Explosion in a nitrogenous fertiliser plant

21 September 1921

Oppau – [Rhénanie] Germany

Chemical industry
Disaster
Ammonium Sulphonitrate
Victims
Material damage
Modifications

FACILITIES INVOLVED

Facility:

The facility built in 1911 over 8 hectares started to produce nitrogenous fertilizers two years later. This included mainly a mixture of potassium chloride and ammonium nitrate in equal proportions. The raw material ammonia was produced using the new Haber-Bosch process that uses atmospheric nitrogen. There were 8,000 people working on the site.

During war times, ammonia salts were produced for military use such as constituents for explosives. However after 1918, ammonium salts continued to be produced for civil purposes.

Since 1919, the potassium chloride/ammonium nitrate mixture was gradually replaced by a 50/50 mixture of ammonium sulphate and ammonium nitrate called "mischsaltz". This highly hygroscopic mixture had the disadvantage of clogging together under the pressure of its own weight during storage. It was common practice to loosen the "aggregated" product by firing explosives in holes drilled using a jumper bar in the hardened mass. Until the day of the accident over 20,000 firings were carried out in the "mischsaltz" without any sign of accident being observed.

Current geographical position of Oppau (*Source : www.viamichelin.fr*)

Facilities involved:

The shop called "silo 110" is a 60m X 30m X 20m half-buried building that is 4m below the ground.
On the 21 September 1921 morning, 4,500 tonnes of ammonium sulphonitrate were stored in the shop. On the previous day, several firings were carried out in the building to use up a portion of the fertilizer.

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

Accident:

On 21 September 1921, when the technician was preparing the holes for the firings in the "silo 110" at 7.00 am, a very powerful explosion took place in the silo at 7.32 am, creating a 90m X 125m crater and 20m deep!

According to witnesses, there were two successive explosions, the first one being weak and the second one devastating. Seismographic readings from Stuttgart, at 150 km from Oppau also showed two distinctive explosions that occurred at an interval of half a second.

The explosion was heard in Munich, 275 km from the plant and caused panic among the masses. Material damage was reported at several dozens of kilometers away from the accident site. A dark green cloud overcast the skies of Ludwigschafen and Mannheim. The entire region was then covered in thick smoke that along with the interruption of telegraph and telecom services made rescue operations even harder.

Soon after the explosion, there were multiple fires on the facility and other less intense explosions occurred on the site and the air was heavy with ammonia vapours.

Consequences:

The official human casualty reported included 561 deaths, 1,952 injured and 7,500 people left homeless. Among the victims include passengers from three worker trains arriving on site for change of shift. Several children on their way to school were injured, boats on the Rhine river sustained damage with numerous sailors also injured.
Eye injury was observed in several cases.

Around 80% of the buildings in Oppau were destroyed. Substantial damage was also reported in Ludwigschafen and Mannheim. Massive glass debris on the roads of Heidelberg (30 km from Oppau), interrupted traffic in the city.

According to an article in the New York Times dated 29 January 1922, the material damage was assessed at 321,000,000 marks, i.e. 1,700,000 $.

European scale of industrial accidents

Even though the accident dates back, 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, based on the information available.

According to experts only 10 % of the stored fertiliser, i.e. 450 tonnes was involved in the explosion. However, its effects (shattering of glass seen around 30 km), being more devastating than an explosion involving 500 tonnes of TNT, the "dangerous materials released" index is at 6 (Q2 parameter).

The "human and social consequences" index is rated at 6 since 561 people lives their lives in the accident (H3 parameter).

However, the unavailability of statistical information makes it impossible to rate the environmental consequences index.

According to the New York Times dated 29 January 1922, the material damage was evaluated at 321,000,000 marks, i.e. worth 1,700,000 $ at that time. A rough estimation assesses the material damage at over 20 M€ (1993 reference) given that 1$ was worth 17 F at that time. The economic consequences index is thus rated at 6 (€17 parameter).

ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

The investigation subsequent to the accident led by an expert panel headed by a parliamentary commission was difficult to carry out due to the extent of damage and absence of direct witnesses, all victims of the disaster. The investigation lasted 2 years and the report was finally published in 1925.

