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Dust Explosions: What is the risk? What are the statistics?

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Introduction

It is well known that dust explosions have a very large damage potential and that they actually occur in industrial plant. On the other hand, most plants operate for many years without incident. It is therefore useful, at the start of this seminar, to review the historical evidence of dust explosions, and to see whether significant trends can be found.

Risk and hazard

Two different words are used when discussing dust explosions (and other incidents): risk and hazard. Although often these words are used interchangeably, they really have a different meaning.

"Hazard" can be described as the potential to cause damage and / or injury. "Risk" includes the frequency or probability with which the incident occurs. Often risk is defined as the product of the probability multiplied by the damage caused. This does, however, not take into account the perception that one incident with a large number of casualties is worse than many incidents with few casualties each.

What is a dust explosion?

Later presentations will cover the topic in more detail, but it is necessary to define a dust explosion before we can discuss the dust explosion hazards.

A dust explosion is the rapid burning of a flammable mixture (cloud) consisting of dust particles and (usually) air. The burning is initiated at one point by an ignition source of sufficient energy and propagates through the entire mixture. It is required that the dust particles are combustible and so fine that the flame is self-sustained. The dust concentration must be within the flammable range. Experience in testing dusts shows that at least 70% of all fine powders is flammable.

When the cloud is unconfined the heat generated by the combustion will cause an expansion of the cloud, which will be noticed as a "flash fire".

When the cloud is confined in equipment or a building, the expansion is impeded and instead the pressure rises and the event is called an "explosion". The maximum pressure that can be generated, usually in the order of 10 bar, is sufficient to destroy any building and virtually all equipment.

Although an explosion is very fast, it is not instantaneous and this provides a means of mitigating the consequences of the explosion.

What is special about dust explosions?

The above description could easily be written for gas or solvent vapour explosions, if we disregard the reference to the particles. There are, however, a few aspects of dust explosions that make dust explosions special.

When a flammable dust cloud is created, the dust particles are suspended in air, either because it falls from a height or because a blast of air raises the dust from a surface. Since dust is heavier than air, this will only last as long as the force that created the cloud is active. After that, the dust will settle on the floor or on top of equipment. Especially in this phase, the finest particles will remain in suspension while the larger particles settle.

Once the dust has settled, it can be raised again to form another flammable dust cloud. This is different from gases and vapours that, once dispersed to below the lower flammable limit, cannot form an explosive mixture again.

This capacity to be re-suspended has its most serious consequences when a small explosion whirls up the dust deposits in the plant and then ignites the cloud. These so-called secondary dust explosions are the reason why some plants have been destroyed virtually completely.

Another special aspect of dust explosions is that dust deposits can be ignited, for example due to self-heating, or because the dust sits on a hot surface. A smouldering or burning dust deposit can be an ignition source for any dust cloud that is generated. Alternatively, the deposit may burn, causing fire damage.

Are things changing?

One would expect that the continued research into dust explosions and the increased safety awareness should lead to fewer and smaller dust explosions. The requirement to perform systematic risk assessments of all operations, as is becoming more and more common (for example because of European Union Directives) will lead to identification of hazardous situations and many should be eliminated before an explosion can occur.

Better housekeeping is required for occupational hygiene reasons. In many cases GMP (Good Manufacturing Practice) imposes even more strict housekeeping standards.

On the other hand, dust extraction is increasingly used to protect workers from exposure. This leads to more dust collection systems. Because the emissions into the environment must be reduced, cyclones have been replaced by ever better dust filters. Dust filters not only collect all the fine dust from the plant, they also create dust clouds during cleaning of the filter elements and suck up many ignition sources.

Whether the positive or negative effects win is difficult to predict from first principles. The available statistics are not suitable to detect such trends. There is an indication that dust collectors are involved more often (Beck and Jeske, 1996), but it cannot be seen if the total number of explosions has decreased because of the reasons indicated. The attached figure, based on data from Owens and Hazeldean (1995) shows a slow but steady decrease in the number of fires and explosions, but the trend for "solids" is not very clear and the last two years show how the numbers can vary from year to year.

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Statistics

Most countries do not keep specific statistics on dust explosions. It would be tempting to judge the situation in a country on the basis of the few large incidents that get widely reported. Obviously that is not a good way to estimate the risk.

