WHAT ARE THE DRIVING FORCES IN THE SELECTION OF A HAZARDOUS LOCATION ELECTRIC MOTOR - DIVISIONS vs ZONES?

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Abstract – The National Electrical Code (NEC) [1] and Canadian Electrical (CE Code) [2] both discuss the installation requirements for an electric motor to be installed in "Division" or "Zone" hazardous locations. Also, both the NEC [1] and the CE Code [2] discuss the interchangeability provisions for "Division" and "Zone" area classifications, meaning that one can install a "Division" area suitable motor in a "Zone" area or vice-versa. Even though the interchangeability is permitted, the motor design, materials, and accessories may differ due to testing and marking requirements of the country-specific adaptations of UL, CSA, or IEC standards. These requirements impact the cost and delivery of the motor. Stock, or off-the-shelf products, may not be able to be utilized. This paper covers the design, construction, and testing differences between a motor that is "identified for use" in a Division 2 or a Zone 2 location, versus one that is not. Motor accessory devices and the end users' perspectives are also included.

Index Terms — Division, Zone, Class, arcing/sparking, ignition, electric machines, motor, corona, PD, API, IEC, NEC, CE Code, NFPA

I. INTRODUCTION

Electric motors are the front line prime movers in drive trains or systems running processes in the petrochemical industry. The selection process used for motors is equally applicable to generators. The term machine is used in this paper to apply to both motors and generators. Typical machines applied in industry are either asynchronous (induction) or brushless synchronous machines. Synchronous machines are selected where the rating of asynchronous machines exceed operation cost and starting capability of the power supply system. This is often in the neighborhood of 15 MW. In a few cases, these machines may be operated on an adjustable speed drive (ASD) system to optimize processes or as one of the "soft start" methods.

We assume the readers of this paper have the basic knowledge of hazardous locations or explosive gas atmosphere and protection techniques of machines installed in this area. The authors would like to cover machines mainly selected or installed in Class I, Division 1 or Class I, Division 2; or the equivalent in Zone 1 or Zone 2 areas in North America in accordance with the NEC [1] or the CE Code [2].

Motors are selected in accordance with Article 501 of the NEC [1] when following the Division system or Article 505 when following the Zone system in the USA. When following the CE Code [2], the referenced text is Section 18 for Zones or Appendix J18 for Divisions. According to the NEC [1], machines are allowed to be installed using either of these sections. The CE Code [2] requires new installations to use the Zone system and reserves the Division system for legacy installations. The Division system has been used for many years in North America while the Zone system was introduced based on IEC (including North American national differences). Further details on this topic are covered in the paper.

The paper will concentrate on Class I, Division 2 and Zone 2 and will discuss the following topics when one chooses a motor of Division system over Zone system or vice-versa:

- Design considerations
- Challenges in procuring machines
- Regulatory requirements
- Codes and standards
- End users' perspectives

II. DESIGN CONSIDERATIONS

Key differences are discussed below between motors designed for Division 2 and Zone 2 classified areas since the majority of motors are installed in those locations. Division 1 or Zone 1 area are significantly less than 10% of the total installed base and have been well protected by specific enclosure protection techniques; therefore, they are discussed only briefly. [3]

A. Machines Certified to Division Requirements

Machines designed for Class I, Division 1 locations are typically either explosionproof per UL 674 [13] (USA) or C22.2 No 145 [15] (Canada) or pressurized per NFPA 496 [14] (both USA and Canada). These machines are third party certified by a Nationally Recognized Testing Laboratory (NRTL) for the USA or a Certification Body (CB) for Canada Generally, smaller frame motors are designed in an explosion proof enclosures and large motors in a fabricated frame with a pressurization. Machines that do not carry certification for use in the specific hazardous location cannot be employed in Class I Division (or Zone) 1 installations.

Machines operating in Class I, Division 2 (Zone 2) installations are often certified for hazardous (classified) locations but certain machines, as specified in the NEC [1] or CE Code [2], may be of a non-hazardous design. These non-hazardous design machines are designed as a minimum to meet NEMA MG-1 [4] on a voluntary base and also mandatory requirement for electrical safety as specified in UL 1004-1[5] or UL 60034-1 [20]

for the USA or CSA C22.2 No. 100 [6] for Canada. Documents such as UL 1836 [7] and IEEE Std 1349 [8] provide guidance on the application of machines in Class I, Division 2. A few major components are discussed below:

1) *Machine enclosure:* Machines of open or totally enclosed construction are allowed to be installed per Section 501.125 (B) of the NEC [1] as long as they do not produce arcs or sparks, and have no hot surfaces in normal operation. Figs 1 and 2 below show typical permissible enclosures.

