Approval Standard

for

Nonincendive Electrical
Equipment for Use in Class I
and II, Division 2, and Class III,
Divisions 1 and 2, Hazardous
(Classified) Locations

Class Number 3611

December 2004
Approval Standards are intended to verify that the products and services described will meet stated conditions of performance, safety and quality useful to the ends of property conservation. The purpose of Approval Standards is to present the criteria for Approval of various types of products and services, as guidance for FM Approvals personnel, manufacturers, users and authorities having jurisdiction.

Products submitted for Approval shall demonstrate that they meet the intent of the Approval Standard, and that quality control in manufacturing and/or applications shall ensure a consistently uniform and reliable product or service. Approval Standards strive to be performance-oriented and to facilitate technological development.

For examining equipment, materials and services, Approval Standards:

   a) must be useful to the ends of property conservation by preventing, limiting or not causing damage under the conditions stated by the Approval listing; and

   b) must be readily identifiable.

Continuance of Approval and Listing depends on compliance with the Master Agreement, satisfactory performance in the field, on successful re-examinations of equipment, materials, and services as appropriate, and on periodic follow-up audits of the manufacturing facility or service/application.

FM Approvals LLC reserves the right in its sole judgement to change or revise its standards, criteria, methods, or procedures.
# TABLE OF CONTENTS

1. PURPOSE ................................................................................................................................................................................... 1

2. SCOPE ........................................................................................................................................................................................ 1

3. DEFINITIONS ........................................................................................................................................................................... 3

4. GENERAL REQUIREMENTS ............................................................................................................................................... 6

5. REQUIREMENTS FOR CLASS I, DIVISION 2 EQUIPMENT ............................................................................................................. 6

6. REQUIREMENTS FOR CLASS II, DIVISION 2 AND CLASS III, DIVISION 1 AND 2 EQUIPMENT .................. 7

7. NONINCENDIVE CIRCUITS AND NONINCENDIVE FIELD WIRING ........................................................................................................... 7

8. NORMALLY NONARCING COMPONENTS ........................................................................................................................................................................... 9

9. MARKING ............................................................................................................................................................................... 10

10. SURFACE TEMPERATURE REQUIREMENTS ............................................................................................................................... 12

11. EVALUATION OF NONINCENDIVE CIRCUITS ............................................................................................................................... 12

12. EVALUATION OF NONINCENDIVE COMPONENTS ............................................................................................................................... 15

13. EVALUATION OF SEALED DEVICE .................................................................................................................................................. 16

14. EVALUATION OF ENCLOSURES FOR CLASS II AND III .................................................................................................................... 17

15. DROP AND IMPACT TESTS ......................................................................................................................................................... 19

16. MANUFACTURER’S INSTRUCTIONAL MANUAL AND DOCUMENTATION .............................................................................................. 19

17. OPERATIONS REQUIREMENTS ............................................................................................................................................. 20

APPENDIX A: EXPLANATORY MATERIAL .................................................................................................................................................. 21

APPENDIX B: IGNITION CURVES ............................................................................................................................................... 28

APPENDIX C: GENERAL INFORMATION .................................................................................................................................................. 36
  C-1 Approval Application Requirements .................................................................................................................................................. 36
  C-2 Requirements for Samples for Examination ........................................................................................................................................ 37

APPENDIX D: UNITS OF MEASUREMENT ............................................................................................................................................... 38
1. PURPOSE

1.1 This standard states Approval criteria for electrical equipment for use in Class I and II, Division 2, and Class III, Divisions 1 and 2 hazardous (classified) locations as defined in Articles 500, 501, 502, and 503 of the National Electrical Code®, ANSI/NFPA-70 (NEC®).

1.2 The effective date of an Approval standard mandates that all products tested for Approval after the effective date shall satisfy the requirements of that standard. Products FM Approved under a previous edition shall comply with the new version by the effective date or forfeit Approval.

The effective date of this Standard is January 1, 2005 for compliance with all requirements.

2. SCOPE

2.1 This standard sets performance requirements for the construction and testing of electrical apparatus, or parts of such apparatus, for use in Class I and II, Division 2, and Class III, Divisions 1 and 2 hazardous (classified) locations.

2.2 Electrical equipment intended for use in Class I and II, Division 2, and Class III, Divisions 1 and 2 hazardous (classified) locations is apparatus in which any spark or thermal effect, produced under normal conditions, is incapable of causing ignition of a specified mixture of flammable or combustible material in air.

2.3 Application and Requirements
   A. This standard applies only to equipment, circuits, or components designed and assessed specifically for use in Class I and II, Division 2, and Class III, Divisions 1 and 2 hazardous (classified) locations.
   B. This standard is primarily intended to provide requirements for process measurement and control equipment; however, the principles may be applied to similar types of electrical equipment.
   C. The requirements of this standard are based on consideration of ignition in locations made hazardous by the presence of flammable gases or vapor-in-air mixtures, or combustible dusts, and fibers, and flyings under normal atmospheric conditions. For the purposes of this standard, normal atmospheric conditions are considered to be:
      a) an ambient temperature of -4°F (-20°C) to 104°F (40°C);
      b) an oxygen concentration of not greater than 21 percent by volume; and
      c) a pressure of 12.5 to 15.7 psia (86 to 108 kPa)

   Note: EQUIPMENT SPECIFIED FOR ATMOSPHERIC CONDITIONS BEYOND THE ABOVE LIMITS IS SUBJECT TO SPECIAL INVESTIGATION.

2.4* Mechanisms of Ignition

   This standard does not cover mechanisms of ignition from external sources, such as static electricity or lightning, which are not related to the electrical characteristics of the equipment.

*AN ASTERISK FOLLOWING A WORD OR A SECTION NUMBER SIGNIFIES THAT EXPLANATORY MATERIAL APPEARS IN THE APPENDIX.
2.5 Applicability of Other Standards

A. Except where modified by the requirements of this standard, electrical equipment shall comply with the applicable requirements for ordinary locations, in accordance with Approval Standard 3600.

B. This standard does not cover equipment for use in Class I and II, Division 1 hazardous locations, such as equipment constructed to be intrinsically safe, explosion-proof or dust-ignition proof; however, such equipment is suitable for use in Class I and II, Division 2, and Class III, Divisions 1 and 2 hazardous (classified) locations in the same Group for which it is suitable in Division 1 when installed in accordance with the NEC®.

C. This standard does not cover equipment utilizing purged or pressurized enclosures; however, such equipment is considered suitable for use in Class I and II, Division 2 and Class III, Divisions 1 and 2 hazardous (classified) locations when designed to meet the requirements of ANSI/NFPA Standard 496-1998, Purged and Pressurized Enclosures for Electrical Equipment.

D. For flashlights and lanterns the requirements of this standard are supplemented by Approval Standard 3613 “Electric Flashlights and Lanterns for Use in Class I, Division 2, Class I, Zone 2 Hazardous (Classified) Locations”

E. This standard does not cover electric lighting fixtures for use in Division 2 hazardous (classified) locations.

F. This standard does not cover electric motors, electric heaters, heat-tracing cables, and similar heat-producing devices, except where they are an integral part of the equipment under evaluation for use in Division 2 locations. The requirements covered in ANSI standards whose scope includes such equipment will be considered.

2.6 Basis for Requirements

See Approval Standard 3600.

2.7 Basis for Approval

Approval is based upon satisfactory evaluation of the product and the manufacturer. These requirements are listed in Approval Standard 3600.

2.8 Basis for Continued Approval

Continued Approval is based upon:

a) production or availability of the product as currently FM Approved;

b) the continued use of acceptable quality assurance procedures;

c) satisfactory field experience;

d) compliance with the terms stipulated in the Master Agreement;

e) re-examination as necessary, of production samples for continued conformity to requirements.

2.9 System of Units

Where units of measurement are expressed in U.S. customary units, they are followed by their arithmetic equivalents in International System (SI) units, enclosed in parentheses. Conversions are in accordance with ANSI/IEEE/ASTM SI 10-97 Standard for Use of the International System of Units (SI): The Modern Metric System. Where units of measurement are expressed in SI units, no US customary units may be provided.

*AN ASTERISK FOLLOWING A WORD OR A SECTION NUMBER SIGNIFIES THAT EXPLANATORY MATERIAL APPEARS IN THE APPENDIX.
2.10 This document does not cover the requirements for Class I, Zone 2 except as permitted by NEC® (ANSI/NFPA 70:1999) Article 505-10 (b)(1). Specific requirements can be found in Approval Standard 3600 and ANSI/ISA 12.12.02 (IEC60079-15-1987 Mod).

3. DEFINITIONS

For purposes of this standard, the following terms apply:

3.1 associated nonincendive field wiring apparatus: Apparatus in which the circuits are not necessarily nonincendive themselves, but that affect the energy in nonincendive field wiring circuits and are relied upon to maintain nonincendive energy levels. Associated nonincendive field wiring apparatus may be either of the following:

a) Electrical apparatus that has an alternative type of protection for use in the appropriate hazardous (classified) location or

b) Electrical apparatus not so protected that shall not be used in a hazardous (classified) location

Note: ASSOCIATED NONINCENDIVE FIELD WIRING APPARATUS HAS DESIGNATED ASSOCIATED NONINCENDIVE FIELD WIRING APPARATUS CONNECTIONS FOR NONINCENDIVE FIELD WIRING APPARATUS AND MAY ALSO HAVE CONNECTIONS FOR OTHER ELECTRICAL APPARATUS.

