Session 13:

Hazardous Area Classification: The dangers of using standards for determination of hazard zones

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Abstract

There are many benefits to using standards to determine the hazard radius in hazardous area classification applications. By codifying existing knowledge they ensure rapid and timely delivery of required results. However, they suffer from a number of limitations - chief of which is a lack of specificity.

This paper discusses the pitfalls/challenges of using standards for establishing hazard radii and then discusses how they can be addressed by the use of detailed consequence modelling. A case study comparison of the two approaches is also outlined as well as the benefits of using a more targeted approach.

1. Introduction

Standards play a key role in hazardous area classification activities. In the particular case of determining hazard radii, they offer many benefits. By codifying existing knowledge they ensure rapid and timely delivery of required results. However, they suffer from a number of limitations - chief of which is a lack of specificity. Other challenges include the limited data coverage and potential for application to cases which are not relevant due to lack of knowledge of the underlying bases for the standard values.

This paper discusses the pitfalls/challenges of using standards for establishing hazard radii and then discusses how they can be addressed by the use of detailed consequence modelling. A case study comparison of the two approaches is also outlined as well as the benefits of using a more targeted approach.

This paper is organized as follows. This section introduces the subject matter and scope of the current work. The subsequent section (Section 2) offers a brief introduction to hazardous area classification and highlights determination of hazard radii as a key step in the process. Here, some of the challenges in using standards are brought to light. This is then followed by a summary outline of the two key approaches used to determine hazard radii including a comparison of both methods (Section 3). A case study to demonstrate the issues highlighted in the paper is the focus of Section 4. An extended discussion of the results achieved is also outlined here. Overall conclusions are given in Section 5. Literature sources consulted and referenced are detailed in Section 6.

2. What is Hazardous Area Classification?

Many definitions of what Hazardous Area Classification (HAC) is and what it aims to achieve are available in literature. A particularly useful one is that given by (Roberts, 2001) which states "Hazardous area classification requires that an assessment be made of the extent of the zone enclosing an operational area where flammable materials are handled and where small leaks might occur unnoticed for a short period of time. With this knowledge, precautionary steps can be taken to reduce the potential for ignition, for example by placing constraints on electrical installations". In this, two key considerations are brought into sharp focus. First, the definition of the extent of the zone (which is established by dispersion modelling). Second, the role this zone plays in decision making with the aim of ensuring safety. It is worth noting that the "extent of the zone" is synonymous with the "hazard radii". Other phrases such as "extent of classified locations" and "hazard zone" have also been used to capture the concept. In this paper, "Hazard radii" is used to express this notion. It is notable that in general, safety practitioners consider a hazard zone to be the area where an event may arise but also the affected area. For example the area into which thermal radiation may be experienced from a fire or where impulse or overpressure may be experienced from an explosion. In HAC we are seemingly concerned with only the flammable zone itself.

2.1 The Hazardous Area Classification process

There are many steps involved in the hazardous area classification process. Assessing the need for classification (an assessment of the material present, type, phase etc.), characterizing the nature and environment of the release (release frequency, ventilation etc.) and determination of the hazard radii are key steps in the process. The methods by which the extent of the zones is determined form the subject matter of this paper. Particular emphasis is placed on how that is performed for outdoor locations or locations with a similar ventilation profile (as opposed to enclosed areas such as buildings or partially enclosed structures).

That is not to say that the other steps are not important; indeed they are as they will have an influence the results of this step. The current reason for this emphasis is simply that this output of the process forms the key basis upon which decisions are made and mitigating actions are taken. There are also significant practical consequences (both safety and economic) associated with the zone definition. Wrongly defined zones (too small) can have disastrous impacts in terms of safety. Larger sized zones (beyond that needed to provide a margin safety) results in excessive expenditure with no commensurate safety benefit.

3. Establishing Hazard Radii: Approaches

Approaches for establishing hazard radii fall into two broad categories: the use of standards and other such codified knowledge and detailed modelling (also called the Source of Hazard, SoH, approach (Cox, Lees and Ang, 1990 or the Point Source method (API 505, 2013). These can be described as occupying opposite ends of a scale. The former involves using "looking up" hazard radii data (often codified in standards) based on some key input data. Examples of such look up data can be found in API 505, BS EN 60079-10-1:2009, IGEM/SR/25. The latter as the name suggests involves determination of the hazard radii via scientific modelling, often via the use of specialist consequence modelling software.

