Pyrotechnics
Packaging
Cartridge loading
Dynamite
Maintenance
Adjustment
Modifications
Organisation / Procedure
Victims

Explosion in a dynamite manufacturing plant

March 3, 1988

Ablon – [Basse – Normandie] France

THE INSTALLATIONS IN QUESTION

Company history and location

Built in Ablon (Calvados) between 1873 and 1878 on 30 ha of land, the explosive products manufacturing plant began production in June 1879. In 1884, the company was bought by a firm specialising in the manufacture of dynamite.

A blasting cap and igniter storage facility was built in 1885, followed by a guncotton drier in 1893 (destroyed by an explosion in April 1894 and rebuilt in 1896), a cartridge loading and safety powder (type N) packaging workshop in 1904, and workshops for the fabrication of sulphuric acid (installed by the Farcot firm, of Honfleur) in 1916. In 1951, a continuous nitration device (Biazzi type) replaced the discontinuous nitration equipment (Nathan type). The fabrication process was automated between 1952 (Draiswerke mixer and Atlas grinders) and 1965 (Rollex cartridge loading machine). The Ablon plant produced 5,500 tons of dynamite in 1972 and between 20 and 25 tons/day in 1988.

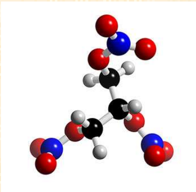
The plant's workforce has varied throughout the years:

Number of workers	Year
265	1916
181	1917
165	1926
360	1950
299	1953
183	1975
160	1984
122	1988

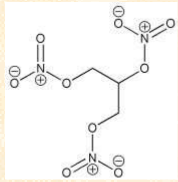
Governed by Order of September 26, 1876, November 9, 1893 and May 9, 1897, its was authorised to operate by the Decree of 07/31/1961 modified 01/07/1966, owing to the specific terms to which these installations were subject prior to the enactment of the Act of 07/03/1970 regarding the powder and explosives monopoly. In 1982, the manufacturer invested 15 MF to automate its manufacturing processes:

- the manual transport of nitroglycerin in jugs was replaced by hydraulic transports in the form of emulsions,
- recycling of circulating waters,
- removal of manual operations for the weighing, pouring of nitroglycerin into the mixing tanks (remote control),
- removal of all human presence during the mixing operation,
- removal of the workshops (cartridge loading-packaging) including the area passing through the neighbouring workshops (lines in "comb" configuration) which could facilitate the propagation of the explosion from one work cell to another.

NITROGLYCERIN



Ascanio Sobrero



Nitroglycerin was discovered by chemist **Ascanio Sobrero** in 1847, while working under Théophile-Jules Pelouze at the University of Torino. He was seriously injured during the experiment; a victim of an unexpected powerful explosion:

$$C_3H_5(ONO_2)_3 + 3/2\ O_2 \Rightarrow 3/2\ N_2 + 3\ CO_2 + 5/2\ H_2O + \frac{1}{4}\ O_2$$

In the 1860s, **Alfred Nobel** developed the industrial manufacturing process for nitroglycerin. His company exported a liquid combination of nitroglycerin and gunpowder called "Swedish blasting oil", but proved to be extremely dangerous as a result of its extreme instability, as shown in a number of "appalling catastrophes". In 1866, he discovered that nitroglycerin can be stabilised when mixed with a natural silica sand, ***kieselguhr***. This discovery led to the development of dynamite (and similar mixtures such as dualine and lithofracteur), by mixing nitroglycerin with inert or combustible absorbents (e.g. nitrocellulose to produce the yellow gel, **blasting gelatine**).

