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Explosion In A Filter

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1. INTRODUCTION

This paper considers an actual explosion caused by an electrostatic discharge.

The company concerned had a filter to collect the material. The filter was one of the types with numerous internal socks. A reverse jet of air pulses down the inside of the sock, displacing the powder that has attached to the fabric of the sock.

For no apparent reason, there was an explosion in the filter. Fortunately, it was sited externally and no one was injured. Chilworth Technology was asked to investigate the incident and to determine what the cause of the explosion was, and how it could be prevented in future.

The filter was set up with a double-cone hopper under the bags so that the powder could collect in the cones, and be easily removed from the body [see photograph 1, taken after the filter body had been removed from the hopper section after the explosion]. The powder entered into each of the two cones through ductwork. The powder-laden air was drawn to the filters by extraction of air at high level above the socks. The extracted air was sent to atmosphere and the accumulated powder could be collected from the bottom of the two cones for disposal or re-use as appropriate.

In fact the filter was no different from many such reverse air-jet filters in use in many different industries world-wide. But, they had an explosion in their filter, so the question they rightly asked was 'what happened?'

2. INVESTIGATION

In order to determine what the cause of the incident was, all possible scenarios had to be identified, and then eliminated. This would then leave only those scenarios that could have caused the incident and more detailed investigation may then be able to narrow them further, hopefully to the correct scenario.

This approach was taken with this incident.

The possible sources of ignition were identified as:

A) Impact from the fan blade;
B) Fan motor defect;
C) An electrostatic brush discharge that ignited the powder;
D) An electrostatic propagating brush discharge that ignited the powder;
E) An electrostatic cone discharge that ignited the powder;
F) Smouldering materials that flared up in the hopper;
G) An electrostatic spark discharge; and
H) Loose metal impacting inside the hopper.

The remains of the filter were examined to determine if any evidence was present that could allow one or more of the scenarios to be eliminated. The evidence found was as follows.

1. There was structural damage to the body of the filter, and the sides were pushed outwards by an internal force. [See photograph 1.]
2. There was evidence of an explosion, and one of the filter socks had been blown into the explosion vent (albeit a very small vent) and was partially protruding through it. [See photograph 2.]
3. The bottoms of the filter socks were burnt to one side. This one side relates to where the powder had accumulated in the bottom cone and partially blocked the powder/air inlet. [See photographs 3 and 4.]
4. The bottom cones of the filter were filled with powder, such that the inlet to the filter on one side was partially blocked. [See photograph 5, which was taken after the interior had been emptied out.]
5. There was no evidence of damage to the fan or fan blade.
6. There was no evidence of tramp material entering the filter.
7. There was no evidence of self-heating of the material. All fire/smoke damage was on the top of the accumulated powder, rather than underneath a pile of material.
8. There was evidence of the powder vitrifying, in that over time, in the elbow of just one of the air/powder inlet lines, the powder had turned to a glassy material.
9. The minimum ignition energy for the powder concerned was between 5 and 7 mJ.

All the above information meant that certain scenarios could be discounted.

Considering each in turn.

Scenario A. There was no evidence of impact from the fan blade on the body of the fan. Additionally, the fan was on the extraction (clean) side of the filter, so to be an ignition source one or more filter socks would have had to fail to allow flammable material through.

Scenario B. The fan motor was not affected, and could not have ignited a flammable powder, as the motor was outside the ductwork.

Scenario C. A brush discharge has sufficient energy to ignite most gases and very sensitive powders. But, there has not been a recorded case of a brush discharge igniting a powder. Theoretically, though, it is possible, so this is considered further. The maximum energy possible in a brush discharge is physically restricted to between 3 and 4 mJ. The minimum ignition energy of the powder concerned was 5 to 7 mJ. This is the minimum energy required to ignite it under optimal conditions. Hence, although close, there is a high probability that a brush discharge is incapable of having sufficient energy to ignite this powder.

Scenario D. A propagating brush discharge is different from a brush discharge. It is a much higher energy event. It occurs when a highly charged non-conducting surface is backed by an earthed conducting surface[1]. Then, in effect, a capacitor is created, that can store very large amounts of charge. When the insulating material breaks down, and allows the charge across it, energy in the order of thousands of mJ (i.e. Joules of energy) can be discharged.

