Introduction to Hazardous Electrical Location Classifications

Introduction

In North America the target audience for this white paper and the electrical code classification ratings for various types of areas has been based around the Class/Division system. In Europe, this has been based around what is called the multi-tier Zone system. While harmonizing of these two systems is in process in North America, there are differences between the Canadian and USA national electrical codes when it comes to the Zone system. In addition, the Class/Division and Zone systems are similar, but distinct differences exist.

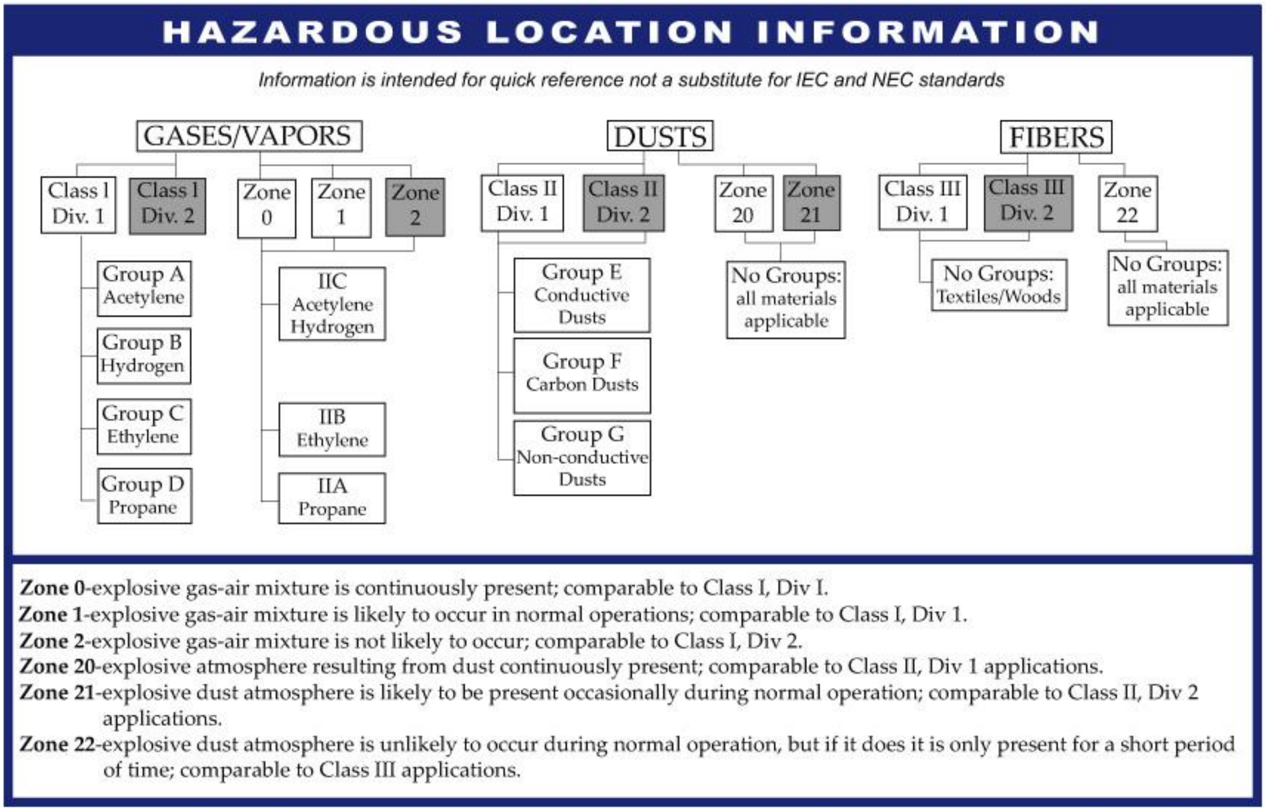
Fundamentals of hazardous locations are consistent and apply to both the Class/Division and Zone systems. But, the definition of a hazardous environment and the construction of the instrumentation can differ. We illustrate the differences and make a comparison later in this white paper. Refer to the below table and then we will explain some basics from the perspective of the Class/Division system.

