Electrical Hazardous Area Classification Design as a Basis for Safer Operations

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Abstract — The use of Electrical Hazardous Area Classification drawings as a basis for communicating the degree and extent of explosive hazards within industrial facilities is explored. Existing occupational health and safety regulations are referenced to determine a link between operational activities and the use of electrical hazardous area classification drawings as a tool for hazard assessment and management. How the drawings may be used to improve worker safety in a process facility is discussed. A case study is presented.

Index Terms — Hazardous Area Classification, Hazardous Locations, Plant Safety, Occupational Health and Safety Legislation, Safety Education.

I. INTRODUCTION

Occupational health and safety (OH&S) regulations require that employers communicate the nature of the hazards that may exist in the workplace. This is especially important in locations where flammable or combustible materials are handled. Employees must be able to identify and assess the hazard in order to properly mitigate the hazard. This requires a standard means of communicating the nature of the hazard.

Electrical hazardous area classification drawings define the possible frequency and duration of flammable materials in quantities to pose a risk of ignition. They are primarily used to influence the selection and installation of electrical equipment. They can also be used as a means for communicating the potential explosion hazards associated with electrical and non-electrical operational activities. The drawings can be used as a tool for enhancing operational safety.

II. PURPOSE OF A HAZARDOUS AREA CLASSIFICATION DRAWING – HISTORICAL

Historically, the purpose of a hazardous area classification was to designate locations where flammable materials may be present and to determine the electrical protection and wiring methods suitable for the environment. The documentation was primarily referenced by the electrical installation codes and standards and was primarily used by electrical and instrumentation personnel for facility construction purposes. The documentation was seldom used by others outside of the electrical discipline as it was not referenced by other regulations, codes or standards.

III. OCCUPATIONAL HEALTH AND SAFETY LEGISLATION FOR HAZARDOUS LOCATIONS – AN OVERVIEW

Occupational health and safety is a prime concern for workers exposed to potentially explosive atmospheres. Many jurisdictions throughout the world have adopted regulations to ensure that these hazards are identified and communicated in the workplace. Over time it was recognized that the hazardous area classification design for a facility could provide valuable information in identifying workplace hazards. Many jurisdictions began to make references to the hazardous area classification design documentation as a basis for the hazard assessment process. The requirement to develop and maintain a hazardous area classification design was incorporated into OH&S regulations. The following are examples of such legislation.

A. Europe

Occupational health and safety in potentially explosive atmospheres is covered under Directive 1999/92/EC or more commonly known as the ATEX Directive 137 “Use” Directive. Article 7 of the directive requires employers to assess the risk associated with an explosive atmosphere existing in the workplace. Where explosive atmosphere may exist, they must be classified into “Zones” based on the frequency and duration of the occurrence. The employer is then obligated to create an “explosion protection document” that demonstrates that the explosion risks have been determined and assessed and that adequate measures have been taken to mitigate the hazard. This includes both electrical and non-electrical ignition sources. The employer has an obligation to train all workers with regards to explosion protection and incorporate a permitting system with written instructions for work in hazardous locations. Warning signs must be placed in locations where explosive atmospheres may occur.
B. UK

The Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) apply to all workers who may be exposed to the risk of fire and/or explosions in the workplace. DSEAR requires that the risks associated with dangerous substances be assessed, and eliminated or reduced. DSEAR requires that employers classify their installations into hazardous and non-hazardous areas. Where locations are deemed hazardous, they must be classified into zones. The results of the classification are then used to control the equipment installed and the work activities in locations where an explosive atmosphere may be present.

C. Canada

Occupational health and safety in Canada is covered under provincial jurisdiction and as such the legislation differs from province to province. Alberta, with its large oil and gas industry, has incorporated specific OH&S regulations related to fire and explosion hazards. Where a hazard assessment determines that flammable or combustible materials may be present in the workplace, the area must be classified into zones or divisions in accordance with Section 18 of the Canadian Electrical Code (CEC).

The hazardous area classification design must also be maintained over the life of the facility. OH&S regulations also require that hazardous locations be physically marked to warn workers of a potential fire and/or explosion hazard.

D. US

Worker safety in the United States is under federal jurisdiction and is covered under the Occupational Safety and Health Administration (OSHA) Act. OSHA Standard 29 CFR1910.307 for Hazardous (Classified) Locations requires all areas designated as hazardous locations be properly documented. This documentation shall be available to those authorized to design, install, inspect, maintain, or operate electric equipment in accordance with the National Electrical Code (NEC). OSHA does not reference the use of hazardous area classification drawings as a basis for regulating work activities in locations where an explosive atmosphere may exist.