Opinions and perspectives vary on what methodology should be adopted and on the whole the views occupy a spectrum from strong advocates on one hand to vehement detractors on the other; not forgetting the various shades of opinion that occupy the middle belt. Advocates of the “standards” approach argue that by leveraging existing work it eliminates the need for rework and thus offers an efficient, speedy, consistent and readily actionable way to facilitate HAC. By codifying knowledge, standards also reduce the requisite technical expertise requirement for practitioners. A particularly striking contention offered by this group is that the results of a detailed approach (considered to be time and resource heavy in comparison) are not so disparate from using a general approach i.e. a general approach will suffice, and as a consequence, it is a huge expense for little return.

Opponents point to the many methodical challenges associated with it. They maintain that it lacks specificity and does not address particular issues (e.g. non-traditional materials, weather conditions and the like). It is difficult to ascertain if the prevailing context applies to the case at hand. It does not offer the possibility to take into account specific engineered safety measures designed to reduce risk. They generally only address pure compounds and not mixtures (API 505, Section D.5.1). Standards are not updated frequently resulting in a lag between the modelling technology and the data contained therein. Above all, they are largely designed to be deliberately conservative due to their generic nature which has the attendant consequence of excessive cost for what they perceive to be for little or no benefit.

The preponderance of available standards (often disparate and conflicting) on this issue available also provides challenges in their practical application. The first is a problem of knowing which standard to use. The second is that the results achieved using the various standards often differ and often appreciably. Inconsistencies have been observed and reported by many practitioners familiar with the subject. Evidence to support this view is provided in Table 1.

Table 1 Variation in hazard radii for a LPG pump given by selected standards and codes (Data reproduced from Cox, Lees and Ang, 1990)

Standard	Hazard Radii	% difference
ICI/RoSPA	21	100% (Anchor)
Health and Safety Executive CS5: LPG (UK)	10	-53%
CPP: LPG (France)	7	-69%
Det Norske Veritas (Norway)	16	-25%
SS 421 08 20 (Sweden)	7	-69%
API 500 (US)	7	-69%

NFPA 30 (US)	11	-50%
BCI (West Germany)	21	100%

The overall upshot of the above is that the standards approach gives a low level of assurance regarding the results and that there must be a better way.

The source of hazard approach is offered as the solution to the deficiencies of the standards approach. It not only addresses the limitations identified above but by ensuring a dedicated and targeted focus it forces the practitioner to be more critical and reflective and pay attention to the details of the case. The method ensures specific details are accounted for – fluid properties, operating conditions, weather conditions etc. as opposed to being based on generalizations. Additionally, as only specific as opposed to generic leak sources are identified, potential changes in leak sources are captured.

The key differences between the two approaches are shown in Table 2.

Table 2: Comparison of the standards and detailed approach to determination of hazard radii.

Methodology	Standards Approach	Detailed Approach
Generic		
Ability to reflect specific engineered safety measures designed to reduce risk	No	Yes
Can be applied to all leak sizes and fluid categories[1]	No	Yes
Level of requisite technical expertise needed[2]	Low	High
Effort required	Low	High
Considered conservative	Yes	Variable
Time required[2]	Low	High
Ability to reflect prevailing weather conditions	No	Yes
Ability to assess the sensitivity of the results	No	Yes

[1]NB the details given are relative to one another and not absolute. [2]The tables cannot cater to every possible situation; hence there are limits to the applicability of the data contained therein. For cases outside these limits, specific modelling is required.

Advances in modern technology have largely addressed or severely mitigated the criticisms of the detailed approach, particularly those related to the amount of effort required. Software programs are smarter and are capable of running numerous combinations and permutations of scenarios in a relatively short period of time. They also produce the results is a readily accessible format (e.g. with composite radii drawn) thus negating the need for further manipulation.

The calculation speed has also been significantly reduced over time for complex calculations by developments in computing power.

4. Case Study

A simple case study comparing the output from both methods has been conducted to shed a light on the issues raised above. The key preliminary steps here were to 1) Identify a HAC scenario to be used as a basis for comparison and 2) Select the standard and software model to be used.

