

IEEE Guide for the Application of Electric Motors in Class I, Division 2 and Class I, Zone 2 Hazardous (Classified) Locations

IEEE Industry Applications Society

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IEEE Industry Applications Society

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Abstract: Three-phase and single-phase AC synchronous and induction electric motors in ratings 0.18 kW (1/4 hp) and larger are covered in this guide. Primary emphasis is on the use of open or nonexplosionproof or nonflameproof enclosed motors in Class I, Division 2 and Class I, Zone 2 locations as covered in NFPA 70-2011. Surface temperature test methods and sine wave and non-sine wave applications are covered. Precautions against excessive surface temperatures and sparking are included. To mitigate hot surface temperatures and sparking, this document provides guidance for selecting, operating, and maintaining motors in Class I, Division 2 and Class I, Zone 2 locations. This guide does not cover AC wound rotor motors and DC electric motors. Motors installed in locations other than Class I, Division 2 and Class I, Zone 2 as covered in NFPA 70-2011 are not covered in this guide. This document is not a specification and is not intended to be used as a specification for purchasing motors. The voltage breaks in this document are 1000 V and less, and over 1000 V.

Keywords: adjustable speed drive; autoignition temperature; Class I, Division 2; Class I, Zone 2; classified locations; enclosure sparking; hazardous locations; IEEE 1349; induction motor; label test; motor; motor enclosure; motor temperature; multisection motor; paint test; rotor; rotor sparking; rotor temperature; synchronous motor; T Code; temperature code

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Introduction

This introduction is not part of IEEE Std 1349-2011, IEEE Guide for the Application of Electric Motors in Class I, Division 2 and Class I, Zone 2 Hazardous (Classified) Locations.

This guide was developed to assist individuals, organizations, and suppliers with the application of motors in Class I, Division 2 and Class I, Zone 2 locations, where flammable gases and vapors may occasionally be present.

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1. Overview

This guide is divided into several clauses. Clause 1 provides the scope of this guide. Clause 2 lists references to other standards that are inclusive when applying this guide. Clause 3 provides definitions, abbreviations, and acronyms that are either not found in other standards, or have been modified for use with this guide. Clause 4 describes the phenomenon of a motor as a possible ignition source. Clause 5 provides guidance for Common applications of motors in Class I, Division 2 and Class I, Zone 2 locations. Consideration should be given to the maximum recommended Class I, Division 2 or Zone 2 exposed motor surface temperatures described in 5.2 for Common applications. Clause 6 provides guidance for Uncommon applications of motors in Class I, Division 2 and Class I, Zone 2 locations. Clause 7 discusses the operating and maintenance considerations that mitigate hot surface temperatures and sparking, specifically focusing on ~~when the~~ motors ~~are~~ located in Class I, Division 2 or Zone 2 locations. Clause 8 describes preferred test methods for determining internal ~~and external~~ motor surface temperatures for the purpose of applying motors in Class I, Division 2 and Class I, Zone 2 locations.

Ten annexes are included: A) bibliography, B) ~~major~~ regulations and standards ~~for covering applications of~~ motors ~~used in areas where flammable gases or vapors may be present~~ ~~potentially flammable atmospheres~~, C) AITs (~~autoignition temperature~~) and group designations for Class I materials, D) motor enclosure types ~~and protection techniques~~, E) motor information tables to check a motor data sheet, F) multisection motor inspection procedure, G) motor sparking considerations, H) surface temperature ~~study results and~~ considerations, I) ~~motor~~ surface temperature test methods ~~and limitations~~, and J) event history.

1.1 Scope

Three-phase and single-phase AC synchronous and induction electric motors in ~~ratings 0.18 kW (1/4 hp) sizes from fractional horsepower~~ and larger are covered in this guide. Primary emphasis is on the use of ~~open or nonexplosion proof or nonflame proof enclosed motors in Class I, Division 2~~ ~~general-purpose enclosures~~ and ~~Class I, Zone 2 locations as covered in National Electrical Code[®] (NEC[®]) (NFPA 70-2011).~~¹ ~~Surface temperature test methods and sine wave and non-sine wave applications are covered.~~ Precautions against excessive surface temperatures and sparking ~~are included. To mitigate hot surface temperatures and sparking, this document of rotor bars and enclosure joints. This guide~~ provides guidance for ~~selecting, operating, and~~ maintaining ~~the life-cycle integrity of~~ motors in Class I, Division 2 ~~and Class I, Zone 2~~ locations.

This guide does not cover AC wound rotor motors and DC electric motors. Motors installed in locations other than Class I, Division 2 ~~and Class I, Zone 2 as covered in NFPA 70-2011~~ ~~locations~~ are not covered in this guide. ~~This document is not a specification and is not intended to be used as a specification for purchasing motors.~~

The voltage breaks in this document are 1000 V and less, and over 1000 V.

1.2 Purpose

Existing codes and standards contain cautionary notes for ~~open or nonexplosion proof or nonflameproof enclosed motors~~ ~~general-purpose motor applications~~ in Class I, Division 2 ~~and Class I, Zone 2 locations as covered in the NEC areas.~~ This guide documents industry experience and established practices ~~for the application of general-purpose motors in Class I, Division 2 locations~~ and provides guidance for applying motors in these locations. ~~This guide is not a specification and is not intended to be used as a specification for purchasing motors installed in Division 2 locations.~~

1.3 Background

As early as 1905, the *National Electrical Code*[®] (*NEC*[®])² recognized that a suitable enclosure would be required when an electric motor was installed in the vicinity of combustible materials ([National Electric Code, 1905](#)) [B54].³ In the early 1920s, the *NEC* began to designate and recognize flammable and combustible materials by the current Class system without Division subcategories. With this system, an electric motor located within a Class I location was required to have an explosion proof enclosure.

In 1931, Classes were introduced to the *NEC*; in 1935, Groups A, B, C, and D were added; and in 1947, Divisions 1 and 2 were added. By allowing a Division 2 location to be individually evaluated on the basis of the amount of material that may escape during abnormal operating conditions, adequacy of ventilation, total area involved, and the history of the type of installation, the *NEC* allowed open-type, nonexplosionproof electric motors to be installed in Division 2 locations. During this same period, electric motor manufacturers also developed the totally enclosed, fan cooled (TEFC) motor. By 1947, the *NEC* permitted open-type and TEFC motors “without brushes, switching mechanisms or integral resistance devices” for installation in Division 2 locations. From that time until the mid-1980s, hundreds of thousands of open-type and TEFC motors, ranging in size from fractional horsepower to over 10000 hp, had been installed in Class I, Division 2 locations.

This guide addresses two [Informational Notes for Division applications](#): Fine Print Note (~~(FPNs): Section 501-8(b)~~ FPN) No. 1 was added to the *NEC* in 1984 [to Section 501 and currently is in Section 501.125\(B\) Informational Note No. 1](#) as follows: “It is important to consider the temperature of internal and external surfaces that may be exposed to the flammable atmosphere.”⁴ FPN No. 2 was added to the *NEC* in 1993 to Section 501 and [currently is in Section 501.125\(B\) Informational Note No. 2](#) 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.”⁵

¹[Information on references can be found in Clause 2.](#)

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In 1996, Zones were added to the NEC. This guide addresses two Informational Notes: Section 505.20(C), Informational Note No. 1 and Informational Note No. 2, which were added to the NEC in 1999 for Zone applications as follows: Section 505.20(C), Informational Note No. 1: “It is important to consider the temperature of internal and external surfaces that may be exposed to the flammable atmosphere.”⁶ Section 505.20(C), Informational Note No. 2: “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.”⁷

Since the mid-1980s, at least ~~eight~~ ~~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~~ 6.0 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 characteristics during motor starting, motor running, and motor overload conditions. Additional testing is expected to continue to identify further those elements that contribute to the successful installation of motors in Class I, Division 2 and Zone 2 locations.

1.4 Industry experience

By far the world’s largest user of open-type and TEFC motors in Class I, Division 2 and Zone 2 locations is the petrochemical industry. Electric motors are used to drive centrifugal and positive displacement pumps, compressors, mixers, fans, and blowers. The typical motor utilized has been an open-type or TEFC, squirrel cage induction motor designed to operate at a fixed speed and started across the line with full rated voltage.

