UL 120101

STANDARD FOR SAFETY

Definitions and Information Pertaining to Electrical Equipment in Hazardous Locations

UL Standard for Safety for Definitions and Information Pertaining to Electrical Equipment in Hazardous Locations, UL 120101

First Edition, Dated December 3, 2019

Summary of Topics

This First edition of ANSI/UL 120101 is an Adoption of ANSI/ISA-12.01.01, Definitions and Information Pertaining to Electrical Equipment in Hazardous Locations.

The requirements are substantially in accordance with Proposal(s) on this subject dated October 26, 2018 and August 16, 2019.

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Standard for Definitions and Information Pertaining to Electrical Equipment in Hazardous Locations

First Edition

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This ANSI/UL Standard for Safety consists of the First Edition.

The most recent designation of ANSI/UL 120101 as an American National Standard (ANSI) occurred on December 3, 2019. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at https://csds.ul.com.

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Preface (UL)

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1 Purpose

1.1 This document provides definitions and information pertaining to protection techniques, terminology, and the installation of electrical equipment in hazardous (classified) locations and provides an introduction and basic background to the UL Standards Technical Panel (STP) 60079, Electrical Equipment for Hazardous (Classified) Locations, series of publications and committee activities.

1.2 This document provides a general review of applicable codes and standards, and it should not be used in lieu of those codes and standards for equipment design, manufacture, installation, maintenance and test criteria.

2 Scope

2.1 This document provides general guidance for safe design, installation, and maintenance of electrical equipment in hazardous (classified) locations using appropriate means to prevent ignition of flammable gases and vapors, flammable liquids, combustible dusts, or ignitable fibers or flyings.

2.2 This document covers only locations made hazardous, or potentially hazardous, due to the presence of flammable gases or vapors, flammable liquids, combustible dusts, or ignitable fibers or flyings. The document is not necessarily relevant to the hazards posed by pyrophoric materials, explosives or propellants containing their own oxidizers.

2.3 This document is concerned only with design, manufacture, installation, maintenance, and test criteria related to arcs, sparks, or hot surfaces produced by electrical and non-electrical* equipment that may cause ignition of flammable gas or vapor-in-air mixtures, clouds or blankets of combustible dust, or easily ignitable fibers or flyings. Equipment is also required to comply with the applicable ordinary location requirements (e.g.,UL 508 and UL 61010-1) either by direct reference in hazardous locations standards or by other regulations.

* Under development (Mechanical and ESD for example). Some equipment may produce static electricity or cause high temperatures or sparks due to mechanical failure. The materials of construction of parts in such equipment will be an important consideration for application in hazardous locations.

2.4 This document does not cover mechanisms of ignition from external sources, such as static electricity or lightning. Some equipment may produce static electricity. The materials of construction of parts in such equipment will be an important consideration for application in hazardous locations. The extra precautions necessary for this are beyond the scope of this document.

2.5 This document does not consider the effects of installation in corrosive atmospheres and the resulting deleterious conditions to the original design integrity of the equipment. The additional precautions necessary for these conditions are outside the scope of this document.

2.6 This document is not an instruction manual. However, it is intended to provide introductory guidance to those involved with the design, manufacture, installation, and maintenance of equipment used in hazardous (classified) locations. It is also intended to promote uniformity of practice among those skilled in the art. Nothing contained in this document is to be construed as a fixed rule without regard to sound engineering judgment.

2.7 For hazardous location equipment, atmospheric conditions are generally considered to be:

a) an ambient temperature range of -20 °C (-4 °F) to 40 °C (104 °F) for zones and to -25 °C (-13 °F) to +40 °C (104 °F) for divisions;

b) air with normal oxygen content, typically 21 percent by volume; and

c) a pressure of 80 kPa (11.6 psia) to 110 kPa (16 psia).

NOTE Equipment specified for atmospheric conditions beyond the above is generally permitted but may be subjected to additional requirements.

