

Fire Incident in a Multi-Purpose Plant

1997

North Rhine-Westphalia State Germany

Explosion
Pipeline
Isopropyl alcohol
Hydrogen
ATEX
Organisation
Instructions / procedures
Domino effects
Victims
Property damage

THE INSTALLATIONS IN QUESTION

The following incident took place at the low pressure hydrogenation unit of a multi-purpose plant. In the plant a variety of organic substances are produced by chemical reactions, e.g. hydrogenation.

The plant was subject to licence according to German Federal Immission Control Act and basic obligations of the Hazard Incident Ordinance had to be fulfilled. Therefore a safety analysis has not been proved.

The process unit affected by the incident was a two step production of an organic substance. In the first step a hydrogenation of phenyl acetyl carbinol with benzyl amine in a isopropyl alcohol/water mixture by means of a catalyst was carried out. In the second step the catalyst is removed and the hydrogenation of the solution goes on.

THE ACCIDENT, ITS BEHAVIOUR, EFFECTS AND CONSEQUENCES

The accident

At the moment the incident occurred the operator was preparing the make-up of the first step of the planned hydrogenation. The following scenario took place:

- **At 17:04 o'clock** : The automatic signalling fire detector actuates. The alarm is firstly transmitted to the gate keeper and then to the establishments fire brigade. At the same moment an explosion occurred.

- **At 17:06 o'clock** : The establishments fire brigade arrives and begins to extinguish the fire. At the same moment an employee notices that there is a hydrogen flux from the feeding tank to the source of fire. He closes an interlock.

- **At 17:20 o'clock** : It is noticed that there is a flow of phenyl acetyl carbinol into the source of fire by a broken pipeline. The pump at the tank farm is tuned out.

- **At 17:44 o'clock** : The fire is extinguished. The fire alarm could be cancelled. Un opérateur prépare le démarrage de la première phase du process lorsque l'accident se produit. Le scénario suivant se déroule alors :

The consequences :

The operator, who was alone in the plant at the moment the incident occurred, got hurt by the fire. His injuries were so heavy, that he died a few weeks later. Three members of the fire brigade were injured by smoke. They could leave the hospital the same day.

The plant has been destroyed completely. The costs of damage reached several million marks.

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, based on the information available.

Dangerous materials released		<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Human and social consequences		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Environmental consequences		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Economic consequences		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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

The accident involves substances, such as hydrogen and isopropyl alcohol, that are listed in Appendix 1 of the 'SEVESO' directive. The 'dangerous materials released' index is thus at least 1 (parameter Q1) although the lack of accuracy relative to the tonnage of chemical products involved does not allow fine-tune this estimate.

The death of an employee of the establishment explains why the 'human and social consequences' index is 2 (parameter H3).

Finally, the 'economic consequences' index is rated 2 (parameter €15) as property damage was estimated at several million marks.

ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

An independent expert group got the task to find out the reasons leading to the incident especially to its tremendous consequences. The job was very difficult because due to the death of the operator there was no witness. Furthermore all operating instructions, print-outs and operation recorders were burnt. So the experts on one hand had to interview the employees working in the neighbourhood and the foreman of the operator. On the other hand they had to do some research about circumstantial evidences.

The stock-taking showed that the operator was preparing the make-up of the first step of a planned hydrogenation.

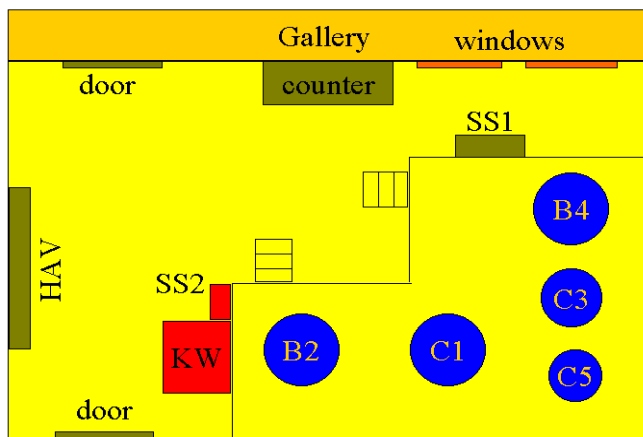
The stock-taking showed that the operator was preparing the make-up of the first step of a planned hydrogenation.

At the counter for the following substances values were adjusted:

- phenyl acetyl carbinol
- benzyl amine
- isopropyl alcohol.