When I was based in the Netherlands, my colleagues and I used to keep an informal database of dust explosions. Most of the data that we found was not from widely published sources. Careful analysis of fire brigade reports often showed that a dust explosion preceded or followed a fire. Contact with clients revealed many small incidents that did not even make the local press, let alone the national press. Clearly, much information became only available with a long delay. Nevertheless, with these incomplete means we were able to estimate that in a small country like the Netherlands approximately one dust explosion incident happened every week!

How difficult it is to obtain complete data is shown by Abbott, who used questionnaires to obtain data on fires and explosions involving dusts for the period 1979-1984 for a study for the British Materials Handling Board (BMHB). He was able to find 84 incidents (from 56 questionnaires). The HSE (Health and Safety Executive) provided data on 143 incidents, of which only 3 were also included in the BMHB data set!

In West Germany, insurance sources indicated that about 300 dust explosions with at least DM 50.000 damage occurred every year. Beck and Jeske (1982, 1987) estimate that they are only able to capture about 15 % of the dust explosions with their scheme. The good thing about their scheme is that is continues, starting in 1965, to record and analyze information.

Most other schemes are limited to a certain type of industry, such as the regularly updated statistics on the USA grain dust explosions (see for example Schoeff, 1995), although he considers occasionally a wider range of industries, see Schoeff (1992).

Others cover only a limited period of time, such as Abbott's BMHB study and Lunn (1992).

When looking at published data, we must be aware of the "accident triangle": for every incident that causes deaths, several incidents with major injuries and even more incidents with minor injuries occur. This has often been represented as the tip of the iceberg, where most of the occurrences remain hidden from view.

It would be nice to be able to compare statistics from various sources, but unfortunately, as the attached figures show, each source divides the dusts, equipment and ignition sources in different ways.

The data for the UK (Lunn, 1992) cover both dust fires and dust explosions. Attached are a few graphs showing the UK statistics for 1979-1988. Because fires have been included, it is possible to compare fires and explosions. The graph shows that many fires were considered "small", causing neither significant damage nor injuries. The same was never said of explosions. Fires never caused injuries in these incidents, but explosions did. It is interesting to note that some fires and many explosions did not cause damage because of the precautions taken! Abbott also shows how the lost time (time before the plant could be re-started) was divided: almost half the incidents led to significant lost time.

Beck and Jeske (1996) just published the latest statistics for Germany, now covering 600 explosions. It is significant that the distribution of the incidents over the types of equipment and the ignition sources hardly changes from previous data (Beck and Jeske, 1982, 1987).

Because the German statistics are analyzed per type of industry and per equipment type as well as for all incidents together, interesting differences can be found. The attached figure (based on earlier data from Beck and Jeske (1987) shows how the ignition sources vary from one type of equipment to the next. The results are not surprising, just as the data per type of industry reveal that different ignition sources and different types of equipment are important in different industries, but this is the only source to data that supports this.

Very few attempts are made to correct the available data for the number of installations that are present. So the fact that in former East Germany 36.5 % of dust explosions was recorded in the Coal/Peat/Lignite sector (in West Germany the figure is 9.5 %), can be explained by the extensive use of lignite in East Germany, but without a numerical foundation for the explanation (Beck and Jeske, 1996).

Most explosions in protected plant, when no damage is caused, are never reported. In fact, most people do not even consider these explosions to be incidents worth reporting. This is a pity, since the fact that ignition occurred is significant and can help in the identification of the most relevant ignition source in that type of installation. Also the fact that the protection system was (almost) adequate is important, since that information can be added to the research data in developing design guidelines for protection systems.

Conclusions

Dust explosions happen in every industry handling flammable dusts and in every country. Luckily, very few large explosions occur, but because the smaller incidents and near misses are under-reported it is not possible to define the true extent of the problem.

Statistical information is only available in some areas, and even there it is incomplete. The available data is not corrected for the number of installations that exist of a certain type. It is therefore impossible to prove, using these statistics, that a certain operation is not hazardous or less so.

It would be nice if also explosions in protected plant would be reported in more detail so that lessons can be learned from them as well.

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