

Recommended Practice for Design, Installation, and Maintenance of Electrical Systems for Fixed and Floating Offshore Petroleum Facilities for Unclassified and Class I, Division 1, and Division 2 Locations

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Foreword

This recommended practice (RP) contains information for use primarily by engineers with a working knowledge of electrical systems and production operations. Some of the information can be useful to experienced electrical maintenance and operating personnel. The intent of the document is to identify important features of offshore electrical systems and to present generally accepted practices for electrical design and installation that experience in the offshore petroleum industry has shown results in safe, reliable, efficient, and maintainable operations. Nothing in this RP is to be construed as a fixed rule without regard to sound engineering judgment, nor is it intended to supersede or override any federal, state, or local regulation where applicable.

The First Edition of API 14F was published in July 1978 as API 14F, *Design and Installation of Electrical Systems for Offshore Production Platforms*, under the jurisdiction of the API Production Department. The Second Edition was published on July 1, 1985. The Third Edition was published September 1, 1991. The Fourth Edition was published June 1999, with a new title, *Recommended Practice for Design and Installation of Electrical Systems for Fixed and Floating Offshore Petroleum Facilities for Unclassified and Class I, Division 1 and Division 2 Locations*. The Fifth Edition was published in July 2008. A related document, API 14FZ, *Recommended Practice for Design and Installation of Electrical Systems for Fixed and Floating Offshore Petroleum Facilities for Unclassified and Class I, Zone 0, Zone 1 and Zone 2 Locations*, First Edition, was published in September 2001 to address zone classifications and wiring methods introduced initially in Article 505 of the 1996 *National Electrical Code (NEC)* and referenced the 1999 *NEC*. API RP 14FZ Second Edition was published in May 2013 to address zone classifications and wiring methods in Article 505 in the 2011 *NEC*.

This document includes usage of the verbs *shall* and *should*—whichever is the more applicable to the function. For the purpose of this document:

Shall: As used in a standard, “shall” denotes a minimum requirement in order to conform to the specification.

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Suggested revisions are invited and should be submitted to the Standards Department, API, 1220 L Street, NW, Washington, DC 20005, standards@api.org.

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Recommended Practice for Design, Installation, and Maintenance of Electrical Systems for Fixed and Floating Offshore Petroleum Facilities for Unclassified and Class I, Division 1 and Division 2 Locations

1 Scope

1.1 General

1.1.1 This document recommends minimum requirements and guidelines for the design, installation, and maintenance of electrical systems on fixed and floating petroleum facilities located offshore. For facilities classified as Zone 0, Zone 1, or Zone 2, reference API RP 14FZ, *Recommended Practice for Design, Installation, and Maintenance of Electrical Systems for Fixed and Floating Offshore Petroleum Facilities for Unclassified and Class I, Zone 0, Zone 1, and Zone 2 Locations*. These facilities include drilling, producing, and pipeline transportation facilities associated with oil and gas exploration and production. This recommended practice is not applicable to mobile offshore drilling units (MODUs) without production facilities. This document is intended to bring together in one place a brief description of basic desirable electrical practices for offshore electrical systems. The recommended practices contained herein recognize that special electrical considerations exist for offshore petroleum facilities. These include the following:

- a) the inherent electrical shock possibility presented by the marine environment and steel decks;
- b) space limitations that require that equipment be installed in or near hazardous (classified) locations;
- c) the corrosive marine environment;
- d) motion and buoyancy concerns associated with floating facilities.

1.1.2 This recommended practice applies to both permanent and temporary electrical installations. The guidelines presented herein should provide a high level of electrical safety when used in conjunction with well-defined area classifications. This recommended practice emphasizes safe practices for hazardous (classified) locations on offshore petroleum facilities but does not include guidelines for classification of areas; for guidance on the classification of areas refer to API RP 500.

1.2 Applicability of the *National Electrical Code*

Electrical systems for offshore petroleum facilities shall be designed and installed in accordance with the *National Electrical Code (NEC)*, 2017 edition, except where specific departures are noted.

2 Normative References

2.1 Industry Codes, Guides, and Standards

Various organizations have developed numerous codes, guides, and standards that have substantial acceptance by industry and governmental bodies. Codes, guides, and standards useful in the design and installation of electrical systems are listed below as references only. These are not considered to be a part of this recommended practice except for those specific sections of documents referenced elsewhere in this recommended practice.

API RP 2L, *Recommended Practice for Planning, Designing, and Constructing Heliports for Fixed Offshore Platforms*

API RP 14C, *Recommended Practice for Analysis, Design, Installation, and Testing of Basic Surface Safety Systems on Offshore Production Platforms*

API RP 500, *Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Division 1 and Division 2*

API RP 505, *Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Zone 0, Zone 1, and Zone 2*

API Standard 541, *Form-wound Squirrel Cage Induction Motors—375 kW (500 Horsepower) and Larger*

API Standard 546, *Brushless Synchronous Machines—500 kVA and Larger*

API Standard 547, *General Purpose Form-Wound Squirrel Cage Induction Motors—250 Horsepower and Larger*

ANSI/IEEE C37.04 ^{1,2}, *Rating Structure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis*

ANSI/IEEE C37.13, *Standard for Low-Voltage AC Power Circuit Breakers Used in Enclosures*

ANSI/IEEE C37.20.1, *Standard for Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear*

ANSI/IEEE C37.20.2, *Standard for Metal-Clad and Station-Type Cubicle Switchgear*

ANSI/IEEE C37.20.7, *Guide for Testing Metal-Enclosed Switchgear Rated up to 38 kV for Internal Arcing Faults*

ANSI/IEEE C57.13, *Requirements for Instrument Transformers*

ANSI/IEEE C57.110, *Recommended Practice for Establishing Liquid-Filled and Dry-Type Power and Distribution Transformer Capability When Supplying Nonsinusoidal Load Currents*

ANSI/ISA 60079-29-1 (12.13.01)-2013 ³, *Explosive Atmospheres — Part 29-1: Gas Detectors — Performance Requirements of Detectors for Flammable Gases*

ANSI/ISA 60079-29-2, *Explosive Atmospheres — Part 29-1: Gas Detectors — Selection, Installation, Use and Maintenance of Detectors for Flammable Gases and Oxygen*

ANSI/ISA 92.00.01, Part 1, *Performance Requirements for Toxic Gas-Detection Instruments: Hydrogen Sulfide*

ANSI/NEMA WC 70/ICEA S-95-658 ^{4,5}, *Power Cables Rated 2000 Volts or Less for the Distribution of Electrical Energy*

ANSI/NEMA WC 71/ICEA S-96-659, *Nonshielded Cables Rated 2001-5000 Volts for Use in the Distribution of Electric Energy*

ANSI/NEMA WC 74/ICEA S-93-639, *5-46 kV Shielded Cables for Use in the Transmission and Distribution of Electrical Energy*

ASME A17.1 ⁶, *Safety Code for Elevators and Escalators*

ASME A17.1A, *Addenda to ANSI/ASME A17.1, Safety Code for Elevators and Escalators*

ASME A17.5, *Elevator and Escalator Electrical Equipment*

ASTM E119 ⁷, *Standard Test Methods for Fire Tests of Building Construction and Materials*

¹ American National Standards Institute, 25 West 43rd Street, New York, New York 10036, www.ansi.org.

² Institute of Electrical and Electronics Engineers, 445 and 501 Hoes Lane, Piscataway, New Jersey 08854, <https://www.ieee.org>.

³ International Society of Automation, 67 T.W. Alexander Drive, Research Triangle Park, North Carolina 27709, www.isa.org.

⁴ National Electrical Manufacturers Association, 1300 North 17th Street, Suite 900, Arlington, Virginia 22209, <http://www.nema.org>.

⁵ Insulated Cable Engineers Association, P.O. Box 2694, Alpharetta, Georgia 30023, <http://www.icea.net>.

⁶ American Society of Mechanical Engineers, Two Park Avenue, New York, New York 10016, www.asme.org.

ASTM D149, *Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies*

ASTM D178, *Standard Specification for Rubber Insulating Matting*

FF-844 ⁸, *Foundation Fieldbus Cable Specification*

IEC 60331 ⁹, *Tests for Electric Cables under Fire Conditions — Circuit Integrity — Part 11: Apparatus — Fire Alone at a Flame Temperature of at Least 750 °C*

IEC 60331, *Tests for Electric Cables under Fire Conditions — Circuit Integrity — Part 21: Procedures and Requirements — Cables of Rated Voltage up to and Including 0,6/1,0 kV*

IEC 60331, *Tests for Electric Cables under Fire Conditions — Circuit Integrity — Part 23: Procedures and Requirements — Electric Data Cables*

IEC 60331, *Tests for Electric Cables under Fire Conditions — Circuit Integrity — Part 25: Procedures and Requirements — Optical Fibre Cables*

IEC 61158-2, *Industrial Communication Networks — Fieldbus Specifications — Part 2: Physical Layer Specification and Service Definition*

IEC 62271-100, *High-voltage Switchgear and Controlgear — Part 100: Alternating-current Circuit-breakers*

IEC 62271-200, *High-voltage Switchgear and Controlgear — Part 200: AC Metal-enclosed Switchgear and Controlgear for Rated Voltages above 1 kV and up to and Including 52 kV*

IEEE Std 45, *Recommended Practice for Electrical Installations on Shipboard*

IEEE Std 45.8, *Recommended Practice for Electrical Installations on Shipboard — Cable Systems*

IEEE Std 841, *Standard for Petroleum and Chemical Industry — Premium-Efficiency, Severe-Duty, Totally Enclosed Fan-Cooled (TEFC) Squirrel Cage Induction Motors — Up to and Including 370 kW (500 hp)*

IEEE Std 1202, *Standard for Flame Testing of Cables for Use in Cable Tray in Industrial and Commercial Occupancies*

IEEE Std 1580, *Recommended Practice for Marine Cable for Use on Shipboard and Fixed or Floating Platforms*

IEEE Std 1717, *Standard for Testing Circuit Integrity Cables Using a Hydrocarbon Pool Fire Test Protocol*

IEEE Std 1810, *Guide for the Installation of Fire-Rated Cables Suitable for Hydrocarbon Pool Fires for Critical and Emergency Shutdown Systems in Petroleum and Chemical Industries*

IMO ¹⁰, *International Convention for the Safety of Life at Sea, SOLAS 1974, as amended*

NACE RP01-76 ¹¹, *Corrosion Control of Steel, Fixed Offshore Platforms Associated with Petroleum Production*

NEMA 250, *Enclosures for Electrical Equipment (1,000 Volts Maximum)*

⁷ ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, <https://www.astm.org>.

⁸ FieldComm Group (previously Fieldbus Foundation), 9430 Research Blvd, Suite 1-120, Austin, Texas 78759, www.fieldcommgroup.org.

⁹ International Electrotechnical Commission, Rue de Varembe 3, 1211 Geneva 20, Switzerland, <http://www.iec.ch>.

¹⁰ International Maritime Organization, 4 Albert Embankment, London, England, SE1 7SR, United Kingdom, www.imo.org.

¹¹ NACE International, 1440 South Creek Drive, Houston, Texas 77084, www.nace.org.

NEMA MG 1, *Motors and Generators*

NEMA MG 10, *Energy Guide for Selection and Use of Polyphase Motors*

NFPA 70¹², *National Electrical Code (NEC)*

NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance*

NFPA 70E, *Standard for Electrical Safety in the Workplace*

NFPA 101, *Life Safety Code—Code for Safety to Life from Fire in Buildings and Structures*

NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment in Hazardous (Classified) Locations*

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*

UL 44¹³, *Thermoset-Insulated Wires and Cables*

UL 66, *Fixture Wire*

UL 83, *Thermoplastic-Insulated Wires and Cables*

UL 347, *High Voltage AC Contactors, Controllers and Control Centers*

UL 489, *Molded Case Circuit Breakers, Molded Case Switches, and Circuit Breaker Enclosures*

UL 514B, *Conduit, Tubing, and Cable Fittings*

UL 845, *Motor Control Centers*

UL 891, *Switchboards*

UL 913, *Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, III, Division 1, Hazardous (Classified) Locations*

UL 1203, *Explosionproof and Dust-Ignition-Proof Electrical Equipment for Use in Hazardous (Classified) Locations*

UL 1309, *Marine Shipboard Cable*

UL 1558, *Metal Enclosed Low-Voltage Power Circuit Breaker Switchgear*

UL 1581, *Reference Standard for Electrical Wires, Cables, and Flexible Cords*

UL 2196, *Standard for Tests for Fire Resistive Cables*

UL 2225, *Metal-Clad Cables and Cable-Sealing Fittings for Use in Hazardous (Classified) Locations*

UL 2556, *Standard for Safety Wire and Cable Test Methods*

UL 122701, *Requirements for Process Sealing Between Electrical Systems and Flammable or Combustible Process Fluids*

¹² National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02169, www.nfpa.org.

¹³ Underwriters Laboratories, 333 Pfingsten Road, Northbrook, IL 60062, <https://www.ul.com>.