Table 1: Class/Division Verses Zone - Frequency of Occurrence

Condition Frequency/Material	Class/Division System	Zone System
Continuous/Vapor	Class I, Division 1	Zone 0
Intermittent/Periodic/Vapor	Class I, Division 1	Zone 1
Abnormal/Vapor	Class I, Division 2	Zone 2
Continuous/Dust	Class II, Division 1	Zone 20
Abnormal/Dust	Class II, Division 2	Zone 21
Continuous/Fibers	Class III, Division 1	Zone 22
Abnormal/Fibers	Class III, Division 2	Zone 22

You can see from Table 1 that Class I, Division 1 is broken into Zone 0 and Zone 1 within the European zone system. This is where one primary difference exists between the two systems. The reason behind the difference is said by Zone proponents to be that many systems in Class I, Division 1 areas are "over-classified". The Zone system allows a vast majority of Class I, Division 1 areas to be classified as Zone 1 or 2.

Electrical instrumentation is applied into a wide variety of industrial environments. Users and the manufacturer of the instrumentation must be aware of the "type" of area the instruments are being installed within. We mean the "type" of area from an electrical code standpoint. It is the purpose of this white paper to provide an introductory amount of information and guidance regarding area electrical classifications and the approvals that may be required for electrical instrumentation to be installed in the required area. However, this white paper is not an exhaustive authority on this subject and the National Electrical Code and other governmental regulations should be consulted as they are the final authority in this matter.



Explosive Environments Defined

The National Electrical Code (NEC) classifies flammable and combustible liquids on the basis of their likelihood to produce explosive vapors and these vapors being present. A fluid considered to be a *flammable liquid* is one having a flash point below 100° F and a vapor pressure not exceeding 40psia. A *combustible liquid* is one having a flash point at or above 100° F. The "flash point" is the minimum temperature at which the fluid will emit vapor in sufficient concentration in order to become an ignitable mixture with air at the air/liquid interface. Remember, one of the fundamental laws of chemistry is that a fire can exist if the right combination of fuel, heat and oxygen are present. This is sometimes known as the "fire triangle".

Examples:

1. Aviation grade gasoline: This fluid has a flash point of -50° F (-46° C) and emits explosive vapors at most ambient air conditions.

2. Number1-D diesel fuel: This fluid has a flash point of 100° F (38° C) and does not emit vapor unless heated to higher temperatures. Facilities handling Number1-D diesel fuel would not necessarily be classified as hazardous except in hot locations, or locations where the fluid could come into contact with hot surfaces.

All flammable gases and liquids heated above their flash points can be ignited. However, the "concentration" also needs to be considered. There is a minimum and maximum concentration level below and above which the propagation of flame will not occur (essentially mixtures of fuel and oxygen are too lean or too rich). These concentrations are known as the "lower and upper limits of flammability or explosiveness" of the fluid. An increase in temperature or pressure of the fluid will lower the lower limit and raise the upper limit of flammability. A decrease in temperature or pressure has the opposite effect.

Some materials have a very wide range of flammability and some materials have a narrow range. Acetylene has a low concentration limit of 2.5% by volume in air and an upper limit of 100%. Gasoline has a narrow range of 1.4% to 7.6%. Combustible dusts also present serious hazards and have flammable limits, usually called explosion concentrations.

Regarding dusts, the United States CSB (chemical safety board) speculates it is a more serious hazard than vapor hazards because of lack of awareness as of the writing of this white paper. The CSB has produced an excellent video on the subject of dust flammability and explosion hazards. We highly recommend viewing this approximately 30 minute video as it explains the process of dust hazard explosion and illustrates several serious dust explosion and fire accidents. It is available from within the Media section of the BlueLevel Technologies website. The direct URL is as follows:

http://www.youtube.com/watch?v=3d37Ca3E4fA.