The petrochemical industry has experienced an excellent history utilizing these open-type and TEFC motors in Class I, Division 2 [and Zone 2](#) hazardous locations; see Haynes and Messec [B39]. For more than 60 years, there have been no known incidents caused by sparking or excessive surface temperatures involving motor sizes up to 5 MW or motor voltage ratings up to 6.0 kV; see Bartels and Bradford [B16] and BEAMA Ltd. [B66]. (Refer to Annex J.)

2. [Normative](#) references

[The following referenced documents are indispensable for the application of this document \(i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained\). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document \(including any amendments or corrigenda\) applies.](#)

~~This guide shall be used in conjunction with the following publications.~~

⁵ [See Footnote 4.](#)

⁶ [See Footnote 4.](#)

⁷ [See Footnote 4.](#)

API 541-~~2004~~¹⁹⁹⁵, Form-Wound Squirrel-Cage Induction Motors—~~500 250~~ Horsepower and Larger, ~~Fourth~~^{Third} Edition, ~~June 2004.~~^{8 April 1995.}⁴

API 546-~~2008~~¹⁹⁹⁷, Brushless Synchronous Machines—500 kVA and Larger, ~~Third~~^{Second} Edition, ~~June 1997.~~^{September 2008.}

API 547-2005, General-Purpose Form-Wound Squirrel Cage Induction Motors—250 Horsepower and Larger, First Edition, January 2005.

IEEE Std 303TM-~~2004, 1991 (Reaff 1996),~~ IEEE Recommended Practice for Auxiliary Devices for [Rotating Electrical Machines](#) ~~Motors~~ in Class I, ~~Groups A, B, C, and D,~~ Division 2 [and Zone 2](#) Locations.^{9, 10}⁵

IEEE Std 841™-[2009](#) ~~-1994~~, IEEE Standard for Petroleum and Chemical Industry—Severe Duty Totally Enclosed Fan-Cooled (TEFC) Squirrel Cage Induction Motors—Up to and Including [370 kW](#) (500 hp).

IEEE Std 1068™-[2009](#) ~~-1996~~, IEEE [Standard Recommended Practice](#) for the Repair and Rewinding of [AC Electric Motors in the Petroleum, Chemical, and Process](#) Industries.

NEMA MG-1-[2009 \(Revision 1-2010\)](#), ~~1998~~, Motors and Generators.¹¹

NFPA 70-[2011](#) ~~1999~~, *National Electrical Code*® (NEC®).¹²

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. ~~IEEE 100™~~—*The IEEE Standards Dictionary: Glossary of Terms & Definitions*, ~~Seventh Edition~~, should be consulted for terms not defined in this clause.¹³

abnormal operating condition: As applied to motors, including, but not limited to, starting, locked rotor, voltage unbalance, overload, and short-circuit. As applied to equipment in classified locations, equipment failure is considered to be an abnormal operating condition.

adjustable speed drive (ASD): An electric drive designed to provide easily operable means for speed adjustment of the motor, within a specified speed range. (See *IEEE Standards Dictionary: Glossary of Terms & Definitions*.)

ambient temperature: Ambient temperature is the temperature of the surrounding cooling medium, such as gas or liquid, which comes into contact with the heated parts of the apparatus. (See NEMA MG-3.1.)

approved: Acceptable to the authority having jurisdiction.¹⁴

⁸ API publications are available from the American Petroleum Institute, 1220 L Street NW, Washington, DC 20005-4070, USA (<http://www.api.org/>).

⁹ IEEE publications are available from the Institute of Electrical and Electronics Engineers, Inc., 445 Hoes Lane, Piscataway, NJ 08854, USA (<http://standards.ieee.org/>).

¹⁰ The IEEE standards or products referred to in this clause are trademarks of the Institute of Electrical and Electronics Engineers, Inc.

¹¹ NEMA publications are available from the Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80122, USA (<http://global.ihs.com/>).

¹² NFPA publications are available from Publications Sales, National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101, USA (<http://www.nfpa.org/>).

¹³ The *IEEE Standards Dictionary: Glossary of Terms & Definitions* is available at <http://shop.ieee.org/>.

autoignition temperature (AIT): The minimum temperature required to initiate or cause self-sustained combustion of a solid, liquid, or gas independently of the heating or heated element.¹⁵

Class B rise: Based on a maximum 40 °C ambient, a motor stator temperature rise at 1.0 service factor of 80 °C (measured by resistance) or 80 °C, 85 °C, or 90 °C (measured by [embedded detectors](#) ~~RTD~~) in accordance with NEMA MG-1-[2009 \(Revision 1-2010\)](#),~~1998~~,¹⁰ depending on the motor size, motor type, enclosure type, and voltage rating. The rise at 1.0 service factor corresponds to Class B type of insulation system in the NEMA MG-1-2009 (Revision 1-2010) temperature rise tables.

Class I, Division 2: A location 1) in which volatile flammable gases, flammable liquid-[produced vapors](#), [or combustible liquid-produced](#) ~~and~~ vapors are handled, processed, or used, but in which the liquids, vapors, or gases will normally be confined within closed containers or closed systems from which they can escape only in case of accidental rupture or breakdown of such containers or systems or in case of abnormal operation of equipment, or 2) in which ignitable concentrations of [flammable](#) gases, [flammable liquid-produced vapors](#), [or combustible liquid-produced](#) ~~or~~ vapors are normally prevented by positive mechanical ventilation and which might become hazardous through failure or abnormal operation of the ventilating equipment, or 3) that is adjacent to a Class I, Division 1 location, and to which ignitable concentrations of [flammable](#) gases, [flammable liquid-produced](#) vapors, or [combustible liquid-produced vapors above their flash points](#) might occasionally be communicated unless such communication is prevented by adequate positive-pressure ventilation from a source of clean air and effective safeguards against ventilation failure are provided. [See Section 500.5(B)(2) of the [2011 NEC](#).]¹⁶~~1999 NEC~~.⁸

Class I, Zone 2: [A location 1\) in which ignitable concentrations of flammable gases or vapors are not likely to occur in normal operation and, if they do occur, will exist only for a short period; or, 2\) in which volatile flammable liquids, flammable gases, or flammable vapors are handled, processed, or used but in which the liquids, gases, or vapors normally are confined within closed containers or closed systems from which they can escape, only as a result of accidental rupture or breakdown of the containers or system, or as a result of the abnormal operation of the equipment with which the liquids or gases are handled, processed, or used; or, 3\) in which ignitable concentrations of flammable gases or vapors normally are prevented by positive mechanical ventilation but which may become hazardous as a result of failure or abnormal operation of the ventilation equipment; or, 4\) that is adjacent to a Class I, Zone 1 location, from which ignitable concentrations of flammable gases or vapors could be communicated, unless such communication is prevented by adequate positive pressure ventilation from a source of clean air and effective safeguards against ventilation failure are provided. \[See Section 505.5\(B\)\(3\) of the 2011 NEC.\]](#)¹⁷

Common application: A Common ~~motor~~ application in Class I, Division 2 or Class I, Zone 2 location is where a synchronous or low-slip (typically less than 3%) induction motor is operating at rated or below full-load steady-state conditions and within the defined parameters.

NOTE—The defined parameters for Common applications are provided in 5.1.¹⁸

Common ASD application: A Common ASD application in Class I, Division 2 or Class I, Zone 2 location is where a synchronous or low-slip (typically less than 3%) induction motor is operating within the defined parameters.

NOTE—The defined parameters for Common ASD applications are provided in 6.3.2.

common-mode voltage (CMV): In the context of adjustable speed drives (ASDs), CMV is the displacement of the neutral point (and each phase voltage) of the ASD output from ground due to the switching of the solid state devices in the drive. It is an alternating voltage whose magnitude and frequency components are dependent on the drive topology. All present drive topologies create CMV to some extent. CMV can also be created at the motor if phase circuit conductors, unsymmetrical with respect to the equipment grounding conductor(s) or grounded sheaths or raceways, are used between the ASD output and the motor.

