HAZARDOUS AREA CLASSIFICATION

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Introduction

Hazardous (classified) areas are defined and categorized by the National Fire Protection Association (NFPA) 70, the *National Electric Code* (NEC). In particular, Articles 500, 501, 504, and 505 cover hazardous areas that are created by common gas utility processes. Although the NEC provides a general definition of hazardous areas and the installation requirements of electrical equipment located within them, it does not classify specific natural gas and petroleum industry processes that can create a hazardous area, nor the extent of the hazardous areas created by such processes. Instead NFPA technical committees and the American Petroleum Institute (API), among other industry-recognized organizations, determine the specifics of hazardous areas created by gas and petroleum industry processes. Two particular publications have become the de facto standards for defining hazardous areas in the natural gas and petroleum industry: the API 500 and the American Gas Association's (AGA) XL1001.

Hazardous Area

Hazardous areas, as defined by the NEC, are "locations where fire or explosion hazards may exist due to flammable gases, flammable liquid-produced vapors, combustible liquid-produced vapors, combustible dusts, or ignitable fibers/filings" (National Fire Protection Association, 2017). The NEC distinguishes these hazards into three different types: Class I, Class II, and Class III. Class I locations are those areas where flammable gases or vapors may be present. Class II locations are identified as areas where combustible dust may be present. Class III locations are areas where ignitable fibers and filings may be present. For natural gas processes the primary hazardous compounds are methane and propane; therefore, natural gas processes are identified as Class I locations. Depending on the gas supply and energy rating there may be additional flammable gases or liquids involved in the process facilities; however, these gases are identified as Class I as well. The focus of this paper will be on Class I locations.

Class I, Division 1 and 2

The NEC further breaks down Class I hazardous areas in two divisions, depending on the likelihood for the hazardous substances to be present. Division 1 is defined as a location: where flammable gases will be present as part of regular operation, where flammable gases may be present due to frequency of maintenance or repair, or where flammable gases may be released due to process or equipment failure.

A Division 2 location is: where flammable gases are normally confined in a closed system but may be released due to accidental mechanical rupture, where flammable gases are normally mechanically ventilated, and ventilation may be interrupted by abnormal operation or failure, or where it is adjacent to a Class I, Division 1 area.

The requirements for electrical equipment installed in Class I, Division 1 locations are more stringent than those in Class I, Division 2 locations, because hazardous substances are more likely to be present in a Division 1 location. To simplify, Division 1 is a location where a hazard may be present under a "normal" condition, and Division 2 is a location where the hazard may be present under an "abnormal" condition.

In addition to the Division 1 and Division 2 locations, a third area is identified as an unclassified location. Unclassified locations are locations determined not to be Class I, Division 1 nor Division 2, and do not fall under the additional requirements for classified areas.

As stated earlier, the NEC does not define the specifics of hazardous locations created by gas and petroleum industry processes. To determine the parameters, distances, and degrees of hazard in these locations, the designer or engineer can rely on API 500 and AGA for guidance.

Using API 500 for Classified Areas

The intent of API 500 is to "provide guidelines for classifying locations Class I, Division 1 and Class I, Division 2 at petroleum facilities for the selection and installation of electrical equipment" (American Petroleum Institute, 2014). The scope of API 500 does not include welding areas, smoking areas, or other hazardous activities in a gaseous environment, nor does it include the requirements for installation of non-electrical equipment in these areas.

In its recommendations for design of electrical equipment in a classified area, API 500 takes the following factors into consideration: determination of adequate ventilation, the presence of combustible gas detection equipment, topography, physical plant layout and presence of structures.

Extent of Classified Areas

In determining the extents of the classified area when flammable gases are involved, engineering judgment should be utilized to assess the volume, temperature and volatility of the flammable gases. In determining possible sources of ignition for the classified area, both electrical and non-electrical equipment need to be considered and evaluated.

When determining classified areas in outdoor locations, it is assumed the gas will disperse uniformly from the emission source, provided there are no obstructions such as barriers or walls. A lighter-than-air gas disperses upwards from the point of release. The chance of combustion increases directly above the point of release and the chances of combustion decrease as you expand outward from the source of emission. There is little chance of ignition of lighter-than-air gases below the point of release.

Heavier-than-air gases will disperse across the ground and will tend to collect in below-grade recesses, such as sumps or trenches. These locations have higher chance of combustion. The chances of combustion of heavier-than-air gases decrease the further you go above grade and it is very unlikely to have combustion of heavier-than-air gases above the point of emission. See Figure 1, Appendix A for depiction of API boundaries.

The extent of dispersion of a flammable gas may be changed by environmental factors as well. Low speed winds may extend a classified area further downwind of the point of release. However, wind is also considered to disperse the flammable gases faster, which can negate the extension of the classified area from moving the gas. Therefore, it is assumed that in a well ventilated outdoor facility, most locations can be classified as either Class I, Division 2 or unclassified.

