Toxic leak on factory piping
October 6, 2003
Saint Chély d'Apcher – [Lozère]
France

Metallurgy
Piping
Ammonia
Maintenance
Nut rupture
Intervention procedure
Personnel training

The purpose of this article is to reveal avenues of improvement in light of the information gathered about the accident that occurred October 6, 2003. The weak points of the installations and safety management system are stressed by insisting on the approach put into place after the accident.

PART OF THE PLANT CONCERNED

The metal manufacturing plant, operating on the *commune* of Saint Chély d'Apcher (Lozère), produces magnetic sheets with non-oriented grains. A leak on an anhydrous ammonia pipe occurred October 6, 2003.

Ammonia is used in the cracking unit to produce the hydrogen required in the manufacturing process. The installations concerned include a tanker truck unloading area, 2 storage tanks, and a transfer pipe leading to the cracking unit. These installations, although rather old, have gradually been modernized over the years. The ammonia is maintained in a liquefied state under pressure at ambient temperature, i.e. at a service pressure ranging from 3 to 8.10^5 Pa. The 2 tanks have a unitary capacity of 16 tons. The storage facility is of semi-confined type (construction with a reduced opening on 2 sides and an automatic water curtain). The transfer pipe (diameter 33 mm, length 250 m) holds 146 kg of ammonia. It is broken down into 3 sections by automatic valves slaved to an ammonia detection system.
The installations do not fall within the scope of European Directive 96/82/EC (thresholds for ammonia 50 and 200 t).

Fig. 1. General view

Considering the potential seriousness of the hazards identified and evaluated by the operator in its danger study, the installation is equipped with an integrated safety management system as part of its environmental management system (site certified ISO 14001). Since 1987, the site has been the subject of danger studies and a critical analysis in 2001. Internal and External Contingency Plan are in place. Information for the public accompanied the implementation of the intervention plans.

Urbanisation control has been part of the commune's urbanisation plan since 1989 up to a distance of 290 m from the storage tanks and 190 m from the transfer pipe.

Since its creation in 1917, the establishment is authorised to operate classified installations. The regulatory obligations at the time of the accident are the result of the "summary" prefectorial order of 1998, which has since been completed by an additional order in 2003; a new summary order is currently being drawn up.

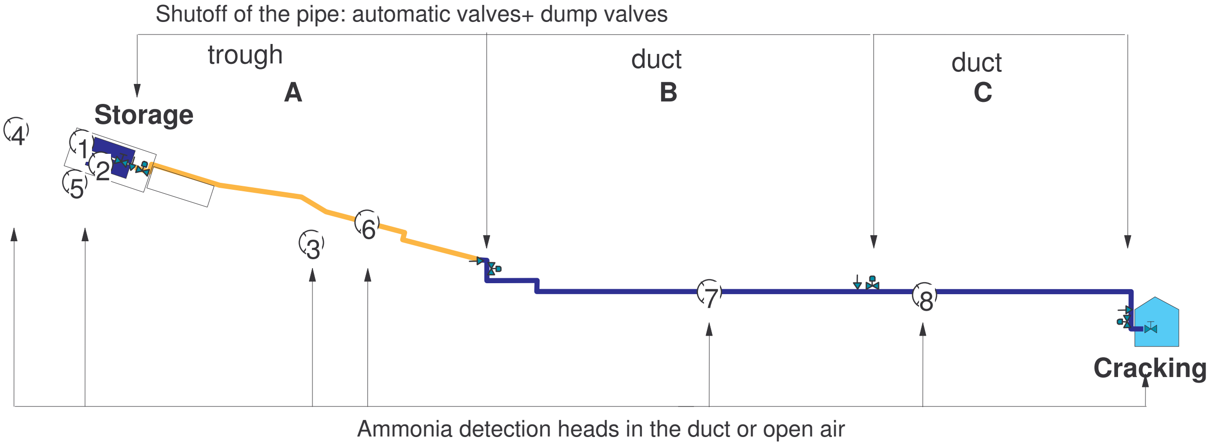


Fig. 2. Ammonia pipe equipment and diagram

ACCIDENT BEHAVIOUR AND CONSEQUENCES

1 Accident behaviour

Monday, October 6, 2003. The night-shift operators smelled an ammonia order. A foreman reported a weak although visible leak, on the valve fitting on an ammonia transfer pipe. The 1 m/s vent was coming from the south.
The temperature was 5°C.

