Explosion of a paper pulp storage tank
18 January 2011
Nogent-sur-Seine (Aube)
France

Explosion
Hydrogen
Paper mill
Victims
Works / modifications

THE FACILITIES INVOLVED

The site:

The Nogent-sur-Seine paper mill manufactures and sells paper for corrugated board; the pulp used for these operations is exclusively produced from recycled paper and cardboard.

The factory is owned by a French industrial group specialised in the design and manufacturing of cardboard packaging.

The 24-ha site, which launched production in 2005, features the following installations:

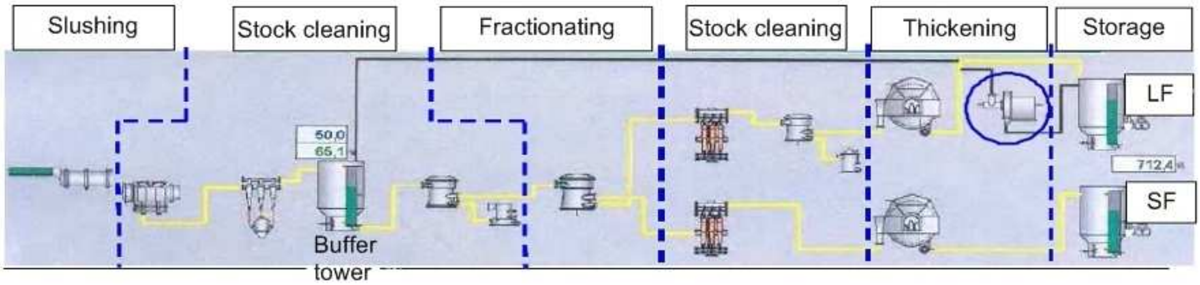
- external zone for storing bales of recycled paper and cardboard,
- steam production room,
- paper pulp preparation workshop,
- workshop dedicated to manufacturing paper reels for corrugated board,
- finished product storage building,
- units and activities ancillary to the production process, including the industrial effluent treatment plant.

The factory offers an annual production capacity of 270,000 tonnes with a permanent workforce of some 100 employees.

The unit involved and the process being applied:

The incident occurred at the periphery of the paper pulp preparation workshop, whose operations entailed a purely mechanical implementation process devoid of any chemical product input.

The various stages of this process were as follows:



The paper pulp processing path is depicted by the yellow line.

The slushing step consisted of placing the recycled paper and cardboard into suspension in water heated to 50℃, within a pulper, in order to obtain paper pulp with a dryness of between 4% and 5%.

The stock cleaning operation, conducted over several stages, was intended to eliminate all undesirable solid matter. This cleaning was being performed by centrifugation and screening through calibrated holes.

Next, fractionating served to separate short fibres (SF) from long fibres (LF) by means of injection into a rotating basket with very narrow slits.

The thickening step, carried out in parallel on both the LF and SF lines using a disc filter, yielded a dryness equal to 10%.

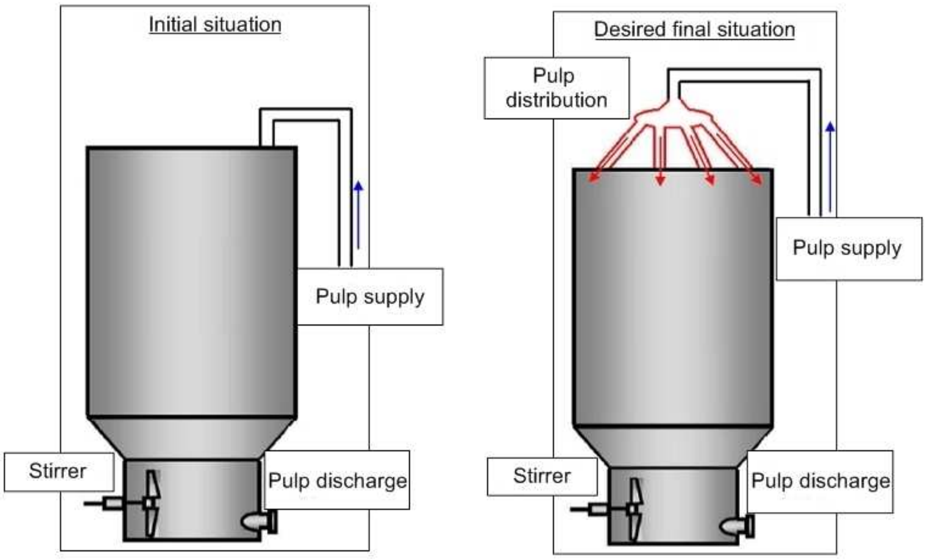
Two categories of paper pulp were under production, one with long fibres the other with short fibres, and then stored in two distinct towers (designated LF and SF). Each tower held a capacity of 1,000 m^3 and was placed near a 1,200-m^3 "buffer" tower, containing paper pulp at a dryness to 3.5%.