UL 121203, *Standard for Safety Portable Electronic Products Suitable for Use in Class I and II, Division 2, Class I, Zone 2 and Class III, Division 1 and 2 Hazardous (Classified) Locations — First Edition*

UL 60079-1, *Standard for Safety Explosive Atmospheres — Part 1: Equipment Protection by Flameproof Enclosures “d” — Seventh Edition*

UL 60079-2, *Standard for Safety Explosive Atmospheres — Part 2: Equipment Protection by Pressurized Enclosure “p” — Sixth Edition*

UL 60079-6, *Standard for Safety Explosive Atmospheres — Part 6: Equipment Protection by Oil Immersion “o” — Fourth Edition*

UL 60079-7, *Standard for Safety Explosive Atmospheres — Part 7: Equipment Protection by Increased Safety “e” — Fifth Edition*

UL 60079-11, *Standard for Safety Explosive Atmospheres — Part 11: Equipment Protection by Intrinsic Safety “i” — Sixth Edition*

UL 60079-15, *Standard for Safety Explosive Atmospheres — Part 15: Equipment Protection by Type of Protection “n” — Fourth Edition*

UL 60079-29-2, *Standard for Safety Explosive Atmospheres — Part 29-2: Gas Detectors – Selection, Installation, Use and Maintenance of Detectors for Flammable Gases and Oxygen — Fourth Edition*

2.2 Government Codes, Rules, and Regulations

Federal regulatory agencies have established certain requirements for the design, installation, and operation of facilities on offshore production facilities. These requirements may influence the design, installation, and operation of the electrical systems. In addition to federal regulations, certain state, municipal, and local regulations may be applicable. The following documents may pertain to offshore oil and gas producing operations and shall be used when applicable.

Code of Federal Regulations (CFR):

DOI/Bureau of Mines Bull 627 ¹⁴, *Flammability Characteristics of Combustible Gases and Vapors*

NOTE No longer available from the U.S. Bureau of Mines, but included as an Appendix in ANSI/ISA 60079-29-2.

DOI/BOEMRE 30 CFR Part 250 ¹⁵, *Oil and Gas and Sulphur Operation in the Outer Continental Shelf*

DOL/OSHA 29 CFR Part 1910 ¹⁶, *Subpart H. Process Safety Management of Highly Hazardous Chemicals*

DOL/OSHA 29 CFR Part 1910, *Subpart S. Electrical (Occupational Safety and Health Administration)*

DOL/OSHA 29 CFR Part 1926, *Subpart K. Electrical Construction (Occupational Safety and Health Administration)*

DOT 49 CFR Parts 190, 191, 192, 193, and 195 ¹⁷, *Pipeline Safety Regulations*

¹⁴ U.S. Department of the Interior, Bureau of Mines. The *Code of Federal Regulations* is available from the U.S. Government Publishing Office, 732 N. Capitol Street NW, Washington, DC 20401.

¹⁵ U.S. Department of the Interior, Bureau of Ocean Energy Management, Regulation and Enforcement. The *Code of Federal Regulations* is available from the U.S. Government Publishing Office, 732 N. Capitol Street NW, Washington, DC 20401.

¹⁶ Occupational Safety and Health Administration. U.S. Department of Labor. The *Code of Federal Regulations* is available from the U.S. Government Publishing Office, 732 N. Capitol Street NW, Washington, DC 20401.

¹⁷ U.S. Department of Transportation. The *Code of Federal Regulations* is available from the U.S. Government Publishing Office, 732 N. Capitol Street NW, Washington, DC 20401.

DOT/FAA ¹⁸, *Heliport Design* (Advisory Circular 150/5390-2A)

DOT/FAA, *Obstruction Marking and Lighting* (Advisory Circular 70/7460-1F)

DOT/USCG 33 CFR Parts 140–147 ¹⁹, *Subchapter N - Outer Continental Shelf Activities*

DOT/USCG 33 CFR Part 67, *Subchapter C - Aids to Navigation*

DOT/USCG 46 CFR Parts 107–108, *Shipping Subchapter I-A - Mobile Offshore Drilling Units*

DOT/USCG 46 CFR Parts 110–113, *Shipping Subchapter J - Electrical Engineering*

LADOTD/HSAC ^{20,21}, *Offshore Heliport Design Guide*, APT No. 5100-R223

2.3 Classification Society Rules and Regulations

Classification societies have also established certain requirements for the design and installation of facilities on offshore production facilities. In addition to statutory requirements, these requirements may also influence the design and installation of the electrical systems. The following documents pertain to offshore oil and gas producing operations and may be applicable:

ABS ²², *Rules for Building and Classing Steel Vessels*

ABS, *Rules for Building and Classing Mobile Offshore Drilling Units*

DNV ²³, *Rules for Classification of Mobile Offshore Units*

DNV, *Rules for Classification of Fixed Offshore Installations*

LR ²⁴, *Rules and Regulations for the Classification of Mobile Offshore Units*

LR, *Rules and Regulations for the Classification of Floating Offshore Installations at a Fixed Location*

LR, *Rules and Regulations for the Classification of Fixed Offshore Installations*

3 Acronyms, Abbreviations, and Definitions

3.1 Acronyms and Abbreviations

A	ampere
ABS	American Bureau of Shipping
AHJ	authority having jurisdiction
ASD	adjustable speed drive

¹⁸ U.S. Department of Transportation, Federal Aviation Administration. The *Code of Federal Regulations* is available from the U.S. Government Publishing Office, 732 N. Capitol Street NW, Washington, DC 20401.

¹⁹ United States Coast Guard, U.S. Department of Defense. The *Code of Federal Regulations* is available from the U.S. Government Publishing Office, 732 N. Capitol Street NW, Washington, DC 20401.

²⁰ Louisiana Department of Transportation and Development, 1201 Capitol Access Rd, Baton Rouge, Louisiana 70802, <http://www.sp.dotd.la.gov>.

²¹ Helicopter Safety Advisory Conference, <http://www.hsac.org>.

²² American Bureau of Shipping, 16855 Northchase Drive, Houston, Texas 77060, www.eagle.org.

²³ Det Norske Veritas, Veritasveien 1, 1363 Høvik, Norway, <https://www.dnvgl.com>.

²⁴ Lloyd's Register, 71 Fenchurch Street, London EC3M 4BS, United Kingdom, www.lr.org.

AWG	American wire gauge
CENELEC	European Committee for Electrotechnical Standardization
CIV	corona inception voltage
EMI	electromagnetic interference
EPR	ethylene propylene rubber
GFCI	ground-fault circuit interrupter
HMWPE	high molecular weight polyethylene
hp	horsepower
Hz	hertz (cycles per second)
IGBT	insulated gate bipolar transistor
IMMS	integrated marine monitoring system
IP	ingress protection
kV	kilovolt
kVA	kilovolt-ampere
kW	kilowatt
LEL	lower explosive limit (LFL preferred)
LFL	lower flammable limit
MESG	maximum experimental safe gap
MIC ratio	minimum igniting current ratio
<i>NEC</i>	<i>National Electrical Code</i>
NEMA	National Electrical Manufacturers Association
NRTL	Nationally Recognized Testing Laboratory
OA	open air
OSHA	Occupational Safety and Health Administration
PA	public address
PMG	permanent magnet generator
PVC	polyvinyl chloride
PWM	pulse width modulated inverter
RMS	root-mean-square
TEAAC	totally enclosed air-to-air cooled
TEFC	totally enclosed fan cooled

TENV	totally enclosed nonventilated
TEWAC	totally enclosed water-to-air cooled
THD	total harmonic distortion
TUTA	topside umbilical termination assembly
UEL	upper explosive limit (UFL preferred)
UFL	upper flammable limit
UPS	uninterruptible power supply
USCG	United States Coast Guard
V	volt
VAR	volt-ampere reactive
VRLA	valve-regulated lead-acid
XLPE	crosslinked polyethylene

3.2 Definitions

3.2.1

accessible (as applied to equipment)

Admitting close approach: not guarded by locked doors, elevation, or other effective means. (See **accessible, readily**.)

3.2.2

accessible, readily

Capable of being reached quickly for operation, renewal, or inspections, without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, etc. [See **accessible (as applied to equipment)**.]

3.2.3

accessible (as applied to wiring methods)

Capable of being removed or exposed without damaging the building structure or finish, or not permanently closed in by the structure or finish of the building.

3.2.4

adjustable speed drive

ASD

An electric drive designed to provide easily operable means for speed adjustment of the motor, within a specified speed range. These are also known as variable frequency drives, variable voltage drives, current source drives, adjustable frequency drives, and other similar names.

3.2.5

AEx

Required marking prefix for electrical apparatus to be installed in hazardous (classified) locations meeting one or more types of protection in accordance with harmonized American National Standards as defined in Article 505 of the *NEC*.

3.2.6

aluminum, copper-free (or low copper content)

Aluminum alloys containing 0.4 % or less copper.

3.2.7**apparatus, intrinsically safe**

Apparatus in which all the circuits are intrinsically safe.

3.2.8**approved**

Acceptable to the authority having jurisdiction. (Electrical devices that are listed or approved by a Nationally Recognized Testing Laboratory [NRTL], e.g. UL, FM, or CSA, normally are acceptable.)

NOTE The means for identifying listed equipment can vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction normally utilizes the system employed by the listing organization to identify a listed product.

3.2.9**area, enclosed (room, building, or space)**

A three-dimensional space enclosed by more than two-thirds of the possible projected plane surface area and of sufficient size to allow personnel entry. For a typical building, this would require that more than two-thirds of the walls, ceiling, and/or floor be present (see API RP 500).

3.2.10**area, safe**

See location, nonhazardous (unclassified).

3.2.11**arc-fault circuit interrupter****AFCI**

A device intended to provide protection from the effects of arc faults by recognizing characteristics unique to arcing and by functioning to de-energize the circuit when an arc fault is detected.

3.2.12**associated apparatus**

Apparatus used in intrinsically safe systems in which the circuits are not necessarily intrinsically safe themselves but affect the energy in the intrinsically safe circuits and are relied on to maintain intrinsic safety (see *NEC* Articles 504.4 and 505.8 for additional details).

3.2.13**atmosphere, explosive**

A mixture with air, under atmospheric conditions, of flammable substances in the form of gas, vapor, mist, or dust in which, after ignition, combustion spreads throughout the unconsumed mixture.

3.2.14**bus, cable**

An approved assembly of insulated conductors with fittings and conductor terminations in a totally enclosed protective metal housing (see *NEC* Article 370).

3.2.15**busway**

A grounded metal enclosure containing bare or insulated conductors that usually are copper or aluminum bars, rods, or tubes (see *NEC* Article 368).

3.2.16**cable, circuit integrity**

Cable that is used for critical circuits to ensure survivability for continued circuit operation for a specified time under fire conditions (see 6.7.8 for recommended applications and cable selection).

3.2.17**cable, impervious sheathed**

Cable constructed with an impervious metallic or nonmetallic overall covering that prevents the entrance of gases, moisture, or vapors into the insulated conductor or cable.

3.2.18**cable, ITC**

Type ITC instrumentation tray cable is a factory assembly of two or more 300 V insulated copper conductors, Nos. 22 through 12 AWG (American wire gauge), with or without grounding conductor(s), and enclosed in a nonmetallic sheath with or without an armor as defined by *NEC* Article 727.

3.2.19**cable, ITC-ER**

Type ITC instrumentation tray cable is a factory assembly of two or more 300 V insulated copper conductors, Nos. 22 through 12 AWG, with or without grounding conductor(s), and enclosed in a nonmetallic sheath without an armor as defined by *NEC* Article 727. This cable is suitable for exposed runs (ER) between cable tray and utilization equipment where the cables are supported and secured. Reference *NEC* Article 336 for installation details.

3.2.20**cable, ITC-HL**

Type ITC instrumentation tray cable is a factory assembly of two or more 300 V insulated copper conductors, Nos. 22 through 12 AWG, with or without grounding conductor(s), and enclosed in a nonmetallic sheath with an armor as defined by *NEC* Article 727. This cable is suitable for use in Class I, Divisions 1 and 2. Reference *NEC* Article 501 for installation details.

3.2.21**cable, jacketed**

Cable with a nonmetallic protective covering.

3.2.22**cable, marine**

Same as cable, marine shipboard.

3.2.23**cable, marine shipboard**

Impervious sheathed armored or unarmored cable constructed in accordance with UL 1309/CSA C22.2 No. 245, or IEEE Std 1580, except that an overall impervious sheath is required over the armored construction, and listed as "Shipboard Cable, Marine" by an NRTL.

3.2.24**cable, MC**

Metal-clad cable as defined by *NEC* Article 330.

3.2.25**cable, MC-HL**

Metal-clad cable for hazardous locations as defined by *NEC* Article 501.

3.2.26**cable, MI**

Mineral-insulated metal-sheathed cable as defined by *NEC* Article 332.

3.2.27**cable, MV**

Medium-voltage single or multiphase solid dielectric insulated conductor or cable rated 2001 V or higher as defined by *NEC* Article 328.

3.2.28**cable, PLTC**

Type PLTC nonmetallic sheathed, power-limited tray cable. Suitable for cable trays and consisting of a factory assembly of two or more insulated copper (solid or stranded) conductors suitable for 300 V, Nos. 22 through 12 AWG, under a nonmetallic jacket. The cable is resistant to the spread of fire, and the outer jacket is sunlight and moisture resistant as defined by *NEC* Article 725.

3.2.29**cable, PLTC-ER**

Type PLTC nonmetallic sheathed, power-limited tray cable. Suitable for cable trays and consisting of a factory assembly of two or more insulated copper (solid or stranded) conductors suitable for 300 V, Nos. 22 through 12 AWG, under a nonmetallic jacket. The cable is resistant to the spread of fire, and the outer jacket is sunlight and moisture resistant as defined by *NEC* Article 725. This cable is suitable for exposed runs (ER) between cable tray and utilization equipment where the cables are supported and secured. Reference *NEC* Article 725 for installation details.

3.2.30**cable, TC**

Power and control tray cable as defined by *NEC* Article 336.

