Seminar introductory speech

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MR. CYRILLE SCHOTT

Prefect of the Basse Normandie Region, Prefect of the Calvados Departement

Welcome everyone!

As Prefect of the Basse-Normandie Region and Prefect of the Calvados *Departement*, it is with immense pleasure and interest that I welcome the 2005 international seminar on industrial accidentology and feedback to Caen, the "county seat" of the Basse-Normandie region and Calvados.

This event has been organised for the 6th time by IMPEL, "a national network for the application and respect of environmental law." This structure, established in 1992, is designed not only to encourage the exchange of information and the comparison of experiences but also to promote a consistent approach in terms of the implementation, application and monitoring of environmental law.

I would like to welcome all of the industrial installation inspectors from the various member states of the European Union united within this network. Twelve countries are represented this morning: Germany, Austria, Belgium, Italy, Spain, Portugal, Sweden, Lithuania, Czech Republic, Slovakia and the Netherlands. And of course the French inspectors in charge of the classified installations and labour inspectorates. This extensive international participation can only contribute to enriching our exchanges and debates.

As you know, our fellow citizens, French and European, have long been aware that major risks are no longer “inevitable”. This is also true for natural hazards. Lack of foresight and awareness are highlighted at each new disaster. But we all know that "zero risk" cannot, unfortunately, be guaranteed. Proper control of technological risks is thus a primary requirement for both companies and public authorities. This implies a certain understanding, shared by all public and private players, of the conditions and actions required to reduce the probability of an incident and the potential effects.

In all countries of the OECD, the prevention of industrial hazards is based on the postulate that the company is the primary entity responsible for the operational safety of a hazardous installation. The public authorities are in charge of defining the conditions in which the company's activity can be authorised and in checking that the operator properly controls the risks and nuisances throughout the installation's service life. You perform this essential mission for society and I am convinced that you perform your duties with rigour, competence and commitment, as your presence here today demonstrates.

I would like to speak to you briefly about the tasks of the Prefect. As you know, the Prefect represents the government and ministries at the regional and county (*département)* level. He is thus in charge of implementing the government's policies in a wide variety of areas, including the one which concerns you in particular. This area is of primary importance for the Prefect and has become increasingly so over the last few years. For me, the "Direction Régionale de l'Industrie, de la Recherche et de l'Environnement" (DRIRE) is one of the key departments of territorial government.

Before becoming Prefect of the Caen region in late July 2004, I was previously posted in regions which had their fair share of sensitive industrial installations, including Pas de Calais, Seine & Marne and Alsace, with the well known Fessenheim nuclear power plant, and the chemical installations in southern Alsace near Basel. The DRIRE was obviously crucial for my activity in the field of risk prevention.

Although the Basse-Normandie region is not a major industrial region, it is nevertheless home to installations that are, though few in number, notable in terms of hazards. I am obviously referring to the nuclear installations, as well as the 14 SEVESO establishments: petroleum depots, chemical factories and explosives depots, which dot our territory.

Feedback from the AZF accident in Toulouse led the public authorities to reinforce existing regulations for these types of installations. The Act of July 30, 2003 pertaining to industrial risk, represents a new approach and major challenge, requiring greater involvement of society in risk management, notably with the implementation of CLICs ("Comités Locaux d'Information et de Concertation", Local Committees for Information and Consultation). The Basse-Normandie Region is significantly involved in the implementation of this act. One of the eight pilot sites for experimentation relative to the implementation of PRRT ("plans de prévention des risques technologiques", technological risk prevention plans) is located in the region, in Vire, and concerns a liquefied petroleum gas depot. Studies of the stakes and contingencies are being finalised.

In the near future, the DRIRE and DDE hope to present these stakes and contingencies and submit for approval new urbanisation rules for the identified vulnerable zones. The results of this work will form the technological risk prevention plan. For the region, there are eight PPRTs in all that will be developed from now until 2007. It is an arduous task because protection zones must be foreseen with urbanisation rules that sometimes interfere with community development or expansion projects. It must obviously be strict in these matters and ensure that sensitive installations do not pose new risks in their perimeter, due for example to the construction of new housing which would increase the number of people living near these industries. This important and difficult task obviously involves the DRIRE and often the Sub-Prefects, and even the Prefect, must intervene repeatedly in the debate.

If risk prevention is a fundamental point of the system, crisis management must not be neglected, despite the precautions taken, as accidents are still possible. The anticipation of crisis situations, with contingency plans and exercises, are required for better control, at the crucial moment.

We have programmed two special intervention plans for key installations in the Calvados area for this year and early 2006. This reminds me of the three-year exercise cycle (1995-96-97) that I had to manage with the DRIRE in relation to the Fessenheim nuclear installation when I was Prefect in Alsace. The first year, we tested the special intervention plan under the Prefect's authority concerning the plant, and we mobilised the entire civil population of the villages (500 people) around Fessenheim. The second year, we implemented the internal contingency plan at the nuclear power plant, with the measurements to be taken by the company's management, and the special intervention plan outside the plant. The third year, we organised a bilateral Franco-German exercise, and mobilised our German colleagues. When I was organising my crisis centre at Colmar as the Prefect of the Haut-Rhin, the "Regierungspräsident" had formed a crisis centre at Fribourg. The exercise took place on both banks of the Rhine. The context was not easy, as this power plant was the subject of debates and ecological movements began to flourish in France and Germany. In the end, these exercises were seen as a major success. They required extensive mobilisation of the DRIRE, of course, but also all the other departments concerned: firemen, police, gendarmerie, infrastructure, and the Prefecture. They also required extensive mobilisation of the Prefect himself and his sub-prefects, owing to the special media attention brought on by these exercises.

I think that one shouldn't hesitate in conducting such exercises on sensitive installations. Their preparation must be very careful and demands extensive joint action, particularly with elected officials, representatives of local populations, so that the exercise is correctly understood and that everyone grasps the meaning and ensures that it is successful. You know, during these exercises, the prefectorial authority is at the core of the program in terms of cooperation with the operators, municipalities, elected officials, governmental departments and the press, which relay information. The round-table discussion here on this theme is an excellent idea. It will be presided by Alain Schmitt of DRIRE Basse-Normandie and Alain Gueydan, the Director of my office at the Prefecture. I believe that it will be instructive and useful.

I was telling you earlier that after the preparation, after the exercises, a crisis could still occur. The crisis that I faced in the "Noroxo affair" in the Pas-de-Calais had very dire consequences: 86 people were afflicted by Legionella and 18 died. Management of the crisis over time required an extremely close link between the Prefect, the DRIRE and other agencies such as the DDASS, the CIRE ("cellule inter régionale d'épidémiologie", inter-regional epidemiological unit), the national bureaus such as the DPPR ("Direction de la Prévention des Pollutions et des Risques", risk and pollution prevention department), the health department, as well as the Legionella national treatment centre located in Lyon. The Prefect's office played a central role in the crisis management. It all began when the DDASS became aware of two sick people who were living just 300 m from one another, near the Noroxo plant in the city of Harnes. I received a telephone call from the sub-prefect on duty on a Saturday afternoon, to tell me that two people had been contaminated, one of whom had died, and his suspicion about Noroxo and the DRIRE's draft proposal to shut down the installations to clean them. I immediately implemented this proposal. An epidemic was predicted and the companies located nearby were suspected. I immediately set up a crisis centre with my office, the civil protection department, the DRIRE and the DDASS. The plant cleaned up its installation and we are searching for other potential sources of contamination in the communities around Harnes. The crisis progressively spread. It should be mentioned that nearly 1,500 analyses were conducted in other installations over a 2-month period. Around mid-December, we were able to confirm that the bacterial strain found among the contaminated individuals was the same as that taken at Noroxo.

We found the answer and the crisis should therefore have ended, but that wasn't the case. After the first wave of contaminations, a second wave followed. It was at this time that the crisis extended to the national level. Despite contacts already established between all the experts at the county, regional and national level, I requested an additional expert assessment. The government then set up a task force of specialists from both the public and private sectors. We became aware that the people contaminated during the second wave had the same strain of *Legionella* as that found at Noroxo. For the second time, it was decided to shut down the plant and we requested higher-level cleanup operations. Meanwhile, the specialists discovered that during the cleanup phase, which had been conducted normally, contaminated aerosol emissions could still occur. It took a long time to develop the protocol for the plant's second cleanup operations and required a very thorough assessment. During the second wave of contamination, in the month of January, the same strain as that found at Noroxo was discovered, in concentrations below the regulatory threshold, in another local plant that employs several hundred people. So what was to be done? Shut down the plant and put several hundred people on partial unemployment? Or not shut it down, as it would be difficult to relaunch the activity?

The professor managing the specialised Legionella unit in Lyon raised three points during our meetings. The Legionella concentration is one element, of course, but it's not the only one. The virulence of the bacterial strain must be taken into account; it was highly virulent since we already had fifteen or so deaths. The sensitivity of the population in this former mining town must also be taken into account; it was fragile for various reasons and the number of deaths has shown this. In light of these elements, a decision had to be made and I requested that the plant be shut down, working in close cooperation with the director of the DRIRE, in a context where the population still had questions and the elected officials had a hard time keeping up. Difficult decisions had to be made, like explaining the plant's second shutdown under extreme media pressure. At the height of the crisis, I met regularly with the mayors and issued a press release every day. Those are some of the key points I wanted to raise about crisis management. During a crisis of this type, it was obvious that the Prefect had to be play a leading role and work closely with the DRIRE, your colleague Pierre-Franck Chevet, and his entire team, as well as the Director of the DPPR, Mr. Trouvé, and the Health Commissioner.

But the topic here is to specifically discuss the activity of the DRIRE and the DPPR.

