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Grid-based individual risk calculation in the classification of hazardous area with a risk-based approach

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ABSTRACT

The energy institute model code of safe practice, part15, 2005 (EI15) is one of the most widely-used practices in studies of hazardous area classification, which adopts a risk-based approach in order to determine the hole size of secondary grade sources of release (such as valves, flanges, and pumps). Employing an average parameter for the whole unit, the approach determines the number of effective release sources, affecting an individual in hazardous area, within its risk calculation. In case of high dissipation among the number of secondary grade sources of release in different locations of a plant, such an average value ends up overestimating the risk for hole sizes where there are few release sources or in case of places in which there are many release sources, it results in an underestimation of the risk. Therefore, this paper aims to propose a grid-based approach to calculate the exact value of the risk from secondary grade sources of release, in order to determine the accuracy of such a practice. In its risk calculations, the proposed approach uses the accurate number of effective secondary grade sources of release in each location of the plant, instead of an average number. For so doing, the hole sizes from secondary grade sources of release are calculated for a gas dehydration and dew point control of natural gas unit by means of EI15 approach for risk calculation. Afterwards it calculates the risk of the releases with different hole sizes by means of the grid-based approach on the intended unit, specifying the appropriate hole size for secondary grade sources of release in different areas of the intended unit. It then compares the results of zone 2 from both approaches, in turn measuring the error rate of EI15 approach as it determines the hole size of secondary grade sources of release. Eventually, it is proposed that utilizing multiple average values for the number of effective release sources in different parts of the unit will increase the precision of EI15.

1. Introduction

Hazardous Area Classification (HAC) divides the facility into areas, based on the probability of flammable gas cloud presence (IEC EN 60079-10-1, 2009). To minimize the sources of ignitions, where presence of flammable gas cloud is more probable, any potential ignition sources (electrical or non-electrical), employed in a classified hazardous area, must be suitable to use in the respective zone.

Several standards and codes provide information regarding HAC assessment. The EI model code of safe practice, part 15: Area classification code for installations handling flammable fluids (hereafter referred to as EI15) and standard IEC, 60079-10-1:2009 classify the zones based on the frequency of occurrence and persistence of the flammable atmosphere. The zones are defined in Table 1.

Based on EI15, one can determine the zone type knowing the grade of release and the degree of ventilation. Three grades of release are defined in terms of their occurrence frequency and duration:

Continuous grade release: A release that is continuous or nearly continuous, or that occurs frequently and for short periods of time.

Primary grade release: A release that is likely to occur periodically or occasionally in normal operation i.e. a release which, in operating procedures, is anticipated to occur.

Secondary grade release: A release that is unlikely to occur in normal operation and, in any event, will do so only infrequently and for short periods i.e. a release which, during the operating

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Table 1
Zone types description.

Zone 0	A Place in which a flammable atmosphere is present continuously or for long periods or frequently. (Examples: inside a closed vessel, near the liquid surface in an open vessel)
Zone 1	A Place in which a flammable atmosphere is likely to occur in normal operation occasionally. (Examples: Sample points, relief valves, drainage points)
Zone 2	A place in which a flammable atmosphere is not likely to occur in normal operation but, if it does occur, will persist for a short time only. (Examples: near flanges, pipe fittings, valve stems, pumps glands)

procedures, is not anticipated to occur. (Releases from potential release sources such as flanges, valves and pumps).

Under unrestricted ventilation condition continuous, primary and secondary grade releases will normally result in zone 0,1 and 2 respectively, but poor ventilation may result in more stringent zone.

Three different types and degrees of ventilation are defined as:

Open area: An outdoor area where the vapor is rapidly dispersed by wind and natural convection. Typically, air velocities will rarely be less than 0.5 and will frequently be above 2 m/s.

Sheltered or obstructed area: an area within or adjoining an open area where, as a result of obstruction, natural ventilation is restricted and less than true open area.

Enclosed area: any enclosed space within which, in the absence of artificial ventilation, the air movement will be limited and any flammable atmosphere will not be dispersed naturally.

Underestimation of HAC is a design error and shall be avoided; on the other hand its overestimation can be very expensive, so the accurate HAC could be a challenge.