3.2 control drawing: A drawing or other document provided by the manufacturer of the nonincendive field wiring apparatus or the associated nonincendive field wiring apparatus that details the allowed interconnections with other circuits or apparatus.

3.3 dust-tight: Constructed in a manner that dust will not enter the enclosing case under specified test conditions.

3.4 hermetically sealed device: A device that is sealed against the entrance of an external atmosphere and in which the seal is made by fusion – e.g., soldering, brazing, welding, or the fusion of glass to metal.

3.5 maintenance, corrective: Any maintenance activity that is not normal in the operation of the equipment and requires access to the equipment’s interior. Such activities are expected to be performed by qualified personnel who are aware of the hazards involved. Such activities typically include locating causes of faulty performance, replacing defective components, and adjusting service controls.

3.6 maintenance, operational: Any maintenance activity, excluding corrective maintenance, that is intended to be performed by the operator and is required for the equipment to serve its intended purpose. Such operational maintenance activities typically include the correcting of “zero” on a panel instrument, changing charts, keeping of records, and adding ink.

3.7 make/break components: Components having contacts that can 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, and connectors.

3.8 maximum external capacitance \( (C_a) \): Maximum capacitance in a circuit that can be connected to the connection facilities of the apparatus.

*AN ASTERISK FOLLOWING A WORD OR A SECTION NUMBER SIGNIFIES THAT EXPLANATORY MATERIAL APPEARS IN THE APPENDIX.
3.9 maximum external inductance ($L_a$): Maximum value of inductance in a circuit that can be connected to the connection facilities of the apparatus.

3.10 maximum external inductance to resistance ratio ($L_a/R_a$): Ratio of inductance ($L_a$) to resistance ($R_a$) of any external circuit that can be connected to the connection facilities of the electrical apparatus without invalidating nonincendive field wiring circuits.

3.11 maximum input current ($I_{\text{max}}$): Maximum current (peak a.c. or d.c.) that can be applied to the connection facilities of the apparatus.

3.12 maximum input power ($P_i$): Maximum power in an external circuit that can be applied to the connection facilities of the apparatus.

3.13 maximum input voltage ($V_{\text{max}}$): Maximum voltage (peak a.c. or d.c.) that can be applied to the connection facilities of the apparatus without invalidating the type of protection.

3.14 maximum internal capacitance ($C_i$): Total equivalent internal capacitance of the apparatus which is considered as appearing across the connection facilities of the apparatus.

3.15 maximum internal inductance ($L_i$): Total equivalent internal inductance of the apparatus which is considered as appearing at the connection facilities of the apparatus.

3.16 maximum internal inductance to resistance ratio ($L_i/R_i$): Ratio of inductance ($L_i$) to resistance ($R_i$) that is considered as appearing at the external connection facilities of the electrical apparatus.

3.17 maximum output current ($I_{\text{sc}}$): Maximum current (peak a.c. or d.c.) in a circuit that can be taken from the connection facilities of the associated nonincendive field wiring apparatus under normal operation. Normal operation includes opening, shorting, or grounding the field wiring.

3.18 maximum output current — multiple channel apparatus ($I_t$): The maximum dc or peak ac current that can be extracted from any combination of terminals of a multiple-channel associated nonincendive field wiring apparatus.

3.19 maximum output power ($P_o$): Maximum electrical power in a circuit that can be taken from the apparatus.

3.20 maximum output voltage ($V_{\text{oc}}$): Maximum output voltage (peak a.c. or d.c.) in a circuit that can appear under open-circuit conditions at the connection facilities of the associated nonincendive field wiring apparatus under normal operation.

3.21 maximum output voltage — multiple channel apparatus ($V_t$): The maximum dc or peak ac open circuit voltage that can appear across any combination of terminals of a multiple-channel associated nonincendive field wiring apparatus.

3.22 nonincendive circuit*: A circuit, other than nonincendive 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-, dust-air mixture, fibers or flyings.

3.23 nonincendive component: Construction of a component having contacts for making or breaking an incendive circuit and the contacting mechanism such that the component is incapable of igniting the specified flammable gas- or vapor-air dust-air mixture fibers or flyings. The housing of a nonincendive component is not intended to exclude the flammable atmosphere or contain an explosion.

*AN ASTERISK FOLLOWING A WORD OR A SECTION NUMBER SIGNIFIES THAT EXPLANATORY MATERIAL APPEARS IN THE APPENDIX.
3.24 nonincendive equipment: Equipment having electrical/electronic circuitry that is incapable, under normal operating conditions, of causing ignition of a specified flammable gas-, vapor-, or dust-air mixture of fibers or flyings due to arcing or thermal means.

3.25 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 fibers or flyings. Normal operation includes opening, shorting, or grounding the field wiring.

3.26 normal operating conditions: Conditions under which equipment conforms electrically and mechanically with its design specification and is used within the conditions specified by the manufacturer. These conditions include:
   a) supply voltage, current, and frequency;
   b) environmental conditions (including process interface);
   c) all tool-removable parts, (e.g. covers) in place;
   d) all operator-accessible adjustments at their most unfavorable settings; and
   e) opening or grounding of any one or shorting of any two of the nonincendive field-wiring conductors.

3.27 operator-accessible part: A part that is intended for adjustment, switching, or replacement by the operator during intended use or operational maintenance, or a part that is readily accessible to the operator without the use of a tool.

3.28 sealed device: A device so constructed that it cannot be opened during normal operational conditions or operational maintenance; it is sealed to restrict entry of an external atmosphere. See Section 13 for detailed requirements for sealed devices.

3.29 nonincendive field wiring apparatus: Apparatus intended to be connected to nonincendive field wiring.

3.30 unclassified locations: Locations that have been evaluated by the classification process defined in ANSI/NFPA 70 and determined to be neither Class I, Division 1; Class I, Division 2; Class I, Zone 0; Class I, Zone 1; Class I, Zone 2; Class II, Division 1: Class II, Division 2; Class III, Division 1; Class III, Division 2; or any combination thereof.

3.31 maximum output power – multiple channel apparatus (Pt): The maximum power that can be extracted from any combination of terminals of a multiple-channel associated nonincendive field wiring apparatus.

3.32 current controlled nonincendive field wiring apparatus: Apparatus where the input current is regulated within a set of specific limits as defined by the manufacturer.

Note: THE CURRENT MAY BE REGULATED AT SPECIFIC VALUES WITHIN THE RANGE DEPENDING UPON THE CONDITION BEING MONITORED, FOR EXAMPLE: AS IS THE CASE IN TYPICAL 4-20MA CONFIGURATION.

*AN ASTERISK FOLLOWING A WORD OR A SECTION NUMBER SIGNIFIES THAT EXPLANATORY MATERIAL APPEARS IN THE APPENDIX.
4. GENERAL REQUIREMENTS

Requirements for equipment intended to be used in Class I and Class II, Division 2 and Class III, Division 1 and 2 hazardous (classified) locations are established on the basis that the equipment in its normal operating condition is incapable of causing ignition of a specified flammable gas, vapor-in-air mixture, dust, or fibers, or flyings. The tolerances associated with the components of the equipment must be considered. Subsequent arcs or thermal effects within the equipment, resulting from opening, shorting, or grounding of nonincendive field wiring, shall be taken into consideration as they affect the suitability of the equipment for use in Division 2 locations. Equipment also shall comply with the ordinary location requirements for the particular category of equipment except as specifically amended herein.

5. REQUIREMENTS FOR CLASS I, DIVISION 2 EQUIPMENT

5.1 Protection shall be provided according to 5.1.1 and 5.1.2 to ensure that under normal operating conditions such equipment is not capable of igniting the specified flammable gas or vapor-in-air mixture.

5.1.1* Each make/break component shall be either:
   a) a normally nonarcing component that meets the requirements of Section 8;
   b) used in a nonincendive circuit that meets the requirements of Section 7;
   c) a nonincendive component that meets the requirements of Section 12; or
   d) a sealed device that meets the requirements of Section 13;

5.1.2 Equipment with a surface temperature in excess of 212°F (100°C) shall comply with the requirements of Section 10.

5.2 Enclosures shall provide protection to prevent deterioration of the equipment that would adversely affect its suitability for use in Class I, Division 2 locations. Although general-purpose enclosures normally will suffice, particular attention should be given to the possible need for weatherproofing, general protection from corrosion, and preventive maintenance.

5.3 Equipment shall be capable of being installed according to the requirements of the NEC® ANSI/NFPA 70.

5.4* Fuses used in circuits that are subject to overloading in normal use must be of a type suitable for use in Division 2 locations or housed in an enclosure suitable for Division 1 locations.

5.5* If a replaceable fuse is provided, a switch suitable for the location where it is installed must also be provided to remove power from the fuse. The switch need not be integral to the equipment if the equipment installation instructions indicate the need for such a switch.

5.6 A circuit breaker that may be used as a switch must be of a type suitable for use in Division 1 locations or housed in an enclosure suitable for Division 1 locations.

*AN ASTERISK FOLLOWING A WORD OR A SECTION NUMBER SIGNIFIES THAT EXPLANATORY MATERIAL APPEARS IN THE APPENDIX.
6. REQUIREMENTS FOR CLASS II, DIVISION 2 AND CLASS III, DIVISION 1 AND 2 EQUIPMENT

6.1* For Class II, Division 2 equipment, protection shall be provided by the use of an enclosure that meets the requirements of Section 13 or 14 or shall be a nonincendive circuit meeting the requirements of Section 7 with consideration for possible ignition in accordance with Section 7.1.1 due to the ingress of dust (see NOTE below), or by a combination of these methods. For Class III locations, protection shall be provided by a dust-tight enclosure that meets the requirements of Section 14.

