AREA CLASSIFICATION AS A TOOL FOR RISK ASSESSMENT

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Hazardous area classification identifies locations where flammable atmospheres can exist on process plant. It has long been used as part of the procedure for specifying suitably protected electrical equipment. Over time the method has broadened from defining so-called "flameproof" areas to its present form in which it is implicit that other ignition sources (e.g. hot work, static electricity) are also controlled. Future European legislation will broaden the practice further to encompass explicitly the control of all ignition sources.

One often overlooked aspect of a classification exercise is the potential to reduce the size and relax the zone designation of the hazardous areas. Ideally, this should be done before the hazardous areas are finalised. However, the sources of release and their potential size or frequency are often accepted as unchangeable. Moreover, the process does not examine the consequences of an ignition. With these limitations, we believe that the full potential of hazardous area classification is not being used.

This paper proposes an extension to the structured approach of hazardous area classification in order, firstly, to assess the risk of the coincidence of ignition sources and flammable atmospheres and secondly to examine the consequences of such an ignition. In other words the exercise can be used to point the way to controlling flammable atmospheres as well as ignition sources. If neither can be sufficiently controlled, then explosion protection or other means to reduce the risk to an acceptable level can be chosen.

Keywords: Risk assessment, area classification, explosion prevention

INTRODUCTION

Hazardous area classification, is a simple, structured means of assessing risks and assigning appropriate preventive measures to one particular industrial hazard: the ignition of flammable atmospheres by electrical equipment. This is achieved by dividing a plant into three types of hazardous areas; the remainder being designated as non-hazardous. The areas are assigned according to the probability of causing a flammable mixture. Electrical equipment that is designed to prevent ignition to different levels of integrity is then specified for the different areas.

It is often referred to simply as area classification or electrical zoning. We shall use the term hazardous area classification (HAC) throughout this text.

The need for preventing electrical apparatus from being an ignition source was first recognised in the coal mining industry in the early part of this century. From this the first

standard (BS229:1929) on flameproof equipment was developed. It is from this background that the misnomer of "flameproof" areas has arisen.

Over the years, other means of protection of greater and lesser integrity were devised. Concurrently, the need to define the areas where this apparatus could be used was broadened from a simple two zone system with a "dangerous" and a "safe" area to the present "three zone" system. The three zone system in fact implies a fourth zone designated as non-hazardous.

AREA CLASSIFICATION PROCEDURE

An essential part of our methodology involves (but is not limited to) the complete implementation of the current HAC procedure. Although it is well documented in literature such as Cox *et al* (1), BS 5345 (2), IP Part 15 (3) and BS EN 60079-10 (4), it is worth summarising the procedure as a half-hearted use of HAC will severely limit the usefulness of the resulting risk assessment.

A flow chart summarising the procedure is shown in Figure 1.

Firstly, flammability data of the materials should be obtained. For pure gases and vapours, this is a straightforward process as these properties are well documented in the literature, e.g. (2), NFPA 325M (5). For mixtures of two or more materials, there may be no alternative to laboratory tests. This is also the case with powders capable of forming flammable dust clouds as the flammability properties can be influenced by particle shape and size distribution, moisture content and even age of the material.

The next step is to identify sources of release of flammable material. In a lot of industries, the wording of this is somewhat confusing. The idea of release of material arises from large-scale continuous process industries where the aim tends to be to contain gases and liquids. In other industries, such as pharmaceutical and small-scale batch chemical manufacture, handling in drums and bags together with the use of open vessels means that flammable atmospheres are created in and around the equipment in normal operation. It is perhaps more convenient there to talk about identifying the potential flammable atmospheres themselves.

After the potential releases have been identified, the spread of the flammable atmosphere should be determined. This can be done from first principles with great difficulty as some statistical analysis relating to factors such as wind direction, plant geometry etc. have to be taken into account. Happily, some guidance has been published in (3), ICI/RoSPA (6) where the extent of zones for different commonly encountered situations have been suggested. These zone sizes are derived from calculations and experimental evidence. For situations not covered by the guidance, published dispersion equations (1) can be used.