In terms of standards, EI15 (Table C9a) (EI 2005) was selected on the basis that it amongst one of the widely known and referenced codes in this area. In terms of software models, the Phast software package (version 7.11) was selected. It is widely used in the industry for analysis of this type and thus was considered to be an ideal choice. Phast is a free-field dispersion tool so its application fits nicely with the key focus of this paper i.e. open releases or releases in non-enclosed areas.

The selected scenario is a range of leak sizes from an equipment item containing LPG. The specifications of the scenario are outlined in Table 3. In selecting the scenario, particular attention was given to the fact that the selected standard (EI15) did include some case information otherwise a comparison would be impossible. It is noted that there is some variability in the prevailing atmospheric temperature whilst other variables remain constant.

Table 3: Modelling input parameters for selected case study scenario

Characteristic	Value
Material type	LPG (70/30)[1]
Ambient Temperature, (°C)	-20, 0, 20, 30, 40
Storage and Process temperature, (°C)	30
Process Pressure, (bar(a))	100
Hole sizes considered, (mm)	1, 2, 5, 10
Release Direction	Horizontal
Release height, (m)	5
Surface Roughness length, (m)	0.03
Wind Speed (m/s)	2
Stability Class	D

[1] This is consistent with EI15 fluid category A, an LPG like fluid with composition is given as molar 70 % Propane, 30% Butane.

4.1 Results

The results acquired using both methods are shown in Table 4. This shows the Hazard Distance R1 for the various combinations of leak hole size and ambient temperature.

Table 4: Hazard Distance R1; release height 5m (10 bara)

Release Hole Diameter, R_1	EI 15 30°C	Phast -20°C	Phast 0°C	Phast 20°C	Phast 30°C	Phast 40°C
1mm	2.5	2.39	2.49	2.59	2.63	2.67
2mm	4	4.17	4.35	4.57	4.68	4.77
5mm	9	8.09	8.45	8.99	9.29	9.54
10mm	16	12.71	13.22	14.17	14.74	15.25

4.2 Discussion

Speed of acquiring data

As expected, finding the requisite results was much quicker using EI15. This simply involved looking up certain numbers in the data tables. That said, in contrast, the time taken to define, calculate and extract the results from Phast was of the order of 10 minutes for an experienced user.

Data Availability

Review of the calculation basis for the data presented in EI15 indicates they are based on an ambient temperature of 30°C. Consequently, this standard could not be used to ascertain hazard distances for all temperature conditions outlined for the scenario in Table 3. This highlights a key limitation in the use of standards, namely that their scope is limited and they cannot address all foreseeable scenarios and conditions.

Comparison of EI Data versus Modelling Results

In general, good agreement was observed between the modelled results and the data from EI15 which is reassuring. Some differences exist though. Phast predicts an 8% shorter hazard distance versus EI15 for the 10mm hole size. Phast predicts a 17% larger hazard distance versus EI15 for the 2mm hole size. The average variation shows that Phast predicts a 4% larger distance than EI15 for this case; however as is shown in Table 4, the results differ from case to case for those cases that can be compared. The range of comparison is shown in Figure 1.