Note: CONSIDERATION MUST BE GIVEN TO SHORTING OR BYPASSING COMPONENTS BY CONDUCTIVE DUST.

Exception: Portable battery-powered equipment for use in Class II, Group G or Class III, need not have all electrical components and wiring enclosed provided both the following conditions are met:

a) Entrance of dust does not result in ignition or charring of the dust; and

b) Circuits with make/break components shall be determined to be nonincendive by testing with a propane-air mixture in accordance with the spark-ignition test. See 11.1 through 11.5 or 7.1.

7.* NONINCENDIVE CIRCUITS AND NONINCENDIVE FIELD WIRING

7.1* Either of the following two methods may be employed to determine that a circuit(s) or field wiring is nonincendive:

a) Testing the circuit according to Section 11; or

b) Comparing the maximum calculated or measured values of current, voltage, and associated inductances and capacitances to the appropriate values in Figures B-1 through B-8 in Appendix B to establish that the current and voltage levels are below those specified in 7.1.2. For Class II and III locations the curves for propane are to be used.

Note: FIGURES B-1, B-2, B-3, B-4, B-7, AND B-8 APPEARING IN APPENDIX B ARE BASED ON INFORMATION IN CERTIFICATION STANDARD SFA 3012, 1972 EDITION, DEPARTMENT OF TRADE AND INDUSTRY, BRITISH APPROVAL SERVICE FOR ELECTRICAL EQUIPMENT IN FLAMMABLE ATMOSPHERES. FIGURES B-5 AND B-6 ARE BASED ON INFORMATION IN “SOME ASPECTS OF THE DESIGN OF INTRINSICALLY SAFE CIRCUITS,” RESEARCH REPORT 256, 1968, BY D. W. WIDGINTON, SAFETY IN MINES RESEARCH ESTABLISHMENT, SHEFFIELD, ENGLAND. FIGURES B-7 AND B-8 REPRESENT CAPACITOR DISCHARGE ONLY. THEY DO NOT INCLUDE THE ADDITIONAL CURRENT THAT MAY BE AVAILABLE FROM THE POWER SUPPLY.

7.2 When evaluating a circuit as nonincendive, the following ignition sources shall be considered as normal operating conditions:

a) Discharge of capacitive circuits;

b) Interruption of inductive circuits;

c) Intermittent making and breaking of resistive circuits; and

d) Grounding opening and shorting on nonincendive field wiring circuits.

*AN ASTERISK FOLLOWING A WORD OR A SECTION NUMBER SIGNIFIES THAT EXPLANATORY MATERIAL APPEARS IN THE APPENDIX.
7.3* The maximum voltage and current levels (DC or AC peak) in circuits determined to be nonincendive by
the comparison method, for given circuit constants, shall be less than:

a) 90% of the current from Figures B-1 through B-6, and
b) 90% of the voltage from Figures B-7 and B-8.

Figures B-1 and B-2 apply only to circuits whose output voltage/current characteristic is a straight line
drawn between open-circuit voltage and short-circuit current.

Circuits with nonlinear outputs shall be subject to special investigation.

The maximum normal open-circuit voltage and the maximum short-circuit current shall be determined
under the worst-case normal operating conditions.

7.4* For evaluating nonincendive field wiring of equipment supplying energy, use the maximum normal circuit
voltage $V_{oc}$ (or $V_l$), and maximum short circuit current $I_{sc}$ (or $I_t$), employing applicable ignition figures
in Appendix B to determine the maximum allowable connected capacitance, $C_a$, and maximum allowable
connected inductance, $L_a$, respectively.

7.5* The Nonincendive Field Wiring Circuits Concept allows interconnection of nonincendive apparatus with
associated nonincendive apparatus not specifically examined in combination as system when:

$$V_{max} \geq V_{oc} \text{ or } V_l; \ C_a \geq C_i + C_{cable}; \ L_a \geq L_i + L_{cable}$$

7.6 Nonincendive field wiring enables interconnection of nonincendive field wiring apparatus with associated
nonincendive field wiring apparatus not specifically examined in combination as a system under one of the
following conditions:

a) Current Controlled

Normal operating current controlled or limited by the nonincendive field wiring apparatus (unlike the
requirements for intrinsically safe apparatus $I_{max}$ of the nonincendive field wiring apparatus need not be
greater that the $I_{sc}$ of the associated nonincendive field wiring apparatus)

$$V_{max} \geq V_{oc} \text{ or } V_l; \ C_a \geq C_i + C_{cable}; \ L_a \geq L_i + L_{cable}$$

b) Not Current Controlled

Normal operating voltage or current not controlled or limited by the nonincendive field wiring apparatus

$$V_{max} \geq V_{oc} \text{ or } V_l; \ I_{max} \geq I_{sc} \text{ or } I_t; \ C_a \geq C_i + C_{cable}; \ L_a \geq L_i + L_{cable}$$

Note: $I_{max}$ might also be the rated current of the device.

*AN ASTERISK FOLLOWING A WORD OR A SECTION NUMBER SIGNIFIES THAT EXPLANATORY MATERIAL APPEARS IN THE APPENDIX.
8. NORMALLY NONARCING COMPONENTS

8.1 Make/break components that are to be considered nonarcng in normal operation shall comply with the requirements of Sections 8.2 through 8.7 as applicable.

8.2 Connectors and plug-in components used in incendive circuits and incorporated within equipment shall be considered normally nonarcng if disconnection is not required under operational maintenance conditions and if they require a separating force of at least 3.4 pounds (15 N) or if they are mechanically prevented from separating. If accessible during operational maintenance, connectors in an incendive circuit shall be tool-secured and provided with a caution marking in accordance with Section 9.2.

*Exception: Plug-in components internal to the equipment need only pass a pull test of 3 times the mass of the component.*

8.3 In incendive circuits, fuses that are removable during operational maintenance shall be removable only with the use of a tool. The fuseholders for such fuses shall be provided with a caution marking in accordance with Section 9.2 and located adjacent to the fuseholder.

8.4 Circuit breakers that cannot be manually switched off, i.e., have a reset button that is only accessible by use of a tool, may be used in circuits that are not subject to overloading in normal use. These circuit breakers are subject to special examination by FM Approvals. All such circuit breakers shall be provided with a caution marking in accordance with Section 9.3 and located adjacent to the circuit breaker.

8.5 In incendive circuits, removable lamps that are accessible during operational maintenance shall be removable only with the use of a tool. The lampholders for such lamps shall be provided with a caution marking in accordance with 9.2 and located adjacent to the lampholder. The lampholder shall provide protection to prevent breakage of the bulb.

*Exception: When used in Class I, Division 2 hazardous locations, a tool need not be required to remove the lamp if the lamp is accessible only after removal of a separate protective cover. The cover need not require a tool to remove.*

8.6 If accessible during operational maintenance, connectors used for nonincendive field wiring shall not be interchangeable with other field wiring connectors

*Exception: Where interchange does not affect nonincendive circuits or where connectors are so identified that interchange is unlikely, interchangeable connectors are allowed.*

8.7 If accessible only by the use of a tool, manually operated make/break components in an incendive circuit are considered normally nonarcng components.

Note: CIRCUIT BREAKERS MAY BE USED IN CIRCUITS THAT ARE NOT SUBJECT TO OVERLOADING IN NORMAL USE.
9. MARKING

9.1 In addition to the marking required for general-purpose equipment and Approval Standard 3600, the equipment shall be marked with the following minimum information.

9.1.1 Hazardous location suitability: Class, Division, and Group(s). In lieu of Group(s), a specific gas, vapor or dust;

9.1.2 *

9.1.3 Any other markings or cautions necessary for the installation and safe operation of the equipment;

Note: THE INTERNATIONAL SYMBOL \( \Delta \) MAY BE USED TO REFER THE OPERATOR TO AN EXPLANATION IN THE EQUIPMENT INSTRUCTIONS.

9.1.4 The Approval mark, in accordance with the artwork appearing in Approval Standard 3600, Appendix; and –

9.1.5 WARNING – SUBSTITUTION OF THE FOLLOWING COMPONENTS MAY IMPAIR SUITABILITY FOR DIVISION 2: Followed by a list of critical components.

Alternatively the warning and component list may be included with the equipment instructions and the apparatus marked with the international symbol \( \Delta \).

9.2 Connectors, fuseholders, and lampholders required to be marked according to Subsections 8.2, 8.3, and 8.5 shall be marked with the following or an equivalent warning:

\[ \text{WARNING: DO NOT REMOVE OR REPLACE WHILE CIRCUIT IS LIVE WHEN A FLAMMABLE OR COMBUSTIBLE ATMOSPHERE IS PRESENT.} \]

If practical, this marking shall be either on or adjacent to the component. Otherwise, this marking shall be displayed on a prominent place on the enclosure.

If disconnecting the equipment supply could ignite the flammable atmosphere, the equipment shall be marked with the following or an equivalent warning:

\[ \text{WARNING — EXPLOSION HAZARD. DO NOT DISCONNECT EQUIPMENT WHEN A FLAMMABLE OR COMBUSTIBLE ATMOSPHERE IS PRESENT.} \]

9.3 Circuit breakers required to be marked according to 8.4 shall be marked with the following or an equivalent warning:

\[ \text{WARNING: DO NOT RESET CIRCUIT BREAKER WHEN A FLAMMABLE OR COMBUSTIBLE ATMOSPHERE IS PRESENT UNLESS POWER HAS BEEN REMOVED FROM THE EQUIPMENT.} \]

9.4* The following information shall either be marked on the equipment or contained in the Control Drawing for equipment with nonincendive field wiring connections.