The grade (or probability) of release then has to be assigned. The release may be continuous (or for long periods), primary in which a release may occur periodically or occasionally during normal operation and secondary in which it is not expected to occur, but if it does so if will be infrequent and for short periods. Note that some factors will influence the duration of the flammable atmosphere. For example if a secondary release occurs in a

poorly ventilated area it may persist for long periods and the area may become a zone 1 or even a zone 0 instead of a zone 2.

The hard work is now done. All that remains is to assign the relevant zone number to the different grades of release, as shown in Figure 1.

Hazardous area classification for dusts follows a very similar procedure, though current practice in the UK is to assign only two zones, Z for primary releases and Y for secondary releases. This will undoubtedly change to a three zone system paralleling the system for gases and vapours once the new European standards are published. Nevertheless, some important differences between dusts and gases exist with corresponding differences in the detail of the procedure. These differences take account of factors such as settling to form dust layers and thermal decomposition.

LIMITATIONS OF HAC

Hazardous area classification is a very limited exercise. Some of the limitations are inherent to its objectives as stated in the various standards and codes of practice. However, a blinkered implementation of the procedures can limit the practice still further (presumably) beyond the intention of the authors of the official guidance.

Perceived limitations

As HAC relates to electrical equipment, it is carried out more often than some other risk assessment techniques because it is seen as a legal requirement. In fact the only legal onus (in the UK) is to maintain a safe system of work and to control ignition sources where flammable atmospheres could occur. Hazardous area classification is merely a tool that facilitates the observance of these requirements. In some other countries, HAC is more rigorously enshrined in national and local legislation.

Thus, HAC is often seen as a costly exercise that has to be carried out rather than a beneficial study of the plant. Moreover, guidelines may often be followed blindly without consideration for the implications of the results. The reason for this may not just be a perceived time saving but also an attempt to move responsibility for the decision-making onto the authors of the guidance.

For example, we are often asked about the legal status of out of print guidance such as the ICI/RoSPA guide (7). In truth, it never had a legal status and the decision as to whether to use such guidance (much, though not all of it is still valid) rests with those responsible for the HAC study.

Another consequence of the narrow approach is that "blanket" zones are often applied. This means identifying the worst releases and then classifying the whole of that section of plant as one zone appropriate to the worst release to be "on the safe side". While there is nothing wrong with over-specifying equipment for reasons such as site standardisation, spares availability and playing safe, the opportunity to examine the releases of flammable atmospheres in more detail has been lost.

Such detailed examination may identify procedures where a modification to operational procedures or equipment may be used to alter the designation of the zone. Making the zone smaller would not have much effect on electrical equipment if a minimum electrical standard is applied. Nor would increasing the zone number if another zone in the vicinity has a lower one. However, reducing the frequency and/or extent of a release clearly leads to a reduced risk of explosion.

One other aspect that is not often given due attention is that the HAC has to change if modifications to procedures or plant are made. As some of the modifications (especially the way procedures are interpreted) may not be documented, it is important that the HAC is revisited periodically, even when no revisions are thought to be required.

Limitations of available guidance

This is a recurring issue in the UK as the British Standard (previously (2), but also the current (4)) gives little practical guidance. Moreover, the widely used ICI/RoSPA guide is out of print and some of its guidance is obsolete. These issues are not really the subject of this paper. However, some brief observations may be useful.

Another difficulty arises from the fact that the different guides give very different zone designations and extent for supposedly similar sources of release. This is dramatically illustrated by some examples in (1). One of the reasons for this is that the some of the guides are meant to cover different industries and consequently different materials and operating practices. One of the most recently published UK codes of practice is (3) which comprehensively covers the petroleum industry. However, its guidance is hardly suited to pharmaceutical production.

Where guidance does not exist, BS 5345 and BS EN 60079-10 instruct the reader to use dispersion equations and some are provided in (1). However, many users encounter difficulties with using dispersion equations as some knowledge of the thermodynamic and fluid properties of the material are required. This is especially the case with complex mixtures. This problem is mitigated to some extent as the petrochemical industry is one of the largest handlers of mixtures and has the most comprehensive guidance in the UK.

Nevertheless, the available guidance, and in particular, the dispersion equations are a useful tool in extending HAC into the realms of a more general risk assessment.