Wearing a respirator, he installed a ladder and went up to tighten the fitting located at a height of 3 m. The leak was stopped. However, in order to orient the opening of the valve outlet upwards, he tightened the fitting a little more and it ruptured.

11.00 pm – The ammonia vaporised before reaching the floor, forming a fog. The foreman alerted the guards by telephone who triggered the Internal Contingency Plan.

11.05 pm – No automatic shut-off. The foreman stopped the transfer of liquid ammonia using the manual valves located roughly one hundred meters from the leak, on the storage tanks. Emergency shutdown was actuated: the pipe was closed.
The homes on the other side of the road, roughly fifteen meters from the leak, were alerted.

11.09 pm - Firemen were called at the request of the executive on duty, then were contacted by the plant's guard shack at 11.13 pm. The foreman, assisted by several individuals including one person from the emergency response team, installed the firefighting equipment underneath the leak and which had not been accessible when the leak started due to its greater output. They sprayed the leak with water until the firemen arrived.

11.26 pm - The firemen arrived at the site with chemical unit equipment. They conducted an inspection of the area.

00.20 am – End of the reconnaissance. End of alert.

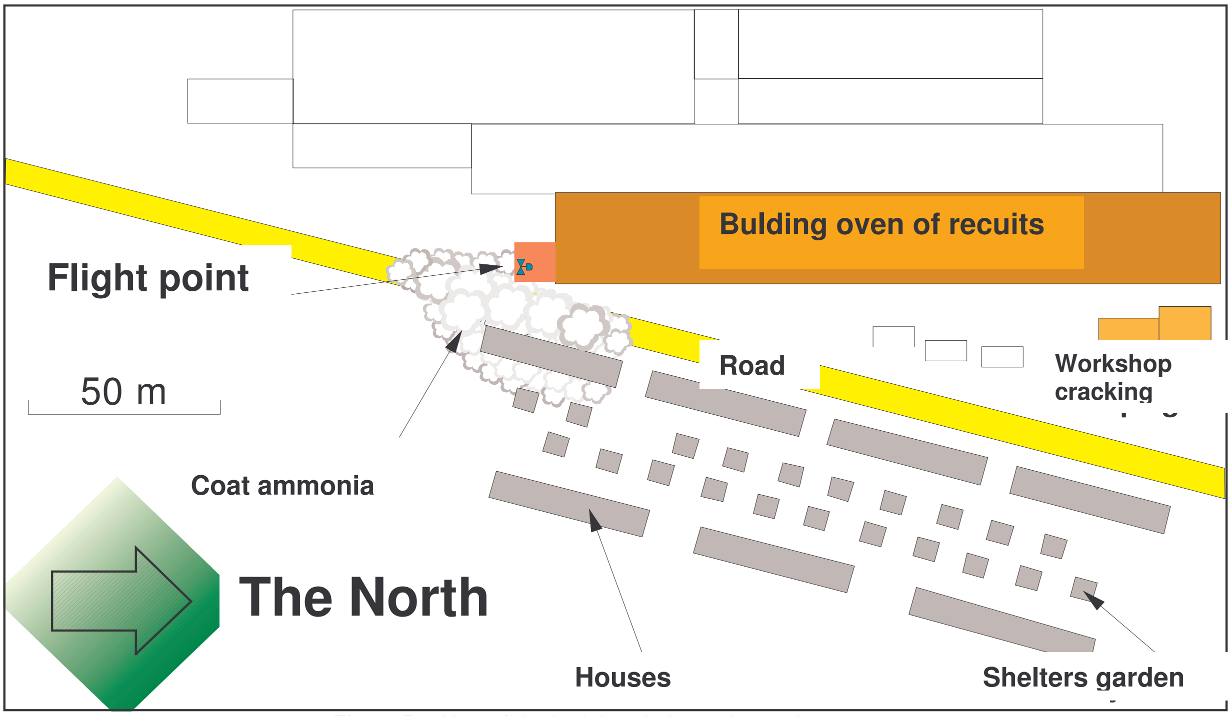


Fig. 3. Position of the leak in relation to its environment

2 Consequences of the accident

The leak lasted approximately 10 minutes (the time required for manual shutdown + drainage of the pipe section) in the middle of the 8 mm branch connection. The operator estimated that approximately 60 kg of ammonia had been released.

