Dust explosion in a port-based silo
23 February 2018
Grande Synthe (59)
France

Silos
Explosions
Dust
Wood
Cereals

THE INSTALLATIONS CONCERNED

The site:

The site is a port-based silo subject to operating authorisation, especially with regard to section 2160-2.a relating to silo storage installations for cereals, grains, food or any other organic products emitting flammable dust.

The site includes 45 vertical storage cells, two interstice silos (or star-bin silos) and two flat cereal storage silos. The total storage volume is 437,720 m^3.

The current prefectoral decree imposes various measures, notably on conveyor installations in terms of safety equipment, the action to be taken in the event these devices are triggered and maintenance rules governing these devices. For example, the prefectoral decree requires:

- temperature sensors on the bearings of elevators and belt conveyors;
- conveyor and sling shift sensors at the base of elevators and at each end of the belt conveyors;
- rotation controllers on the tail bearings of elevators and conveyors;
- strap elongation detectors or strap tension controllers and jamming detectors on elevators.

Detecting or exceeding the predefined thresholds of these devices leads to:

- a shutdown of the installation and the equipment located upstream;
- triggering of an alarm in the control room.

The installation may only be restarted after intervention by the personnel.

The unit involved:

Several units were involved in the accident:

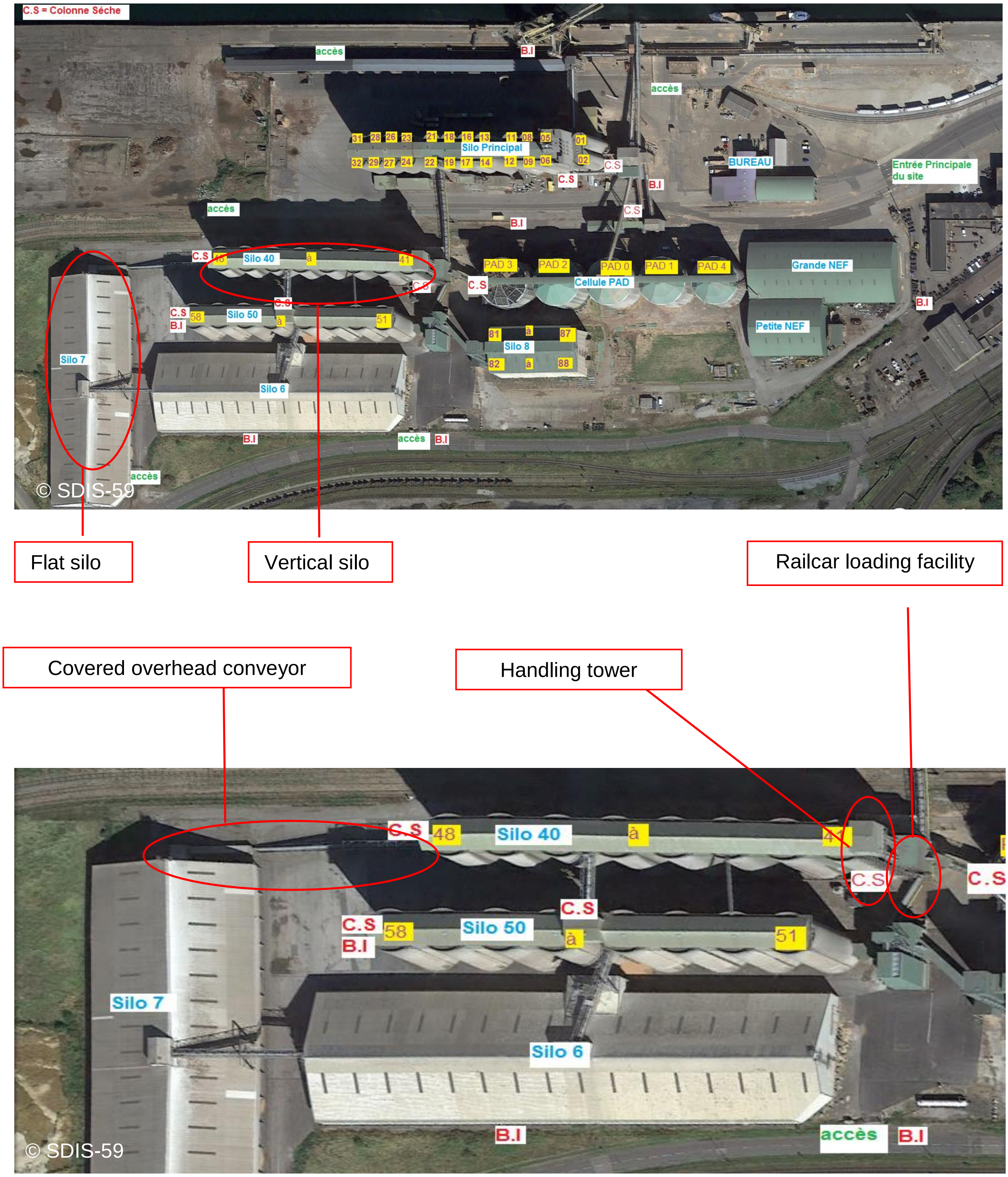
- a flat silo (silo 7);
- a vertical silo (silo 40), consisting of 8 cylindrical concrete silos, built in 1988, open in the upper sections on an over-cell gallery and its conveyor. This gallery is covered by a metal cladding-type roof;
- a sub-cell gallery, at ground level, through which a covered conveyor passes;
- a semi-open handling tower with several bucket elevators;
- a weighing room in the railcar loading building;
- a railcar loading facility adjacent to the handling tower;
- a covered conveyor, passing at a height of 4 m above the ground, between the flat silo and the vertical silo;
- this overhead conveyor empties into a 1.5 m^3 hopper that discharges over the sub-cell conveyor.