I hope that you have understood that the Prefect is responsive to the needs of your field, because in the event of a crisis that threatens lives, makes people sick, and causes great concern, we must all be mobilised.

I hope that the presentations and discussions today are genuinely productive, that the discussions produce some solutions for the accomplishment of your daily tasks. I again welcome you to our region and sincerely hope that you will enjoy your stay in Caen. The organisers have done everything possible with this goal in mind.

In conclusion, I would particularly like to extend my heartfelt thanks to Mr. Alain Schmitt, Director of the DRIRE Basse-Normandie, for his personal involvement and that of his entire team in organising these two days. Thank you for you attention.

MRS. MARIE-CLAUDE DUPUIS

Head of the Industrial Environment Department

Goodmorning,

It is always an immense pleasure for me to open this seminar on industrial accidentology and feedback, organised under the aegis of the IMPEL network.

Firstly, I would like to extend my most sincere thanks to our hosts for having welcomed us in such wonderful conditions. I would particularly like to thank Mr. Cyrille Schott, Prefect of the Basse Normandie Region, who, despite his numerous commitments, expressed his desire to welcome us personally this morning. I would also like to thank Alain Louis Schmitt, Regional Director for Industry, Research and the Environment, and his entire team for their involvement in organising this seminar in close cooperation with the BARPI.

I'm also thinking of the numerous contributions - no less than 18 this year! - the European inspectors (13 French inspectors and 5 from other European countries) who prepared the presentations, assisted by the labour inspectorate in many cases.

Changes continue to be made since the previous sessions following the Toulouse catastrophe.

Firstly, in the texts: in order to facilitate the application of the Act of July 30, 2003, 3 decrees, 2 orders and a memorandum state the principle of proportionality and the consideration of safety hazard analysis. This concerns the steps taken by the operator to control risk at the source (how far should the operator go to reduce the risk?) as well as the assessment of this approach by the Inspectorate and the Prefect, either when authorisation is given or when the danger study is revised, or to define the measures proportional to the residual risks within the scope of plans for the prevention of technological risks:

- 3 decrees, including: the decree of February 1st, 2005 deals with the organisation of CLICs ("Comités Locaux d'Information et de Concertation", local information and joint action committees) / the second, relative to PPRTs ("Plans de Prévention des Risques Technologiques", plans for the prevention of technological risks), was validated last May 7th by the State Council / the third decree concerns the modification in progress of Decree of September 21st. In particular, it stipulates the content of the danger studies, and introduces the notion of risk control by the operator at a level that is "as low as possible along technical and economic lines, considering the state of the art on the one hand and the vulnerability of the installation's environment on the other".
- 2 orders: one determines the technical criteria and the Probability, Severity, and Kinematics evaluation thresholds of accidents, the second modifies and adds consistency to the "SEVESO" order of May 10, 2000, in terms of risk control,
- 1 memorandum deals with the Prefect's assessment of the steps taken by the operator to control risks.

In close cooperation with the French Equipment Ministry, we will be finalising the PPRT development guide. Another memorandum will set the criteria used to determine risk zones, as well as the urbanisation rules to be observed according to the risks. Experimental steps aimed at developing PPRTs on 8 test-sites, such as that of the VIRE, mentioned by the Prefect of the Basse Normandie Region, will allow us to fine tune the method.

The objective of sector-based working groups, in which the Inspectorate actively participates, is to support these methodological changes at the technical level. Controlled by the DRIRE and mandated by the DPPR, they include operators, labour unions, experts, and inspectors of classified installations and the SEI (Service de l'environnement industriel", industrial environment department), to concretely define the new evaluation and risk control methods, sector by sector.

Accidentology feedback, often taken from the ARIA database, is often used within these groups as they need to base their positions on real-life events. The analysis of past accidents remains a pragmatic and relatively reliable means to provide points for discussion or answers to questions.

This arrangement, at the core of risk prevention, requires enhanced openness and transparency of all players so that everyone can benefit from the lessons to be learned. Since the Dijon seminar in November 2003, the small circle of contributing labour unions has widened; protocols have thus been passed with the UIC ("Union des Industries Chimiques", the French Union of Chemical Industries), which recently submitted 60 incident analysis reports. Since late 2004, the CFBP ("Comité Français du Butane Propane", the French Butane Propane Committee) has taken part in BARPI's consultations, thus joining the program initiated in late 2001 by the GESIP ("Groupement d'Etudes et de Sécurité de l'Industrie Pétrolière"). The AFF ("Association Française du Froid", French Cooling Association) and the CNF ("Conseil National du froid", the National Cooling Council) have also

recently joined. This type of initiative should be developed more widely as the organisation of feedback sharing is still too rare…

More than ever, risk poles and centres actively request feedback in order to analyse accidents and files. The Inspectorate's share in the requests submitted to BARPI has thus increased from 10% to nearly 30% from 2003 to 2005; this is a step in the right direction and should be encouraged. In compliance with the request of the DPPR in November 2003 in Dijon, nearly 30,000 accident or incident summaries are now available on the web site www.aria.ecologie.gouv.fr. Our foreign colleagues will certainly appreciate that the main sections of this site have been translated into English. In return, the system relies on the fact that everyone submit their data in real time: reports, notes, diagrams, and photos, etc. to BARPI.

This requires that you collect the information from the operators regarding the circumstances of the accident, the intervention measures and the positive feedback. Positive feedback refers to the corrective actions implemented from both the technical and organisational standpoint. In this respect, I would also like to remind you that an electronic accident report was created through the joint efforts of inspectors and SEI representatives. This format can be used to draft reports to the Prefect or the Public Prosecutor. The form can de downloaded from the BARPI web site. Currently one inspection report out of two submitted to the BARPI respects this format. It is highly desirable that the Inspectorate make a special effort to use the format systematically.

During the previous IMPEL seminar in Dijon, the DPPR had insisted on the assimilation of the European scale for industrial accidents by the Inspectorate and the operators. The characterization of various cases, according to this scale, are provided in your file. In order to facilitate this assimilation, the BARPI now systematically includes this 4-icon representation on its site and in its various publications. This representation helps the reader understand the effects and consequences of the accidents by placing all elements in perspective. It is in the Inspectorate's best interest to continue using this tool in its exchanges with both operators and experts. The stakes are clear: place the events into better perspective through impartial analysis.

In case of an incident or crisis, the public also needs a reference framework. In this spirit, guidelines and index for urgent communication were designed in 2004 to meet the request of the Higher Council for Registered Installations and the DPPR. Experiments were also launched in 8 French regions in 2005. I repeat that, despite the difficulties and the natural unwillingness of the "'technicians" to communicate, the objective of this approach is get the operators to provide press releases after an incident or accident. Special effort deserves to be made in this field. The dangerous materials index, consistent with the European scale, is designed to give easy-to-use and easily understandable points on the source term of the event. A report detailing this experiment will be issued at the end of the year. The objective is to help the public understand the realities and difficulties of risk prevention.

Beyond the obligation to declare incidents and accidents in real time in application of article 38 of the order of 1977, you have also noted that the act of July 30, 2003 introduced the obligation of periodic dialogue within the scope of the CLIC, in article L125-2 of the Environmental Code, on the theme of incidents and the actions taken.

Openness vis-à-vis the general public is a very important issue. This will require many years of work on our part.

Today, we are aware that our profession must integrate this component by aiming to increase society's involvement in managing these risks. It is also a means for reducing the severity of crises and making them more manageable. This question will undoubtedly be brought up during the crisis management round table that we integrated in the case study program cycle. Alain-Louis Schmitt, who presided over the DRIRE working group on this theme in 2004, will present it later this afternoon.

In conclusion, I'd like to mention that the seminar kit includes, notably:

- the Dijon seminar technical sheets (in French or in English)
- a brochure on the technological accidents from 1992 to 2004 in France.
- A CD-ROM presenting feedback on the accidentology of installations in which chlorine was involved. This document, the presentation of which has just been completed by the INERIS, results from a joint effort with the MEDD and the Inspectorate represented within the chlorine working group involving experts and the "Syndicat des Halogènes et Dérivés" (SHD).
- an accompanying document summarising accidents taken from the ARIA database and presenting analogies with the cases dealt with. They can be used as a reference during the various presentations.

I propose the following schedule for presentations:

- this morning, the problem of operations and maintenance
- this afternoon, prior to the round-table discussion, technical themes related to the crisis
- tomorrow, technical and organisational failures in the operational phase
- then, more varied themes having severe consequences in common
- and lastly, events involving natural elements.

Our seminar is organised on a half-hour cycle with presentations lasting a maximum of 15 to 20 minutes, each followed by a 10 to 15-minute discussion period with the audience.

Thank you for your attention and I hope that your exchanges are enlightening…

Explosion and fire of a reactor in a chemical plant

April 17, 2003

Oudalle – [Seine-Maritime] France

Esterification
Mineral oils
Heating
Operations
Temperature
Control room

THE INSTALLATIONS IN QUESTION

The plant, specialised in the manufacture of additives for lubricants, is classified as high-level Seveso II. It is located in the Havre industrial estate.

The site is equipped with various manufacturing and product mixing units. The damaged unit was used to synthesize dispersing agents. It features two identical production lines. The equipment mainly consists of synthesis reactors and filtration installations.

THE ACCIDENT, ITS BEHAVIOUR AND CONSEQUENCES

The accident:

On April 17, 2003 at approximately 3 am, an explosion occurred in a dispersing agent manufacturing unit that uses oils.

The consequences:

The explosion resulted in very localised property damage. The effects were observed up to twenty metres from the accident (projectiles and broken glass). The reactor had opened up (see photo) despite the overpressure protection device installed.

The personnel was not affected as the accident happened at night. One person was shocked however.