A heavy, colourless, oily and highly toxic chemical compound, **nitroglycerin** or glycerylnitrate is used in the manufacture of explosives, specifically dynamite. It is manufactured in a laboratory through the nitration of glycerin (glycerol). The temperature must not exceed 30 °C during the reaction, creating a risk of explosion. The extremely dangerous chemical reaction is performed by professionals in specially equipped laboratories. Nitroglycerin can be neutralised with a sodium carbonate and water mix. Alfred Nobel's brother was killed during the preparation of nitroglycerin.

http://fr.wikipedia.org/wiki/Nitroglyc%c3%a9rine; http://mendeleiev.cyberscol.qc.ca/chimisterie/9611/SCharest.html

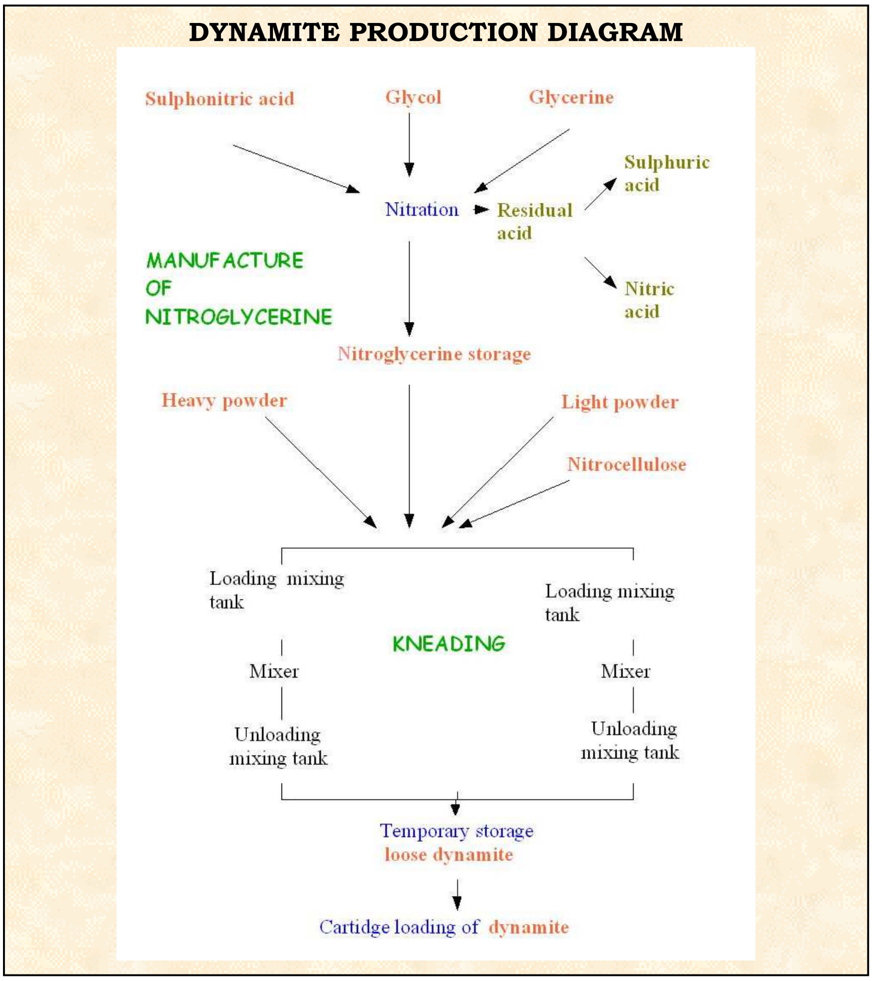
The establishment's administrative status was modified by the Prefectoral Order of May 7, 1984 when the company requested authorisation for a new manufacturing process and the implementation of additional safety devices. After 2 accidents in 1985 and 1987, the Prefectoral Order of 11/25/1987 authorised the installations to resume activities contingent on the opinion of the IPE ("Inspection des Poudres et Explosifs", Powers and Explosives Inspectorate) and the IIC ("Inspection des Installations Classées", Classified Installations Inspectorate)

The main manufacturing phases include:

- the nitration or synthesis of nitroglycerin through the action of sulfonitric acid on a glycerin-glycol mixture,
- the preparation of nitroglycerin mixtures and various charges (ammonium nitrate, nitrocellulose, dinitrotoluene…) and their mixing to obtain dynamite,
- the cartridge loading of the dynamite produced.