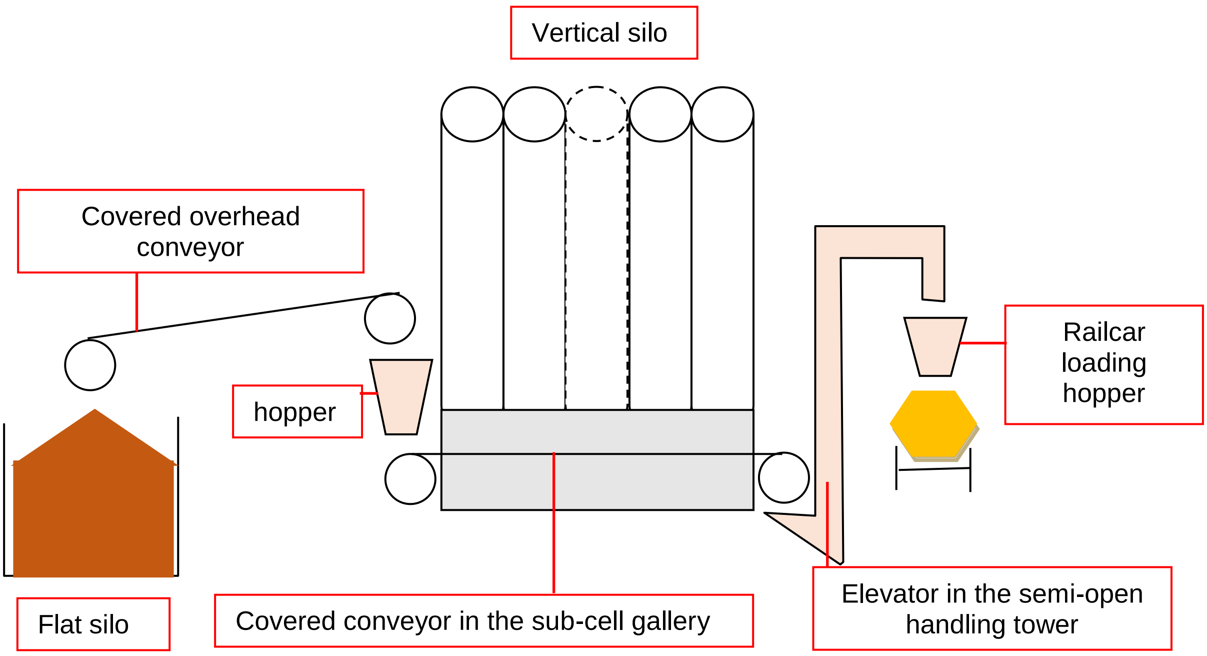
The status of the stocks in the units involved:

- In the flat silo: corn is stored in the southern part and wood pellets in the northern part;
- In the vertical silo:

Cell No.	Quantity stored in tonnes	Type of product stored
41	1,000	wheat
42 and 45	0	/
43	3,000	wood pellets

Cell No.	Quantity stored in tonnes	Type of product stored
44	1,300	barley
46	2,500	wood pellets
47	1,000	corn
48	5,000	barley





THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

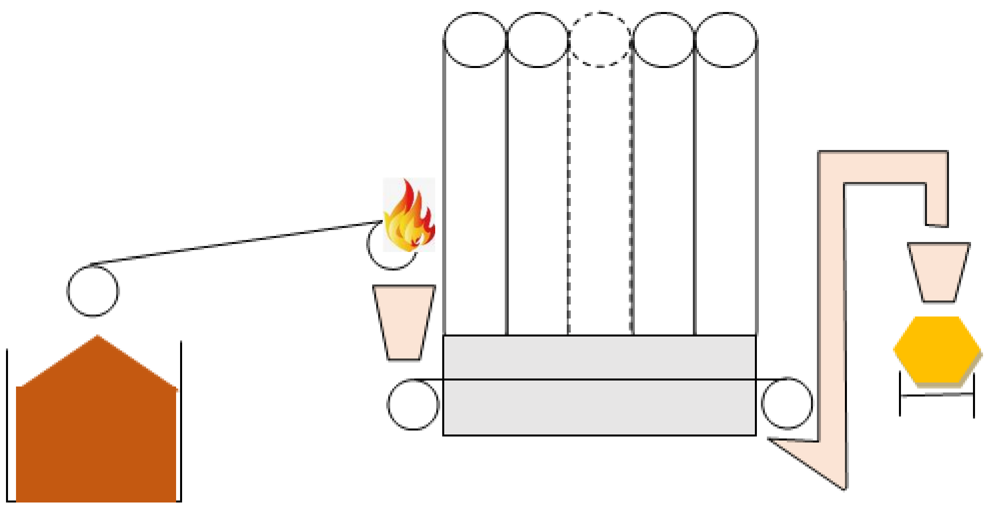
The accident:

In the morning, starting at 6 a.m., pellets were being transferred from flat silo 7 to the railcar loading facility via the sub-cell gallery of vertical silo 40. The railcar loading operation took just a quarter of an hour. Then, a 2-3-minute pause in the loading operations is required to allow the train to move forward and to position a new railcar under the loading facility.

The accident occurred between two railcar loading operations. The conveyors are kept running during this operation. **They were running empty at the time of the accident.**

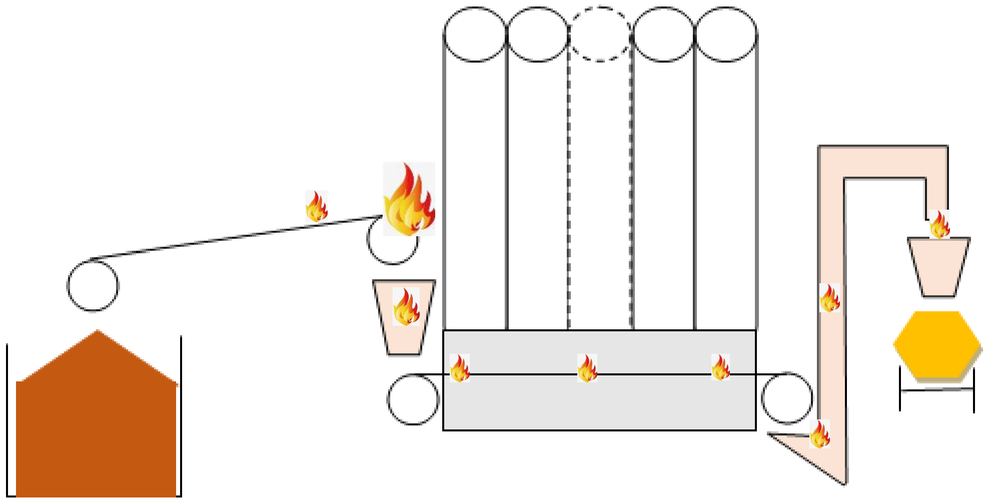
At 7 a.m., alarms in the zone, at the head of the conveyor, were noted in the control room, **although the technicians did not react**:

Type of alarm	Interpretation by the operators	What was actually happening
Conveyor belt offset alarms	Conveyor jamming in progress.	Outbreak of fire at the conveyor head which triggered the alarm
The alarm stops a few moments later	They assume that the system has returned to normal.	The fire would have burnt the electrical wiring; the alarms were fail-safe.



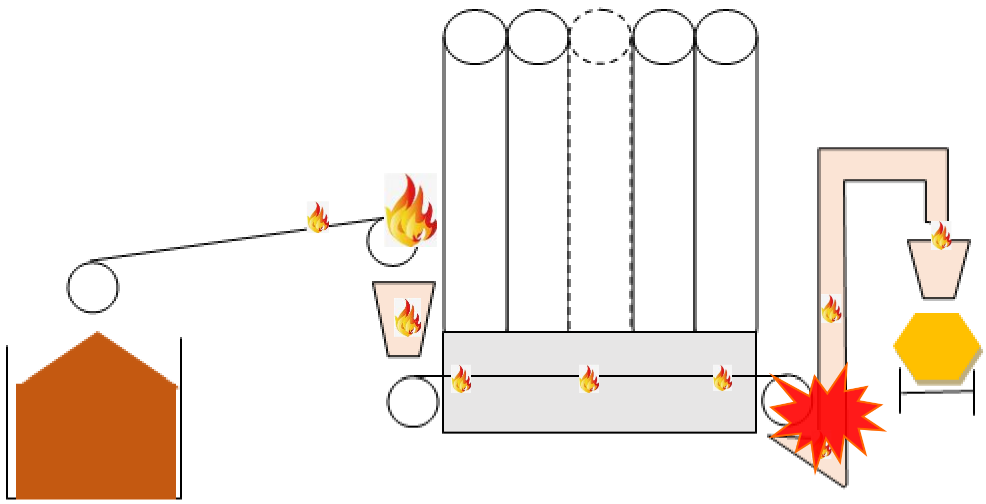
Spread of the fire:

1. The fire that had started on the motor at the head of the conveyor, above the hopper, spread to both the overhead conveyor and the hopper.
2. Embers were carried along by the conveyor in the sub-cell gallery.
3. These embers then fell into the handling tower's bucket elevator.
4. Some of the embers were able to reach the loading facility before the first explosion occurred at the bucket elevator.



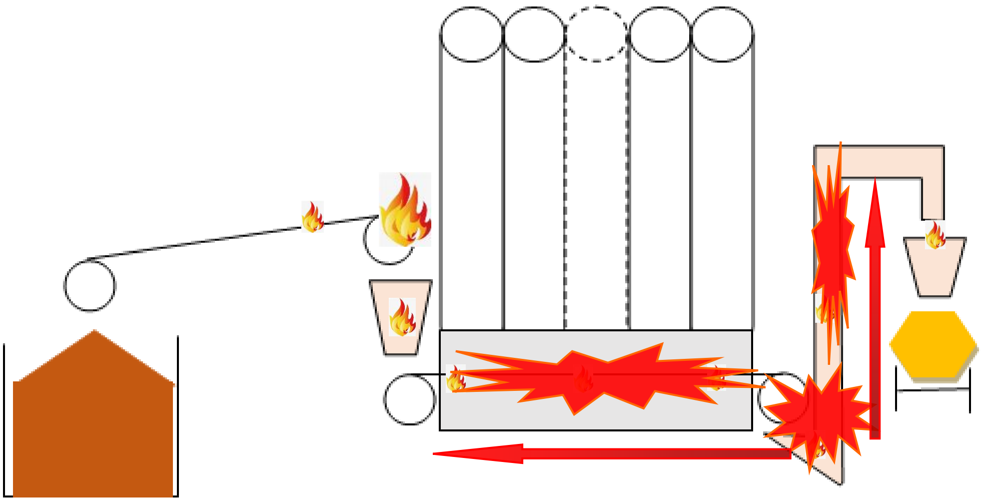
First explosion:

The first explosion was caused by embers falling into the elevator. The **dusty atmosphere** inside the elevator created an ATEX atmosphere. The embers thus provided the ignition source for the dust explosion in this elevator.