Overall view of the reactor

View of the damaged reactor from above

The firefighting water was routed to a buffer tank to avoid it being released into the natural environment. Atmospheric releases were mainly associated with the emission of products during the fire.

The operator estimated the costs generated by the incident (including the replacement of equipment, operating losses…) at 11 million euros (direct costs: 6.5 M€ - indirect costs: 4.5 M€).

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.

The parameters, which 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

Quantities of dangerous substances	□ □ □ □ □ □
Human and social consequences	□ □ □ □ □ □
Environmental consequences	□ □ □ □ □ □
Economic consequences	■ ■ ■ □ □ □

Level 3 of the "economic consequences" index results from parameters 15 (6.5 M€ of property damage in the establishment) and 16 (4.5 M€ of production losses).

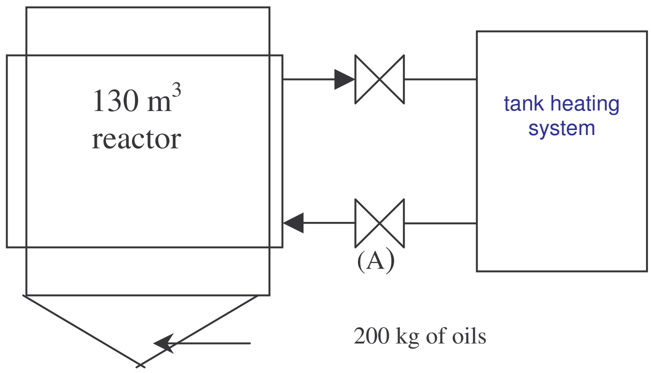
ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

The operator and the French "Welding Institute" (which specialises in materials testing), an external laboratory (for the tests) and an engineering firm (for the a posteriori estimate of the energy potential released when the reactor exploded) lead to detailed investigations during the inquiry that followed the accident.

Circumstances:

Just prior to the accident:

- the unit concerned directly was completely shut down,
- the 130 m^3 esterification reactor (with a capacity of 90 t) was empties after the last batch and rinsed with mineral oils (estimate: there was approximately 200 kg of oil with 5% additive in the reactor's drainage cone – which corresponds to level "0"),
- temperature rise tests were being conducted on the reactor's heating system,



- the reactor was not disconnected from the heating system. The inlet valve (A) on the reactor's heating coil remained open,
- the atmospheric temperature of the reactor thus increased and caused the mineral oils in the bottom of the reactor to evaporate and decompose,
- the unit's monitoring parameters were reported in the control room although no specific action was taken by the operators as the unit was shut down and the production personnel did not consider that the unit presented any danger, a priori.

Subsequent analysis of the unit's parameters reported to the control room showed that:

- the temperature of the thermal fluid had reached 250 °C,
- the atmospheric temperature remained around 200°C for many hours with a sudden increase in temperature just prior to the explosion. This was not noticed in the control room as the temperature alarm was set above 300°C only for "product quality"-related questions (handling of non-flammable products).
- The valve of the heating coil had opened when the boiler was made available (according to the procedure) but had to be closed when the heating system of the tanks was restarted.

Causes:

The fault tree showed:

- operating conditions prior to the accident which caused the mineral oil vapours to exceed the lower explosivity limit (temperature in the reactor above 180°C, flashpoint of the rinsing oil used, for approximately 20h). The operator assessed that in these conditions, the oil contained in the reactor had reached the boiling point.
- The presence of oxygen in the reactor at the time of the accident may be the result of degassing of a line via the reactor during maintenance work being performed near the unit concerned. According to the operator, the degassing manoeuvre was performed several times in the days prior to the accident.
- The investigations enabled several possible ignition sources to be identified:
    - <u>Self-ignition of decomposition products generated by the reactor heater:</u>

      Specific tests were conducted on the rinsing oils used by the operator in order to reproduce the incident in a laboratory setting.

      According to the supplier's MSDS, the self-ignition temperature of the oil used is greater than 250°C.

      The laboratory analyses on the rinsing oil indicated a self-ignition temperature of 370°C. Analyses conducted on the additive at 5% showed that the product started to decompose above 435°C. The operator also postulated that there may have been an accumulation of reaction products or sub-products in the reactor. However, the self-ignition points of these components are above 350°C. According to the parameter report, these temperatures were not reached in the reactor.

      The operator however referred to the literature, stipulating that the self-ignition temperatures of the products can be lowered by various parameters, such as: surface area of the metal, presence of oxides functioning as a catalyst, and the nature of the materials present.

      In addition, it is possible that maintaining the atmosphere of the tank at different high temperatures may have promoted the decomposition of the oil that would have reached their self-ignition temperature.

      A third-party organisation conducted tests on the oil contained in the bottom of the reactor prior to the accident. These tests did not provide information relative to the cause of the explosion. The mass effect presented by the industrial equipment can produce phenomena that cannot be detected in a laboratory setting.

      The theory of the self-ignition of fumes was neither confirmed nor overruled.

    - <u>Static electricity:</u>

      The non-excluded potential presence of static electricity may have caused the oil vapours to ignite. The presence of boiling oil may have generated a liquid flux on the walls of the reactor against the flow of oil vapour. This phenomenon may be the cause of a potential difference and thus an electric discharge. Nevertheless, the conclusions of the theoretical ignition analysis by an independent organisation showed that the risk was not zero, also it remains extremely low. This point was thus neither confirmed nor overruled.

- Electric spark:

  This hypothesis was disregarded by the operator since the equipment that could potentially cause a spark is insulated or explosion-proof and there was no impact associated with lightning at the site.

ACTION TAKEN

Technical action:

Although the exact cause of the accident was not clearly determined, the operator implemented various corrective measures prior to restarting the unit in order to prevent an accident of this type from happening again, considering the two probable causes of the ignition of the vapours. Firstly, these measures were designed to limit the heating of empty equipment during shutdowns and to limit the presence or the formation of static electricity in the installations. Several measures were taken:

✓ Limitation of oil vaporization.
The operator undertook the following actions:

- installation of a temperature control system on the coolant system to limit it at 210°C. In addition, the literature indicates coolant fluids for which the flashpoint may sometimes be lowered to 60°C depending on its water content and the ageing of the fluid. It must thus be renewed regularly, which the operator does.
- review of the operating instructions to include checks to be performed during shut down, transitory operation of installations, particularly to stop the heating of tanks in the product transfer phases and when the mixer is not operating,
- modification of the high temperature alarm on the reactor to set it at 210°C,
- increase of the sampling frequency of the IPS (several times per minute) to obtain more precise information about parameter changes.

Furthermore:

- the shut-down and maintenance procedure integrates the disconnection of the heating system equipment,
- the monitoring of shut-down installations and the maintenance procedure relative to the heating systems of the industrial capacities were applied through the site,
- the personnel received training in the new procedures,
- the inspection parameters of the installations while shut down are monitored from the control room,
- the monitoring equipment (temperature, for example) were doubled at the reactor level.

✓ Limitation of the presence of air in the reactors:

- the restarting procedure for the unit's procedure was reviewed to integrate the inerting of the nitrogen tanks.

✓ Limitation of the risk associated with the static electricity in the reactor:

- the operator installed equipment to limit the formation of static electricity. The products are introduced by a dip tube to limit the formation of static electricity.

Administrative actions:

Within the scope of actions taken following the accident, four inspections were conducted jointly by the "environment" and "pressurised equipment" agents of the DRIRE regarding the on-site reports (April 2003), and the verification of the provisions for the partial, then total restart of the unit (June and July 2003).

The actions proposed during the second quarter of 2003 by the classified installations inspectorate:
The accident was not considered a major accident in terms of Article 2 of the Ministerial Order of May 10, 2000 and did not have significant consequences for the environment.
The operator met the provisions of the Prefectorial order of March 31, 2003 – title III which governs the unit in question.
The classified installations inspectorate did not note any violation meriting a fine, nor any element requiring formal notification. The only administrative actions consisted in a Prefectorial emergency measures order outlining the conditions required for placing the installations back into service.
This Prefectorial order was issued April 25, 2003 and the operator satisfactorily complied with the provisions of this order, prior to the last start-up phase of the units in July 2003.

LESSONS LEARNED

The major feedback elements retained:

- Avoid heating tanks considered to be "empty".
- Include this restriction in the shut-down and start-up procedures of the units and the heating systems.
- Reinforce the monitoring of process parameters of the units shut down.

Accidental spillage of a reaction mixture in a busy area

March 4; 2003

Clamecy – [Nièvre]

France

Projections
Chemistry
Reactor
Alkaline sulfone
Batch
Burst disk
Manufacturing tolerance
Fatigue
at high temperature

THE INSTALLATIONS IN QUESTION

The group:

The group is a major chemical manufacturer with annual revenue of 5.5 billion euros. It employs 23,000 people throughout the world, enjoys a commercial presence in 150 countries and has a research and development budget of nearly 200 million euros.

The corporate body includes 9 different companies. The Clamecy site belongs to one of these companies which, with annual revenue of 620 million euros in 2003, is one of the world leaders in the detergent, cosmetics, agrochemical formulations markets and produces specialties for the industrial polymers and petrochemical industries.

The site:

The Clamecy plant is located **to the north of the Clamecy city centre, on the banks of the YONNE River** and the Nivernais Canal. The establishment, classified as **high-level SEVESO,** is authorised with public easement (French regulations) for the storage and use of liquid toxic products (222 t).

The Clamecy site produces more than 400 fine chemistry specialty products. Its activity is divided between 2 hubs that meet the following needs:

- ✓ Organic chemistry: consolidation of soil, waterproofing, solvent, aerospatial-aeronautics, textile, hygiene, agriculture, petroleum products,
- ✓ Mineralogical chemistry: post-combustion catalyst, high-purity industry, colorants for plastic, cosmetics, and detergent.

