Deadly dust explosions inside a silo

7th April 1993

Floriffoux (Floreffe)

Belgium

Explosions
Silo
Food processing
Dust
Hot spot works /
Hot work permitting
Victims

THE FACILITIES INVOLVED

The site:

The Floreffe cereal warehouse was one of Belgium's largest, with installations located along the banks of the SAMBRE River on a site accessible to 1,500-tonne barges and equipped with loading facilities capable of processing at rates of around 120 tonnes per hour.

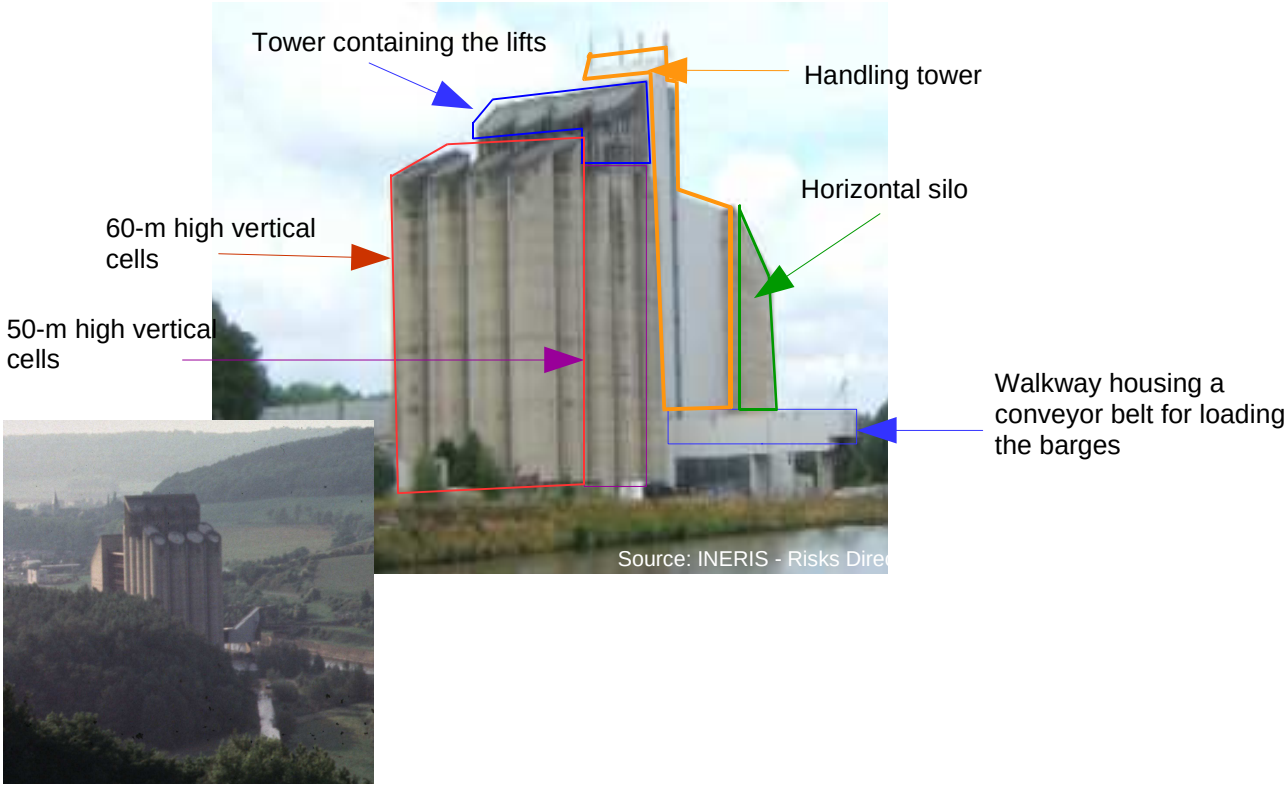
After a bankruptcy filing by the cooperative that had been responsible for running the business, on-site warehousing activities slowed. Another firm bought out the site shortly before the accident.

