Explosion in a malt house silo

October 18, 1982

Metz (Moselle)

France

Explosion
Food processing industry
Silo
Cereals
Building works
Hotspots
Victims
Waste / effluent (industrial, residual, etc.)

THE FACILITIES INVOLVED

The site:

The facility was located on the right bank of the Moselle River, between the port and the A31 motorway. Built in 1973-74, this malt house offered a capacity of 62,000 tonnes/year, accommodating barley shipments by rail and road as well as by conveyor belt from a port installation set up on the Moselle River. The process was designed around transformation into malt for use by breweries. At the time of the accident, the malt house contained a storage silo for both raw materials (barley and winter barley) and the finished product (malt), with a capacity of around 15,000 tonnes.

The involved unit:

Built in reinforced concrete, the silo was composed of 14 vertical cylinders clustered into 3 rows, the 2 outer rows with 5 cells and the middle row with 4; the cylinders were 7 m in diameter, 43 m high and capable of storing 1,200 tonnes if not separated into multiple storage blocks. Some cylinders contained two superimposed half-cells, with the lower one being vertically partitioned in some cases. The spaces between cells (whose cross-section resembled a curvilinear triangle) were not accessible and not available for storage use.

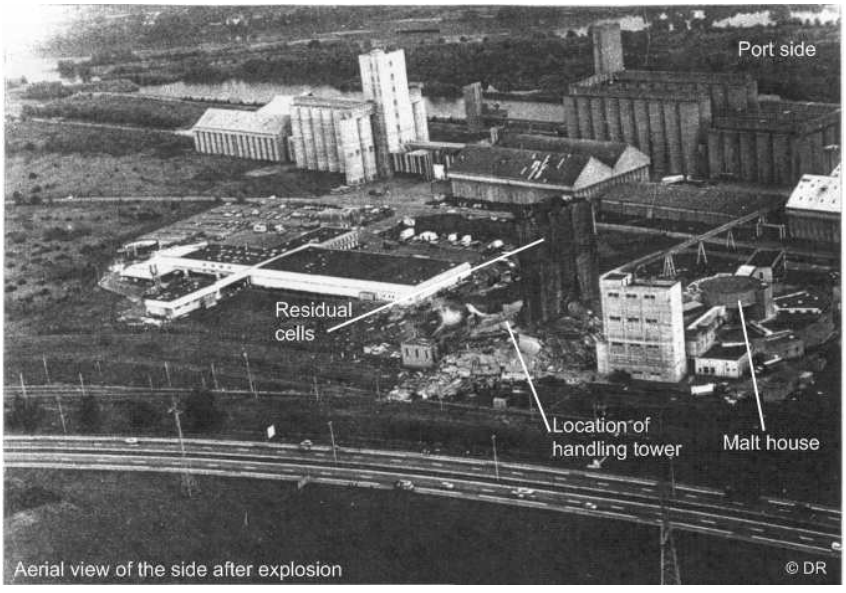
These storage reserves were reached by conveyor belts running to the upper parts (via a 4-m high concrete gallery), as well as to the middle and lower parts, from shared installations grouped in an operating tower (also made of concrete) 62 m high adjoining the cells. This tower comprised ten stories of equipment, including malt cleaning machines, scales, presses and vacuum pumps; in addition, it housed conventional bucket elevators with steel casing. A metal frame warehouse and shipping facility (for both rail and road transport) was built adjacent to the tower.

A portion of the installation had been equipped with a sophisticated dust removal system, complete with a vacuum pump, leading to a single plenum chamber. The lateral suction eyes of the upper gallery had been permanently obstructed in order to both improve ventilation unit efficiency and avoid water intake without first efficiently removing dust from the premises.

The facility was lacking a vent to release excess pressure in the event of an explosion. Electrical equipment was assumed to be impervious to dust (IP55 rating). Only the elevator motors were fitted with rotational speed controllers.

With the exception of a few isolated rooms on the ground floor (control room containing process diagrams of the entire installation, laboratory), no heating device was present in the tower.

The rate of humidity of the stored barley was less than 16%, while the rate for malt did not top 4%. No fumigant was used in the process.



THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

The explosion occurred at 2:15 pm. At the time of the accident, the condition of the facility was as follows:

- The filling rate of silo cells was high: approximately 12,000 tonnes for a theoretical capacity of 15,000 tonnes. The products in storage were kept very dry.
- The site work performed by 3 subcontractors was underway inside the grain handling tower: 4 boilermakers were installing a set of dust removal ducts between elevations 25 and 37 m; this task was apparently taking place without welding (flange and bolt assemblies); 3 masons were repairing slabs, with among other things a jackhammer fed by a compressor located outside the installations at ground level, with at least one mason assigned to monitor the compressor.
- The installation was operational: 2 malt house employees were in the elevator pit below the tower ground level performing cleaning tasks, while a crew foreman was examining some process charts in the control room. 3 drivers ready to load a vehicle were also present at the tower ground level or nearby; one driver was inside the cab of his lorry underneath the loading hopper and another was accompanying the crew foreman.

Witnesses reported 2 successive explosions "a few seconds" apart, the second more powerful than the first. Flames could be seen at various spots inside the silo boundary. Partial combustion of the grains lasted several days over the upper part of the 4 middle row cells, which remained intact along with their contents during the explosion.

Consequences of this accident:

Except for some minor damage, the human and property consequences were confined to the silo and its immediate surroundings over a distance of approximately the height of the facility.

✓ Human toll

Of the 13 individuals present inside the handling tower or in the immediate vicinity (the drivers) when the explosion struck, only one in very serious condition was removed alive, several hours after the accident. The other twelve were killed by the blast or from being crushed or suffocated by the weight of explosion debris; their bodies were recovered several days hence; the last victim was finally removed on October 23rd at 5:45 pm.

Two other people were slightly injured, one in the courtyard of an adjacent workshop, the other inside the malt house enclosure.

✓ Property damage

The installations collapsed. The operational tower fell on top of the rail spur leading to the malt house, spanning a distance roughly equal to its height. Moreover, 8 of the 14 cells were completely destroyed; 2 empty cells were heavily damaged over their lower part but remained upright, as did the other 4 cells (along with their contents), all positioned in the silo's middle row. The instability of residual structures plus the tremendous pile of concrete rubble and spare equipment covered by grain strewn by the explosions severely complicated the work of emergency responders. A total of 600 rescue personnel, including canine units, were mobilised in the hope of finding survivors; two cranes capable of lifting 150 and 300 tonnes were brought onsite.

An estimate of property damage caused by the accident amounted to 70 million francs (MF).

✓ Other consequences

The barley and malt debris disposed at the dumpsite of the former gravel pit in Moulins-les-Metz wound up polluting the Moselle River alluvial fan for 2 years within a water extraction zone. As ordered by Prefecture decree issued on February 16, 1983, a motion was filed enjoining the malt house operator to pay 5 million francs in May 1983 to defray the cost of required cleanup work. Site cleanup entailed aerating gravel pit water and then removing the cereal grain waste once the pit had thoroughly dried; a total of 12,500 m³ of contaminated barley and malt were discharged to a certified waste storage centre.

The European scale of industrial accidents:

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

The parameters composing these indices and their corresponding rating protocol are available from the following Website: http://www.aria.developpement-durable.gouv.fr

The "1" value ascribed to the "Hazardous materials released" index corresponds to a TNT equivalent of less than 100 kg (with damage being confined to the silo and its immediate surroundings - parameter Q2).

The "4" assigned for the "Human and social consequences" index stems from the deaths of 12 employees, both company and subcontractor personnel, lorry drivers (perhaps clients?) (parameter H3).

The rating of the "Economic consequences" index is at least a "4", given an estimation of property damage amounting in 1982 to 70 MF (parameter €15).

The "environmental consequences" index went unrated due to the absence of impact on the accident site itself. At the location of the gravel pit, this index equals at least "1" (parameter Env13), yet the lack of precision regarding the actual surface area affected prevents refining this estimation.

