

HAZOP FOR DUST HANDLING PLANTS: A USEFUL TOOL OR A SLEDGEHAMMER TO CRACK A NUT?

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The HAZOP technique was developed by ICI during the 1960s, and has been refined and codified extensively since then, and applied well outside the chemical industry. In ICI, HAZOP was one of six stages of study - from initial design to beneficial operation. It was generally applied when the design was virtually complete and was intended to mop up outstanding safety issues and expose potential operability and maintainability issues. A top-down study usually preceded the HAZOP to expose the most significant potential hazards when it was still possible to modify the design before retrospective changes incurred extra costs. However, HAZOP has comparatively rarely been applied to the powder handling industries, and the intention of this paper is to explore the reasons, and the circumstances in which it perhaps ought to be more widely used.

Choosing the right guide words is important at the outset of a HAZOP study, and there are different lists commonly used for batch type processes, and continuous processes. The powder handling industries have plenty of examples of both types of operation. Examples of essentially continuous processes include flour milling; chipboard manufacture milk spray drying and sewage sludge drying. Batch type operations are commonly found in places which blend different components, such as animal feed mills, and bakeries, and also at the beginning of many processes where powders are brought to site in road tanker loads or introduced to the process from sacks and IBCs. Many sites will have activities of each type. The standard guideword lists might need to be refined at the outset of a study, but this should create no difficulties.

The origins of HAZOP go back to complex chemical plant, which may have chemical and physical processes going on simultaneously, recycle streams and phase changes, together with large amounts of heat being input or withdrawn from the process. In contrast plants handling dry powders are very rarely designed to carry out any form of chemical process, few will have recycle loops, and many run at or close to ambient temperature. Where there are no chemical reactions, serious risks such as exothermic runaways, release of gases, causing the wrong reaction by adding an incorrect component or in the wrong amount, boilovers caused by overheating or loss of mixing in a two phase system are not an issue.

If there is no recycle requirement, some complexities are avoided, and if there is no need to add or remove heat, another major source of problems is eliminated. Put bluntly, most powder handling plants in places which handle food or bulk polymers as powders look like very simple operations to engineers used to designing or running chemical processes.

Powder handling plants do however often have some common hazardous features that can often be avoided in the gas and liquid type of processes for which the HAZOP study was developed. In particular a key example is the extent to which flammable atmospheres are inevitably formed inside the process equipment. Most continuous processes using flammable liquids and gases are designed to exclude air as far as possible, e.g. continuous processes running above atmospheric pressure. Batch processes may be provided with an inert gas blanket to achieve the same aim, while large tanks for flammable liquids may have a floating roof for the same purpose.

The situation is different with powders. The commonest operation run above atmospheric pressure is pneumatic conveying, and this nearly always uses air. Somewhere in the system a flammable atmosphere is bound to form, not only during continuous running, but perhaps at different locations during start up or shut down. Furthermore, many processes are far from completely enclosed, making inerting an unattractive option, and this is not likely to change as long as low value materials are handled.

Adding to the problem, is difficulty of excluding ignition sources from many processes. Sometimes these arise directly from the product or powder itself, which may gradually self heat in the presence of air until at some point flaming combustion is possible. Milk powder and many vegetable products containing unsaturated oils are prone to this phenomenon.

Just as common is the presence of mechanical ignition sources. Static clumps of powder in contact with moving parts in a screw conveyor or mill are liable to get hotter through frictional processes. Better design of the process or equipment can reduce this problem, but it cannot be eliminated.

A third ignition source that can be hard to exclude is static where the powder is highly insulating, since any movement of the powder will generate charge. The methods of avoiding this are often simple, but lack of attention to detail of earthing has caused many incidents.

Faced with the widespread extent of flammable atmospheres inside the process, many dust handling plants are designed on the basis that sooner or later, an ignition source is likely to arise, and we must cater for the consequences of an ignition. The widely adopted techniques of explosion venting and suppression are in effect an admission that explosion prevention cannot be achieved. This is backed up by explosion isolation, which is a recognition that flammable atmospheres or at least the powder and air components that have the potential to create a flammable atmosphere can spread far through a system and make it very vulnerable to extensive damage far from the site of ignition. This approach is set out in the I Chem E book on dust explosion prevention and protection, which discusses the choice of a basis of safety, limiting these effectively to venting, suppression, inerting or control of ignition sources. There is no reference here to the use of the HAZOP tool.

From the point of view of the HAZOP study carried out to assist in designing a safe plant, it might be argued that there is no need to go looking for all the process deviations that might cause a hazard, if we have designed all the parts of the plant to cope with the worst case event, i.e. the ignition of a flammable atmosphere. It is a resource intensive process, and needs quite a range of expertise. The value will be easily lost unless issues identified are discussed until there is an agreed conclusion, and suitable recording of this.