Second explosion:

The explosion generated a flame front and a pressure wave that travelled to the handling tower and to the sub-cell gallery. The dust dispersed by the shock wave and the frame front created the conditions for the secondary, more violent explosion.



After the explosion, flames may have been projected by the open handling tower on its upper part affecting the inside of the vertical cells, which were also open on the upper part. Hot spots were detected in 2 empty cells, and surface fires were discovered in a cell containing 1,000 t of wheat and a cell containing 2,500 t of wood pellets.

It took the fire department 3 days to finish emptying these cells.

The analysis of the accident conducted by the INERIS estimates an explosion overpressure of between 100 and 350 mbar. This value is lower than the bursting pressure of the external reinforced concrete walls of the cells (430 mbar), which is consistent with the observed lack of damage to the concrete walls.
The overpressure distances in the elevator shaft are 3 m for 50 mbar and 7 m for 20 mbar.

The consequences:

Material consequences:

In the overhead conveyor between the flat silo and the set of vertical cells:

- The covered conveyor belt was destroyed by fire. The belt, which had been replaced in 2002, was ISO 340-compliant. The shelter covering the belt created a tunnel effect that promoted the belt's combustion;
- The filter and hopper showed significant traces of combustion. Charred pieces of wood.

Overhead conveyor belt

Upper part of the hopper

Pieces of wood trapped in the hopper

In the sub-cell gallery:

- the gallery's 16 blast panels were thrown more than 50 m away;
- traces of combustion were visible inside the gallery. These traces become increasingly evident closer to the handling tower.

Projected doors

Doors torn from the sub-cell gallery

Traces of combustion in the sub-cell gallery

Handling tower:

- Numerous structural steel elements on the closed side were deformed.
- Only the bucket elevator used for the operation in progress showed signs of combustion.

Elevator on the 2nd level

Elevator on the 1st level

Handling tower and railcar loading facility

Railcar loading facility:

- siding deformed.

Railcar loading facility

Weighing room:

- The upper sheeting had expanded and the hatch was open.

Weighing room

Human consequences:

One employee, who was located at the railcar loading station at the time of the explosion, was slightly injured. A second employee complained of ringing in the ears.

Social consequences:

The plant's internal contingency plan was initiated at 9:30 a.m., and the site was shut down. Nineteen employees were evacuated, and traffic was interrupted.

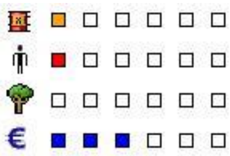
Economic consequences:

The cost of property damage and operating losses was evaluated at several million euros.

European scale of industrial accidents:

By applying the rating rules applicable to the 18 parameters of the scale officially adopted in February 1994 by the Member States' Competent Authority Committee for implementing the "SEVESO" Directive for hazardous substances and in light of available information, this accident can be characterised by the following four indices:

Hazardous materials released
Human and social consequences
Environmental consequences
Economic consequences



The parameters associated with these indices and their rating scale are available at the web site: http://www.aria.developpement-durable.gouv.fr.

The effects of the explosion were not characterised in terms of TNT equivalent, but taking into account the damage observed, the rating level of the “hazardous materials released” index is estimated to be at least 1.

As the accident caused minor injuries to 1 technician, the overall level of the “human and social consequences” index consequently reached level 1.

No information is available on possible environmental consequences, so the parameter is not rated.

As the amount of property damage was estimated at several million euros, the “economic consequences” index, therefore, reaches level 3.

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THIS ACCIDENT

It was determined that the origin of the fire was due to a collapse, and then the heating up of the bearing at the head of the overhead conveyor between the flat silo and the vertical silo. The conveyor was not equipped with a temperature sensor. The collapse of the bearing may have been due to either a lack of lubrication, a broken roller or an accumulation of material.