¹⁵ Reprinted with permission from NFPA 497, *Recommended Practice for the Classification of Flammable Liquids, Gases or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*. Copyright © 2008, National Fire Protection Association, Quincy, MA. 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.

¹⁶ See Footnote 4.

¹⁷ See Footnote 4.

¹⁸ Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard

⁴⁰ ~~Information on references can be found in Clause 2.~~

continuous duty: Operation at a substantially constant load for an indefinitely long time. This is also known as continuous rating in NEMA MG-1.

corona: A type of localized discharge resulting from transient gaseous ionization on an insulation system when the voltage stress exceeds a critical value. The ionization is usually localized over a portion of the distance between the electrodes of the system. (Corona activity can result in surface discharges and surface tracking on motor windings.) [Corona is visible partial discharges in gases adjacent to a conductor. \(See IEEE Std 1434 \[B50\].\)](#)

explosionproof ~~proof~~ [equipment](#) ~~apparatus~~ : Equipment enclosed in a case that is capable of withstanding an explosion of a specified gas or vapor that may occur within it and of preventing the ignition of a specified gas or vapor surrounding the enclosure by sparks, flashes, or explosion of the gas or vapor within, and that operates at such an external temperature that a surrounding flammable atmosphere will not be ignited thereby.¹⁹

exposed surface: A surface that is internal to an enclosure or an external surface of an enclosure that could be exposed to the surrounding flammable atmosphere, without the benefit of an enclosure that would contain an explosion or exclude the hazardous gas. (An exposed internal surface may be the rotor, stator, or space heater surfaces of open and totally enclosed fan cooled (TEFC) motors. An exposed external surface is the exterior surface, which could be exposed to the surrounding flammable atmosphere such as the exterior surface of explosionproof, pressurized, or force ventilated enclosures.)

[identified:](#) (as applied to equipment). [Recognizable as suitable for the specific purpose, function, use, environment, application, and so forth, where described in a particular Code requirement.](#)²⁰

[IC Code:](#) [The IC Code designates the method of electrical machine cooling as described in NEMA MG-1, Part 6.](#)

[IP Code:](#) [The IP Code designates the degree of protection provided by the enclosure of a rotating machine as described in NEMA MG-1, Part 5.](#)

[listed:](#) [Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.](#)²¹

maximum experimental safe gap (MESG): The maximum clearance between two parallel metal surfaces that has been found, under specified test conditions, to prevent an explosion in a test chamber from being propagated to a secondary chamber containing the same gas or vapor at the same concentration.²²

minimum igniting current (MIC) ratio: The ratio of the minimum current required from an inductive spark discharge to ignite the most easily ignitable mixture of a gas or vapor, divided by the minimum current required from an inductive spark discharge to ignite methane under the same test conditions.²³

¹⁹See Footnote 4.

minimum ignition energy (MIE): The minimum energy required from a capacitive spark discharge to ignite the most easily ignitable mixture of a gas or vapor.²⁴

multisection motor: A motor whose construction utilizes a component block approach in the assembly of the enclosure, that is, the enclosure has a number of bolted joints which could connect together the stator frame, the ventilation hood, the motor base, the bearing supports, and enclosure covers.

NEMA frame: [This refers to the NEMA MG-1 system of a standardized frame designation for AC machines including 449 frame size and smaller. NEMA MG-1-2009 \(Revision 1-2010\). Part 4 provides critical mounting dimensions for each frame size.](#)

normal operating condition: As applied to motors, a normal operating condition is operating at rated full-load steady state conditions.²⁵ Locked-rotor, [starting](#), single-phasing, and operating above base nameplate kilowatt or horsepower are not normal operating conditions.

overload: Loading in excess of normal rating of equipment. For a motor, it is considered overloaded when operated above its base nameplate kilowatt or horsepower.

partial discharge: A localized electric discharge resulting from ionization in an insulation system when the voltage stress exceeds the critical value. This discharge partially bridges the insulation in the voids internal to the motor winding insulation.

per unit torque: [Per unit torque is the test value of load torque divided by the motor rated torque at nameplate rated conditions, such as rated voltage and rated frequency.](#)

[NOTE—As applied in Annex H.](#)

service factor: A multiplier that, when applied to the rated power, indicates a permissible power loading that may be carried under the conditions specified for the service factor.

spark: A sudden and irreversible transition from a stable corona discharge to a stable arc discharge. It is a luminous electrical discharge of short duration between two electrodes in an insulating medium. It is generally brighter and carries more current than corona, and its color is mainly determined by the type of insulating medium. It generates radio noise of wider frequency spectrum (extending into hundreds of megahertz) and wider magnitude range than corona. A spark is not classified as corona. [Sparking can also include static discharge, sparking due to mechanical contact, and capacitive discharges \(i.e., across bearing oil film and separating switch contacts\).](#)

Uncommon application: An Uncommon ~~motor~~-application in Class I, Division 2 [or Class I, Zone 2 locations is where the motor is operating or applied outside the defined parameters for Common applications.](#)

[NOTE—Operating or applied outside those defined parameters for Common application given in 5.1.](#)

Uncommon ASD application: An Uncommon ASD application in Class I, Division 2 or Class I, Zone 2 locations is where the motor is operating or applied outside the [defined parameters for Common ASD applications.](#)

[NOTE—Operating or applied outside those defined parameters for Common ASD applications given in 6.3.2.](#)

3.2 Acronyms and abbreviations

AFD	adjustable frequency drive (ASD is the IEEE preferred term)
AHJ	authority having jurisdiction
AIT	autoignition temperature
API	American Petroleum Institute
ASD	adjustable speed drive
ASTM	American Society for Testing and Materials
CEC	Canadian Electrical Code
CENELEC	European Committee for Electrotechnical Standardization
CMV	common-mode voltage
CSA	Canadian Standards Association International
DPFV	Dripproof Forced Ventilated
FLC	full-load current
FLT	full-load torque
FPN	Fine Print Note (formerly used in the <i>NEC</i>) IC IC Code
IEC	International Electrotechnical Commission
IP	IP Code
LCI	Load Commutated Inverter
LFL	lower ~~flammable~~ explosive limit
LRC	locked rotor current
MESG	maximum experimental safe gap
MIC	minimum igniting current
MIE	minimum ignition energy
MOV	metal oxide varistor
<i>NEC</i>	National Electrical Code
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
ODE	opposite drive end
ODP	open dripproof
OEM	original equipment manufacturer
PWM	pulse-width modulation
RP	recommended practice
RPM	revolutions per minute
RTD	resistance temperature detector

SCR	silicon controlled rectifier
SF	service factor
T Code	Temperature Code or Identification Number per 2011 ~~1999~~ NEC Table 500.8(C)
TEAAC	totally enclosed air-to-air cooled
TEFC	totally enclosed fan cooled
TEFV	totally enclosed force-ventilated
TENV	totally enclosed nonventilated
TEPV	totally enclosed pipe-ventilated
TEWAC	totally enclosed water-to-air cooled
TFE	tetrafluoroethylene
UFL	upper flammable limit
UL	Underwriters Laboratories Inc.
VFD	Variable Frequency Drive (ASD is the IEEE preferred term)
VSD	Variable Speed Drive (ASD is the IEEE preferred term)
WPI	weather protected Type I
WPII	weather protected Type II

4. Phenomenon of a motor as a possible ignition source

The phenomenon of a motor being a possible ignition source in a Class I, Division 2 [or Class I, Zone 2](#) location is discussed in this clause. [One of the steps in selecting the proper motor for a location is determining the area classification where the motor will be located; this document\(s\) identifies possible fuel sources and their characteristics.](#) As a consequence of facility improvements, a particular facility's area classification may have changed from when the facility first went into service.

NOTE—[As an example](#), significant improvements have been made over the years in equipment integrity, which has resulted in an improved general safety record of petrochemical process plants. This is due to the following:

- Improved equipment and containment measures.

- Reduction in accidental and escaping emissions.