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

Onsite findings made it possible to establish that the explosive wave propagated along the silo's longitudinal axis. Traces of explosion or combustion appeared outside the cells over the upper third or half, as well as inside the storage spaces above the grain level and in the spaces between cells. On the other hand, no trace of combustion could be found in the lower parts of cells, nor in the tower basement (especially the elevator pit, as evidenced by the presence of earlier dust), nor on electrical equipment (which had undergone regular inspection by an independent body), seemingly excluding electrical sources as the cause of the accident.

The investigation revealed a large quantity of dust covering the site, to such an extent that company management had considered undertaking works to upgrade the dust removal system. The system in place was only partial, given the complications resulting from interdependence of the various installations due to a single dust room and its subpar performance.

The risk of fire and explosion had gone practically unnoticed and at the very least underestimated by all malt house staff. More specifically: no memorandum had ever been circulated regarding site safety; no instructions written on the precautions to take when performing onsite work, either under "normal" operations or for special intervention by company personnel or subcontractors; and no "burning permit" protocol adopted. Moreover, no rule forbidding smoke inside the installations was being enforced.

A dust explosion is the most likely hypothesis, since the presence of fermentation gas can apparently be excluded given the dryness of stored contents.

Without suggesting that the origin and sequence of explosions can be determined with precision, the following scenario still seems reasonable: an initial explosion in the tower generated by the combination of an ignition source introduced during the works (or a careless smoker) with an explosive atmosphere caused dust to scatter inside the facility, which in turn led to the second explosion throughout the tower, extending into the upper gallery and spaces between cells and eventually producing the observed collapses (outer row cells, handling tower).

ACTIONS TAKEN

An administrative investigation was conducted by the classified facilities inspection office. Given the severity of this accident and although practically no impacts were recorded beyond the site boundary, France's Environment Minister proceeded by commissioning a general inspection to clarify the causes of this tragic event and record all suggestions aimed at mitigating the risks involved in silo operations.

The General Inspector's report dated February 7, 1983 underscored the need to reduce dust accumulation inside such installations (through dust collection, cleaning, etc.), in addition to improving operations and maintenance procedures and minimising the consequences of an eventual explosion by concentrating more heavily on facility design (e.g. excess pressure vents, tower/cell decoupling).

A technical memorandum regarding storage silos that contain cereals, food grains for distribution and all other organic products capable of releasing inflammable dust was enacted on August 11, 1983 and published in the French legislative official journal. The dramatic outcome of the Metz accident also gave rise to the 1985 introduction of "silos" into the nomenclature adopted by the classified facilities authorities for environmental protection.

In its July 15, 1991 ruling, the Metz Court of First Instance issued a suspended sentenced against the malt house managing director of 6 months jail time with a fine of 20,000 francs for involuntary homicide and injury.

LESSONS LEARNT

Beyond the inadequacy of the technical devices on hand (dust removal system, no vents installed, etc.), this accident highlights the fundamental importance of human and organisational factors relative to the execution of both "normal" operations and special works, whether they be preventive or remedial maintenance or facility renovation.

The lack of written safety procedures or burning permits for performing work and, more generally, the absence of a risk analysis and subsequent prevention / monitoring measures all constitute anomalies that induced this accident.

The combination of hands-on managerial involvement, adapted training of malt house personnel and adequate information circulated to subcontractors would undoubtedly have compensated for the failings exhibited by onsite workers regarding the risks incurred and resources to be implemented in order to better mitigate, if not fully control, the given risks.

At the time of these events and despite an ongoing dialogue between the Environment Ministry and the profession on the need to improve risk prevention in silos, as made plainly evident by the explosion of a German flour mill silo in Bremen in February 1979, malt house executives seemed relatively unaware of the presence of dust explosion risks.

In closing, this accident also underscores the necessity of managing waste discharge following an accident to ensure that such wastes are not generating subsequent pollution.

Other silo explosions occurring while site work was ongoing:

- Bourges – ARIA No. 784
- Floreffe (Belgium) – ARIA No. 4417
- Lorient – ARIA No. 12041
- Albert – ARIA No. 20340
- Aigueperse – ARIA No. 31588