A pile of combustible materials, such as large pieces of wood, was found near the dislocated bearing rollers. The silo had not been authorised to store wood pellets, and no information about this new activity was provided to the inspection services.

Pieces of wood trapped in the hopper

The installation is not equipped with screening equipment in the material receiving areas.

The bearings undergo maintenance, which is performed internally. The last preventive maintenance operation on these bearings was performed 4 months prior to the accident. Between each preventive maintenance operation, a roundsman conducts a daily visual inspection, although nothing particular was detected.

The accident investigation also revealed that the equipment (dust collector, conveyor systems, hopper and dust collector) had not been earthed. The equipotentiality between these devices was therefore not ensured properly, and electrostatic sparking may have occurred.

The conveyor belt was equipped with a dust collector at the point where it empties into the hopper. At regular intervals, this dust collector discharges the dust accumulated into the hopper. This dust can then be re-injected as a “cake” but sometimes, especially when the conveyor system is running empty, the dust collector releases a small amount of dust in suspension into the hopper.

On the day of the accident, it is possible that the reinjected dust may have helped fan the flames.

According to the inspection authorities, the site was quite dusty, and the targets at ground level are regularly covered with dust. The condition of the installations was confirmed by the post-accident analysis. The sub-cell gallery is cleaned every 45 days by connecting a suction system. According to the operator, the last cleaning operation on the sub-cell gallery had been performed 15 days before the accident.

Example of dust accumulation in the sub-cell gallery

Graphical modelling of the accident makes it possible to highlight proven and supposed organisational causes (dotted line):

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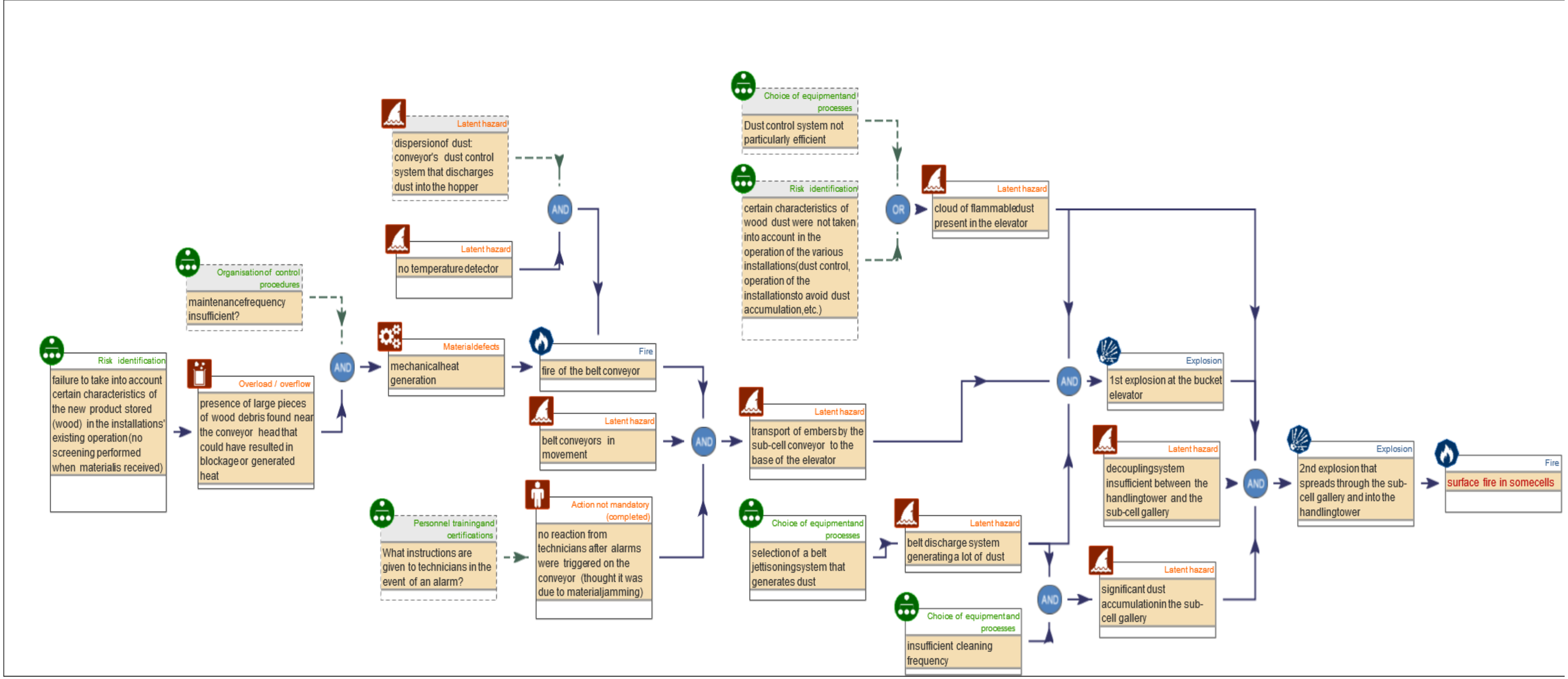

