A Common Sense Approach to Hazardous Area Classification for Electronic Instrumentation

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KEYWORDS

All keywords are identified in the body of this paper by italicized print.

ABSTRACT

This paper is intended to present a practical and common sense approach to determining the proper hazardous area classification of a manufacturing or process facility. Industrial processes involving flammable or combustible materials may produce explosive atmospheres. The concept of assessing and limiting the risk associated with the installation of electrical devices in areas where potentially explosive atmospheres may be present is referred to as “Area Classification”. Many people take a “by the books” approach to area classification assessment. Unfortunately, this method almost always increases cost and sometimes compromises safety. This paper seeks to define a well-understood common sense approach to area classification so that industrial owners and managers can reduce risk while mitigating capital waste.

INTRODUCTION

There are several entities that provide information regarding hazardous area classification assessment. The ISA, NFPA, OSHA, and API are a few of the more familiar. The concept of hazardous area classification assessment and the application of various recommended practices from the aforementioned entities are often mis-understood, confusing, and therefore mis-applied. This often results in a very conservative area classification assessment. Areas are classified as Division 1 when the location should have been classified as Division 2 and likewise, areas classified as Division 2 should have been classified as non-hazardous. To establish the framework for the common sense approach to hazardous area classification assessment, you must first have a basic understanding of its key definitions and develop an assessment methodology that is well understood by all that are involved in the assessment study. It should be the common goal of all involved parties in the assessment study to strive to achieve a classification assessment that defines an acceptable level of safety commensurate with an acceptable level of risk that results in the reduction of the cost of electrical installations. This paper is divided into four basic parts: Part 1 provides insight into the definition of several key terms that are associated with area classification assessment, Part 2 provides discussion regarding the development of an assessment methodology, Part 3 describes how the area classification assessment is conducted, and Part 4 shows how to develop hazard reduction methods to comply with the classified area. No mention is made of the zone concept in this report.

(PART 1) THE DEFINITION OF KEY TERMS

An understanding of key definition of terms is required in order to establish the foundation for assessing the classification of an area. Several of these definitions are taken directly word for word from the publications that are listed in the reference section. Paraphrasing is done to assist in the understanding of the intent of the definition.

What is "hazardous area classification assessment"?

Hazardous area classification assessment is a probability analysis and risk assessment evaluation of a manufacturing or process area processing a potentially flammable atmosphere that focuses exclusively on the minimization or elimination of electrical energy as a potential source of ignition.

To fully understand what is meant by the definition above, it is also important to understand what area classification is NOT.

Hazardous area classification is NOT intended to be a secondary line of defense against:

- Poor process design
  Includes such issues as poor elastomer compatibility causing excessive emissions from valve packing, pump seals, and/or pipe flanges.
- Poor facility and equipment maintenance
  This often occurs when PM programs are poorly managed or not properly implemented.
- Faulty equipment operation
  This is an issue when apiece of equipment is a routine source of frequent leaks and is often caused by mis-application.
- Catastrophic vapor releases
  This scenario occurs when a vessel is breached by some other means and the corresponding vapor release is uncontrollable and instantaneous. Often these types of releases are quite large in vapor mass and energy and will often find sources of ignition other than those associated with the normal operation of electrical equipment i.e. static charges, open flames, or hot surfaces. (Figure 1 shown

below illustrates the expansive nature of a catastrophic release of hydrogen from a closed containment system. Dispersion model derived from PHAST. PHAST is dispersion modeling software licensed through Det Norske Veritas Risk Management Software Division).