The visible whitish cloud that formed extended over approximately 50 m. The very dense part remained around the first block of the factory's 3 apartment buildings across the road.

The residents of the first apartment building detected a strong ammonia odour and sealed themselves inside using wet towels at the base of the door.

The residents of the second apartment building only noticed a slight ammonia smell.

On the road, a car coming from the south was blocked in front of the cloud approximately 5 minutes after the leak started. The engine had stalled.
The driver directed his car into a slope to the right in order to get further away from the cloud, and then sought shelter on foot.

The residents of the third apartment building didn't smell anything (they were not even woken by the alarm siren!). There were no documented cases of victims or intoxicated individuals.

Production operations on the annealing lines were stopped for approximately 2 shifts.

The operator declared that 60 kg of ammonia had been released.

The Classified Installations Inspectorate considers this value to be inconsistent with both the effects observed (cloud visible at 50 m), and the leak conditions (8 mm diameter for 5 to 10 minutes).

According to the data opposite, the amount release was more likely in the order of 150 kg.

Periods min	Source	Output kg/min	Quantity released kg
0 - 5	Tanks and piping	15	75
5 - 10	Piping section B	15	75
Total			150

Based on 15 kg per minute for 10 minutes, the toxic cloud is estimated to have travelled approximately 120 m for the limit of irreversible effects.

After the cloud had passed, the concentration inside a closed but unsealed dwelling of the first building may have become dangerous if it had not been evacuated.