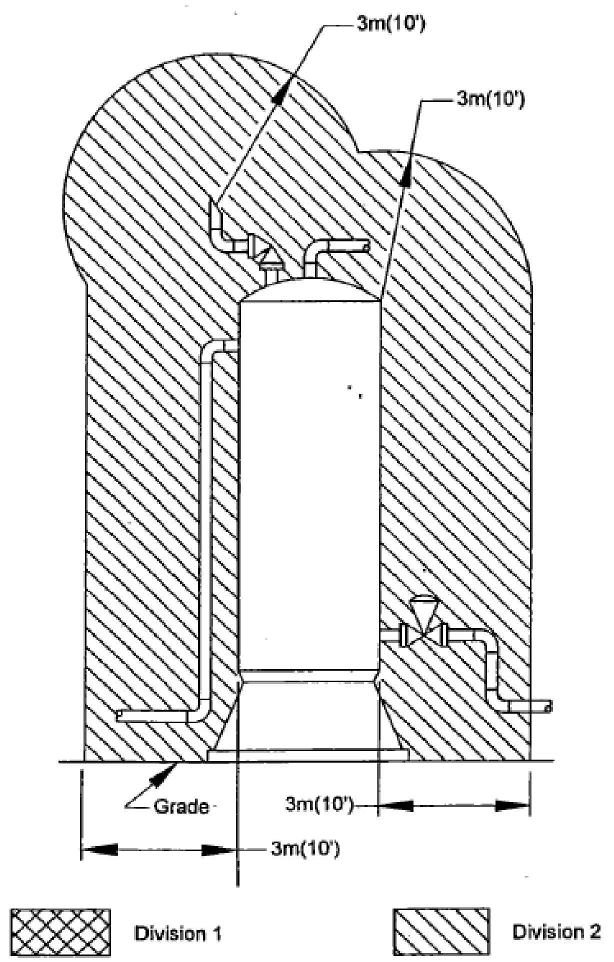

Figure 2 - Hydrocarbon Pressure Vessel or Protected Fired Vessel in a Non-enclosed Adequately Ventilated Area (taken from API 500, Figure 48)

Ventilation

Proper ventilation at a gas process site allows for the dissipation of flammable gases. Ventilation can be achieved by either passive or active means. Passive ventilation includes louvers and open roofs, floors and walls. Active ventilation facilitates moving air in from an unclassified area or circulates the air inside of the enclosure under consideration. Neither active nor passive ventilation can be used to declassify a Division 1 or Division 2 location to unclassified; however, adequate ventilation can be the difference between a Division 1 and Division 2 rating.

API 500 defines adequate ventilation as ventilation that prevents the accumulation of flammable gases up to 25% of the Lower Explosive Limit (LEL). For ease of calculation, the flammable gas to air mixture can be considered homogeneous or evenly distributed across the enclosure. The ventilation system should be adequately designed for both heavier–than-air and lighter-than-air gases that may be found in a process enclosure. This includes ventilated pits or sumps for heavier-than-air gases or roof vents for lighter-than-air gases.

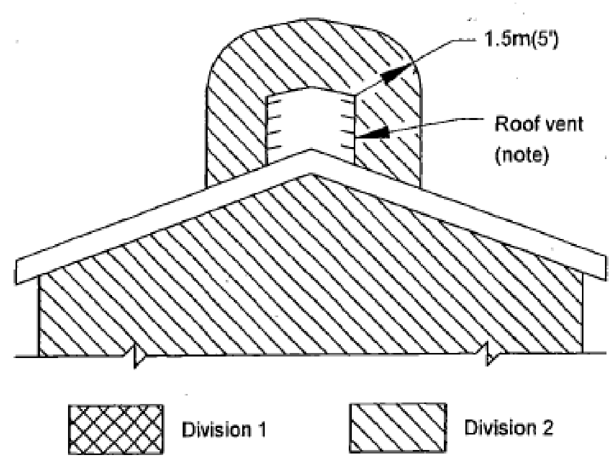

Figure 3 – Atmospheric Vent From a Division 2 Area (taken from API 500, Figure 17)

For an enclosure to be considered adequately ventilated there are several possible ventilation options to choose. One method is for the ventilation system to pass one cubic foot of air volume per minute per square foot of floor area and have a minimum of at least six total enclosure volume air changes per hour.

$$Qm = (1\ ft * A)/(1\ min) \quad (1)$$

-and-

$$Qh \geq (V) * (6/hour) \quad (2)$$

where:
Qm = required minimum ventilation flow rate in cubic feet per minute
Qh = required minimum hourly ventilation flow rate in cubic feet
A = enclosure bottom area in square feet
V = volume of enclosure in cubic feet

For example, a gas process enclosure is 10'x10'x8'; it would have a surface area of 100 square feet and a volume of 800 cubic feet. For the enclosure to be considered adequately ventilated a flow rate of 100 cubic feet per minute would be required. That flow rate equates to 6,000 cubic feet per hour which is greater than the required six air changes per hour or 4,800 cubic feet per hour.

However, if the process enclosure was 10'x10'x12', if would still have a surface area of 100 square feet but a volume of 1,200 cubic feet. Using the same analysis, the ventilation system would equate to 100 cubic feet per minute or 6,000 cubic feet per hour. This however is less than the required 7,200 cubic feet per hour for the required six air changes per hour. To be considered adequately ventilated it needs to meet both criteria.