The specific unit involved:

This particular site contained two groups of silos.

- a horizontal concrete silo with an 85,000-tonne capacity forced ventilation system containing 62,000 tonnes of product;

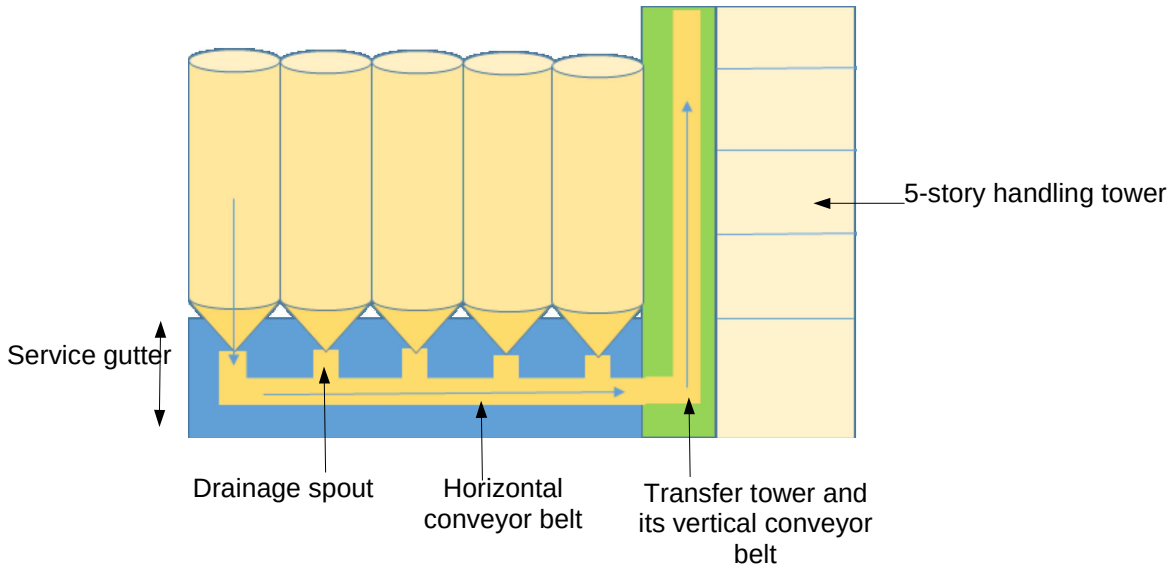
- a compact storage unit, composed of two groups of vertical concrete cells 50 and 60 metres high and featuring a 40,000-tonne storage capacity where some 30,000 tonnes of product were warehoused.



These cells were joined by means of a 5-story, 50-m high transfer and handling tower built with a metal frame and cladding. The first floor above ground was separated from the ground level by a concrete slab.

Underneath the 60-m vertical cells, three service gutters had been laid out with connections to one another. These gutters contained:

- the steel sheet drainage spouts of the various cells;
- the conveyor belts moving the cereal to lifts installed in the tower abutting the silos.



The installation had initially been fitted with a dust suction system, yet of the type without a filter. The system malfunctioned 2 years prior to the accident and had never been repaired. Dust was thus able to accumulate on all floors of the facility.

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

At the time of this accident, three operations were ongoing:

- A general cleaning of the tower had been underway for a few days by the new owner.

This task was being executed by 3 employees working for the site's new operator, assisted by 3 temp personnel with little experience. Since the building's general dust removal system was idle, cleaning had to be carried out using brooms and dustpans. These cleaning operations began on the handling tower's 5th floor, with cereal dust and debris being precipitated out floor by floor. In an attempt to disperse the cloud of suspended dust, all of the building's doors and shutters were opened, and dust spread throughout the various installations. Witness accounts made mention of a 40-cm thick dust layer hovering above the 1st floor.

- The loading of a barge with 600 tonnes of cereal was underway from a storage cell.

These grains dated from a 1989 harvest. They were dry (11% humidity) and partially eaten by weevils, which had generated a large proportion of the fine particles present.