- Improved understanding of the processes and their control requirements.

- Advances in use of computerized control techniques.

- Improvements in reclamation of volatile fluids (e.g., orifices that were normally open to the atmosphere during tank filling operations may now be closed vent systems).

- Improvements to sample lines in relation to their attachment points and/or their placement position in relation to drains.

- Improvements to drainage systems, e.g., open drains have been converted to closed drains or modified to prevent hydrocarbon accumulation.

A common practice in petrochemical facilities is to specify that [electrical](#) equipment be designed for ~~a~~-Class I, Division 2 [or Zone 2](#) locations even when originally placed in an unclassified location to prepare for potential future facility modifications. Refer to API RP 500 [B11], API RP 505 [B12], NFPA 497-[2008 \[B59\]](#) ~~1997 [B32]~~ and the [2011](#)~~1999~~ NEC for guidance when determining area classifications and equipment requirements.

For motor applications, there are basically two potential types of ignition sources: hot surface temperatures and sparking. Mitigating hot surfaces and sparking conditions or containing sparking in approved enclosures are paramount to preventing ignition events caused by motors or their accessories. Sparking is discussed in Annex G. Surface temperatures are discussed in Annex H. The phenomenon of a motor causing an ignition is discussed in 4.1 through 4.4.

4.1 Ignition overview

For a fire or explosion to occur, three things are needed: oxygen ([air](#)), a source of fuel, and an ignition source ([heat or spark](#)), which are discussed in 4.2. The characteristics of the fuel are critical to determining potential ignition sources. One of the critical characteristics of flammable gases and vapors is the autoignition temperature (AIT). The group designation of flammable gases and vapors is also important for the design of enclosures. These characteristics are described in 4.3.

External surfaces can come into contact with gas releases, so external surface temperatures should be considered potential ignition sources. If the gas can enter the motor enclosure, then internal surface temperatures may need to be considered as potential ignition sources. Motor enclosure gas ingress is discussed in 4.4.

Under normal operating conditions, the exposed surface temperatures should be within acceptable limits, [specifically, below the AIT of the potential flammable gases or vapors](#); and there should not be any sparking devices, except inside enclosures approved to contain such events. Experience has shown that the probability of the three ignition components ([air, fuel, and ignition source](#)) being present simultaneously and an ignition occurring is very small. (See API 2216-2003 [B8], Bredthauer et al. [B21], Buschart et al. [B23], and Hamer et al. [B36].)

4.2 Ignition components

Ignition is the process or means of igniting a fuel mixture, and igniting causes a fuel mixture to burn or cause combustion. Combustion is simply a rapid oxidation reaction that is accompanied by the emission of energy in the forms of heat and light. It normally takes place in air, which is composed of approximately 21% oxygen. In order for combustion to occur, a Class I material, such as gasoline, would be present and there would be enough oxygen to sustain combustion as well as enough heat to raise the Class I material to its ignition temperature; see API 2216-2003 [B8]. This is often represented as a fire triangle, as shown in Figure 1.



Figure 1—Fire triangle

4.3 Gas AIT and group designation

The AIT of a flammable gas or vapor is important in determining the acceptability of equipment that operates at relatively high exposed surface temperatures (above 100 C). Explosionproof equipment is designed with an external surface temperature below the AIT, but the internal temperature can be above the AIT. The explosionproof enclosures contain an internal explosion and prevent the hot explosive gases from igniting the surrounding flammable atmosphere by cooling the gases as they exit the enclosure. The surface temperature of all exposed internal and external components of general-purpose equipment should also be below the AIT of potential flammable sources so that the surface does not become a potential ignition source.

The tests conducted by the IEEE P1349 Working Group confirmed that materials ignited in operating motors at higher temperatures than published AIT values. The Working Group test results are summarized in H.2.1.

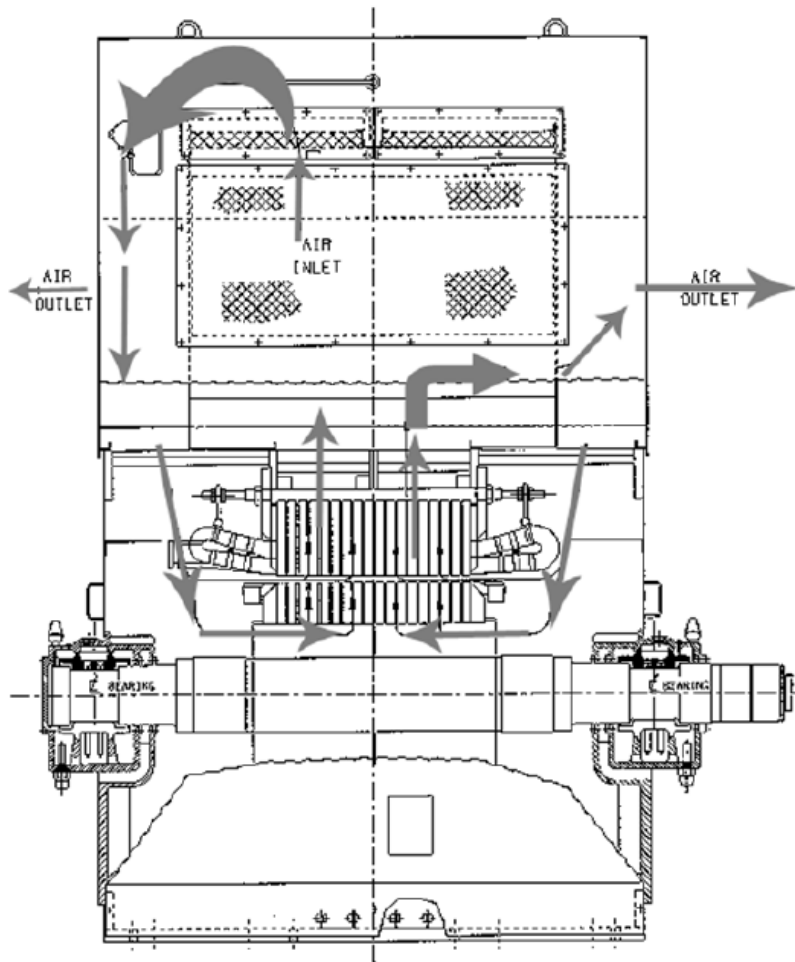
The group designation reflects that different gases and vapors cause varying maximum explosive pressures when ignited and is characterized by different maximum experimental safe gaps (MESGs). Enclosures designed to contain/cool an explosion have group designations and are applied within their listed, labeled, and/or tested group(s) for which they were approved.

For additional information, Annex C describes the AIT characteristics of flammable gases and vapors. [The AITs of components are in NFPA 497-2008 \[B59\] and ANSI/ISA TR 12.13.01-1999 \(R2005\) \[B7\]. The AIT of mixtures can be determined by testing using the methods described in Annex C. Gas mixture flammability \(UFL and LFL\) and Gas Group classification can sometimes be approximated using Le Chateleier's method described in the Bozek and Rowe paper \[B20\]. See NFPA 497-2008 \[B59\] also for information on Le Chateleier's method.](#) ~~shows~~ the Group designations are defined in the 2011 ~~1999-NEC~~ [and single components are in NFPA 497-2008 \[B59\].](#)

4.4 Gas ingress

Gases and vapors infiltrate most types of motor enclosures with the exception of forced ventilated or inert gas-filled motors when the protection system is working properly. The rate at which the gas exchange occurs is a function of many factors.

Open-type motors have a rapid exchange because the gas can readily enter the motor through the ventilation openings. For the open dripproof (ODP) and similar enclosures, any gas release surrounding the motor is taken directly into the motor along with the cooling air. The gas is rapidly mixed with the cooling air and diluted. In the motor air gap, a laminar-to-turbulent flow exists. Close to the rotor surface, there is a narrow band of air only a few molecules thick that moves with the rotor and tends to act as a thermal barrier between the rotor surface and the gas in the air gap annulus. While the rotor is spinning, this thin band prevents the gas from igniting ~~reaching~~ even if the rotor surface temperature is higher than the published AIT, [similar to experiences described in API 2216-2003 \[B8\]](#). As the motor speed approaches zero, this thermal barrier influence diminishes. Therefore, the worst case for open motors occurs just after the hot motor stops. See Figure 2 for an illustration of the free exchange of outside atmosphere to the inside of the motor enclosure.