Another method to determine adequate ventilation is to design a system where the ventilation has a flow rate high enough to dilute the expected fugitive emissions to below 25 percent of the LEL with at least 3 air changes per hour. With this method, it is recommended that gas detectors be implemented to verify that the fugitive emissions stay below 25% LEL.

These various methods to determine adequate ventilation may be used on an air recirculation system as well; however, the recirculated air shall be continuously monitored by an adequate gas detection system. If flammable gases are detected in the recirculation system, then the recirculation system must stop, activate a visual or auditory alarm and exhaust the enclosure at a rate that meets or exceeds the required flow rate for a ventilation system.

Buildings can be considered ventilated without an air flow system if they include required ventilation for both heavier- and lighter-than-air gases and include one of the following construction criteria:

(1) The building must have a floor and ceiling with walls comprising 50% or less than total possible wall surface area (i.e. 50% or greater wall space is open).
(2) The building must have neither a floor nor a ceiling; the total wall space does not matter in this configuration (a crate floor to an open area below may be considered to not have a floor).
(3) The building has either no floor or no ceiling and a minimum of 25% of the total wall space has no wall.

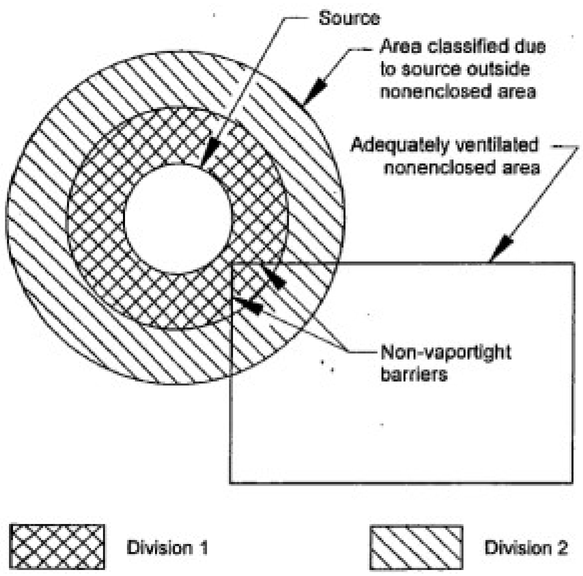

Figure 4 – Adequately Ventilated Non-enclosed Area Adjacent to Classified Area (taken from API 500, Figure 2)

Thermal Stack Effect

For passive ventilation systems using the thermal stack effect, API 500 adds an additional safety factor of two to the calculations. This would require a complete twelve air changes per hour or a complete air change every five minutes. To calculate the design of the thermal stack ventilation system, API 500 uses the ASHRAE (American Society of Heating, Refrigerating, and Air Conditioning Engineers) Handbook of Fundamentals, Chapter 12 to derive the following equations:

$$A = V / \{1200 \sqrt{[(h(T_i - T_o)/T_i]}\} \qquad (3)$$

where:
A = Area of openings (including 50% effectiveness factor), in square feet
V = Volume of building being ventilated, in cubic feet
h = see Equation 4
T_i = Internal temperature, in Rankin
T_o = External temperature, in Rankin

$$h = H / \{1 + [(A_1/A_2)^2(T_i/T_o)]\} \qquad (4)$$

where:
h = height from the center of the louver opening to the Neutral Pressure Level (NPL), in feet. NPL is the point on the vertical surface of the building where internal and external pressures are equal
H = Vertical height between mid point of openings, in feet
A_1 = free area of lower opening, in square feet
A_2 = free area of upper opening, in square feet

(Note: Equations (3) and (4) apply when $T_i > T_o$. If $T_o > T_i$, then substitute T_i for T_o and vice versa.

Also, in thermal stack ventilation systems, there should be a method to distribute the air throughout the enclosure and prevent the system from circulating solely between the openings. It is not recommended to use this system in enclosures greater than 1,000 cubic feet.

Inadequately Ventilated Areas

API 500 defines an inadequately ventilated area as a room or enclosure that does not satisfy the above requirements for adequate ventilation. However, API 500 does allow for parts of an enclosure to be considered adequately ventilated. The classification of the structure would depend on what sections do and do not meet the ventilation criteria. For example, a canopy could be described as inadequately ventilated if it lacked vents along the ridge; however, the open area beneath the canopy could be described as adequately ventilated due to the lack of walls.