9.4.1 Connections for nonincendive field wiring shall be clearly identified.

*AN ASTERISK FOLLOWING A WORD OR A SECTION NUMBER SIGNIFIES THAT EXPLANATORY MATERIAL APPEARS IN THE APPENDIX.
9.4.2 Equipment supplying energy:

a) $V_{OC}$ – normal circuit voltage; or $V_t$ – maximum normal circuit voltage supplied from multiple circuits;

b) $I_{SC}$ – normal circuit current; or $I_t$ – maximum normal circuit current supplied from multiple circuits;

c) $C_a$ – maximum allowable connected capacitance (based on $V_{OC}$ or $V_t$) and $L_a$ – maximum allowable connected inductance (based on $I_{SC}$ or $I_t$); or capacitance.

d) $P_o$ – maximum normal output power (optional); or $P_t$ – maximum normal output power supplied from multiple circuits.

Note: IN ADDITION TO THE ABOVE, PARAMETER L/R MAY ALSO BE MARKED, WHERE L/R IS THE MAXIMUM ALLOWABLE RATIO OF INDUCTANCE TO RESISTANCE.

9.4.3* Equipment receiving energy:

9.4.3.1 Normal operating voltage or current not controlled or limited by the nonincendive field wiring apparatus.

a) $V_{max}$

b) $I_{max}$

c) $C_i$

d) $L_i$

e) $P_i$ (optional).

9.4.3.2 Normal operating current controlled or limited by the nonincendive field wiring apparatus.

a) $V_{max}$

b) $C_i$

c) $L_i$

d) $P_i$ (optional).

Exception: Equipment supplied as a system, including cables supplied for field wiring, need not comply with 9.4.

Note: ORDINARY LOCATIONS STANDARDS SUCH AS ANSI/ISA 82.02.01 REQUIRE THE MARKING OF THE RATED VALUES OF THE SUPPLY VOLTAGES OR RATED RANGE OF THE SUPPLY VOLTAGES, AND EITHER:

A) THE MAXIMUM RATED POWER IN EITHER WATTS OR VOLT-AMPERES OR
B) THE MAXIMUM RATED INPUT CURRENT.

9.5 In addition, equipment may be marked Class I, Zone 2 Group IIA (or IIB, or IIC as applicable) and a temperature class. The temperature classification should be in accordance with 10.2, but without the alpha suffix. The correlations between Groups for Zones and Groups for Divisions are shown below.

<table>
<thead>
<tr>
<th>Class I Division 2 Groups</th>
<th>Class I Zone 2 Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>IIC</td>
</tr>
<tr>
<td>B</td>
<td>IIB + $H_2$</td>
</tr>
<tr>
<td>C</td>
<td>IIB</td>
</tr>
<tr>
<td>D</td>
<td>IIA</td>
</tr>
</tbody>
</table>

Note: (IIB + $H_2$) is not a Group as defined by the NEC®.

9.6 Nonincendive field wiring apparatus and associated nonincendive field wiring apparatus shall be marked with the Control Drawing number.

*AN ASTERISK FOLLOWING A WORD OR A SECTION NUMBER SIGNIFIES THAT EXPLANATORY MATERIAL APPEARS IN THE APPENDIX.
10. SURFACE TEMPERATURE REQUIREMENTS

10.1* The maximum temperature of any surface that may come in contact with a flammable gas or vapor-in-air mixture or dust, fibers, or flyings shall be determined under normal operational conditions. Such measurements need not be made on the internal parts of sealed devices. Measurements shall be made at any convenient ambient temperature between 50°F (10°C) and 104°F (40°C), corrected linearly to 104°F (40°C) or higher marked ambient.

10.2*

Note: COMPONENT SURFACE TEMPERATURE MAY EXCEED THE MARKED TEMPERATURE RATING IF IT CAN BE DEMONSTRATED THAT NO HAZARD EXISTS.

11. EVALUATION OF NONINCENDIVE CIRCUITS

11.1 The spark test apparatus used for performing ignition tests on circuits shall consist of an explosion chamber at least 15.25 cu. in. (250 cm³) in volume, in which circuit-making and circuit-breaking sparks can be produced in the presence of the prescribed test gas.

11.2 Components of the contact arrangement are a cadmium disc with 2 slots and 4 tungsten wires of 0.008 in. (0.2 mm) diameter, which slide over the disc. The free length of the tungsten wires shall be 0.44 in. (11 mm). The driving spindle, to which the tungsten wires are attached, shall make 80 revolutions per minute. The spindle on which the cadmium disc is mounted shall revolve in the opposite direction. The ratio of the speeds of the driving spindle to the disc spindle shall be 50 to 12. The spindles shall be insulated from one another and from the housing. See Figure 1. The explosion chamber shall be able to withstand pressures of 213.2 lb/in.² (1470 kPa) or shall be provided with suitable pressure relief. When cadmium, zinc, or magnesium will not be present, the cadmium disc may be replaced by a tin disc.

11.3* GAS MIXTURE

11.3.1 For Group D, the test mixture shall be 5.25 ±0.25 percent propane by volume in air.
11.3.2 For Group C, the test mixture shall be 7.8 ±0.5 percent ethylene by volume in air.
11.3.3 For Groups A and B, the test mixture shall be 21 ±2 percent hydrogen by volume in air.
11.3.4 For Class II and III, the test mixture shall be 5.25 ±0.25 percent propane by volume in air.
11.3.5* Equipment that is intended for use in a specific gas or vapor-in-air may be tested in the most easily ignitable concentration of that gas or vapor-in-air mixture in lieu of the mixtures specified in 11.3.1 through 11.3.4.
Fig. 1. Test apparatus for evaluating nonincendive circuits.
11.4 Sensitivity Verification of Spark Test Apparatus

11.4.1 The sensitivity of the spark test apparatus shall be verified before and after each test series conducted in accordance with Section 11.4.2. The test apparatus shall be operated in a 24 V DC circuit containing a 95 mH air-core coil. The currents in these circuits shall be set at the corresponding value given for the appropriate group in Tables 2 or 3, as applicable.

11.4.2 Verification of the apparatus shall be satisfactory if ignition of the gas occurs within 400 revolutions of the tungsten wire holder.

### Table 2: Current in Verification Circuit Cadmium Disk

<table>
<thead>
<tr>
<th>Group</th>
<th>Inductive Circuit</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>100 mA</td>
</tr>
<tr>
<td>C</td>
<td>65 mA</td>
</tr>
<tr>
<td>A &amp; B</td>
<td>30 mA</td>
</tr>
</tbody>
</table>

### Table 3: Current in Verification Circuit Tin Disk

<table>
<thead>
<tr>
<th>Group</th>
<th>Inductive Circuit</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>110 mA</td>
</tr>
<tr>
<td>C</td>
<td>90 mA</td>
</tr>
<tr>
<td>A &amp; B</td>
<td>50 mA</td>
</tr>
</tbody>
</table>

11.5 Tests

11.5.1 The spark test apparatus shall be connected in the circuit under test at each point where an interruption normally occurs, taking into account the requirements of this standard.

11.5.2 Ignition Test Conditions

There shall be no ignition of the test mixture under any of the following conditions:

a) For line-connected equipment, the input voltage shall be increased to 110 percent of nominal line voltage;

b) All adjustments shall be set at their most unfavorable positions; or

c) All circuits shall be tested for the following number of revolutions of the tungsten wire holder in the spark test apparatus:

1) For DC circuits, not less than 400 revolutions – 200 revolutions at each polarity, and
2) For AC circuits, not less than 1000 revolutions.

11.5.3 The test apparatus shall be verified according to Section 11.4 after each ignition test. The ignition test shall be considered invalid if the verification test is unsatisfactory.

*AN ASTERISK FOLLOWING A WORD OR A SECTION NUMBER SIGNIFIES THAT EXPLANATORY MATERIAL APPEARS IN THE APPENDIX.*
12. EVALUATION OF NONINCENDIVE COMPONENTS

12.1 Nonincendive components shall be subjected to the tests specified in Section 12.2.

12.1.1 A nonincendive component is limited in use to the rating for which it has been satisfactorily tested according to Section 12.2.

12.1.2 Nonincendive components shall be preconditioned by being operated a minimum of 6000 times at the rate of approximately 6 times per minute while carrying their normal electrical load.

12.2* Spark Ignition Test for Nonincendive Components

12.2.1* Following the preconditioning test, the nonincendive component shall be placed in a suitable test chamber of at least ten (10) times the volume of the device and connected to an electrical load of 150 percent of the AC or DC current (maximum 75 percent power factor if for AC) and at maximum voltage of the circuit for which the component is being tested.

Exception: The 75 percent power factor requirement may be neglected for totally resistive loads only.

Note: NONINCENDIVE COMPONENTS INTENDED FOR USE WITH HIGH INRUSH CURRENT LOADS (E.G., MOTOR OR TUNGSTEN LAMPOADS) SHALL BE SUBJECTED TO OVERLOAD TESTING THAT IS REPRESENTATIVE OF ACTUAL CIRCUIT APPLICATIONS. PRECONDITIONING AND OVERLOAD CONDITIONS SHALL BE ACCORDING TO THE REQUIREMENTS OF NATIONAL STANDARDS THAT COVER THESE APPLICATIONS.

12.2.2 Nonincendive components shall be filled with and surrounded by a gas mixture according to Sections 11.3.1 through 11.3.5. The samples should be prepared by using one of the methods in 12.2.2.1 to 12.2.2.3 and then successfully withstand the test in 12.2.3.