Source: Courtesy of General Electric.

Figure 2—Large motor with a top hat showing the free exchange of outside atmosphere

For TEFC motors, gas in the surrounding atmosphere enters the motor enclosure whenever the interior pressure is negative. This happens when the motor is subjected to a drop in operating temperature, [for example when there is a drop in load, a shutdown, or other event causing a drop in operating temperature.etc.](#) The worst case for high gas concentrations inside the TEFC motor is whenever the gas release occurs while the motor is cooling down at shutdown. Tests done on totally enclosed motors have shown gas/air exchange rates from a few minutes to several hours. For totally enclosed motors many factors such as fits, clearances, gaskets, temperature differentials, and locations are factors that affect the rate of gas exchange.

In 1994, an IEEE paper by Buschart et al. [B23] presented some considerations regarding the application of totally enclosed motors in Class I, Division 2 locations. This paper showed that ~~presented support for~~ gas ingress was possible into totally enclosed motors based on testing. Conditions affecting gas ingress were presented. The paper also discussed motor internal temperatures and the relationships to AITs of potentially hazardous materials that might enter the motor (see 4.3). Normal and abnormal operating conditions that affect motor internal temperatures were discussed.

5. Common applications

Clause 5 provides guidance for Common applications of motors in Class I, Division 2 [and Zone 2](#) locations. The typical rotor operating temperatures shown in Table 1 for motors at full load have been shown by experience not to be an ignition source for motors applied in Class I, Division 2 or Zone 2 locations. The temperatures shown in Table 1 (see also the conditions stated in the footnotes) should permit application of standard, off-the-shelf motors meeting the Common application conditions of 5.1 when used with equipment handling materials having AITs above 200 °C. Motor manufacturers and users should discuss applications, and sound engineering judgment should be used.

Table 1—Motor operating temperatures for common application conditions^a

Size	Enclosure types	Rotor cooling type ^b	Typical rotor operating temperatures at full load ^c (°C)	Maximum recommended exposed surface temperature at full load (°C)
Single phase				
Up to 1.5 kW (2 hp), With arcing device	Explosion proof UL 674 listed [B70]	All	—	Per UL listing and T Code label ^d
Three phase—NEMA frame sizes				
Up to 340 kW (450 hp)	ODP	Nonducted ventilation	110–150 ^e	200
Up to 300 kW (400 hp)	TEFC	Nonducted or axial duct ventilation	115–165	200
Three phase—above NEMA frame sizes				
150 to 300 kW (200 to 400 hp)	TEFC	Nonducted or axial duct ventilation	125–185	200
Above 300 kW (400 hp)			115–200	200
Above 300 kW (400 hp)	WPII	Nonducted or axial duct ventilation	105–190	200
Above 300 kW (400 hp)	TEFV & TEWAC	Nonducted or axial duct ventilation	85–110	180
Above 110 kW (150 hp)	All ^f	Axial duct <u>and</u> radial duct ventilation	80–140	180

^a Table 1 is based on a small sampling of motors. Engineering judgment should be used and users should confer with the motor manufacturer. Temperatures are based on Class B rise at 1.0 SF, low-slip and synchronous motors, with a 40 °C ambient, rated voltage, and rated frequency.

^b See H.1.2 for a discussion of the rotor cooling types. See also Figure 2, which shows axial and radial ventilation ducts in the rotor.

^c Average rotor temperature of tested and calculated values within 1 standard deviation (rounded up or down to the nearest 5°). (See Table H.8, Table H.9, Table H.10, Table H.11, Table H.13, Table H.14, Table H.15, and Table H.16.)

^d Refer to Table H.7 and Annex I for more information on UL 674 surface temperature testing. For explosion proof motors, the group and T Code are on the motor nameplate. (Refer to the 2011 *NEC*.)

^e Typical range is primarily based on motor manufacturer's calculated rotor temperatures on NEMA Design B motors. (Refer to Table H.8.)

^f Radial ventilation is currently not used for NEMA frame-sized TEFC enclosures and is rare for above NEMA frame-sized TEFC enclosures.

Motors should have exposed surface temperatures at or below the maximum Class I, Division 2 or Zone 2 exposed surface temperature in Table 1 when: 1) built in accordance with NEMA MG-1-2009 (Revision 1-2010), IEEE Std 841-[2009, API 547-2005](#) , API 546-2008, and/or API 541-[20041995](#), and 2) applied within the Common application conditions outlined in 5.1.

The majority of motors applied in Class I, Division 2 or Zone 2 locations conform to one or more of the above standards without special requirements. Most of the AITs shown in NFPA 497-[2008 \[B591997 \[B32\]](#) and [for example](#) encountered in the petrochemical industry are above 200 C. Some applications have products, gases, and vapors with AITs 200 C or less, which are considered Uncommon applications. Few motor applications in Class I, Division 2 or Zone 2 locations should require special motor designs. For Class I, Division 2 and Zone 2 applications, this is only a guide; engineering judgment should always be used, and users should always confer with the motor manufacturers.

When applying a motor under conditions other than those in 5.1 in a Class I, Division 2 or Class I, Zone 2 locations, users should discuss the application with the motor manufacturer regarding the maximum exposed motor surface temperature. Hotter surface temperatures can occur under Uncommon application conditions, which are discussed in Clause 6.

5.1 Common application conditions

This subclause defines the parameters for Common application conditions for motors in a Class I, Division [2 and Zone 2](#) location as follows:

- a) The maximum recommended Class I, Division 2 or Zone 2 exposed motor surface temperature should be as shown in Table 1 and should be less than the AIT.
- b) Motors should have a maximum Class B rise at 1.0 service factor when tested with sine wave power at rated nameplate conditions. Refer to NEMA MG-1-[2009 \(Revision 1-2010\)](#),~~1998~~, Parts 12.43, 12.44, 20.7, and 20.8.
- c) Motors should be operated at or below their base nameplate kilowatt or horsepower.
- d) The ambient temperature range should be -15°C to 40°C [for grease-lubricated bearings, \$0^{\circ}\text{C}\$ to \$40^{\circ}\text{C}\$ for oil-lubricated bearings](#) or ~~the ambient temperature range should be~~ 5°C to 40°C when water cooling is used
- e) The maximum altitude should not exceed 1000 m above sea level.
- f) The motors should have sine wave power and fixed speed operation.
- g) The motors should be designed for continuous duty operation.
- h) The number of starts should not exceed the motor's design limitations.
- i) The load inertia should be within NEMA MG-1-[2009 \(Revision 1-2010\)](#) ~~1998~~ requirements.
- j) [Induction](#) motor torque [and speed](#) characteristics at rated load should be low slip (e.g., NEMA Design A or B [for NEMA Frame size motors, typically less than 3%](#)).
- k) The voltage or frequency variation should not exceed 10% of rated voltage or 5% of rated frequency or a combination of not more than 10%.
- l) The voltage unbalance should be within 1%.

Motors that are applied in conditions other than the Common application conditions defined above require special consideration by the applications engineer and possibly the motor manufacturer. Refer to Clause 6 for Uncommon applications.

5.2 Surface temperatures

As described in the [2011~~1999~~ NEC](#) Section 501.[125\(B\) Informational Note-8\(b\)-FPN](#) No. 1, “It is important to consider the temperature of internal and external surfaces that may be exposed to the flammable atmosphere.”²⁶ The typical and maximum temperatures given in Table 1 are based on motor tests and calculations conducted by companies participating in the development of this guide and the experiences of the Working Group participants. A summary of the tests conducted by the Working Group is in H.2.2. Some of the test and calculation data from [motor](#) manufacturers are presented in H.2.3 in Table H.7 [through](#) Table H.17. [Some of the test data from motor manufacturers using ASDs are presented in H.2.4 in](#) Table H.18 through Table H.20. Other test data are in Hamer et al. [B36]. The sample group of motors tested is small compared to the number of motors in service.