The installation:

The accident involved the RAE 105 reactor of workshop F5 where the following products are manufactured:

- High temperature-resistant resins for the aerospace and aeronautical industries,
- Surface active agents for the detergent and cosmetic products industry,
- Dispersing agents for the agrochemical industry, and
- Intermediate products for textiles.

On the day of the accident, the 12-m^3 reactor RAE105 was being used **to produce GN base, which is used by the leather tanning industry.** Manufacturing operations are discontinuous.

Operating principle:

Solubilisation of resol: Resol is rendered soluble in water through interaction with sodium bisulphite, soda lye and formaldehyde. The solubility obtained by fixation of the sulfonic methyl group CH_2SO_3Na also allows **soluble alkaline crude sulfone** to be obtained. It is then neutralized by sulfonic tetralene acid and formic acid, discoloured by a sodium bisulphite / formic acid mixture, then adjusted to the desired density.

Notably used in the manufacture of Bakelite, resol is a resinous substance obtained by sulfonation of phenol with sulphuric acid, neutralisation with soda lye and condensation with formaldehyde.

Operating procedure:

- ✓ Loading of reagents (soda lye 30%, sodium bisulphite and formaldehyde); the temperature of the environment after loading is approximately 60 °C,
- ✓ Heating (steam at 3 bar) up to 125 °C,
- ✓ Shut-down of the heating and increase in temperature up to 137 °C (+ or – 3 °C) by exothermy,
- ✓ The temperature is monitored by a local thermometer and the heating is restarted, as required,
- ✓ Salt content is monitored (target level: 50 to 52) by a sample being taken every 2 hours.

The complete phase takes place over a period of approximately 16 hours.

THE ACCIDENT, ITS BEHAVIOUR AND CONSEQUENCES

The accident:

March 4, 2003 at 5.40 am: The burst diaphragm on reactor RAE105 burst and 5,000 litres of reaction mixture (soluble alkaline crude sulfone) was projected outside and spilled into 200 m^2 of storage space.

Workshop personnel, including the operator controlling the installation in question, informed the plant's monitoring station.

The firemen at Clamecy's main emergency response centre and the Rhodia site spread neutralising products and absorbents. The substance solidifies at ambient temperature, thus enabling an external company to collect the residues and clean the ground soil.

The consequences:

The chemical substance expelled is not classified under the terms of the SEVESO directive and the accident had **no sufficiently significant consequences to be rated on the European scale for industrial accidents**.

However, **personnel located in the zone of the burning and corrosive discharge could have been seriously injured in the accident.** As luck would have it, the accident occurred very early in the morning when fewer employees were at the site. In addition, **the storage area's retaining basin was able to contain the product, thus minimising the effects on the environment.**

ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

Circumstances:

March 3 at 2 pm: reactor loading operations (30% soda lye, sodium bisulphite, formaldehyde)

2.40 pm: Start of heating - temperature increase to 125 °C (3 bar).

Once the heating was shut down, the exothermic reaction allows the temperature to rise to 137 °C. The operator monitors this temperature on a local thermometer and can turn the steam heating back on as required.

A sample is taken every 2 hours (salinity content) in order to monitor the reaction's progress. All measurements were in compliance with estimates until the next day at 4.30 am, i.e. 12 hours after the start of the solubilisation process.

March 4: Upon arriving at his workstation around 4.15 am, the operator noted a temperature reading of 140 °C and pressure between 2.4 and 2.6 bar.

4.30 am: The cure index measured had been constant for 2 hours.

5 am: The reactor was heated once again to maintain pressure at 2.5 bar.

5.30 am: The pressure was oscillating between 2.4 and 2.6 bar and the temperature was 139 °C.

5.40 am: The newly replaced graphite burst diaphragm, calibrated at 3 bar, ruptures; 5,000 litres of reaction mixture (**soluble alkaline sulfone**) was projected outward and spilled into the 200 m^2 storage zone protected by retaining catchpit.

Upper part of the reactor: mixer and burst disk discharge line

Hypotheses:

- ✓ **Runaway reaction (increase in pressure): this hypothesis was very quickly dismissed** as the operator had just checked the pressure and temperature which were normal and the salinity index practically constant which indicates that the reaction was nearly completed.
- ✓ **Incorrect installation of the burst diaphragm when replaced: this hypothesis was also dismissed** as the installation procedure was performed in accordance with the supplier's instructions (particularly the tightening torque); the diaphragm was installed in the proper direction. No trace of cracking or foreign bodies along the gasket plane, or other anomaly was reported.
- ✓ **Leak of the heating coil (steam): this hypothesis was dismissed;** no leak was detected during post-accident testing.
- ✓ **Failure of the steam regulator: This hypothesis was also dismissed** because the temperature was normal (139 °C) just a few minutes prior to the rupture and the regulator was operating after the installation had been put back into service.
- ✓ **Insufficient burst diaphragm rupture pressure**

The recently replaced burst diaphragm came from the same batch as the previous one. It was installed in compliance with the supplier's installation recommendations. GN base production is the 1st operation performed in reactor RAE105 since the diaphragm was replaced within the framework of the installation's preventive maintenance program. **The manufacturing tolerances, as well as the drop in the material's efficiency due to fatigue and the operating temperature, were not taken into account when the diaphragm was dimensioned.** These elements confirm the hypothesis of a burst diaphragm calibrated at a burst pressure too close to the reactor's operating temperature.

As a result, the operator maintains that the probable cause of the accident was **a burst diaphragm that was calibrated too close to the reaction's service pressure resulting in its rupture by fatigue.**

ACTION TAKEN

2-tier action plan:

✓Placement of the reactor back into service

The reactor's design pressure is 5 bar at 20 °C. The experts deduced that its maximum service pressure must not exceed 4.8 bar at 140 °C.

The installation was modified:

- High-pressure alarm with a threshold at 3 bar.
- Exhaust valve calibrated at 3.5 bar.
- Burst diaphragm calibrated at 4.8 bar maximum at 140 °C.
- Discharge of the burst diaphragm's discharge conduit directed temporarily to a hermetic zone that is not frequently used.

Furthermore, the operating instructions were updated (T and P indicated on the existing log sheet).

✓Verification report of static safety devices

During 2003-2004, a complete report on valves and burst diaphragms associated with the reactors and utilities was drawn up at the site. The study cost 50,000 euros. Nearly 250 devices were recorded and inspected, as well as the collection of their discharges. Their adequacy with the equipment and the processes was also checked. Analyses were conducted on the reactions implemented in order to determine the normal operating conditions and the possible deviations: runaway, overheating… To this end, the following conclusions were made:

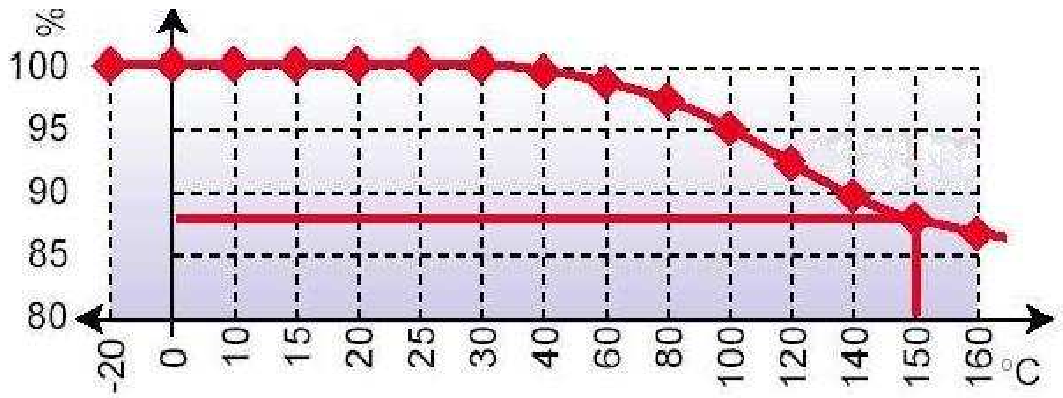
✓ Only the manufacture of GN base is performed under pressure during normal operation at the site.
✓ Correct dimensioning (pressure and diameter) of the diaphragms and valves was determined. Some of these devices were changed.
✓ None of the burst diaphragms are connected to a collection network at the Clamecy site. The diaphragms of workshop F5 were equipped with a catch-tank retaining system. The other workshops, not presenting any particular risks in case of a diaphragm rupture, were not equipped in this manner.

LESSONS LEARNED

✓The importance of correctly installing the burst diaphragm: installation direction, number of screws, tightening torque…
✓Releases from the burst diaphragm are to be collected in confined areas and without risk for personnel.
✓During safety device design, correctly account for not only the manufacturing tolerance, but also its loss of efficiency through fatigue and loss of efficiency under special conditions (in this case, the temperature).

In this case:

- **Temperature 140 °C**. According to a chart published by the diaphragm's manufacturer, the burst pressure at 140 °C is equal to 90% of the nominal pressure given for 20 °C.



- **Manufacturing tolerance +/- 10%:** this tolerance generally varies between 3 and 10% depending on the nature and the price of the diaphragm.
- **Fatigue coefficient 85% of the minimum bursting pressure.** On a batch process, a diaphragm is subjected to repetitive stresses that weaken it. The fatigue coefficient or service rate enables this phenomenon to be taken into account. It can vary from 70 to nearly 100% depending on the type of diaphragm.

Thus on the incriminated diaphragm, the **nominal burst pressure of 3 bar at 20 °C** is no more than 2.7 bar at 140 °C with a tolerance of +/- 10%. In the unfavourable case, the burst pressure of the new diaphragm is thus 2.43 bar. After being commissioned, however, and subject to fatigue, **the diaphragm may rupture beyond a pressure in the reactor equal to 2.07 bar**.

