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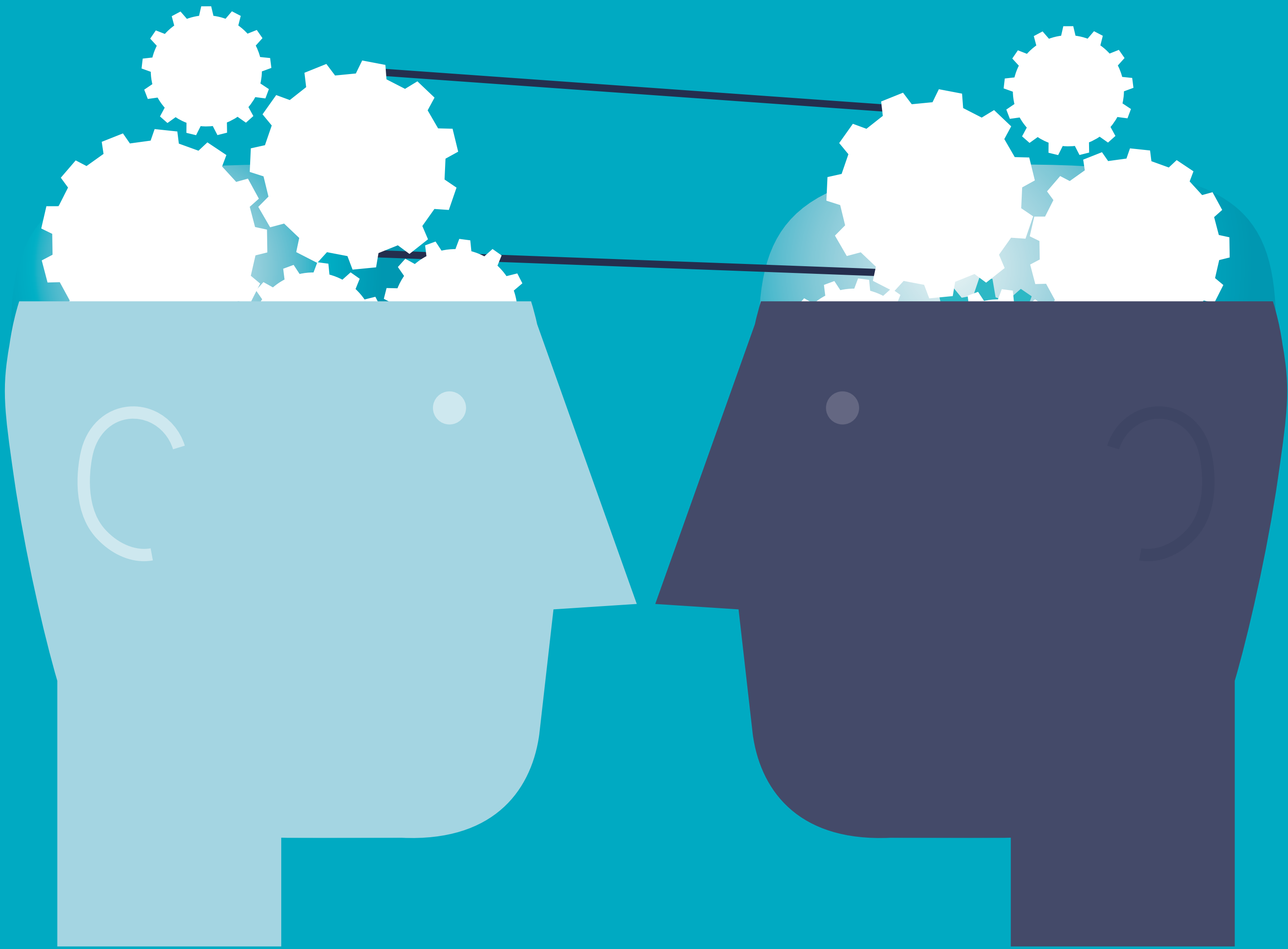

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Fatal flaws?