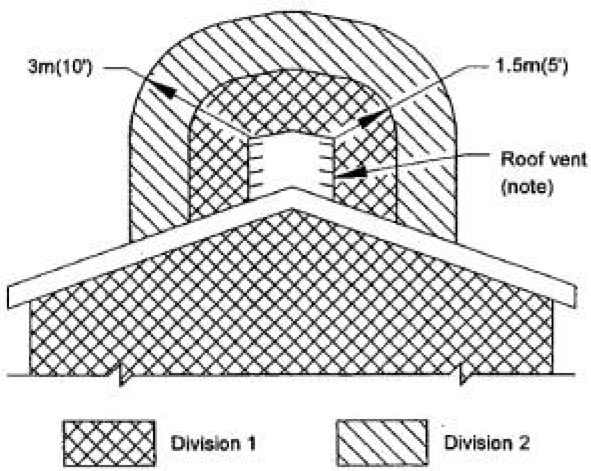

Figure 5 – Atmospheric Vent From a Division 2 Area (taken from API 500, Figure 16)

If a classified area extends to an inadequately ventilated portion of an enclosure, then it is possible that the area classification will extend into the enclosure. If the enclosure is separated from the classified area by a vapor tight barrier, then the classified area does not extend into the enclosure, however, if the enclosure is not separated by a vapor tight barrier, then the classification will extend through the enclosure. The new classification inside the enclosure will match the rating of the most stringent area classification overlapping the structure. For example, if a portion of an inadequately ventilated enclosure is overlapping with a Class I, Division 2 area, then the entirety of the enclosure shall be rated as Class I, Division 2. However, if that same enclosure was partly in a Class I, Division 2 area and partly in a Class I, Division 1 area, then the entirety of the enclosure would be Class I, Division 1.

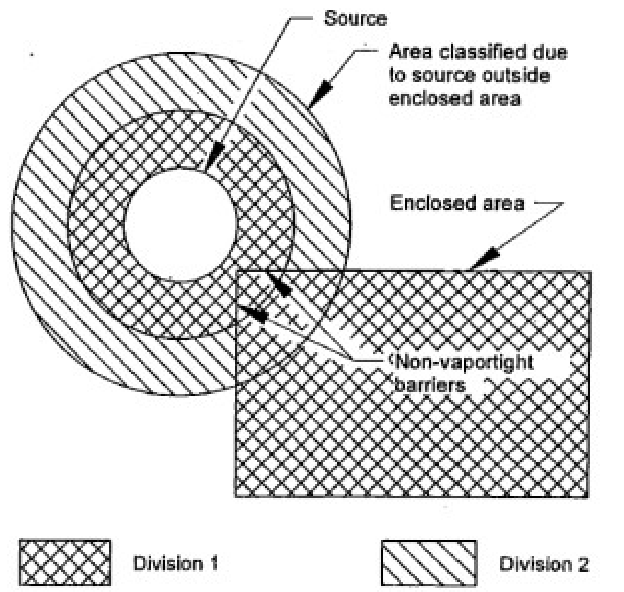

Figure 6 – Enclosed Area Adjacent to Classified Area (taken from API 500, Figure 4)

Combustible Gas Detectors

API 500 allows combustible gas detectors to be used in certain situations to lower the classification of an enclosure or area. Gas process equipment that would normally produce a Class I, Division 2 area in a well ventilated location, when placed in an inadequately ventilated enclosure, would increase the classification of the enclosure to Division 1, however, the use of gas detectors may maintain the classification at Division 2. The use of gas detectors cannot drop the classification to unclassified. In addition, a vapor-tight enclosure not housing any gas sources in a Division 2 area may still be considered unclassified with the implementation of gas detectors.

API 500 has several recommendations on the correct installation of the gas detector to allow for the changes to the hazardous area classification. The detectors must be stationary and permanently installed at the facility. The detectors must be approved or listed by a nationally recognized testing laboratory and should meet ANSI/ISA S12.13. The number of sensors installed should be capable of effectively detecting combustible gases. In addition, the sensors should be located in areas when gases may collect.

If the gas sensors detect a combustible gas concentration of 20% LEL, a local alarm should be activated; the alarm may be auditory and/or visible. If the sensors detect a 40% or more LEL combustible gas concentration or if the sensors malfunction then the system will activate the local alarms and begin an automatic shutdown of the electrical equipment in the vicinity that is not rated for Class I, Division 2. The disconnecting means for the shutdown should be rated for Class I, Division 1 if located inside the vicinity. The disconnecting means may be rated at a lower level if it is located outside the affected area.

In order to prevent an accidental shutdown due to sensor failure, redundant sensors may be installed to provide continuous detection on the site. If the automatic disconnecting mechanism causes additional hazards, then the automated detection should not be used to lower the area class rating. In addition, if the area contains heated components that operate at 80% of the combustible temperature, then the gas detectors should not be used due to the lag between the initial deactivation of the equipment and the subsequent temperature loss.

API 500 requires that gas detectors be calibrated at least every 3 months by a known mixture of combustible gases. These sensors may implement bypass mechanisms to test the detection of the gas mixture without activating the automatic shutdown system. The bypass may only be used during testing maintenance and while qualified personnel are available to address a possible fugitive emission buildup. When the gas detection device is in bypass mode, it should be noticeable by an auditory or visible alarm to facility staff.

API 500

By combining these topics and using sound engineering judgment, the hazardous area extents can be defined for any gas plant configuration. API 500 provides several approaches for a designer or engineer to define the hazardous area and how to best specify the electrical equipment to be installed in it. However, since API 500 covers a broad list of industries, it provides limited details regarding gas utility processes. For a more specific look at how to address hazardous locations in gas utilities, you may choose to follow AGA XL1001, *Classification of Locations for Electrical Installations in Gas Utility Areas*.