3.2.31**cable, TC-ER**

Power and control tray cable as defined by *NEC* Article 336. This cable is suitable for exposed runs (ER) between cable tray and utilization equipment where the cables are supported and secured. Reference *NEC* Article 336 for installation details.

3.2.32**cable, TC-ER-HL**

Power and control tray cable that is suitable for Class I, Division 1 locations for flexible connections as specified in *NEC* Article 501.10 (A)(2).

3.2.33**circuit, intrinsically safe**

A circuit in which any spark or thermal effect is incapable of causing ignition of a mixture of flammable or combustible material in air under test conditions prescribed by ANSI/UL 913 and UL 60079-11.

3.2.34**classified locations**

A hazardous (classified) location is a location classified as Division 1 or Division 2, or Zone 0, Zone 1, or Zone 2.

3.2.35**Class I location**

A Class I location is one in which flammable gases or vapors are or may be present in the air in quantities sufficient to produce explosive or ignitable mixtures (see *NEC* Article 500 and *NEC* Article 505 and API RP 500 and API RP 505).

3.2.36a**Class I, Division 1 location**

A Class I, Division 1 location is a location 1) in which ignitable concentrations of flammable gases or vapors exist continuously, intermittently, or periodically under normal operating conditions; or 2) in which ignitable concentration of such gases or vapors may exist frequently because of repair or maintenance operations or because of leakage; or 3) in which breakdown or faulty operation of equipment or processes might release ignitable concentrations of flammable gases or vapors, and might also cause simultaneous failure of electrical equipment (see *NEC* Article 500 and API RP 500).

3.2.36b**Class I, Special Division 1 location**

In some Division 1 locations, ignitable concentrations of flammable gases or vapors may be present continuously or for extended long periods of time. Examples of these type areas include the internal spaces of tanks and piping systems vented to the atmosphere (i.e. operating at or near atmospheric pressure) intended to contain active drilling mud or produced crude oil or natural gas, and other locations in which flammable liquid, gas, or vapor is present continuously for long periods of time. These locations are identified as Class I, Zone 0 in *NEC* Article 505 and are discussed in detail in API RP 505. Locations where such conditions may exist are identified separately, and added precautions may be desirable if electrical equipment is installed therein. Also, authorities having jurisdiction (e.g. the United States Coast Guard [USCG]) may require special considerations for electrical equipment installed in such locations.

NOTE Special Division 1 locations are utilized within this document and are an exception to the *NEC*.

3.2.37**Class I, Division 2 location**

A Class I, Division 2 location is a location 1) in which volatile flammable liquids or flammable gases are handled, processed, or used, but in which the hazardous liquids, vapors, or gases will normally be confined within closed containers or closed systems from which they can escape only if accidental rupture or breakdown of such containers or systems or abnormal operation of equipment occurs; or 2) in which hazardous concentrations of gases or vapors are normally prevented by positive mechanical ventilation but that 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 hazardous concentration of gases or vapors 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 *NEC* Article 500 and *API RP 500*).

3.2.38**code of practice**

A term referring to a document that describes basic safety features and methods of protection and recommends, e.g. the selection, installation, inspection, and maintenance procedures that should be followed to ensure the safe use of electrical apparatus.

3.2.39**component, make/break**

Components having contacts that interrupt a circuit (even if the interruption is transient in nature). Examples of make/break components are relays, circuit breakers, servo potentiometers, adjustable resistors, switches, connectors, and motor brushes.

3.2.40**component, protective (as applied to intrinsic safety)**

A component that is so unlikely to become defective in a manner that will lower the intrinsic safety of the circuit that it is considered not subject to fault when analyses or tests for intrinsic safety are made.

3.2.41**conditions, normal**

Equipment is generally considered to be under normal conditions when it conforms electrically and mechanically with its design specifications and is used within the limits specified by the manufacturer.

3.2.42**control drawing**

A drawing or other document provided by the manufacturer of intrinsically safe or associated apparatus that details the allowed interconnections between the intrinsically safe and associated apparatus.

3.2.43**device, arcing**

A device that, during its normal operation, produces an arc with sufficient energy to cause ignition of an ignitable mixture.

3.2.44**device, hermetically sealed**

Equipment sealed against the entrance of an external atmosphere where the seal is made by fusion, for example, soldering, brazing, welding, or the fusion of glass to metal.

3.2.45**device, high-temperature**

A device, the maximum operating temperature of which exceeds 80 % of the autoignition temperature in degrees Celsius (°C) of all the gas or vapor involved (see 4.2).

3.2.46**device, sealed**

A device so constructed that it cannot be opened during normal operational conditions or operational maintenance and is sealed to restrict entry of an external atmosphere. Such devices may be incorporated into equipment having the type of protection referred to as "nC."

3.2.47**dilution, continuous**

The technique of supplying a protective gas flow continuously to an enclosure containing an internal potential source of flammable gas or vapor for the purpose of diluting any flammable gas or vapor that can be present to a level below its LFL/LEL.

3.2.48**EEx**

Designation of explosion-protected electrical apparatus complying with harmonized CENELEC (European Committee for Electrotechnical Standardization) standards.

3.2.49**encapsulation**

A type of protection in which the parts that could ignite an explosive atmosphere by either sparking or heating are enclosed in an encapsulant in such a way that this explosive atmosphere cannot be ignited. This type of protection is referred to as "m."

3.2.50**enclosure, electrical**

The case or housing of electrical apparatus provided to prevent personnel from accidentally contacting energized parts, and/or to protect the equipment from physical damage and the environment. Also, certain enclosures serve to prevent electrical equipment from being a source of ignition of flammable mixtures outside the enclosure.

3.2.51**enclosure, explosionproof**

An enclosure that is capable of withstanding an explosion of a gas or vapor within it and of preventing the ignition of an explosive gas or vapor that may surround it, and that operates at such an external temperature that a surrounding explosive gas or vapor will not be ignited thereby.

3.2.52**enclosure, NEMA type**

A United States (National Electrical Manufacturers Association [NEMA]) system of rating standard levels of protection provided to electrical apparatus by enclosures for 1) the protection of persons against contact with live or moving parts inside the enclosure, 2) the protection provided by the enclosure against ingress of solids and/or liquids, 3) the protection provided by the enclosure against the deleterious effects of corrosion, and 4) the protection provided by the enclosure against damage to the formation of external ice. This enclosure type is in addition to (and not an alternative to) the types of protection necessary to ensure protection against ignition in hazardous (classified) locations (see Table 14).

3.2.53**enclosure, purged and pressurized**

An enclosure supplied with clean air or an inert gas at sufficient flow and positive pressure to reduce to an acceptably safe level any flammable gas or vapor concentration initially present, and to maintain this safe level by positive pressure with or without continuous flow (see 4.3.5).

3.2.54**entity concept**

A concept that allows interconnection of intrinsically safe apparatus to associated apparatus not specifically examined in such a combination. The criteria for interconnection is that the voltage (V_{max}) and current (I_{max}) that intrinsically safe apparatus can receive and remain intrinsically safe, considering faults, shall be equal to or greater than the voltage (V_{oc} or V_t) and current (I_{sc} or I_t) levels that can be delivered by the associated apparatus, considering faults and applicable factors. In addition, the maximum unprotected capacitance (C_i) and inductance (L_i) of the intrinsically safe apparatus, including interconnecting wiring, shall be equal to or less than the capacitance (C_a) and inductance (L_a) that can safely be connected to the associated apparatus. If these criteria are met, then the combination may be connected without compromising intrinsic safety. For additional information refer to ANSI/ISA-RP12.06.01.

3.2.55**entry, cable (cable gland)**

A device permitting the introduction of an electric cable into an electrical apparatus.

3.2.56**entry, direct**

A method of connection of an electrical apparatus to the external circuits by means of the connecting facilities inside the main enclosure or in a terminal compartment having a free opening to the main enclosure (see IEC 60050, IEC 426-04-07).

3.2.57**entry, indirect**

A method of connection of an electrical apparatus to the electrical circuits by means of a terminal box or a plug and socket connection that is external to the main enclosure (see IEC 60050, IEC 426-04-08).

3.2.58**equipment, oil-immersed**

Equipment immersed in electrical insulating oil for the purpose of preventing an ignitable or corrosive gas or vapor from coming in physical contact with the equipment or for the purpose of reducing arcing of circuit breaking devices.

3.2.59**Ex**

Designation of explosion-protected electrical apparatus complying with IEC standards.

3.2.60**Ex component**

Part of electrical apparatus for explosive atmospheres that is not to be used alone in such atmospheres and that requires additional evaluation of any electrical apparatus with which it is used.

3.2.61**Ex scheme**

An international system of certification for explosion-protected electrical apparatus administered by the IECEx and described by IECEx-01. The eventual goal of this scheme is that a manufacturer of hazardous location electrical apparatus would be able to obtain a single "Ex" Certificate of Conformity from one certification laboratory and provide that product in any participating country without legal or technical obstacle and without the need to get it recertified locally.

3.2.62**explosive limits or flammable limits**

The lower and upper percentages by volume of concentration of gas in a gas-air mixture that will form an ignitable mixture (reference NFPA 497). The upper limit is typically expressed as UFL or UEL, and the lower limit is expressed as LFL or LEL. See API RP 500 for additional details concerning flammable and explosive limits.

3.2.63**exposed (as applied to live parts)**

Capable of being inadvertently touched or approached nearer than a safe distance by a person. It is applied to all parts that are not suitably guarded, isolated, or insulated; see accessible and concealed (*NEC*).

3.2.64**exposed (as applied to wiring methods)**

On or attached to the surface or behind panels designed to allow access; see accessible: as applied to wiring methods (*NEC*).

3.2.65**facility, manned**

A facility on which people are routinely accommodated for more than 12 hours per day.

3.2.66**flame-proof**

A type of protection of electrical apparatus in which an enclosure will withstand an internal explosion of a flammable mixture which has penetrated into the interior, without suffering damage and without causing ignition, through any joints or structural openings in the enclosure, of an external explosive atmosphere consisting of one or more of the gases or vapors for which it is designed. This type of protection is referred to as "d."

NOTE See also **enclosure**, **explosionproof**.

3.2.67**flammable**

Capable of igniting easily, burning intensely or having a rapid rate of flame spread.

3.2.68**gas, protective**

The gas used for pressurization or for the dilution of flammable gases to a level well below their lower explosive limit, usually below 25 % LFL/LEL. The protective gas can be air, nitrogen, other nonflammable gas, or a mixture of such gases.

3.2.69**gas groups (division classification method)**

For purposes of testing, approval, and area classification, various air mixtures (not oxygen enriched) are grouped as shown below.

3.2.70**Group A**

Atmospheres that do or may contain acetylene.

3.2.71**Group B**

Atmospheres that do or may contain hydrogen, or other substances specified by NFPA 497.

3.2.72**Group C**

Atmospheres that do or may contain hydrogen sulfide (H₂S), or other substances specified by NFPA 497.

3.2.73**Group D**

Atmospheres that do or may contain natural gas, hydrocarbons, or other substances specified by NFPA 497.

3.2.74**gas, Group I**

A term used by ANSI/ISA-60079-10-1 to describe atmospheres containing firedamp (a mixture of gases, composed mostly of methane, found underground, usually in mines). Because this standard does not apply to installations underground in mines, this term is not used further.

3.2.75**gas, Group II**

The group used to describe gases found aboveground and subdivided into IIC, IIB, and IIA, as noted below, according to the nature of the gas or vapor, for protection techniques "d," "ia," and "ib" and, where applicable, "n" and "o."

3.2.76**gas, Group IIA**

Atmospheres containing acetone, ammonia, ethyl alcohol, gasoline, methane, propane, or flammable gas, flammable liquid-produced vapor, or combustible liquid-produced vapor mixed with air that may burn or explode having either a maximum experimental safe gap (MESG) value greater than 0.90 mm or a minimum igniting current ratio (MIC ratio) greater than 0.80 (see NFPA 497).

3.2.77**gas, Group IIB**

Atmospheres containing acetaldehyde, ethylene, or flammable gas, flammable liquid-produced vapor, or combustible liquid-produced vapor mixed with air that may burn or explode having either an MESG value greater than 0.50 mm and less than or equal to 0.90 mm or MIC ratio greater than 0.45 and less than or equal to 0.80 (see NFPA 497).

3.2.78**gas, Group IIC**

Atmospheres containing acetylene, hydrogen, or flammable gas, flammable liquid-produced vapor, or combustible liquid-produced vapor mixed with air that may burn or explode, having either an MESG value less than or equal to 0.50 mm or MIC ratio less than or equal to 0.45 (see NFPA 497).

3.2.79**grounded (earthed)**

Connected to earth or to some conducting body that serves in place of earth.

3.2.80**ignition capable**

Apparatus or wiring that under normal conditions, or under specified abnormal conditions, can release sufficient electrical or thermal energy to cause ignition of a specific explosive atmosphere.

3.2.81**increased safety**

A type of protection applied to electrical apparatus that does not produce arcs or sparks in normal service and under specified abnormal conditions, in which additional measures are applied so as to give increased security against the possibility of excessive temperatures and of the occurrence of arcs and sparks. This type of protection is referred to as "e."

3.2.82**ingress protection (IP), degree of**

A system of rating standard levels of protection provided by apparatus for the protection of persons against contact with live or moving parts inside the apparatus, as well as the protection provided by apparatus against ingress of solids and/or liquids. This type of protection classification is in addition to (and not an alternative to) the types of protection necessary to ensure protection against ignition in hazardous (classified) locations. Definitions are found in IEC 60529.