Normally, the above scenario is associated with insulating coatings on the inside of equipment. No such coatings were applied to the inside of the filter or the ducting.

However, the powder is insulating, and, at the elbow where it enters the bottom of the filter, had formed thick deposits. These deposits had vitrified (turned to a glassy substance) which would increase the resistance, and is also indicative of high flow rates.

Where the thickness of powder deposits is too thick, the effect can not occur. Similarly if it is too thin, the high charge levels cannot be created before the charge breaks through the insulating layer. But, where the deposits had formed, layers from virtually nil to centimetres thick, and everything in between, had built up. Hence there was an appropriate thickness for a charge build-up to occur.

Thus the possibility exists for a propagating brush discharge to have occurred.

Scenario E. Cone discharges can occur when highly charged powder or granules of a high resistivity material drop onto a heap or cone. The charge on the particles wants to keep the particles apart by electrostatic forces, but the material bulks up under the influence of gravity. This leads to very high charge densities, giving rise to discharges on the surface of the bulk powder. The maximum discharge energy is a function of particle size and silo diameter. The bigger the particle and the bigger the silo, so the greater the energy that can be given off in a discharge.

The particle size of the powder involved in the incident, combined with the diameter of the filter bottom means that there would not be sufficient energy to ignite the powder.

[1] Propagating brush discharges can also occur if both sides of an insulating film are charged with opposite polarity.

Scenario F. There was no evidence of smouldering materials being present, and no evidence of a flare up in the hopper, other than the burning at the bottom of the filter socks. There was no path for a smouldering material to enter the filter stream, and the material did not exhibit exothermic behaviour. This scenario can therefore be eliminated.

Scenario G. There was sufficient metal present that a spark discharge could occur if the metal was not earthed. Such sparks are capable of being in the range of a few hundred mJ. However, all the metal plant in the filter and ductwork was earthed, and therefore could not have been the cause of a spark discharge.

Scenario H. The inside of the hopper was examined and there was no tramp material found. Additionally, there was little likelihood of a spark of sufficient energy being generated by tramp metal inside the filter. This scenario was also discounted.

3. PROPOSED SCENARIO

It was apparent that an explosion had occurred in the filter. It had damaged the filter body and fire had damaged the bottom of the filter socks to one side of the filter body. That location was where large deposits had built up in one inlet into the filter, and where the glassy accumulation was discovered.

Considering that all scenarios but one have been dismissed, a possible sequence of events has to be put together that accounts for all the observational evidence and uses the one remaining scenario:

> The inlet to the hopper was split into two. Due to the design of the duct, the material was more likely to favour one side of the filter. [See photograph 6.] This is because the powder/air flow would tend to travel straight on to one inlet, rather than bending to the other.
>
> In addition, the two cones at the bottom of the filter hopper should have been cleaned out regularly. Instead, the powder had been allowed to accumulate over time. This meant that the level in the cone rose until it started blocking the inlet most in use. This caused a restriction on the diameter of the inlet, and caused speeding up of the powder/air flow.
>
> The faster flow caused the powder to vitrify, and also caused high charging levels on the surface of the deposits.
>
> Eventually, the charge build-up was greater than the deposit could stand, and a high energy propagating brush discharge occurred. This ignited the powder in the vicinity of the inlet, and the flames were drawn up into the socks by the fan. As the reverse air jets in the filter then tried to clean the socks, a flame was already present and an explosion occurred causing the damage to the filter body.
>
> The explosion relief panel was too small and was blocked by the presence of the filter socks. Hence they were ineffective in protecting the structure of the filter body.

Luckily no one was present when the explosion occurred.

It is ironic that the cleaning of the inside of the plant could have prevented the incident. It is normally recommended to clean external areas to prevent a 'secondary explosion', but little attention is given to areas inside the plant where high charging levels may occur.

4. RECOMMENDATIONS

The following recommendations were made to prevent a similar incident occurring again.

R1. Places where powders (that are likely to vitrify) can accumulate in process plant over periods of time should be regularly cleaned. This is especially true of locations where high charging processes are, or may be, occurring.

R2. The vent panel should be sized correctly and should be situated below the socks. Alternatively, it should be at a level at the bottom of the socks, and with any socks that might block the vent removed, and the remainder restrained from moving into the path of the venting.

R3. The explosion relief panel should vent to a safe location.

R4. Explosion suppression could be considered as an option.