For isopropyl alcohol the allowed value was a little bit bigger than the value adjusted. This means that a small amount of isopropyl alcohol must have been pumped when the pump has been tuned out by an emergency shutdown. The emergency shutdown switch at the counter of isopropyl alcohol has been activated. Before the pipeline for isopropyl alcohol passed the counter there was a bifurcation leading to the catalyst washing plant, an apparatus built out of glass. So there was a change-over from steel to glass in the pipeline. To protect the glass apparatus there were two valves, one in the steel-part of the pipeline and one in the glass-part. In operating instructions it is said that both have to get closed if the glass apparatus is out of operation. But interviews with other employees and with the foreman showed that the valve in the steel-part of the pipeline has never been closed. So the change-over from steel to glass always got the maximum overpressure of 3,5 bar at the begin of pumping.

In the following picture you can have a look to the room the fire occurred.



C1, C3, C5 : hydrogenation reactors

B2, B4: vessels

SS1,2 : switch cupboards

KW : catalyst washing plant

HAV: main shut-off valve

Evaluation of all perceptions available led to the following most likely scenario:

- ① Due to material destruction of the glass apparatus there must have been a release of isopropyl alcohol. The substance wets the ground floor, creates a pool and evaporates. This leads to an ignitable atmosphere which is fired by an unknown ignition source. The operator activates the emergency shutdown at the counter and tries to put out the fire with a halone extinguisher. After having no success due to unknown reasons he chooses an uncertain escape which is located very near the fire source. There he gets hurt by the fire in a tremendous manner.
- ② Above the source of fire there was a hydrogen pipeline. Due to the heat of the fire a soldering point of the pipeline fails. Hydrogen is released and an explosion happens.
- ③ At the broken part of the pipeline a big flame appears destroying the windows in the wall near the gallery. So the manual shut-off valve located in the gallery cannot be reached. Furthermore the hydrogen flame fires with high energy a wall with several shut-off valves. This can be concluded due to burned out valves and leaky flanged.
- ④ A switch cupboard located in the area of fire influence gets on fire. A short circuit and a fire of the electric installation happens. The pump for phenyl acetyl carbinol misunderstands the signal and starts pumping phenyl acetyl carbinol through a leaky flanged joint into the source of fire. It needs 15 minutes till this is recognised and the pump is tuned out.

As reasonable for the apparatus failure supposed the opened position of the ball valve in the steel pipeline was indicated.

It was not possible to find out the ignition source. The installations of the room were performed in ex-zone 1. Due to regulation it would have been adequate to perform the room in ex-zone 2. Therefore the measures preventing ignition sources were of higher quality as they had to be. The development from a small fire up to such a catastrophic fire accident was an interlacing of several ill-fated circumstances.

ACTION TAKEN

The incident had been classified as a major accident because

- ✓ It was a fire respectively an explosion with great consequences with participation of substances listed in annex II of the Hazardous Incident Ordinance
- ✓ One person died.

The incident showed defects or malfunction of the plant the operator didn't take into account before, for example the change-over from steel to glass or the deficiency of plant emergency shutdown. It is most likely that these defects would have been recognized in context with systematic safety analysis. So due to a demand of the competent authority the operator did an accurate safety analysis in context with plant rebuilding.

On the other hand it is a typical incident which lead to its final extent of damage due to bonding of ill-fated circumstances, a kind of internal domino effect. If you take a look to other incidents happening over the year you may see that most of the great material damages correspond with such bonding of ill-fated circumstances.

But it also has to be recognized that the main consequence, the death of the operator, is a direct result of the rising fire. Furthermore this example shows how difficult and speculative finding out of reasons can be. The scenario I presented was the most likely scenario but a rest of uncertainty remains.

LESSONS LEARNED

The expert group worked out the following measures taken into account when the plant was rebuilt sometimes later :

- ✓ Steel pipelines were chosen instead planned glass pipelines. Only if absolutely necessary glass was used.
- ✓ The manual valve in the hydrogen pipeline got a pneumatic drive. This valve closes automatically if the hydrogen detectors give an alarm.
- ✓ Emergency shutdown buttons were installed which can convert the whole plant to safe operation.
- ✓ As you've seen the main reason for the incident was the open valve in the steel pipeline. Now there is an automatic interlocking to prevent erroneous positions of valves. Starting of pumps is only possible if every valve gets the right position due to operating instructions.
- ✓ Additional to quarterly safety training now short talks about safety take place every month.