Explosion of inflammable gas in a Chemical plant

January 12th 1964

Hebronville, USA

Chemistry
Polymerization
Vinyl chloride
Autoclave
Batch
Inspection porthole
Organisation / maintenance
Manual operations

THE INSTALLATIONS CONCERNED

The plant entered service in 1957. Originally its production was limited to polyvinyl chloride (PVC) in building V-1. At the South-East corner of this building was a tank farm of chloride vinyl monomer (CVM). To the North was a building housing the boiler room, as well as a maintenance workshop, to the South another building housed the laboratory, offices and a warehouse. In order to increase the production of PVC, building V2 was constructed later, as well as another tank farm at the North-West angle of the site and an extension to the West of the initial warehouse.

Building V-1 comprising metal framing, measured 8.50 m high with two work levels, or two floors of the same height. The metal framing on the second level carried the reactors. Each of these overhung the floor of the second level by 90 cm, with their base being 1.50 m above the tiling of the ground floor. The walls in corrugated fibrocement were fixed to the framing by attachments. The second floor was partly built with sheet iron cladding and partly with flat plates of cement attached to the metal framing. The roof was a cement slab on a steel support. This type of construction was designed to limit damage in the event of an explosion.

The warehouse contained sacs of granulated PVC and several hundred kilometres of watering pipes. All the buildings were equipped with sprinklers. A manually operated water spraying system protected the CVM tank farm.

The CVM, delivered in tank wagons, was stored in the form of liquid gas in 4 tanks of 180 m³ at their gas pressure, which was 2.46 bars at 21 °C. It was then pumped through surface piping to a treatment unit in building V-1. The polymerization was performed in 20 reactors, each with a capacity of 7.5 m³ located in building V-1. A batch process was used, each reactor contained several tonnes of a mixture of CVM and water. Once the polymerization was completed, the PVC was dried in a dryer at the western extremity of building V-1, then bagged and stored in the warehouse.

Each reactor included, in the upper part, the stirring motor, the loading conduits and the vents, as well as two glass inspection portholes oriented at 180 ° opposite each other. One of these had a diameter of 10 cm, enabling inspection of the reaction, the other was of 15 cm diameter and included a flameproof light source to illuminate the interior of the reactor. This second inspection porthole, designed to resist a pressure of 14 bars, consisted of a glass disc of 20 cm diameter and was 32 mm thick, of a lower joint in asbestos with a lead coating, an upper joint in asbestos fibre, retaining rings, a bell shaped support and lighting.

THE ACCIDENT, THE SEQUENCE OF EVENTS AND THE CONSEQUENCES

On Sunday January 12th 1964, an operator on the daytime shift replaced the glass on the porthole in which the lighting for the reactor A4 was installed, in the North-East part of building V-1. This lighting had become obscured. This maintenance was conducted at the end of a polymerization cycle, after the emptying of the reactor. Once the repair was completed, the reactor was re-loaded in the afternoon, without prior verification that the porthole was leak-proof under pressure.

Three hours later, a small leak developed around the repaired porthole. While a workman was tightening the bolts on the retaining ring, after having removed the light, the glass shattered and sliced into his face. Three employees led the victim to the changing room of the building which housed the offices and the laboratory, using a covered passage. After first aid treatment, the injured man was taken to the main gate.

In the meantime, the leak had increased and became impossible to stop. The personnel still present evacuated the building, falling back on the warehouse and a changing room in the building housing the offices and laboratories. At 18h51, or 5 to 10 minutes after the rupture of the porthole, the air/CVM mixture exploded violently; the deflagration, which was heard over 60 km away, almost totally volatilised the lateral walls and the roof of building V-1, causing the collapse of the walls and metallic structures of the buildings close to the warehouse, the building with the offices and the laboratories as well as the building housing the boiler room and the maintenance workshop.

Five workmen and the boiler-man were killed on the spot, crushed by walls and roofing or killed by flying debris. A seventh victim, seriously wounded, died the following day. There were also numerous more or less seriously wounded.

The piping serving the 20 reactors, like the rest of the production installation, was breached in several places, releasing nearly 70 tonnes of CVM which immediately ignited and was rapidly consumed, mainly in the form of a fireball overhanging the debris of building V-1. Part of an iron post, projected onto the storage tank the furthest to the West and containing nearly 115 m³ of monomer, broke a threaded connector on a small CVM pipeline and this, in turn, ignited.

The explosion also caused the breach of two riser columns of the sprinkler network and another which supplied the production units. The housings of the two fire hydrants at the East and the West of V-1 were destroyed, putting out of service the local sprinkler network as well as causing a serious pressure drop in the water supply to the factory and in the closest public network to the installations.