12.2.2.1 Remove the housing adjacent to the contacts to permit free access of the air-gas mixture to the contacts.

12.2.2.2 Drill at least two holes in the enclosure that will assure propagation of an ignition from the inside to the outside of the enclosure. The test gas shall flow through the device. A tube may be connected to one of the holes for this purpose.

12.2.2.3 Draw a vacuum within the chamber and maintain the vacuum for 100 seconds. Fill the test chamber with the specified air-gas mixture and maintain the concentration for 100 seconds before applying the required electrical load. An explosion detection device (e.g., a pressure transducer) shall be connected to the device under test to detect ignition.

12.2.3* The component shall be operated a minimum of 50 times at not less than 10-second intervals, renewing the air-gas mixture after each set of 10 operations (or more frequently, if necessary to ensure the presence of the air-gas mixture within the nonincendive component). There shall be no ignition of the air-gas mixture.

*AN ASTERISK FOLLOWING A WORD OR A SECTION NUMBER SIGNIFIES THAT EXPLANATORY MATERIAL APPEARS IN THE APPENDIX.
13.** EVALUATION OF SEALED DEVICE**

13.1 This section covers the requirements for electrical equipment or parts of electrical equipment or components that contain normally arcing parts or heat-producing surfaces that, by their location in a sealed enclosure, are intended to be made incapable of causing ignition of the specified gas or vapor-in-air mixtures at their most easily ignitable concentration.

Hermetically sealed devices (See definition in Section 3) shall be considered to meet these requirements without test.

13.2* Except as permitted in Section 13.1, the free internal volume of the device shall be less than 6.1 in$^3$ (100 cm$^3$).

13.3 Resilient gasket seals or poured seals shall be arranged so that they are not subject to mechanical damage during normal operational conditions and shall retain their sealing properties for the intended conditions of use.

Sealing and encapsulating material shall have softening or melting points at least 36°F (20°C) higher than the maximum rated operating temperature of the device.

Note: A SEALED DEVICE SHOULD HAVE STRUCTURAL INTEGRITY AND SHOULD BE CONSTRUCTED OF MATERIALS SUITABLE FOR THE INTENDED ENVIRONMENT WITH FULL CONSIDERATION FOR ANTICIPATED ATMOSPHERIC CONTAMINANTS AND CORROSIVE COMPOUNDS. THE ENCLOSURE SHOULD BE SUFFICIENTLY RUGGED TO WITHSTAND NORMAL HANDLING AND ASSEMBLY OPERATIONS WITHOUT DAMAGE TO ANY SEALS PROVIDED.

13.4*

13.5 To ensure that damage affecting safety of operation will not occur during normal operational conditions of the sealed device, three samples shall be preconditioned by oven aging according to 13.5.1 and subjected to an air leakage test according to 13.5.2.

13.5.1* OVEN AGING

If the device contains a gasket or seal of elastomeric or thermoplastic material or a composition gasket utilizing an elastomeric material, each sample shall be subjected to temperature aging in a circulating air oven in accordance with the following formula:

\[
t = 2685e^{-(0.0693)(T-T1)}
\]

where:

- $t =$ the test time in hours;
- $e =$ 2.7183;
- $T =$ the aging temperature in °C and
- $T1 =$ the maximum rated operating temperature in °C (40°C minimum).

For $T =$ 80°C, and $T1 =$ 40°C, $t =$ 168 hours

*AN ASTERISK FOLLOWING A WORD OR A SECTION NUMBER SIGNIFIES THAT EXPLANATORY MATERIAL APPEARS IN THE APPENDIX.
13.5.2* Air Leakage Test

Each of the samples shall pass one of the following tests:

a) At an initial temperature of 77°F (25°C) the test samples shall be immersed in water at a temperature of 122°F (50°C) to a minimum depth of 1 in. (25 mm) for a minimum of 1 minute. If no bubbles emerge from the samples during this test, they are considered to be “sealed” for the purpose of this standard.

b) The test sample shall be immersed to a minimum depth of 3 in. (75 mm) in water contained in an enclosure that can be partially evacuated. The air pressure within the enclosure shall then be reduced by 4.7 in. (120 mm) of mercury. If no visible bubbles emerge from the samples during this test, samples are considered to be “sealed” for the purpose of this standard.

c) The test sample shall be shown to leak at a rate not greater than $10^{-5}$ ml of air per second at a pressure differential of 1 atmosphere (101.3 kPa) by means of a suitable leak-rate detector.

14. EVALUATION OF ENCLOSURES FOR CLASS II AND III

14.1 An enclosure that is required to exclude the entry of dust shall pass the test according to Section 14.2, 14.3, or 14.4.

14.1.1*

14.1.2 A gasket used to make an enclosure dust-tight shall be made of material acceptable for the purpose, e.g. plant-fiber sheet packing or similar material. A gasket of elastomeric or thermoplastic material may be used if it is resistant to aging when tested in accordance with 14.1.3 or 14.1.4. Gaskets shall be either secured or captive if they could be dislodged during installation or maintenance of the equipment.

14.1.3 Aging Test

A gasket of an elastomeric or thermoplastic material, or a composition gasket utilizing an elastomeric material, shall be of such quality that samples have a tensile strength of not less than 60 percent and an elongation of not less than 75 percent of values determined for unaged samples, when subjected to temperature aging in a circulating air oven in accordance with the following formula:

$$t = 2685e^{-0.0693(T-T1)}$$

where:

- $t =$ the test time in hours;
- $e =$ 2.7183;
- $T =$ the aging temperature in °C and
- $T1 =$ the maximum rated operating temperature in °C (40°C minimum).
14.1.4* As an alternative to the test detailed in 14.1.3 and prior to the test in 14.3, a gasket of an elastomeric or thermoplastic material, or a composition gasket utilizing an elastomeric material, shall be tested by submitting the enclosures or parts of enclosures in plastic materials on which the integrity of the type of protection depends to continuous storage for one week in an ambience of (90 ± 5) % relative humidity and at a temperature of (20 ± 2) K above the maximum service temperature but at least 80 °C.

In the case of a maximum service temperature above 75°C, the period of one week specified above will be replaced by a period of 84 hours at (95 ± 2) °C and (90 ± 5) % relative humidity followed by a period of 84 hours at a temperature of (20 ± 2) K higher than the maximum service temperature.

14.2*

14.3* Circulating Dust Method

In preparation for the test, connectors and plug-in components that do not meet the requirements of Section 14.1.1 or 14.1.4 shall be removed. The test is made using equipment in which talcum powder is maintained in suspension in a suitable closed chamber. The talcum powder used shall pass through a square-meshed sieve whose nominal wire diameter is 50 micrometers and whose nominal width between wires is 75 micrometers. The amount of talcum powder used shall be 4.4 lbs (2 kg) per cubic yard (cubic meter) of the test chamber volume. It shall not have been used for more than 20 tests.

Enclosures shall be determined to fit in one of two categories:

a) Enclosures where the normal cycle of the equipment causes a reduction in the air pressure within the enclosure below the surrounding atmosphere (e.g., caused by thermal cycling effect); or

b) Enclosures where reductions in pressure below the surrounding atmospheric pressure are not caused by normal cycles of the equipment.

For enclosures of category (a) the equipment under test should be supported inside the test chamber, and the pressure inside the equipment should be maintained below atmospheric pressure by a vacuum pump. If the enclosure has a single drain hole, the suction connection shall be made to this hole and not to one specially provided for the purpose of the test. If there is more than one drain hole, the other drain holes shall be sealed for the test. The object of the test is to draw into the equipment, if possible, a minimum of 80 times the volume of air in the enclosure without exceeding an extraction rate of 60 volumes per hour with a suitable depression. In no event shall the depression exceed 7.9 in. (200 mm) of water. If an extraction rate of 40 to 60 volumes per hour is obtained, the test shall be stopped after 2 hours. If, with a maximum depression of 7.9 in. (200 mm) of water, the extraction rate is less than 40 volumes per hour, the test shall be continued until 80 volumes have been drawn through, or a period of 8 hours has elapsed. For an enclosure of category (b), the equipment under test should be supported in its normal operating position inside the test chamber, but the test chamber shall not be connected to a vacuum pump. Any drain hole normally open shall be left open for the duration of the test. The test shall continue for a period of 8 hours. If it is not possible to place the complete assembly in the test chamber, one of the following procedures shall be used:

a) Individual testing of separate enclosed sections of the equipment;

b) Testing of representative parts of the equipment (such as doors, ventilating openings, joints and shaft seals), with the vulnerable parts of the equipment (such as terminals and slip rings) in position at the time of testing; or

c) Testing of smaller equipment having the same full-scale design details.

The enclosure shall be deemed to pass the test if no visible dust is detected inside the enclosure at the end of the test.

14.4*
15. DROP AND IMPACT TESTS

15.1 Portable equipment (as defined Approval Standard 3810) shall be subjected to a drop test as specified in Section 15.2. There shall be no damage to the equipment that may affect its acceptability for use in Division 2 hazardous locations.

15.2 Equipment is to be dropped six times, not more than once on any one equipment surface, from a height of 3 feet (0.9 m) onto a smooth concrete floor. A nonrestrictive guide may be used.

15.3 Equipment intended for Class II, or Class III hazardous locations shall be subject to an impact test prior to dust tests in accordance with Section 5.1.2 of Approval Standard 3600:1998.