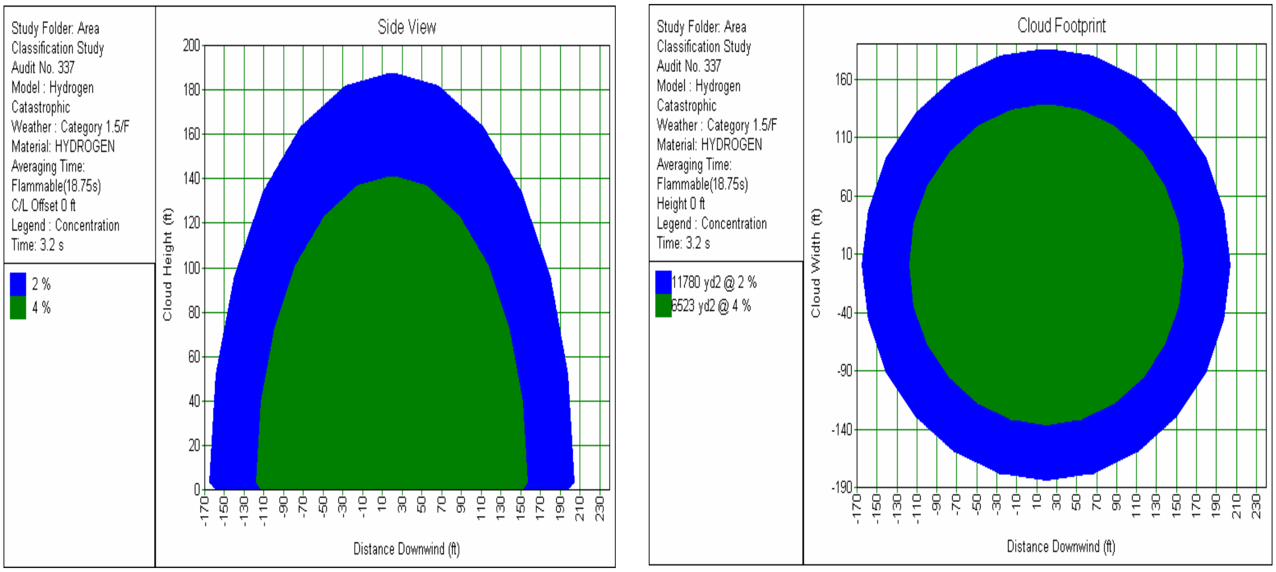

FIGURE 1 CATASTROPHIC H^2 RELEASE

What are "Hazardous Area Classes"?

Hazardous Areas are divided into three distinct classes that are totally dependent on the type of material that is encountered in the process. They are described as follows:

Class I Areas

These are locations in which flammable gases and/or vapors are or may be present in the air in quantities sufficient to produce an explosion or ignitable mixture. In Class I Areas that utilize the division concept methodology there are two distinct divisions that are predicated on the operational interpretation of the words normal vs. abnormal and frequent vs. infrequent. The formal definitions are described as follows:

Division 1 - These are locations in which ignitable concentrations of flammable gases or vapors can exist:

- under normal operating conditions.
- frequently because of maintenance or repair.
- because of frequent leakage.
- below grade where adequate ventilation does not exist.
- when releases from faulty operations of process equipment results in the simultaneous failure of electrical equipment.

Division 2 - These are locations in which ignitable concentrations of flammable gases or vapors can exist due to:

- failure of closed containment systems.
- abnormal operation or failure of processing equipment.
- abnormal operation or failure of ventilation equipment.
- area is adjacent a division 1 location.

In Class I Areas that utilize the division concept methodology there are four distinct groups that are based solely on the liquid or gas ease of ignitability and its corresponding range of flammability. Figure 2 on the next page illustrates this concept. The formal definitions are described as follows:

Group A – These are atmospheres that contain acetylene

Group B – These are flammable gas/vapor atmospheres having either an *(MESG)* ***M****aximum* ***E****xperimental* ***S****afe* ***G****ap* less than or equal to .45mm or an *(MIC)* ***M****inimum* ***I****gnition* ***C****urrent* ratio less than or equal to .40mm.

Group C – These are flammable gas/vapor atmospheres having either an *(MESG)* greater than.45mm and less than .75mm or an *(MIC)* ratio greater than .40mm and less than or equal to .80mm.

Group D – These are flammable gas/vapor atmospheres having either *an (*MESG) greater than .75mm or an *(MIC)* ratio greater than .80mm.