Using AGA for Classified Areas

The AGA method for determining hazardous areas is very similar to that covered by API 500. The AGA's step-by-step approach uses three main factors to determine the existence, extents, and degree of the hazardous location: the flammability of the product, the likelihood of release and the size of the area of release.

Using the AGA Process

For AGA the first step in determining a hazardous area is to determine the flammability of the substances involved. For a natural gas processing facility, there are plenty of flammable substances since natural gas is made primarily of methane. However, depending on the processes, there may be other liquid hydrocarbons separated and stored in the area.

Once all the flammable substances in a process facility have been identified, their likelihood of release must be determined. For various flammable gases there are a variety of dispersion rates. Natural gas, which is lighter than air, will dissipate rapidly and therefore have a smaller impact area than other released hydrocarbons such as liquid propane. And while gases will have a relatively small impact area, flammable liquids, especially those with low vapor temperatures, may spill over a significant area before the liquids convert into a flammable vapor.

Finally, the release sites must be evaluated for whether release would be resultant of normal or abnormal operation. For AGA, an abnormal condition is defined as a case where standard protection can be applied to accidental release. AGA states that the release of a flammable substance on welded pipe is infrequent and does not need to be classified unless the area contains equipment such as flanges, fittings and valves. In addition, it is unnecessary to classify a location with a permanent ignition source. Direct-fired heaters would not be considered a point of release, however, pumps, valves and fuel lines should be considered and caution should be used for placing electrical equipment nearby. Finally, engine rooms do not need to be classified for the reason of that engine fuel lines are exempt.

In determining the extents of a classified area AGA uses many of the same metrics as API 500. For instance, both API 500 and AGA use the same definition and comparison of Division 1 and Division 2 that is found in the NEC. Additionally, AGA uses a more streamlined evaluation of an adequately ventilated area than API 500. However, AGA concurs with API 500 that a well ventilated area determination can lower an enclosure classification from Division 1 to Division 2.

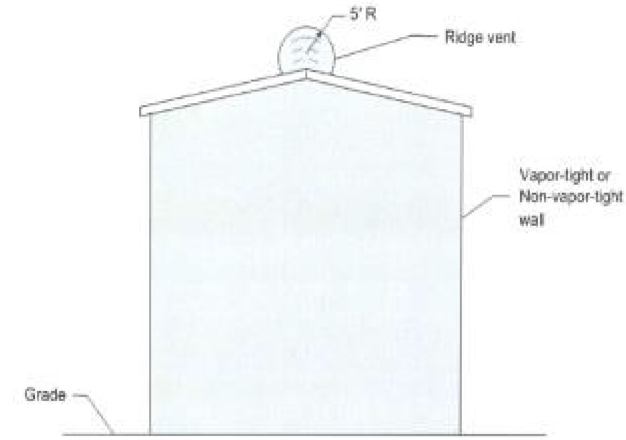

Figure 7 – Class I, Division 2 Enclosure (taken from AGA, Figure 6)

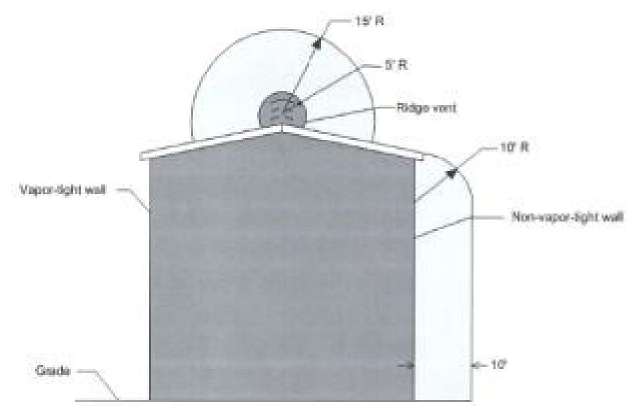

Figure 8 – Class I, Division 1 Enclosure (taken from AGA, Figure 7)

AGA Requirements for Ventilation

According to AGA, an enclosure is adequately ventilated if the air flow keeps the air-to-flammable substance mixture below 25% LEL. AGA applies the one cubic foot per minute per square foot of area criteria for enclosures with a floor area of up to 2,000 square feet. The air source for the ventilation shall be clean air and ventilation may be accomplished by either mechanical or natural means, with the air vented into an area with no possible ignition sources or with equipment rated for the possible release. Again, the ventilation should account for the type of flammable substance being vented; low vents and ventilated pits for heavier-than-air gases and high and roof vents for lighter-than-air gases.

Extent of Hazardous Area

AGA uses many of the same key points as API 500 with regards to hazardous area extents. First of all, the designer or engineer must determine whether a lighter- or heaver-than-air substance is being released and its position relative to the point of release. Once again, lighter-than-air gases are rarely found below the release point and heavier-than-air gases are rarely found above the release point. Additionally, without any outside stimulus the hazardous substance would disperse evenly in all directions from the point of release. This would create a spherical hazardous area centered on the release point.