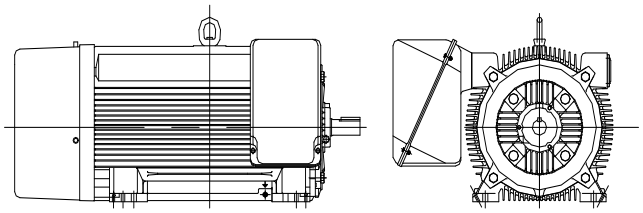

Fig. 1 Totally enclosed frame enclosure

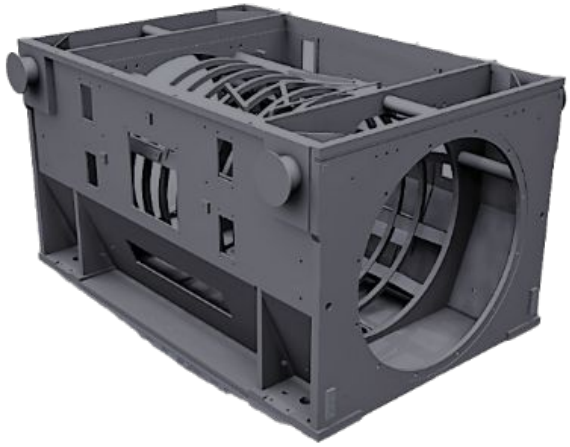

Fig. 2 Open Fabricated frame enclosure

Weather protected open machines such as WP I (weather protected Type I) or WP II (weather protected Type II) are considered open enclosures. Most large medium-voltage or high-voltage motors are designed using a fabricated frame construction. To avoid arcing/sparking across the multiple sections of the fabricated enclosures, equipotential bonding cables or shunts are provided. Enclosures of either open or enclosed types of motors have no limitation on voltage ratings if specified through the applicable API standards. Machines designed to meet IEEE Std 841 [9] are required to be in totally enclosed enclosures as they are intended for use in severe-duty applications in the petroleum, chemical, and similar industries. WP II machines, designed for medium voltage or high voltage operation, are commonly installed in Division 2 outdoor areas. WP I machines are generally provided with extra environmental protection, perhaps under a roof or other means of permanent shelter.

2) *Windings.* Machines with an operating voltage below 1000 V typically use a random-wound coil construction. For voltages above this, the general practice is to use form-wound coil construction. The primary difference in the two winding constructions is the material and shape of the individual coils. No extra treatment is provided other than that required by the manufacturer during processing or to meet specific end-user requirements. Windings may employ a thermal class 130 (B), thermal class 155 (F), or thermal class 180 (H) rated insulation system. Note that rotor and stator insulation systems may not be of the same temperature class. Large machines commonly have thermal class 155 (F) or better insulation systems, and limit operating temperatures to those of thermal class 130 (B) to increase the longevity and reliability of the winding. Machines operated on an adjustable speed drive (ASD) may have additional turn-to-turn insulation to handle the resulting transient peak voltages associated with the switching operation of the power electronics. To pass mandatory dielectric strength tests, specific creepage and clearances are maintained. Medium voltage or high voltage form wound windings are typically rated for 6 kV and higher and are treated with conducting and semi-conducting tapes or coatings to minimize partial discharge. Special tests to meet end-user specifications may be performed such as resin penetration in coils, surge comparison tests etc. at an extra cost. Fig. 3 shows an end winding section of the motor winding with no special requirements, and Fig. 4 illustrates areas of the winding that require special attention.

Fig. 3 Typical AC stator winding – no special requirement

To avoid condensation in areas with high humidity, anti-condensation heaters are installed inside the machine enclosure. In some cases, they are additionally marked with hazardous location information in accordance with the NEC [1] or CE Code [2].

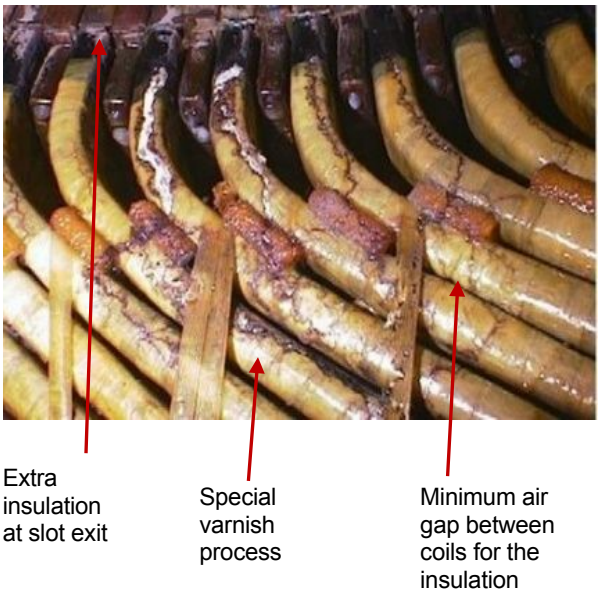

Fig. 4 Stator special insulation system for test in gas mixture (highlight of areas for special attention)

3) *Rotor construction.* There are two types of basic rotor construction. The first, shown in Fig 5, uses an aluminum diecast process and is predominantly found in low voltage applications with small- to medium-power ratings. The second, shown in Fig 6, uses a fabricated squirrel cage rotor bar construction and is predominantly found in higher voltage and higher power applications.

Fig. 5 Aluminum die cast rotor

Copper alloys with different conductivities are available for both the rotor bars and end rings employed in the fabricated construction. This allows a manufacturer to optimize the design for a variety of torque profiles while also considering other performance factors such as efficiency.