16. MANUFACTURER’S INSTRUCTIONAL MANUAL AND DOCUMENTATION

16.1 The manufacturer’s instructional material shall include, in addition to the information required for ordinary locations, the information shown in 16.2 through 16.5 to emphasize the precautions required when operating the equipment in a Division 2 location.

16.2 The following or equivalent specification for the location of the equipment shall be included:

Note: THIS EQUIPMENT IS SUITABLE FOR USE IN CLASS (AS APPLICABLE), DIVISION 2, GROUPS (AS APPLICABLE) OR NONHAZARDOUS LOCATIONS ONLY.

16.3 The following or equivalent information for use of the equipment shall be included.

16.3.1 In the case where apparatus is intended to be installed with nonincendive field wiring circuits, a Control Drawing shall be provided with each unit, or all sales orders, and to installers and shall be made available upon request.

16.4* If equipment contains sealed components the following shall be provided.

16.4.1 A warning such as:

‘WARNING – EXPOSURE TO SOME CHEMICALS MAY DEGRADE THE SEALING PROPERTIES OF MATERIALS USED IN THE FOLLOWING DEVICES”; identification of the sealed devices.

16.4.2 Where possible the list of materials used in the construction of these devices.

Name of sealed device: Generic name of the material and the supplier’s name and type designation.

16.4.3 A recommendation for the user to periodically inspect the devices named above for any degradation of properties and replace if degradation is found.

*AN ASTERISK FOLLOWING A WORD OR A SECTION NUMBER SIGNIFIES THAT EXPLANATORY MATERIAL APPEARS IN THE APPENDIX.
16.5 The following warning or equivalent warnings for repair of the equipment shall be included.

16.5.1 If replacement of a lamp, or fuse, or removal of a connector could ignite the flammable or combustible atmosphere:

**WARNING** – EXPLOSION HAZARD. DO NOT REMOVE OR REPLACE LAMPS OR FUSES UNLESS POWER HAS BEEN DISCONNECTED OR WHEN A FLAMMABLE OR COMBUSTIBLE ATMOSPHERE IS PRESENT.

16.5.2 If disconnecting the equipment supply could ignite the flammable or combustible atmosphere:

**WARNING** – EXPLOSION HAZARD. DO NOT DISCONNECT EQUIPMENT WHEN A FLAMMABLE OR COMBUSTIBLE ATMOSPHERE IS PRESENT.

16.5.3 Documentation accompanying nonincendive components that are not factory-installed in equipment shall state the circuit parameters for which the components have been determined to be safe.

16.5.4 If replacement of a cell or battery could ignite the flammable or combustible atmosphere:

**WARNING** – EXPLOSION HAZARD. DO NOT OPEN ENCLOSURE OR REPLACE BATTERY WHEN A FLAMMABLE OR COMBUSTIBLE ATMOSPHERE IS PRESENT.

16.6 Documentation accompanying nonincendive components that are not factory-installed in equipment shall state the circuit parameters for which the components have been determined to be safe.

17. OPERATIONS REQUIREMENTS

The manufacturer shall comply with the requirements of Approval Standard 3600:1998, Section 6.0
APPENDIX A:
EXPLANATORY MATERIAL

This appendix is not part of this standard but is included for informational purposes only. The paragraph numbers herein refer to those asterisked in the standard.

A1. General Information

This standard was prepared to provide more detailed requirements than the requirements identified in the NEC® for electrical equipment suitable for use in Class I and II, Division 2 and Class III, Divisions 1 and 2 hazardous (classified) locations.

This standard reinforces the practice of many years in North America of supplying general-purpose electrical equipment for use in Class I, Division 2 locations where the equipment is of normal industrial quality and in which sources of electrical or thermal ignition do not exist under normal operational conditions.

The principles involved are based on the low probability of the presence of an explosive gas-air mixture occurring for a substantial period of time in an area classified as Division 2, coincident with an abnormal condition in the electrical equipment capable of igniting the gas mixture.

Reference information was obtained from ANSI/ISA S12.12:1994. This document defines equipment for use in Division 2 classified areas.

A2.3 (c) The experimental data on which the requirements of this document are based were determined under normal laboratory atmospheric conditions. Ignition parameters are not easy to extrapolate from normal laboratory conditions to other conditions (such as might exist in process vessels) without careful engineering consideration. Increasing the initial temperature of a flammable or combustible mixture will decrease the amount of energy required to cause ignition so that, at the auto-ignition temperature of a gas or vapor, the electrical energy required for ignition will be zero. The nature of the energy variation between these limits is not well documented. Temperature variations also can change the concentrations of flammable materials in the mixture. Oxygen enrichment decreases the energy necessary for ignition. The minimum ignition energy of mixtures of flammable materials with oxygen may be as low as 1 percent of that required for the same material mixed with air. As a general rule, the minimum ignition energy of a gas or vapor is inversely proportional to pressure squared. When examining a situation where the gas mixture is above atmospheric pressure, one must consider whether a flammable mixture exists under such pressure conditions. At high pressure, many flammable materials will condense.

A2.4 Consideration should be given to apparatus employing polymeric enclosures for their possible static electricity properties.

A3.22 Nonincendive circuit: The concept of a nonincendive circuit for equipment in Division 2 locations was first identified in ISA-RP12.2.

A3.25 Nonincendive field wiring is recognized in the exception shown in Articles 501-4 (b) and 502-4 (b) of ANSI/NFPA 70:1999.

A5.1.1 It is recognized that other means of protection are acceptable. Purging and positive pressurization are described in Approval Standard 3620 and oil immersion requirements are covered in, ANSI/ISA S12.26.01 and ANSI/NFPA 70:1999.

Approval Standard 3620: Purged and Pressurized Electrical Equipment for Hazardous (Classified) Locations.
A5.4 It is unlikely that some malfunction will occur causing a fuse to open concurrent with the location becoming flammable.

For “signaling,” “alarm,” “remote-control,” and “communications” systems, Article 501-14(b)(3) of the ANSI/NFPA 70:1999 permits fuses in a general-purpose enclosure in Division 2 locations.

A5.4 This precludes a fuse housed in a general-purpose enclosure from being used in a motor circuit where a possibility of a stalled motor opening the fuse exists, or where there is the possibility of an overload not caused by a fault in the circuit.

A5.5 Switches not integral to the equipment should be suitable for the locations in which they are installed.

A6.1 The NEC® recognizes only dust-tight enclosures for Class III. In view of this limitation, other alternatives were not included in this edition of the standard.

A7 The exception to Section 501-4(b) of ANSI/NFPA 70:1999 states. “Nonincendive field wiring shall be permitted using any of the methods suitable for wiring in unclassified locations.” This exception is intended to permit what is termed “nonincendive field wiring circuits” by this standard.

One problem facing both manufacturers and users in applying the nonincendive field wiring concept is the ability to interconnect different manufacturers’ equipment with nonincendive field circuit connections and be assured the combination will provide a nonincendive field circuit. In order to facilitate this interconnection, the marking method covered in this section provides a convenient way to assess the compatibility of different manufacturers’ equipment with respect to nonincendive field wiring circuits.

The criteria for the comparison are that the voltage \( V_{\text{max}} \) that the load device can receive must be equal to or greater than the normal circuit voltage \( V_{\text{OC}} \) or \( V_{\text{T}} \) that can be delivered by the source device. The current that the load device can receive is independent of the current that the power source can supply. In addition, the maximum capacitance \( C_i \) to the load device is based on the maximum voltage available. However the inductance \( L_i \) of the load is based on the maximum normal operating current of the load device. The capacitance and inductance of the interconnecting wiring must be equal to or less than the capacitance \( C_{a} \) or inductance \( L_{a} \) that can be driven by the source device. When cable parameters are unknown, the following values may be used:

- Capacitance: 200 pF/m (60 pF/ft)
- Inductance: 0.66 µH/m (0.20 µH/ft)

a) Determine \( V_{\text{max}} \) from the appropriate curve, based on the maximum unprotected capacitance at the field wiring terminals of the device.

b) Determine \( I_{\text{max}} \) from the appropriate curve, based on the maximum unprotected inductance at the field wiring terminals.

c) Determine, either analytically or experimentally, from the values of \( V_{\text{max}} \) and \( I_{\text{max}} \) determined in steps (a) and (b) above, that the device will not produce an ignition-capable temperature rise of components for that combination. Verify also that some lower value of current will not cause ignition-capable hot spots. Since this step can be quite time consuming, a manufacturer may arbitrarily specify a voltage lower than \( V_{\text{max}} \) as determined in step (a).

A7.1 Figures B-1 through B-8 represent very simple circuits. Unless the circuit can clearly be identified as conforming to the special conditions from which the curves are derived, analysis may prove invalid. Testing is required in such cases. As an illustration, the capacitance discharge curves do not include the effects of the charging circuit.
A7.3 It is recognized that the margin of safety lies in (a) a test apparatus more sensitive than any probable ignition condition and (b) an ideal gas mixture.

A7.4 Normal conditions for nonincendive circuits include opening and closing of contacts, adjustments, operation at the maximum pressure etc. Normal conditions for nonincendive field wiring include opening, shorting or grounding of field wiring.

A7.4 The maximum current (I_{SC} or I_{T}) from the source is not related to the maximum input current of the load device. The maximum inductance (L_{a}) permitted to be connected to the source is calculated based on the maximum short circuit current available from the source (I_{SC} or I_{T}). The maximum capacitance (C_{a}) permitted to be connected from the source is based on the maximum open circuit voltage (V_{OC} or V_{T}) of the source.