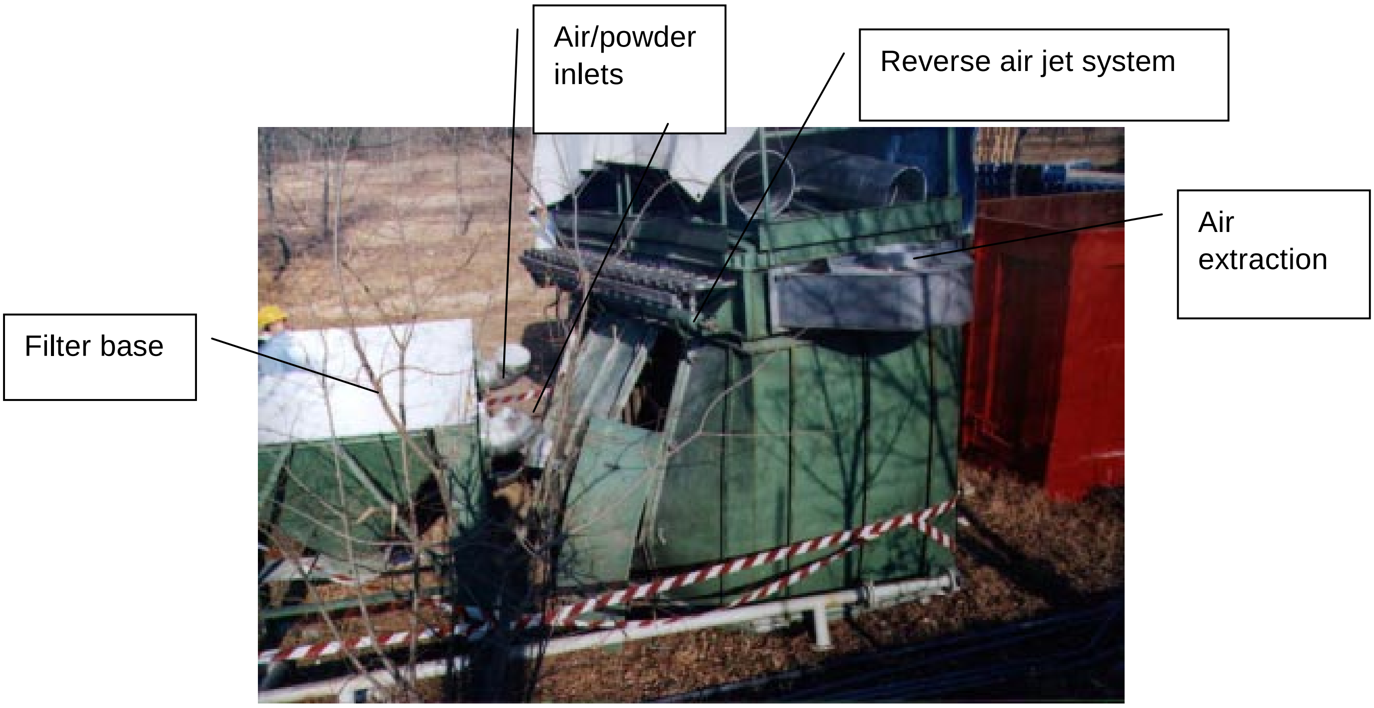
5. CONCLUSION

The conclusion to this investigation is that an event as rare as a propagating brush discharge on a glassy deposit formed by the product itself can, and did, occur. Stopping powder accumulating, which itself increased the speed of the powder/air mixture could have prevented the incident occurring.

A tell tale sign for a propagating brush discharge is the presence of vitrified material. Where powders are starting to change their nature, and become more like glass, then the possibility of a propagating brush discharge increases.

All plant should be checked to ensure that such an event as this cannot occur, when cleaning out regularly would eliminate the potential.

6. PHOTOGRAPHS



Photograph 1: Top of filter showing socks inside and damage to body and filter base (to left)

Photograph 2: Filter sock pushed through small explosion relief panel

Area of most fire damage

Photograph 3: Looking into underside of filter housing

Photograph 4: Showing burning to one side of filter sock bottoms

Glassified material found around metalwork

Photograph 5: Inlet to filter (from inside) showing powder accumulation

Photograph 6: Duct detail. The nearest two outlets fed the filter's two inlet ports

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