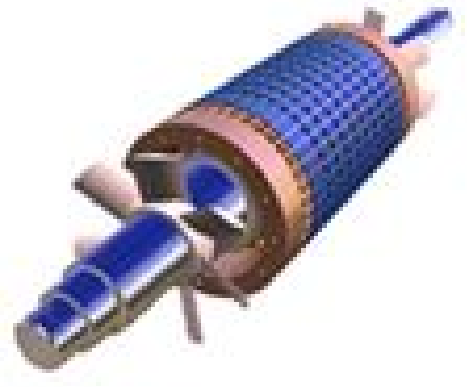

Fig. 6 Fabricated coper bar rotor

Synchronous motors may also have a starting cage (amortisseur winding) with bars embedded on the periphery of the rotor and connected to a shorting ring, as well as a main field rotor winding on the pole.

Large motors with fabricated rotor bars have a potential for arcing/sparking in the airgap during acceleration of motor as shown in Fig. 7. Because of the arc/spark possibility in these machines, some Zone 2 applications may use additional pre-start ventilation for special applications, although the risk is minimal during starting in a Zone 2 area.

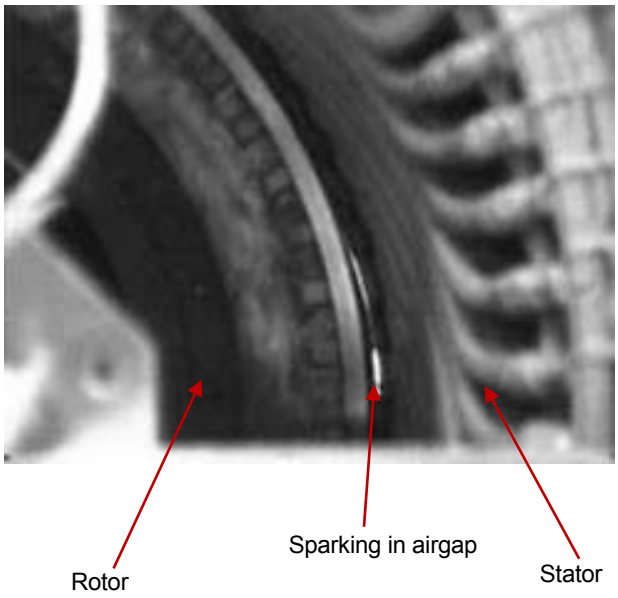

Fig. 7 Air gap sparking

4) *Accessories.* Most machines are supplied with accessories such as temperature sensors, leak detectors, vibration probes/detectors, surge protectors, etc. Accessories that can produce an arc or spark or that can have surface temperatures in excess of the auto-ignition temperature of the applicable hazardous

vapor or gas are required to be in an enclosure approved for the location. Other non-incendive accessories are assessed in accordance with IEEE Std 303 [10]. Shaft bonding devices can be assessed for non-incendivity in accordance with UL 1836 [7] or IEEE Std 1349 [8].

5) *Validation/Testing.* Standard routine tests and type tests on a first-off sample for all asynchronous machines are performed as specified in IEEE Std 112 [11], NEMA MG-1 [4], and other product standards such as UL 1004-1 [5] for USA and CSA C22.2 No. 100 [6] for Canada. Apart from these, additional maximum surface temperature assessments or tests may be performed to validate that the surfaces of space heaters and other accessories / components do not exceed the auto-ignition temperature of the gas or vapor in the location where a motor is installed as mandated in NEC 501.125 (B) [1] for USA and CE Code [2] for Canada.
6) *Markings.* Unless certified for a Class I, Division 2 location, the machine is not be required to marked with Class, Division, Group, Temperature Class, or ambient temperature range on the main rating nameplate. However, an anti-condensation heater nameplate with voltage, wattage, maximum surface temperature of the heaters, is required to be provided. All other makings as specified by UL 1004-1 [5] for USA and CSA C22.2 No. 100 [6] of non-hazardous location standards are provided. Marking for the hazardous location is provided where a Nationally Recognized Testing Laboratory (NRTL) or Certification Body (CB) have assessed the machine as meeting voluntary standards as specified under the certification section below.
7) *Certification.* If hazardous location certification, although voluntary, is provided to support a customer requirement, this will generally be in accordance with UL 1836 [7] for USA or a specific Letter of Technical Requirement (LTR E-013) [12] issued by the Canadian Standards Association (CSA) for Canada.

B. Machines Certified to Zone Requirements

Machines specified to operate in Zone classified are designed per NEC Article 505 [1] addressing IEC-based protection techniques. They are required to be identified or be certified by an NRTL in the USA. They follow IEC-based standards, with some specific USA national differences. The main protection technique for Zone 2 location is “ec” in accordance with UL 60079-0 [16] and UL 60079-7 [17].

The CE Code [2] in Canada requires that these machines be certified by a Standards Council of Canada (SCC) recognised CB. The certification must follow IEC-based standards with Canadian national differences. Here, the main accepted protection technique is “ec” in accordance with CSA C22.2 No. 60079-0 [18] and CSA C22.2 No. 60079-7 [19].

Both in USA and in Canada, machines designed for Division 2 or Zone 2 are allowed to be installed in either location. In addition, these machines have to meet the appropriate standard of industrial equipment such as UL 1004-1 [5] or UL 60034-1 20] for USA and CSA C22.2 No. 100 [6] for Canada.