A7.5 Unlike the entity concept in intrinsic safety, the maximum input current of the receiving apparatus does not have to be greater than the maximum output current of the source. This is because under normal operating conditions the current drawn by the receiving equipment will be limited by the normal operation of the circuit. When opening, grounding and shorting of the nonincendive field wiring takes place, provided the maximum voltage remains the same, the current drawn by the receiving equipment will not exceed that drawn under maximum worst case normal operating conditions.

A8 Section 8 applies to components that would cause ignition-capable arcs if the make/break contacts interrupt the circuit. They are permitted because the arc is likely to occur only during servicing if the component complies with the requirements in this section. This section is written essentially for parts replaced, disconnected, or operated during servicing – such as fuses, lamps, connectors, and tool-accessible controls and switches.

A9.1.2 The text from ANSI/ISA S12.12:1994 was deleted but the clause number has been left in to leave the clause numbering structure the same.

A9.4 For practical reasons the symbols used for voltage, current capacitance, inductance, and L/R ratio may be replaced by the symbols used in ISA S12.2.01:1999 (IEC 60079-11 Mod) Electrical Apparatus for Use in Class I, Zones 0, 1, & 2 Hazardous (Classified) Locations – Intrinsic Safety “i”. A comparison is shown in the following Table. Intrinsic safety and nonincendive parameters should not be mixed.

<table>
<thead>
<tr>
<th>Electrical Parameter</th>
<th>Nonincendive Marking</th>
<th>Intrinsic Safety Marking</th>
</tr>
</thead>
<tbody>
<tr>
<td>For Associated Equipment or Associated Apparatus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum output voltage</td>
<td>V_{OC}</td>
<td>V_{OC}</td>
</tr>
<tr>
<td>Maximum output voltage – multiple channel equipment</td>
<td>V_{T}</td>
<td>V_{T}</td>
</tr>
<tr>
<td>Maximum output current</td>
<td>I_{SC}</td>
<td>I_{SC}</td>
</tr>
<tr>
<td>Maximum output current – multiple channel equipment</td>
<td>I_{T}</td>
<td>I_{T}</td>
</tr>
<tr>
<td>Maximum output power</td>
<td>P_{O}</td>
<td>P_{O}</td>
</tr>
<tr>
<td>Maximum external capacitance</td>
<td>C_{a}</td>
<td>C_{a}</td>
</tr>
<tr>
<td>Maximum external inductance</td>
<td>L_{a}</td>
<td>L_{a}</td>
</tr>
<tr>
<td>Maximum external inductance to resistance ratio</td>
<td>L_{a}/R_{a}</td>
<td>L_{a}/R_{a}</td>
</tr>
<tr>
<td>For Equipment or Apparatus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum input voltage</td>
<td>V_{MAX}</td>
<td>V_{MAX}</td>
</tr>
<tr>
<td>Maximum input current</td>
<td>I_{MAX}</td>
<td>I_{MAX}</td>
</tr>
<tr>
<td>Maximum internal capacitance</td>
<td>C_{I}</td>
<td>C_{I}</td>
</tr>
<tr>
<td>Maximum internal inductance</td>
<td>L_{I}</td>
<td>L_{I}</td>
</tr>
<tr>
<td>Maximum input power</td>
<td>P_{I}</td>
<td>P_{I}</td>
</tr>
<tr>
<td>Maximum internal inductance to resistance ratio</td>
<td>L_{I}/R_{I}</td>
<td>L_{I}/R_{I}</td>
</tr>
</tbody>
</table>
A9.4 Items (c): After determining the maximum open circuit voltage ($V_{oc}$) and maximum short-circuit current ($I_{sc}$) of the source device according to 7.1.2, determine the appropriate values of maximum allowed capacitance ($C_a$) and maximum allowed inductance ($L_a$) from Figures B-3 through B-8.

A9.4.3 Note: MAXIMUM L/R RATIO

The maximum L/R ratio, as currently used in Europe, is another parameter that is assigned to the field wiring terminals of equipment supplying energy to nonincendive field wiring and nonincendive equipment. This parameter allows the distributed nature of cable resistance and inductance to be considered, rather than multiplying the cable inductance per-unit-length times the total length of the cable, and comparing it to the lumped inductance value, $L_a$. The L/R ratio for a cable is calculated with the cable short circuited, and as long as the L/R ratio is less than the source L/R rating, the cable inductance can be disregarded.


In a two-wire circuit the maximum allowable load-plus-line inductance is determined by the maximum short circuit current. Assume that $L_a$ is the maximum allowable connected inductance, line and load. If the inductance is in the line (long cable), the inductance of the line is proportional to the resistance and to the length. Maximum energy storage occurs when the sum of the line and load resistance equals the internal resistance of the source ($V_{oc}/I_{sc}$), the current $= I_{sc}/2$, and the inductance is $4 L_a$. The maximum L/R ratio is, therefore, given by the following equation:

$$\text{Maximum L/R ratio} = 4 \frac{I_{sc}}{V_{oc}} L_a.$$

If the line is short and all the inductance is in the load, the same results are obtained. Therefore, safety is assured if either the above situation exists or if both the line and load have L/R ratios that do not exceed the above limit. Other conditions must be evaluated individually.

Marking Example:

$V_{oc} = 40 \text{ V}; I_{sc} = 64 \text{ mA};$

$C_a = 0.14 \text{ uF}; L_a = 19 \text{ mH};$

$L/R = 122 \text{ uH/ohm}.$

A10.1 Tests should be performed under “worst-case” heating conditions, for example, the highest or lowest extreme of specified supply voltage plus the worst-case load conditions, such as the maximum operating pressure for a pressure transmitter.

A10.2 Note: THE LOWEST IGNITION TEMPERATURE OF THE IGNITABLE ATMOSPHERES CONCERNED MAY BE ABOVE THE MAXIMUM SURFACE TEMPERATURE. HOWEVER, FOR COMPONENTS HAVING A TOTAL SURFACE AREA OF 10 CM² OR LESS (E.G., TRANSISTORS OR RESISTORS USED IN LOW-POWER CIRCUITS PROTECTED BY THE ENERGY LIMITATION TECHNIQUE), THEIR SURFACE TEMPERATURE MAY EXCEED THAT FOR THE TEMPERATURE CLASS MARKED ON THE ELECTRICAL APPARATUS IF THERE IS NEITHER A DIRECT NOR AN INDIRECT RISK OF IGNITION FROM THESE COMPONENTS, APPLYING THE FOLLOWING SAFETY MARGIN:

50 K for $T_1, T_2, T_2A, T_2B, T_2C, T_3, T_3A, T_3B$ and $T_3C$, or

25 K for $T_4, T_4A, T_5$, and $T_6$
The safety margin should be ensured by experience of similar components or by test of the electrical apparatus itself in representative ignitable mixtures.

**Note:** DURING THE ABOVE TEST, THE SAFETY MARGIN MAY BE PROVIDED BY INCREASING THE AMBIENT TEMPERATURE AN APPROPRIATE AMOUNT.

If the temperature of a component is below the auto-ignition temperature (AIT) of a given material, the component can be considered suitable for use in a circuit without regard to thermal ignition. When the temperature of a component is above the AIT, it must be determined by test whether or not it will thermally ignite the material. The ability of any small component to thermally ignite a material is dependent on the AIT of the material it is exposed to and the temperature, size, and shape of the heated component. A test that has been used to verify the suitability of a small component (from a thermal standpoint) may be conducted using a 5 percent diethyl ether-in-air mixture. Diethyl ether represents the material having the lowest AIT of the Class I atmospheres currently listed in NFPA 497. Various characteristics of diethyl ether are as follows:

- **Name:** diethyl ether
- **Formula:** C\(_2\)H\(_5\)OC\(_2\)H\(_5\)
- **LFL % of Vol:** 1.9
- **UFL % of Vol:** 36
- **AIT:** 320°F (160°C)
- **Vapor density (Air = 1):** 2.6

*Synonyms: ether, ethyl ether, diethyl oxide, ethyl oxide.*

The test apparatus shall consist of a test enclosure with a gas-tight cover and viewing port. The enclosure shall contain a low-velocity fan, a diethyl-ether dish, through-wall component terminal connections, and an igniter for mixture-ignition verification. The component under test shall be suspended within the enclosure with connections (via the terminal connections) to the external associated component’s circuitry or power source. An appropriate amount of liquid ether shall be placed in the dish. If a 3-liter enclosure is used, 0.65 cm\(^3\) of liquid ether will be needed for a 5 percent mixture. The cover shall be closed, and the fan shall be turned on to aid in the evaporation process and to maintain a homogeneous mixture. Power shall be applied to the component until thermal equilibrium is reached, the component fails open, or the surrounding material is ignited. If the component fails to ignite the mixture, the sensitivity of the mixture shall be verified by activating the igniter circuit. A minimum of six tests shall be made.

A11 The test apparatus using 0.2 mm diameter fine tungsten wires yields low ignition currents. Since the tungsten wires reach a high temperature when the test currents approach 3 A, testing with higher currents may require wires of a different material (such as copper), or a different type of apparatus may be needed. The apparatus described above is suitable for testing circuits up to 300 V. For tests of capacitance circuits, modified apparatus (such as apparatus with one or more of the tungsten wires removed) is required.

A11.3 The purity of commercially available gases and vapors normally is adequate for these tests, but those of purity less than 95 percent should not be used. The effect of normal variations in laboratory temperature and pressure and of the humidity of the air in the gas mixture is also likely to be small. Any significant effects of these variables will become apparent during the routine verification of the sensitivity of the spark test apparatus.
A11.3.5 The most easily ignitable concentration may not be the stoichiometric mixture.