Accident modelling makes it possible to highlight certain organisational causes:

- no **risk analysis** was undertaken following storage of a new product (wood pellets). However, wood and cereals have different physical and flammability characteristics. Such a risk analysis would have made it possible to identify any process and equipment changes to be carried out;

- equipment **poorly adapted** to prevent risky situations. For example, belt discharges conducive to the creation of dust or the absence of temperature sensors on certain conveyors or the absence of screening systems in the receiving areas when materials of non-compliant dimensions may be received;

- **significant accumulation of dust** from installations that may be related **to insufficient** cleaning;

- in response to the technicians' reaction following the alarms, an update of **the technician training and instructions** provided seems necessary. Indeed, without a video display in the control station and not having sent out a roundsman to physically inspect anomalies, the technicians misinterpreted an alarm (fire and not equipment jamming) and were therefore unable to take appropriate action to avoid the accident or to warn the technicians present in the risk area;

- the collapse of the bearing at the head of the belt raises questions **regarding the conditions under which maintenance was carried out**. Is the maintenance frequency sufficient? Are the criteria defined for this maintenance adapted to the changes in products stored at the site?;

- a **decoupling** system exists between the sub-cell gallery and the handling tower, yet the explosion was still able to spread from the handling tower through the sub-cell gallery. This point was not discussed in the accident report, and it is therefore not possible to know whether the decoupling system was correctly installed or not.

The existence of safety barriers such as vents and blowout panels limited the consequences of this accident by relieving pressure and preventing the structures from collapsing.

ACTIONS TAKEN

The operator plans to:

- equip all its receiving areas with a screening system (40/40 mesh) to avoid storing materials having noncompliant dimensions which could generate heat;
- design softer transitions with shock absorbers at product discharge points to avoid materials being placed in suspension;
- draft a new cleaning procedure and assign an additional person to this task.

LESSONS LEARNT

This accident highlights the importance of conducting risk analyses each time an industrial site is modified. Technical and organisational process adaptations are often required.

The new risks which came about due to the storage and transfer of wood were not analysed even though the process had been designed and maintained for the storage and transfer of cereals only.

The accident reminds us of the importance of monitoring dust accumulation in installations. The presence of dust is a well-known risk, although it is sometimes still underestimated among elevator operators.

Generally speaking, proper equipment maintenance also appears to be an important point in preventing silo incidents. In this accident, simple visual inspection was unable to detect the bearing breakdown that was about to occur. The lack of follow-up or traceability of maintenance operations made it impossible to ensure that they were carried out or checked.

Reminders concerning operator training and the updating of instructions are also crucial for managing safety on a site. This allows operators to respond appropriately to risks. Exercises can be useful in reinforcing automatic responses.

Explosion prevention equipment played a very positive role in this accident, including vents and blowout panels that allowed the release of pressure during the explosion. This remark should be qualified with regard to the decoupling system between the handling tower and the sub-cell gallery. As the system did not prevent the propagation of the explosion, further investigations would have been useful in understanding what went wrong.

Sources:

Presentation INERIS – May 2018 – DRA-18-175131-04842A

Inspection report following the accident of 01 March 2018

Operator's accident report of 14 March 2018 (ref.: JR/CA 180301)