The product's high dust concentration made it necessary to call for cleaning services. The dust collected was then poured into a container by means of a nozzle positioned well above the container. In the absence of a general dust removal system, the successive operations of filling and emptying the weight scale system was also accompanied by significant dust releases.

- A torch cutting operation was taking place in the service gutter.

Subsequent to the formation of an arch inside the cell being emptied, a congestion relief effort had been initiated. It was decided to use a grinder to cut out a square, 15 cm x 15 cm orifice in the steel sheeting of the lower hopper in order to insert an iron rod. At the same time, a lid intended to plug the orifice after unclogging was cut from sheet metal using an oxyacetylene torch in the workshop located on the ground floor of the handling tower. This practice, obviously quite commonplace on the site (given the number of patches found on other hoppers in the vicinity), had been assigned to 3 temp workers.

It was 1 pm when the explosion was triggered by the cutting operation with the grinder. The explosion spread violently through all basement levels until reaching the handling tower. A very small-scale fire ensued, and this outbreak could be quickly brought under control by first responders.

Consequences of this accident:

The human toll was extremely severe.

Five employees, including the 3 temp workers, died on the spot or within a few days due to the burns sustained or the shock associated with the explosion.

Two employees were seriously burned and two others injured by projectiles and falling debris.

Extensive property damage attested to the violence of these explosions.

The tower's metal cladding was blasted distances of up to 100 m.

Some parts of the concrete shell surrounding the lifts were destroyed to a height of 40 m. Debris was scattered over a 15-m radius.

The concrete slab on the first floor was raised; it was heavily cracked and its embedded reinforcements exposed.

The effects of pressure in 2 of the 3 service gutters ripped out the hoppers positioned under the cells.

Traces of combustion were visible all the way to the top of the building.

Moreover, broken windows and more minor damage to nearby dwellings were observed up to 300 m away, including the explosion of tiles at a nearby dairy.

A mound of earth approx. 20 m high, planted with trees and located between the silo and the closest residences, was certainly responsible for preventing even further damage.

Damage recordings served to determine that the pressure surge level had climbed to 6-8 kPa inside the building, 0.7-2 kPa at a distance of between 200 and 250 m, and 0.5-1 kPa at 270 to 300 m from the point of the blast. According to an INERIS Institute study conducted in 1993, the pressure surge reached in the gutter where the explosion originated would have exceeded 100 kPa.

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 four following indices:

Hazardous substances released	■ □ □ □ □ □
Human and social consequences	■ ■ ■ □ □ □
Environmental consequences	□ □ □ □ □ □
Economic consequences	■ ■ □ □ □ □

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

Since the effects of this explosion had not been characterised in terms of TNT equivalent but instead by the 300-m radius over which broken windows were reported, the "hazardous substances released" index was thus scored a "1".

Given that the accident caused the death of 5 workers, the overall rating of the "human and social consequences" index was assigned a "3".

With no information available on the ultimate environmental consequences, this parameter could not be evaluated.

Since the amount of property damage had been estimated at €1.5 M, the "economic consequences" index received a "2" rating.

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THIS ACCIDENT

The origin of this accident was linked to the simultaneity of two causes:

- the very high concentration of dust at all levels of the installation due to:
  - manual cleaning operations underway for several days;
  - the absence of an automated dust removal system;
  - the grain loading operation initiated at a cell containing very dry grains, stored over several years and including a significant proportion of fine particles.
- the execution of hot spot works intended to unclog the cell undergoing drainage, more specifically through use of a grinder in the service gutter running beneath this cell.

The analysis of this accident has exposed other causes as well:

- the lack of employee training regarding explosion risks, especially in the case of excessive dust accumulation;
- human errors:
  - the choice of operator to pursue site activities despite the lack of a proper dust removal system adapted to the risks generated by excessive dust accumulation;
  - the decision made by the experienced agricultural engineer to set up on-site hot spots under these conditions of heavy dust accumulation, which naturally raised the risk of explosion.
- failure to write up a hot work permit prior to proceeding with hot spot operations;
- poor design of the product recovery system installed under the silos, in particular the emergency hatch in the event of clogging.