3.2.83**intrinsic safety**

A type of protection in which a portion of the electrical system contains only intrinsically safe apparatus, circuits, and wiring that is incapable of causing ignition in the surrounding atmosphere. No single device or wiring is intrinsically safe by itself (except for battery-operated, self-contained apparatus such as portable pagers, transceivers, gas detectors, etc., which are specifically designed as intrinsically safe self-contained devices) but is intrinsically safe only when employed in a properly designed intrinsically safe system. This type of protection is referred to as "i."

NOTE See also **associated apparatus**.

3.2.84**intrinsic safety barrier**

A component containing a network designed to limit the energy (voltage and current) available to the protected circuit in the hazardous (classified) location under specified fault conditions.

3.2.85**intrinsic safety ground bus**

A grounding system that has a dedicated conductor separate from the power system so that ground currents will not normally flow and that is reliably connected to a grounding electrode. (For further information, refer to Article 504 of the NEC and ANSI/ISA-RP12.06.01.)

3.2.86**intrinsically safe circuit**

A circuit in which any spark or thermal effect, produced either normally or in specified fault conditions, is incapable, in the specified test conditions, of causing ignition of a given explosive atmosphere.

3.2.87**intrinsically safe electrical apparatus**

Electrical apparatus in which all the circuits are intrinsically safe circuits.

3.2.88**intrinsically safe system**

An assembly of interconnected intrinsically safe apparatus, associated apparatus, other apparatus, and interconnecting cables in which those parts of the system that may be used in hazardous (classified) locations are intrinsically safe circuits.

3.2.89**labeled**

Equipment or materials with a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

NOTE Some testing agencies use the term “approved,” “listed,” or “certified” to indicate compliance with the applicable standard.

3.2.90**lighting fixtures, enclosed and gasketed**

Lighting fixtures (formerly referred to as “vapor-tight”) designed to prevent the entrance of gas and vapors. Such enclosures will not absolutely prevent the entrance of gases and vapors, as such tend to “breathe” as they are heated and cooled.

3.2.91**listed**

Equipment or materials included in a list, published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation, which maintains periodic inspection of production of listed equipment or materials, and whose listing states either that the equipment or material meets appropriate designated standards or has been tested and found suitable for use in a specified manner.

NOTE The means for identifying listed equipment can vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction normally utilizes the system employed by the listing organization to identify a listed product.

3.2.92**maintenance, corrective**

Any maintenance activity that is not normal in the operation of equipment and requires access to the equipment’s interior. Such activities are expected to be performed by a qualified person. Such activities typically include locating causes of faulty performance, replacement of defective components, adjustment of internal controls, and the like.

3.2.93**maintenance, operational**

Any maintenance activity, excluding corrective maintenance, intended to be performed by the operator and required in order for the equipment to serve its intended purpose. Such activities typically include the correcting of zero on a panel instrument, changing charts, record keeping, adding ink, and the like.

3.2.94**minimum ignition energy****MIE**

The smallest amount of energy that can ignite the most easily ignitable mixture of a specific gas or vapor-in-air mixture or dust-in-air mixture.

3.2.95**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.

3.2.96**minimum igniting current ratio****MIC ratio**

The ratio derived by dividing the minimum current required from an inductive spark discharge to ignite the most easily ignitable mixture of a gas or vapor by the minimum current required from an inductive spark discharge to ignite methane under the same test conditions.

3.2.97**mixture, ignitable (flammable)**

A gas-air mixture that is capable of being ignited by an open flame, electric arc or spark or high temperature.

See **explosive limits**.

3.2.98**Nationally Recognized Testing Laboratory****NRTL**

The Occupational Safety and Health Administration (OSHA) designation given to testing facilities that provide product safety testing and certification services to manufacturers.

3.2.99**nonincendive circuit**

A circuit, other than field wiring, in which any arc or thermal effect produced, under intended operating conditions of the equipment, is not capable, under specified test conditions, of igniting the flammable gas-, vapor-, or dust-air mixture. See also **nonincendive field wiring**.

3.2.100**nonincendive component**

A component having contacts for making or breaking an incendive circuit, and the contacting mechanism is constructed so that the component is incapable of igniting the specified flammable gas- or vapor-air mixture. The housing of a nonincendive component is not intended to exclude the flammable atmosphere or contain an explosion. Such devices may be incorporated into equipment having the type of protection referred to as "nC."

3.2.101**nonincendive equipment**

Equipment having electrical/electronic circuitry and components that are incapable, under normal conditions, of causing ignition of the flammable gas-, vapor-, or dust-air mixture due to arcing or thermal effect. Such devices may be incorporated into equipment having the types of protection referred to as "nA," "nC," or "nR."

3.2.102**nonincendive field wiring**

Wiring that enters or leaves an equipment enclosure and, under normal operating conditions of the equipment, is not capable, due to arcing or thermal effects, of igniting the flammable gas-, vapor-, or dust-air mixture. Normal operation includes opening, shorting, or grounding the field wiring. See also **nonincendive circuit**.

3.2.103**number, temperature identification (T Code/Temperature Class)**

A system of classification by which one of 14 temperature identification numbers (for zones, six temperature classes) is allocated to apparatus. The temperature identification number represents the maximum surface temperature of any part of the apparatus that can come in contact with the flammable gas or vapor mixture.

3.2.104**oil-resistant**

Ability to withstand exposure to oil as defined by ANSI C-33.80 (see UL 83).

3.2.105**oil-sealed**

See **equipment, oil-immersed**.

3.2.106**oil immersion**

Type of protection in which the electrical apparatus or parts of the electrical apparatus are immersed in a protective liquid in such a way that an explosive atmosphere that can be above the liquid or outside the enclosure cannot be ignited. This type of protection is referred to as "o."

3.2.107**panelboard**

A single panel or group of panel units designed for assembly in the form of a single panel, including buses, automatic overcurrent devices, and equipped with or without switches for the control of light, heat, or power circuits; designed to be placed in a cabinet or cutout box placed in or against a wall or partition and accessible only from the front.

3.2.108**potting**

The encapsulation of electrical components with epoxy, elastomeric, silicone, or asphaltic or similar compounds for the purpose of excluding moisture or vapors. Potted components are not necessarily hermetically sealed.

3.2.109**powder filling**

A type of protection in which the parts capable of igniting an explosive atmosphere are fixed in position and completely surrounded by filling material to prevent the ignition of an external explosive atmosphere. This type of protection is referred to as "q."

NOTE This type of protection may not prevent the surrounding explosive atmosphere from penetrating into the apparatus and Ex components and being ignited by the circuits. However, due to the small free volumes in the filling material and due to the quenching of a flame that can propagate through the paths in the filling material, an external explosion is prevented.

3.2.110**pressurization**

The technique of guarding against the ingress of the external atmosphere into an enclosure by maintaining a protective gas therein at a pressure above that of the external atmosphere. This type of protection is referred to as "p."

3.2.111**pressurization, Type X**

A method of reducing the classification within an enclosure from Division 1/Zone 1 to nonhazardous (unclassified).

3.2.112**pressurization, Type Y**

A method of reducing the classification within an enclosure from Division 1/Zone 1 to Division 2/Zone 2.

3.2.113**pressurization, Type Z**

A method of reducing the classification within an enclosure from Division 2/Zone 2 to nonhazardous (unclassified).

3.2.114**protection, type of**

The specific measures applied to electrical apparatus to avoid ignition of a surrounding explosive atmosphere. Examples are “e” and “n.”

3.2.115**purging**

In a pressurized enclosure, the operation of passing a quantity of protective gas through the enclosure and ducts, so that the concentration of the explosive gas atmosphere is brought to a safe level.

3.2.116**restricted breathing**

A protection technique in which the gas- or vapor-tight integrity of an enclosure is ensured so that short-term presence of a flammable gas or vapor cloud around the enclosure will not cause the concentration inside the enclosure to reach the LFL/LEL because of breathing or diffusion. This type of protection is referred to as “nR.”

3.2.117**seal, environmental**

A seal that uses O-rings, epoxy, molded elastomer, silicone compound, or potting compound to prevent corrosion due to moisture or vapors.

3.2.118**seal, explosionproof cable**

A cable termination fitting filled with compound and designed to contain an explosion in the enclosure to which it is attached or to minimize passage of flammable gases or vapors from one location to another. An explosionproof conduit seal may also be used in combination with a cable termination fitting as an explosionproof cable seal.

3.2.119**seal, explosionproof conduit**

A sealing fitting, filled with a poured potting compound, designed to contain an explosion in the enclosure to which it is attached and to minimize passage of flammable gases or vapors from one location to another.

3.2.120**seal, process**

A process seal is a device to prevent the migration of process fluids from the designed containment into the external electrical system.

3.2.121**seal, factory**

A construction where components capable of initiating an internal explosion due to arcing, sparking, or thermal effects under normal conditions are isolated from the wiring system by means of factory installed flame-proof seal or joint for the purpose of eliminating the need for an external, field-installed conduit seal and, in some cases, a field-installed cable seal.

3.2.122**seal, hermetic**

See **device, hermetically sealed**.

3.2.123**simple apparatus (as applied to intrinsic safety)**

A device that will not generate or store more than 1.2 V, 0.1 A, 25 mW, or 20 mJ. Examples are switches, thermocouples, light-emitting diodes, connectors, and resistance temperature detectors. Apparatus reliant on voltage or current limiting or suppression devices for remaining within the limits given in the definition, and sensors (e.g. certain gas detector sensors) that utilize catalytic reaction or other electrochemical mechanisms are excluded by UL 60079-11 from the category of “simple apparatus.” Temperature limitations as described in 4.2 are applicable to simple apparatus.

3.2.124**source of release**

A point from which flammable gases or vapors, flammable liquid, combustible dusts, or ignitable fibers or flyings can be released into the atmosphere.

3.2.125**sunlight-resistant**

Ability to withstand exposure to direct sunlight as defined by UL 2556.

3.2.126**system, intrinsically safe**

An assembly of interconnected intrinsically safe apparatus, associated apparatus, and interconnecting cables in which those parts of the system that may be used in hazardous (classified) locations are intrinsically safe circuits. An intrinsically safe system may include more than one intrinsically safe circuit.

3.2.127**temperature, autoignition**

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

3.2.128**type of protection**

See **protection, type of**.

3.2.129**umbilical**

Single or group of functional components, such as electrical cables, optical fiber cables, hoses, and tubes, layed up or bundled together, that generally includes an unsupported, suspended section. See 11.18.2 for definitions of the various types of subsea umbilicals.

3.2.130**unclassified location**

An unclassified location is a location not classified as Division 1 or Division 2, or Zone 0, Zone 1, or Zone 2.

NOTE The term “unclassified location” is used synonymously with the term “nonclassified location.”

3.2.131**ventilation, adequate**

Ventilation (natural or artificial) that is sufficient to prevent the accumulation of significant quantities of vapor-air mixtures in concentrations above 25 % of their lower flammable (explosive) limit, LFL (LEL). See 6.3.2 of API RP 500 or 6.6.2 of API RP 505, as applicable.

3.2.132**ventilation, inadequate**

Ventilation that is less than adequate. See 6.3.3 of API RP 500 or 6.6.3 of API RP 505, as applicable.

3.2.133**zone**

A method of specifying the probability that a location is made hazardous by the presence, or potential presence, of flammable concentrations of gases and vapors, or combustible mixtures of dusts.

3.2.134**Zone 0, Class I**

A Class I, Zone 0 location is a location 1) in which ignitable concentrations of flammable gases or vapors are present continuously or 2) in which ignitable concentrations of flammable gases or vapors are present for long periods of time; see *NEC* Article 505.5(B)(1).

3.2.135**Zone 1, Class I**

A Class I, Zone 1 location is a location 1) in which ignitable concentrations of flammable gases or vapors are likely to exist under normal operating conditions; or 2) in which ignitable concentrations of flammable gases or vapors may exist frequently because of repair or maintenance operations or because of leakage; or 3) in which equipment is operated or processes are carried on, of such a nature that equipment breakdown or faulty operations could result in the release of ignitable concentrations of flammable gases or vapors and also cause simultaneous failure of electrical equipment in a mode to cause the electrical equipment to become a source of ignition; or 4) that is adjacent to a Class I, Zone 0 location from which ignitable concentrations of vapors could be communicated, unless communication is prevented by adequate positive-pressure ventilation from a source of clean air and effective safeguards against ventilation failure are provided; see *NEC* Article 505.5(B)(2).

3.2.136**Zone 2, Class I**

A Class I, Zone 2 location is 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 the 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 the 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 *NEC* Article 505.5(B)(3).

3.3 Definitions Specific to Floating Facilities**3.3.1****cargo**

A flammable gas or vapor or combustible liquid, flammable liquid, or liquefied flammable gas with a (closed cup) flash point below 60 °C (140 ° F).

3.3.2**cargo handling room**

Any enclosed space where cargo is pumped, compressed, or processed. Examples of cargo handling rooms are cargo pump rooms, cargo compressor rooms, and cargo valve rooms.

3.3.3**cargo tank**

Any tank or vessel, located in the below deck area, designed to contain cargo.

3.3.4**corrosion-resistant material or finish**

A term used to describe any material or finish that meets the testing requirements of ASTM B117 or Test Kb in IEC 68-2-52 for 200 hours and does not show pitting, cracking, or other deterioration more severe than that resulting from a similar test on passivated AISC Type 304 stainless steel.

3.3.5**corrosive location**

A location exposed to the weather, salt water, or other corrosive substances such as drilling fluids.