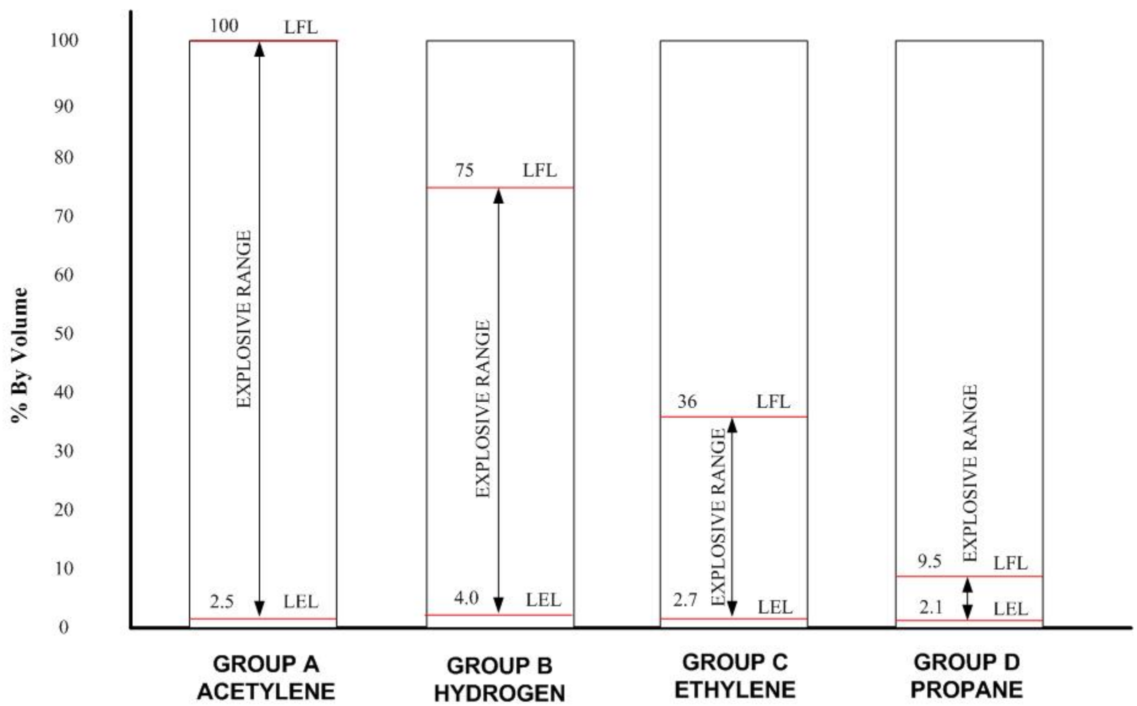

FIGURE 2 EXPLOSIVE RANGE BY VAPOR GROUPING

The explosive ranges, as indicated in figure 2 above, are based upon normal atmospheric pressure and temperature. As the temperature of the mixture increases, the flammable range shifts downward. As the temperature of the mixture decreases, the flammable range shifts upward. It can be easily determined from examination of the graph, contained in figure 2 above, the volatility of the mixture is much greater for Group A mixtures and much less for Group D mixtures.

Other important definitions pertaining to Class I areas include the following:

Flash Point is the minimum temperature at which a liquid gives off a vapor in sufficient concentration to form an ignitable mixture with air at the liquids surface. This is an empirically derived number that is usually contained in the materials *MSDS,. (****M****aterial* ***S****afety* ***D****ata* ***S****heet).* Typical test methods to determine this number can be obtained, depending on the liquids viscosity, from the either the Tag or Pensky-Martens Closed Cup Tester. (See *NFPA* 30 section 1.7.4 for more detail).

A flammable liquid is any liquid that has a closed-cup flash point below 100^{o} F.

A **combustible liquid** is any liquid that has a closed-cup flash point at or above 100^{o} F.
Classes of Combustible Liquids include Class II which is any liquid with a flash point greater than 100^{o}F and less than or equal to 140^{o}F and Class III liquids which are any liquids with a flash point greater than 140^{o}F. Class III liquids are further divided as either a Class IIIA liquids, which is a liquid with a flash point greater than 140^{o}F and less than or equal to 200^{o}F, or a Class IIIB liquids, which is a liquid with a flash point greater than 200^{o}F. Some of the greatest confusion lies in how these types of materials, specifically Class III liquids, are treated when it comes to the assessment of an areas classification. The *API (**A**merican **P**etroleum **I**nstitute)* in RP500 section 5.2.4 basically says to disregard the classification of areas that are processing Class III liquids even if processed above their respective flash points. The *NFPA (**N**ational **F**ire **P**rotection **A**ssociation)* specifically *NFPA* 497 basically gives no credence to this issue especially when it comes to the definition of the extent of classified areas in section 3.8. *OSHA (**O**ccupational **S**afety and **H**ealth **A**dministration)* states in 1910.106 (a)(18)(iii) that when a combustible liquid is heated to within 30^{o}F of its flash point, it shall be handled in accordance with the requirements of the next lower class of liquids. So now the question becomes how do you handle the combustible class of liquids. First of all, if the material is a combustible liquid that is not heated to within 30^{o}F of its flash point, then the consensus is to not require the area to be classified. In other-words, its contribution to the assessment of a hazardous area can be ignored. The other and most often encountered scenario is when the combustible liquid is heated within the process to several hundred degrees in excess of its flash point. This is typical in refinery and petrochemical operations in the US today. Figure 3 shown below represents a vapor dispersion model of a Class IIIB mixture in a typical refinery operation. Both the vapor cloud footprint and side view are shown.

