Pyrotechnics
Dynamite
Start-up
Victims
Property damage
Organisation/ inspection
Expert evaluation

Explosion in a dynamite loading workshop

March 27, 2003

Billy-Berclau – [Pas-de-Calais] France

THE INSTALLATIONS IN QUESTION

The establishment, with roughly one hundred employees and spread over 75 ha, produces two types of explosives:

- ✓ Dynamite manufactured from nitro-glycerine, nitrocellulose and ammonium nitrate;
- ✓ Explosives made from ammonium nitrate and fuel oil (ANFO).

For 2002, the site produced 6,500 t of dynamite and 8,500 t of ANFO.

The plant is divided into four main sectors:

- ✓ An administrative sector,
- ✓ A raw material storage sector,
- ✓ A "dynamite" manufacturing sector, including the fabrication of nitro-glycerine, paste dynamite manufacturing shops, automated (shop 18 or Tellex) or non-automated (several shops where the paste is produced in low-volume mixer-dryers or "guédus"), dynamite loading shops and an ANFO manufacturing and packaging shop.
- ✓ An explosive storage sector.

Nitro-glycerine is synthesised from nitric and sulphuric acids to form a sulpho-nitric mixture to which glycerine and glycol are added to obtain a nitro-glycero-glycol mixture (called nitro-glycerine). Following the separation steps, this nitro-glycerine is mixed with ammonium nitrate, nitrocellulose (gun cotton), and barium sulphate,…. The "bare dynamite" is formed in this manner. This dynamite paste is then sent to the loading shops to be shaped into sticks of dynamite to be marketed.

The is governed by the SEVESO classification for the storage of explosive substances (350 t – Seveso / high level), the manufacture of explosives (25 t – "AS" level) and the storage of ammonium nitrate (2,200 t – Seveso / low level). It is also subject to pyrotechnic regulations.

The SEVESO danger zones extend 783 m, and the pyrotechnic danger zones up to 1,565 m (Scenario: explosion of explosive stores) and the radius of the PPI ("plan particulier d'intervention", special intervention plan) is 1,900 m (Scenario: explosion of ammonium nitrate). 4 communes are located within the pyrotechnic radii. A procedure to reduce the risk at the source was underway prior to the accident.

The workshop involved in the accident (workshop 50) is an automatic dynamite cartridge loading workshop (a "Rollex" type cartridging machine). The production capacity is 900 kg/h. The dynamite is brought in bins on rollers containing 80 to 150 kg. The bins are tipped into a feeder that includes a loading hopper and two screws that mix the paste and extrude it through a die. The strip of paste thus obtained is then driven by a belt conveyor and shaped to the desired thickness by a smoothing roller, then cutup by a knife into parallelograms that are pushed and packaged into waxed paper into a keg. The dynamite cartridges are then transferred to the neighbouring workshops to be packaged into shipping containers.

The workshop is fully automated once the production cycle has been initiated, with the operators monitoring from a protected control room located in an adjacent shop. For a complete production line, the crew during normal operation consists of a machine operator, who ensures correct operation and makes the necessary adjustments, and one or two operators, who take care of the counting, bagging and loading into cases. These operations are performed remotely or in the associated workshops. However, during start-up and shutdown phases, which require adjustments or emptying of the machine, one to three people may be located next to the machine.

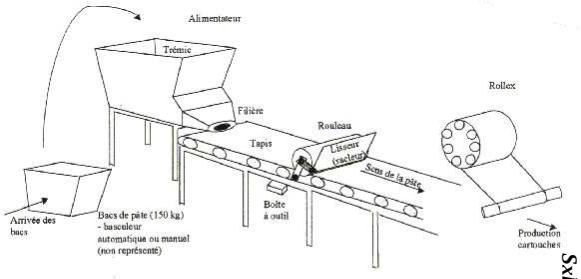

Figure 1 : Schéma représentant l'alimentateur et la Rollex de l'atelier 50

Schéma : R. D.

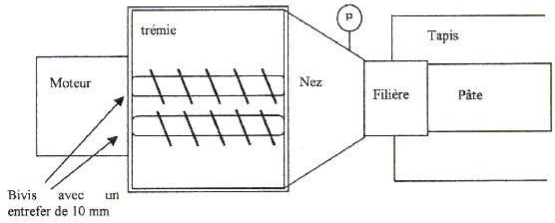

Figure 2 : Vue longitudinale de l'alimentateur de la Rollex 50

THE ACCIDENT, ITS BEHAVIOUR, EFFECTS AND CONSEQUENCES

The accident

On March 27, 2003 at 6.16 am, there was an explosion in workshop 50. The sound of the explosion was heard more than 10 km away.

At the time of the accident, adjustment operations were underway as the shift had begun exceptionally early (5 am instead of 7 am). The adjustment phase was a little longer than normal. The workshop contained a total of 580 kg of dynamite.