In regards to explosive dusts, dust clouds can be so thick that it is impossible to discern objects more than three to five feet away, even when present in minimum explosion concentrations. Usually the concentration is probably below the lower explosion limit if you can see your hand in front of your face. However, danger of fire propagation may still exist even if the concentration is low! This can also produce secondary explosions and can be even more hazardous as the CSB video explains. Please view the CSB video for further information.

Defining Hazardous Areas

The terms hazardous area, hazardous location and classified location can be used interchangeably. The most common industry term is "hazardous location" and that is what we use here. These terms are also interchangeably used in National Fire Protection Association (NFPA) codes and standards and in the United States NEC.

Hazardous locations deal with physical areas of facilities where fire or explosion hazards can or do exist due to the presence of flammable gases/vapors, flammable liquids, combustible dust, or ignitable fibers. The specific type of hazard is defined as an "explosion hazard" in Class I and II locations, and a "fire hazard" in Class III locations.

Class I Locations

Hazardous locations known as or classified as Class I are areas where flammable gases or vapors may be present in the air in quantities sufficient to produce explosive or ignitable mixtures. Class I hazardous locations are broken down into Divisions, and Divisions categorized into Groups. The Divisions indicate how likely or frequent the hazardous gas or vapor exists in the area. This is defined in further detail later in this white paper.

Groups: Class I Groups exist to permit classification of locations based on the explosion characteristics of a reference fluid, regardless of the Division classification as defined later. The NEC definition of Groups within Class I for hazardous gases and vapors is as follows:

- **Group A:** acetylene
- **Group B:** hydrogen, or gases/vapors of equivalent hazard
- **Group C:** ethyl ether vapors, ethylene or cyclopropane
- **Group D:** gasoline, hexane, naptha, benzine, butane, propane, alcohol, acetone, benzol, lacquer solvent vapors, natural gas

Class II Locations

Whereas Class I deals with explosive gases and vapors, Class II deals with combustible dusts. The dust may be suspended in the air, such as in a cloud, or in a layer resting on electrical equipment or even on the floor, railings and other structures as a result of a lack of proper dust collection equipment. In 1979 the National Materials Advisory Board reported to OSHA that for most all dusts the ignition temperature of a dust layer is usually lower than for a dust cloud. In those cases where the dust cloud ignition temperature was lower than the layered temperature it was apparent that either 1) there was a change in state from a dust to a gas, 2) the material in the cloud was somewhat different than in the layered form or 3) the difference in temperatures between layered and cloud were not really significant.

However, as the CSB video referenced before clearly illustrates, dust layers can become airborne as a result of cleaning and even initial explosions and then provide fuel for subsequent explosions and fire propagation. Class II locations are broken down into Divisions, which represent the likelihood of a dust explosion if ignition sources are not carefully controlled.

Groups: As with Class I, Class II Groups exist to permit classification of locations based on the explosion characteristics of the material. For Class II locations there are three Groups:

- **Group E:** metal dusts (aluminum, magnesium and their alloys) and other combustible dusts whose particle size, abrasiveness and conductivity present similar hazard
- **Group F:** carbonaceous dusts (carbon black, charcoal, coal or coke) that have more than 8% total entrapped volatiles, or dusts sensitized by other materials so they present an explosion hazard
- **Group G:** combustible dusts not included in groups E & G

Instrumentation/Equipment Design

Class I locations are a more serious hazard to protect against, from the standpoint of instrument design. Therefore, we will only look at the impact this Class upon instrument design. In the design and manufacture of instrumentation suitable for use in a Class I environment there are two approaches; 1) the most common is to build the instrument to be “explosionproof” or capable of withstanding an explosion, 2) the second approach is to build an instrument that is designed with increased safety in that the device is “intrinsically safe”. An intrinsically safe device is one which will never generate the minimum energy necessary to ignite an explosive atmosphere. With an explosionproof instrument it is assumed the flammable mixture will enter the enclosure and that the enclosure will contain any source of ignition from escaping the instrument housing even if an explosion occurs within the instrument enclosure. The later is the most common approach.