2.8 Specialized industries such as, but not limited to, mining and shipping may be regulated by the specific authority having jurisdiction. This document does not include specific requirements or the rules and regulations unique to any specific industry.

2.9 Various organizations have developed 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 instruments in hazardous (classified) locations are listed in Annex C. These are not considered to be a part of this document except for those specific sections of documents referenced elsewhere in this document.

2.10 In accordance with the purpose of this document, an attempt was made to avoid originality in principles whenever possible, but rather to utilize definitions, explanations, etc., from accepted publications. As a result, much of the material, except for minor changes, is directly as published by others. While specific credit is not given for each reference, all references are included in Annex B.

3 Definitions

The following are terms and definitions commonly used for hazardous (classified) locations.

NOTE The list is not intended to be all inclusive. Throughout this document, reference is made to areas, spaces, locations, and zones. These terms should be considered interchangeable terms designating a three-dimensional space. Additional definitions may be found in IEC 60050-426 (The International Electrotechnical Vocabulary (IEV 426-04-07).

3.1 ABNORMAL OPERATION – process-linked malfunctions that occur infrequently. (IEV 426-03-29)

3.2 ADEQUATELY VENTILATED AREA – an adequately ventilated area is an area that has a ventilation system (natural or artificial) that, as a minimum, prevents the accumulation of gases or vapors to an explosive level. Most standards and recommended practices recommend preventing levels in excess of 25 percent of the Lower Flammable Limit, LFL.

NOTE Adequate ventilation of an area alone is not an effective means for the prevention of dust explosions.

3.3 AEx – required marking prefix for equipment meeting one or more types of protection in UL 60079-0 or previously in ANSI/ISA-61241-0.

3.4 AMBIENT TEMPERATURE – temperature of the air or other media, in the immediate vicinity of the equipment or component. (IEV 426-04-09)

NOTE 1 This does not refer to the temperature of any process media, unless the equipment or component is totally immersed in the process media.

NOTE 2 If Ex Equipment or an Ex Component is located inside or adjacent to another piece of equipment, the “"ambient temperature"” is the temperature of the air or other media surrounding the Ex Equipment or Ex Component and may be higher than the ambient air surrounding the complete equipment due to the additional heat dissipated within the complete equipment.

NOTE 3 The ambient temperature referred to in the UL 60079 series, CSA 60079 series and IEC 60079 series is only related to the explosion safety and not the performance of the Ex Equipment or Ex Component.

3.5 APPROVED – acceptable to the authority having jurisdiction.

NOTE 1 See AUTHORITY HAVING JURISDICTION.

NOTE 2 In determining the acceptability of installations or procedures, equipment, or material, the authority having jurisdiction may base acceptance on compliance with appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listing or labeling practices of product-testing organizations. These organizations are in a position to determine compliance with appropriate standards for the current production of listed or labeled items.

3.6 AREA – three-dimensional region or space. (IEV 426-03-28).

3.7 ASSOCIATED APPARATUS – electrical apparatus which contains both intrinsically safe circuits and non-intrinsically safe circuits and is constructed so that the non-intrinsically safe circuits cannot adversely affect the intrinsically safe circuits. (IEV 426-11-03)

NOTE Associated apparatus is either:

a) additionally protected by a type of protection suitable for use in the appropriate explosive atmosphere, or

b) not protected by a type of protection suitable for use in the appropriate explosive atmosphere and therefore is not to be used within an explosive atmosphere.

See also INTRINSIC SAFETY.

3.8 ATEX, ATEX Directive – European Directive 2014/34/EU related to equipment and protective systems intended for use in potentially explosive atmospheres. A parallel directive for use, 1999/92/EC (also referred to as ATEX 137 Directive) requires area classification and risk assessment in the workplace.

3.9 AUTHORITY HAVING JURISDICTION (AHJ) – the organization, office, or individual that has the responsibility and authority for approving equipment, installations, or procedures.