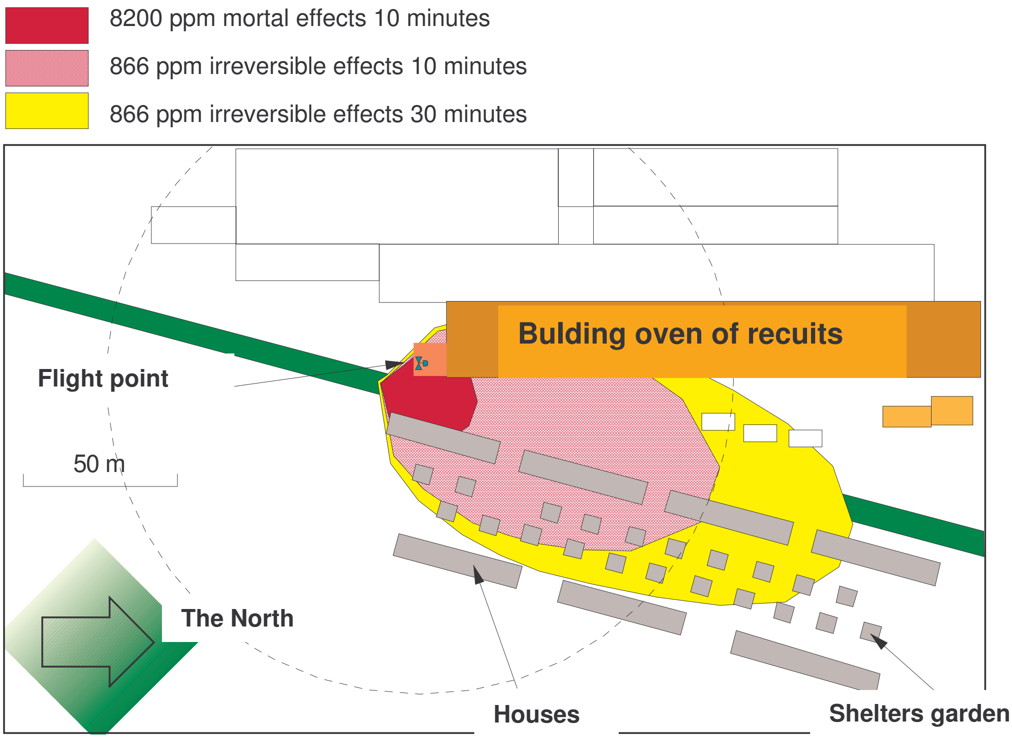


Fig. 4. Probable path of the toxic cloud

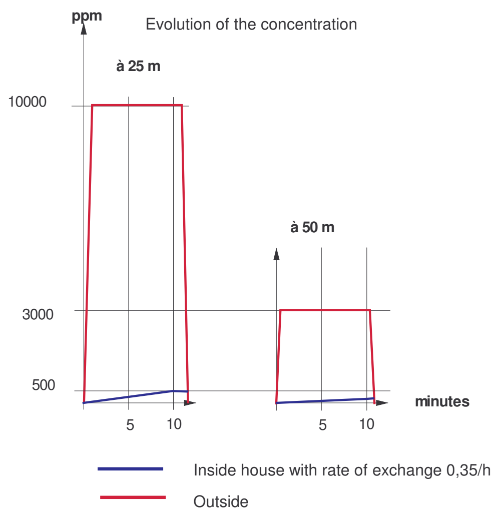


Fig. 5. Development of the concentration at specific distances

European scale of industrial accidents

In application of 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.

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

The 150 kg of ammonia released represent 0.075% of the corresponding Seveso threshold (200 t – toxic), i.e. level 1 according to parameter Q1 of he "Quantities of dangerous materials" index.

CIRCUMSTANCES, ORIGIN, CAUSES OF THE ACCIDENT

1 Circumstances of the accident

On the morning of October 6, 2003, a slight ammonia odour led to an examination of the piping and a small leak was located on a valve fitting.

The repair operation was scheduled for Tuesday morning considering the requirements:

- a lifting device must be used to remove the leaking fitting which is located at a height of 3 m;
- production must be shut down and the pipes purged prior to the operation.

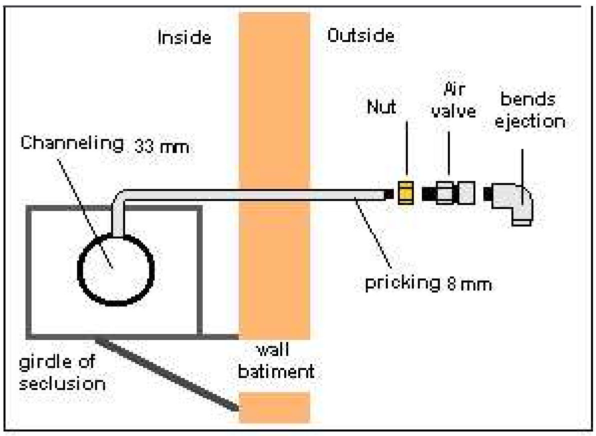


Fig. 6. cut prinking lid

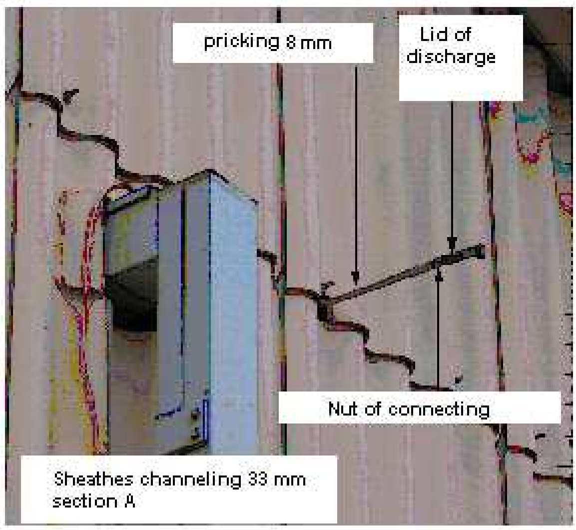


Fig. 7. Valve outlet on building facade

The fitting had been installed by a sub-contractor who frequently intervenes at the site.