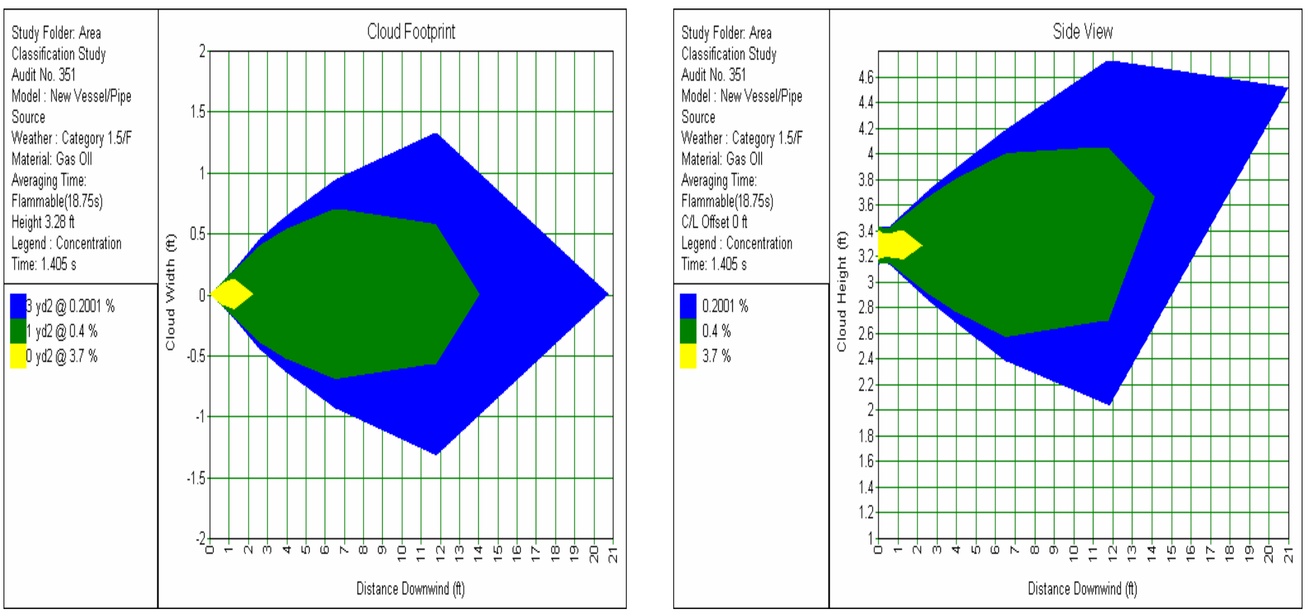

FIGURE 3 CLASS III LIQUID VAPOR CLOUD DISPERSION

Figure 3 shown above is a vapor dispersion model of gas-oil which has a flash point of 180^{o}F. The release scenario is 500 lbs of product through a .1 inch orfice leak in a vessel. The process pressure is 220 psig at a temperature of 675^{o}F. The area shown in green is the mass of the vapor cloud that is above the LFL (**L**ower **F**lammable **L**imit) and below the UFL (**U**pper **F**lammable **L**imit). This is the mass that is in the explosive or flammable region. The ignitable portion of the vapor cloud extends outward some 14 feet. The recommendations set forth by both The NFPA and API would have ignored this scenario. Notice that the range of flammability was reduced significantly by the increase in process temperature, (from 6 to 13.5% in air to .4 to 3.7% in air). The dispersion model was derived from PHAST. PHAST is a dispersion modeling software licensed through Det Norske Veritas Risk Management Software Division.