NOTE The term authority having jurisdiction is used in a broad manner since jurisdiction and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state/provincial, local, other regional department, or an individual such as an inspector from a labor or health department, electrical inspector, or others having statutory authority. An insurance inspection agency, rating bureau, or other insurance company representative may be the authority having jurisdiction. An owner or his designated agent may also assume the role. At government-owned installations, the commanding officer, departmental official, or designated agent may be the authority having jurisdiction.

3.10 AUTO-IGNITION TEMPERATURE (AIT) – the minimum temperature required to initiate or cause self-sustained combustion of a solid, liquid, or gas independently of the heating or heating elements.

NOTE 1 For additional information refer to NFPA Fire Protection Handbook.

NOTE 2 A distinction is made between ignition temperature and flash point. See FLASH POINT.

3.11 AUTOMATIC – self-acting, operating by its own mechanism when actuated by some impersonal influence, as for example, a change in current strength, pressure, temperature, or mechanical configuration.

3.12 BONDING – connecting to establish electrical continuity and conductivity.

3.13 CABLE GLAND – a device permitting the introduction of one or more electric and/or fibre optics cables into an electrical Ex Equipment enclosure so as to maintain the relevant Type of Protection, and provide a degree of strain relief. (IEV 426-04-18)

3.14 CERTIFICATE – document that conveys the assurance of the conformity of a product, process, system, person, or organization with specified requirements. (IEV 426-04-23)

NOTE The certificate may be either the supplier's declaration of conformity or the purchaser's recognition of conformity or certification (as a result of action by a third party) as defined in ISO/IEC 17000.

3.15 CERTIFIED – generic term referring to equipment that has been evaluated by a recognized testing agency and confirmed to be in compliance with the applicable standard(s).

NOTE Some agencies use the terms *approved*, *listed*, or *labeled equipment* to indicate compliance with the applicable standard.

3.16 CLASS I LOCATION – a location in which flammable gases, flammable liquid – produced vapors, or combustible liquid – produced vapors are or may be present in the air in quantities sufficient to produce explosive or ignitible mixtures. (NEC 500.5 (B))

NOTE Class I locations can include those rated Division 1 or 2 and Zone 0, 1 or 2.

3.17 CLASS I, DIVISION 1 LOCATION – a location (1) In which ignitible concentrations of flammable gases, flammable liquid – produced vapors, or combustible liquid – produced vapors can exist under normal operating conditions, or; (2) In which ignitible concentrations of such flammable gases, flammable liquid–produced vapors, or combustible liquids above their flash points 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 ignitible concentrations of flammable gases, flammable liquid – produced vapors, or combustible liquid – produced vapors and might also cause simultaneous failure of electrical equipment in such a way as to directly cause the electrical equipment to become a source of ignition. (NEC 500.5 (B) (1))

NOTE In some Division 1 locations, ignitible concentrations of flammable gases or vapors may be present continuously or for long periods of time. Examples include the following:

(1) The inside of inadequately vented enclosures containing instruments normally venting flammable gases or vapors to the interior of the enclosure

(2) The inside of vented tanks containing volatile flammable liquids

(3) The area between the inner and outer roof sections of a floating roof tank containing volatile flammable fluids

(4) Inadequately ventilated areas within spraying or coating operations using volatile flammable fluids

(5) The interior of an exhaust duct that is used to vent ignitible concentrations of gases or vapors

Experience has demonstrated the prudence of avoiding the installation of instrumentation or other electrical equipment in these particular areas altogether or where it cannot be avoided because it is essential to the process and other locations are not feasible, using electrical equipment or instrumentation approved for the specific application or consisting of intrinsically safe systems.

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

3.19 CLASS II LOCATION – a location that is hazardous because of the presence of combustible dust. (NEC 500.5 (C))

NOTE Class II locations can include those rated Division 1 or 2 and Zone 20, 21 or 22.