The subsequent step in the paper production process involved other products, notably starch.

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

A preliminary transformation completed in December 2010 had included pre-installing a new pulp distribution system on the LF storage tower by replacing the single pipe with one splitting into four tubes (shown in red in the figure below). On the day of the accident, the mission assigned to a subcontractor specialised in sheet metal work entailed connecting the pulp supply pipe to the distribution system.



At 8:20 am, in preparation of this works, technicians turned off pulp supply into the tower and proceeded with a 10-minute sequence of pipe rinsing with water. This procedure consisted of rinsing all process equipment by injecting 20 to 40 m^3 of water into the pipes, thus adding to the quantity of pulp already present in the tower.

At the same time, they shut down the pulp bleeding operation; once rinsing water had been introduced, the paper pulp level in the LF storage tower then remained constant throughout the subcontractor's intervention.

The characteristics of pulp still inside the tower were as follows:

- a tower fill rate on the order of 95%,
- pulp dryness of approx. 10%.

The LF storage tower exploded some 40 minutes after supply shut-off and pulp bleeding.

Two temp workers, commissioned by the specialised sheet metal firm to perform these works, were stationed on the tower roof.

One of them was cutting the pulp supply pipeline with an grinder, while his partner was positioned near the middle of the roof to avoid debris flying from the tool. The explosion occurred just as the grinding disc punctured the pipe wall. A witness observing the scene from an adjacent tower confirmed this account of the event and noticed the presence of a flame leaving the same tower.

The blast violently raised the tower's sheet metal roof, throwing the technician over the guardrail and causing him to fall onto the roof of an adjoining building 15 metres below.

Mill employees, including the site's emergency response team, heard the deflagration and rushed to the scene to rescue the victim, who was still conscious but unable to move.

Public rescue services, along with a physician from emergency medical services, arrived at 8:55 am; the injured subcontractor was taken by helicopter to a Paris hospital, where he succumbed to his injuries in the early evening.

Consequences of the accident:

The human toll amounted to the one death (the worker ejected from the roof).

As for property loss, the LF storage tower sustained heavy damage and its use was immediately prohibited by the Inspection Authorities for Classified Facilities. This decision led to a production shutdown, as the tank involved was critical to factory operations.

Economic losses were assessed at €1.5 million.


Source DREAL Champagne-Ardenne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The 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 II' directive on handling hazardous substances, and in light of the information available, 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 level 1 assigned to the "hazardous substances released" index corresponds to a TNT equivalent of less than 100 kg (damage being confined to the tank - parameter Q2).

The level 2 scored for the "human and social consequences" index was due to the death of the subcontractor's employee.

The "economic consequences" index (parameters €16 and €15) was rated at 2 or more, given the financial losses valued at €1.5 million.

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

A specialised consulting firm analysed the circumstances of this accident and appraised all damaged equipment so as to develop a complete understanding of the causes. The paper pulp samples extracted in the tank on the day of the explosion were tested by this firm as well as another consulting firm in an effort to reproduce in the laboratory the conditions leading up to the accident.

The conclusions of both organisations matched, and the causes of this explosion could be stated with certainty: paper pulp stored under a given set of conditions can ferment and produce hydrogen.

The final appraiser's report established that the explosion occurred according to the following sequence:

- paper pulp stored in the tower released hydrogen at a rate such that the lower explosive limit (LEL) could be reached within a few hours,
- the hydrogen then mixed with air present in the tower vapour space to form an explosive atmosphere (ATEX),
- the source of ATEX ignition was a spark generated by the grinder during cutting of the pipe connected to the tower vapour space,
- the pressure surge created by the explosion caused the tower roof to fail at the level of the seam on the tie-in weld with the cylindrical shell.