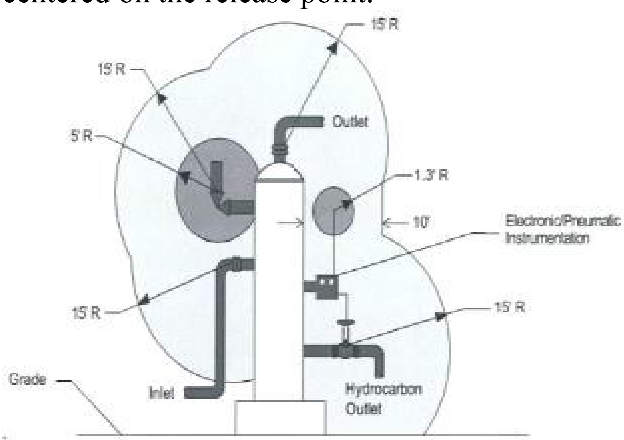

Figure 9 – Adequately Ventilated Non-Enclosed Area (taken from AGA, Figure 8)

AGA, like API 500, addresses the possibility of wind currents affecting the border of a hazardous area. Again, there is a negation that while light winds may extend the dispersion downstream high winds will cause the hazardous substance to disperse faster. Therefore, AGA calls for the Division 1 and Division 2 borders to be defined by experience and not the possibility of being affected by theoretical diffusion of hazardous gases.

Hazardous area borders may be limited by the presence of a vapor tight barrier. Vapor tight barriers may be used to limit the extents of a classified area and separate it from electrical equipment. AGA recommends that any pipe or conduit installed in the area go around the vapor tight barrier instead of through it, however, if it must be installed through the vapor tight barrier then it should be sealed in accordance with the NEC.

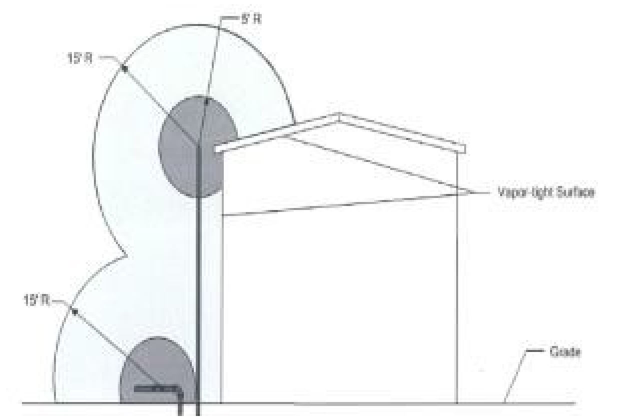

Figure 10 – Enclosed Area Adjacent To A Classified Area With A Vapor-Tight Wall (taken from AGA, Figure 28)

AGA

AGA uses a streamlined process to help designers and engineers determine the hazardous area for a natural gas processing facility. Using these guidelines they can establish an electrical hazardous area and mitigate possible risks.

The Southern California Gas Company

The Southern California Gas Company (SCG) takes a fairly conservative approach to hazardous area classification; the safety of our employees and customers is always the highest priority.

SCG applies hazardous area classification to a variety of possible sites. These include large commercial/industrial meter sets, pressure-limiting stations, compressor stations and storage fields. Common sources of hazardous substances in these locations include natural gas regulators, gas chromatographs, hydrocarbon storage tanks and natural gas vehicle filling stations. SGC uses the NEC, API 500 and AGA as well as its own standards in its engineering evaluation of the hazardous area.

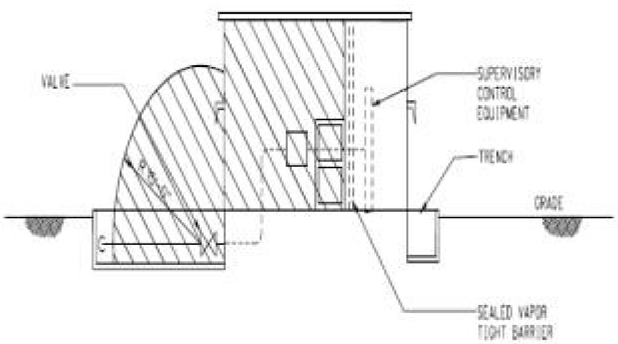

Figure 11 –Measurement Building

SCG defines a Class I, Division 1 area as an area where ignitable concentrations of gases or vapors may exist under normal operating conditions or ignitable concentrations of gases or vapors exist frequently because of repair, maintenance operations or because of leakage. It may also exist where a breakdown or faulty operation of equipment or processes would release ignitable concentrations of flammable gases or vapors and would also cause simultaneous failure of electric equipment. Examples of these locations are interiors of paint spray booths and the vicinity of spraying and painting operations where volatile, flammable solvents are used; open tanks or vats, compressed natural gas fueling dispensers, relief valves, etc.