To provide explosionproof protection the objective of the instrumentation manufacturer in designing the instrument is to build the enclosure strong enough to withstand the anticipated explosion and to prevent the resulting flames and hot gases from igniting the surrounding atmosphere outside of the instrumentation enclosure.

To assist the instrumentation manufacturer during design, a “maximum experimental safety gap” (MESG) is defined for each Group of materials. This gap is a maximum dimension through which an ignition on the inside of the enclosure will not propagate flame to a mixture of flammable material on the outside of the enclosure. The joints in an enclosure are considered to be the “flamepath” and these are evaluated and properly designed in addition to the strength of the enclosure itself. Each material or fluid is classified into a Group based on its value for the MESG.

The maximum allowable joint gap depends on the type of joint (plain, stepped or threaded), the Group classification and the volume of the instrument enclosure. Threaded joints also are concerned with the width of the sealing joint area, the thread itself (</= 20 threads per inch) and having a minimum thread engagement (5 minimum). The detail for the design of instrumentation regarding the MESG is laid out within the applicable country standards such as CSA (Canadian Standards Association) and UL (Underwriters Laboratory). Refer to standards documents for further information.

Instrument Surface Temperature

The ignition temperature of a flammable material is critical in determining the acceptability of instrumentation operating in hazardous locations. The reason for this is that the external surface of the enclosure itself can act as an ignition source. This assumes the surface temperature of the external area of the enclosure can rise to a point that exceeds the ignition temperature of the flammable material. This is why the ignition temperature of the material is important. High surface temperatures can exist not just because of a fault (overheating) within the instrument but also as a result of normal operation.

To assist in understanding whether an instrument may produce surface temperatures greater than the ignition temperature of the material, instruments destined for installation in hazardous areas are marked with a code that represents the maximum external surface temperature that can be expected with the instrument.

Equipment cannot be used in hazardous areas when the maximum surface temperature is greater than the ignition temperature of the gases/vapors present. The allowable ambient temperature may be limited to comply with the temperature rating of the device. External surface temperature codes and their related temperatures can be found in Table 2:

Table 2: Maximum Allowable Surface Temperature on External Surface of Instrument Enclosure

Maximum Temperature	Identification Number
450° C (842° F)	T1
300° C (572° F)	T2
280° C (536° F)	T2A
260° C (500° F)	T2B
230° C (446° F)	T2C
215° C (419° F)	T2D
200° C (392° F)	T3
180° C (356° F)	T3A
165° C (329° F)	T3B
160° C (320° F)	T3C
135° C (275° F)	T4
120° C (248° F)	T4A
100° C (212° F)	T5
85° C (185° F)	T6

Classification "Divisions"
In the Class system within the NEC, Divisions are used to identify the likelihood or frequency of a flammable mixture being present. Divisions within Class I are as follows:

Class I, Division 1: Ignitable concentrations of flammable gases or vapors can exist under normal operating conditions. These ignitable concentrations may exist frequently because of maintenance or leakage. Ignitable concentrations can exist because of faulty operation of equipment or processes resulting in failure of electronic equipment.

Instrument enclosures approved for Class I, Division 1 locations include those that provide protection by being explosionproof (sometimes referred to as flameproof) or being purged / pressurized. Explosionproof enclosures are the most common method of protection for instrumentation in these hazardous locations. The instrument enclosure is capable of withstanding an internal explosion of a specified gas or vapor and preventing the ignition of the same gas or vapor in the surrounding ambient environment outside of the instrument enclosure as a result of any sparks, flashes, etc. from the explosion inside of the enclosure. The external surface temperature of the instrument enclosure is such that the surrounding gases or vapors will not be ignited.