It was established that one of the firings carried out in "silo 111" to loosen the fertiliser mass was the cause of the accident; some holes were drilled in an area of the mixture softened by the firings of the previous day.

The study of the explosive properties of the 50-50 ammonium sulphonitrate and mixtures of similar composition show:

- the explosibility of the 50-50 mixture in highly confined conditions and a relatively low density, the explosion is limited to the region around where the explosives are placed.
- the significant influence of some physical properties of the fertiliser (density, humidity, etc.) on its capacity to explode.
- an increase in the concentration of ammonium nitrate in a 50 to 55% mixture and especially in a 55 to 60%, contributed to significantly increasing the explosivity and explosive power of the mixture.

The investigation shows that a few months before the accident, the manufacturing process was modified: the humidity level (2% instead of 3 to 4%) as well as the apparent density of the mixture produced was lower than before. The experts concluded that these modifications made it easier for the mixture to explode.

Moreover, several testimonies which tally lead us to believe that the composition of the 4,500 tonne pile of mixture in the silo that was built up in the month before the explosion was not uniform. There may have been several dozen tonnes of zones richer in ammonium nitrate even if the post-accident samples and analysis have shown that ammonium nitrate levels in the mixture were between 47 and 49%.

Consequently, the accident scenario can be explained as follows

- holes were drilled in a zone containing a 55-60% mixture of ammonium nitrate
- during firing, this mixture enriched in ammonium nitrate could explode causing the adjoining 50/50 mixture to detonate,
- only 10% of the stock was involved in the explosion; the entire content of the silo 110 did not detonate, especially in zones of 50/50 composition where the density of the aggregated product is relatively high

ACTION TAKEN

The extent of material damage and casualties made rescue operations particularly hard.

The emergency services that were rapidly alerted could not arrive on the site before 9.00 am out of the fear of new explosions. The French army based in Ludwigshafen and Mannheim created a safety line around the site. Emergency services (doctors, fire fighters, ambulances, French and German red cross volunteers, army, etc.) arrived from the neighbouring cities. Private and public vehicles were requisitioned.

The emergency hospitals based in Ludwigshafen were full-up very soon and the injured had to be moved to Mannheim, Heidelberg, Frankenthal and Worms. The homeless were accommodated in schools, sanatoriums or in families living in neighbouring towns. Many however refused to leave their destroyed homes.

It took over three years to wipe out the visible marks of the accident in a politically, socially and economically agitated period.

LESSONS LEARNT

There are many lessons to be learnt from the studies conducted subsequent to the Oppau disaster. They show that parameters such as the composition of the mixture, as well as physical parameters (density, humidity, etc.) may increase the capacity of the ammonium sulphonitrate mixture to explode.

During the tests conducted in 1919, the operator concluded that the ammonium nitrate and sulphate mixtures containing less than 60 % of de ammonium nitrate were not likely to explode. Consequently, this fertiliser was considered to be a very safe substance. For instance, it was stored in enormous quantities on site in storage buildings, namely building 85, a 165 X 30 X 50 m building with a storage capacity of 50,000 tonnes.

When the process was modified in 1921, similar tests ought to have been conducted for the new mixture. Such tests were however not performed. This accident illustrates that a modification, even when it appears to be minor can bring about a significant increase in the sensitivity of the manufactured product to trigger an explosion.

The accident also underlines the poor application of feedback: two months before the Oppau accident, 19 people died in Kriewald (Germany) when a wagon containing ammonium nitrate exploded following when an explosive was detonated (ARIA 17974). This event ought to have sounded the warning bells on loosening fertilises by firing explosives.

After this disaster, the use of ammonium nitrate based coatings around the fertiliser granules has been encouraged to avoid clodding. Unfortunately, the use of a highly organic coating led to accidents in Texas City (ARIA 12271) and Brest (ARIA 14732) in 1947.

Moreover, the disaster highlights the effects of wind and temperature profiles in the upper atmosphere on sound propagation, generating the phenomenon of "silence zone". These geographical zones, which in the case of Oppau were located about 100 to 200 km from the explosion site, are zones where no sound from the explosion was heard whereas the sounds of the explosion were heard in a wider radius (until nearly 300 km in a case study).

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