Leaks on a phosphorus trichloride iso-container

August 25, 2003

Fos sur Mer – [Bouches du Rhône] France

Chemistry
Loading
Degassing
Communication
Internal Contingency Plan

THE INSTALLATIONS IN QUESTION

The site:

In 2003, the chlorine fabrication plant and auxiliary buildings, including a phosphorus trichloride (PCl_3) manufacturing facility equipped with a loading station for shipments, were operated by a single company. In 2004, an international company specialised in the manufacture of phosphorus and its derivatives bought the PCl_3 unit and became the registered operator. The former operator, however, remained to run the unit under a partnership agreement. The site is classified as AS ("High Threshold" Seveso).

The unit concerned:

The production capacity of the PCl_3 manufacturing unit is 16,000 t/year, 550 tons of PCl3 (unit and storage) and 200 tons of phosphorus are stored and implemented on the site that also produces chlorine.

The manufacturing reaction employed is very exothermic: $3\ Cl_2 + ½\ P_4 \rightarrow 2\ PCl_3$. Phosphorus trichloride is a liquid (Tm = -93°C, Boiling point = 76 °C), is heavier than water (d = 1.6) and its vapours are heavier than air (d = 4.8). Classified as being highly toxic (by inhalation and ingestion), it hydrolyses spontaneously in contact with humidity, producing suffocating fumes (hydrogen chloride). Being a corrosive and non-flammable product, its very exothermic hydrolysis and its decomposition can be related to an "explosion".

THE ACCIDENTS, THEIR BEHAVIOUR AND CONSEQUENCES

Accidents:

Accident on the morning of 08/25/03 – Loading:

At around 10 am, the operator at the PCl_3 loading station began filling a new type of iso-container with 14.6 m^3 (23.5 t) of product. The container was being used for the first time in the establishment. The driver of the vehicle combination on which the tank was secured was assisting him.

Following the preliminary tests on the automatic valves, the operator connected the iso-container according to the colour coding and the indications on the 2 couplings: one green (the colour used for nitrogen which can be used to accelerate the drainage), and the other marked by 2 red lines (the usual marking for the eduction tube). He removed the plugs on the automatic valves, connected the fill hose to the valve marked with the eduction tube, connected the capacitive overfill probe and the flexible fumes evacuation tube toward the stack to the valve marked with the green colour coding. He then began transferring the PCl_3 by releasing the pneumatic automatic valves by the manual valves, connecting them to the tractor's compressed air system and then starting the loading pump. These manual valves are marked "gaspendel" and "steigrohr", which mean nothing to the operators.

After 3 minutes, the capacitive overfill probe was triggered causing the loading pump to stop and the automatic valves to shut. As there was no obvious anomaly, the operator cleaned the probe and repeated the loading procedure twice, the alarm was triggered again after 2 minutes.

During the 4th attempt, the operator first spread the probe's contacts then started the loading sequence again. The PCl_3 overflowed from the degassing pipe (a flexible, non-hermetic hose).

Accident in the afternoon of 08/25/03 – Degassing:

After having analysed and understood the causes of the incident that same morning (confusion between the eduction and vent pipes), the iso-container's degassing operation was undertaken. The latter has a slight overpressure due to exposure to the sun. After the driver had operated a valve, the internal pressure caused liquid to be sprayed onto the operator.

The consequences:

Accident on the morning of 08/25/03 – Loading:

According to the operator, roughly one hundred litres of phosphorus trichloride released into the atmosphere hydrolysed to form a compact and dense cloud of hydrogen chloride, which is extremely difficult to dissipate.

Upon seeing the white cloud, the operators in the control room put the establishment's Internal Contingency Plan into action. A "peacock tail" type water curtain was set up. Problems were encountered in triggering the fire fighting pumps: 3 calls were necessary. The Internal Contingency Plan was lifted 20 minutes after it had been initiated.

Pushed by a slight northerly wind (4 to 5 m/s), the cloud moved several hundred metres without dissipating. Five employees in a neighbouring chemical site (High Threshold Seveso) were affected. That site also initiated its Internal Contingency Plan and 10 employees from an industrial waste treatment company ordered its personnel to confine themselves. No one was injured (including the operator or the driver) on the site that was directly involved.

Accident in the afternoon of 08/25/03 – Degassing:

The legs of the operator sprayed by the PCl_3 were burned (1^{st} degree burns). The driver, standing to the side, was affected and received slight burns on the forearms.

The volume of PCl_3 released was evaluated to be at less than one hundred litres, although the size of the resulting hydrogen chloride cloud lead the operator to trigger his Internal Contingency Plan once again. As a result of a wind change (westerly – 10 m/sec), the neighbouring sites were not concerned by the cloud, but the neighbouring chemical site nevertheless put its Internal Contingency Plan into motion as a precautionary measure.

During these 2 incidents, the tank contained only 4.65 t (2.9 m^3) of PCl_3, approximately 200 l (300 to 350 kg) of which was probably vapourised.

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, both accidents can be characterised by the following 4 indices, based on the information available.

The parameters which 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

Quantities of dangerous substances	■ ■ ■ □ □ □
Human and social consequences	■ ■ ■ □ □ □
Environmental consequences	□ □ □ □ □ □
Economic consequences	€ □ □ □ □ □ □

The 350 kg of phosphorus trichloride released represents 1.75 % of the corresponding Seveso threshold (20 t – highly toxic), which equals level 3 of the "quantities of dangerous materials" index according to parameter Q1. Level 3 of the "human and social consequences" index is associated with paragraph H5: 15 individuals in the surrounding population and 2 site employees received care at the site for slight burns.

ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENTS

Accident on the morning of 08/25/03 – Loading

The inversion of the filling and degassing line connections caused the PCl_3 to leak via the eduction pipe connected to the degassing pipe. The coloured couplings (removable) differentiating the valve connected to the eduction pipe from the one connected to the iso-container's vent and the indications in German on the manual valves were not understood by the operators ("gaspendel" and "steigrohr" mean "vent" and "eduction pipe" respectively).

Accident in the afternoon of 08/25/03 – Degassing

During the degassing operation, the 2 blind flanges were removed but only the degassing pipe and the probe were installed on the vent. The eduction tube was thus not protected. By erroneously actuating the eduction tube's manual opening valve instead of the vent's opening valve, the driver opened the eduction tube through which the liquid sprayed due to the slight overpressure in the container.

Degassing is not habitual at the site. Although it had been analysed, this operation did not follow the normal process with regard to "process control"; the prior examination was conducted without regard for safety and analysis instructions that notably specify lists of elements to be examined, which was omitted in this case.

ACTION TAKEN

Immediate technical action:

The next day, degassing was continued prior to taking the container to the German contractor site. To do this, the operators intervened wearing hermetic suits and breathing apparatus. An emergency response team stood by during the operation (Marseilles public services). In addition, in order to better manage the degassing operation, 2 manual valves were added in addition to the automatic valves.

Short and medium-term technical and organisational actions:

The loading station was modified with a rigid arm on the loading line and with a hermetic collection pipe for connecting it to the stack.

Personnel protection was improved. Plastic gloves and overalls are maintained, although new hardhats with protective visors will be supplied.

In addition to the measures taken to ensure that firefighting means are deployed faster (water pumps), the procedures of the Internal Contingency Plan were modified to include information about the surrounding sites should an alert be sounded.

The approval procedure for new packaging was reviewed: all new container models can be admitted only following a validation procedure with the material's technical manuals and drawings in French.

Following the changes made by the operator, the site personnel (operator) went to the contractor's main site in Germany (the group became operator in 2004) to exchange good practices with the German operators.

A working group, internal to the Group's European units (The Netherlands, Germany, France), was set up to more closely examine the specificities and the risks associated with the loading stations and the chemical products, in terms of both 'hygiene and safety' and the environment.

LESSONS LEARNED

Several elements of feedback can be retained:

- ✓ The loading and unloading phases are particularly accident-risk operations which require enhanced awareness in this respect.
- ✓ Despite the term "iso-container", there are no European standards regarding these tanks or the colour-coding associated with their openings. At each industrial site, it is also important to define clear and standardised signage for connecting elements, valves, and conduits…and ensure that the operating instructions are written in French.
- ✓ The use of new equipment and materials is a risk factor: a validation procedure for this equipment associated with personnel training should improve safety.
- ✓ An inhabitual or exceptional operation – which could lead to an accidental situation as described above – must be subjected to a complete risk analysis beforehand in order to avoid creating an accident.

Explosion of a tank in TDI production unit

November, 28th, 2002

Mestre – Italy

toluene diisocyanate
TDI
stirrer
cooling
domino effect

THE INSTALLATIONS IN QUESTION

Generality

The company was found on 01/05/2001 after the acquisition of the polyurethane division from an other major Italian company. The installation is located inside a chemical pole in an industrial area, which is about 2,5 km far away from a residential area, 1 km from a village and 4 km from a city. Besides the plant there are other plants/ storage facilities, inside or adjoining the ancient installation, owned by almost 11 important Seveso companies. The plant has a production capacity of 118,000 tons/year. A total of 248 persons are employed, in particular the TDI plant is operated by 102 persons. The plant is under Seveso II Directive (upper tier plant).

The process cycle foresees:

- Production of Dinitrotoluene (DNT)/ sulphuric acid recycling: Dep. TD1/TD7

  DNT is obtained through the reaction between toluene and nitric acid in presence of sulphuric acid, which acts as promoter of the reaction and as dehydrating agent for the water formed as a by-product during the reaction.

  The department TD7 was set up in 1996 to substitute the department for the purification of sulphuric acid by means of toluene and urea, which was closed down and partially dismantled.