Class II Areas

These are locations that are hazardous because of the presence of combustible dust. A combustible dust is defined as any solid material 420 microns or less in diameter that presents a fire or explosion hazard when dispersed in air. Like Class I areas, Class II areas are also divided into two distinct divisions that again depend on operational interpretation of the words normal vs. abnormal. The formal definitions are described as follows:

Division 1 is a location where combustible dust is present in the air

- under normal operating conditions in quantities sufficient to produce an explosive or ignitable mixture.
- is electrically conductive. Dusts are considered to be electrically conductive if the electrical resistivity of the solid material from which the dust is formed has a value of less than 10^5 ohm-cm.
- releases from faulty operation of process equipment results in the simultaneous failure of electrical equipment causing the electrical equipment to become a source of ignition.

Division 2 is a location where combustible dust

- is present in the air only under abnormal operating conditions in quantities sufficient to produce an explosive or ignitable mixture.
- accumulations are normally insufficient to interfere with the normal operation of electrical equipment or other apparatus, but combustible dust could be in suspensions in the air due to infrequent malfunctions of process equipment.
- 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 ignitable by abnormal operation or failure of electrical equipment.

The following information contained in Table 1 is a rule of thumb guideline in determining dust layer accumulation vs. the required classification. The dust accumulations in Table 1 are based upon a 24 hour build-up on horizontal surfaces.

TABLE 1 DUST LAYER ACCUMULATIONS VS. CLASSIFICATION

Thickness of Dust Layer	Recommended Classification
Greater than 1/8 inch (3mm)	Division 1
Less than 1/8 inch (3mm), but color not discernable	Division 2
Surface color discernable under the dust layer	Un-classified

In Class II Areas, there are three distinct groups that are based primarily on the physical characteristics of the dust. The formal definitions are described as follows:

Group E - these are atmospheres that contain combustible metal dusts, including aluminum, magnesium, and their commercial alloys, or other combustible dusts whose particle size, abrasiveness, and conductivity present similar hazards in the use of electrical equipment.

Group F - these are atmospheres containing combustible carbonaceous dusts that have more than 8% total entrapped volatiles or that have been sensitized by other materials so that they present an explosion hazard. Representative combustible dusts that fall into this grouping are coal, carbon black, charcoal, and coke.

Group G - these are atmospheres containing other combustible dusts, including flour, grain, wood flour, plastic, and chemicals.

Other important definitions pertaining to Class II areas include the following:

Explosion severity is a measure of the damage potential of the energy released by a dust explosion. The US Bureau of Mines has defined the equation for calculating explosion severity as:

$$\text{Explosion severity} = \frac{(P_{max} \times P)_2}{(P_{max} \times P)_1} \qquad (1)$$

Where P_{max} = maximum explosion pressure
P = maximum rate of pressure rise
Subscript 1 refers to the values used for Pittsburgh seam coal

Where
Pmax = 8.1 bar
P = 214 bar / sec
Subscript 2 refers to the values for the specific dust in question

Ignition Sensitivity is a measure of the ease by which a cloud of combustible dust can be ignited. The US Bureau of Mines has defined the equation for calculating ignition sensitivity as:

$$\text{Ignition Sensitivity} = \frac{(T_c \times E \times M_c)_1}{(T_c \times E \times M_c)_2} \qquad (2)$$

Where T_c = minimum ignition temperature
E = minimum ignition energy
M_c = minimum explosion concentration
Subscript 1 refers to the values used for Pittsburgh seam coal

Where
$T_c = 591^oC$
E = 160 mj
$M_c = 70\ g/m^3$
Subscript 2 refers to the values for the specific dust in question

Dusts that have ignition sensitivities equal to or greater than .2 or explosion severities equal to or greater than .5 are considered to have enough volatility to warrant locations processing these dusts to be classified.. The material published by the US Bureau of Mines is no longer in print and copies are hard to find.

Class III Areas

These are locations that are hazardous because of the presence of easily ignitable fibers and flyings. In Class III areas, there are no groupings as in Class I and Class II areas. There are however divisions that are based upon how the material is processed. The formal definitions are described as follows:

Division 1 is a location where easily ignitable fibers producing combustible flyings are handled, manufactured, or used.

Division 2 is a location where easily ignitable fibers are stored or handled other than in the process of manufacturing.