A significant cloud of black smoke was released from the site but the fire that followed the explosion was quickly brought under control.

At the alleged time of the explosion, 4 employees were in the shop or in the immediate vicinity: the machine operators, an individual in charge of collecting waste and a mechanic who was passing in front of the shop near the tunnel. All 4 died in the accident

In the diagram opposite, the individuals who died are indicated in red, and the injured in blue and green.

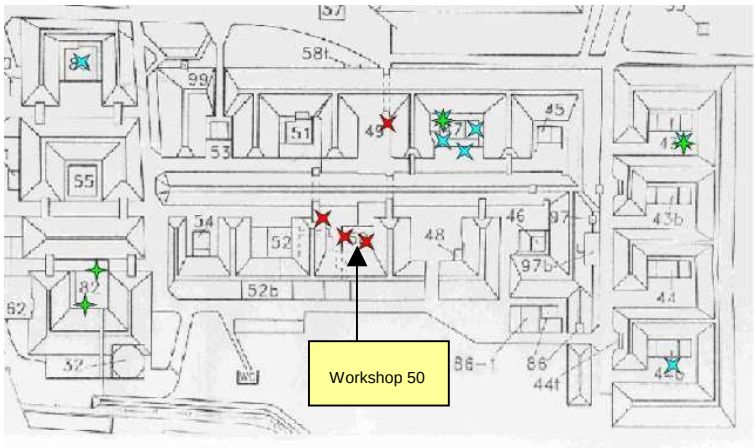

Schéma : R. D.

The consequences

The cartridging shop was destroyed, leaving large craters:

✓ One near the passageway between workshops 50 and 48 (1m x 1.30 m and 0.60 m deep) in the location where 2 dynamite bins were positioned, according to witnesses,

✓ The other near the feeder itself (0.80 m in diameter x 0.20 m, the floor consisting of a 15 to 20 cm concrete slab then backfill).

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Photo DRIRE NPC

Crater at the location of the machine

Photo DRIRE NPC

What's left of the machine

Parts of the cartridging machine were found in a radius of 600 m. According to the expert appointed by the Inspectorate, considering the resulting damage, it is difficult to accurately quantify the amount of charge involved: it could be in the neighbourhood of an equivalent of approximately one hundred kg of TNT, although less than an equivalent of 300 kg of TNT.

In the adjacent workshops, serious although more limited damage occurred: for example, the structures and the accessories such as cable trays were destroyed. The mounds of earth surrounding the shops definitely attenuated the effects of the blast. The damage observed was primarily broken windows, siding and structural damage and disturbed roofing tiles. No domino effect was observed in the other shops or pyrotechnic stores.

On the outside of the site, broken windows and the displacement of roofing tiles were observed (up to approximately 1 km).

Photos DRIRE NPC

Workshop 50

Dynamite paste store

Photos DRIRE NPC

Workshop hallway

Machine impact in concrete wall

European scale of industrial accidents

By applying the rating rules of the 18 parameters of the scale made official in February 1994 by the Committee of Competent Authorities of the Member States which oversees the application of the 'SEVESO' directive, the accident can be characterised by the following 4 indices.

Les paramètres composant ces indices et le mode de cotation correspondant sont disponibles à l'adresse suivante : http://www.aria.ecologie.gouv.fr

The 580 kg of dynamite present in the warehouse represents 1.2% of the corresponding Seveso threshold (50 t – explosive substances classified in a division other than 1.4 as per the European Agreement Concerning the International Carriage of Dangerous Goods (ADR) (United Nations)), which equals level 3 of the "quantities of dangerous substances" index per parameter Q1 (Q1 between 1% and 10%).

Parameter Q2 is rated as level 2: although it is difficult to accurately quantify, the dynamite load can be compared to roughly 100 kg of TNT, while still being lower than 300 kg of TNT (Q2 between 0.1 t and 1 t).
The overall "dangerous materials released" rating is thus 3.

Two parameters are involved in determining the level of the "Human and social consequences" rating: H3 and H5.
- Parameter H3 reaches level 3, as 4 employees were killed in the explosion (H3 between 2 and 5 deaths).
- Parameter H5 is rated 2, as 9 employees were injured in the explosion (H5 between 6 and 19 injured).

As a result, the overall "Human and social consequences" rating is 3.

ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

Several inquiries were conducted following the accident:

✓ A judicial inquiry (the police department assisted by two experts from the Paris police explosives laboratory),

✓ An administrative inquiry (a commission of several general inspections assisted by the expert appointed by the Inspectorate),

✓ Internal inquiries conducted by the operator.

The expert submitted a preliminary report and the operator's final report is to be completed at the request of the Registered Installations Inspectorate. However, the inquiries are still in progress and responsibility for the accident has thus not yet been established.