Process safety consultant **Keith Plumb** highlights some fundamental problems with hazardous area classification for dusts

DUST explosions can be deadly, delivering tragic consequences caused by what many of us consider are benign products such as sugar or aluminium dust. Dispersed into the air, however, and given a source of ignition, we have seen these products level production facilities, as happened at a UK wood mill in Bosley earlier this year, killing four members of staff.

Having reviewed the measures designed to prevent explosive dust atmospheres from forming, I am concerned they are fundamentally flawed.

For instance, in many countries there is a legal requirement to carry out a 'hazardous area classification' (HAC) where there is an expectation that an explosive atmosphere could occur. In the EU this requirement is covered by Directive 1999/92/EC, which is frequently referred to as the ATEX 137 Directive. I will simply refer to it as the Directive for the rest of the article.

However, as I will explain, the measures for HAC do not require a formal risk assessment or provide a basis for assessing whether the selected equipment requires further protection measures. Furthermore, it does not consider the inventory of the combustible dust, the level of confinement, the likely power of an explosion, the number of people working in the vicinity of the equipment or its location.

That's a lot of flaws.

explosive atmospheres definition is too narrow

The first flaw is that the Directive only covers explosive atmospheres within the following range:

1) Temperature –20°C to +60°C;

2) Pressure 80 kPa to 110 kPa; and

3) Air with a normal oxygen content, ie ~21%

It does not take much process knowledge to know that there are plenty of processes that operate outside this range. An explosive atmosphere including air with only ~21% oxygen is limiting since many processes include an oxygen concentration over a very wide range. It also ignores oxidants such as chlorine.

This limit encourages flawed thinking since it suggests that mixtures with a concentration less than 21% are not hazardous, which is not true. Mixtures of dust in air will remain explosive down to the limiting oxygen concentration which typically ranges from 5–15% depending on the dust. This can occur when working with reactions that generate non-combustible gases or use non-combustible solvents.

Left: 14 people were killed and 42 injured at a dust explosion at the Georgia sugar refinery, US, in 2008.

little emphasis on the 3 Rs: replace, reduce and refine

You might expect that measures aimed at classifying hazardous areas and reducing the risk of dust explosions would require us to:

1) **Replace** - replace the combustible dust(s) with other dust(s) that are not combustible, or if this is not possible;
2) **Reduce** - reduce the inventory of the material or replace some or all of the materials with materials that are less hazardous, or if this is not possible;
3) **Refine** - refine the process to make it less hazardous eg by eliminating a dust dispersal process.

But this is not always the case. The international standard on classification of areas in relation to explosive dust atmospheres is IEC 60079-10-2 (*see Figure 1*). It does not require us to consider the three Rs. The Directive is arguably less flawed as it requires the employer to take measures to prevent the formation of explosive atmospheres. Furthermore, the UK version of the Directive incorporated into the Dangerous Substance and Explosive Atmospheres Regulations (DSEAR) places a strong emphasis on replacement and reduction but not so much on refinement.

A recent flash fire at a US Ink facility[5] shows how important the three Rs can be. US Ink had a facility with an unnecessarily high inventory of combustible carbon black and a complex pneumatic conveying system. The US Chemical Safety Board (CSB) in its investigation report places most of its emphasis on following US National Fire Protection Agency (NFPA) guidance and not on reducing the inventory of dust or refining the process to make it less hazardous. Whilst the NFPA guidance cited is based on good engineering practice, in my opinion the CSB would have given a much stronger message on risk reduction had they focussed much more on the three Rs.

The measures for HAC doesn't require a formal risk assessment or provide a basis for assessing whether the selected equipment requires further protection measures. It does not consider the inventory of the combustible dust, the level of confinement, the likely power of an explosion, the number of people working in the vicinity of the equipment or its location. That's a lot of flaws.

Figure 1: what is hazardous area classification for dusts?

HAC is covered by a number of international standards but one that is particularly relevant is IEC 60079-10-2 since this is recognised by the 162 members of the International Standards Organisation (ISO).

It offers the following definition: "This standard adopts the concept, similar to that used for flammable gases and vapour, of using area classification to give an assessment of *the likelihood of an explosive dust atmosphere occurring*." The last part of this definition in italics is the important part.