Inherent limitations

These are the limitations that we are addressing. The others (above) are mentioned in the hope of increasing the awareness of the usefulness of the standard HAC procedure. Nevertheless, there is no point in addressing the inherent limitations until the full scope of the existing procedures has been realised.

Until now, the focus of HAC has been on the specification of electrical apparatus. Nevertheless, the standards do address other issues in passing. Reference (2) has an appendix on the risk of thermite sparks. It also mentions the need for controlling hot work such as welding and brazing. Reference (7) on electrostatic ignition hazards recommends precautions

against such hazards to be observed in hazardous areas. Reference (4) mentions in a note that the standard "may be used with judgement for other ignition sources".

Hazardous area classification cannot be used sensibly when there are unavoidable ignition sources present. Examples of this would be hot surfaces on an industrial gas turbine or the flame on flash point testing apparatus in a laboratory. In both these instances a powerful ignition source is present. In the first, a flammable atmosphere should only exist due to leakage or malfunction and would therefore be a secondary release. In the second, a primary release exists as flammable material is handled in open containers as a normal procedure.

An everyday example is a petrol station. It is clearly impracticable to eliminate all ignition sources here. The more wayward ones such as lighted cigarettes are banned but unlike on a chemical plant, this ban is difficult to enforce and one has to hope that common sense will prevail!

Hazardous area classification does not consider catastrophic failure. This is partly because it is often assumed that a large release of flammable material will eventually find an ignition source somewhere. However, by applying the principles of HAC to the assessment of a catastrophic release, a large part of the risk assessment work will have been completed.

Finally, HAC does not examine the consequences of an ignition. Originally BS 5345:Part 2 limited the scope of HAC to more than 50 l of flammable material. It is not clear whether this meant 50 l of liquid or vapour. However, 50 l of gas could produce a stoichiometric flammable mixture in air of around 1000 l. If ignited, this would cause a fireball about 3.5 m in diameter. Alternatively, in a room 10 m square and 5 m high (500 m^3) this would cause an overpressure of 0.016 bar (1600 Pa). This would be sufficient to break windows and cause the collapse of many typical brick walls. Clearly the consequences of an explosion of the vapour from 50 l of liquid would be far more severe.

An amendment in 1989 changed the wording to exclude situations where "the total quantity of flammable material available for release is small", without defining what is meant by small. A consideration of the consequences of an ignition might be an appropriate means of defining a "small quantity".

BS EN 60079-10 explicitly does not take into account the effects of consequential damage, but it requires to classify hazardous areas where "the quantity of flammable material is capable of producing a dangerous volume of explosive gas atmosphere".

EXTENDING THE HAC PROCEDURE

In extending the HAC procedure, the scope of HAC is stretched a bit to formalise some of the aspects that the engineer should be applying anyway.

The Additional Steps

The approach starts with the rigorous application of the HAC procedure up to the point where the grades of release are assigned (Point A in Figure 1).

Table 1: Ignition sources possible on chemical plant

- flames (open fire) and hot gases
- hot surfaces
- electrical installations and equipment
- static electricity
- lightning
- mechanical sparks and welding sparks
- chemical reactions
- adiabatic compression, shock waves, flowing gases
- optical radiation
- HF electromagnetic radiation
- ionising radiation
- ultrasound
- stray current

Once a flammable atmosphere has been identified, the question should be asked as to whether it can be reduced, both in extent and frequency. At this point the need for and cost of this reduction should be judged. In simple situations, where the costs are small, a decision can be made at this stage. In more complicated circumstances further examination may be necessary.

Part of this more detailed analysis is the assessment of all possible ignition sources. It is useful to make this assessment anyway so it could be carried out in parallel with the assessment of flammable atmospheres. This is illustrated on the upper part of Figure 2.

Clearly, it does not make sense to consider only electrical ignition sources when others exist too. Table 1 lists all the ignition sources that might exist. All these should be considered when assessing fire and explosion hazards on a plant.

Some of these may not be powerful enough. With gases and vapours, the chances are all of them are potential ignition sources. With dusts that are insensitive to ignition, many of these will not be applicable.