The manufacturing operation consists of a series of steps performed in several workshops:

- loading of dynamite ingredients (nitroglycerin, nitrocellulose...) in workshop P10 into a mixing tank in order to synthesise 300 kg of dynamite,
- manual transport from the loaded tank to the mixing workshop P11,
- mixing in workshop P11,
- transfer of the full tank of dynamite to the unloading workshop E44,
- unloading of the tank into plastic recipients (20 kg of dynamite) and loading these containers using an industrial truck (300 kg of dynamite),
- the truck is taken to a buffer storage workshop,
- transport from this workshop to the cartridge loading warehouse E30,
- cartridge loading and packing into cases in E30,
- transport of cases to E20,
- closing of cases in E20,
- transport of the cases of dynamite to the storage depots.



Installation concerned

Building E30, measuring 6.5 m x 6.7 m and surrounded by four 4.5 m-high mounds of dirt and accessible via 2 tunnels, is a light-duty building set on a concrete wall base and consisting of a wood framework and fibrocement roofing. An light-duty double skin interior partition separates the cartridge loading workshop from the electrical equipment (the cartridge loading machine's drive unit and the feed belt, electric hot air generator for welding the polyethylene film that encases the cartridges).

The plant operates 3 cartridge loading-packaging lines.

A NIEPMANN type automatic cartridge loading machine, delivered in October 1986, was installed in early 1987 following approval by the DTE ("Direction départementale du Travail et de l'Emploi", Departmental Office of Labour and Employment) on Nov. 14, 1986 based the favourable opinion of the IPE and pending consideration of a few comments, one of which concerns the examination of the safety systems in place on the machine. As of 06/22/1987, 200 tons of dynamite, or roughly 150,000 cartridges were manufactured on this machined that was used essentially for cartridge loading of F15 dynamite (production made from "blasting gelatine"…). Commissioning of the cartridge loading machine for packaging the dynamite was delayed due to:

- operating difficulties:
  - continuous marking of the film abandoned in favour of a pre-printed film and limitation to the mandatory information (France) regarding the packing fabrication date of the packaged cartridge.
  - implementation of a protective heat screen for the hot air welding (230 ℃) of the pre-printed film
- shutdown of manufacturing operations following the accident of March 5, 1987 (see site accident history)

The hopper has a capacity of 40 kg; with a cartridge loading rate of 10 cartridges/min., the final cartridge weight (∅ 80) is 2.5 kg.

In compliance with the conclusions of the safety study, the number of operators, supervisors or visitors present simultaneously in the workshop is limited to 5.