- Production of 2,4-toluendiamine (TDA): Dep. TD3

  TDA is obtained through the reaction between dinitrotoluene (DNT) and hydrogen in presence of palladium as a catalyst, water is formed as by-product of the reaction.

- Production of Phosgene: Dep. TD4

  Phosgene ($COCl_2$) is obtained through the reaction between carbon monoxide (CO) and Chlorine (Cl_2) in gas phase over a catalyst made of active coal.

  CO and Cl_2 are transferred by pipeline respectively from Dep. 12 and CS23.

- **Production of Toluene di-isocyanate (TDI): Dep. TD 5**

  Toluene diisocyanate is obtained through the reaction between 2,4 toluenediamine (TDA) and Phosgene in presence of dichlorobenzene (DCB) as solvent, by-products of the reaction are hydrochloric acid and high-boiling compounds (tars).

- Storage and shipment of TDI: Dep. TD6

  Storage and shipping area in barrels or road tankers. The purified TDI is first transferred to a tank in which ionol (colour stabiliser) is added, then stored in tanks where, if necessary, the pH value is corrected by adding benzoil chloride. The TDI is then transferred from these tanks either to the barrel filling plant or the loading ramp for road-tankers and rail-tankers or for on-site storage near the South tank park

- Production of carbon monoxide and hydrogen: Dep. TD12

Description of the process unit involved

The accident occurred in a section of high-boiling tars of the TDI department TD5. In the department TD5 toluene di-isocyanate (TDI) is produced through the reaction of 2,4-toluendiamine (TDA) and phosgene.

The reaction is performed in 3 successive steps with increasing temperature from approximately 80℃ to 170℃, with decreasing pressure and with production of hydrogen chloride acid as a by-product. TDA is fed to the reaction in DCB solution at 12%, while phosgene is fed in stechiometric excess (5:1 in moles) in relation with TDA. Chloride acid and phosgene not reacted are taken away from the reaction in gas phase to be separated: phosgene is remitted in cycle, while chloride acid in transferred to other departments.

TDI reaction product remains in DCB solution with high-boiling tars. This solution is sent successively to the distillation, after which a TDI - high-boiling tars mixture is obtained. This mixture is then evaporated in D521, to produce TDI with low high-boiling tars contents (1%) from the top, and a TDI /high-boiling tars mixture in report 1:1 from the bottom. The evaporator D521 is forced circulation cooled by a vapour boiler at 18 bar. Its operation parameters are: 180℃ and 850 mm w.c. absolute.

The TDI /high-boiling tars mixture in report 1:1 from the bottom of the evaporator is sent to tank D522 to cool it to 90℃, which is equipped with a stirrer and water refrigerated coils manually regulated. The mixture is then sent to the tanks D 528/1-2-3 for storage, which feed the section of high-boiling tars treatment, where in a vacuum batch process is carried out a discontinuous recovery of a part of TDI from the same mixture (a simplified scheme of TDI section is shown in fig. 1).

The TDI is recovered by evaporation in the concentrator D 525/1, equipped with a stirrer, steam heated coils and maintained at vacuum pressure. It works at 10 mm Hg of residue P, and 130-150℃ of T. Concentrator D 525/1 is fed by the tanks D 528/1-2-3 working also as compensation tanks. The TDI vapours are then condensed and then the liquid is transferred for storage, the residual gas is sent through a separator and then suctioned by the 3stage vacuum units P 509/1-3.

The concentrate present in D 525/1 is composed of 18-20% TDI and for the remaining part of high-boiling tars is diluted with toluene, mixed and transferred over a pump in tank D 541, where it is continuously stirred at a temperature of 115 - 120℃ to get a sufficiently fluid and stable mass to be sent into the incinerator B 502/2 for combustion.

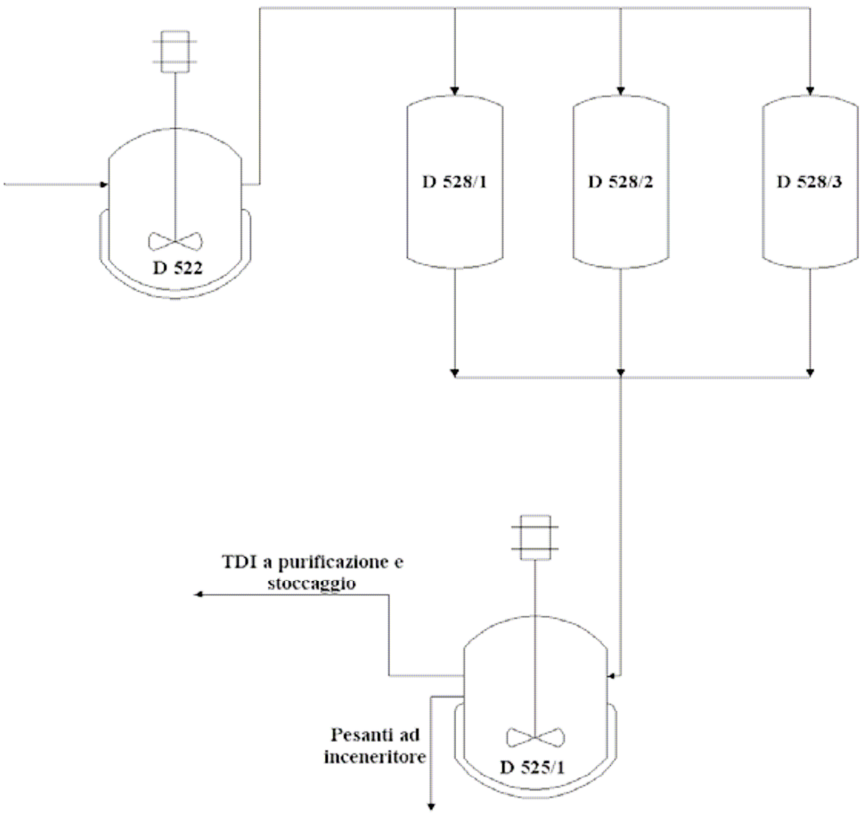


Fig. 1 - Simplified scheme of TDI section

THE ACCIDENT, ITS BEHAVIOUR, ITS EFFECTS AND CONSEQUENCES

The accident :

The event occurred inside the Department TD5 for the processing of high boiling tars of the TDI plant, and in particular in the tank D 528 1-2 for the temporary storage of bottoms of D 521 expecting to be distilled in D525/1.

Two days before the accident, at about 17:40, the shift assistant of department TD 4-5 shut down the stirrer P 507 of tank D 522 due to the excessive noise of the reduction gear of the motor, caused by an insufficient lubrication (registered in the logbook). Following the shutting down of the stirrer P 507, the temperature in tank D 522 started to rise gradually and stabilised at 125°C according to the value recorded by the DCS (Distributed Control System) switchboard assistant. These values cannot be considered reliable due to the fact that the instrument TI was calibrated to measure temperatures up to 120°C. Tank D 522, which receives the high-boiling tars and the TDI from the evaporator D 521, operates at a maximum temperature of approximately 95°C in normal operating conditions.

In the day before the accident, at 7:30 hrs, the feed to tank D 522 is reduced from 4000 kg/h to 1900 kg/h, maintaining the water circulation in the cooling coils of tank D 522 constant. The reduction of the feed charge reduced the temperature in tank D 522 to 65°C.

At approximately 12:00 hrs the temperature of tank D 522 rose again in connection with the increased load of the evaporator D 521, which went up from the previous 1900 kg/h to 7000 kg/h. For the remaining part of the day and until approximately 17:30 hrs on the day after, when the stirrer was started again, the DCS registered a temperature beyond the top of the measurement scale (above 120°C).

At 4:00 hrs in the day of the occurrence, the shift personnel registered a temperature rise in tanks D528/1-2-3, and in the work-sheet the temperature registered for tanks D 528/1-2-3 were respectively 136-142 and 131°C. The operating temperature normally foreseen for the tanks is 105°C.

The switchboard operator reported to the shift assistant an abnormal batch distillation, characterised by the fastness and a low amount of distilled product; the shift assistant explained that the T increase already persisted by some time. The temperature of concentrator D 525/1 was 139°C instead of 105-110° expected at the beginning of the distillation. The operation procedure did not indicate the measures to be adopted in case of high temperatures in D 522 and D 528/1-2-3.

In the meantime, at 16:30 in the same day, the tank 528/2 filled to 60% reached the temperature of 170°C. The design temperature of the equipment D528/1-2-3 is 150°C.

When the stirrer was started again, at about 17:30, the homogenisation of the mixture in D522 led to a T decrease also in D 528/1, that was the only one under loading. But, at 18:00 hrs the temperature in tank D 528/2 reached once more to 181°C and it was not possible to discharge tank D 528/2 because distillation was in progress in D525/1, and tank D541 feeding the incinerator B 502/2 was full and could not receive the high-boiling tars from D 525/1.

Only at 18:35, when the distillation process in D 525/1 finished, it was possible the discharge into D 541, which has the capacity to receive the content of D 525/1.

At 18:50 valve XV 5316 was opened to start the discharge operation of tank 528/2 into tank D 525/1; in that point tank D 528/2, with a nominal capacity of 10m3, was 59.5% full and the temperature was 220.7°C. The attempt to discharge tank D 528/2 did not succeed, due to the fact that the inhomogeneous product inside the tank contained solid matter which blocked the discharge of the tank. Inside the tank unwanted chemical reactions had been going on for hours with development of gas and increase of the temperature and viscosity of the reaction mass. Moreover, discharge procedure of D528/2, considering the opening-closing valves logic, did not permit its loading with product at lower temperature.