I don't think that these sorts of considerations control how often HAZOP is used in the powder industries. Instead it is more likely a consequence of the training and mindset of those who design powder processes, but it does give us a reason to pause and wonder what this design tool has to offer.

I would argue that even if we intend to build in comprehensive explosion venting or suppression, the designer should aim to minimize the risk of ignition, and that is likely to require consideration of unintended events or conditions. Well designed explosion protection will prevent danger to operators, or limit plant damage to trivial levels, but there remains a downtime cost of cleaning out burnt material, and checking that all is safe to restart.

A HAZOP study is intended to stand back from looking at what is intended to happen in a process, and ask what could cause a deviation from this, and what would be the consequences – WHAT IF? If only a few deviations from the intended condition can be envisaged it is likely that these will be considered without the need for a special study. In the case of a very manual operation like adding sacks of product into a blender making a two or three component mix, and bagging off the blend, a HAZOP would surely be an unnecessary tool. Likewise a local dust collection system, with a single filter and modest number of collection hoods is unlikely to merit a study.

Many continuous powder handling processes have a whole series of linked operations. As an example, from the chipboard industry we would expect to see sequentially logs turned to chips, the chips being dried, the dried product being graded, separate streams for dust, and chips of different sizes, some intermediate storage, and perhaps dust going to a bagging unit, or combustion plant, while the chips go on to be mixed with binder and turned to board. Dust will be present to a different extent in different places through the process. Not all these steps have explosion risks, but all have operability issues if one step in the process or item of equipment goes wrong. Are we sure we know how to get the process running again if power is lost to one of the conveyors, or how some flow blockage will be detected before it causes such a back up of material that the whole plant has to be shut down?

Among the statistics of dust explosion incidents, drying plants feature quite prominently. The most serious incidents are associated with continuous processes, largely because these are typically much larger, but fires and explosions in batch driers are not uncommon.

The hazards associated with driers are no surprise, as soon as you start to heat material you take it closer to the temperature at which ignition occurs. Monitoring temperatures is often difficult, as large temperature gradients can exist within a small distance in the absence of any convectional mixing, and the low thermal conductivity of most bulked powders. What sort of deviations might we need to consider? The volatile content of the material being dried can vary, and this will affect the flow properties; the residence time in the heated zone may be affected by process upsets elsewhere; and there is always the probability that some material may be heated longer than intended. Leaks from or into the system may create flammable atmospheres where they were not intended. It is probable that a HAZOP for a continuous drying process will highlight issues like this needing to be resolved.

It has long been recognized that dust explosions have the ability to spread through a process plant from unit to unit, even though there is probably not an explosive atmosphere throughout the plant at the time of ignition. The shockwave from an initial small explosion disturbs dust, and creates new dust clouds. The solution to this is to provide explosion isolation, but that immediately begs the question of where, and how? The practical reality is that it is often not possible to isolate every item of plant, and moreover, that many of the isolation techniques are not 100% effective. Rapid acting isolation valves may react too slowly, rotary valves may have clearances worn until they allow flame to pass, or water spray systems linked to spark detectors may fail if a spray head is blocked.

What is needed is an overview of the process, looking at the plant as a whole, and an assessment of the probability of particular deviations which could result in a dust explosion which propagates with serious consequences. This type of HAZOP might well be most effectively carried out at the outline design stage. Suitable instrumentation to detect the deviation might be more cost effective than an explosion barrier whose reliability was debatable.

Start up and shut down of continuous plant with multiple unit operations always needs consideration at the design stage, whether the plant has fully automated controls, or is largely under the control of the operators. In particular, the sequence required for an unplanned or emergency shutdown must not be overlooked.

A large coal mill associated with a power generation or cement plant is likely to run for extended periods, and generate considerable heat. The heat will be carried away in the milled product, and may dissipate in the downstream process. One normal way of operating a controlled shutdown is to run the mill feed to empty, and remove residual product in the mill through an inspection port into a movable hopper. In the case of an unplanned stoppage, coal will remain in the mill, and may draw heat from the casing. If the stoppage is brief, restart may cause no problems, but if the restart is delayed, the coal may have started to smoulder, and burst into flame when fresh air is blown through the system. When the plant is first tripped, the operators may not know whether it can be restarted in a few minutes, or whether much longer will be needed to rectify the problem. Different actions may be needed in the two cases, and good operating instructions will be needed, rather than any change in plant design. A HAZOP is not the only way of identifying this issue, but done properly, it might well ensure that the potential problem is not overlooked.

One cause of hazards not associated with combustion is overpressure caused by a deliberate supply of compressed air, when not all the parts of the plant can withstand the full pressure of the air supply, or where the air pressure can produce unintended consequences.