3.20 CLASS II, DIVISION 1 LOCATION – (1) In which combustible dust is in the air under normal operating conditions in quantities sufficient to produce explosive or ignitible mixtures, or (2) Where mechanical failure or abnormal operation of machinery or equipment might cause such explosive or ignitible mixtures to be produced, and might also provide a source of ignition through simultaneous failure of electrical equipment, through operation of protection devices, or from other causes, or (3) In which Group E combustible dusts may be present in quantities sufficient to be hazardous. (NEC 500.5 (C) (1))

3.21 CLASS II, DIVISION 2 LOCATION – a location (1) In which combustible dust due to abnormal operations may be present in the air in quantities sufficient to produce explosive or ignitible mixtures; or (2) Where combustible dust accumulations are present but are normally insufficient to interfere with the normal operation of electrical equipment or other apparatus, but could as a result of infrequent malfunctioning of handling or processing equipment become suspended in the air; or (3) In which combustible dust accumulations on, in, or in the vicinity of the electrical equipment could be sufficient to interfere with the safe dissipation of heat from electrical equipment, or could be ignitible by abnormal operation or failure of electrical equipment. (NEC 500.5 (C) (2))

3.22 CLASS III LOCATION – a location that is hazardous because of the presence of easily ignitible fibers or where materials producing combustible flyings are handled, manufactured, or used, but in which such fibers/flyings are not likely to be in suspension in the air in quantities sufficient to produce ignitible mixtures. (NEC 500.5 (D)

NOTE Class III locations can include those rated Division 1 or 2 and Zone 20, 21 or 22.

3.23 CLASS III, DIVISION 1 LOCATION – a location in which easily ignitable fibers or materials producing combustible flyings are handled, manufactured, or used. (NEC 500.5 (D) (1))

3.24 CLASS III, DIVISION 2 LOCATION – a location in which easily ignitable fibers are stored or handled other than in the process of manufacture). (NEC 500.5 (D) (2))

3.25 COMPOUND – any thermosetting, thermoplastic, epoxy resin or elastomeric materials with or without fillers and/or additives, in their solid state. (IEV 426-04-41)

3.26 CONNECTION FACILITIES – terminals, screws or other parts, used for the electrical connection of conductors. (IEV 426-04-25)

3.27 CONTINUOUS DILUTION – the technique of supplying a protective gas flow continuously to an enclosure containing an internal potential source of flammable gas or vapor release for the purpose of diluting any flammable gas or vapor that could be present to a level below its LFL. Refer to 6.2.2.

3.28 CONTROL DRAWING – drawing or other document that is prepared by the manufacturer for the intrinsically safe or associated apparatus, detailing the electrical parameters to allow for interconnections to other circuits or apparatus. (IEV 426-11-46)

NOTE Refer to UL 120202 for the applicable ANSI recommendations for the preparation, content, and organization of control drawings.

3.29 DEGREE OF PROTECTION (IP) – numerical classification according to IEC 60529 or IEC 60034-5 (as applicable) preceded by the symbol IP applied to the enclosure of equipment to provide:

- protection of persons against contact with, or approach to, live parts and against contact with moving parts (other than smooth rotating shafts and the like) inside the enclosure;

- protection of the equipment against ingress of solid foreign objects; and

• where indicated by the classification, protection of the equipment against harmful ingress of water. (IEV 426-04-02)

NOTE 1 The detailed test requirements for rotating electric machines are in IEC 60034-5.

NOTE 2 The enclosure which provides the degree of protection IP is not necessarily the same as the equipment enclosure providing the Type of Protection.

NOTE 3 An enclosure which provides the degree of protection required by one of the types of protection will have been subjected to other tests prior to the tests for degree of protection.

NOTE 4 See also enclosure type.

3.30 DUST, COMBUSTIBLE – finely divided solid particles, 500 µm or less in nominal size, which may form explosive mixtures with air at standard atmospheric pressure and temperatures. (IEV 426-02-18)

NOTE See ASTM E 1226-12a, Standard Test Method for Explosibility of Dust Clouds, or ISO 6184-1, Explosion protection systems – Part 1: Determination of explosion indices of combustible dusts in air, for procedures for determining the explosibility of dusts.