Four external contractors went to the distillation unit D 525/1 to verify the conditions inside through a visual inspection window installed on the dome cap. A dense white smoke inside the distillation unit did not allow the workers to look inside the equipment, and the pipe connecting tank D 528/2 to the rupture disk was particularly hot.

At 19:25 a second attempt to discharge the tank was made, but failed. The temperature on the control panel indicated 220°C, while there was no system to measure the pressure inside the vessel.

At 19:30 the four external contractors were still verifying the hydraulic guard in the plant when a strong whistle was heard and white smoke, leaking from the flanged coupling located on the delivery tube of the distillation unit D 525/1, was seen. Instinctively the four external contractors tried to escape but a strong explosion was heard, at 19:42 hrs tank D 528/2 exploded. The tank contained a mixture of TDI and TDI high-boiling tars. Due to the pressure wave of the explosion one of the escaping workers fell, while all the workers were hit and covered by a dense, warm, semi-solid substance with a high viscosity and a granular structure.

After a few (dozen) seconds a fire developed. The explosion ignited a fire involving the terminal part (southern side) of the framework of the "TDI high-boiling tars processing" department. The fire was mainly fed by 20 tons of diathermic oil (Aerthem 320) and one ton of toluene, after the rupture of the corresponding pipes. The fire affected the second of the three TDI - high-boiling tars storage tanks, D 528/1 (85% full when the accident occurred), causing its mechanical failure and a second explosion at approximately 20:25 hrs.

The explosion of tank D 528/1 extinguished the main fire leaving only some residual secondary fires.

According to the estimates made by the operator the quantities of chemical substances involved and released during the accidental event are:

Substance name	**Amount**	**Physical state**
TDI and high-boiling tars	15 ton	liquid/solid
Toluene	1 ton	liquid
Diathermic oil	20 ton	liquid

The safety data sheet of the diathermic oil does not classify the oil as an hazardous substance (falling under the scope of the annexes of legislative decree 334/99).Shutting down and restarting the oven is a lengthy process in which the oven has to cool down, before it can be restarted. Restarting has to be done gradually, starting with the pilot burners, after which the main burners can be started.

The consequences :

The consequences of the event were limited, not involving significant off-site consequences, even if the accident generated distress in the population, which was taken into account by the media and the public authorities.

Material effects

The explosion of tank D 528/2 generated a pressure wave with an extremely rapid expansion speed and the release of the hot liquid contained in the tank which solidified at ambient temperature. The pressure wave had a destructive effect on equipments and plant parts in the vicinity of the tank with projection of metal fragments, damage to the support frames of the plant equipment, rupture/damaging of connection pipes and electrical cables and utilities. TD5 department damaged is shown in fig. 2.

The fire was fed by the rupture of the toluene pipe and by the rupture of the diathermic oil (Aertherm) pipe installed at a height of 8 meters, and propagated to tank D 528/1 containing TDI - high-boiling tars which was 85% full when the explosion occurred. It is assumed that the explosion of tank D 528/1 was caused by overpressure generated from the decomposition reactions of TDI, thermally activated by the temperature of the flames and thermal radiation hitting the tank. As for tank 528/2, the high temperature triggered and accelerated the same exothermic decomposition reactions between TDI and high-boiling tars, releasing carbon dioxide.

The associated effect of the pressure wave, generated by the explosion of tank D 528/1 followed by the strong air movement generated by the blast wave, and the effect of the carbon dioxide formed by the chemical reactions described above, caused the displacement of the flame sources, extinguishing most of the fires, avoiding the creation of domino effects to other plants, which could cause major damage to the plant structures. Damages due to 1st and 2nd explosions of tank D 528/2 and tank D 528/1 respectively, are shown in fig. 3 and 4.

Human effects

Personnel present on-site: when the event occurred there were 30 internal employees and 6 external technicians for activities on the TD1-2 plant; of these only 4 external contractors needed medical treatment as specified below :

- Worker 1 : 3 days of incapacity to work due to pharyngeal hyperaemia and facial erythema
- Worker 2 : 31 days of incapacity to work due to I and II degree burns on the scalp
- Worker 3 : 31 days of incapacity to work due to the consequences of exposure to toxic industrial substances.
- Worker 4 : 53 days of incapacity to work due to the after effects of a trauma, caused by a contusion associated with a distortion of the right knee, and state of reactive anxiety

The 4 external workers who were performing controls in proximity of the plant equipment, were involved in the accident but were only partially exposed to the effects of the explosion of tank D 528/2. All received first medical treatment at the infirmary of the petrochemical establishment, and then at the emergency department of the hospital in the nearest city.

The medical reports of the emergency department contain following diagnosis :

- persons involved off-site : the population was not involved in the accidental event
- no fatalities and hospitalised injuries were registered

Environmental effects

Consequent to the accident, the personnel of the Antipollution Department of the Water Authority performed a series of controls on the drains of the site connected to a lagoon. Considering the position in which the accident occurred, it was considered appropriate to concentrate the controls on the community sewage drain SM15 (in particular, on the section drain SM15/3 directly connected to the TDI production department, and on the drain SM15/22 of the central biological sewage treatment plant of the installation, which might have suffered consequences from the event).

The analysis of TDI (toluene di-isocyante) and aromatic amines showed the presence of TDI with concentrations corresponding to 5280 mg/l and traces of aromatic amines. The concentration values of dichlorobenzenes (chlorinated solvents not mentioned elsewhere) and of organic aromatic solvents (toluene)- all compounds used in the production process involved in the accident - were also particularly high.

The accident caused a temporary but consistent pollution of the lagoon water. The polluting substances were channelled into the lagoon via the general drain SM15 of the establishment, spreading in the aquatic environment and modifying the chemical characteristics of the water in the lagoon up to 1 km from the establishment.

The characteristics of the fire and the atmospheric conditions, characterised by very slight wind and stability, probably favoured an umbrella like fallout pattern of the pollutants around the establishment, which resulted quite uniform. The TDI fire and of the other substances present in the installation caused an increase of the substances typical for combustion processes (nitrogen oxides, carbon oxide and hydrocarbons in a minor proportion), even if the absolute values measured are comparable with the values measured during traffic peak hours in stable meteorological conditions.

The increase of toluene is much more significant and to a minor extent the increase of Ethyl-benzene and Xylenes. Moreover the values measured for styrene, methylene chloride, trichloroethylene, perchloroethylene, trimethylbenzene do not differ much from the values indicated in literature for highly urbanised and industrialised areas.

It is important to note the absence of dichlorobenzenes in all air samples of the urban areas, even the ones taken in the most critical fallout phase, whereas dichlorobenzenes were found in significant concentrations in proximity of the accident place even the morning after the fire. The concentrations of dioxins, furans, and PCBs similar to dioxins, measured in the total particulate were undoubtedly low, the total values were comparable with the background concentration levels indicated by literature for urban areas.

Fig. 2 - TD5 department damaged

Fig. 3 – tank D 528/2 : 1st explosion

Fig. 4 – tank D 528/1 : 2nd explosion

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 characterized by the following 4 indexes, based on the information available.
The parameters which compose these indexes 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 level of the hazardous substances index is 3 because 5 tons of TDI were released. The level of the human and social index is 2 because 4 workers were injured.

The accident has been considered a 'major accident' according to the criteria set in Annex VI of the Seveso II Directive:

– Substances involved :
  Any fire or explosion or accidental discharge of a dangerous substance involving, a quantity of at least 5 % of the qualifying quantity laid down in column 3 of Annex I.

– Damage to property :
  damage to property in the establishment at least ECU 2 million,
  damage to property outside the establishment; at least ECU O,5 million.

About 15 tons of TDI have been involved, so exceeding the limit indicated in Annex VI: 5 tons (5% of 100 tons). Damage to property was estimated almost 2,8 millions Euros, exceeding the 2 millions Euros that represents the limit in Annex VI.

ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

The principal causes assumed are the following:
- interruption of the stirring movement in tank D 522
- missing operative instructions concerning the management of abnormal conditions caused by high temperature in tanks D 522 and D 528 1/2/3
- missing information on the hazards involved in managing the abnormal process conditions relating to the specific case
- missing pressure measurement instruments in tanks D 528 1/2/3

According to the information given by the operators and from the analysis of the plant data on the section involved in the accident, it is assumed that the accident was caused by an unwanted condensation reaction between the high-boiling tars and TDI, thermally activated first in tank D522 and then developed in tank D 528/2, with the release of heat and carbon dioxide causing the mechanical explosion of tank D 528/2 due to overpressure.
The high temperatures and the prolonged residence time of the mass in D 528/2 (approximately 13 hours), supported the development of exothermic condensation reactions associated with the formation of carbon dioxide and a significant pressure increase.

When the explosion occurred the internal temperature of tank D 528/2 was above 220°C and clearly the tank was in extreme overpressure conditions. When the event occurred the tank was filled to 60% of its design capacity of 10 m^3.
A study has been performed by the Company on the thermal stability of the substances involved in the accident, and in particular on the results of the adiabatic calorimetric tests (ARC) performed on a tar sample collected immediately after the accident from tank D 522, with the goal of understanding the behaviour of the substances involved in the accident.
The tests were made by heating a known quantity of material, composed by high-boiling tars and TDI, in an adiabatic thermal system, and registering the temperature and pressure evolution over time. This test simulated the heating process of the product in D 528/2 involved by the explosion.

The test results agree basically with the values registered by the DCS during the accident, and demonstrated the development of two distinct reactions, one exothermic reaction (fig. 6 and 7) and another one developing carbon dioxide (fig. 5).
The rupture disk failed due to a plug produced by the solidification of foams of the "boiling" mass inside the pipe connecting the tank with the rupture disk, and with the venting manifold.