A few major components are discussed below to show design variations for installation in a Zone 2 location versus the motors designed for installation in a Class I, Division 2 location.

1) *Machine enclosure*. Enclosures having bare live parts, typically the terminal compartment, are required to be protected with minimum enclosure ingress protection of IP 54. The motor compartment with insulated windings required to be protected with minimum enclosure ingress protection of IP 44, if the two compartments are not interconnected. Interconnection of the two compartment is permitted for motors with rated voltages less than 1 kV. There are relaxations which permit a reduced degree of protection of IP23 in a clean environment with protection from falling solid bodies
2) *Windings.* Stator windings of Zone 2 motors are very similar to the windings of general industrial motors as specified above under Division 2 except with a few differences as outlined below.
    a) All stators with a rated voltage above 1 kV are required to be fitted with anti-condensation heaters. For Level of Protection “ec”, a special stator insulation system as described in **Error! Reference source not found.**4 is required to be tested in an explosive gas test mixture as specified in the standard. This test is to validate the required creepage, clearances, and distances of insulated windings between phases to minimize partial discharge activity.
    b) The allowed types of factory connections and field connections are specified in the standard.
3) *Rotor construction.* Rotor constructions are very similar to the machines for Class I, Division 2 with a few extra requirements to be validated. To minimize or to avoid air gap sparking, a minimum airgap requirement has to be fulfilled along with assessment for possible air gap sparking. Machines with rated output exceeding 100 kW and an intermittent duty classification such as S3, S4, S5, S8 or S10 require a sparking assessment as specified in the standard. If the assessment score exceeds sum of the total factors, one of the additional protective measures must be applied. They are,
    a) Sample tested in gas test mixture as specified in the standard
    b) Special measure such as pre-start ventilation, fixed gas detection etc.
    c) starting current be limited to 300%.

Motors with duty types S1, S2, S6, or S9 do not require possible airgap sparking assessment, since the risk of sparking during starting and the risk of the gas mixture being present at the same time are considered unlikely.

4) *Accessories.* All accessories supplied with motors, including termination boxes, shall be certified for the hazardous location.
5) *Validation/testing.* Routine tests and type tests are very similar to those for the motors designed for Class I, Division 2, except for a few additional tests:
    - Conduct stator insulation test in flammable gas (also known as stator incendivity test)
    - Validate service temperature of motor
    - Validate maximum surface temperature tests considering worst case scenarios

- Conduct Ingress protection (IP) test to validate IP54 enclosure protection, as applicable
- Conduct enclosure impact tests
- Validate maximum surface temperature test with comparable converter (ASD) for converter-fed (ASD-fed) motors

6) *Marking.* Markings shall meet the applicable USA or Canadian IEC-based standards. They include as a minimum: Machine rating, certification marking of agency, applicable standards, za minimum IP rating, temperature class, gas group, ambient and more. The IEC defined Zone system does not have as many temperature codes as specified under the Division system. One needs to select T1, T2, T3, T4, T5 or T6, or a specific maximum surface temperature in degrees Celsius. Another variation from Zone to Division is the identification of gas groups. Gas groups are labelled as IIA, IIB or IIC (for Zones) or A, B, C or D (for Divisions). Machines supplied according to UL 60079-7 [17] for the USA has the marking with "A" prefix to the "Ex" in front of Level of Protection such as: "AEx ec" vs "Ex ec" for Canada.

7) *Certification.* Certification cost and the work involved in assessment is almost more than double that for a motor that is not third party certified. This results in a longer time for certification along with documentation preparation. North American manufacturers may choose to have their machines meet Division criteria while those from outside North America may instead opt to meet Zone criteria.

8) *Zone 1 location.* Machines are protected using the enclosure features, except for machines of increased safety "eb". Machines of Zone 1 are designed as: flameproof "db", pressurized "pxb" or increased safety "eb". An additional concept that differs from Division 1 is the Level of Protection technique "eb". Ex "eb" motors required extra safety assessments as specified in the applicable increased safety standards. There are no similar design requirements to be maintained for industrial equipment in Type of Protection "d" or "p". Design validation of Zone 1 machines include the same steady state conditions as Zone 2 – and two others: starting conditions and expected equipment malfunctions.

III. PROCUREMENT CHALLENGES

Motors are selected for the location either by engineering companies working for end users or directly by the end users. In all cases, they are specified to meet local codes, regulations and standards; though one may specify a higher degree of protection of machine such as a motor designed for Class I, Division 1 over Class I, Division 2; or Zone 1 over Zone 2, at a higher cost.

Machines are available to meet the requirements of either Division or Zone area classification systems, and therefore they are specified or procured depending upon the requirement of the authority having jurisdiction (AHJ). As mentioned earlier, machines designed for Division locations are equally allowed to install in Zone locations and vice-versa.

Many standards have been developed for the petroleum, chemical, and similar industries to make procurement easier; among those are API Std 541 [21], API Std 546 [22] or API Std 547 [23]. Each standard was developed with specific construction features for a manufacturer to include at the design stage, with design validation by test. Since chemical processes are very expensive either to run or maintain, machine reliability is as important as the cost of a machine. All of these standards specify the minimum requirements for a machine, along with reliability aspects, to assure a machine life of a minimum of 25 years. API data sheets have been developed for each of these API standards to make procurement easier, clear, and definitive.