The company in question had made modifications on the piping during the month of August 2003:

- closing in 3 parts that could be isolated automatically in the event of a leak, owing to ammonia detectors;
- installation of protective valves (dump valves) on each of the 3 sections.

The company specialises in chemical installations, and notably in the field of ammonia.

2 Immediate causes of the accident

The search for the immediate causes of the accident was carried out around the main "fitting nut failure", event, which was found in pieces.

Cause No. 1
The material did not withstand the operating stresses.
The nut was apparently made of chromium-plated brass, which is not ammonia-resistant (it should have been made of stainless steel). The fitting shows signs of oxidation, most likely due to the leak and the weakening of mechanical performance characteristics.

Fig. 8. Piece of the defective nut

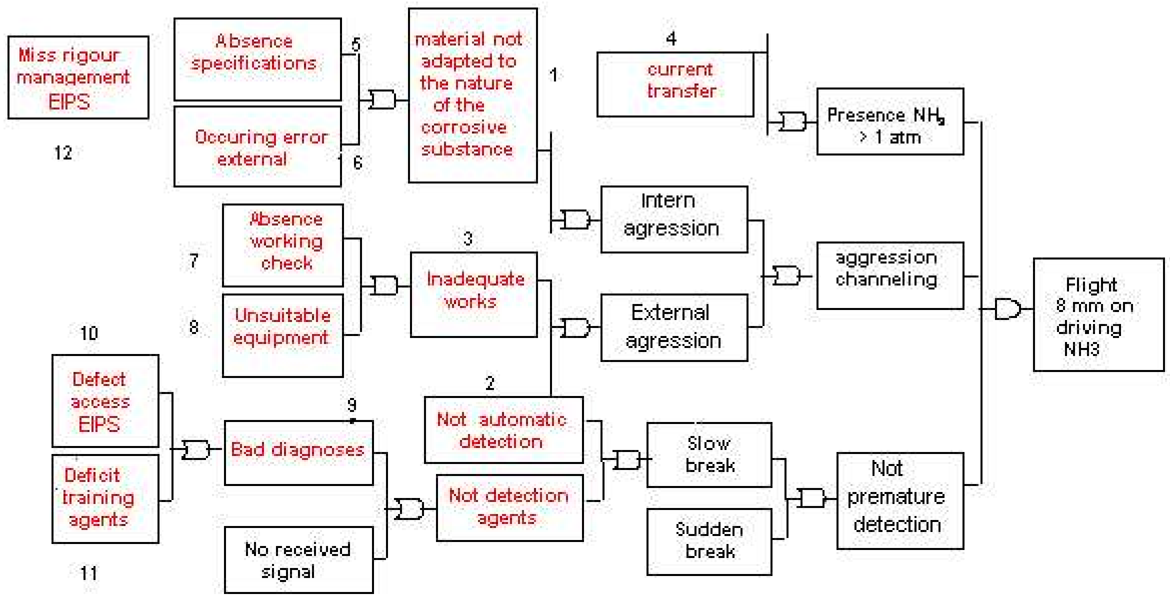


Fig. 9. Summary of faults that led to the branch connection rupture

Cause No. 4
Intervention on a pipe under load.
Cause No. 5
Lack of specifications relative to interventions on the ammonia system.
Cause No. 6
External contractor insufficiently informed of ammonia-related risks and hazards
Cause No. 7
Lack of thoroughness in the SMS (management of modifications and monitoring of safety-related equipment).
Causes Nos. 3, 7, 8
Inadequate operations, performed without a work order and with inappropriate equipment.
Causes Nos. 2, 9
Despite slow corrosion of the nut and the slight leak found, the morning shift then the night shift made an incorrect diagnosis.
The leak had been detected by the morning shift, although they had incorrectly diagnosed the situation and/or did not implement the required measures: shutdown of the transfer operation then drainage of the pipe, followed by intervention.