IV. PURPOSE OF HAZARDOUS AREA CLASSIFICATION DRAWINGS – FOR DESIGN AND OPERATIONS

A. Design

Due to the alignment between occupational health and safety regulations and electrical code area classification requirements, the quality and use of hazardous area classification drawings have improved over time. Process engineers are increasingly involved in the classification of hazardous locations, resulting in greater definition of fluid properties and more appropriate area classifications. And while updates to area classification drawings may have been approached in a casual manner in the past, they are now handled with more rigor. The nature of today’s oil and gas facilities is such that modifications may be frequently made, ranging from small equipment additions to full facility expansions and debottlenecks. In this context, the hazardous area classification drawings may be used in conjunction with other design documents, such as layout and spacing guidelines, to specify new mechanical equipment that incorporates potential ignition sources.

B. Operations

The inclusion of area classification requirements and fire and explosion and fire hazard identification within health and safety regulations, supports the integration of these tools to ensure safe facility operations. Hazardous area classification drawings are based on facility process conditions, incorporating both steady state and process upset operations, and they take into account expected duration and boundaries of flammable gas atmospheres during normal operation. They can therefore be used to convey the degree and extent of explosion and fire hazards to facility personnel. Furthermore, they can be used to control potential non-electrical explosion and fire hazards in the same way they are used to manage electrical explosion and fire hazards. These hazards must be addressed and managed through the safe work permitting process. In effect, the hazardous area classification drawings become the basis for hot work permitting processes.

Hot work is defined as any process or activity that can act as a source of ignition when a flammable material is present. Regulations serve to outline not only what hot work is, but also what types of ignition sources need to be considered. Examples include welding or grinding work, introduction of fired heaters, use of portable electrical or electronic devices, and introduction of internal combustion engines (such as vehicles). Regulations also require the use of procedures and precautionary measures to prevent the ignition of flammable atmospheres that cannot be prevented, such as those released during operations and maintenance activities.

The hot work permitting process serves to assess hot work activities including ignition sources and flammable atmospheric hazards, and to outline the required mitigations. It involves planning discussions between operational and/or safety personnel, and the workers who will be performing the hot work. The hot work map and other operations documents are used as part of this planning process. Results of these assessments and required mitigations are recorded; work activities, scope, and duration are specified; and sign-offs are recorded on a document known as a hot work permit.

V. PROCESS FOR INCORPORATING THE USE OF ELECTRICAL CLASSIFICATION DRAWINGS FOR SAFE OPERATIONS

The evolution towards incorporating the hazardous area classification drawings into plant operations requires four key steps:

1) Support from senior management
2) Development of an education program for personnel
3) Development of a hot work map
4) Updates to the hot work permitting process
A. Support from Senior Management

The first key step in incorporating the concepts of hazardous area classification into plant operations is to obtain senior management support. This may seem self-evident; however, it is management that provides resources and a budget for such work. Even more importantly, they set the expectation for safe behaviour at site. Without their awareness, understanding, and support for the introduction of the area classification drawings as an operational tool, the attempt at change will be less successful.

B. Development of an Education Program for Personnel

Once management support has been obtained, an education program must be developed. Such a program must identify the current level of hazardous location knowledge at the facility, key curriculum components to be covered, the target audience(s) that will receive training, and how the trainees will be certified as trained and competent.

a) Curriculum Overview

In order to provide a comprehensive integration with operations, the curriculum should include information on the history of hazardous location classification as a design tool, and the regulatory requirements (electrical as well as occupational health and safety) that support its use by operations. Detailed information related to classification zones, the relative hazards in each zone, and how the classification is assigned must also be included, along with discussion of fluid properties and the fire triangle. Finally, in order to be effective for operations and maintenance personnel, the curriculum should discuss temporary situations that may introduce flammable vapours, such as bleeding, purging and breaking apart process lines. It must also discuss non-electrical sources of ignition, and how these can be controlled through the hot work permitting process.

Additional curriculum components should also be considered for electrical and engineering staff who work at the facility and provide day-to-day support to operations.

b) Certification of Personnel

Certification of personnel must be defined by the employer, and may include both specific training requirements and a hands-on practical component. The delivery and tracking of these components can be integrated with current corporate training programs, and tracked in a similar manner to other company training. Recertification timelines and requirements should also be considered.