3.3.6**drip-proof**

Equipment enclosed so that it meets at least NEMA 250 Type 1 with a drip shield, NEMA 250 Type 2, or IEC IP 32 rating.

3.3.7

embarkation station

A location from which persons embark into survival craft or are assembled prior to embarking into survival craft.

3.3.8

space, machinery

An enclosed area that contains rotating equipment or internal combustion machinery with a total aggregate power of at least 500 brake horsepower or a place containing internal combustion machinery, thermal fluid heaters, or fired boilers that use fuel gas or a liquid fuel that has a flash point of less than 43.3 °C (110 °F).

3.3.9

location not requiring an exceptional degree of protection

A location that is not exposed to the environmental conditions outlined in the definition of 3.3.10. These locations include a) accommodation spaces such as quarters buildings, b) dry store rooms, and c) other locations with similar environmental conditions.

3.3.10

location requiring an exceptional degree of protection

A location exposed to weather, seas, splashing, pressure-directed liquids, or similar moisture conditions. These locations include a) on-deck areas; b) machinery spaces; c) cargo spaces; d) locations within a galley or pantry area, laundry, or water closet that contains a shower or bath; and e) other spaces with similar environmental conditions.

3.3.11

watertight

Equipment so enclosed that it meets at least NEMA 250 Type 4 or 4X or an IEC IP 55 or 56 rating.

4 Electrical Equipment for Hazardous (Classified) Locations

4.1 General

4.1.1 The selection of proper electrical equipment for offshore petroleum facilities depends directly on whether a particular area is classified or not and whether a hazardous (classified) area is Division 1 or Division 2. Because the safety of an installation is highly sensitive to equipment selection, it is very important to have a clear understanding of the reasons behind the classification of areas and of the different methods employed by electrical equipment manufacturers to make their equipment suitable for the different hazardous (classified) locations.

4.1.2 Through engineering judgment in planning electrical installations for offshore petroleum facilities, most equipment may be placed in lower classified or unclassified locations to reduce the amount of special equipment required. The degree of classification may be reduced or eliminated by purging, as described in 4.3.5. The installation of electrical equipment of lower area classification rating may be accomplished with the use of combustible gas detection as detailed in 11.2. For electrical equipment installed in buildings in unclassified locations, see 12.6.

4.1.3 The "Definitions" section of this recommended practice includes brief definitions of hazardous (classified) locations and various types of equipment used in hazardous (classified) locations. This section expands upon certain of these definitions and provides guidance to proper application of electrical equipment. For specific guidance on classification of petroleum facilities, refer to API RP 500.

4.1.4 Dual classification: In instances of areas within the same facility classified separately, Class I, Zone 2 locations can abut, but shall not overlap, Class I, Division 2 locations. Class I, Zone 0 or 1 locations shall not abut Class I, Division 1 or 2 locations.

4.1.5 Reclassification: Class I, Division 1 or 2 locations may be reclassified as Class I, Zone 0, 1, or 2 locations provided that all of the space classified due to a single flammable source is reclassified.

4.2 High-temperature Devices

4.2.1 High-temperature devices are defined as those devices, the maximum operating temperature of which exceeds 80 % of the autoignition temperature in degrees Celsius (°C) of the gas or vapor involved. The maximum operating temperature refers to the skin temperature of components in the interior of enclosures and to the surface temperature of lamps inside lighting fixtures. For offshore applications, the most commonly encountered explosive gas is natural gas, composed primarily of methane. The autoignition temperature of natural gas is usually considered to be 482 °C (900 °F), and any device, the operating temperature of which exceeds 386 °C (726 °F) in natural gas environments, shall be considered a high-temperature device. The autoignition temperature of hydrogen sulfide (H₂S) is usually considered to be 260 °C (500 °F), and any device, the operating temperature of which exceeds 208 °C (406 °F) in H₂S environments, shall be considered a high-temperature device. A review of production installations shall be made to determine the presence of other gases with lower autoignition temperatures.

4.2.2 High-temperature electrical devices shall be installed in explosionproof or purged and pressurized enclosures unless they have been determined to be suitable for the specific area by an NRTL.

4.2.3 Certain equipment is tested by an NRTL and given one of 14 Temperature Class (T Codes). This equipment may exceed the temperature determined by the 80 % rule, but the T Code shall be below the autoignition temperature of the specific gas or vapor involved. As an example, equipment rated T1 has been verified not to exceed 450 °C (842 °F), and therefore is suitable for most natural gas applications. Reference *NEC* Table 500.8(C).

4.3 Protection Techniques Related to Equipment Installed in Locations Classified as Division 1 or Division 2

4.3.1 Explosionproof Equipment

4.3.1.1 An explosionproof assembly is electrical equipment packaged in an enclosure that is capable of withstanding an internal explosion and preventing its propagation to the external atmosphere. Such explosionproof equipment shall be NRTL approved for use in both Division 1 and Division 2 locations.

4.3.1.2 Explosionproof enclosures breathe when the ambient temperature changes and, therefore, can accumulate flammable gases within. If an explosion occurs within, the enclosure will withstand a very rapid buildup of pressure. The gases escaping will relieve the pressure buildup. These gases will be cooled sufficiently before they reach the surrounding atmosphere to prevent ignition if the surrounding atmosphere is flammable. Three methods are widely used to achieve this cooling:

- a) precision ground flanges or joints machined to specific widths and narrow tolerances,
- b) threaded joints, and
- c) precision serrated joints.

4.3.1.3 In addition, the surface temperature of the enclosure shall not be higher than 80 % of the autoignition temperature in degrees Celsius (°C) of the gas or vapor involved or the assembly shall be determined to be suitable for the specific area by an NRTL T Code (see 4.2.3).

4.3.1.4 It is important that explosionproof enclosures be installed and maintained in accordance with the manufacturer's instructions. If covers are not installed with the number and specified types of bolts, properly torqued, or other specified securing devices, internal explosions can discharge insufficiently cooled gasses that are capable of igniting external flammable atmospheres. Additionally, external flammable atmospheres can be ignited if precision ground flanges or joints are damaged by mechanical means or corrosion or if all entries are not provided with approved entry methods or specified plugs (see 12.1.1).

4.3.2 Hermetically Sealed Devices

4.3.2.1 Hermetically sealed devices are designed to prevent hazardous gases from coming in contact with sources of ignition such as arcing contacts. These devices are suitable for use in Division 2 and unclassified locations. The materials employed to accomplish the hermetic sealing shall be resistant to mechanical abuse and durable enough to withstand normal aging, exposure to hydrocarbons, and any other chemicals and the effects of severe weather. The bond between the different materials employed shall be permanent, mechanically strong, and capable of withstanding the surrounding environment.

4.3.2.2 Hermetically sealed devices are sealed against the entrance of an external atmosphere where the seal is made by fusion, for example, soldering, brazing, welding, or the fusion of glass to metal and has been determined to be suitable for specific Division 2 location by an NRTL. Enclosures the seals of which are accomplished by O-rings, epoxy, molded elastomer, potting, or silicone compounds are not to be considered hermetically sealed unless such equipment has been determined to be suitable for specific Division 2 location by an NRTL.

4.3.3 Intrinsically Safe Systems

4.3.3.1 Intrinsically safe circuits are incapable of releasing sufficient electrical or thermal energy under prescribed test conditions (as specified by UL 913 and UL 60079-11) to cause ignition of a specific hazardous atmospheric mixture in its most easily ignitable concentration. Test conditions include both normal and abnormal operating conditions. Abnormal equipment conditions include accidental damage to or failure of the equipment, wiring, insulation, or other components and exposure to overvoltage. Normal conditions include periods of adjustment and maintenance. The most common applications are found in the fields of instrumentation and communications.

4.3.3.2 Intrinsically safe apparatus is apparatus in which all the circuits are intrinsically safe. Associated apparatus is apparatus in which the circuits are not necessarily intrinsically safe themselves, but that affect the energy in the intrinsically safe circuits and are relied upon to maintain intrinsic safety. Typically, associated apparatus are shunt diode safety barriers (frequently referred to as intrinsically safe barriers) that limit the transfer of energy to a level that cannot ignite flammable atmospheres. The devices are connected in series with signal conductors to transducers and other devices in process plants. Associated apparatus shall be installed in an unclassified location or provided an alternate type protection (e.g. an explosionproof enclosure) suitable for the area in which it is installed.

4.3.3.3 An intrinsically safe system is an assembly of interconnected intrinsically safe apparatus, associated apparatus, and interconnecting cables in which those parts of the system that may be used in hazardous (classified) locations are intrinsically safe circuits. Intrinsically safe systems are suitable for use in unclassified, Division 1 or Division 2 locations. However, such systems may require that specific equipment items, such as controllers or panel instruments, be located in an unclassified location. Where an NRTL has rated such equipment (apparatus) intrinsically safe, it may be employed with various end devices to form an intrinsically safe system. No end device is intrinsically safe by itself, but is intrinsically safe only when employed in a properly designed intrinsically safe system. Proper design of an intrinsically safe system requires adherence to strict rules, detailed mathematical analysis, and, in most cases, laboratory testing. UL 913, ANSI/ISA-60079-11, or *NEC* Article 504 shall be followed when designing and installing an intrinsically safe system. Also, control drawings shall be followed. Control drawings are drawings or other documentation provided by the manufacturer of the intrinsically safe or associated apparatus that detail the allowed interconnection between the intrinsically safe and associated apparatus.

4.3.3.4 The two most important advantages of intrinsically safe equipment are as follows.

4.3.3.4.1 Safety: Intrinsically safe apparatus does not require explosionproof enclosures. Thus, missing bolts and covers, open enclosures during maintenance and testing operations, corroded conduit systems, etc., do not impair the safety of the systems from the standpoint of igniting gas or vapors. The low voltages and currents involved can reduce the hazard of electrical shock.

4.3.3.4.2 Convenience: Wiring for intrinsically safe systems needs only to meet the requirements of *NEC* Article 504, eliminating the requirement for bulky, explosionproof enclosures. Intrinsically safe apparatus and wiring is allowed using any of the wiring methods suitable for unclassified locations. Maintenance and calibration operations may be performed in hazardous (classified) locations without de-energizing the equipment or shutting down process equipment. These activities shall be performed in accordance with the manufacturer's instructions and with approved testing equipment.

4.3.4 Nonincendive Equipment

4.3.4.1 Nonincendive equipment shall not be capable of igniting a hazardous mixture under normal circumstances, but ignition is not necessarily prevented under abnormal circumstances. Such equipment is suitable for use only in Division 2 and unclassified locations. Nonincendive equipment is similar in design to other equipment suitable for Division 2 locations; however, in nonincendive equipment, sliding or make-and-break contacts need not be explosionproof, oil-immersed, or hermetically sealed, as such contacts are incapable of releasing sufficient energy to cause ignition under normal operating conditions.

4.3.4.2 Because portions of the system can operate at energy levels potentially capable of causing ignition, wiring methods used shall conform to area classification requirements. Nonincendive equipment is normally limited to instrumentation and communications systems. When employing nonincendive systems, extreme care shall be exercised.

4.3.5 Purged Enclosures

4.3.5.1 Purging (also referred to as pressurizing) is a method of installing electrical equipment in a hazardous (classified) location without using explosionproof enclosures. NFPA 496 provides information for the design of purged enclosures and purging methods to reduce the classification of the area within an enclosure:

- a) from Division 1 to unclassified (Type X purging);
- b) from Division 1 to Division 2 (Type Y purging);
- c) from Division 2 to unclassified (Type Z purging).

4.3.5.2 NFPA 496 discusses the different requirements for purging of small enclosures, power equipment enclosures, and large volume enclosures such as control rooms. On an offshore facility, the use of humid salt air for purging can cause corrosion damage to equipment; thus, use of inert gas or dehydrated air should be considered where practicable. The source of purge air should be from an unclassified location.

4.4 Protection Techniques Related to Equipment Approved for Zones Used in Division Locations

4.4.1 Acceptance of protection techniques related to equipment approved for zones vary between authorities having jurisdiction (AHJs). Specific requirements such as the individual NRTL or the certification itself will have to be addressed for AHJ approvals. See Table 1.

4.4.2 Equipment listed and marked in accordance with *NEC* Article 505.9(C)(2) for use in Zone 0, 1, or 2 locations shall be permitted in Class I, Division 2 locations for the same gas group (or a group having more onerous requirements) and with a suitable temperature class. Equipment listed and marked in accordance with *NEC* Article 505.9(C)(2) for use in Zone 0 locations shall be permitted in Class I, Division 1 or Division 2 locations for the same gas group and with a suitable temperature class.

Table 1—Types of Protection Designation for Zone Equipment Used in Divisions

Designation	Technique	Divisions ^a
d	Flameproof enclosure	2
e	Increased safety	2
ia	Intrinsic safety	1,2
ib	Intrinsic safety	2
ic	Intrinsic safety	2
[ia] ^b	Intrinsically safe associated apparatus	Unclassified
[ib] ^b	Intrinsically safe associated apparatus	Unclassified
[ic] ^b	Intrinsically safe associated apparatus	Unclassified
ma	Encapsulation	1,2
mb	Encapsulation	2
mc	Encapsulation	2
nA	Nonsparking equipment	2
nC	Sparking equipment in which the contacts are suitably protected other than by restricted breathing enclosure	2
nL	Energy limited—limit the energy of sparks and surface temperatures	2
nR	Restricted breathing enclosure	2
o	Oil immersion	2
px	Pressurization	2
py	Pressurization	2
pz	Pressurization	2 ^c
q	Powder filled	2
^a Does not address use where a combination of techniques is used. ^b See 4.4.2.3. ^c Dependent upon factors such as the provision of automatic shutdown or alarm only on loss of pressurization, the arrangement for the exhaust of the protective gas, the inclusion of sparking/arcing or high-temperature devices within the enclosure, etc.		