This was the case with the very old incident at General Foods in Banbury, where the initial problem was caused by a pneumatic conveying system. A single transfer system was used to fill multiple bins, and a failure in a diverter valve caused one bin to be overfilled. The filter on the bin soon blocked, and then air pressure from the conveying system caused the filter unit to become detached from the bin. A large dust cloud quickly formed, and ignited, creating an explosion which caused substantial damage.

There have been similar more recent incidents where we have seen filters mounted on silos become detached but the consequences have not been as severe, because the silos were outside.

A different problem with the same type of origin came to light following incidents of ignition within pneumatic tanker discharging systems. Typically these use top pressure above the powder in a road tanker, and a venturi system at the discharge point to fluidise the powder and induce flow in the transfer line. It transpired that in the case of the fire incidents, the operator had turned the venturi off towards the end of a transfer, and left the top pressure in the tanker to empty the last of the load. This had the unintended consequence when the tanker barrel emptied of causing reverse flow in the venturi and powder entered the blower. Subsequently friction in the blower caused burning material to be blown down the transfer line.

A particular generic example comes from dense phase conveying where the air pressures used in the blow egg are much greater than those found in a lean phase system, typically up to 7 bar. There is a steady drop in pressure along the transfer line in normal operation. The amount of air to be disengaged is comparatively small, but it has to go somewhere. If air at 7 bar entered an empty transfer line, what would happen? If the body of the downstream filter equipment could not withstand anything like this pressure, could the filter elements pass the amount of air that would flow? Would this still be the case with a partly blocked filter? It is clear that robust arrangements to prevent weak plant being overpressurised are necessary. It seems to me that HAZOP is a useful tool to consider this type of operational problem, as it forces the designers of the system to consider what could happen when all does not operate as intended.

Many powder plants suffer from flow blockage from time to time, and often the first reaction from the operator is to get the hammer out, and vibrate the accumulation until it is displaced. A flow blockage may have no safety consequences, but it will have to be moved sooner or later. A HAZOP might help identify the causes of a reduction of flow, and from the discussion identify improvements to the instrumentation which would identify problems before flow stops completely.

Most powder handling systems are essentially enclosed to prevent major release of dust to the surroundings. Any major release is likely to create a dust cloud and the risk of an explosion. I have often asked operators of powder handling plant how they would detect a release from some fault such as a failed filter element, flexible coupling, or torn explosion vent panel. This may not be an issue if the area is constantly supervised, but if plant is highly automated, and the operator rarely leaves the control room, it is necessary to consider the adequacy of the instrumentation. A HAZOP study might be appropriate, and it could be done either at the design stage or on an existing plant.

CONCLUSIONS

The title of this paper set a question, and I'd like to draw together some conclusions.

There is no general reason why the HAZOP technique should be seen as unnecessary or unsuitable for application to powder handling plants.

Many powder handling processes are comparatively simple, and may not merit the effort of a HAZOP study. This is most likely to be the case where, there is only a single unit operation involved, where there are no particular problems associated with stopping or starting the process at any point, and where the process operates at essentially atmospheric temperature and pressure.

The traditional approach to mitigating the consequence of dust explosions by explosion venting or suppression together with explosion isolation between items of plant will enable the most serious potential risks to be controlled, but used alone will fail to identify potential ways of improving the design to reduce the risk of a process upset which has the potential to lead to a fire or explosion incident. HAZOP will be appropriate in some cases.

Selective HAZOP's, using appropriate guide-words (prompts), applied ideally at an early stage of design may be useful as a means of identifying hazards in powder handling plants other than those caused by fire and explosion events, specifically the implications of using compressed air together with some plant or equipment that is not built to pressure vessel standards.

HAZOP is particularly useful in considering multistage processes, where the wrong sequence of operations during start up or shut down can create problems.

HAZOP is likely to be useful when considering the potential for unintended releases from the process, and how these would be identified and controlled promptly.

Most particularly, a HAZOP study on a process or design that incorporates all the normal dust explosion precautions is likely to identify issues that are more operational than safety related, and a study could usefully be undertaken with this as the primary aim.

REFERENCES

Corn starch dust explosion at General Foods Ltd, Banbury, November 1981, HMSO ISBN 011 8836730

BS IEC 61882 : 2001 Hazard and Operability Studies, Application Guide

Fire and Explosion hazards during pneumatic discharge of road tankers handling explosible dusts HSE internal circular see www.hse.gov.uk/foi/internalops/fod/oc/200-299/283_14.pdf

Dust Explosion Prevention and Protection, a practical guide, ed John Barton, I Chem E, 2002 ISBN 085295-410-7