Within a radius of 600 m around building V-1, the explosion damaged housing and other buildings including two schools, displacing walls and shattering windows…

The intervention of the emergency services:

The organisation of the emergency services was seriously hindered by the large number of dead and wounded, as well as by the media impact (radio and television); thousands of spectators gathered on the site, blocking access by the reinforcements. Only the first aid and the police arrived rapidly. Neither did the thick black toxic smoke cloud stagnating at ground level facilitate the work of the firemen, who had to wear masks. Furthermore, for the first hour, the emergency services feared further explosions caused by the burning monomer leaking into the warehouse, which risked reaching building V-2.

The firemen connected their hoses to hydrants on the public network of Seekonk and to the hydrants in the tank farm to the North and the West of V-1, as well as to the South-West of the warehouse. However the water pressure was

insufficient in the public network of Attleboro, close to the site as well as in the supply network to the tank farm. The equipment was then directed to the basin of the cooling tower. The firemen hesitated to enter the main gate, fearing that the gas fire from the monomer tank farm might be propagated to the other tanks and to the 4 full tank wagons parked close by. Under the protection of water jets supplied from the Seekonk network, which had not been damaged, the firemen succeeded in closing the monomer feed valve of the leaking tank. The fire burned out, for lack of combustible material, around 19h30. At the same time, the monomer supply to building V-1 was also cut off, which caused the extinction of the fire in this building.

The search for the missing personnel was organised. Around 19h45, firemen attempted to enter the warehouse. During this time employees purged the reactors in building V-2 as a precautionary measure to avoid vapours of CVM being drawn towards the western extremity of the warehouse. The company personnel advised the firemen to stay clear of this building and they concentrated their efforts on the fire in the building housing the boiler room and the maintenance warehouse. A little after 20 h, the police evacuated the population close to the plant on account of a light breeze which was blowing the thick cloud towards the inhabited area. 100 families were thus evacuated around 21 h.

The firemen attempted to close the stopcocks controlling the water supply to the damaged sprinkler network, but the stopcocks that were directly accessible had been destroyed by the explosion. A valve in the trench connecting the network to the town water supply, unknown to the first firemen to arrive, was closed at around 23 h. This action caused a rapid rise in the water pressure of the public network and in the tank farms to the South of the warehouse but it was no longer possible to control the fire in building V-1, of which the roof had partly collapsed and in which the contents continued to burn during several days under the debris of the roof. However, around 1 h in the morning, the authorities considered that the fire was under control and cancelled the evacuation order.

For the whole duration of the fire, the products of combustion of the CVM and the PVC, acrid and toxic, hindered the efforts of the emergency services. The following morning, a heavy snowstorm started, complicating further the efforts of the firemen and holding the toxic fumes close to the ground.

The consequences :

Seven members of the personnel were killed and several others, plus inhabitants of the area and firemen, were wounded by projections of debris or poisoned by smoke inhalation. Some forty wounded were counted.

Material damage was considerable: 3 of the 6 main buildings of the plant had been destroyed. Damage to the V-1 building, the warehouse, the laboratory and office building, and the building housing the boiler-room and the workshop, was evaluated at nearly 4 million dollars (1964). For the public buildings, schools and others, the estimated damage was 60 000 dollars.

The boiler rooms no longer supplied steam and the temperature being below 0 °C, the installations in t he other buildings froze. The resulting damage necessitated an interruption of activities causing operating losses of several million dollars.

Production of PVC was abandoned in this plant, in particular as a result of unfavourable reactions in public opinion.

EUROPEAN SCALE OF INDUSTRIAL ACCIDENTS

Using the scoring rules of the 18 parameters on the scale approved in February 1994 by the Committee of Competent Authorities of the Member States in application of the 'SEVESO' directive, the accident can be characterised by the four following indices, taking into account the available information.

The accident in Hebronville is characterised by the following indices:

The parameters comprising these indices are available at the following address: http://www.aria.ecologie.gouv.fr

Nearly 70 t of CVM escaped and were burned, or 35% of the Seveso threshold for this substance (200 t). The index relating to dangerous materials released for this percentage is equal to 4 (see parameter Q1). Furthermore, windows were broken up to a distance of 600 m or Q2 = 2.

The accident caused the death of 7 employees, injuries to some forty people, which explains the index relating to human and social consequences of 4 (see parameter H3).
Material damage to the plant was evaluated at 4 million dollars (1964), those caused outside (schools…) were of the order of 60 000 dollars. To this must be added the operating losses. The total leads to an index relating to economic consequences equal to 3 (see parameter €15).

THE ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

The plant had been manufacturing PVC for 7 years during which time neighbours had made numerous complaints; frequent and noisy ruptures of safety valves, smells and dust. Taking into account the substances used (CVM…), the authorities had requested the operators to take greater safety measures. The management assured the population that all precautions had been taken and that there was no risk of major explosion. Regular exercises were undertaken with the fire brigade from Attleboro which was in constant contact with the in-house fire brigade. An automatic fire alarm system and a sprinkler network had been installed.

However, despite these precautions, the neighbouring population remained worried by the frequent explosions with relatively minor consequences. These had taken place on January 10th at 2h29, waking up the inhabitants. The 2 explosions, separated by 14 seconds only inflicted minor damage to the plant.