(PART 2) RISK ASSESSMENT METHODOLOGY DEVELOPMENT

A risk assessment methodology must be developed prior to beginning the actual area classification assessment itself. This methodology sets the ground-rules by which the assessment is conducted. The deliverables presented at the completion of the assessment methodology are as follows:

- Key members of the assessment team are identified along with their respective roles and responsibilities required to support the assessment process. Typically this core team will consist of an operations representative, a mechanical integrity representative, the individual who is conducting the actual assessment, and a process engineer.
- The assessment concept point source vs. the blanket classification will be determined.
- All potential point source of emissions will be identified. Point sources are process equipment that continuously or intermittently release flammable vapors into the atmosphere during routine modes of operation. Typical equipment that should be considered are:
    - Mechanical pumps seals
    - Valve packing (typically modulating service control valves only)
    - Overpressure protection devices such as relief valves, rupture discs, and conservations vents
    - Filters
    - Compressor seals
    - Process drains and vents
- Operationally define such terms as normal vs. abnormal and frequent vs. infrequent
- Determine how to address the following scenarios:
    - extent of classified areas that extend beyond unit battery limits
    - areas where sources of ignition other than electrical are present under normal operating conditions
    - areas where pipe bridges and racks either cross or are adjacent roadways
    - impact of facility or unit operational history
    - discovery of errors and omissions in documentation (typical documentation consists of scaled plot plans, *PFD's (**p**rocess **f**low **d**iagrams)* , *P&ID's (**p**iping and **i**nstrumentation **d**iagrams)* Unit *SOP's **(s**tandard **o**perating **p**rocedures**)*** and *MSDS's*
- Determine how the various codes and standards writing organizations will apply. Typically NFPA is used for all petrochemical applications and API is used for refinery applications.
- Determine whether the division or zone concept will be utilized. Typically the division concept is used in the US and the zone concept is used in Canada and Europe.
- Determine who is the authority that has jurisdiction.

(PART 3) AREA CLASSIFICATION ASSESSMENT

Once the risk assessment methodology is developed then the actual process of classifying the area is ready to begin. A typical assessment study will include the basic 7 step process as follows:

Step 1 Obtain the required documentation that was determined from the assessment methodology. *PFD's* provide information about the process stream such as pressures, temperatures, flow rates and stream compositions. Plot plans will become the backgrounds used for the area classification plan drawings. *MSDS's* are the source of process information about each component in the process stream. *P&ID's* provide a lower level view of the process for equipment identification and process arrangements.

Step 2 Field survey the area in question to determine the accuracy of the plot plans and verify location of all point sources of emissions. The plot plans will serve as the background for the area classification plan drawings. Area classification background drawings should show all vessels, tanks, pumps, sumps, compressors, building structures, dikes, partitions, levees, and other items that might impact the dispersion of the process material. These drawings should also indicate the prevailing wind direction.

Step 3 Determine the extent of the classified area that surrounds each point source of emission. This will determine the role that each point source will play in the overall composite area classification diagram. The extent of classification diagrams should come from The *NFPA* 497 for petrochemical applications, *API* RP500 for petroleum refinery applications, and/or gas dispersion modeling software tools. Gas/vapor dispersion modeling software should be utilized when one out of the two scenarios exist. 1) Extreme process conditions are encountered such as large flow rates > 250 gallons/minute *(gpm)*, pressures > 275 lbs/in^2 (*psig)*, and liquids with a vapor pressure > 70 lbs/in^2 absolute *(psia)* at operating temperature. 2) Combustible Liquids are heated to temperatures > 100^{o}F of their respective flash point.

Step 4 Develop the composite area classification plan drawing that embellishes the contribution of all point sources.

Step 5 Develop elevation drawings to provide clarity where there are emissions sources located in multilevel process structures. A plan view will be required for each level in the process structure.

Step 6 Conduct the compliance audit

Step 7 Create a detailed assessment report that documents the following information:

- The rationale used to classify the areas.
- The critical process material information usually obtained from *MSDS's*.
- A detailed listing of all point sources of emissions that appear on the drawings.
- Special out of the ordinary exceptions that were taken when classifying a particular location
- The results or findings obtained from the compliance audit

All area classification documentation should be placed under the protection of the facilities *MOC* *(**m**anagement **o**f **c**hange)* process control. As modifications are made to the facility these documents should be reviewed to verify the impact of these modifications.