4.4.2.1 Flameproof “d”

Flameproof is a type of protection of electrical equipment in which the enclosure will withstand an internal explosion of a flammable mixture that has penetrated into the interior, without suffering damage and without causing ignition, through any joints or structural openings in the enclosure, of an external explosive atmosphere consisting of one or more of the gases or vapors for which it is designed. This protection technique is permitted for equipment in Class I, Zone 1 locations for which it is approved. For further information, see UL 60079-1.

4.4.2.2 Pressurization “p”

4.4.2.2.1 In some cases, hazards may be reduced or hazardous (classified) locations limited or eliminated by adequate positive-pressure ventilation from a source of clean air in conjunction with effective safeguards against ventilation failure. Pressurization “p” is a type of protection of electrical equipment that uses the technique of guarding against the ingress of the external atmosphere that can be explosive, into an enclosure by maintaining a protective gas therein at a pressure above that of the external atmosphere. This protection technique is permitted for equipment in those Class I, Zone 1 or Zone 2 locations for which it is approved. For further information, see NFPA 496 and UL 60079-2.

4.4.2.2.2 From Zone 1 to unclassified (Type px pressurization).

4.4.2.2.3 From Zone 1 to Zone 2 (Type py pressurization).

4.4.2.2.4 From Zone 2 to unclassified (Type pz pressurization).

4.4.2.3 Intrinsic Safety “ia,” “ib,” and “ic”

4.4.2.3.1 Intrinsically safe circuits are incapable of releasing sufficient electrical or thermal energy under prescribed test conditions to cause ignition of a specific hazardous atmospheric mixture in its most easily ignitable concentration. Test conditions include both normal and abnormal operating conditions. Abnormal equipment conditions include accidental damage to or failure of the equipment, wiring, insulation, or other components and exposure to overvoltage. Normal conditions include periods of adjustment and maintenance. The most common applications are found in the fields of instrumentation and communications. Intrinsic safety is designated as Type “i” protection. Type “i” protection is subdivided into categories “ia,” “ib,” and “ic.”

4.4.2.3.2 “Intrinsic safety” suitable for use in Zones 0, 1, and 2 locations is designated category “ia” by UL 60079-11.

4.4.2.3.3 “Intrinsic safety” suitable for use in Zones 1 and 2 locations is designated category “ib” by UL 60079-11.

4.4.2.3.4 “Intrinsic safety” suitable for use in Zone 2 locations is designated category “ic” by UL 60079-11.

NOTE For further information, see UL 913 *Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, III, Division 1, Hazardous (Classified) Locations*.

4.4.2.4 Simple Apparatus

Simple apparatus incorporated in intrinsically safe circuits is permitted in Class I, Zone 0 or Zone 1 locations, according to the category of the associated apparatus. Such apparatus need not be listed, certified, or approved, provided that the associated apparatus is suitably listed, certified, or approved and provided that neither the capacitance nor the inductance of the simple apparatus, considered together with the electrical parameters of the field cabling, exceeds the relevant limits given in the documentation or marking of the associated apparatus.

4.4.2.5 Associated Apparatus

Intrinsically safe associated apparatus, designated by [ia], [ib], or [ic], is connected to intrinsically safe equipment (“ia,” “ib,” or “ic,” respectively), but is located outside the hazardous (classified) location unless also protected by another type of protection such as flameproof (“d”).

4.4.2.6 Type of Protection “n”

Type “n” protection is a type of protection applied to electrical equipment such that, in normal operation, the electrical equipment is not capable of igniting a surrounding explosive gas atmosphere and a fault capable of causing ignition is not likely to occur. This protection technique is permitted for equipment in Class I, Zone 2 locations for which it is approved. Type of protection “n” is further subdivided into nA, nC, nL, and nR. See Table 1 for the descriptions of subdivisions for type of protection “n.” For further information, see UL 60079-15.

NOTE The use of nL protection technique is a departure from the *NEC* as the type of protection nL is not listed in the 2017 edition of the *NEC*.

4.4.2.7 Oil Immersion “o”

Oil Immersion is a type of protection in which the electrical equipment or parts of the electrical equipment are immersed in a protective liquid in such a way that an explosive atmosphere that may be above the liquid or outside the enclosure cannot be ignited. This protection technique is permitted for equipment in Class I, Zone 1 locations for which it is approved. For further information, see UL 60079-6.

4.4.2.8 Increased Safety “e”

Increased safety is a type of protection applied to electrical equipment that does not produce arcs or sparks in normal service and under specified abnormal conditions, in which additional measures are applied so as to give increased security against the possibility of excessive temperatures and of the occurrence of arcs and sparks. This protection technique is permitted for equipment in Class I, Zone 1 locations for which it is approved. For further information, see UL 60079-7.

4.4.2.9 Encapsulation “ma,” “mb,” and “mc”

Encapsulation is a type of protection in which the parts that could ignite an explosive atmosphere by either sparking or heating are enclosed in a compound in such a way that this explosive atmosphere cannot be ignited. This protection technique is permitted for equipment in Class I, Zone 1 locations for which it is approved. Encapsulation suitable for use in Zone's 0, 1, and 2 locations is designated category “ma.” Encapsulation suitable for use in Zones 1 and 2 locations is designated category “mb.” Encapsulation suitable for use in Zone 2 locations is designated category “mc.” For further information, see UL 60079-18.

4.4.2.10 Powder Filling “q”

Powder filling is a type of protection in which the parts capable of igniting an explosive atmosphere are fixed in position and completely surrounded by filling material (glass or quartz powder) to prevent the ignition of an external explosive atmosphere. This protection technique is permitted for equipment in Class I, Zone 1 locations for which it is approved. For further information, see UL 60079-5.

4.5 General Purpose Equipment

4.5.1 General purpose equipment or equipment in general purpose enclosures is permitted in Division 2 locations if the equipment does not constitute a source of ignition (arcing, sparking, or high-temperature devices) under normal operating conditions.

4.5.2 *NEC* Article 501.115 permits the installation of fused or unfused disconnect and isolating switches for transformers or capacitor banks in general purpose enclosures in Division 2. Disconnect switches in general purpose enclosures shall not be used offshore in hazardous (classified) locations; this is a departure from the *NEC*.

4.6 Listing, Marking, and Documentation

4.6.1 Listing

Equipment that is listed for a Division 1 location is permitted in a Division 1 or Division 2 location of the same gas or vapor, subject to *NEC* Article 500.8 (B)(2) requirements.

4.6.2 Marking

Equipment for use in hazardous (classified) locations shall be marked in accordance with this section.

4.6.2.1 Division Equipment

Equipment required by the *NEC* to be approved and labeled for Class I, Division 1 or Class I, Division 2 locations shall be marked to show the class, group, and operating temperature or temperature range (see T Code/Temperature Class) referenced to a 40 °C (104 °F) ambient as follows:

- a) Class I, Division 1 or Class I, Division 2, as applicable;
- b) applicable gas group(s);
- c) temperature class.

4.6.2.2 Temperature Marking

Equipment suitable for ambient temperatures between -25°C to $+40^{\circ}\text{C}$ shall require no ambient temperature marking. Equipment suitable for ambient temperatures other than -25°C to $+40^{\circ}\text{C}$ shall additionally be marked with the maximum and minimum ambient temperature in degrees Celsius. The marking shall include either the symbol "Ta" or "Tamb."

4.6.2.3 Zone Equipment

Equipment approved for Class I, Zone 0, Zone 1, or Zone 2 locations shall be marked as follows:

- a) Class,
- b) Zone,
- c) symbol "AEx,"
- d) protection technique(s),
- e) applicable gas group(s), and
- f) temperature class.

An example of such a required marking is "Class I, Zone 0 AEx ia IIC T6."

4.6.3 Gas Group

Equipment of certain types is marked to show one or several of four Gas Groups (A, B, C, and D) (reference API RP 500). Equipment marked for Group D is suitable for use in natural gas environments. Zone equipment of certain types is allocated to one of three Gas Groups (IIA, IIB, or IIC). Zone rated equipment is described in API RP 14FZ.

4.6.4 Zone Rated Equipment Used in Division Classified Areas

Equipment listed and marked in accordance with *NEC* Article 505.9(C)(2) [Class, Zone, Symbol "AEx," Protection technique(s) in accordance with Table 505.9(C)(2)(4) in the *NEC*, applicable gas group(s) in accordance with Table 505.9(C)(1)(2) in the *NEC*, and the temperature class in accordance with Table 505.9(D)(1) in the *NEC*] for use in Class I, Zone 0, 1, or 2 locations shall be permitted in Class I, Division 2 locations for the same gas and with a suitable temperature class.

5 Electric Power Generating Stations

5.1 General

5.1.1 Electric power generating stations discussed in this section consist of one or more generator sets that can be either portable or permanent by design. Consideration may be given to number, selection, and sizing of prime movers to allow for maintenance and availability. These recommendations include both sound engineering practices and special considerations for safe and reliable operation on offshore petroleum facilities.

5.1.2 Natural gas-fueled prime movers are most practical for the majority of applications, but diesel engines are usually utilized where natural gas is not available or for standby or portable units. Due to flammability concerns, gasoline engines are unacceptable.

5.1.3 The location and installation of generating sets should allow access for inspection, maintenance, and repair. There should be sufficient space between the generator set and surrounding objects to provide accessibility. It is recommended that sufficient room and lifting capability be provided to facilitate service and removal of the generator rotor or its armature.

5.1.4 The power quality from the power generating station is an important aspect to the proper functioning of the equipment interconnected to the electrical distribution system. The measurement of power quality is usually determined at the main power generation bus and is normally limited to a voltage total harmonic distortion (THD) of 8% for low-voltage systems and 5 % for medium- and high-voltage systems. It is recommended to perform a power quality analysis on any facility with a power generation capacity of 1000 kilowatt (kW) or greater whenever additional equipment capable of introducing a significant change in harmonic levels is added to the distribution system. See IEEE Std 519 for additional information concerning the measurement and mitigation of harmonics in the electrical power system.

5.2 Prime Movers

The generator and its driving unit should be mounted on a common rigid sub-base or other means engineered to ensure proper alignment. For reciprocating engine driven generators, it is recommended that the instrument and electrical control panels be mounted locally on the generator set sub-base and be isolated to prevent damage from vibration.

5.2.1 Sizing

It is recommended that prime movers for generator applications have a minimum continuous shaft horsepower output according to Equation (1):

$$HP_{MIN} = \frac{1.0 \times \text{Design kw Load}}{0.746 \times \% \text{ Generator Efficiency}} \quad (1)$$

The efficiency of 25 kW and larger generators typically ranges from 88 % to 94 %. Allowing 1.5 hp per kW output yields a conservative prime mover power requirement. All prime mover ratings should be adjusted for the highest expected ambient temperatures offshore and derated for total system inlet and exhaust pressure losses and end of life degradation. Generally, gas turbines are much more sensitive to these conditions.

Special consideration should be made when sizing prime movers for service where large motors will be started across the line. Consideration may be given for step load changes when considering the numbers and size of generator sets. Split shaft drivers have less of a step load capability.

NOTE Low-emission prime movers (such as Dry Low NOx or DLE) are sometimes used because their combustion temperature minimizes NOx emissions. These drivers generally have reduced step load capability and a narrower operating load range to achieve emissions targets. Operating this type of prime mover outside of its preferred operating range can result in increased emissions and decreased stability as compared to a non-DLE prime mover.

5.2.2 Air Intakes

It is recommended that engine combustion air intakes be located in unclassified locations to minimize the risk of ingestion of flammable mixtures. Reciprocating diesel-fueled prime movers shall be equipped with an air-intake shutoff valve or other suitable device that operates on an overspeed condition that requires shutdown of the prime mover.

5.2.3 Exhausts

It is recommended that engine exhausts be located in unclassified locations, whenever possible, to minimize the risk of ignition of flammable mixtures.

5.2.4 Speed

Reciprocating engines normally are coupled directly to generators and operate at 720 rpm, 900 rpm, 1200 rpm, or 1800 rpm for 60 hertz (Hz) generators. For reduced maintenance and increased life, it is recommended that reciprocating-type engines for prime (continuous) power installations be operated at 1200 rpm or less. Reciprocating-type engines for standby (noncontinuous) applications often are operated at speeds up to 1800 rpm. Gas turbines normally operate at higher speeds and drive generators through gearbox assemblies but may include generators operated at speeds up to 3600 rpm.

5.2.5 Reciprocating Engine Controls

5.2.5.1 It is recommended that automatic controls be provided to shut down all reciprocating engines that are driving generators and open generator breaker when any of the following occurs:

- a) low lube oil pressure;
- b) high jacket water temperature;
- c) overspeed shutdowns operate independently of governor controllers and should be set at no more than 115 % of rated speed;
- d) overvoltage, for generators 500 kW and larger (it is recommended that overvoltage shutdown controls be provided and that generator circuit breakers be tripped and voltage regulators are de-energized);
- e) over crank/fail to start;
- f) high exhaust temperature when applicable, such as turbocharged units.