5.3 Sparking

Sparking in motors is not expected under normal conditions and Common application conditions except from auxiliary devices, temperature/overload switches, centrifugal switches used in single-phase motors, and in some motors with higher voltages, particularly with high speeds. [Refer to IEEE Std 303-2004 for proper application of auxiliary devices in Class I, Division 2 and Zone 2 locations.](#) Sparking that can occur is discussed in Annex G.

5.4 General equipment considerations

The following subclauses describe general equipment considerations that apply to motors applied in Class I, Division 2 or Zone 2 locations in Common applications.

5.4.1 Enclosures

General-purpose enclosures are acceptable in Class I, Division 2 or Zone 2 locations for nonsparking devices as long as surface temperatures meet the requirements of the [2011~~1999~~ NEC](#). [See NEC Sections 501.125\(B\) and 505.20\(C\) Exception 4](#). Enclosures meeting the requirements of Class I, Division 1 locations can be used in Class I, Division 2 or Zone 2 locations provided that they are applied within the equipment listing or labeling requirements. For example, explosionproof motors [or flameproof \[Zone protection method “d”, ref. NEC 505.8\(A\)\]](#) are [required to be](#) applied within their “T” Code and group designation indicated on their nameplate.

The more commonly applied open-type and totally enclosed type motor enclosures applied in the petrochemical industry are described in Annex D. Other selections of open-type motors are described in NEMA MG-1-[2009 \(Revision 1-2010\)](#) Part 1.25-~~1998~~, and totally enclosed type motors are described in NEMA MG-1-2009 (Revision 1-2010), Part 1.26. Within the enclosures options, the most commonly applied are the weather protected Type I (WPI [or IP23](#)), weather protected Type II (WPII [or IP24W](#)), totally enclosed fan-cooled (TEFC or IP44/54), explosionproof (TEFC-XP or IP44/54), totally enclosed water-to-air cooled (TEWAC or IP54), and totally enclosed air-to-air cooled (TEAAC or IP54). In some cases, these base enclosures are modified for forced ventilation. Refer to Annex D for further discussion on the selection of motor enclosures.

Open drip proof enclosures are generally not [recommended for](#) use in Class I, Division [2 or Zone](#) 2 dirty environments because the contaminants add to the surface heating in the motors, and in higher voltage motors winding contamination can lead to corona and surface tracking as discussed in Dymond et al. [B33].

²⁶ See Footnote 4

[For Zone applications, NEC Section 505.8 defines several protection techniques applicable to motors, namely, flameproof \(“d”\), purged and pressurized \(“p”, “p_x”, or “p_y”\), and increased safety \(“e”\), all suitable for Class I, Zone 1 and Zone 2. The purged and pressurized \(“p_z”\) and non-sparking \(“nA”\) protection techniques are only suitable for Class I, Zone 2 use. These protection methods are further discussed in Annex D.](#)

For locations where liquid or condensed vapors may accumulate within a motor enclosure, the motor should be equipped with breather-drainage fittings suitable for the location, as noted in 2011 NEC 501.15 (F)(2) and NEC 505.16(E)(2).

5.4.2 Fans and ventilation systems

For motors over 1000 V, motors of the forced ventilated/air over designs (e.g., pipe ventilated or WP11 where the air is ducted from another cooling source) typically use blowers driven by TEFC or IP44/54 motors that are suitable for Class I, Division 2 or Zone 2 applications. In the event of ventilation failure, an alarm or an indicator interlocks may be appropriate for type Z purging per NFPA 496-2008 [B58].

TEPV or TEFV or TEAAC or IP44/54 motors where cooling is required external to the motor, the fans, fan assembly and ventilation systems should be non-sparking construction. Motors and auxiliary devices operating such systems should be suitable for Class I, Division 2 or Zone 2 locations. Motors with internal fan systems for WP11 or open type should be designed non-sparking type construction.

Plastic fans should be fabricated of a non-sparking, ~~conductive or~~ semiconductive material to prevent sparking due to mechanical contact or ~~avoid continuous~~ static ~~sparking hazards.~~ discharge. Other materials suitable for the environment commonly used are aluminum (with copper content of less than 0.2%), bronze, reinforced conductive plastic (to bleed off static charges), or epoxy-coated steel. ~~As such, nonsparking metal fans are desirable, but are not considered a requirement for Division 2 locations.~~

For motors over 1000 V and/or larger horsepower motors, fans are often made of metal, e.g., bronze, steel, or aluminum. For metal fans, consideration should be given to nonsparking materials (i.e., aluminum), but the condition of a fan rubbing is not considered a normal condition. The cooling fan assembly and materials should be designed to prevent sparking as a result of mechanical contact or static discharge

5.4.3 Accessories

Motor auxiliary devices should be of the nonsparking type, nonincendive, hermetically sealed, or be installed in an explosionproof enclosure.

Examples of sparking devices are temperature switches, vibration switches, shaft grounding brushes, zero-speed switches, certain types of motor winding temperature sensors ([e.g., thermal bi-metallic switch elements](#)), leak detector switches, [relays, fuses](#), etc. These devices should be installed in enclosures suitable for the Class, Group, and Division [or Zone; or the switch contacts should be hermetically sealed](#).

Examples of nonsparking devices are [auxiliary fans](#), resistance temperature detectors, [thermocouples](#), space heaters, current transformers, motor surge capacitors, gapless type arresters, noncontacting shaft vibration probes and their oscillator/demodulators (drivers), [partial discharge sensors](#), and other devices that do not spark during normal operation. These devices are typically installed in general-purpose enclosures, [typically metallic](#), unless other environmental considerations suggest a different type enclosure.

The more commonly applied accessories are discussed [in 5.4.3.1 through 5.4.3.5](#) ~~below~~. Additional information on other auxiliary devices is in IEEE Std 303-[2004](#)~~1991~~.

5.4.3.1 ~~Space~~ Heaters

Moisture on motor windings can lead to premature aging and even motor winding failures. To prevent moisture condensation when the motor is not in operation, space heater(s) can be installed to maintain the internal temperature of the motor approximately 5 °C above the ambient temperature. Large terminal boxes, especially those with accessories such as surge protection, may also be equipped with space heaters to prevent moisture condensation, thereby reducing contamination of insulator surfaces and corrosion. In addition, heaters submerged in the oil reservoir may be used for motors equipped with oil-lubricated bearings that are exposed to low ambient temperatures. The purpose of this oil heater is to maintain the oil temperature high enough to permit adequate lubrication of the bearing. [Thermostats, suitable for the area classification, or other means should be installed to control the required oil temperature, typically 10–15 °C above the ambient temperature when motor is not operating. Bearing oil heaters should not be energized in the absence of oil.](#)

~~Precautions should be taken to assure that the space heater maximum surface temperature does not exceed 80% of the AIT of the flammable mixture that may be present in Class I, Division 2 locations. The space heater should comply with the requirements of the 1999~~ [2011 NEC](#) Section 501.125(B) ~~requires 8(b) which states:~~

~~“The exposed surface of~~ space heaters [be identified for use in Class I, Division 2 location](#) the maximum [exposed](#) surface temperature (based on a 40 C ambient) ~~used to prevent condensation of moisture during shutdown periods~~ should not exceed 80% [of the AIT when operated](#) ~~of the ignition temperature in degrees Celsius of the gas or vapor involved when operated~~ at rated voltage. ~~shall be permanently marked on a visible nameplate mounted on the motor.~~ (To correspond to an AIT of 200 C, the maximum space heater surface temperature would be 160 C.) 2011 *NEC* Section 505.20(C) requires space heaters be listed for use in Class I, Zone 2 location.