C. Development of a Hot Work Map

The hot work map is a visual tool that is derived from the engineered hazardous area classification drawing. However, the boundaries shown on area classification drawings are based on very specific distances from equipment, and in the eyes of the operator or tradesman often fall in seemingly random places within the plant. While such specific boundaries make sense to the design engineer, they are not practical for plant operations and maintenance staff, and bring confusion to the work permitting process. Therefore, the hot work map boundaries must be extended beyond the electrical area classification so they better align with obvious physical boundaries such as roadways, fence lines, and skid edges. In addition, areas that routinely undergo maintenance work or have a high concentration of Pressure Safety Valves (PSVs) that could release flammable vapours, may also be included as hot work areas even if this exceeds the electrical area classification. In essence, the hot work map exceeds and simplifies the hazardous location drawing, and incorporates operations and maintenance knowledge of plant hazards. It should also be noted that the hot work map becomes increasingly important the bigger the plant site becomes, due to the complexity of the area classification and the evolution of inherent operations and maintenance hazards.

Various stakeholders need to be involved in developing and approving the hot work map, including engineering, operations, and safety personnel with various backgrounds and expertise. And, as the engineered hazardous area classification drawing is revised with time to time or operations and maintenance circumstances change, the hot work map must be adjusted accordingly. Since the hot work map is a derivative of the area classification drawing, it must be treated with the same rigor and follow the same numbering and drawing update process as other controlled documentation.

D. Hot Work Permitting Process

The hot work map is used as part of the hot work permitting process to convey the areas where fire and explosion hazards exist if an ignition source were introduced to the area. It improves the permitting process by providing a consistent reference point for all plant personnel for hot work permitting, thereby reducing interpretation errors and lowering the risks inherent with hot work activities. However, the hot work permitting process must also identify all temporary operating and maintenance conditions not shown on the map that may introduce flammables into the work area. Such activities include bleeding down piping and vessels, purging, ventilation of tanks and breaking apart process lines. It is imperative that plant personnel understand the limitations of the map, and also identify and manage these temporary hazards through the hot work permit.

The key aspects of the hot work permit process are as follows:

1) Use of area classification drawings in order to identify areas where flammable vapours may be present and how frequently
2) Identification of work activities that may temporarily introduce flammables to non-classified areas
3) Determination of the work location and types of potential ignition sources
4) Identification and implementation of required safeguards to prevent ignition

For normal and upset operational conditions, the area classification drawings (and related supporting detailed drawings) provide an easy-to-understand way of identifying where flammable vapours may occur and how frequently. As previously noted, special work activities or situations such as equipment blow down or purging, some types of maintenance work, or fluid spills may introduce flammable vapours in locations or to extents that are beyond the scope of the area classification drawings. These must still be addressed as per OH&S regulations; therefore, the hot work permit process should also identify these special situations, and communicate the hazards and requirements for the workers.

Next, the work scope defines the location where the work is going to be performed, along with what potential ignition sources are involved; for example vehicle entry, welding or grinding, or the use of a non-hazardous location rated laptop computer. If these potential ignition sources will be utilized in the classified area, or an area where a flammable atmosphere could exist due to operations or maintenance activities, then a hot work permit is required for these tasks.

Finally, any required mitigations are determined in order to reduce the likelihood of ignition of flammable vapours, and to reduce the severity if ignition should occur. Examples may include:

1) Monitoring the area for flammable vapours prior to and during the work activity, or as long as the potential ignition source is present
2) Use of body-worn, personal gas monitors
3) Restricting vehicle access to certain locations
4) Restricting use of portable electronic devices to those certified for the location, etc.

VI. CASE HISTORY EXAMPLE

A. Facility Background

Area classification and related Hot Work Map training was introduced to a large, 120,000 barrels of oil per day (BOPD) Steam-Assisted Gravity Drainage (SAGD) oil sands facility in northeastern Alberta, Canada. The primary reason for introducing this training was to increase the awareness of the hazards associated with handling flammable fluids in the process under normal and abnormal (upset or small leak) conditions in order to increase worker safety. Additionally, workers are also made aware of the potential for additional releases during plant maintenance or turnaround activities, plant upsets, or emergency blow downs.

During normal conditions, only very small, trace quantities of flammable vapours are released from fittings and components. Under normal conditions there are some areas of the plant where there are somewhat larger releases, especially around the hatches and vents of product or diluent storage tanks, and at truck loading facilities. The area classification methodology is very good at identifying locations where vapours can be present under these conditions, as well as during small upsets or leaks (abnormal conditions), but must be supplemented with awareness of the potential for larger scale releases from time to time, especially during special situations such as production tank servicing, equipment blow down for maintenance, operational purging, etc. Thus the full hazard awareness for the worker involves a knowledge of the hazardous area boundaries and definitions as well as awareness of other special conditions present in the plant at any point in time.

Figure 1 shows an example of the area classification detail for a typical production tank.
in other vessels, and are collected and used as fuel gas. These gases consist of methane plus other heavier hydrocarbons.

6) Toxic and flammable hydrogen sulphide gas is present through much of the process.

A summary of the flashpoint, flammable range, and relative densities of some of these materials is provided in Table 1 below.