It is likely that this ATEX atmosphere had not always been present in the tower vapour space and moreover that it was especially dependent on variations in the tower filling rate. On the day of the explosion, all conducive conditions (ATEX formation and ignition) were present, which had not been the case during previous hot works (conducted at a much lower tower filling rate).

ACTIONS TAKEN

A few hours after the explosion, the Classified Facilities Inspectorate made an unannounced visit to the site. Since the damaged tower risked collapsing and the roof, already partially torn off, risked falling or blowing away entirely at any time, the site operator was requested to mark off the hazardous zone and limit access.

With the operator's consent and for the purpose of learning the composition of the gaseous atmosphere under the roof of the exploded tank, the Inspectorate immediately undertook an analysis of the gas present in the adjacent so-called "buffer" tower, which was the only one still accessible. This analysis was performed with a small portable device calibrated for H_2S, CO, CH_4 and O_2, in taking all the necessary precautions (i.e. turning off the electric power supply and proceeding with a harness). The results did not indicate the presence of an explosive atmosphere. Moreover, none of the site managers interviewed were able to provide input that could potentially explain the underlying causes of this accident.

In light of these circumstances, on 20 January 2011 (2 days after the accident), the operator was issued a formal notice outlining emergency measures, as stipulated in the following points:

- prescribe the measures required to put the facility in safe condition,
- request the operator to extract a representative paper pulp sample in order to perform analyses and reproduce, to the greatest extent possible, the conditions leading to this accident,
- submit in 2 months' time a detailed accident report,
- update the site's safety report within 2 months of the date of receipt of the accident report,
- require a verification of installations by a consultant specialised in structures before reusing the damaged tank and its accessories.

The tank verification report was submitted on 21 January and the operator authorised to resume site activities as of that same date, provided that the tank was only being used up to a maximum 50% of its capacity and that basic works had already been completed to ensure site safety, as proposed by the consultant.

Moreover, within the scope of the safety report update, additional measures were introduced, for the most part on a semi-continuous basis, in other storage facilities typical of paper mill operations.

These measures suggested that for large tanks (i.e. > 1,000 m^3), like the one that had exploded, when the filling rate is high and pulp is beginning to move (via filling or bleeding) following an extended downtime, the release of H_2 means that the LEL may be quickly reached. Gas bubbles, most likely trapped inside the fermenting pulp, were freed as the pulp began to move. For smaller tanks, this same phenomenon was observed without the LEL actually being reached (max. 80% of the LEL threshold).

The H_2 concentration can therefore, in certain configurations, exceed LEL and lead to the formation of an ATEX atmosphere over part of the vapour space in some towers and storage facilities.

The updated safety report acknowledged these findings; it identified a new set of hazardous phenomena, i.e. storage tower explosion and (to a lesser extent) the explosion of storage facilities used to prepare paper pulp.

The modelling of these phenomena, which relied on conservative hypotheses, revealed that the effects of an explosion did not spread beyond the site boundary. Consequently, no special measure was required to ensure the protection of third parties outside the mill.

In contrast, measures were required to provide for employee protection, namely a more accurate redefinition of the ATEX zones. A mapping of the typical movements of personnel in various areas on the facility's grounds, cross-referenced with the impact zones in the event of an explosion, confirmed that the placement of additional safety barriers was unnecessary.

Nonetheless, in order to avoid an ignition source during onsite works, intervention procedures were enhanced and updated to recognise the possibility of hydrogen release, as this phenomenon had not been taken into consideration prior to the accident. The "training of technicians on detection of explosive atmosphere" was in particular included to ensure technicians were skilled in the use of portable gas detectors.

Even though the effectiveness of such a measure remained difficult to quantify, the large-capacity storage tanks and mixing tanks installed adjacent to an outer wall in the workshop were nonetheless equipped with additional vents.

LESSONS LEARNT

The Nogent-sur-Seine accident revealed that paper pulp, obtained without a chemical process using recycled paper and cardboard, may give rise to acetogenic microbial activity.

This phenomenon produces hydrogen that, under certain conditions (high filling rate, stirring of pulp following extended downtime), causes the formation of an explosive atmosphere in paper pulp storage tanks.

In this type of paper mill, the risk of pulp tank explosion must therefore be taken into account, especially during the risk analysis preceding any kind of works-related activity.