There are many voluntary industry standards developed by engineering societies such as IEEE (Institute of Electrical and Electronic Engineers) to provide guidance on good design practices, safe installation, maintenance practices, etc. Examples are IEEE Std 1349 [8], IEEE Std 303 [10], IEEE Std 841 [9]. The equipment safety related standards are generally developed by the recognized 3rd parties such as UL, CSA, and FM to meet normative requirements of the various codes and regulations, such as UL 1836 [7], UL 674 [13], CSA C22.2 No. 145 [15], UL 60079 series or CSA C22.2 No. 60079 series IEC-based standards. Machine generally installed in Division 2 or Zone 2 do not require 3rd party certification, however, it can be obtained at an extra cost upon request by an end user.

For motors to be procured from outside the USA or Canada, it may be easier to specify them using the IEC-based system in accordance with the NEC [1] Article 505 or the CE Code [2], Section 18. To avoid complexity and procurement challenges, a manufacturer would not mix two systems in a machine. It will be simpler and easier if a machine ~~be~~ is designed to meet either the Division system or the Zone system. Often procuring suitably certified accessories incorporated with a machine is a greater challenge for a North American manufacturer to design and build a Zone compliant machine compared to a division compliant machine.

A short survey has been conducted by the authors to assess when Division equipment are selected over Zone equipment in North America. The feedback from the survey is provided in the Appendix A. As mentioned earlier, NEC [1] equally allows Division and Zone compliant equipment while CE Code [2] prefers Zone equipment for a new installation over Division equipment. Guidance on Zones versus Division with respect to the CE Code [2] can be found in PCIC-2015: HO-22 [3].

IV. REGULATORY REQUIREMENTS

A. **USA.** In the workplace, electrical safety is regulated by the Occupational Safety and Health Administration (OSHA) under the federal Department of Labor (DOL).

Fundamental requirement from 1910.303(a) of Title 29 of the Code of Federal Regulations [26] is that all electrical equipment be "approved" as defined by Section 1910.399. Approval means:

a) It is accepted, or certified, or listed, or labeled, or otherwise determined to be safe by a nationally recognized testing laboratory (NRTL) recognized pursuant to §1910.7.

b) With respect to an installation or equipment of a kind that no nationally recognized testing laboratory accepts, certifies, lists, labels, or determines to be safe, it has been inspected or tested by another Federal agency, or by a State, municipal, or other local authority responsible for enforcing occupational safety provisions of the National Electrical Code, and

found in compliance with the provisions of the National Electrical Code as applied in this subpart.

c) With respect to custom-made equipment or related installations that are designed, fabricated for, and intended for use by a particular customer, if it is determined to be safe for its intended use by its manufacturer on the basis of test data which the employer keeps and makes available for inspection to the Assistant Secretary [of labor] and his authorized representatives.

Most motors used in the petroleum, chemical, or similar industries fall into either (1) or (3). Smaller motors are generally available with a NRTL Listing with the electrical safety compliance documented as part of the Listing. Most larger motors fall into the “custom” category of (3) with the electrical safety examination and test data conducted by the motor manufacturer and provided to the end user.

B. **Canada.** Electrical safety is regulated by the Provinces and Territories. All electrical equipment is required to be Approved, generally by a Certification Body (CB) recognized by the Standards Council of Canada (SCC). If the electrical product is not certified by a CB, it will be required to be subjected to a Field Evaluation, generally in accordance with SPE-1000 [27].

V. SUMMARY OF CERTIFICATIONS / STANDARDS

US Standards:

Non-Hazardous Locations:

- *UL 1004-1, Rotating Electrical Machines – General Requirements [5]*
- *UL 1004-8, Inverter Duty Motors [28]*
- *UL 1004-9, Form Wound and Medium Voltage Rotating Electrical Machines [29]*

Class I, Division 1 Hazardous (Classified) Locations

- UL 674, *Electric Motors and Generators for Use in Hazardous (Classified) Locations (Explosionproof) [13]*
- NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment [14]*

Class I, Zone 1 Hazardous (Classified) Locations:

- UL 60079-0, Explosive Atmospheres – Part 0: Equipment – General Requirements [16]
- UL60079-1, Explosive Atmospheres – Part 1: Equipment Protection by Flameproof Enclosures “d” [30]
- UL60079-2, Explosive Atmospheres – Part 2: Equipment Protection by Pressurized Enclosure "p" [31]
- UL60079-7, Explosive atmospheres – Part 7: Equipment protection by increased safety "e" [17]

Class I, Division 2 or Zone 2 Hazardous (Classified) Locations
(If NRTL Listing for the location is required by the end user)

- UL 1836, *Outline of Investigation for Electric Motors and Generators for Use in Class I, Division 2, Class I, Zone 2, Class II, Division 2 and Zone 22 Hazardous (Classified) Locations [7]*
- UL 60079-0, Explosive Atmospheres – Part 0: Equipment – General Requirements [16]
- UL60079-7, Explosive atmospheres – Part 7: Equipment protection by increased safety "e" [17]

Special Allowances - NEC [1] has allowances for the acceptance of non sparking Article 501.125(B) and 505.20(C) Exception No. 4

Canadian Standards:

Non-Hazardous Locations:

- C22.2 No. *100*, Motors and Generators [6]

Hazardous Locations:

- CSA C22.2 No. 145, *Electric Motors and Generators for Use in Hazardous (Classified) Locations (Explosionproof) [15]*
- NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment [14]*
-

Class I, Zone 1:

- CSA C22.2 No. 60079-0, Explosive Atmospheres – Part 0: Equipment – General Requirements [18]
- CSA C22.2 No. 60079-1, Explosive Atmospheres – Part 1: Equipment Protection by Flameproof Enclosures “d” [32]
- CSA C22.2 No. 60079-2, Explosive Atmospheres – Part 2: Equipment Protection by Pressurized Enclosure "p" [33]
- CSA C22.2 No. 60079-7, Explosive atmospheres – Part 7: Equipment protection by increased safety "e" [19]

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- CSA C22.2 No. 60079-7, Explosive atmospheres – Part 7: Equipment protection by increased safety "e" [19]

Special Allowances – The CE Code [2] also has allowances for the acceptance of non-sparking in Rule 18-150e) for “Zones”, and Rule J18-150 e) for “Divisions”.

See Appendix B and Appendix C for additional information on applicable standards.

VI. END USERS' PERSPECTIVE

Historically, most (estimated to be 99%) applications of motors in hazardous locations in the United States have been a Division 2 area classification and have been guided by the installation requirements of the National Electrical Code (NEC) [1] since the 1947 edition. As such, the 2020 NEC [1], in Article 501.125(B) and 505.20(C) Exception No. 4, open or non-explosionproof enclosed motors are permitted to be installed "… that are not identified for use in a Class I, Division 2 location" – if the motor does not have brushes, switching mechanisms, or similar arc-producing devices. "Identified" equipment is defined by the NEC [1] as:

(1) Equipment listing or labeling

(2) Evidence of equipment evaluation from a qualified testing laboratory or inspection agency concerned with product evaluation

(3) Evidence acceptable to the authority having jurisdiction such as a manufacturer's self-evaluation or an owner's engineering judgment.

Section 3 above led to the long-standing and safe practice of the use of conventional (i.e., not identified for a hazardous location) motors, without arcing or sparking devices, in Class I, Division 2 or Zone 2 classified locations.

On December 3, 1993, and August 31, 1994, Underwriters Laboratories (UL) requested public comments on its proposed first edition for a "Standard for Electric Motors and Generators for Use in Class I, Division 2 and Class II, Division 2 Hazardous (Classified) Locations, UL 1836" [7]. In response to the requests, many user companies submitted comments that recommended the proposed standard not be issued, citing the years of safe operating experience of using non-identified motors and the lack of any NEC [1] requirement for motors identified for use in a Class I, Division 2 area. On May 5, 1995, UL withdrew the proposed standard, UL 1836. UL has, however, retained the document as "UL 1836 - Outline of Investigation for Electric Motors and Generators for Use in Class I, Division 2, Class I, Zone 2, Class II, Division 2 and Zone 22 Hazardous (Classified) Locations" [7] The current revision is Issue Number 5, dated September 3, 2014, and its content predominantly includes requirements related to the general industry standard, UL 1004-1 [5], static electricity, and surface temperature limits. Prior IEEE technical investigations [34] and IEEE Std 1349, Annex H [8] have demonstrated that conventional motors, not identified for use in Class I, Division 2 and Zone 2 locations, are appropriate for safe application in Class I, Division 2 or Zone 2 locations. For applications involving flammable materials with autoignition temperatures below 200 °C (notably, diethyl ether), users should work closely with the motor manufacturers to address the exposed surface temperatures of the motors [34]. Some agencies use the UL 1836 [7] Outline of Investigation to test and mark motors. However, testing and marking is not required for motors installed in accordance with Section 501.125(B) or 505.20(C) Exception No. 4 of the NEC [1].

During 2005, the IEC Maintenance Team for non-sparking equipment "nA") was formulating proposals for new requirements to be added for electric motors in the next edition. These requirements would have applied to motors commonly installed in a Zone 2 area. These proposed additions were moderated somewhat during the Maintenance Team deliberations, but are in excess of what is required by the NEC in the US in Division 2 or Zone 2 locations, and other applicable NEC jurisdictions. As part of this effort, the requirements for non-sparking "nA" motors were migrated to the standard for increased safety equipment "e" as Level of Protection "ec", to be applied to electric machines installed primarily in a Zone 2 area. The standard also includes requirements for Level of Protection "eb" for equipment installations principally in Zone 1. These requirements were subsequently adopted in the US and Canadian standards UL 60079-7 [17] and CSA C22.2 No. 60079-7[19].

When looking at both the USA and international environments, it has been observed that many international jurisdictions tend either to overclassify a location as compared to the API or US practices (designate an area Zone 1 even though it would normally be classified as a Zone 2 area), or to require motors installed in a Zone 2 area to be suitable for Zone 1. This is very country-dependent and demands that the end user pay detailed attention to the local standards and regulations, which may be adaptations of the IEC standards with country-specific requirements. If the end user does not do this, an engineering contractor may over-specify the electrical equipment and installation requirements, which will result in higher project costs.