Cause No. 10
The lack of creating proper access to the valve promoted diagnostic errors and made intervention operations clumsy. This circumstance is to be combined with the management of modifications. The operator has an anomaly management procedure, but the leak that was detected the morning of October 6 (an intermittent leak on the valve connection) was not considered to be an anomaly. No information was passed on to the personnel of the following shifts.
The incident was made possible through incomplete analysis of the modifications made to the pipe during the month of August to reduce the hazards (by dividing it up into 3 sections). The automatic safety feature did not function as a portion of pipe had been installed that was not monitored by an ammonia sensor.
The fact that the pipe was not considered "safety-related", and that it was not taken into account in the management of safety-related purchases, made it possible to procure and install a part made of a metal that was non-compatible with ammonia, and the subsequent leak.
Cause No. 11
The behaviour of the agents, particularly the tinkering on the pipe under load, and the lack of their "emergency stop" reflex reflects the agents' lack of training and practice.

MEASURES TAKEN

1 Immediate measures taken among the inhabitants

The firemen visited each residence to inform the inhabitants once the situation had returned to normal.

2 Modifications prior to resuming operations

The installations (NH3) were secured during the night shift, including the shutdown of the annealing furnaces for 2 shifts and continuance of monitoring operations.
The operator conducted an in-depth inspection of all ammonia-related installations. The fittings of the other branch connections were replaced on the two other sections of the pipe. It appears that one of them was also made of chromium-plated brass. The installation was then purged and put back into service upon approval of the Classified Installations Inspectorate.

3 Summary of action taken by the operator in early 2005

- The operator established specifications for the ammonia piping modifications.
- The list of safety-related equipment was reviewed.
- A training procedure involving all personnel consisting of 4 levels and 3 types of "ammonia" certification is currently being developed.
- The automatic shut-off valve test procedure was improved.
- Visual inspections on the concrete trench were planned.
- Expansion of the ammonia detector network to cover the remaining valves.
- Access and protection arrangements of certain remaining safety-related equipment.
- The modification management procedure remains to be improved.

4 Administrative action

The Classified Installations Inspectorate conducted the following actions:
- Visitation of the premises after the accident (Oct. 7 in the morning).
- Exchange of fax and letters for resumption of activity.
- Inspection of the SMS on November 12, 2003.
- Additional requirements on 01/21/2004, bearing on the management of safety-related equipment, and additional elements to the danger study (confidence levels of the safety-related equipment).
- Updating of the risk report in September 2004.

LESSONS LEARNED

The first lesson is that secondary leaks must not be underestimated.

The local measurements taken "initially" by the operator (organisational and equipment-related) and by the Classified Installations Inspectorate (enhanced monitoring of the management of safety-related equipment and a study of their confidence levels) were described above.

Beyond the lessons learned and the actions taken "immediately", it progressively become obvious that further information can be learned from this accident.

In particular, after further study in August 2004, and following the inspection conducted relative to the action taken in early 2005, the inspectors noted that their requirements were occasionally too point-to-point.