A12.2 These requirements were obtained from ISA, CSA, and IEC reference documents.

A12.2.1 A plastic bag may be used as a test chamber. The test factor of 150 percent of rated load is greater than the requirement of the IEC 79-15 document.

A12.2.3 Depending on the method used to fill the nonincendive component, more frequent renewing of the gas or vapor-in-air mixture may be required.

A13 These requirements were obtained from IEC 60079-15:1987. For products to be used in damp environments, polymeric enclosures should be tested for resistance to fungi according to ASTM G21-1970:1985.

The free internal volume applies to each independent chamber containing arcing contacts.

A13.2 The 100 cm² limitation is consistent with the IEC referenced document.

A13.4 The principle applied to "sealed devices" is not one that prevents entry of the external atmospheres, but rather restricts it to a degree commensurate with the probabilities that relate to the presence of an ignitable gas-air mixture in a Division 2 location. Sealed devices are covered in IEC 60079-15 (1987).

For static seal applications, most commercially available sealing materials, even sealing materials that are considered unacceptable for process wetted applications, are suitable for short term vapor exposure (short term is relative to Division 2 exposure).

Dynamic seals are inherently more susceptible to mechanical damage and, therefore, warrant a more comprehensive evaluation involving the expected chemical exposure and the dynamic motion of the component.

The NACE/Materials Technology Institute has been conducting tests of plastics and elastomers for years, but has been unsuccessful in determining a relationship of vapor exposure over time to predicted life. For this reason, the solvent exposure test that was contained in previous editions of this standard has been omitted.

A13.5.1 This equation is based on the Arrhenius equation. It relates the rate of most chemical reactions and how they increase rapidly with increasing temperature.

A13.5.2 Historically, three test methods have been used by Approval bodies in North America. Different results may occur. FM Approvals considers that the atomized water test and the dust blast method are not realistic; therefore these tests are not incorporated in this standard.

A14.1.1 The text from ANSI/ISA S12.12:1994 was deleted but the clause number has been left in to leave the clause numbering structure the same.

A14.1.4 This requirement is based on a test in IEC 60079-0:19. Some gasket materials are foamed-in-place or poured-in-place and it is not possible to conduct the tensile test required by 14.1.3 on this type of gasket.

A14.2 The text from ANSI/ISA S12.12:1994 was deleted but the clause number has been left in to leave the clause numbering structure the same.
A14.3 This test is based on the IEC 529 test for IP 6X enclosures.

A14.4 The text from ANSI/ISA S12.12:1994 was deleted but the clause number has been left in to leave the clause numbering structure the same.

A16.3.2 The text from ANSI/ISA S12.12:1994 was deleted but the clause number has been left in to leave the clause numbering structure the same.

A16.4 No simple test of components can verify compatibility with every chemical that might be present in all foreseeable concentrations. Therefore, the user of sealed devices must assure, by testing, reference to the literature, or by contacting the manufacturer of the sealing material, that chemicals in the atmosphere surrounding the device are not likely to degrade the sealing of the device. Because this judgment is not precise, sealed components should be inspected periodically for any sign of attack or degradation. If signs of physical degradation, (e.g., crazing, swelling, or deformation) are observed, the component should be replaced.
APPENDIX B:
IGNITION CURVES

Figure B-1

igniting currents applicable to all circuits containing aluminum, cadmium, magnesium, or zinc.
Figure B-2

igniting currents applicable to circuits where aluminum, cadmium, magnesium, and zinc can be excluded.
Figure B-3

IGNITING CURRENTS AT 24 VOLTS APPLICABLE ONLY TO CIRCUITS WHERE ALUMINUM, CADMIUM, MAGNESIUM, OR ZINC MAY BE PRESENT.

HYDROGEN GROUP A AND B

ETHYLENE GROUP C

PROPANE GROUP D

METHANE
Figure B-4

IGITING CURRENTS AT 24 VOLTS APPLICABLE ONLY TO CIRCUITS WHERE ALUMINUM, CADMIUM, MAGNESIUM, AND ZINC CAN BE EXCLUDED.
Figure B-5

IGNITING CURRENTS FOR VARIOUS VOLTAGES IN GROUP B. APPLICABLE TO ALL CIRCUITS CONTAINING ALUMINUM, CADMIUM, MAGNESIUM, OR ZINC.
Figure B-6

IGNITING CURRENTS FOR VARIOUS VOLTAGES IN METHANE AND APPLICABLE TO ALL CIRCUITS CONTAINING ALUMINUM, CADMIUM, MAGNESIUM, OR ZINC.
IGNITION VOLTAGES IN METHANE.

THE CURVES CORRESPOND TO VALUES OF CURRENT LIMITING RESISTANCE AS INDICATED. THE CURVE MARKED Sn IS APPLICABLE ONLY WHERE ALUMINUM, CADMIUM, MAGNESIUM, AND ZINC CAN BE EXCLUDED.
IGNITION VOLTAGES IN GROUPS A AND B. THE CURVES CORRESPOND TO VALUES OF CURRENT-LIMITING RESISTANCE AS INDICATED. THE CURVE MARKED Sn IS APPLICABLE ONLY WHERE ALUMINUM, CADMIUM, MAGNESIUM, AND ZINC CAN BE EXCLUDED.
APPENDIX C:
GENERAL INFORMATION

C-1 Approval Application Requirements

To apply for an Approval examination the manufacturer, or its authorized representative, should submit a request to the Electrical Group Manager at FM Approvals, 1151 Boston-Providence Turnpike, PO Box 9102, Norwood, MA 02062, U.S.A.

For the purposes of 1) assessing compliance of equipment with FM Approvals requirements; 2) determining what test samples will be required for the test and examination program; and 3) providing a means for design modification control, the manufacturer shall submit documents which give a full and correct specification of the critical construction aspects of the equipment. One copy (except as noted) of the following documentation as it pertains to the Approval request should be assembled in an organized manner and submitted prior to scheduling of the test program. All documents shall identify the following:

- the manufacturer’s name,
- document number or other form of reference number identification,
- title, and
- date of latest revision of document and/or the revision reference (i.e. number or letter indicating revision level).

Note: TEST PROGRAMS WILL BE SCHEDULED ONLY UPON RECEIPT OF ALL THE MATERIAL LISTED HEREIN.

Note: DRAWINGS IN A LANGUAGE OTHER THAN ENGLISH MAY REQUIRE PARTIAL TRANSLATION FOR USE IN AN APPROVAL PROGRAM.

- Marketing/Ordering Literature showing general specifications and functions of the equipment. These are generally very useful in determining project costs and may also be used as attachments to the final report for equipment Approval projects. Typically, one copy will be sufficient at the beginning of a program but 15 copies may be necessary for use as report attachments at the conclusion of the program.
- Model Number Breakdown drawing or sales specification sheet showing all model variations and options to be examined. Each model variation must have a unique means of identification.
- Instruction Manual(s) providing installation, operation, and maintenance instructions.
- Quality Control Procedures document(s) detailing routine testing and final inspection procedures.
- Production Drawings
- Electrical Schematic(s)
- Final Assembly drawing and parts lists
- Sub-assembly drawings or piece-part drawings/assembly drawings sufficient to detail primary circuit components, operator controls, enclosure design, and safety interlocks.
- Product label drawing(s) showing all required marking information. The label drawing should show proposed artwork indicating the manufacturer’s name, address, model and serial numbers, equipment ratings, warning markings, and the Approval mark.
- Protective Grounding Detail drawing(s) showing the method of protective grounding provided, including location, size, and marking.
• Documentation Control Specification showing proposed method of controlling documents which may be identified as Critical Documents by FM Approvals. These drawings will be identified by FM Approvals at the conclusion of the Approval program. FM Approvals must be notified of changes to these documents via Form 797, “Approved Product Revision Report”.

• Any Approval documents from other Nationally Recognized Testing Laboratories (NRTL) or National Certification Bodies (NCB) needed to support an Approval process, i.e., component recognitions, Listing reports, Certification reports, IEC/CB Scheme reports, IEC/CCA reports, etc..

C-2 Requirements for Samples for Examination

C-2.1 Following authorization of an Approval examination, the manufacturer shall submit samples for examination and testing based on the following:

• Sample requirements to be determined by FM Approvals following review of the preliminary information.

C-2.2 Requirements for samples may vary depending on design features, results of prior or similar testing, and results of any foregoing tests.

C-2.3 The manufacturer shall submit samples representative of production. Any decision to use data generated utilizing prototypes is at the discretion of FM Approvals.

C-2.4 It is the manufacturer’s responsibility to provide any necessary test fixtures.
APPENDIX D:
UNITS OF MEASUREMENT

LENGTH: 
mm – “millimeters” (in. – “inches”)
in. = mm × 0.03937

AREA: 
mm² – “square millimeters” (in.² “square inches”)
in.² = mm² × 1.550 × 10⁻³
m² – “square meters” (ft² – “square feet”)
ft² = m² × 10.76

TEMPERATURE: 
°C – “degrees Celsius” (°F – “degrees Fahrenheit”)
°F = (°C × ⁹⁄₅) + 32

PRESSURE: 
kPa – “kilopascals” (psi – “pounds per square inch”);
psi = kPa × 0.1450

FORCE: 
N ~ “newtons” (lb-f- “pound-force”)
lb-f = N × 0.2248

ENERGY: 
J – “joules” (ft·lb-f – “foot pound-force”)
ft·lb-f = J × 0.7375

FREQUENCY: 
Hz – “hertz” (Also the SI unit)