The classification procedure includes three steps that require the identification of the following:

1) If any the materials being used are combustible and determining the materials characteristics;
2) Where the combustible material(s) is/are used; and
3) The likelihood that an explosive dust cloud can be generated.

The likelihood of an explosive dust closed being generated is divided into three grades of 'release':

1) **Continuous** – exists continuously or for long periods or for short periods that exist frequently;
2) **Primary** – occur periodically or occasionally during normal operation; and
3) **Secondary** – not expected to occur in normal operation and if it does occur, is likely to do so infrequently and for short periods.

These grades of release notionally lead to an equivalent hazardous area or zone ie continuous grade of releases gives a zone 20, primary zone 21 and secondary zone 22.

inside and outside equipment

Another weakness is the thinking required when it comes to the equipment itself. The approach to hazardous area classification was originally aimed at the selection of electrical equipment; NFPA 499 is still based on this requirement. However, there is little electrical equipment with the exception of instrumentation inside process equipment, which means that the traditional emphasis has been on the outside of equipment.

Now that non-electrical equipment is covered by the IEC standards, and many dust handling processes including pneumatic conveying, milling, drying, and mixing can create an explosive dust cloud, it has become clear that considering the inside of equipment is as important, if not more important, than the outside.

The regulations, standards and guidance use the concept of a 'source of release'. The Directive refers to, "Any escape and/or release...of...combustible dusts". Similarly IEC 60079-10-1 and NFPA 499 frequently refer to a 'source of release.'

Although the Directive, IEC 60079-10-1 and NFPA 499 do contain references to the formation of explosive dust clouds inside equipment, none of them specifically states the need to consider the much wider concept of any dispersion that can create an explosive dust atmosphere.

In my opinion this is a fundamental flaw and a much more useful concept for HAC is 'sources of dispersion' which covers all of the mechanisms for forming an explosive atmosphere both inside and outside equipment.

'Sources of release' include leaks from equipment joints or dust generated by open processing. 'Sources of dispersion' include these but also include dust generated by contained processes such as pneumatic conveying, milling, blending and gravity charging of hoppers.

hazardous area classification drawings

The Directive states that an explosion protection document should be produced to demonstrate which areas are classified as hazardous zones. This is usually interpreted to mean that drawings should be created to show the extent of the hazardous zones. IEC 60079-10-2 and NFPA 499 show typical hazardous zones on plan and elevation drawings.

However, since these drawings were

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Left and top right: Further photographs reveal the extent of the damage to the Georgia sugar refinery; bottom right, a dust explosion killed six people, injured dozens, and destroyed the West Pharmaceutical Services plant in North Carolina, US, in 2003.

traditionally considered to only be relevant to electrical equipment (and still are in NFPA 499) they often only show hazardous zones on the outside of equipment. This approach means that the hazardous zones inside equipment which are likely to be the most hazardous are not shown on the drawing. Without this record there is a significant risk that these classified areas will be overlooked during any future modifications.

Furthermore, IEC 60079-10-2 and NFPA 499 do not give any clear guidance on the size of zones, this seems to be a fundamental flaw. NFPA 499 does give some indicative simple calculations but I am sure that more detailed calculations indicating the likely size of zones would help to provide more meaningful zone sizes.

level of ventilation

Ventilation is not formally considered in IEC 60079-10-2 (unlike the comparable gas standard). However, this is a key oversight, as ventilation has an impact in three areas. Firstly, the use of local extract ventilation reduces the quantity of dust in the extracted space so could conceivably downgrade the classification from a zone 20 to a zone 21 (*see Figure 1*). On the other hand the extracted dust will now be concentrated in the dust collection unit where the risk of an explosion can be high.

Secondly, general ventilation can also reduce the quantity of dust in the extracted space and for small quantities of dust may prevent an explosive dust cloud forming at all. General ventilation may also be helpful with housekeeping.

Thirdly, fluctuating ventilation such as natural ventilation created by the wind may be helpful in reducing the quantity of dust in an area but it may also create explosive dust clouds where housekeeping is poor and layers of powder can be raised up into a dust cloud.