(PART 4) METHODS OF PROTECTION AND HAZARD REDUCTION

Hazard reduction is the means by which a facility reduces the probably or risk of significant property damage and/or loss of life as the result of an explosion of fire. It helps insure that the installation of electrical equipment in a hazardous location does not significantly raise the risk or probability of an explosion or fire. This is the point where steps are taken to provide compliance with the area classification assessment.

METHODS OF PROTECTION IN CLASS I AREAS

Physically isolate the hazard Place or relocate the normal arc producing electrical devices to a non-hazardous area. This is an attractive option when approved equipment for the classified area is not readily or commercially available.

Confine the explosion This is the most common and widely accepted method of protection. It deploys the use of vendor certified, through listing or labeling the device, as explosion proof. Explosion proof means that the device enclosure is designed and tested in a manner that guarantees if a flammable vapor enters the enclosure and is ignited by an electrical arc or hot surface within the enclosure, the resulting explosion is contained within the enclosure. The electrical apparatus contained within the enclosure should still be operational.

Energy Limiting This concept is known as intrinsic safety, which prevents ignition by limiting the released energy resulting from wiring and component failures or faults. *UL (Underwriters Laboratory)* listed intrinsically safe electrical devices are incapable of releasing enough energy under normal or abnormal conditions, to cause ignition of a specific hazardous atmosphere in its most easily ignitable concentrations.

Hermetically sealed This type of protection insures that the arc or heat producing devices are sealed against the intrusion of the hazardous vapor.

Purging and Pressurization Pressurization is the process of supplying an enclosure with a protective gas with or without continuous flow to prevent the entrance of a flammable vapor, a combustible dust, or an ignitable fiber. Purging is the process of supplying an enclosure with a protective gas at a sufficient flow and positive pressure to reduce the concentration of any flammable vapor initially present to a safe level.

TYPES OF PRESSURIZED SYSTEMS

Type X reduces the classification within a protected enclosure from Division 1 to un-classified. The design requirements for a Type X purge system is as follows:

- Maintain a positive pressure > .1 inch of water with equipment energized.
- Exchange 4 enclosure volumes of purge gas before energizing components with a required interlock.
- Interlock is required to remove power from internal electrical components in the enclosure when the purge pressure falls below .1 inch of water.
- Must remove power from enclosure when enclosure is opened
- The pressure alarm must be located in a continuously attended area.

Type Y reduces the classification within a protected enclosure from Division 1 to Division 2.

Type Z reduces the classification within the protected enclosure from Division 2 to unclassified. The design requirements for a Type Y or Z purge system is as follows:

- Maintain positive pressure greater than or equal to.1 inch of water with equipment energized.
- Exchange 4 enclosure volumes of purge gas before energizing components (no interlock required)
- Must detect failure of purge system with alarm.

Oil Immersion This method of protection is where the arc producing or heat generating devices are immersed in oil thereby eliminating the intrusion of potentially hazardous vapors. This method can only be used for Division 2 areas.

METHODS OF PROTECTION IN CLASS II AREAS

Physically isolate the hazard (same as for Class I areas)

Utilize Dust Ignition Proof Equipment The use of dust ignition proof equipment means two things. 1) The enclosure is dust-tight, and 2) the enclosure is constructed so that heat generated inside will not ignite a dust layer on or a combustible cloud surrounding the enclosure.

Pressurization There are no levels of protection for as noted for Class I areas you must follow the requirements for purging as noted in *NFPA* 496.

Energy Limiting Is the same level of protection applies as did for Class I areas.

METHODS OF PROTECTION IN CLASS III AREAS

The methods of protection for Class III areas employ the same methods that were utilized for Class II areas. The basic requirement is to make use of dust-tight enclosure for all normal arc-producing electrical devices.

CONCLUSION

A common sense approach to area classification assessment is to follow the basic 4-part process as outlined in this paper. First, develop a risk assessment methodology that lays out the framework from which the assessment will be conducted. Second, obtain a common understanding of all pertinent terms and their corresponding definitions that impact area classification assessment. Third, perform the assessment and compliance audit providing all drawings and reports. Fourth, determine and implement the proper methods of hazard reduction. This approach will help to insure that the installation of electrical equipment in hazardous classified areas will not increase the probability of an explosion or fire while at the same time mitigating capital waste trying to comply with conservatively rated hazardous areas.

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