3.31 DUST-IGNITIONPROOF – under the division system, a term used to describe an enclosure that will exclude dust and that, when installed in accordance with the original design intent, will not permit arcs, sparks, or heat otherwise generated or liberated inside the enclosure to cause ignition of exterior accumulations or atmosphere suspensions of a specified dust in the vicinity of the enclosure.

NOTE Refer to UL 1203 or CSA 25 for applicable ANSI and CAN certification requirements respectively.

3.32 DUST LAYER, COMBUSTIBLE – any surface accumulation of combustible dust that is thick enough to propagate flame or will degrade and ignite.

3.33 DUST-PROTECTED ENCLOSURE – for ordinary locations ingress protection, enclosure in which the ingress of dust is not totally excluded, but is unlikely to enter in sufficient quantity to interfere with the safe operation of the equipment and does not accumulate in a position within the enclosure where it is liable to cause an ignition hazard. (IEV 426-04-35)

NOTE Refer to NEMA 250 or IEC 60529 for the applicable ANSI and IEC ingress protection requirements respectively.

3.34 DUST-TIGHT ENCLOSURE – under the Division System or for ordinary locations ingress protection, enclosure capable of excluding the ingress of observable dust particle deposits. (IEV 426-04-34)

NOTE Refer to UL 121201, CSA 213, NEMA 250 or IEC 60529 for the applicable ANSI, CAN and IEC ingress protection requirements respectively.

3.35 ELECTRICAL EQUIPMENT – items applied as a whole or in part for the utilization of electrical energy. These include, among others, equipment for the generation, transmission, distribution, storage, measurement, regulation, conversion, and consumption of electrical energy and items for telecommunication.

3.36 ENCLOSURE – all of the walls, doors, covers, cable glands, rods, spindles, and shafts, etc. which contribute to the Type of Protection or the degree of protection IP of the equipment. (IEV 426-04-01)

3.37 ENCLOSURE TYPE – for ordinary locations ingress protection, a North American system of rating standard levels of protection provided to electrical equipment 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 due 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.

NOTE 1 Refer to Definitions found in UL 50, UL 50E, CSA 94.1, CSA 94.2 or NEMA 250 for the applicable ANSI, CAN or IEC definitions.

NOTE 2 See also DEGREE OF PROTECTION.

3.38 ENCAPSULATION – under the Zone system, 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 type of protection is referred to as “ma”, "mb", or "mc".

Also: process of applying a compound to enclose an electrical device(s) by suitable means. (IEV 426-04-77)

NOTE Refer to UL 60079-18, CSA 60079-18 or IEC 60079-18 for the applicable ANSI, CAN or IEC certification requirements.

3.39 ENERGIZED – electrically connected to a source of potential difference.

3.40 ENTITY CONCEPT – method used to determine acceptable combinations of intrinsically safe apparatus and associated apparatus through the use of intrinsically safe parameters assigned to connection facilities. (IEV 426-11-47)

The criteria for interconnection is that the voltage (V_{max} or U_i) current (I_{max} or I_i) and power (P_{max} or P_i) which intrinsically safe equipment can receive and remain intrinsically safe, considering faults, must be equal to or greater than the voltage (V_{oc} or V_o), and current (I_{sc} or I_o) and power (P_o) levels which 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 equipment, including interconnecting wiring, must be equal to or less than the capacitance (C_a or C_o) and inductance (L_a or L_o) that can safely be connected to the associated apparatus. If these criteria are met, then the combination may be connected without compromising intrinsic safety.

NOTE Refer to ANSI/ISA-RP12.06.01, UL 60079-25, CSA 60079-25 and IEC 60079-25 for additional ANSI, CAN and IEC information.