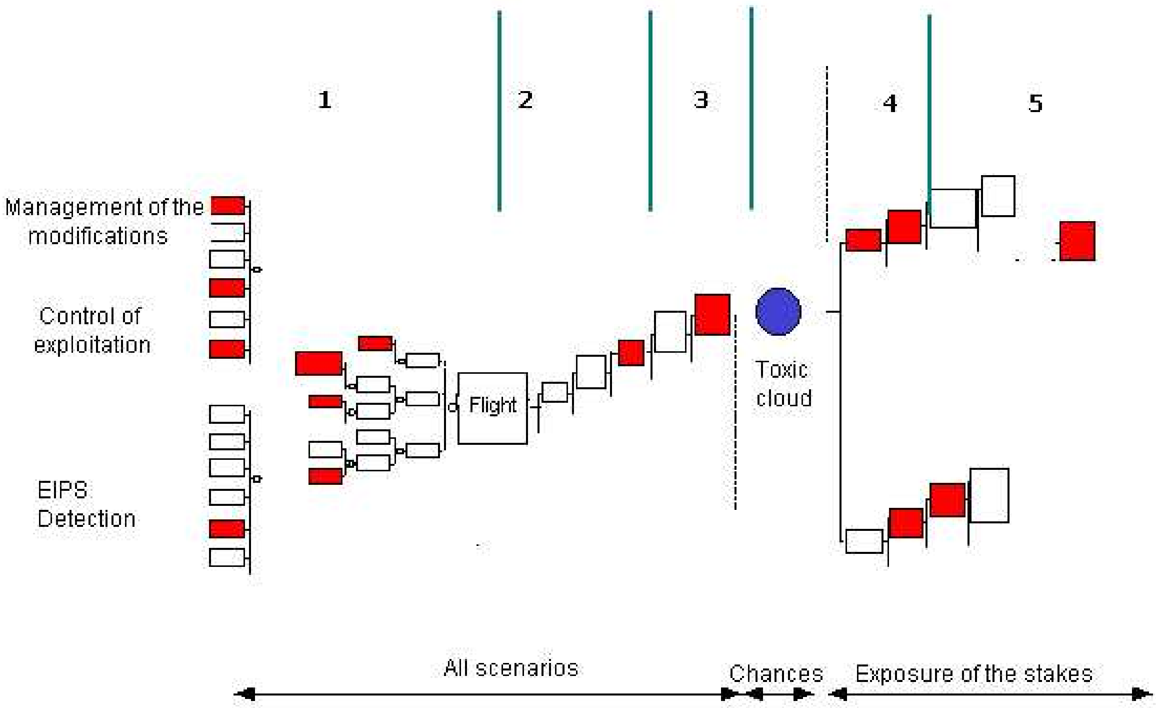
Thus, the search to assess the sufficiency of the measurements taken highlighted a flaw in the system's overall design.

This approach led to additional lessons being brought out.

1 System design

The accident prevention and effect limitation system was designed as a 5-tier defence program in order to then encompass a systematic examination of each layer of defence.

The defence system features: 3 "internal" layers of defence and 2 "external" layers of defence

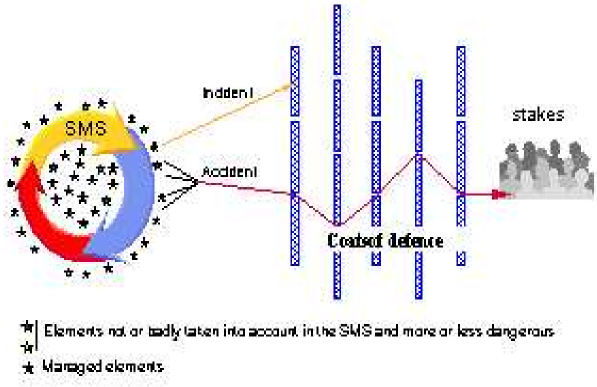


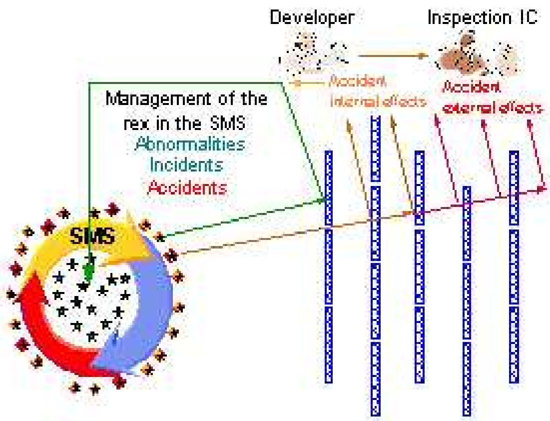
1. Primary confinement (ammonia tanks + piping).
2. Limitation of quantities released in the event of a leak.
3. Secondary confinement.
4. Distancing of the stakes involved.
5. Protection of interests (housing - siren and instructions for local residents).

The system studied includes:
- known, identified, managed, and stabilised elements, events within the scope of the SMS;
- elements not identified and not taken into account by the SMS.

These later elements often appear insignificant (anomalies, incidents that do jeopardize the defence layers) and sometimes sudden (accidents that pass through one or more layers of defence).