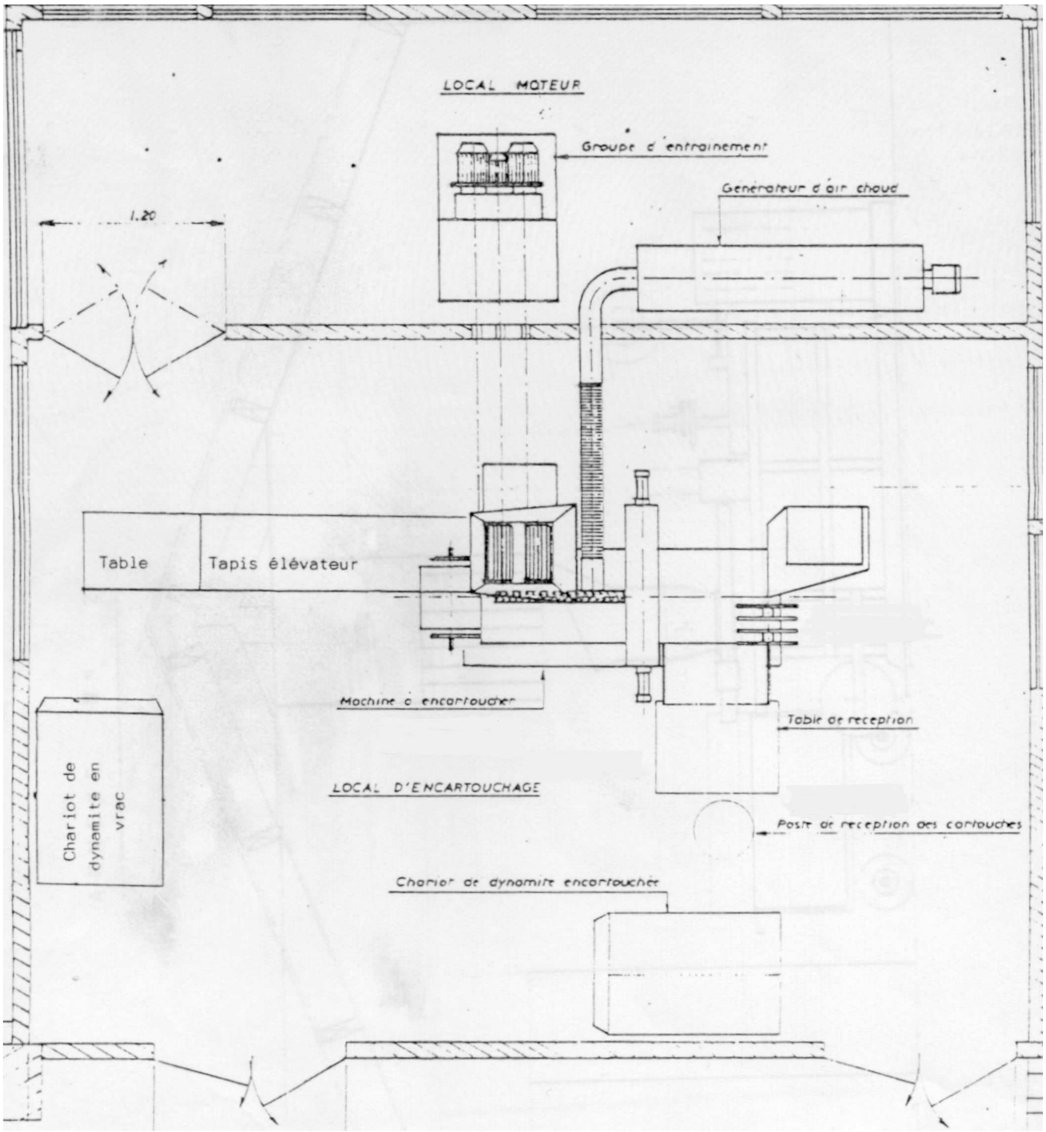


Figure 1 **–** Building E30

Site accident history

- March 5, 1987: the detonation of the nitroglycerin storage workshop (1,200 kg) claimed no victims. The plant was closed until Dec. 10, 1987.
- March 12, 1987: the detonation of a mixing tank holding raw materials used in the manufacture of dynamite kills 3 people. The blast is felt 10 km away (Honfleur Port).
- May 18, 1949: an explosion of 300 kg of explosives in a workshop kills 4 people.
- August 31, 1928: explosion of several workshops and a depot kills 8 people and kills 20.
- October 30, 1899: an explosion during the packing of dynamite kills 4 people and injures 1.

THE ACCIDENT, ITS BEHAVIOUR, EFFECTS AND CONSEQUENCES

The accident

On 03/03/1988, the dynamite pastes prepared the day before were being cartridge in the E30 dynamite cartridge loading workshop equipped with a new automatic cartridge loading machine. The machine, however, had been difficult to adjust since its installation. The cartridge loading machine was put into service at 6 am. At 6.15 am, the compressed air line supplying the cartridge injection became disconnected; a maintenance worker stopped the machine for 10 minutes. 200 kg of poorly closed cartridges were disassembled due to the polyethylene film being poorly centred causing the sleeve to be poorly welded. At 7 am, the radial blade was no longer operating as accumulated deposits and the resistance of the clipping wire being greater than previous days. All the parts were cleaned. At 8 am, the clipping-cutting station became blocked once again. A second cleaning operation was performed. An explosion occurred at 8.45 am; 300 kg of dynamite transported in a trolley were in the facilities at the time of the blast. The detonation was heard up to several kilometres away. Significant emergency response resources (including a dog team…) were dispatched to the site.

