XV SAFEX INTERNATIONAL CONGRESS
May 26, 2005 Geneva, Switzerland

15/WS2-3 EXPLOSION AT A BLACK POWDER PLANT on 12 February 2003

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ABSTRACT

- *On February 12, 2003 at about 3:00 p.m., an explosion occurred at the Aubonne site. The explosion took place in the corning house of the black powder plant.*

- *One employee was inside the building and was injured in the accident.*

- *The explosion destroyed the corning machine, the sieving unit and the building. Damage to other buildings was minor.*

PRESENTATION

1. Background

An accident happened at the Poudrerie d'Aubonne on February 12, 2003 at about 3:00 p.m.

Weather conditions were fine and dry; temperatures were below 0°C a few days before the accident.

Product at issue: Black powder

Type: shooting powder in corning phase; non-polished powder or graphited

General composition:	Charcoal	11.6%
	Sulfur	9.9%
	Potassium nitrate	75.0%
	Humidity	3.5% (estimate)

An operator was sweeping the floor between the corning machine and the sieving equipment (Plansichter) when suddenly an explosion occurred.

The operator was seriously injured (first and second-degree burns on 60% of his body and light injury to the face).

The quantity of black powder in the building was approx. 180kg. The approximate quantities were located in the building as follows:

- 20kg in processing in the corning machine and 20kg in the reception boxes underneath the sieve of the corning machine or on a trolley near the entrance

- 15kg in the sieving unit (in antistatic plastic boxes underneath the installation and in the installation itself)

- 120kg in bags (3 x 40kg) near the building entrance

This building was officially authorised to store max. 200 kg.

2. Process and Equipment

2.1 Corning Process

The black powder is first compressed into black powder plates, then crushed and sieved in the corning installation through a machine with crushing rollers to obtain the desired grain size. The black powder plates enter the corning machine through three sets of crushing rollers placed one above the other.

The top set of crushing rollers has a picked surface. The two next crushing rollers have a smooth surface. The space between each crushing roller is adjusted according to the specified grain size. The granulated black powder then drops into a set of sieves in order to separate them as correct grain, coarse grain (mixed fraction) and fine (dust) grain. The coarse grain is reintroduced to the crushing rollers by means of a conveyor belt, whereas the fine (dust) grain is reintroduced in the previous working process. After granulation, the black powder undergoes further processing.

Machines installed in this workshop are driven by hydraulic power (hydraulic wheel outside the building); this power is transmitted by a system of shaft, pulleys and belts. The building has no electric installations.

2.2 Circumstances of the Accident and Establishment of the Facts

The last batch of the day was in processing in the corning machine.

At first, the operators present on site but working in different operations buildings, heard a loud noise and observed smoke exiting the doors of the corning building. Then they heard 2 closer but distinct explosions.

According to the injured operator, the blast threw him into the pit containing the transmission shaft of the sieving machine. This protected him from the impact of the main explosion. A blood stain on the wall of the pit confirms this fact. He was able to leave the plant without outside help. Except for his shoes, his clothes had been ripped off. He explained to his colleagues what had happened before being taken to the hospital.

A key chain belonging to the injured worker was found in a meadow across the river, about 30m west of the explosion. This illustrates how close the operator happened to be near the site of the explosion.

The stone walls and the first floor remained intact. The other walls and the two sides of the roof (wood construction) were projected several meters.

The east wall of the building was entirely dislocated. 120kg of black powder was located at the bottom of this wall, near the front door of the building.

Several boxes (approx. 5mm of metal thickness) forming a part of the frame of the corning machine were opened by internal explosions. Openings in these boxes allowed axles to run through. The vacant space (about a cm) allowed black powder dust to accumulate without the possibility of inspection.

The most important damage to the corning machine was caused by the black powder explosion on the lower set of cylinders where the black powder was most confined and probably where the largest quantity had accumulated.

The roof of two adjacent buildings (press and packaging room) suffered light damage.

The door on the west wall of the packaging room (which opens to the inside) was forced open by the impact. A Plansichter sieve was projected in the room.

Several glass window panes were shattered by the projectiles (up to 50m). Others were left intact.