Blanket zoning is not good engineering practice because it does not encourage the team carrying out the classification to give sufficient thought to reducing the risk.

blanket zoning

When designing facilities it is common practice to provide blanket zoning to allow for uncertainty and future proofing. To some extent this is encouraged by IEC 60079-10-2 and NFPA 499 because they suggest the edge of zone 22 may be the walls of a room or other containing structure.

In my opinion, blanket zoning is not good engineering practice because it does not encourage the team carrying out the classification to give sufficient thought to reducing the risk. It also implies that it is acceptable to have operating staff working in an area where there is risk that in the event of explosion they could be engulfed in the resulting flames.

housekeeping

Good housekeeping is perhaps the most important tool we can use to minimise the risk of dust explosions as it minimises the volume of combustible dust and the consequences of an explosion.

Poor housekeeping, however, creates layers of dust that will act as a source of easily dispersed combustible material. If dispersed by a small primary explosion this can quickly lead to a much larger secondary dust explosion. Also, dust layers that form on the top of equipment can be heated and act as a source of ignition.

IEC 60079-10-2 defines three levels of housekeeping: good, fair and poor. In the case of poor housekeeping, it suggests that this should be taken into account in the HAC. In my opinion this approach does not sit well with the rest of the HAC procedure and housekeeping would be much better addressed as part of a formal dust explosion risk assessment.

selection of equipment

Once a hazardous zone has been identified the next step is to select equipment that has an inherent risk of becoming a source of ignition commensurate with the zone identified. So equipment for use in a zone 20 must have a very low risk of becoming a source of ignition. This selection procedure focuses on electrical equipment and non-electrical (generally mechanical) equipment that includes their own potential source of ignition. This ignores three important sources of ignition: process sources, including static electricity; cleaning procedures; and maintenance procedures. This is another fundamental flaw.

Also, the logic behind this selection is that the event that causes a dust cloud to form is independent of the event that leads to an ignition source becoming active. This is probably true for electrical equipment, less so for non-electrical equipment and could be completely wrong for an electrostatic spark where the creation of the dust cloud could also create the spark.

residual risk and consequences

Finally, HAC is not a formal risk assessment. Having selected the equipment for the zones we now see it does not provide a method for us to assess if the basis of safety is adequate or if further protection measures, such as explosion venting, are required.

Furthermore, HAC does not consider the consequences of explosion since it does not consider the inventory of the combustible dust, the level of confinement, the likely power of an explosion, the number of people working in the vicinity of the equipment or the location of the equipment.

conclusions

Taken altogether, we can see the approach to HAC embodied in regulations and standards is fundamentally flawed. It contains a very simplistic approach to equipment selection based solely on the hazardous area classification, and does not include a full assessment of all of the sources of ignition. Also it does not consider the consequences of an explosion.

On top of this it does not include a rigorous approach to consider the requirement to replace, reduce and refine. This means that methods of protection against dust explosion are also frequently fundamentally flawed.

I would recommend that all users of combustible dust carry out full formal risk assessments. For full details of an approach to a formal risk assessment readers can register for IChemE's upcoming series of webinars on the topic. **tce**

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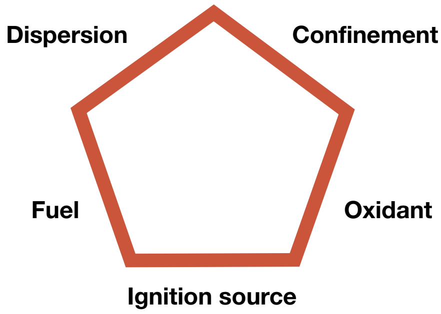

Figure 2 – The explosion pentagon. An explosion cannot occur without all five faces of the pentagon being present. A flash fire will occur without confinement. A fire can occur without confinement or dispersion.

Chemical Engineering Matters

The topics discussed in this article refer to the following lines on the vistas of IChemE's technical strategy document *Chemical Engineering Matters*:

Energy *Line 24*

Food and nutrition *Lines 9–10*

Health and wellbeing *Lines 8–9, 11–14, 18*

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