It appears that the accident occurred when cartridge loading operations began on the newly mixed paste.

Following this deadly accident, the plant stopped its activities in 1988.

Consequences

Human losses were significant: **5 dead and 8 injured**. The 4 people present in the workshop at the time of the blast (Director, Manufacturing Supervisor, Laboratory Manager – Safety Engineer, and the cartridge loading machine operator) were all killed. Certain bodies were found dismembered. Five employees were present in the neighbouring workshop E31: 1 individual died of projections from the blast, the 4 others were injured, 2 of which were seriously injured (elbow fracture and a compound fracture of the leg). These 4 employees were dug out from underneath the rubble and hospitalised. Three of the four workers in building E33 were slightly injured (contusions). One of the two people in building E20 were slightly injured. In all, 8 employees were injured in the neighbouring buildings.

Property damage was extensive:

- building E30 was pulverised: Northern wall shattered, North tunnel partially collapsed, 3 craters including 1 main crater corresponding to the supply trolley and the feed belt, a secondary crater at the cartridge receiving table and a small crater (projection) in the SE corner of the cartridge loading facility…
- building E31 destroyed – located 8 m from the blast, and separated by a 4.75 m-high barricade, connected to the same concrete entry under the barricade (the blast visibly came from the passageway under the barricade)
- building E33, located at a distance of 20 m, was severely damaged
- buildings E36 (42 m), E38 (58 m), and E40 (71 m) were damaged. The damage, decreasing further away from the blast, is greater in the direction of buildings E30 / E40 most likely due to the position of the main charge that exploded.
- other buildings damaged (roofs, windows…) as a result of the blast or projections in a radius of raison of 1 km
- the barricades surrounding building E30 were slightly damaged.

The trees in the adjacent forest were shredded.

The majority of the windows in the centre of the borough where shattered primarily in a zone of 700 m and even up to 1.16 km (Honfleur).

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 that oversees the application of the ‘SEVESO’ directive, the accident can be characterised by the following 4 indices.

The parameters that comprise these indices and the corresponding rating method are available at the following address: http://www.aria.ecologie.gouv.fr.

The 500 kg of dynamite present in the warehouse represents 1% 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: 500 kg of dynamite equals 550 kg of TNT (Q2 between 0.1 t and 1 t). In addition, broken windows were noted primarily within a zone of 700 m, so parameter Q2 is also level 2.
The overall "dangerous materials released" rating is thus 3.

Three parameters are involved in determining the level of the "Human and social consequences" rating: H3, H4 and H5.

- The parameter H3 reaches level 3: 5 employees were killed (H3 between 2 and 5 deaths).
- The parameter H4 reaches level 2: 4 employees were seriously injured (H4 between 2 and 5 employees seriously injured).
- The parameter H5 reaches level 1: 4 employees seriously injured (H5 between 1 and 5 injured).

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

ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

According to information collected from plant personnel, it had been difficult to adapt and adjust the NIEPMANN cartridge loading machine since its commissioning:

1) Marking problems

Difficulties continued despite the attempted solutions. The film appeared to move laterally in a random manner and did enable the welding head to operate in a regular and complete fashion. As the cartridges produces were poorly closed, the dynamite spread through the clipping and cutting station, and onto the transport trolley.

Figure 2 – SOFRANEX dynamite cartridge

Photo: F. Valla, Cemagref

http://www.avalanches.fr/epaclpa/1public/photo/23025.jpg

2) Problems with the extrusion horn

The output section of the extrusion cone features 4 blades perpendicular to the wall. According to a worker, the original mounting system had been reworked by argon welding, although the date of the operation was not specified.

3) Accumulation of pyrotechnic materials

When the apparatus had been dismantled in early 1988, explosive was found in the cylindrical housing closed at its ends by a metal piece and a piece of felt, and located between the radial blade's control rod and the extrusion screw. To solve this, the machine operators conducted periodic cleaning operations (involving the dismantling of the blade and swabbing) at the end of the week and by the maintenance department with each calibre change. On the day of the accident, this cleaning recommendation had not yet been added to the operating procedure. The presence of dynamite in this location could have resulted in violent reaction resulting from heating or friction.