An alternate method to designing an explosionproof enclosure meeting the Class I, Division 1 requirements for a specific Group is to purge and pressurize the instrument enclosure. This approach eliminates the presence of flammable vapors from within the enclosure. This allows enclosures that are not otherwise acceptable for use in hazardous locations to be useable when this technique is implemented.

How does purging and pressurizing an enclosure work? Purging supplies the instrument enclosure with a protective gas (usually this is nitrogen) at enough flow rate and pressure to lower the concentration of any flammable gas that might exist within the enclosure to an acceptable level according to the standards. There are three types of purging. Type "X" purging lowers the enclosure classification from Division 1 to Ordinary (general purpose). Type "Y" purging will reduce the enclosure requirement from Division 1 to Division 2. Type "Z" purging reduces the enclosure requirement from Division 2 to Ordinary (general purpose).

Enclosures for Ordinary locations (general purpose suitable for non-hazardous locations) are also acceptable for Class I, Division 1 locations if the electronics within them are intrinsically safe. In this situation the proper electrical barriers must be installed on any instrument I/O circuits. Intrinsically safe electronics have low energy circuitry that keeps energy levels below those needed to ignite any flammable gas or vapor that might be present. This intrinsically safe approach takes into account the energy available during normal and abnormal operating conditions.

Class I, Division 2: Instruments used in these Division2 areas are in locations where flammable fluids or gases exist, but in which it is normally confined and can only escape due to accidental bursting of containers or during abnormal operation. Class I, Division 2 locations can also be where the accumulation of ignitable gases or vapors is prevented by mechanical ventilation and can only occur through the failure or abnormal operation of equipment. These locations can be adjacent to Class I, Division 1.

Instrument enclosures approved for use in Class I, Division 1 areas can also be used in Class I, Division 2 locations. Therefore, the same approach to protection and enclosure design can be used. Ordinary location (general purpose) enclosures may be acceptable only if any current interrupting contacts are hermetically sealed against the entrance of any gas or vapor, or if the electronics are nonincendive and intrinsically safe.

The term “nonincendive” only applies to Division 2 locations. It applies to the circuits used in the instrument. A nonincendive circuit is one in which any arc or heat produced during normal operating conditions is not able to ignite a flammable gas/vapor or dust mixture. The use of nonincendive circuits are not allowed in Division 1 areas because they only consider normal operating conditions and not abnormal conditions.

Class II, Division 1: In these areas combustible dust is in the air under normal conditions in sufficient concentration to be able to produce explosive or ignitable mixtures. In these locations the failure or abnormal operation of machinery can cause such mixtures and are a source of ignition. Combustible dusts of an electrically conductive nature are also present in these hazardous areas.

Class II, Division 2: These locations have combustible dust, however, the dust is not present normally in quantities that are sufficient to produce a hazard. Dust accumulation is not sufficient to interfere with electrical equipment. Dust can be in suspension within the air as a result of infrequent equipment breakdown.

Class III: Class III areas are hazardous because easily ignitable fibers are present. However, these fibers are not likely to be in the air in such quantities that would be sufficient to produce any ignitable mixture. There are no Group subdivisions for Class III locations but there are Divisions based on the likelihood of the fiber material being present.

Class III, Division 1: These areas are where the ignitable fibers are handled, manufactured or used.

Class III, Division 2: These areas are where the ignitable fibers are stored or handled not in the process of manufacture.

The IEC (International Electrotechnical Commission)
The IEC classification system differs from the NEC system though both exist for the same reason. The IEC system differentiates between mine and surface areas by classification I being the former and II being the later. The IEC system is based on the IEC standard number 60079-2 and uses a Zone system rather than Class and Divisions. There are three zones (0, 1, and 2). Zone 0 corresponds to the most hazardous part of Division 1. Zone 1 is the remainder of Division 1 and Zone 2 is the same as Division 2. Refer to Table 1

The lettering under the IEC system for dusts (NEC Class II) is Zone 20, 21 and 22. Zone 20 is when a hazardous dust cloud is “likely to be present on a continuous basis or for long periods of time”. Zone 21 for when the hazardous dust is “likely to be present occasionally in normal operation”. Zone 22 is when hazardous dust is “unlikely to occur during normal operation, but if it does it is only present for a short period”.