5.2.5.2 Optional shutdown controls include the following:

- a) low lube oil level;
- b) low jacket water level;
- c) underspeed (it is recommended to open generator circuit only and leave engine running to facilitate system recovery);
- d) vibration, for generators 250 kW and larger;
- e) high lube oil temperature;
- f) undervoltage, for generators 500 kW and larger (it is recommended to open generator circuit only and leave engine running to facilitate system recovery);
- g) underfrequency, for generators 500 kW and larger (it is recommended to open generator circuit only and leave engine running to facilitate system recovery);
- h) loss of excitation, for generators 950 kW or larger or units that are to be paralleled;
- i) generator differential, for generators 950 kW or larger;
- j) overfrequency, for generators 500 kW or larger;
- k) reverse power, for paralleled operation (it is recommended to open generator circuit only and leave engine running to facilitate system recovery).

5.2.6 Gas Turbine Controls

5.2.6.1 It is recommended that automatic controls be provided to shut down gas turbines that are driving generators and open the generator circuit breakers when any of the following conditions occurs:

- a) fail to crank, fail to start, fail to ignite;
- b) high running exhaust temperature;
- c) high lube oil temperature;

- d) low lube oil pressure;
- e) underspeed;
- f) overspeed;
- g) vibration;
- h) overvoltage, for generators 500 kW and larger (it is recommended that overvoltage shutdown controls be provided and that generator circuit breakers be tripped and voltage regulators be de-energized);
- i) high bearing temperature;
- j) high inlet air filter differential pressure;
- k) reverse power, for paralleled operation (it is recommended to open generator circuit only and leave engine running to facilitate system recovery).

5.2.6.2 Optional shutdown controls include the following:

- a) overfrequency, for generators 500 kW and larger;
- b) loss of excitation, for generators 950 kW and larger or units that are to be paralleled;
- c) generator differential for generators 950 kW and larger;
- d) undervoltage, for generators 500 kW and larger (it is recommended to open generator circuit only and leave engine running to facilitate system recovery);
- e) underfrequency, for generators 500 kW and larger (it is recommended to open generator circuit only and leave engine running to facilitate system recovery).

5.2.7 Governors

The prime-mover governor performance is critical to satisfactory electric power generation in terms of constant frequency, response to load changes, and the ability to operate in parallel with other generators. Three basic types of governors are discussed below.

5.2.7.1 Mechanical Governors

Legacy mechanical-type governors have the slowest response to load changes and provide the least accuracy in speed control and, therefore, should be considered only for small generator units where close frequency control is not required. It is not suitable for continuous parallel operation.

5.2.7.2 Hydraulic-mechanical Governors

Legacy hydraulic-mechanical governors provide faster response to load changes and close speed control. This governor can be equipped with an electric motor to allow for remote speed control. The governor is adjustable to operate in either isochronous (constant speed) or droop (speed decreases with load) mode, thus allowing its use for continuous parallel generator operation.

5.2.7.3 Electronic Governors

5.2.7.3.1 The electronic analog or digital governor system provides the highest accuracy and fastest response. It senses engine speed from either the frequency of the generated voltage or a magnetic pickup installed on the engine.

5.2.7.3.2 Automatic load sharing control and automatic synchronization can be incorporated with this type governor and is desirable for multiunit continuous parallel operation. Generally, paralleled units are operated in the isochronous mode, with load sharing controls. Units of different sizes in continuous parallel operation require detailed engineering analysis.

5.2.7.4 Governor—General Requirements

5.2.7.4.1 The steady state speed variation should not exceed 0.5 % (e.g. 0.3 Hz for a 60 Hz machine) of rated speed at any load condition.

5.2.7.4.2 Each prime mover should be under control of a governor capable of limiting the speed, when full load is suddenly removed, to a maximum of 110 % of the rated speed.

5.2.7.4.3 For emergency generators, the prime mover and regulating governor shall be capable of assuming the sum total of all emergency loads upon closure to the emergency bus. The response time and speed deviation shall be within 5 seconds and 10 %, respectively, for 50 % load steps.

5.2.8 Starting Systems

Electric motor, compressed air and natural gas pneumatic motor, and hydraulic motor starters are available for both reciprocating engines and small-to-medium-sized gas turbines. All three types of starters may be safely used in hazardous (classified) locations, provided that electric starter systems are approved for the area. It is recommended that engine-starting batteries not be used for control system power because of a potentially significant voltage drop during and immediately following cranking.

5.2.9 Fuel Systems

A fail-closed fuel shutdown valve shall be provided on natural gas-fueled prime movers. An air-intake shutoff valve shall be installed on reciprocating diesel-fueled prime movers and operated under emergency conditions that require prime mover/generator shutdown as identified by a SAFE Chart analysis performed in accordance with API RP 14C.

5.2.10 Ignition Systems

For prime movers installed in hazardous (classified) locations, ignition systems should be designed and installed to minimize the possibility of the systems being a source of ignition to surrounding flammable gases. All engines with electrical ignition systems shall be equipped with a system designed to minimize the potential for the release of sufficient electrical energy to cause ignition of an external, ignitable mixture. Systems verified by NRTL as suitable for hazardous (classified) locations are recommended. For additional information, see ANSI/UL 122001. Breaker point distributor-type ignition systems shall not be used in areas classified as Class I, Division 1 or 2, by API RP 500. All wiring should be minimized in length; kept in good condition, clean, clear of hot or rubbing objects; suitable for the voltage; and suitable for the ambient temperature. Supplemental mechanical protection of the wiring (metallic or nonmetallic) is not required.

5.3 Generators

5.3.1 General

Electric generators should be designed to perform in accordance with NEMA MG 1. Generators used offshore normally are three-phase, except for small systems that serve only single-phase loads. It is recommended that API Std 546 be considered for the design and testing of medium-voltage generators. For testing of synchronous generators, IEEE Std 115 may also be referenced.

5.3.2 Selection and Sizing

5.3.2.1 Sizing

Generators are designed to carry full nameplate rating in kW provided the nameplate kilovolt-ampere (kVA) rating is not exceeded. Generators normally are rated for 0.8 power factor (power factor = kW/kVA) at sea level. Air-cooled units are designed to operate in 40 °C ambient conditions. Generators operated in ambient temperatures in excess of 40 °C, such as in unit enclosures, should be properly derated. Where generators are totally enclosed water-to-air cooled (TEWAC), the generator should be designed to operate at the maximum site cooling water temperature. The generator station size should be at least equal to the highest expected system operating load. It is recommended that each generator rating should be at least equal to the maximum driver output. A generator operated in excess of its continuous rating will experience a significant reduction in life. If the system load has a large motor or a group of motors starting simultaneously, an analysis of the voltage dip during starting should be performed. It is recommended that this analysis be performed when the total horsepower of the motors being started simultaneously exceeds 20 % of the operating generator(s) nameplate kVA rating. The generator prime mover rating may also need to be increased to be able to accelerate motor(s) to rated speed. Techniques such as soft starting (e.g. reduced voltage autotransformer starters, electronic soft starters, and adjustable speed drives [ASDs]) may be utilized to reduce the required capacity of generators when motor starting is of concern.

5.3.2.2 Load Analysis

It is recommended that a load analysis be performed to determine the aggregate power requirements of all the electric power consuming devices under the various operating conditions of the facility. Various operating conditions include, but are not limited to, start-up, drilling, seasonal variation, environmental conditions, temporary loads, and production life cycle. Operating load factors should be determined for each individual item of equipment and for conditions of operation. The minimum power requirement is of special importance when diesel-engine prime movers are used. Operating these engines at light loads for long time periods will result in excessive maintenance, poor performance, and excess emissions. It is recommended that the load analysis be documented and retained for later review (e.g. by the AHJ or engineering).

5.3.2.3 Frequency

Generators used offshore in North America are normally 60 Hz design. Outside this region, generators can be 60 or 50 Hz design depending on the location.

5.3.2.4 Voltage

Generator design voltage normally matches the majority of the load requirements or is selected for a higher voltage when standard ampacity or short-circuit ratings of switchgear at the load voltage are exceeded. The following are recommended system design voltages for 60 Hz applications: 120/240 V single-phase, and 208Y/120, 480, 480Y/277, 600, 2400, 4160, 6900, 11,000, and 13,800 V three-phase. Care should be taken to maintain the V/Hz ratio of the original equipment design.

5.3.2.5 Generator Design

5.3.2.5.1 Revolving field, brushless-type generators are recommended to eliminate all arcing contacts and to reduce maintenance requirements. The use of permanent magnet exciters should be considered. If a residual magnetism-type exciter is used, it should have capability of voltage buildup after 2 months without operation. It is recommended that generators have a design temperature rise of 80 °C, by resistance (NEMA Class B), but be constructed with a minimum of NEMA Class F insulation to provide optimum balance between initial cost and long-life operations. Generators normally are designed for 40 °C ambient temperatures and thus should be derated in accordance with manufacturer's recommendations if operated in higher ambient temperatures. Insulation of generator windings with quality insulation materials that are designed to be resistant to the salt laden moist atmosphere at offshore locations is recommended. Open, drip-proof generators normally are acceptable, particularly if the generators are installed in buildings or other enclosures that prevent direct exposure to outdoor conditions. Totally enclosed generators will provide optimum protection of windings in outdoor installations. Space heaters should be considered to help keep windings dry when machines are not operating. It is extremely

important for reliable operation that space heaters be adequately sized. If a generating station is to be totally shut down for extended periods of time, it is good practice to provide some means of drying the stator windings prior to restarting to avoid generator damage.

5.3.2.5.2 Special evaluation of winding geometry (pitch, impedance, phase sequence) should be considered if dissimilar machines are to be paralleled. Equipment manufacturers should be consulted for equipment compatibility.

5.3.2.5.3 Design temperature ratings for generators are based on the maximum insulation system temperature at the hottest spot. This is referred to as the total temperature rating and consists of the ambient temperature plus a temperature rise plus hot spot allowance. The ratings are as follows:

- a) Class B (130 °C, 266 °F);
- b) Class F (155 °C, 311 °F);
- c) Class H (180 °C, 356 °F).

5.3.2.5.4 Generators should be designed and specified on total temperature rating, including ambient temperature, temperature rise, and any hot spot allowance. The user should provide the necessary information to the manufacturer so the generator can be properly designed. In some cases, a generator based on the industry standard 40 °C ambient temperature may be used or specified. In these cases, the machine should be derated in accordance with manufacturer's recommendations for operating at higher ambient temperatures.

5.3.2.5.5 The rotor insulation shall have Class F (155 °C, 311° F) total temperature rating and operate at a Class B temperature rise over a 40 °C (104 °F) ambient temperature. For longer rotor life, a Class H (180 °C, 356 °F) insulation system operated at a Class B rise may be considered.

5.3.2.5.6 It is recommended that all form-wound coils for AC generators utilize vacuum-pressure impregnated solvent-less epoxy insulation systems. Vacuum-pressure impregnated, nonhygroscopic, solvent-less epoxy, and/or polyester insulation systems are acceptable for generator rewind and repair applications. It is recommended that after final cure, the windings be given an antifungal treatment.

5.3.2.5.7 Generators exposed to weather should be either totally enclosed air-to-air cooled (TEAAC), TEWAC or provided with an IP (ingress protection) 56 enclosure. Where TEWAC enclosures are used on generators, they shall be of double tube construction and be equipped with leak detection.

5.3.2.5.8 The generator winding shall be capable of withstanding, without mechanical damage, for 30 seconds, a bolted three-phase and phase-to-ground short-circuit at its terminals when operating at the highest capability kVA, rated power factor, and at 5 % overvoltage with fixed excitation.

5.3.2.5.9 The windings shall also be capable of withstanding, without damage, any other short-circuit at its terminals of 30 seconds duration or less, provided the machine phase currents under fault conditions are such that the negative sequence current (I_2) expressed in terms of per unit stator current at highest capability kVA, and the duration of the fault in seconds (t) are limited to values, which given by the integrated product of $(I_2)^2 t$ (negative-phase sequence current squared times time), is equal to or less than 40.

5.3.2.5.10 The generator shall be capable of withstanding for 10 seconds, without damage, an excitation level in the field winding corresponding to a fault current of 300 % of design full-load current in addition to associated short-circuit heating and forces in the armature winding.

5.3.3 Voltage Regulators

5.3.3.1 Solid-state and microprocessor type voltage regulators are recommended for high reliability, long life, fast response, and stable regulation.

5.3.3.2 At least one voltage regulator shall be provided for each generator. Voltage regulation should be automatic and should function under steady state load conditions between 0 % and 100 % load at all power factors that can occur in normal use. Voltage regulators should be capable of maintaining the voltage within the range of 97.5 % to 102.5 % of the rated voltage at steady state. A means of adjustment should be provided for the voltage regulator circuit.

5.3.3.3 Under motor starting or short-circuit conditions, the generator and voltage regulator together with the prime mover and excitation system should be capable of maintaining short-circuit current of such magnitude and duration as required to properly actuate the associated electrical protective devices. This shall be achieved with a value not less than 300 % of generator full-load current for a duration of 2 seconds, or of such additional magnitude and duration as required to properly actuate the associated protective devices.

5.3.3.4 For single-generator operation (no reactive droop compensation), the steady state voltage for any increasing or decreasing load between zero and full load at rated power factor under steady state operation should not vary at any point more than ± 2.5 % of rated generator voltage. For multiple units in parallel, a means should be provided to automatically and proportionately divide the reactive power between the units in operation.

5.3.3.5 Under transient conditions, when the generator is driven at rated speed at its rated voltage and is subjected to a sudden change of symmetrical load within the limits of specified current and power factor, the voltage should not fall below 80 % nor exceed 120 % of the rated voltage. The voltage should then be restored to within ± 2.5 % of the rated voltage in not more than 2.0 seconds.