Traces of black powder were found in the press building. In this building the fire was started by one projectile on fire and was deflected from its trajectory by a tree located on the east side of the building. Traces of black powder left in the rolling mill room, on the floor and in a box ignited the box and a part of the wall near the front door of the room. Part of an aluminium shovel contained in the box melted. The beginning of the fire in this building was observed 2 minutes after the explosion and occurred approx. 30 seconds after the explosion in the corning machine building.

3. Investigation into the Cause of the Accident

3.1 Possible Source of Ignition

Some hypotheses based on concrete observations allow to propose the following scenarios:

1^st^ possibility:

The initial event was started in the sieving machine with fire propagation by black powder traces in the pit of the transmission belt. Decomposition lifted the cover boards and projected them into the air. Simultaneously the operator suffered from the decomposition of the powder in the container placed under the sieving machine. His clothes were ripped off and his keys thrown across. The explosion pushed the injured operator in the direction of the pit, which is now without a cover. The thrust of the explosion was heard as a loud noise by the other operators present on the site.

For the purpose of energy conservation, the cover of the pit had been removed before the worker was thrown against the wall. This may explain why the operator fell into the open pit. At the same time the black powder on the conveyor ignited. The fire on the conveyor spread at an approximate speed of 10m/s (not confined, thin layer). In a second phase, the black powder contained in a box under the conveyor belt and confined to the cylinders of the corning machine and in the blackcurrant boxes ignited. The explosion threw the gear boxes to the west and the conveyor belt to the north, initiated the explosion of the load on the trolley and of the 120kg black powder bags.

2nd possibility:

Fire caused by cleaning work (impact of a shovel on a powder grain) and propagation of fire as described above.

3rd possibility:

The initial event of the corning machine might have been caused by the mechanical action of the cylinders (presence of a foreign body). This scenario does not explain how the key chain landed on the west side. The operator was surprised by the explosion. Incredibly, no metal projectile hit him. He was hit by the principal explosion that projected him to the west.

4th possibility:

Ignition by electrostatic discharge. According to the statements of the concerned operator at the moment of the explosion, he was collecting a small quantity of black powder on the floor of the building where the corning machine is located. He was using a shovel and a small brush. This small quantity was located between the crushing rollers and the sieving unit. Once the operator approached the ground, the explosion occurred.

At the moment of the accident, the operator was wearing insulating shoes. We can assume that he accumulated the electric charge. This electric charge might have been favoured by a level of humidity of the air estimated, at the time of the accident, at less then 60% inside the building. At the time his hand, the shovel or brush approached the electricity-conducting ground of the corning machine, a spark may have set off any accumulated charge. This spark may have lit the black powder dust. The transmission to the black powder found in the rest of the building would be obvious.

4. Conclusion of the Investigation

4.1 General

Black powder can be transformed by thermal or mechanical processing combustion/explosion). The ignition temperature is somewhere between 300°C and 360°C, depending on the size of the grain and on its exposure to high temperatures. A ferrocerium spark, the heat of a cigarette or a metal stick heated over 350°C may suffice as a source of ignition. According to various sources drawn from the literature, the sensitivity to electrostatic sparks is relatively low in comparison with certain primary explosives. Thus, values of more than 16mJ may be found (comparison: primary explosive matter > 1mJ. Those energy values do not give any indications as to the type of black powder (size of grain, graphitisation, etc.). For this reason, we assume that those indications are relative to the black powder granules that have been treated in a process of complete production and that usually reveal graphitisation. In accordance with these indications, the ignition of black powder by electrostatic sparks from a human being is to be ruled out because the energy accumulated in the body is generally lower than 15mJ.

In the corning machine, the semi-processed (raw) black powder, previously pressed in powder plates, is crushed and sieved. Then, the granulated black powder drops onto a set of sieves in order to be separated as correct grains, coarse grains (mixed fraction) and fine (dust) grains. At this stage in the corning process, a fine dust is formed and settles everywhere in the building. It is much more sensitive to the electrostatic sparks than the powder finally obtained after processing. However, we found no data in the literature describing the possible ignition capacity of black powder when it appears as fine dust.

However, a study ordered by another institute following an accident that occurred in a fireworks production plant and conducted by Switzerland's National Safety Institute in Basel showed that an explosive load made up of very fine black powder dust can be ignited by a discharge from sparks of only 0,2mJ. A human not sufficiently grounded can accumulate charges containing much more energy. Consequently, the lighting of fine black powder dust caused by electrostatic discharge from a human being is plausible according to this study.