Heaters are usually resistance heating devices, either of the cartridge type, strip type, or the flexible [strip type](#). ~~All-Both~~ types can be used for winding or terminal box space heaters, but cartridge types are generally used for lube oil heaters. The flexible strip-type heater is typically mounted by wrapping it around the stator end windings. [Flexible strip heaters wrapped around the end windings will reduce the clearance between adjacent coils, which could increase the chances for corona and discharges between coils, particularly on motors over 1000 V. Care must be taken to insure adequate clearances are maintained to prevent discharges between coils due to restricted clearances.](#) Precautions should be taken to avoid excessive temperatures on flexible strip-type space heaters, which are in direct contact with the stator winding. The total strip heater temperature is the winding temperature plus the heater temperature rise. When used for heating motor windings, the cartridge-type or strip type heater is mounted in a space adjacent to the winding. Therefore, it typically requires higher wattage than the flexible strip heater because it first heats the air around it, which then heats the windings of the motor.

Stator winding space heater circuits should be designed so that the heater is energized only when the motor is not in operation. If the stator winding is hot when the space heater is energized, the temperature may be too high for the winding insulation or for the hazardous location.

5.4.3.2 Surge arresters and capacitors

Nonsparking surge arresters, such as metal oxide varistor (MOV), sealed type, and specific duty surge protective capacitors can be installed in general-purpose type enclosures. Surge protection types other than those described above require enclosures approved for Class I, Division 1 locations or Zone 1 locations. [See 2011 *NEC* Article 501.35(B) and ~~1999 *NEC*~~ 505.20(C).]

NOTE—For a motor application, using three single-phase specific duty surge capacitors avoids phase-phase short-circuit faults within the capacitor.

5.4.3.3 Brakes

Brakes are typically mechanical friction devices used for the purpose of either holding a fixed load or producing torque to decelerate a load. When a mechanical friction brake is used to hold a static load, the heat generation is negligible ~~However, when used to decelerate a load, the mechanical friction brake converts rotational energy into thermal energy and the surface temperatures produced can be considerable. In such applications, precautions should be taken to assure the maximum brake temperature does not exceed the AIT of the flammable mixture.~~

5.4.3.4 Shaft grounding brushes and insulated bearings

Shaft voltage was historically only a concern for motors over 1000 V, but the shaft voltage may be a concern for motors 1000 V and below where adjustable speed drives (ASDs) are used. Motor manufacturers should be consulted regarding the applicability of shaft grounding brushes. Shaft voltages can result in the flow of destructive currents through motor bearings, manifesting themselves through pitting of the bearings, scoring of the shafts, and eventual bearing failure. Bearing currents can be attributed to the following three different causes: electromagnetic asymmetries, capacitively coupled bearing voltages, and circulating currents created by operation with some ASDs.

The method of protecting bearings against bearing currents depends on the root cause of shaft voltages. This is application/design specific. In some cases, insulating one bearing is sufficient, but in other cases both bearings should be insulated. [When both motor bearings are insulated, the shaft voltage can be transferred to the driven equipment; and in this case, insulating the coupling should be considered.](#) In extreme cases, a combination of insulated bearings [with either](#) ~~and~~ shaft grounding brushes [or an insulated coupling](#) should be considered. These extreme cases typically occur when motors are operated on ASDs.

Because shaft-grounding brushes are inherently sparking devices, if used in classified areas, they should be contained in explosionproof or purged [and pressurized \(see NFPA 496-2008\)](#) housings or use other approved means to provide suitable guarding of the sparking brushes in accordance with 2011 *NEC* 501.125 (B), for Class I, Division 1 locations or are identified for use in Class I, Division 2 as per 501.105(B); or 2011 *NEC* 505.20 (C) for Class I, Zone 2 locations. That is not to say that the motor itself should be explosionproof, but rather the shaft grounding assembly itself.

5.4.3.5 Nameplate markings

No special nameplate markings are required as noted in the 2011 *NEC*, Article 501.125 (B): “In Class I, Division 2 locations, the installation of open or nonexplosionproof enclosed motors, such as squirrel-cage induction motors without brushes, switching mechanisms, or similar arc-producing devices that are not identified for use in a Class I, Division 2 location, shall be permitted.”²⁷ [Likewise, as noted in 2011 *NEC* Article 505.20\(C\) Exception #4, “In Class I, Zone 2 locations, the installation of open or nonexplosionproof or nonflameproof enclosed motors, such as squirrel-cage induction motors without brushes, switching mechanisms, or similar arc-producing devices that are not identified for use in a Class I, Zone 2 location shall be permitted.”²⁸](#)

[Increased Safety “e” Motors identified for Class I, Zone 1, as per *NEC* 2011 505.22 are permitted in Class I, Zone 2.](#)

General-purpose motors can be marked in accordance with NEMA MG-1-2009 (Revision 1-2010), IEEE Std 841-2009, API 547-2005, API 546-2008, API 541-2004, and/or the 2011 *NEC*. It is not necessary to put temperature codes, maximum surface temperature, or “designed for Division 2 or Zone 2” on the nameplate. However, users may choose to put additional information, such as these, on the nameplate because the users do not produce the nameplates, but can specify additional markings if desired.

Motors listed by third party approval agencies are required to have nameplate markings in accordance with applicable testing standards. For example, the nameplate for an explosionproof single-phase motor listed by a Nationally Recognized Testing Laboratory should show the Class, Division, Group, and Temperature Code classification [and/or Class, Zone, Group, and Temperature Code classification](#).

If the motor has a space heater, then the space heater should have a nameplate in accordance with the 2011 *NEC* showing a T Code or a maximum temperature based on a 40 C ambient.

²⁷See Footnote 4.

²⁸ See Footnote 4.

5.5 Application considerations for motors 1000 V and below

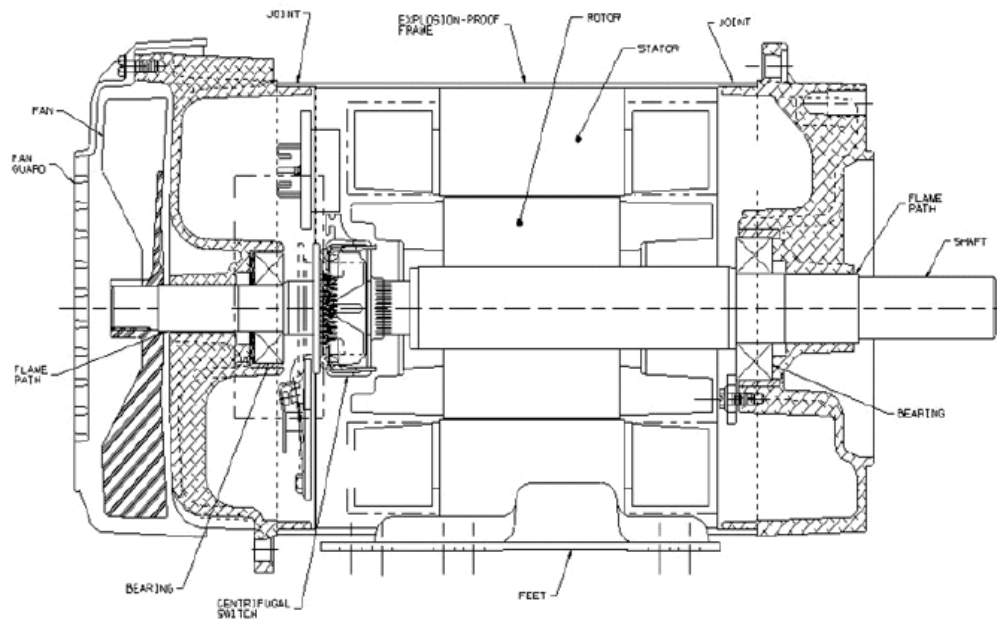
This subclause describes specific application considerations that apply to motors 1000 V and less. These considerations are in addition to the general considerations for motors applied in Class I, Division 2 or Zone 2 locations, discussed in 5.4 and the Common application considerations in 5.1.

NEMA Design A or B motors should be applied for use in Class I, Division 2 or Zone 2 locations where the torque requirements can be matched to load, such as for centrifugal pumps. Where the load torque characteristics require a Design C or D motor (e.g., a positive displacement pump), this application should be considered Uncommon and the motor manufacturer should be consulted regarding the surface temperature limits for the Class I, Division 2 or Zone 2 location.