The accident took place in one of the units producing PVC from CVM which is a highly inflammable gas and is also a carcinogen, with a boiling point of -14 °C. When it is liquefied under pressure at a higher temperature than its normal boiling point, in quantities of the order of several tonnes, any leakage of liquid can cause the release of large quantities of vapour. The leaks with relatively minor consequences which had already taken place on several occasions showed clearly that, despite the few additional safety measures taken by the operators, these remained inadequate in relation to the risk inherent in the use of CVM.

THE MEASURES TAKEN

A few days later, the neighbouring population requested from the plant management a report on the accident. They hired lawyers to defend their interests. Four days after the explosion, the plant management announced that production of PVC would not be resumed on the site. On January 21st, the plant management signed an agreement with the local inhabitants' association not to put back into service the 2 PVC production units.

THE LESSONS LEARNED

On the technical front:

It is possible to reduce to a minimum leaks, by respecting certain conditions: correct assembly, use of materials with technical characteristics which provide sufficient safety, as small as possible flows and quantities, number and dimensions of orifices limited to the minimum possible size, installation of flow regulation valves and emergency equipment for emptying and flushing vessels. By taking these precautions and optimising the ventilation of the premises, it is possible, in the event of a leak, to limit the accumulation of vapour.

In the case of the Hebronville explosion, the glass inspection porthole represented a serious breach of these principles. The porthole with a diameter of 15 cm was, under the conditions described, a very large orifice. The leak could not be controlled once the glass was broken.

In the event of a major explosion like this, the implantation and the separation of the buildings of the plant are elements of primordial importance. The proximity of housing within a small perimeter constituted an aggravating factor, 2 schools were less than 600 m from building V-1. If there had been classes held at the moment of the explosion, a large number of children would have been injured by flying glass shards. The damage caused to the housing consisted essentially of broken windows and the destruction of plastering, but it would have been far more serious if an explosion of similar force had taken place in building V-2 which was closer to a heavily populated zone (500 m). In the present case, building V-2 and the warehouse contributed to the protection of these houses by creating a screen.

The warehouse, the building housing the laboratories and the offices, the building housing the boiler room and the maintenance workshop were only moderately damaged by the explosion thanks to the wall cladding with flat cement slabs. This explosion illustrates the danger for the personnel represented by traditional construction in rubble stone, bricks and tiles which break up into heavy and sharp fragments.

The vulnerability of the classic sprinkler network to explosion was demonstrated. While the loss of the sprinkler network of building V-1 could have been foreseen, in view of the violence of the explosion, that of the networks of the warehouse and the other two buildings could have been avoided if the riser columns had been placed at the other side of the buildings and if the supply network to the tank farms had been installed in such a manner as to allow for the isolation of the breached piping in building V-1.

The organisation of the emergency services and the fight against the fire, crisis management:

The reports established that there existed close cooperation between the personnel of the plant and the fire brigade. The company had prepared an emergency plan and its own fire brigade trained regularly with the local fire service. However

the dispositions of the plan were not always respected. In particular, the pressure in the intact parts of the water supply network should have been re-established more quickly, the fire pump should have been turned on earlier and the broken length of piping isolated also more quickly by the closing of the stopcocks. If all these conditions had been met, the fire could have been mastered in the warehouse at the initial stage and with lesser hydraulic means (hoses).

The immediate media impact of the explosion on the radio and the television seriously hindered the emergency services. The initial confusion was also due to the fact that, on the arrival of the fire brigade, nobody knew precisely where the personnel were. Despite the existing cooperation, the fire brigade from Attleboro immediately engaged the fire instead of reserving a few men to establish a true operational HQ. Instead of becoming personally committed on the site, he should have supervised the operations and ensured the coordination of the various players and the equipment according to the demands of the situation. This would have avoided all the services working independently and would have made for more effective intervention during the incident.

In conclusion:

This accident shows that it is highly recommended to isolate buildings or premises where there is a serious risk of explosion. The determination of distances between the buildings depends on the size of the anticipated explosion and fire, as well as on the vulnerability of the structures and exposed premises.

The presence of glass inspection portholes constitutes a source of frequent failures with potentially very serious consequences, as illustrated by this disaster. While doubtless useful, they can not be considered indispensable. If they must be retained, it is necessary to revise their design to limit the consequences of accidental breakage. For example portholes in armoured or reinforced glass can be used and a fast closing valve, preferably automatic or at least remotely controlled should be placed between the top of the reactor and the porthole.

In zones presenting explosion risks, the sprinkler networks should be designed and installed to resist explosions as far as possible, (piping, columns, risers, valves…).

Finally, companies where this type of risk exists, have a duty to analyse their safety plans to ensure that they take into account a maximum number of incident scenarios, that they have replacements for key employees and that the safety measures designed are effectively implemented during exercises which should be conducted in liaison with external emergency services.