ACTIONS TAKEN

With the approval of Belgian authorities, the Ministry of Ecology's Industrial Environment Division tasked the INERIS Institute to conduct an in-depth investigation of the consequences surrounding this explosion. The investigation in turn gave rise to an experience feedback session on dust explosions and a comparison of lessons learnt from such explosions in cereal silos since the Metz accident, which had caused 12 deaths on 18th October 1982.

Moreover, a judicial investigation was ordered. The trial was held in 1997. Two years of testimony before the Namur Criminal Court were necessary to fully examine such a complex case in terms of responsibility.

The cereal silos had been built by a company that subsequently filed for bankruptcy. Its trustee had sold it off to a cooperative, which however was merely operating as an intermediary: in reality, since 15th March 1993, the sole owner of the site and its warehoused merchandise was a Flemish firm.

In the decision handed down on 29th September 1998, the court acknowledged that the volume of dust had surpassed an acceptable threshold because of the fact that orders had been given, without any precautions, to simultaneously load a barge, sweep out the silos and handle the grains. The risk therefore was quite severe. The engineer present at the time of the accident ordering these various tasks had to know this fact; he was sentenced to 9 months in prison, while the other defendants received 6-month sentences.

LESSONS LEARNT

The site operator had apparently failed to take stock of the permanent risk created when running a cereal silo. Yet other similar accidents, including the one in Metz that killed 12 on 18th October 1982, had already sufficiently highlighted this risk.

When faced with the risks inherent in cereal silo operations, the working methods adopted were unacceptable:

- despite a dust removal system in need of repair, cleaning steps were still performed without any precautions taken;
- cleaning operations continued while grain handling was underway;
- cutting / welding works on the hopper were considered common practice at this site, no matter the extreme hazard they created in the presence of dust;
- this most delicate of operations had been entrusted to three temp employees, who were likely to have the least awareness of the risks involved;
- site personnel and temp workers had not been trained to cope with risks at this installation;
- no "hot work permit" type of procedure had been instituted.

The experience feedback from this accident served to recall the following best practices:

- reactivate the suction system before initiating dust removal steps in the installations;
- use a cleaning method that avoids suspending dust particles, notably by introducing suction;
- inform technicians about ATEX-related risks in silos;
- organise work flows in a way that avoids simultaneous cleaning and grain loading operations;
- plan for an emergency access hatch underneath the silos as of the facility design phase;
- ban the use of sparking tools in dusty zones;
- establish a hot work permitting procedure for all hot spot tasks.

Sources:

Study: INERIS, Floriffoux Accident Investigation Report - November 1993.
INERIS, Guide for the design and operations of agricultural and food storage silos with respect to explosion and fire risks - P. Roux, May 2000.

Video: Floriffoux, The error. Roger Leenhart Films, experience feedback collection - 11 min.

Press: *Le Soir* newspaper.

- √ http://archives.lesoir.be/les-silos-de-floriffoux-ravages-par-une-explosion-ca-de_t-19930408-Z06LVM.html
- √ http://archives.lesoir.be/alors-que-namur-juge-l-explosion-des-silos-de-floriffou_t-19970204-Z0D8Y3.html
- √ http://archives.lesoir.be/a-qui-appartenait-le-silo-qui-a-explose-en-tuant-cinq-p_t-19961126-Z0CZPN.html
- √ http://archives.lesoir.be/une-disqueuse-a-l-origine-du-drame-floriffoux-le-corps-_t-19930410-Z06M1T.html
- √ http://archives.lesoir.be/a-floriffoux-l-explosion-avait-tue-cinq-ouvriers-et-bru_t-19980929-Z0FU6X.html
- √ http://archives.lesoir.be/deux-societes-citent-leur-compagnie-d-assurances-devant_t-19930515-Z06RH0.html
- √ http://archives.lesoir.be/debat-sur-les-mesures-conservatoires-explosion-de-flori_t-19930507-Z06QF0.html