There are two motor designs that are discussed: single-phase motors and three-phase motors.

5.5.1 Single-phase motors

Single-phase motors generally have a [starting winding connected through a series](#) capacitor ~~by start-with~~ a centrifugal switch. The switch may be a sparking device. So, single-phase motors with sparking switches installed in Class I, Division 2 or Zone 2 locations use explosionproof enclosures. Single-phase motors with sparking switches are generally avoided in Class I, Division 2 or Zone 2 locations and three-phase motors are utilized where practicable. Refer to Figure 3 for an explosionproof single-phase motor. Some single-phase motors are designed with switches approved for Class I, Division 2 or Zone 2, and do not require explosionproof motor enclosures.



Source: Courtesy of Marathon Electric.

Figure 3—Explosionproof single-phase motor

5.5.2 Three-phase motors

Three-phase motors are generally used, from fractional horsepower and up, to allow the use of general-purpose enclosures where practicable. Three-phase motors ~~1000 V and less~~ do not spark during normal operation if they are designed, built, installed, and maintained properly. ~~For fan-cooled motors, the external fans are usually plastic in the NEMA frame sizes. Plastic fans should be fabricated of a nonsparking material to avoid continuous static sparking hazards.~~

5.5.3 Specification information

When operating conditions are within the Common application conditions listed in 5.1, the minimum information that should be provided to the motor manufacturer is in Table E.1 and Table E.2 in Annex E. Information is generally provided to the motor manufacturer in a data sheet. For those applications where the operating conditions are outside those defined by 5.1, applicable additional information in Table E.3, in addition to that in Table E.1 and Table E.2, should be provided to the motor manufacturer. These are discussed in Clause 6. Other information that may be needed by the motor manufacturer for a Class I, Division 2 or Zone 2 application is in Table E.4.

As an example, ~~where the AIT is 200 °C, a space heater should have a maximum sheath temperature of 160 °C to comply with this requirement. Once the space heater maximum sheath temperature has been specified, the motor manufacturer provides a nameplate marking for the motor declaring the space heater sheath temperature that has been supplied.~~ one item in Table E.1 is a space heater. When a space heater is required, the motor manufacturer should determine the space heater's maximum sheath temperature [based on information provided](#). Refer to 5.4.3.1 for additional information on space heaters. Refer to API RP 14F-2008 [B9], [API 14FZ-2000](#) [B10], and API RP 540-1999 [B13] for guidance on when to specify space heaters.

5.6 Application considerations for motors above 1000 V

This subclause describes specific application considerations that apply to motors above 1000 V. These considerations are in addition to the general considerations for motors applied in Class I, Division 2 or Zone 2 locations, discussed in 5.4 and Common application considerations in 5.1.

Based on the motor design, application, and operation, consideration should be made to follow certain procedures to mitigate the motor from sparking or being a heat source for potential ignition. The motor system design and operating methods should also reduce introduction of flammable mixtures to potential heat sources. Some of the motor design considerations for Division 2 and Zone 2 applications are included in industry standards such as IEEE Std 841-~~2009~~[1994](#) for motors 500 hp and below, API 547-2005 for motors 250 hp and larger, API 541-2004 (induction) for 500 hp and larger, and API 546-2008 (synchronous) for motors 500 kVA and above. [In addition, for motors above 5 kV consider at least the following: enclosure selection and cooling method \(5.4.1 and Annex D\), pre-start purging and pressurization \(6.12\), gas detection and sniffing \(6.12\), insulation system \(5.6.2.4\), corona energy level \(Annex G\), gas characteristics and area classification \(Clause 4 and Annex C\), and soft-start and other starting methods.](#)

When operating conditions are within the Common application conditions listed in 5.1, the minimum information that should be provided to the motor manufacturer is in Table E.1 and Table E.2 in Annex E. Information is generally provided to the motor manufacturer in a data sheet.

For those applications where the operating conditions are outside those defined by 5.1, applicable additional information in Table E.3, in addition to that in Table E.1 and Table E.2, should be provided to the motor manufacturer. These are discussed in Clause 6. Other information that may be needed by the motor manufacturer for a Class I, Division 2 or Zone 2 application is in Table E.4.

As an example, one item in Table E.1 is a space heater. When a space heater is required, the motor manufacturer should determine the space heater's maximum sheath temperature based on information provided. ~~For example, where the AIT is 200 °C, a space heater should have a maximum sheath temperature of 160 °C to comply with this requirement. Once the space heater maximum sheath temperature has been specified, the motor manufacturer provides a nameplate marking for the motor declaring the space heater sheath temperature that has been supplied.~~ Refer to 5.4.3.1 for additional information on space heaters. Refer to API RP 14F-1999 [B9], API 14FZ-2000 [B10], and API RP 540-1999 [B13] for guidance on when to specify space heaters.

5.6.1 Heat source considerations

Manufacturers sometimes use nonmetallic components as part of the motor to minimize circulating currents. Use of nonmetallic material lowers the stray losses and circulating currents in enclosure housings. Current may be induced in steel bolts used to hold other components to nonmetallic parts where they are located within the magnetic field of the stator winding. This is particularly true during motor starting. If the bolts are made of a magnetic material, they may become hot. Use of nonmagnetic bolts, such as 300 series stainless steel, minimizes circulating currents and hot components. Type 300 series stainless steel may be susceptible to galling and may have lower tensile strength and torque requirements, so the motor manufacturer should be consulted on the uses of this hardware type. Grounding of any ungrounded hardware is recommended, as there are recorded instances of intense sparking between ungrounded hardware and adjacent ground planes. (See Bartels and Brandford [B16], Bredthauer et al. [B21], Costello [B26], Merrill and Olsen [B53], and BEAMA Ltd. [B66].)

One of the main heat sources of motors is the rotor. Rotors with axial and radial ducts for cooling ventilation tend to have cooler temperatures than nonducted or axial duct only rotors. Refer to Annex H and Table 1. However, radial ducts in the rotor increase the possibility of rotor sparking during motor starting. In general, two-pole motors tend to have higher temperatures than slower motors, but many other factors also impact the overall temperature. Refer to H.1 for a detailed discussion of hot motor surfaces.

5.6.2 Sparking considerations

This subclause discusses sparking considerations that are discussed in more detail in Annex G.

5.6.2.1 Sparking across bearing lubrication

Some motor bearing systems are designed by the [motor](#) manufacturer to be insulated to protect the bearing from developing shaft currents across the oil film. In some applications, one bearing is insulated. In some [other](#) applications, both bearings are insulated and a grounding jumper is installed on one bearing. [Voltage induced on a motor shaft may result in a circulating current with a magnitude limited by the bearing impedance. This bearing impedance acts as a capacitor with the oil film acting as the dielectric in a capacitor that is charged by the shaft voltage. When the shaft voltage across the oil film capacitor reaches its dielectric breakdown voltage a discharge occurs which can cause pitting in the bearing. Experience shows that the amount of energy discharged across the oil film does not produce a spark that could cause ignition. It is recommended that](#) the insulation and grounding should be discussed with the [motor](#) manufacturer and maintained to prevent damage to the bearings. (See Costello [B26].) [For ASD applications, refer to 6.3.1.3 and G.3 for CMV calculations showing the amount of energy discharge across the oil film.](#)

5.6.2.2 Joints and clearances

Motor characteristics that would minimize sparking across joints [and clearances include](#) at least the following:

- a) One-piece cast or welded fabricated frames, so there is no risk of sparking across frame joints.
- b) An adequate number of bolts to secure bearing brackets and end-covers to the frame. An adequate number of bolts should provide a path for current flow during starting.
- c) Machined surfaces between bearing bracket and frame mating surfaces ensure good contact between frame and bracket.
- d) Adequate clearances between motor windings and structural parts [to reduce sparks or discharges between the components.](#)

Where needed for multi-section motors, equipotential bonding conductors should be installed to prevent sparking between sections ([see the NEC, Section 501.125\(B\), Informational Note No. 2 and Section 505.20\(C\), Informational Note No. 2\).](#) Bonds should be applied as specified by the [motor](#) manufacturer.