The difficulty with **search for causes** on this type of accident results from the disappearance of the witnesses and the destruction of material elements. In this case, two elements slightly mitigated this difficulty: a witness entered the shop several time during the hour that preceded the accident (the operator of a "*guédu*" mixer-dryer type workshop who was bringing bins of paste to shop 50), on the one hand, and the area surrounding the Rollex machine are filmed in order to continuously monitor and record the operations from the control room, on the other hand.

An examination of the parts shows that the initial explosion took place in the Rollex feeder, then propagated to other explosives present in the workshop. The explosion could have been caused by the presence of a foreign object in the feeder that may have become caught between the extruder screw and the steel housing. According to the expert appointed by the Inspectorate, the special sensitivity of the dynamite cannot be excluded even if tests conducted on the explosives manufactured at the time of the accident show no signs of anomaly.

The accident resulted in a high number of victims in proportion to the number of people likely to be present under normal circumstances. The following individuals were present in the workshop concerned (50) at the time of the accident :

- the machine operator who made adjustments on the Rollex machine; the quality of the paste exiting had posed a few problems,

- an operator came from another shop to assist him,

- a custodial technician, who was passing by the workshop to collect the waste bins specifically designated for pyrotechnic wastes,

- a mechanic who had participated in a maintenance operation not far from workshop 50 and who, having forgotten a tool in that shop, was passing through a hallway in front of the tunnel connecting shop 50 to shop 49.

ACTIONS TAKEN

After the explosion, the operator began evacuating the personnel. Operations to secure the site were undertaken at the same time as the workshops were secured, particularly those of the nitro-glycerine manufacturing shop and the shutdown of power distribution, except those required for safety-related equipment.

The operator engaged the internal contingency plan. The fire that followed the explosion was quickly brought under control. Approximately sixty firefighters arrived at the site. The safety perimeter, first established by the emergency services, was removed at around 10.30 am. Traffic on the Deûle river canal, which runs alongside the site, was closed until 5 pm.

On the proposal of the Registered Installations Inspectorate, the *Prefect* established two orders calling for the following emergency measures:

- ✓ the determination and the implementation of a schedule for securing the installations,
- ✓ a study on the exact causes and circumstances of the accident,
- ✓ determination of the measures to be taken to prevent such an event from happening again,
- ✓ the verification of the security of the installations prior to continuing operations.

Beginning the next day, the intense phase of the crisis having passed, operations to secure the site were undertaken. A certain number of substances were found at the site: this particularly includes work-in-progress such as sludge acids, nitro-glycerine, dynamite paste or ANFO being manufactured, dynamite in the cartridging machine, and cartridges already manufactured.

Site securing operations continued until June with the recovery and the destruction or completion of work-in-progress, a priority was assigned to the various operations according to the stability of the products (nitration sludge acids, then nitro-glycerine then the dynamite paste, …).

The operator then compiled a plan to resume activities at reduced capacity.

The accident exceeds the European Union's notification levels as set Appendix VI of the Seveso directive. In this respect, it formed the subject of a notification report in the MARS database.

The company shut down its nitrate-fuel manufacturing activities in late December 2006 and the explosives storage facility in late March 2007.

LESSONS LEARNED

In its accident report for which the Inspectorate requested additional information, the operator proposed avenues for improvement. The main points are listed below. They can be broken down as follows :

Preventive actions:

Transformation of the des cartridge machine feeders :

✓ Modify or remove the die of the feeders.

✓ Ensure that the protective housings on the ROLLEX machines are adequate.

✓ Limit feeder dimensions.

✓ Make the feeders out of a composite material.

Limitation of manufacturing operations to the least sensitive products :

✓ Specification of a "machinable" paste (bonding, hardness).

✓ Raise the impact sensitivity thresholds of the compounds, and study pastes that withstand the standby time better.

✓ Conduct a study on the pyrotechnic characteristics of a compressed paste.

✓ Determination of tests enabling the behaviour of the paste to be foreseen in the feeders in order to reduce the frequency of blockage.

Reducing the potential sources of foreign bodies :

✓ Continue the prevention campaign against foreign bodies started prior to the accident.

✓ Limit the number of removable parts in the machines.

✓ Remove the tool boxes that are next to the ROLLEX machines and replace them with tool board featuring a silhouette of each tool.

Actions aimed at limiting accident consequences:

Monitoring of materials in the workshops:

✓ Removal of pyrotechnic trash bins by the workshop operators or during times when the workshops are not operation.

✓ Organise preventive inspections to check the condition of paste bins.

✓ Possibly modify the recovery bins that are located under the machines.

Limitation of personnel in the proximity:

✓ Organisation of a light indicator panel showing workshops in operation and locations.

✓ Use the documentation about corridor offsets and protected access routes to better foresee the effect of the corridors on the propagation of blast effects.

Other measures:

✓ Assign codes to the various steps of the test procedure.

✓ Install electronic torque measuring equipment.