4) Problems with the radial cut-off blade

Since early 1988, and notably during the week preceding the accident, the radial dynamite cut-off blade could no longer rotate; the solution was to reduce the production rate to mitigate the difficulty encountered.

5) Abnormal noise

In early February 1988, an employee reported an abnormal noise under the machine housing, near the pneumatic cartridge ejection button. A CHSCT meeting was held 02/02/1988. After dismantling, an examination of the parts showed traces of trolley friction on the housing and impacts on the trolley. The tightness and shimming was checked, then the elements were reassembled. In addition, the ejection cylinder's air pressure was reduced. The noise disappeared when the machine was put back into service.

6) Stringing problems

Dynamite extrusion problems had continued since the cartridge loading machine had been placed into service, in early February. The "stringing" corresponds to the presence of dynamite between 2 cartridges due to the highly sticky nature of the substances that the blade does not manage to cleanly slice off. Also, cartridges are clipped on this wire and the dynamite smears the blade and the clipping head leaving more or less large amounts of deposits. Frequent cleaning of parts, not part of the workshop's operating instructions, was necessary. The presence of dynamite in this location could have resulted in violent reaction resulting from heating or friction. This problem was of great concern to the management staff, and my explain the director's presence in the facility at the time of the explosion.

For these reasons, the establishment's management sought to obtain pastes that were slightly more consistent and less sticky:

- by allowing the dynamite paste to stabiliser a certain time after mixing and loading in cartridges only pastes that had been prepared the day before
- decreasing the mixing time slightly (1 minute less, for example).

The theory of the accidental presence of a foreign body in the paste was also brought up. A piece of gelatine (nitroglycerin impregnated gun cotton) was found in the bottom of the tank in which the dynamite was mixed only 7 minutes instead of 8 (a homogeneity problem). One of the employees removed a piece of gelatine while loading the supply belt, just prior to the accident.

Considering the analyses and studies conducted, the following sequence of evens can be considered based on the certainties (clipping jaws closed…) and probabilities (direct initiation of the explosion without ignition…):

- the cartridge loading machine was shut down following an incident,
- the cartridge possible present on the drawing and evacuation table was removed,
- manual control of the clipping operation by the machine operator in order to prepare for restart,
- the clipping operation initiates the explosion.

The exact cause of the explosion remains unexplained:

- dynamite or gelatin in the clipping block,
- clippage with a foreign body present: gravel, knife blade…
- rupture of a clipping head part…

ACTIONS TAKEN

The establishment's activities were suspended.

The explosive substances and the dynamite not loaded into cartridges were eliminated: dynamite manufactured from the nitroglycerin in stock (1,600 kg of nitric ester) on March 4, cleaning of nitroglycerin transport systems to remove any risk of material accumulation in low points on March 7 and 8.

On March 11, during the inspection by the Classified Installations Inspectorate, there were no explosives present in the manufacturing workshops. The only departments in operation were the maintenance department, explosives warehouse operations annexed to the plant and the pyrotechnic waster burning zone. Bulk dynamite manufactured on March 4 and that recovered in the workshops next to the explosion were transported to the Billy-Berclau dynamite manufacturing facility. Finally, the 3 tons of bulk explosives were sent to Ablon for destruction.

Samples of dynamite pastes (manufactured the eve and morning of the accident) were taken in order to analyse their composition, stability and sensitivity.

In order to gather as much information as possible, IPE requested that a precise map be made of the damage, indicating the origin of the projectiles and the location of blast effect damage.

The manufacturer decided to cease the storage and distribution of explosives and blasting accessories, no later than late 1989, which had been maintained after the accident; 122 employees were laid off.

LESSONS LEARNED

Prior to performing the cartridge loading operation, the IPE recommends that the quality and capacity of the paste be checked. They also recommend that packaging operations should not be developed using dangerous substances and that inert products should be preferred (in the case of unrolling and welding of the film).

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