As a grade of release is applied to the flammable atmospheres, it is logical to apply a similar approach to the ignition sources, though we propose four defined grades. In common with some other qualitative risk assessment methods, this is amenable to a matrix approach as shown in Table 2. The matrix is designed to assist with judging the acceptability (or otherwise) of a given situation.

Some of implications of a combination are obvious, in particular the continuous flammable atmosphere and ignition source. Others arise from the standards on the specification of electrical equipment. For example, it is very unlikely that correctly maintained intrinsically safe (Ex ia, ib) equipment will cause an ignition, though the integrity required for Ex ib equipment is not as rigorous as for Ex ia apparatus.

Table 2: HAC-based risk assessment matrix

Grade of Ignition

Grade of release	Continuous	Frequent	Infrequent	Very infrequent
Continuous	Explosion!	Unacceptable	Unacceptable unless low consequences	Acceptable (e.g. Ex ia apparatus)
Primary	Unacceptable	Unacceptable	Risk assessment required - look at consequences	Acceptable (e.g. Ex d apparatus)
Secondary	Risk assessment required - look at consequences but probably unacceptable	Risk assessment required - look at consequences	Acceptable (e.g. Ex N apparatus)	Acceptable
Non-hazardous	Acceptable but examine catastrophic releases	Acceptable but examine catastrophic releases	Acceptable	Acceptable

Where the need for a risk assessment is required, it may be concluded that explosion protection is needed. However, if the demand rate on the protection system is high, production will suffer. In this case, more rigorous prevention measures will be required - effectively moving towards the bottom right hand corner of the matrix.

The stages in the process where these additional decisions are made are shown in the lower part of Figure 2. Once measures have been taken to control ignition sources and flammable atmospheres, with application of explosion protection where necessary, the standard HAC procedure should be resumed after Point A in Figure 1.

Applying The Procedure

Flammable atmospheres may spread into areas identified as "non-hazardous" after a catastrophic release. It is not practical to control ignition sources in all areas that could be subject to such releases. However, by identifying the location, unnecessary ignition sources can be controlled.

The dispersion calculations used for hazardous area classification can be used for moderately sized "catastrophic" releases. In other words, while a flange leak may be deemed to be within the remit of the HAC exercise, a full-bore rupture may not but could still be applied to the dispersion calculations. Large releases due to major vessel failures, BLEVEs etc. are not applicable to the HAC dispersion calculations and are well covered with other tools.

If the study indicates that there are locations along the middle diagonal of the matrix, then the consequences of an ignition should be considered. This can be done very simply to

a first approximation. A confined explosion of an approximately stoichiometric mixture will generate a pressure of seven to eight times the starting (absolute) pressure. Likewise, if the combustion products are released (e.g. through an explosion vent) they will occupy seven to eight times the initial volume at atmospheric conditions. A similar calculation can be done for dust explosions except that the pressure (or expansion) will be increased by a factor of ten instead of eight.

The resulting pressure and heat effects on surrounding structures can then be assessed and preventive or protective action taken as judged necessary.

As an example, consider the evaporation of a circular pool of ethanol in a ventilated room. Using equation 12.13 from (1), and ventilation equations given in (4), the result in Table 3 can be found.

With a stoichiometric mixture a fireball of 2.4m diameter could result, or if enclosed in the room described previously, could cause an overpressure of 1400 Pa.

In most instances where personnel could be present, such an event would be unacceptable unless the frequency of it occurring can be reduced to very low levels. Referring to Table 2, this would probably mean controlling the grade of ignition to "infrequent" or "very infrequent" if the release could be of primary or continuous grade. If this is not possible then further preventive or protective measures will be required.

Another example of how the techniques could be applied would be a jet leak from a tank. If the dispersion equations reveal that this jet impinges or is close to an adjacent tank, and the risk of ignition is high, then it is likely hat the situation would be unacceptable. This judgement could be made by reference to Table 2 or by a more involved approach such as Quantitative Risk Assessment (QRA) for example.

