A collection of unexpected explosion accidents

Ir. Tom Molkens, Ir. Ake Harmanny, ISMA NV, Kontich, Belgium

Abstract
Over the years ISMA has been involved in many explosion incident investigations. Although in many situations the result of the investigation was more or less as to be expected, sometimes the results were surprising. A number of such cases were presented at the previous VDI Tagung (VDI-Berichte Nr. 2225; 2014). Since then, other interesting cases have occurred which will be shared in this paper.

Introduction
The message of this paper, as the previous one, is to keep an open mind when investigating an explosion incident and never take the obvious ignition source for granted. In addition, the lessons learned from such incident investigations need to be taken into account when designing new installations.

One case of the previous paper was regarding the combination of combustible and inert dusts. When the large majority of a dust cloud is inert, no explosion will arise, which was confirmed in testing. However, an explosion did arise in a filter where the inert dust segregated from the combustible dust as the latter was much finer. The first case in this paper is again related to this risk.

The second case is about an explosion in a dust filter. This is not very unexpected, where it not that it was on the clean air side.

The remaining cases are all related to electrostatic discharges.

1. When ppm’s become significant
An explosion occurred during packing of rubber beads in cardboard boxes. This explosion was highly unexpected as the ignition energy of dust from the rubber beads had been tested and was beyond 1000mJ. In a test after the explosion, the sample could not even be ignited by a 5 kJ ignitor.
After production, the beads are coated. The amount of coating is small, only 400 to 1800 ppm. Dust of this coating is much more sensitive than the rubber beads, a minimum ignition energy between 10 and 25 mJ. After coating, the beads are pneumatically conveyed towards buffer bins. During coating and during pneumatic conveying, there may be some dust formation, which will mainly consist of coating material.

The coated beads can of course not be ignited as these are too coarse. Ground beads can neither be ignited, or are at least very difficult to ignite, as these contain less than 1% of coating. However, if only the outer layer of the beads is eroded, the resulting dust cloud is most likely explosive. Although 400 to 1800 ppm seems low, it does equal a total amount of 4 to 18 grams in 10 kg of beads. With such an amount, a volume of 100 litres can already be filled with an explosive mixture. A cardboard box to pack 10kg of beads is smaller, explosive mixtures are certainly possible.

In the risk analysis of the process, downstream the coater, the relevant MIE is that of the pure coating material. In other situations, the possibility of separation of sensitive products from non-homogeneous particles or mixtures should always be considered.

2. Filter explosion on the clean air side

Unfortunately, filter explosions are rather common in industry. Most filters are therefore protected, usually by explosion venting. For the design of the explosion venting, typically only the dirty part of the filter is taken into account. During the investigation of a recent filter explosion, witnesses reported a large fireball erupting from the top of this filter. The failed top was on the clean air side.

A first inspection of the filter revealed that the filter plate (the separation between dirty and clean part) was deformed downwards. Meaning: the pressure in the clean part must have been higher than in the dirty part.

When inspecting the filter into detail, it was found that the filter cloth was mainly intact. It only displayed some traces of fire and two filter elements had small holes of a few cm² each. This means that dust must have been present in the clean air side before the explosion. Dust on this side of the filter is not unusual. Most filter cloth does leak some fine dust and in case of small leaks, some dust will likely settle in the chamber instead of being blown out with the air.
It is strange that the cloth hardly showed damage. This observation, amongst others, led to the conclusion that the explosion started on the clean air side.

The involved dust has a very low MIE and, within each filter element, there is a rotating element for cleaning. Besides a spark discharge, also mechanical sparks may have been created in the clean air side which may have caused the explosion.

Although explosions in clean air parts of filters are rare, these do occur. These parts should also be treated in the risk analysis, and the various ignition sources need to be prevented here as well. Protection of the clean air side seems exaggerated. In general, a zone 22 is defined which means that ignition sources should not occur during normal operation. By adequate design and maybe some preventive measures, it should be possible to achieve a safe situation.

Propagation of flames from the dirty to the clean side is possible. In such cases, the protection of the dirty side will cover the additional pressure. In case of venting, the vents are already open and will equally be able to vent the clean air side. In case of suppression, the explosion is quenched and should not propagate to the clean air side.

3. Unlikely scenarios
When the explosion risk analysis is conducted for a silo, the risk of explosive mixtures is typically based on the situation during filling. The actual dust concentration that may arise in the silo during filling depends on the product characteristics and the way of filling, but in most situations, explosive mixtures may arise. During emptying of a silo, however, the probability of explosive mixtures is generally considered to be low. Also ignition sources, especially those related to electrostatic charging, typically arise during filling of a silo. Therefore, if there is a silo explosion, it is usually during filling.

ISMA was involved in an investigation of a vented silo explosion which did not occur during filling. The latest filling had been finalized several days before the incident. Any charge built-up inside the silo would have leaked away or would have caused a discharge much earlier. On top of that, the dust cloud had settled long before the explosion.