3.41 ENTRY, DIRECT – a method of connection of an electrical equipment 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. (IEV 426-04-07)

3.42 ENTRY, INDIRECT – a method of connection of an electrical equipment to the electrical circuits by means of a terminal box or a plug and socket connection which is external to the main enclosure.

3.43 EQUIPMENT – apparatus, fittings, devices, and the like used as part of, or in connection with, an installation.

NOTE When specific measures of a Type of Protection are applied to equipment to provide explosion protection, it can be “Ex Equipment” or an “Ex Component”.

3.44 EQUIPMENT GROUPING – classification system of equipment related to the explosive atmosphere for which they are intended to be used:

NOTE UL 60079-0, CSA 60079-0 and IEC 60079-0 identify three equipment groups:

- Group I, equipment for mines susceptible to fire damp;

• Group II, which is divided into sub-groups, equipment for all places with an explosive gas atmosphere other than mines susceptible to fire damp; and

• Group III, which is divided into sub-groups, equipment for all places with an explosive dust atmosphere other than mines susceptible to fire damp.

3.45 EQUIPMENT PROTECTION LEVEL EPL – level of protection assigned to equipment based on its likelihood of becoming a source of ignition and distinguishing the differences between explosive gas atmospheres, explosive dust atmospheres, and the explosive atmospheres in mines susceptible to firedamp. (IEV 426-01-15)

NOTE Although the markings identifying the equipment protection level (EPL) may appear on equipment, they are not yet recognized in NFPA 70.

3.46 Ex – designation of explosion-protected electrical equipment in accordance with the IEC 60079 series standards or national adoptions.

NOTE EEx designation was used for explosion-protected electrical equipment complying with EN50014. The publication of EN60079 was just the next edition of EN50014 and does not indicate that the equipment certified to EN50014 was immediately made obsolete, but might not comply with the latest requirements. See also 3.3.

3.47 Ex COMPONENT – equipment intended to be part of Ex Equipment, marked with symbol "U", which is not intended to be used alone, and requires additional consideration when incorporated into Ex Equipment. (IEV 426-01-13)

3.48 Ex EQUIPMENT – equipment with explosion protection. (IEV 426-01-14)

3.49 EXPECTED MALFUNCTION – disturbances or equipment malfunctions which normally occur in practice. (IEV 426-04-57)

3.50 EXPLOSIONPROOF – under the Division system, a term used to describe an enclosure that is capable of withstanding an explosion of a specified gas or vapor that may occur within it and of preventing the ignition of a specified gas or vapor surrounding the enclosure by sparks, flashes, or explosion of the gas or vapor within, and that operates at such an external temperature that a surrounding flammable atmosphere will not be ignited thereby. (NEC)

NOTE 1 See also "explosionproof" and "flameproof" are similar concepts, but the performance and technical requirements are not the same.

NOTE 2 Refer to UL 1203 or CSA 30 for the applicable ANSI and CAN certification requirements respectively.

3.51 EXPLOSIVE ATMOSPHERE – a mixture with air, under atmospheric conditions, of flammable substances in the form of gas, vapor, mist, or dust in which, after ignition, permits self-sustaining propagation. (IEV 426-01-06)

3.52 EXPLOSIVE DUST ATMOSPHERE – a mixture with air, under atmospheric conditions, of flammable substances in the form of dust which, after ignition, permits self-sustaining propagation.

3.53 EXPLOSIVE GAS ATMOSPHERE – a mixture with air, under atmospheric conditions, of flammable substances in the form of gas or vapour which, after ignition, permits self-sustaining propagation. (IEV 426-01-07)

3.54 FAULT (as applicable to intrinsically safe systems) – a defect or electrical breakdown of any component, spacing, or insulation that alone or in combination with other defects or breakdowns may adversely affect the electrical or thermal characteristics of the intrinsically safe system. If a defect or breakdown leads to defects or breakdowns in other components, the primary and subsequent defects and