5.3.3.6 For two or more generators with reactive droop compensation, the reactive droop compensation should be adjusted for a voltage droop of no more than 4 % of rated voltage for a generator.

5.3.3.7 Where two or more generators are arranged to operate in parallel, it is recommended that VAR (volt-ampere reactive) load sharing voltage regulators or an external control system with crosscurrent compensation (also known as reactive differential compensation capabilities) be provided.

5.3.3.8 Where power electronic devices (such as ASDs, soft starters, and switching power supplies) create measurable waveform distortions (harmonics), means should be taken to avoid malfunction of the voltage regulator, e.g. by conditioning of measurement inputs by means of effective passive filters or three-phase sensing.

5.3.3.9 Power supplies and voltage sensing leads for voltage regulators should be taken from the generator side of the generator circuit breaker. Short-circuit protection should be set at no less than 500 % of the transformer rating or interconnecting wiring ampacity, whichever is less. It is recommended that a means be provided to disconnect the voltage regulator from its source of power.

5.3.4 Protective Devices

Unless specifically noted for the generator protection, all protection functions may be included in one multifunction relay or several single-function relays or any combination of multifunction and single-function relays as deemed appropriate for the application. Generator decrement should be considered when determining the overcurrent settings. For additional information on generator grounding and protection schemes, refer to IEEE Std C37.101, IEEE Std C37.102, and IEEE Std 242.

5.3.4.1 Overload and Short-circuit

5.3.4.1.1 The overcurrent trip setting of the device providing protection of a generator shall not exceed 115 % of the generator full-load current. It is recommended that generators be protected with molded case or power circuit breakers. If a power circuit breaker is used, the use of short-time and long-time breaker trips is recommended to permit better coordination with other breakers or fuses in the distribution system. To reduce the probability of damage to unprotected cabling, the cable length between the generator and power circuit breakers with integral current transformers should be minimized and the cable routing should be designed to reduce the possibility of

mechanical damage. Current transformers, if provided, for the power circuit breaker should be on the neutral side of the generator to detect faults inside the machine, especially where differential relaying is not used.

5.3.4.1.2 If a molded case circuit breaker is used, a circuit breaker rated for continuous operation at 100 % of its trip rating (i.e. a 100 % rated breaker as opposed to a standard [80 % rated] molded case breaker) will allow full utilization of the generator nameplate capacity.

5.3.4.1.3 The use of permanent magnet generator (PMG) should be considered to provide adequate short-circuit current for proper operation of the breaker during fault conditions.

5.3.4.1.4 In generating stations with two or more units not intended to be operated in parallel, generator circuit breakers shall be electrically or mechanically interlocked to prevent accidental out-of-phase paralleling. Molded case circuit breakers may be used for single or parallel operation; however, for larger-sized units that will be paralleled, power circuit breakers are recommended because of their faster operating speed and greater flexibility.

5.3.4.1.5 It is recommended that circuit breakers equipped with instantaneous trip devices or instantaneous elements on overcurrent relays not be used on single generators or two generators operated in parallel or generators that have differential protection. When differential protection is not provided, it is recommended that instantaneous breaker trips be used on generators that normally operate in parallel with three or more other generators. To ensure proper coordination the instantaneous trip setting should be above, but as close as practicable to, the maximum asymmetrical short-circuit current available from any one generator.

5.3.4.1.6 Interrupting capacity of circuit breakers shall be adequate to interrupt available fault current, considering short-circuit current magnitude and power factor (reference ANSI/IEEE C37.06, ANSI/IEEE C37.13, and UL 489). The available fault current shall be re-evaluated when additional generating capacity is added to an existing system.

5.3.4.2 Reverse Power

When two or more generators are to operate continuously in parallel, each unit shall be provided with a reverse power relay to trip the generator breakers, after a time delay, in the event of reverse power flow. The prime mover may be left running to facilitate a quick restoration of electrical power.

5.3.4.3 Undervoltage and Overvoltage Sensing Devices

Undervoltage and overvoltage sensing devices with time delay trips should be considered for protection of the electrical system. The prime mover control system or an undervoltage trip device should open the generator main circuit breaker when the prime mover is shut down.

5.3.4.4 Underfrequency and Overfrequency Sensing Devices

Underfrequency and overfrequency sensing devices with time delay trips should be considered for protection of electrical systems.

5.3.4.5 Synchronizing Controls

It is recommended that the controls of generators intended to be paralleled be equipped with the following.

5.3.4.5.1 Synchroscopes or synchronizing lights, or both, to show when generators are in phase. A synchroscope provides more accurate indication of phase relationship and should be considered in most applications for smoother switching operations. The synchronizing indicators should be visible from the speed and voltage setting controls.

5.3.4.5.2 A synchronizing check relay in the breaker closing circuit of electrically operated circuit breakers to prevent out-of-phase paralleling. Consideration should be given to the installation of automatic synchronizing

controls on units greater than 250 kW. Consideration should be given to connecting the synch check relay to one phase and the automatic synchronizer to another phase. This helps to ensure proper phase rotation.

5.3.4.5.3 Interlocking controls to ensure that all other generator circuit breakers for nonoperating generators and incoming feeders are open when an oncoming generator breaker is closed on a dead bus. Dead bus schemes should include both bus voltage sensing and breaker position sensing to provide a redundant interlock. Some of the protection methods include dead bus relays, potential transformer blown fuse indication, breaker status contacts. Consideration should be given to systems connected to utility that incoming lines include the utility breaker position in the protection scheme.

5.3.4.5.4 Synchronizing controls shall include voltage comparison on units greater than 250 kW.

5.3.4.6 Ground-fault Detection

5.3.4.6.1 When the electrical system is ungrounded, a ground-fault indication system is recommended.

5.3.4.6.2 When the electrical system is high-resistance grounded, a ground-fault alarm is required. For systems up to and including 4160 V, automatic tripping devices are not required if the system insulation (e.g. cable, motors, transformers, etc.) is rated for the increased voltage during ground-fault conditions (i.e. 173 % rated). For high-resistance grounded systems greater than 4160 V, ground-fault protective devices should be provided to open the generator circuit breaker if coordinated downstream devices do not clear the fault.

5.3.4.6.3 When the electrical system is low-resistance grounded, ground-fault protective devices shall be provided to open the generator breaker if coordinated downstream devices do not clear the fault.

5.3.4.6.4 When the electrical system is solidly grounded and the main generator protective device is rated 1000 A or greater, ground-fault protective devices shall be provided to open the generator breaker if coordinated downstream devices do not clear the fault. Consideration should be given to providing ground-fault protection for generators with protective devices rated less than 1000 A.

NOTE For additional information on generator protection and grounding schemes, refer to IEEE Std 141, IEEE Std 142, and IEEE Std 242.

5.3.4.7 Control Voltage

For personnel safety, it is recommended that control voltage for generator instrumentation be nominal 120 V AC or less. The use of a dedicated battery for DC control voltage or capacitors for AC trip units is recommended for the circuit breaker trip coils on power breakers to ensure trip voltage availability.

5.3.4.8 Special Considerations

For generators 1000 kVA and larger or with voltage ratings greater than 600 V, the following protective relaying should be considered in addition to (or in lieu of) the minimum relaying listed above.

5.3.4.8.1 Solid-state or microprocessor type protective relays with self-diagnostics are recommended to operate generator circuit breakers. Microprocessor type relays provide greater flexibility in setting and testing. Electromechanical relays may be used in specific applications.

5.3.4.8.2 Voltage restraint or voltage control overcurrent relays (function 51V).

5.3.4.8.3 Instantaneous current differential relays to detect internal generator faults (function 87).

5.3.4.8.4 Reverse VARs or loss of excitation (loss of field) relays (function 40).

5.3.4.8.5 Ground-fault time-overcurrent relay (function 51G or 51N).

5.3.4.8.6 Negative-phase sequence overcurrent relay for protection against unbalanced current (function 46).

5.3.4.8.7 Stator winding temperature relay (function 49S).

5.3.4.8.8 Voltage balance relay on machines greater than 3000 kW, where a separately derived power source is feeding the voltage regulator. This relay may be used to block the misoperation of protective functions (e.g. 32, 40, and 51V) and protect the system from generator voltage regulator runaway (function 60).

5.3.4.8.9 Inadvertent or accidental energizing protection may be included to protect the machine from accidental energization when the generator is offline (function 50/27 and less commonly 50/81U).

5.3.4.8.10 For large or critical generation application, also consider the following protection: overexcitation (V/Hz) (function 24), breaker failure (function 62BF or 50BF), field ground fault (function 64F), stator ground-fault differential (function 87N or 87GN).

5.3.4.8.11 Where applicable, consider the use of a trip circuit monitor (referred to as trip coil supervision). See IEEE C37.2 for additional information.

5.3.4.9 Multiple Unit Stations

When a shutdown is initiated, it is recommended that in multiple unit stations the generator main circuit breaker or contactor be opened by either the prime mover shutdown system or the generator control panel.

5.3.5 Metering

5.3.5.1 Nonparallel Operation

Minimum metering shall include an ammeter (with a selector switch to meter all phases), a voltmeter, and a frequency meter. A voltmeter selector switch (to provide metering of all phases), a running time meter, a power factor meter, and a wattmeter are optional.

5.3.5.2 Parallel Operation

In addition to the minimum metering described in 5.3.5.1 above, a wattmeter, VAR-meter, and a power factor meter are necessary for continuous parallel operation.

5.4 Generator Packaging Considerations

5.4.1 The following factors should be considered in designing electrical generating units or stations. A station may consist of one or more generating units:

- a) Electrical equipment in generating stations shall be suitable for the area classification.
- b) For continuous power applications, a standby generator is desirable to facilitate maintenance and repair.
- c) Portable generating units for temporary service or standby units that are used only upon prime power failure usually are self-contained, skid-mounted units. Lifting frames and weather protecting enclosures are desirable.
- d) Vibration problems usually can be reduced by mounting electrical controls and metering separately from the generating unit's skid.
- e) In larger stations, it is normally desirable to locate all electrical switchgear in a separate unclassified room. Environmental control of such rooms improves reliability of the electrical switchgear equipment.
- f) The noise level of turbine driven units can be reduced by providing an enclosure for each unit or by locating units in separate rooms.
- g) Adequate space should be provided for maintenance and repair.

- h) The installation of fire and combustible gas detection and fire suppression systems should be considered for enclosed generator/prime mover packaged units.

5.5 Switchboards and Switchgear

The scope of this section includes switchboards, metal-enclosed switchgear, metal-enclosed low-voltage power circuit breaker switchgear, and metal-clad switchgear.

5.5.1 General

Switchboard: A metal-enclosed panel or assembly of panels that may contain molded case, insulated case or power circuit breakers, bolted pressure contact or fusible switches, protective devices, and instruments. These devices may be mounted on the face or the back of the assembly. Switchboards are generally accessible from the rear as well as from the front; however, they can be front accessible only.

Metal-enclosed switchgear: A switchgear assembly completely enclosed on all sides and the top with metal (except for ventilating openings and inspection windows) containing primary power circuit switching or interrupting devices, or both, with buses and connections. The assembly may include control and auxiliary devices. Access to the interior of the enclosure is provided by doors, removable covers, or both.

Metal-enclosed low-voltage power circuit breaker switchgear: A switchgear assembly that contains either stationary or withdrawable low-voltage power circuit breakers for use on low-voltage systems with a maximum rating of 635 VAC or 3200 VDC.

Metal-clad switchgear: A switchgear assembly that contains medium-voltage, withdrawable electrically operated power circuit breakers. Barriers and shutters are required when the circuit breakers are withdrawn. Insulated bus is required throughout. The maximum voltage rating is 38 kV.

Arc-resistant switchgear: A switchgear assembly that meets ANSI/IEEE C37.20.7.

Gas-insulated switchgear: A switchgear assembly that is metal-enclosed, medium-voltage, and SF₆ gas-insulated.

5.5.1.1 Switchgear and switchboards should be arranged to provide convenient and safe access to qualified personnel to operate and perform maintenance on all electrical apparatus and equipment. Switchgear and switchboards shall be provided with working space in accordance with 6.12. Switchboards operating at a root-mean-square (RMS) voltage less than 1000 V shall meet the requirements of UL 891 for dead-front switchboards or ANSI/IEEE C37.20.1 or UL 1558 for low-voltage metal-enclosed power circuit breaker switchgear. Switchgear operating at 1000 V or more shall comply with ANSI/IEEE C37.20.2 for metal-clad switchgear. Gas-insulated switchgear shall be NRTL certified to IEC 62271-100 and IEC 62271-200 in addition to the applicable portions of ANSI/IEEE C37.20.2 and C37.20.7.

5.5.1.2 The sides, rear, and front of switchgear and switchboards shall be suitably guarded and metal-enclosed. Switchgear and switchboards shall be dead-front type construction.

5.5.1.3 Electric grade nonconducting matting meeting ASTM D178 or nonconducting gratings meeting the dielectric requirements of ASTM D149 should be provided in each working area in front of and behind switchgear and switchboards.

5.5.1.4 Consideration should be given to mitigation of electrical arc flash. This may include arc-resistant switchgear, arc detection/suppression, or physical isolation of switchgear with remote operation and monitoring. See 6.11.12 for additional information for arc flash considerations.

5.5.1.5 Switchgear and switchboards shall have a warning label indicating potential electric arc flash hazard. Consider labeling the equipment with the potential amount of incident energy and/or the level of arc flash personal protective equipment required. Refer to NFPA 70E for calculation methods and typical examples. Refer to 6.11.12 for further information.