In this case, the layers of defence were breached by





The identification and the analysis of anomalies and incidents are used to isolate elements that need to be managed in order to improve the overall performance of the system so that accidents can be prevented. The operator set up this function within the scope of its SMS.

The operator does not manage the external layers of defence. In the event of an accident, one must be particularly attentive to the analysis of the behaviour of these layers of defence.

Looking back, the accident of October 6, 2003 was thus re-examined from the "layers of defence" aspect, with two questions being addressed:

- Why was defence layer X breached?
- Would have layer X been breached in other circumstances? At the same point or at a different point.

This "layers of defence" questioning led to a fault tree type approach dealing with events prior to the FAILURE OF THE LAYER OF DEFENCE X event.
The following additional lessons were also learned, bearing not only on the pipe but also on the storage tanks.

2 Structural weakness of the SMS

The need for overall SMS reconstruction appeared:

1. "Comply" with the requirements of Appendix III of the SEVESO Directive.
2. The overall major accident prevention objective deserves to be broken down into permanent, and clearly targeted sub-objectives: reduction of sources, maintenance and consolidation of internal layers of defence.

3 Defence layer No. 1

Primary confinement

A few holes in the "primary confinement" layer were identified:
1. Mechanical protection of small branch connections.
2. Drainage of vents from the small dump valves.
3. Consideration of certain safety-related equipment of this layer in the probabilistic overall approach required an improvement of the level of confidence. For example, the level measurements must be systematically fail-safe.

4 Defence layer No. 2

Limitation of the quantities released.

A few holes in the "limitation of the quantities released" layer were identified:

1. Restructuring of the network of ammonia detectors in 2 detection levels.
2. For the confined detectors: identified fault possibilities require
   - Anti-impact detection on the metal sheath
   - Metal sheath extension to certain branch connections.
3. For the external detectors: insufficient consideration of the heavy gas behaviour.
4. Flow limiters: insufficient control by the operator of detection levels.

5 Defence layer No. 3

Secondary confinement

The confidence levels of the dynamic confinement measures by water curtains are insufficient for consideration in the probabilistic approach. This defence layer must nevertheless maintained and reinforced.

A few holes in the "secondary confinement" layer were identified:
1. Extension of the fixed water curtain protection system necessary along the pipe.
2. More frequent Internal Contingency Plan exercises: 2 to 4 per year.
3. Implementation of a highly efficient isolation system (a mobile metal partition around storage tanks to break the jets in the event of a leak), according to the criteria of the danger study.

6 Defence layer No. 4

Distancing of the surrounding area.

There is no "nearby risk" in the Local Urbanisation Plan, with the exclusion of all residential areas and a clear objective of removing the existing housing from the zone very near the piping owing to the rapid kinetics of the events in the event of a leak.
As owner of the premises concerned, the operator agrees on the principle to demolish the first 3 buildings along the road. These buildings are used for housing company employees.

7 Defence layer No. 5

Protection of the surrounding area

The siren is standardised, the distances are short, but this is obviously not enough.
An information program for residents was requested.

The firemen must be given confirmation of the importance of visiting the housing complexes after the cloud has passed.
An operator-controlled stop light system on the road must be studied.

8 General conclusions on the feedback

Three steps were necessary for the Classified Installation Inspectorate's action after the accident, spaced over a period of a few months:
- "Hot" inspection and immediate action, generally local or pending (additional studies).
- "Cold" inspection after a few months.
- Reformulation of the first actions in a more global approach of the system.

One must not lose sight the need to systematically "contractualise" the lead-times for the improvement brought out by the accident, even if the operator appears to be very invested.

We must also remain focused on the need to carefully examine the "small" scenarios, even those regarding the secondary branch connections.

Contrary to the follow-up of relatively numerous amount of anomalies, performed by operators, the Inspectorate intervenes only on rare events: it is thus important to exploit them to the fullest.

In this spirit, the work on the accident of October 6, 2003, enabled the layers of defence to be conceptualised and to bring the operator to re-examine the analyses of past failures.
This exercise resulted in the **defence strategy concept of the operator and public authorities,** with a requirement for the operator: formalise the defence strategy at the heat of the safety management system.