SCG defines a Class I, Division 2 area as one where volatile flammable liquids or flammable gases are handled, processed or used but where the liquids, vapors or gases will normally be confined within closed containers or closed systems and where they can escape only in case of accidental rupture or breakdown. Division 2 locations are also defined as locations with ignitable concentrations of gases or vapors that are normally prevented by positive mechanical ventilation and which might become hazardous through failure or an abnormal operation of the ventilating equipment. Class I, Division 2 areas also include areas that are adjacent to Class I, Division 1 locations and to which ignitable concentrations of gases or vapors might occasionally be transported unless such transportation is prevented by adequate positive pressure ventilation from a source of clean air and effective safeguards against ventilation failure are provided.

In practical implementation, SCG defines a Division 1 area as a hazardous area with a five foot radius centering on either a relieve valve or process vent. Division 2 areas are identified as a hazardous area with a fifteen foot radius centering on a valve stem, flange or screwed pipe fitting connection. In addition, SCG also defines a Division 2 area as the vicinity adjacent to a Division 1 area. This Division 2 area extends an additional ten feet beyond the border of the initial 5 foot Division 1 radius. Additionally, any sumps or pits located in a Division 2 area are classified as Division 1 for all sections below grade.

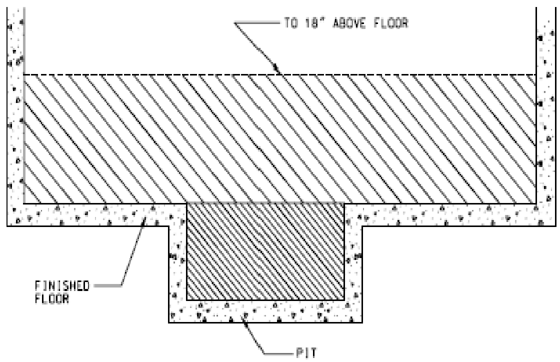

Figure 12 –Pit Without Ventilation

SCG requires that all electrical equipment permanently installed in a classified area be listed for Class I, Division 1 or Division 2 use by either Underwriters Laboratories (UL), Factory Mutual, or CSA. It should be noted that equipment rated for Division 1 may be placed in a Division 2 area; however, the reverse does not apply. If electrical equipment is not rated for the classified area that it is located in, than it shall be enclosed in a NEMA 7 enclosure. Conduits traveling from a classified area to an unclassified area shall be sealed at the boundary of the classified area where they transition to earth, connect to a rated enclosure or connect to rated equipment.

One area of special concern for SCG is hazardous areas for gas process vaults. SCG vaults that contain gas equipment shall be either Class 1, Division 1 or Division 2 depending upon the ventilation of the vault. Electrical conduits, cables and wiring in vaults containing gas equipment will conform to NEC 501-4. Requirements for electrical equipment in vaults containing gas equipment are dependent on the type of vault in which it is installed and will conform as follows: Covered non-ventilated vaults containing equipment such as relays, instrument transformers switches, resistors, rectifiers, thermionic (vacuum) tubes, etc., will be provided with enclosures that are approved for use in Class I, Division 1 locations.

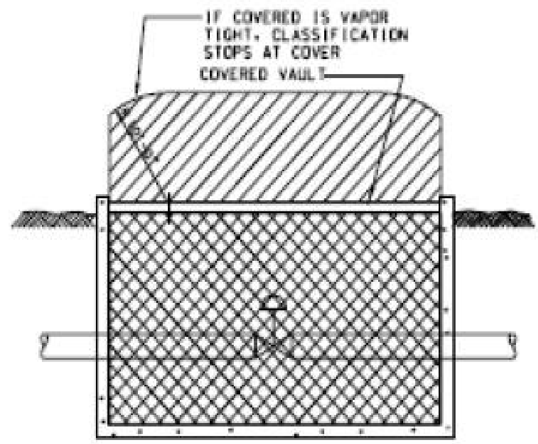

Figure 13 – Inadequately Ventilated Enclosed Vault

For open or adequately vented covered vaults electrical equipment will be permitted in general purpose type enclosures as specified by NEMA if it meets the following conditions: equipment does not have make-or-break or sliding contacts or switches, equipment is intrinsically safe (as defined by NEC) or equipment is separated from the power source by means of solid state approved energy limiting devices (barriers). Finally, the power source and barrier will be located in a non-hazardous location.

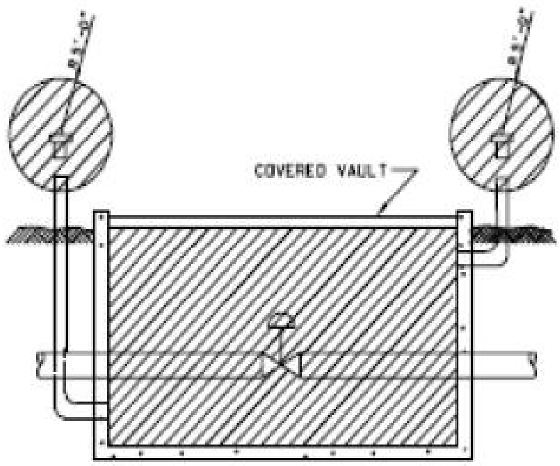

Figure 14 – Adequately Ventilated Enclosed Vault

Summary

Hazardous area classification is often considered a very divisive subject. With a good understanding of the engineering concepts laid out in API 500 and AGA, the engineer or designer for an electrical project in a gas process center can handle and mitigate possible risks. By clearly identifying hazardous areas as Class I, Division 1, Division 2 or unclassified, there can be a clear structure for how to develop and implement a sound engineering plan.

