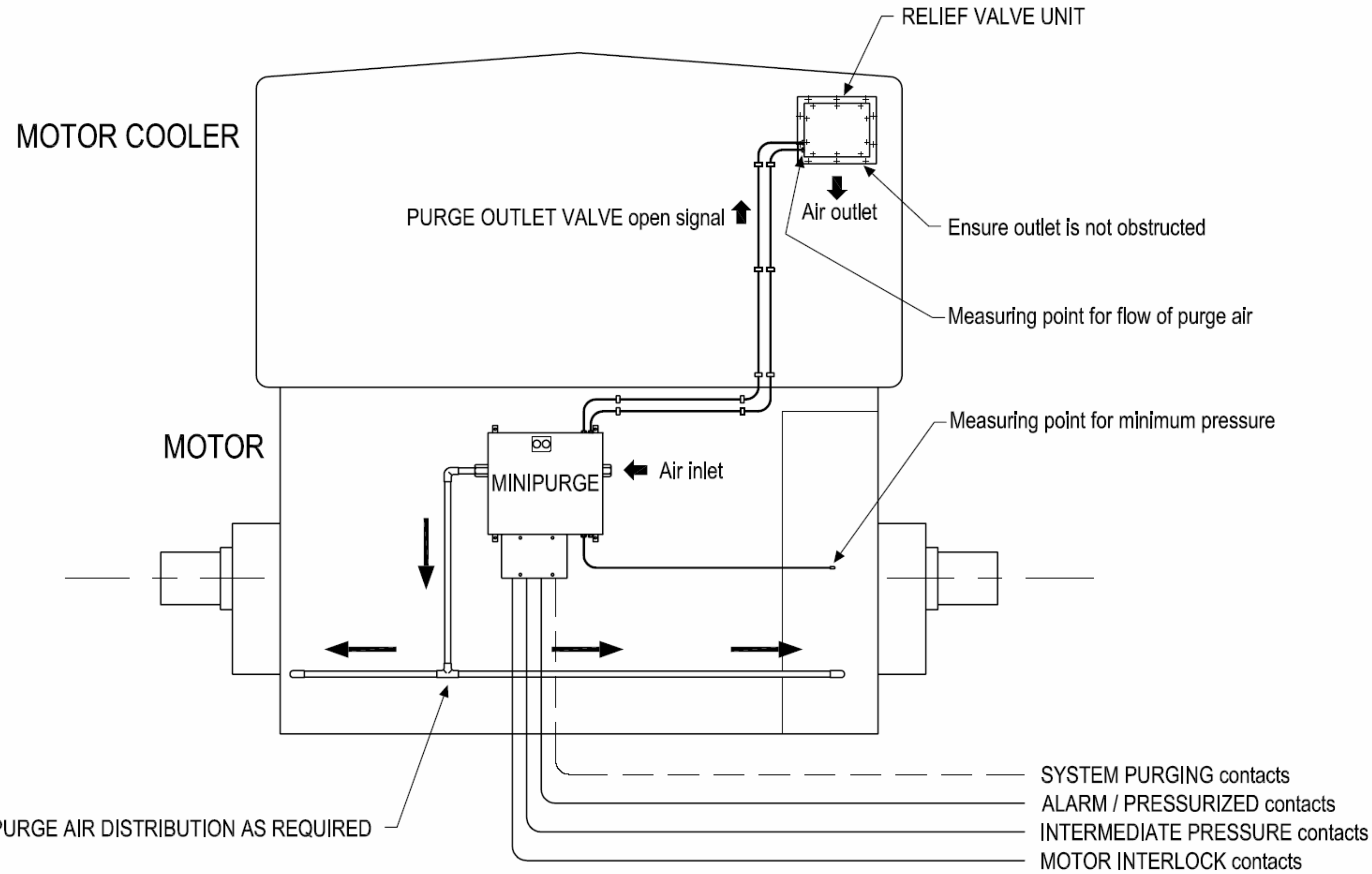
- Growing trend to Ex p machines
- Concept of Ex nA in that the probability of a flammable gas being present in sufficient volume coupled with a simultaneous probability of an abnormal condition was deemed very low.
- Certain experiences in Europe have been to the contrary.
- Customers prefer to install an EX p machine where once they had an Ex nA machine. Especially in large capitally intensive units.
- Only solution where a customer would like a large 11 kV Ex e machine. Present requirements for Ex e certification includes high cost and high risk to OEMs.
- Basic concept is to make the inside environment of the machine a non-hazardous area, i.e. safe.

Ex p Machines (cont.)

- Method of operation has two facets:
  - Pre-start purge cycle
    - 10 complete free-volume changes of air with purge medium
    - Typically dry nitrogen or clean dry air
    - Pressures in order of 4 bar
    - Once successful and overpressure attained move to next operation
  - Maintenance of overpressure
    - Requirement of ΔP to be greater than 50 Pa.
    - Unit monitors pressure in relation to leakage
- Commercially available units are certified for use in Zone 1 areas

Ex p Machines (cont.)

- Typical hook-up diagram



Ex p Machines (cont.)

- Computational Fluid Flow Dynamics
  - Requirement for certification
  - Possible with modern computing power
  - Investigate the two states
    - Pre-Start purge
    - Running in over-pressure
  - Look for “dead-spots”
  - Provide means to agitate these spots to move hazardous gas out
- Test machine under purge and running conditions
- Verify results with CFD predictions

Responsibilities

- In a nutshell - Everyone
- OEM / Repair Facility needs customer involvement
- Repair facility needs to be authorized to work on hazardous area machines
- Testing bodies need to be fully conversant with the dynamic field of hazardous areas
- Agree on what is expected for the hazardous area certification BEFORE not AFTER.
  - Especially relevant with repair of machines

Summary

- Need for explanation defined
- Role players introduced
- Subject matter is vast and dynamic
- Importance of chosen specification
- Standards, areas, zones and principles - introduced and defined
- Protection types “n”, “e”, and “p” discussed in greater detail
- Examples of risk analysis as well as impact of a specification change highlighted
- Responsibilities discussed

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