The conclusion is that electric machines that are installed according to the NEC [1] installation requirements are not required to be "identified for use" in Class I, Division 2 or Zone 2 locations, and avoid the additional costs related to marking and documentation. The relatively few electric machines installed in Class I, Division 1 locations must be either identified for use in a Class I, Division location or meet one of the other requirements of 501.125(A) of the NEC [1]. Zone 1 location installations under the NEC rules require electric machines either be specifically marked as suitable for the location, that the equipment be identified as explosionproof for use in a Class I, Division 1 or be identified as a Type X pressurized enclosure: both at a suitable temperature class. Most international installations that use the IEC 60079 series of standards for equipment, adapted to the USA or Canadian national differences, will require marking and documentation for installation in both Zone 2 and Zone 1 locations.

VII. CONCLUSION

To summarize the driving forces to select motors for hazardous areas: USA installations follow NEC [1] Article 501 for "Divisions" or NEC [1] Article 505 for "Zones" In Canada, the CE Code [2] Section 18 mandates the "Zone" area classification system for all new facilities or major retrofits of existing facilities. Legacy installations are permitted to remain with the "Division" area classification system per Section J18. For Canada, motors made for the of "Zone" system remain the primary equipment choice. In the USA, and in Canadian legacy installations, motors are generally made for the "Division" system.

The authors conducted a short survey among end users and an engineering company. They came back with following take-aways:

1) Installations strictly follow the NEC [1] for the USA and the CE Code [2] for Canada.
2) USA installations use more Division than Zone classifications, even though motors installed within Division 2 classifications are equally allowed to be installed in Zone 2 classifications and vice versa.
3) Installations in Canada are predominantly classified using the Zone system. However, Zone and Division classifications are not mixed at a single installation. Keep Division and Zone installations separate. One end user sees flexibility in adopting Zone equipment even though “eb” motors are not suitable for Division 1 areas. They are easier to install.
4) Motors without hazardous location certifications are accepted in Division 2 or Zone 2 classified areas if they are installed in accordance with the NEC [1] or CE Code [2].
5) Engineering companies follow the instructions and recommendations of the end user unique to each project.

Manufacturers in North America have designed and supplied motors for installation in Division locations for decades, and therefore find it easier to supply motors for Division installations over motors for Zone installations, largely because accessories ~~of~~ for Divisions are readily available, and accessories for Zones~~,~~ are not as common. Manufacturers outside North America prefer motors of Zone system; however, they may still be required to follow the USA or Canada adopted versions of IEC standards for Zone installations.

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IX. VITAE

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APPENDIX A

SURVEY FROM ANONYMOUS END USERS

Survey Company	Which motor to procure? Division or Zone?	Who specify?	Does LAHJ accepts Div2 motors as it is?	Does IEC/Zone compliant motor have extra benefit?	Why some NEC compliant countries procure IEC/Zone machines?
A (USA)	US Gulf operation follow NEC section 501.125 for Division system. LV Motors are TEFC and do not require NRTL certified but generally manufacturer provide certification. MV motors larger than 5MW required NRTL certified for Div 2 location.	Prioritized in order: 1) USCG and BSEE 2) Industry standards 3) Company standards	USCG and BSEE accept	Do not mix match Division and IEC/Zone machines. IEC/Zone facilities where only IEC/Zone machines are installed	Not applicable
B (USA)	US refining and chemical are dominantly Division classified, and accept motors “not identified for use” for Division 2	1) Local AHJ, with end-user or engineering contractor discussion and agreement, 2) Company standards that overlay petrochemical industry IEEE and API standards	Most do; a few jurisdictions require testing and marking	No benefit for areas that are classified as Division 1 or 2. Zone classified areas would specify motors to the IEC 60079 series.	Not aware of reasons, other than possibly regional supply chain considerations (Note: Per the NFPA website, the NEC has been federally adopted by Mexico, Guatemala, Nicaragua, El Salvador, Honduras, Costa Rica, Panama, Dominican Republic, Colombia, Ecuador, Peru, and Venezuela)
C (Canada)	Zone and Division are equally allowed Refinery is divided roughly 50% Zone and 50% Division classified. No mixed match in each category	Engineering company but to follow end user standard	Yes as specified in CE Code 18-150	Yes, More complex but more flexible for cost reduction such as Ex eb motor for Zone 1 / Division 1 area does not exist in Division. Flameproof per IEC is much easier to install than Explosion proof motor etc.	Perhaps IEC/Zone based installations: Zone system has more choices and more types of protection techniques-adds complexity but also adds flexibility and can reduce cost
D (Canada)	Follow CE Code and allowed machines to suit classified area	Engineering company with end user recommendation	Yes	Not aware of any incremental benefits	Not aware of
E Eng comp USA	Depending upon project requirements	Safety team	Yes	IEC motor seems smaller or compact in size	Depending upon end user project requirements

BSEE is Bureau of Safety and Environment Enforcement-USA regulating Offshore Energy Industry