Testing Agencies
Instrumentation and other electrical equipment being used within any of the above hazardous areas should have an approval or certification for the intended area from a third party testing agency. The primary testing laboratories in North America that can test to North American standards in the USA and Canada and render an approved or certified status for the equipment include:

- **Canadian Standards Association**
- **LabTest Certification, Inc.**
- **Factory Mutual**
- **Underwriters Laboratories**

The above agencies are approved to perform testing equipment to determine compliance to the North American standards. Most all have bi-lateral arrangements allowing for testing to both UL (USA) and Canadian (CSA) standards and approvals or certifications, meaning that each are accepted almost everywhere in North America no matter where the testing lab is located.

Conclusion

Level monitoring is a critical application that ensures safety by detecting high and low material levels, and ensures profitability by monitoring and managing the inventory of materials tanks, bins and silos. A wide variety of technologies and brands exist. It can sometimes be a complex task to determine which product to use. In regards to safety of your required electrical classifications, if you haven’t spent decades in the industry you may need an introduction to hazardous areas. We hope this white paper is of service to you. Please do not hesitate to give us a call with any questions.

APPENDIX 1
Enclosure NEMA Ratings

Enclosure Type	Protection Against the Following Environmental Conditions
1	Indoor use.
2	Indoor use only. Limited amount of falling water.
3R	Driptight. Outdoor use, undamaged by a formation of ice.
3	Rainproof. Same as 3R plus windblown dust.
3S	Raintight, Dusttight. Same as 3 with external mechanisms remaining operable when ice laden.
4	Outdoor use, splashing water, windblown dust, hose-directed water, undamaged by ice formation.
4X	Raintight, watertight. Same as 4 plus corrosion resistant.
5	Indoor use to provide a degree of protection against settling airborne dust, falling dirt and dripping non-corrosive liquids.
6	Driptight, dusttight. Same as 3R plus entry of water during temporary submersion at limited depth.
6P	Raintight, watertight. Same as 3R plus entry of water during prolonged submersion at limited depth.
7	Indoor use, in hazardous locations classified as Class I, Division 1, Groups A, B, C or D.
8	Indoor or outdoor use, in hazardous locations classified as Class I, Division 1, Groups A, B, C or D.
9	Indoor use, in hazardous locations classified as Class II, Division 1, Groups E, F or G.
12, 12K	Indoor use, dust, dripping non-corrosive liquids, driptight, dusttight.

APPENDIX 2
Enclosure Ingress Protection

IP X Y

Ingress Protection

Protection Against Solids	**Protection Against Liquids**
0: No Protection	**0**: No Protection
1: Objects > 50mm	**1**: Vertically Dripping Water
2: Objects > 12mm	**2**: Angled Dripping Water -75° to 90° C
3: Objects > 2.5mm	**3**: Sprayed Water
4: Objects > 1.0mm	**4**: Splashed water
5: Dust Protected	**5**: Water Jets
6: Dust-Tight	**6**: Heavy Seas
	7: Effects of Immersion
	8: Indefinite Immersion

A device listed as IP 66 indicates that the device is dust-tight and will be protected against heavy seas during operation. The IP designation sets the degree of environmental protection that a given device has. The IP designation describes how well the device resists both solids and liquid ingress. The applicable IEC standard is IEC 60529.

APPENDIX 3
Safety Instrumented Systems

The need for safety systems within various process industries is greater than ever. Two specific IEC standards have been developed that are related to this subject. These are the IEC 61508 safety standard and the more recently published IEC 61511 involving process safety. Process plants have increasingly been interested in performing rigorous safety system assessment and analysis and have increased their use of products and equipment with appropriate SIL (safety integrity level) ratings. A white paper is available from www.blueleveltechnologies.com that will cover this subject in more detail.