Table 3. Example of evaporation from a pool of ethanol

Surface area of pool	10	m^2
Pool temperature	15	°C
Vapour pressure	4280	Pa
Vapour density	1.95	kg/m^3
Air velocity	0.1	m/s
Evaporation rate	**0.31**	g/s
Ventilation efficiency factor*	2	
Air change rate	20	h^{-1}
Lower explosion limit	3.3	%
Stoichiometric concentration	6.5	%
Volume of mixture at LEL	**1.71**	m^3
Volume of Stoichiometric mixture	**0.87**	m^3

*   The ventilation efficiency factor in (4) is inverse of factor quoted in NFPA 69 (8)

For many types of tank fire protection along with a depressurising system would be appropriate. A straightforward HAC study, concentrating on electrical installations, would not necessarily have identified this need.

In the above example, the ready-made zone diagrams in the published guides could have be used instead of the dispersion equations, though with less rigour. As we have discussed above, different guides can give very different answers. Therefore the results from the risk assessment should be treated with appropriate caution and preferably should be checked against a rough dispersion calculation.

CONCLUSIONS

What we are proposing is more a logical extension of the HAC methodology rather than a radical new way of thinking. Indeed, it is likely that forthcoming European legislation such as the so-called ATEX 118a directive will be along similar lines. We see no reason to delay though. Hazardous area classification is an expensive exercise. One way to make it more cost-effective is to extend the methodology in the manner described. The potential savings in electrical equipment, better plant layouts, inherently safer plant and, ultimately, less fires and explosions should outweigh the small extra effort required when carrying out the HAC study.

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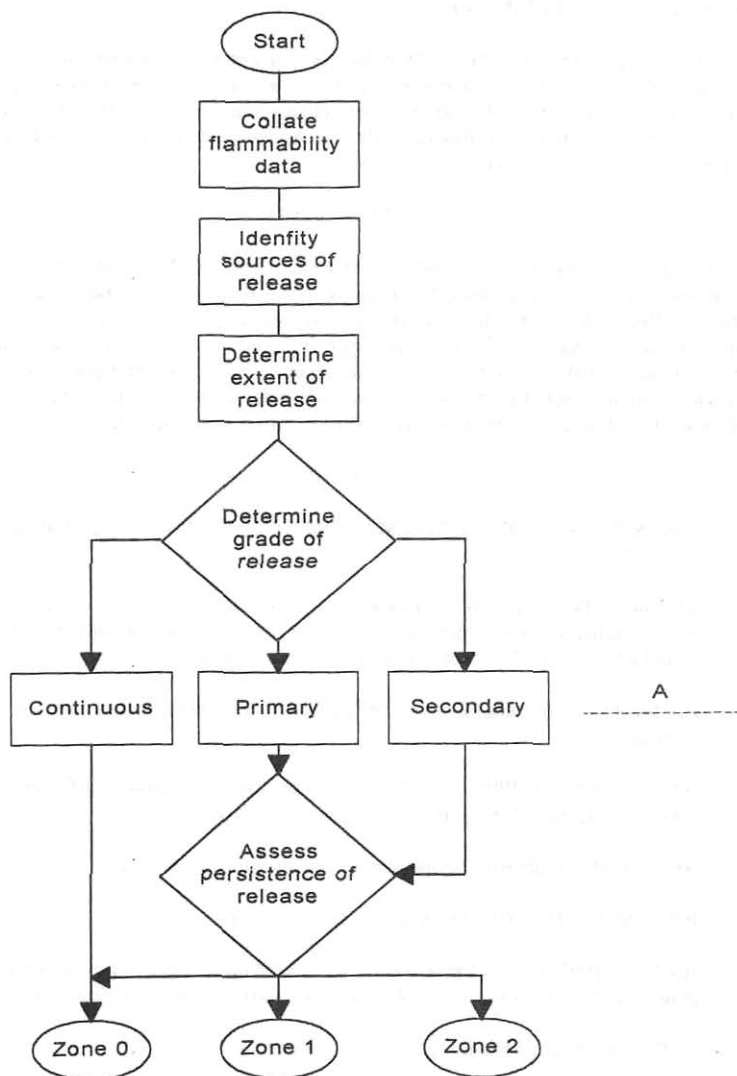
Figure 1: Procedure for hazardous area classification

Figure 2: Extended procedure for HAC-based risk assessment