In addition, API 500 and AGA provide the engineer and designer several methodologies to safely address the possibility of lowering certain Division 1 locations to a Division 2 classification. With the proper implementation, this can be an important tool in lowering cost on a project and still maintaining a safe working environment for both employees and customers.

References

National Fire Protection Association 70: National Electric Code, 2017

American Petroleum Institute Recommended Practice 500; Third Edition, December 2012, *"Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Division 1 and Division 2"*

American Gas Association, Catalog # XL1001, Revised September 2010, *"Classification of Locations For Electrical Installation In Gas Utility Areas"*

Appendix A

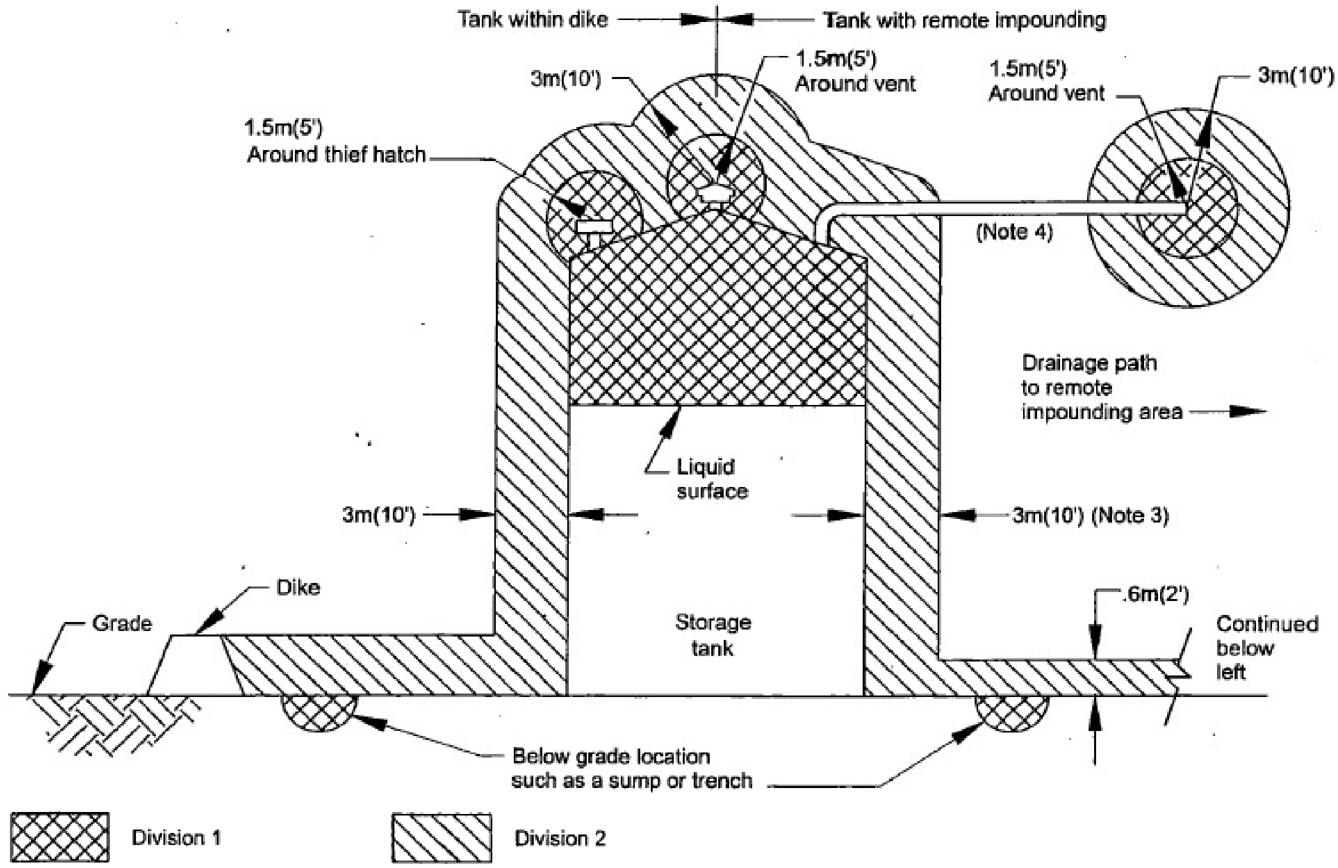

Figure 1 - Fixed Roof Flammable Liquid Storage Tank in a Non-enclosed Adequately Ventilated Area (taken from API 500, Figure 6) Example of Class I, Division 1 and 2 Boundaries for Liquid Storage Tank