An explosion did arise however, hence there had to be an explosive mixture and an ignition source. The silo was being unloaded at the time of the explosion. The amount of product in
the silo could not be verified since the level measurement showed a very unstable behavior, already for several hours. As the product concerned is rather prone to clogging, it was concluded that there must have been bridge formation in the silo. During bridge formation, the product level will not change, although product is unloaded. Upon collapse of such a bridge, a dust cloud is generated which will also disturb the level measurement. Bridge formation in silos is not unusual. The main question remained which ignition source had caused the explosion?

During the initial investigation, only one ignition source was found to be possible, albeit very unlikely: smouldering product. All other ignition sources were found to be basically impossible. However, a critical design aspect of the silo design was overlooked.

The silo concerned was inspected visually after the incident and appeared to have no coating. After emptying of the silo, it was found that the bottom part was in fact coated. The upper part had likely been coated as well, but the coating layer eroded away in time or burnt during the explosion. This observation clearly points in the direction of a propagating brush discharge due to collision of product bridges.

This investigation is a good illustration that a risk analysis needs to combine all aspects. Besides experience and knowhow on how to conduct an explosion risk analysis, it is important to use the relevant explosion characteristics, understand the process details and have the design details. If one of these items is missing or incorrect, false conclusions may be drawn.

4. Cone discharges during gravity feeding
In general, the risk of cone discharges is mainly with pneumatic feeding, especially when conveying rather coarse products with a low conductivity. ISMA was recently involved in an investigation where a cone discharge has likely caused an explosion in a gravity filled FIBC.

The FIBC concerned is gravity filled with resin flakes from a vibratory feeder, through a short chute. The minimum ignition energy had been tested many years ago and was below 3mJ (with inductance). To investigate the likelihood of electrostatic discharges in the FIBC, field strength measurements were carried out during filling. At a pre-defined filling rate, the charging level was not more than 5 kV. If the filling rate was doubled, the charging level increased to 20 kV. Therefore, it was recommended to maintain the filling rate and only use earthed type C FIBC's.
Recently, an explosion did occur in the FIBC. After the incident, the earthing clamp was still in place on the FIBC which was of type C. Other ignition sources were investigated and could all be excluded except one: a cone discharge.

Since the MIE was tested many years ago and it was conducted with inductance, a new test was conducted resulting in MIE without inductance between 1 and 3 mJ. The theoretical energy content of a cone discharge in this FIBC was calculated to be 10 times beyond this MIE (based on the formula in IEC/TS 60079-32-1). If a cone discharge would arise, it could certainly ignite an explosive dust cloud.

As the pre-defined filling rate was still maintained and the process was not changed, charging levels would still be below 5kV. Higher levels (20 kV) are required to create cone discharges. There must have been an additional charging mechanism. This was found to be due to the design and the way of feeding:

- The valve feeding the silo is controlled by the load cells of the FIBC.
- The FIBC filling neck is not positioned straight underneath the chute resulting in a bended entry.

If there would be considerable product accumulation in the bend, the inlet of the FIBC is more or less blocked and there will be hardly any flow into the FIBC. As a consequence, the valve in the chute will automatically open completely. Once the accumulated product does slide into the FIBC, a high flow rate arises and due to the fully opened valve, the high rate is maintained for some time. In this way, it was found possible to cause a hazardous cone discharge.

5. To continue on electrostatic discharges

Over the past years, ISMA has investigated multiple explosion incidents in non-conductive silos or silos coated with a non-conductive layer. These incidents all occurred during pneumatic feeding from a bulk truck. The materials involved were all medium to poorly conductive, and included products such as polymer resins, modified starch or the notorious maltodextrin.

Based on the product characteristics and the design of the installation, most ignition sources could always be excluded: mechanical sparks, hot surfaces, electromagnetic waves ... Smouldering product can usually not be excluded completely but appeared to be very unlikely for the various explosions.
The remaining ignition sources were solely due to electrostatics. Adequate earthing was checked thoroughly and found to be sufficient. There were no thunderstorms at the time of the incidents. Brush discharges are not sufficiently incendive. This leaves only cone and propagating brush discharges.

In some cases, it was found that the flexible hose, used to connect the truck to the silo, was not antistatic or had only an antistatic surface treatment that had eroded. Hence, propagating brush discharges were the most likely ignition source for those incidents. In other incidents, the flexible appeared to be suitable.

Propagating brush discharges across the silo wall were not considered possible or hazardous in the incidents concerned. Hence, a cone discharge must have been the cause. In one case, the calculated energy content of a cone discharge was indeed beyond the MIE. In another case, however, the calculated energy content was insufficient.

Based on these various explosion incidents in non-conductive silos, which could not all be explained based on current knowledge, ISMA wonders whether there are no more powerful electrostatic phenomena occurring in such silos. Evidence or research of discharges in non-conductive silos is rare.