1.1. Determining the hole size for secondary grade sources of release

Since the hole size might be of an unknown and variant quantity in case a secondary grade release occurrence, the EI15 with reference to EI A risk-based approach to hazardous area classification (1998) introduce a methodology to determine the hole size of these releases based on occurrence frequency. The aim of this methodology is to ascertain that the Individual Risk (IR) on the most exposed individual does not exceed the acceptable individual risk criterion from the accidental ignition of flammable substances. Based on a research by K J Glynn (1999), the acceptable risk criterion due to accidentally-ignited releases is 1.0E-5/yr, which is 10 percent of the total IR for a typical onshore plant worker (British Medical Association, 1990). In general this methodology specifies beyond which occurrence frequencies the release from each secondary grade source of release is not acceptable by the IR acceptance criteria, in which case the hazardous areas ought to be classified.

Historical failure data (Health and safety executive, 2005) show that for a given item of equipment the occurrence frequencies of small release holes are greater than the larger ones. Having been evaluated, these data are used in order to obtain the hole sizes, related to release frequency, calculated by the risk acceptance criteria. Thus the hole size, required for hazardous area classification surrounding secondary grade sources of release is determined.

1.2. Risk calculation method and release frequency determination

The basis of risk calculation in this methodology is a couple of equations which will be dealt with in the following.

The contribution of each secondary grade release source on the individual risk is defined as:

$$IR_{ignited\ release}\ (/\ \text{release source} - \text{yr.}) = F_{flam}(/\text{release source} - \text{yr.}) \times P_{ig} \times P_{occ} \times \text{V} \quad (1)$$

And the individual risk from a number of secondary grade release sources in zone 2 is defined as:

$$IR_{ignited\ release}\ (/\text{yr.}) = F_{flam}(/\text{release source} - \text{yr.}) \times P_{ig} \times P_{occ} \times \text{V} \times N_{range} \quad (2)$$

Table 2 briefly describes the parameters, existing in these two equations.

P_{ig}, P_{occ}, and N_{range} are calculated considering conditions of ignition sources in zone 2 boundary, the probability of the most exposed person's presence in hazardous area, and the time-weighted average of the number of effective release sources which affect the individual in hazardous area respectively. The vulnerability, required for hazardous area classification, is the vulnerability of the personnel inside the hazardous area to small ignited accidental releases. EI15 uses two approaches to calculate the individual's vulnerability: Analysis of the historical data, suggesting 0.012 fatalities/ignited incident (Cox et al., 1990), as well as synthesis approach, using conditional probabilities that measure the probability of the individual's vulnerability by means of the following formula.

$$V = P_{dirn} \times P_{fts} \quad (3)$$

where P_{dirn} is the probability of flame impingement of ignited release to the individual, equal to 0.1; and P_{fts}, and the probability of individual's failure to escape from ignited release, considered to be 0.1 as well.

Therefore, by means of this approach a vulnerability of 0.01 fatalities/accidental ignited release is calculated, which is very similar to the vulnerability of the previous approach. Eventually, by substituting the vulnerability of 0.01 fatalities/ignited incident for the acceptable risk criterion of 1.0E-5/yr in Equation (2), the maximum release frequency from each secondary grade source of release, acceptable to risk acceptance criterion will be obtained; in other words, this maximum value and releases with greater frequencies would not be acceptable by the acceptance criterion of risk anymore and they ought to undergo the classification of hazardous area.

Inside zone 2, there are always some secondary grade sources of release that affect the individual in a specific location, varying in their number as the individual moves within the hazardous area from one location to another. In Equation (2), this effect is quantified in N_{range}, a time-weighted average for the number of release sources that affect the individual while he is inside the hazardous area, i.e. it is taken into consideration that on average, the number of N_{range} sources of release has an impact on the individual within the hazardous area. It had been difficult to estimate this average value and there is always a possibility of error and inaccuracy when it is calculated by the associated expert. Additionally, the average for this important parameter might result in overestimation of risk and, consequently, hole size in locations with few sources of release as well as underestimation of the risk in locations with many sources of release. Such inaccuracy, especially in terms of