APPENDIX B

INSTALLATIONS IN CLASS I, DIVISION 1 or CLASS I, DIVISION 2

Guidance for Selection of Protection Technique

Location	Country	Protection Technique	Hazardous Area Standards	General Industrial Standards	Comments
Area Classification (Division System)	US		NFPA 497 [36]	N/A	Chemical process industry
			API RP500 [24]		Oil & gas industry
	CA		NFPA 497 [36]		Chemical process industry
			API RP500 [24]		Oil & gas industry
Class I, Division 1	US	XP	UL 674* [13]	UL 1004-1 [5] or UL 60034-1 [20]	Only practical for machines rated < 800 hp / 600 kW
		Purge	NFPA 496 [14]	UL 1004-1 [5] or UL 60034-1 [20]	Requires an additional “protective gas” supply system along with alarm / shutdown requirements.
	CA	XP	C22.2 No. 145* [15]	C22.2 No. 100 [6]	Only practical for machines rated < 800 hp / 600 kW
		Purge	LTR E-010 (NFPA 496) [35]	C22.2 No. 100 [6]	Requires an additional “protective gas” supply system along with alarm / shutdown requirements.
Class I, Division 2	US	Suitable	NEC 501.125(B) [2]	UL 1004-1 [5] or UL 60034-1 [20]	Implemented by the end user.
		Suitable	UL1836 [7]	UL 1004-1 [5] or UL 60034-1 [20]	Used when third-party certification is sought.
		Purge	NFPA 496 [14]	UL 1004-1 [5] or UL 60034-1 [20]	Requires an additional “protective gas” supply system along with alarm requirements.
	CA	Suitable	CE Code J18-150 2) e) [2]	C22.2 No. 100 [6]	Implemented by the end user.
		Purge	LTR E-010 (NFPA 496) [35]	C22.2 No. 100 [6]	Requires an additional “protective gas” supply system along with alarm requirements.
		Suitable	LTR E-013 [12]	C22.2 No. 100 [6]	Used when third-party certification is sought.
* CSA C22.2 No. 145 / UL 674 / NMX J-652-ANCE - CA/US/MX Trinational Standard					

APPENDIX C

INSTALLATIONS IN ZONE 1 OR ZONE 2

Guidance for Selection of Type Protection

Location	Country	Type of Protection	Hazardous Area Standards	General Industrial Standards	Comments
Area Classification (Zone System)	US	N/A	NFPA 497 [36]	N/A	Chemical process industry
			API RP505 [25]		Oil & gas industry
			UL 60079-10-1 [37]		Not industry specific
	CA	N/A	NFPA 497 [36]	N/A	Chemical process industry
			API RP505 [25]		Oil & gas industry
			IEC 60079-10-1 [37]		Not industry specific
Zone 1	US	"db"	UL 60079- 0 [16] & UL 60079-1 [30]	UL 1004-1 [5] or UL 60034-1 [20]	Only practical for machines rated < 800 hp / 600 kW
		"eb"	UL 60079-0 [16] & UL 60079-7 [17]	UL 1004-1 [5] or UL 60034-1 [20]	May require pre-start ventilation
		"pxb"	UL 60079-0 [16] & UL 60079-2 [31]	UL 1004-1 [5] or UL 60034-1 [20]	Requires an additional "protective gas" supply system along with alarm / shutdown requirements.
		"pyb"	UL 60079-0 [16] & UL 60079-2 [31]	UL 1004-1 [5] or UL 60034-1 [20]	
	CA	"db"	C22.2 No. 60079-0 [18] & C22.2 No. 60079-1 [32]	C22.2 No. 100 [6]	Only practical for machines rated < 800 hp / 600 kW
		"eb"	C22.2 No. 60079-0 [18] & C22.2 No. 60079-7 [19]	C22.2 No. 100 [6]	May require pre-start ventilation
		"pxb"	C22.2 No. 60079-0 [18] & C22.2 No. 60079-2 [33]	C22.2 No. 100 [6]	Requires an additional "protective gas" supply system along with alarm / shutdown requirements.
		"pyc"	C22.2 No. 60079-0 [18] & C22.2 No. 60079-2 [33]	C22.2 No. 100 [6]	
Zone 2	US	"ec"	UL 60079-0 [16] & UL 60079-7 [17]	UL 1004-1 [5] or UL 60034-1 [20]	
		"pzc"	UL 60079-0 [16] & UL 60079-2 [31]	UL 1004-1 [5] or UL 60034-1 [20]	Requires an additional "protective gas" supply system along with alarm requirements.
		"nA"	UL 60079-0 [16] & UL 60079-15 (Ed 1, 2, 3) [38]	UL 1004-1 [5] or UL 60034-1 [20]	Replaced by "ec". Removed from 60079-15, Ed 4
		Suitable	NEC 505-20(C) Exception 4	UL 1004-1 [5] or UL 60034-1 [20]	
	CA	"ec"	C22.2 No. 60079-0 [18] & C22.2 No. 60079-7 [19]	C22.2 No. 100 [6]	
		"pzc"	C22.2 No. 60079-0 [18] & C22.2 No. 60079-2 [33]	C22.2 No. 100 [6]	Requires an additional "protective gas" supply system along with alarm requirements.
		"nA"	C22.2 No. 60079-0 [18] & C22.2 No. 60079-15 (Ed1,2,3) [39]	C22.2 No. 100 [6]	Replaced by "ec". Removed from 60079-15, Ed 4
			CE Code 18-150 2) e) [2]	C22.2 No. 100 [6]	