The risk of ignition of the black powder by friction is relatively low because the sensitivity to friction occurs at more than 360N. The sensitivity to impact is approximately 15J and corresponds to the lowest energy of impact which can cause an explosion of black powder. It corresponds to the energy developed immediately before the impact by a weight of 1kg falling from a height of 1.5m.

5. Conclusions

Upon examination of all the results of analyses and information at our disposal, three causes could be responsible for the accident. An analysis of available material evidence does not allow to establish with certainty which of the three scenarios would apply.

5.1 Ignition in the Granulation Installation Caused by Metal Objects (Tools)

Evidence found on the bronze crushing rollers of the corning machine shows that besides non-identifiable foreign objects, some metal items, such as screws or nails, were introduced repeatedly between the three sets of crushing rollers. In the rubble found around the corning machine, various metal objects, in particular, screws and nails, were identified. Most of these screws and nails are made out of brass, only a few are made from a magnetic material. Several accidents which occurred previously at black powder production plants were caused by foreign matter, in particular metal particles that were introduced involuntarily into the chain of production.

Overheating of one of the bearings located in the crushing rollers of the corning machine cannot be completely ruled out.

5.2 Ignition Caused by Electrostatic Discharge

According to the operator's own statements, he was, at the time of the explosion, collecting a small quantity of black powder on the floor in the building where the corning machine was located. The operator was using a small brush and a shovel. This small quantity was between the corning machine and the sieving unit, placed separately from the corning machine. The explosion happened at the moment the operator approached the ground.

At the moment of the accident, the operator was wearing insulating shoes. Supposedly, he accumulated the electric charge. This electric charge might have been favoured by a level of humidity of the air estimated, at the time of the accident, to be less than 60% inside the building. At the time his hand, the shovel or brush approached the electricity-conducting ground of the corning machine, a spark may have set off any accumulated charge. This spark may have lit the black powder dust. The transmission to the black powder found in the rest of the building would be obvious.

5.3 Fracture in Part of the Sieving Unit (Plansichter)

After the explosion, a fracture was found when the rest of the Plansichter was dismantled.

Among the 4 connecting rods, three showed a fracture of the bearing. We suggest that one of these broken bearings may have caused the impact on metal and therefore left behind traces of powder on the surface of the metal part.

5.4 How to Avoid this Type of Accident?

Black powder is very sensitive to sparks. In the presence of black powder, the formation of sparks must be avoided at all cost. For this reason, material that produces sparks must be banned from the production line. The accidental introduction of metal fragments into the production line must be prevented.

During the production of black powder, the formation of electrostatic sparks also constitutes a high risk. For this reason, it is very important to use conducting material in the production process of black powder and to connect the installations to the ground. Regarding the location where the fine black powder dust may appear, we believe that clothes and shoes should be designed to avoid any accumulation of electrostatic charge.

By observing these rules, the accidental ignition of black powder may be avoided.

Modelling the effects of black powder action based on parameters accepted until now is not directly useful. The accepted model is to consider black powder an explosive with a TNT equivalent of 30%. The explosion of all quantities of powder was also expected. If we consider this model, the operator would in theory have had no chance of survival. He should have been killed by the shock wave caused by the explosion of 120kg of black powder alone. For this quantity a lethality risk of 100% can be expected up to a distance of 7m. In this particular case, the distance was not more than 5m.

5.5 What Action Has Been Taken and What Lessons Have Been Learned

During reconstruction of building and equipment, safety was improved by implementing the following measures:

- Corning and sieving operations must be done in separate rooms. Today, those operations take place in two separate buildings.
- Product quantity must be limited to the quantity that is essential to the process.
- Operators must be protected on the job by construction-related measures (solid walls).
- Nobody should enter the work area, or only if machines have been stopped or if product processing is not underway in the machines.
- Operators need to wear appropriate protective clothing, “Nomex” tracksuit, antistatic shoes, protective gloves, and possibly a protection screen for the face.
- Intermediate products not handled immediately must be stored in a separate room.
- Machines or installations should have no vacant spaces that cannot be easily inspected or checked. They must be easy to clean.
- Risk assessment must take into account the layout of the installations to obtain the highest degree of safety.