Some of these materials are heated due to the steam heating in the reservoir, and/or by fired free water knockout and treater vessels. This heating increases the rate of gas or vapour release.

All of these various processes, materials, and operating conditions can lead to a wide variety of potential release sources and behaviours that the operations and maintenance personnel need to be aware of.

<table>
<thead>
<tr>
<th>Material</th>
<th>Flashpoint</th>
<th>LEL</th>
<th>AIT</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>-40°C</td>
<td>0.6%</td>
<td>223°C</td>
<td>HTA</td>
</tr>
<tr>
<td>Diluent</td>
<td>-40°C</td>
<td>0.8%</td>
<td>200°C</td>
<td>HTA</td>
</tr>
<tr>
<td>Produced Water</td>
<td>By Test</td>
<td>By Test</td>
<td>200°C</td>
<td>LTA/HTA</td>
</tr>
</tbody>
</table>

Table 1
Properties of Flammable Materials Handled Within the Process

B. The Hot Work Map

The hot work map, as previously described, has been developed for the main central plant site at this facility. It incorporates content from the area classification studies, area classification drawings, and other controlled regions identified by safety/operations where hot work or other procedures are required. This last category includes regions where the area classification boundaries are extended in order to simplify the boundaries of the controlled areas, identify controlled areas near flare stacks, identify areas with a high frequency of special operational or maintenance activities occurring that could cause releases, and identify any other special situations. Physical restrictions and notifications such as fences, gates, warning signs, and other controls are introduced in order to keep out unnecessary vehicle traffic, restrict welding/grinding activities, and restrict the introduction of fired or electrical ignition sources. All workers are guided by time-and-condition-bound safe work agreements that reference the boundaries and extent of the hot work map, in order to identify safe work procedures and controls in these controlled areas.

Figure 2 shows the hot work map for the facility involved in this case study.

C. Education Program

Course content was developed by the operating company and a third-party consultant. Several iterations were made in the course content to remove content that was too technical but still keep key facility information necessary for safety awareness. Two types of courses were developed. The first, the "operational training", is for the largest training audience: plant operations personnel with no formal training in this area. The second, "technical training", is for plant electrical and instrumentation technicians and other general engineering personnel. All workers are required to have the operational training, regardless of their technical background. The technical training was provided for maintenance and engineering staff only. Records of course completion and certifications are retained in a corporate database.

In order to rapidly introduce the course content across the staff associated with this operating facility, a classroom-based training approach was used. The operational training was delivered to more than 300 personnel over a 6-month period. The technical training is expected to be in the order of 100 personnel or less.

To help sustain the training for new personnel, an online version of the operational training is under development. This provides a reduced delivery cost per student, more flexible learning scheduling for the students, and convenient remote access to the course training materials.

In support of the classroom and online training, a series of 6-8 short professional video segments are being made in order to communicate the importance of the training, describe critical procedures (including emergency response procedures), and describe actual operating incidents that have occurred in the past at this facility. The incident videos do a very effective job of personalizing the training so the students become aware of actual hazards they may face day-to-day at this facility.

The videos provide the first-hand stories of the workers who were involved. These personal stories are very effective since many of the students personally know the individuals who were involved in the incidents; the students understand that "It just as easily could have been me!"

The operating company has other similar sites that will be required to have similar training, some of which will be site-specific (e.g. some of the procedures, incident stories, etc.).
is anticipated that further developments for other operating facilities will take two more years.

With the influx of new and inexperienced personnel in our workforce, many of whom have never been involved in a release event at a live facility, this training will provide them with lessons learned from those who have had experience with incidents. This will hopefully help them to respect the hazard and encourage them to follow proper procedures.

Additionally, several third-party videos have been introduced into the training. A very good source is the U.S. Chemical Safety Board (http://www.csb.gov/). Their videos and explanations dramatically portray actual incidents involving processes and equipment similar to those found at this operating company.

Smaller subsets of the main training have been developed for special purposes such as large scale/fast delivery turnaround crew training, or initial orientations for new workers. Condensed information sheets are provided to the students as takeaways from this training.

VII. CONCLUSION

This paper reviews how area classification drawings and methodology can be used to enhance workforce safety at operating facilities. Area classification drawings are used to help create a hot work map, which is used as a reference when completing hot work permits. Through management support, an extensive training and awareness program, and adjustments to the hot work permitting process, it is anticipated that workers will have greater awareness and respect for fire and explosion hazards associated with flammable fluids at operating facilities. This represents a new advance in application of the area classification methodology to not only protect workers through safe electrical designs, but also to increase the effectiveness of the hot work permitting process.

VIII. REFERENCES


IX. VITA

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