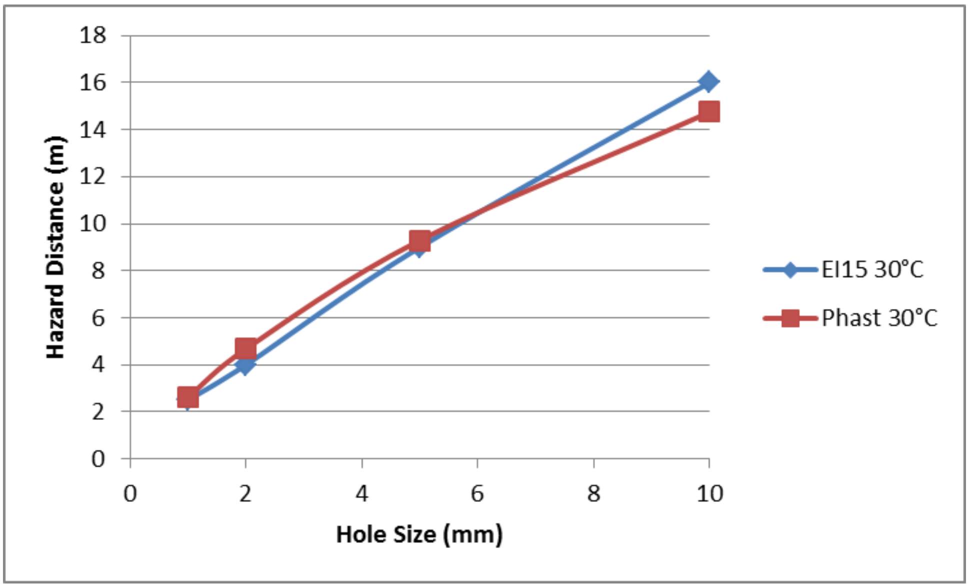

Figure 1 - Comparison of EI15 versus Phast for 30°C ambient temperature cases

Impact of Temperature on Hazard Radii

In the above example, changes in ambient temperature are seen to have a marked effect on the predicted hazard radii. In particular, lower ambient temperatures result in lower hazard radii. The data in EI 15 assumes a reference temperature of 30 °C. The trend appears to be more visible with the larger hole sizes as the 5 and 10mm holes give higher % reductions than the smaller hole sizes (1 and 2 mm). The most significant reduction (of circa 20% versus the EI values) is seen with the 10mm hole size. This has significant implication for applying these standards to the classification of facilities which can experience temperatures much colder than the adopted basis used in the standard.

It is evident from this case study that modelling has the ability to asses more variable dimensions than lookup tables and monograms typical to standards can feasibly provide. In our case study we have varied release hole sizes for the EI15 cases and have varied release hole sizes and weather conditions for the Phast cases. As discussed above we may also wish to vary storage pressure, storage temperature, mixture composition, release direction. It becomes very difficult to represent these lines of enquiry with pre-made results in standards and lookup tables. The 3-dimentional results (hole size, temperature, hazard distance) from Table 4 are represented in Figure 2. The x axis represents the release hole size, the y axis represents the hazard distance and the size of the point represents the ambient temperature. The EI5 cases are shown in orange and the collections of Phast cases for each hole size are shown in blue with their range of ambient temperatures indicated by the diameter of the circle of each result.

Extending this multi-dimensional problem further, it would become difficult to represent 4 and 5 dimensional variations in inputs and results and therefore a model offers a way to answer a question at a time from a multi-dimensional set, rather than the more limited variable world of standards.

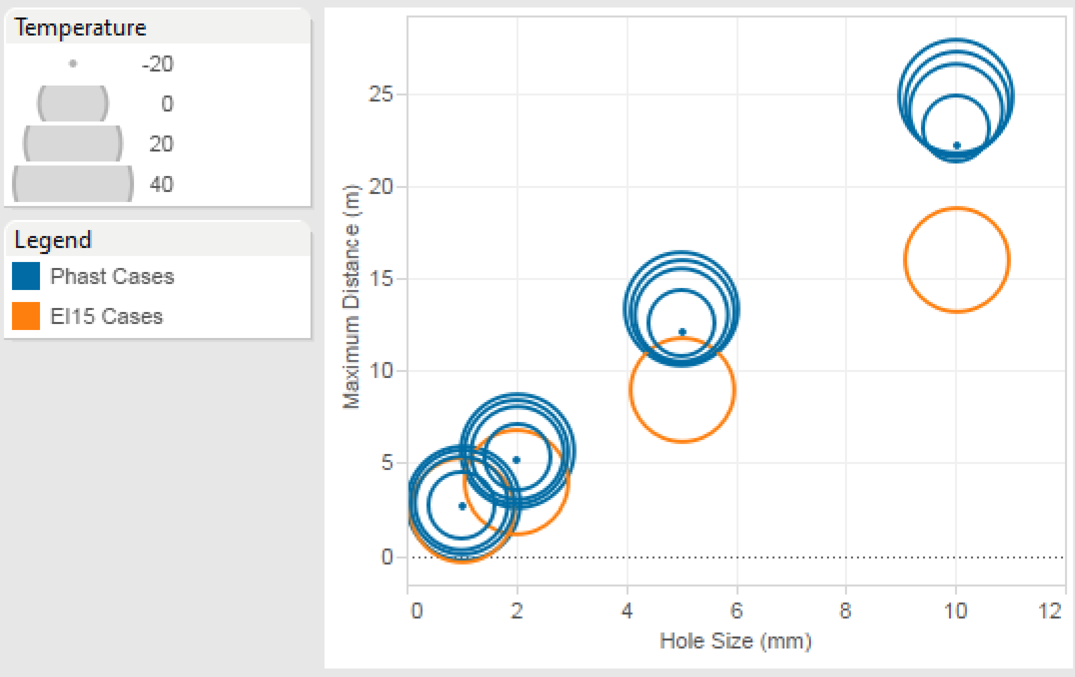

Figure 2 - Hole Size, Hazard Distance and Ambient Temperature 3-D scatter plot

General

The above findings are not new. It is well known that various factors have an influence on discharge and dispersion results. Factors such as fluid composition, prevailing ambient conditions, discharge orifice, averaging time, and concentration of interest are known to have an impact. In the context of hazardous area classification, similar considerations were the primary drivers for some follow on work to IP15 to assess the sensitivity effects of parameters on dispersion characteristics (EI, 2008). The limited scope of coverage of the data in standards is also a known issue.

As a result, EI15 repeatedly highlights the need to undertake specific dispersion modelling for situations that depart significantly from the scope it covers. Specific issues highlighted include: the need to account for actual process fluids and the specifics pertaining to the drain/sample points, venting conditions and secondary grade releases (which are accidental and hence unknown as opposed to primary and continuous releases which are foreseeable and hence designed for).

Generally, standards such as EI15 come with such warnings. The challenge is that the warnings are overlooked amongst the wealth of information provided. For example, most API standards are prefaced with a page of “special notes” that detail such information as how the standard should be used, the need to ensure relevance to the case at hand, the fact that standards generally address matters of a generic nature and should not be used for specific situations, that work places and operational procedures may differ and above all the need to apply sound engineering judgment in ascertaining the situations under which the standard should be utilized. That these provisos are often located in different areas of the document does not particularly help the situation.

Another issue stems from the lack of practitioners adopting a critical and sceptical perspective with respect to such documents. Time pressures in the working environment create as well as exacerbate this issue. A further issue is that every standard has a context and is naturally limited to the state of knowledge that was obtained when it was produced. Hence standards are by default “backward looking”.

The issue here is more to do with how we see the standards than the standards themselves. They should not be seen as immutable, inviolate in a gospel like manner, but rather treated as general guidance that is likely not applicable to your scenario unless you can confirm that it is. They should be the starting point for discourse/debate and subject to rigorous introspection, critical examination, and treated with care each time they are used. An assessment of the quality of fit between the context and the local context should always be executed. If such a view is to be taken when using standards, the overheard involved in their application increases and the balance of cost-benefit that can be observed in Table 2 needs to be rebalanced.

This is not to diminish or disparage in any way the great effort that has and continues to be expended in developing these standards. Quite the contrary, such criticisms are central for improvement. It is the belief of the authors that the more standards that are available, the better the support for industry and the better safety for workers, the public, the environment and society at large. The value of standards is particularly apparent in geographies and areas of industry that lack resources and are knowledge poor. The contribution standards have made to keeping people safe cannot be overstated. Yet, without criticality by industry at large this success is at risk. Our systems are becoming increasingly complex and thus opaque and detailed analysis can reveal otherwise hidden information.

5. Conclusions

The key question is not whether one approach is better or worse than the other but rather understanding that there is intrinsic value associated with either and the challenge is in knowing what to select and apply under what conditions. The use of engineering judgement is key in this regard. Judgement is required to ascertain when the data in the standards will suffice or additional modelling is required.

In sum, both views are helpful to a degree. The reality is that there are situations where either method will be best applied. The key element is to identify this. A simple guideline is that standards work well where standard technology is being employed and not so well for novel cases. For example, Floating Liquefied Natural Gas (FLNG). But these represent two broad extremes. There will be a broad middle ground where the technologies are some combination of standard and novel. In such cases, using the standards (in a relatively conservative way, or multiple standards to test for agreement) as a first pass to ascertain whether there is an issue or not is a useful approach. This can then be followed by a more detailed look.

The fact that all scenarios cannot be done in detail does not mean that none should be looked at all. The more detail applied to a number of identified high risk scenarios can help to increase the level of assurance regarding the output using the standards.

Modelling in itself is not a panacea. It has uncertainties, can be applied wrongly, models have limitations (e.g. zero wind speed or calm conditions).

Differences in models used can also result in challenges. Model simplifications should not be ignored. Models are of course approximations of reality. Applicability to near field is also in question.

6. References

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