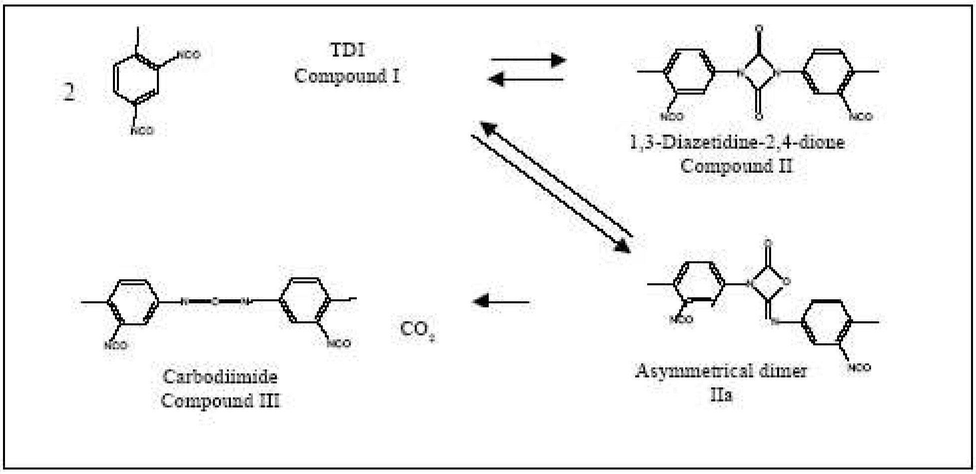


Fig. 5 - TDI dimerization with developing of carbon dioxide

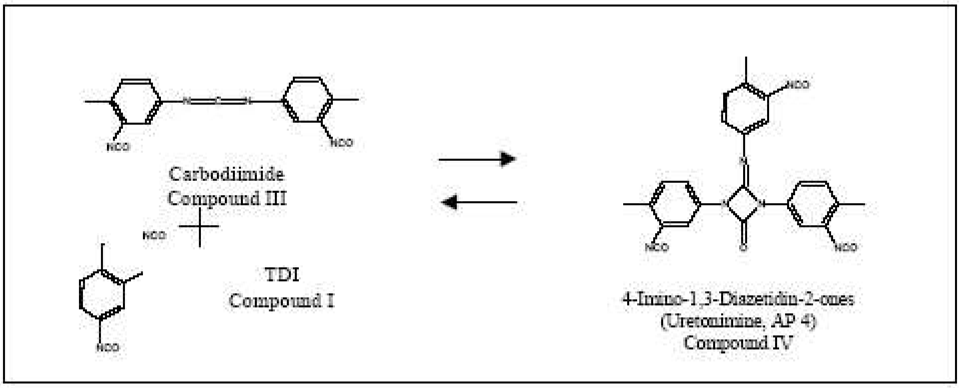


Fig. 6 - TDI exothermic reaction with dimer

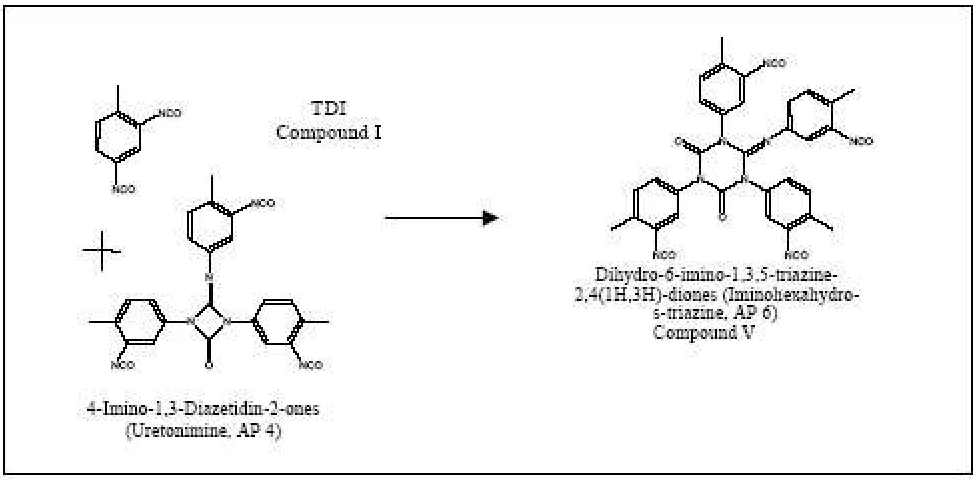


Fig. 7 - TDI exothermic reaction with trimer

ACTION TAKEN

Emergency measures

At 19:47, following the signalling of the emergency by the workers of the plant, the shift technician of near establishment in charge of emergency signalling, alerted the works fire brigade and then the national fire brigade. All equipment was

secured and the fire put under control by approximately 20:30 hrs, thanks to the rapid response of the works fire brigade located inside the chemical pole at a distance of 700-800 meters from the accident place, associated with the intervention of the national fire brigade of the near city, and the rapid response of the plant personnel who activated the emergency shut down of the plant over the automatic shut down systems.
Internal emergency plan

Consequent to the explosion and the subsequent fire, in the control room the assistant on duty in department TD1-3 activated the general alarm and the emergency shut down procedure for securing the plant, while the assistant on duty in plant TD 4-5 put on the self-contained breathing apparatus and performed a series of operations for securing the plant.

At 19:47 hrs the national fire brigade was alerted over the telephone; at 19:49 hrs the preliminary alarm was activated in the department; at 19:52 the general alarm was activated in the whole installation. From 19:59 hrs to 20:06 hrs the procedure of communicating the event via fax to the public authorities was activated.

The extinguishing operations were performed by the fire brigade of near establishment employing extinguishing foam, while the fire brigade of near city carried out the cooling of the adjoining plants and equipment with water hydrants, the containment of the gas emissions with water curtains and the monitoring of temperatures with infrared-cameras. At 20:45 the fire could be considered as extinguished. At 22:45 the on-site emergency was called off.

External emergency plan

At 20:30 hrs the acoustic alarm for the population was activated. At 21:30 the off-site emergency was called off. The members of the fire brigade, equipped with an infrared-camera, monitored the temperature of the structures and of the equipment during the fire and at the same time provided the cooling of the structures and equipment affected by the fire. Composition of the emergency response teams: near company fire brigade intervened with a team of 12 persons; the national fire brigade intervened with a team of 52 persons.

Official action taken

A penal action was started against some mangers of the TDI plant. Some minor civil actions for biological damage were also started. Authority charged with Safety at Work laws enforcement applied sanctions against three managers. The Ministry for the Environment requested the conclusion of the assessment of the SMS foreseen by Seveso implementation (D. Lgs. 334/99).

Corrective actions taken by the Company

Following the accidental event of November 2002, a thorough safety assessment of the plant, starting from the cause analysis, has been further developed by the Company, using different up to date methodologies. The studies and analysis listed below, applied to the high-boiling tars section and to the entire TDI production process, followed by the implementation of technical and procedural changes, should lead to an high safety standard reached and maintained, in particular with regards to process control, management of failures and accident prevention.
The characteristics of the high-boiling tars processing section of department TD5, and particularly concerning the chemical behaviour of the products processed, correlated with the parameter of residence time, temperature and composition, lead to consider the accident dynamics anomalous, due to the fact that it could not have happened in any other section of the department or in any other phase of the processing cycle.

LPP (Loss Prevention Programme) Guidelines for the analysis of the compliance of the process with the accident prevention principles.
This methodology was developed by the technological centre of the company, based on the experience gained in the establishments of the company groups, and other major companies operating worldwide.
The compliance with these guidelines allows the performance in terms of safety and operating reliability in general to be improved.
These guidelines often reflect the entire experience and knowledge gained on the management of process plants and the process anomalies that may occur in any of the activities involved in the management of a chemical plant (design, process control, operation, safety procedures, equipment).

Analysis of the management systems of the combustion plants.
As for the foregoing guidelines this tool is used inside the company to compare the combustion systems (heating furnaces, steam generators) with the most advanced technologies in the field of safety and reliability.
During the audit the problems concerning the management of the furnaces, the safety systems (alarms, shut-down systems), the control systems and the process parameters were analysed, using the most advanced international standards as reference and complying with Italian and European norms.

Layer of Protection Analysis (LOPA)
The LOPA analysis is a simplified form of risk analysis that analyses the risk of an undesired event over the magnitude of the event frequencies, effect gravity and event probability.
The LOPA process builds a risk analysis process using all data available from the company technological centre, from the databases of the company, from the plant histories and using the specific knowledge of the process engineers of the plants (from the same or other companies).

The analysis demonstrates that the implemented safety systems are adequate to obtain acceptable risk levels.

Investigation into the problems concerning chemical reactivity
All aspects concerning chemical reactivity of the substances present in the TDI production cycle were examined very closely; product incompatibilities and eventual instabilities were analysed.
Chemical reactivity matrixes and reference guidelines, based on company's experience, have been issued for the personnel of all company installations and in particular for those producing isocyanates.
A detailed analysis was performed on the reactivity of TDI and high-boiling tar mixtures with respect to different parameters, such as temperature, residence time and composition, referring also to the accident occurred.

Definition of Process Safety Cardinal Rules
Development and implementation of the cardinal rules concerning the process safety during production of dinitrotoluene, toluene di-amine, toluene di-isocyanate and phosgene.
These rules have been developed based on the experience of the Company and other leading companies gained in plant management; the rules indicate in a clear and concise way the criticality of different process phases, pointing out the operations to be avoided, with the goal of operating at the highest safety levels.

Pre start-up Audit
As foreseen by the procedures of the company, an audit was performed on the plant to check if there were the necessary safety conditions to restart the plant following the recent shut-down for maintenance.
The audit was carried out on the entire plant, with particular attention on the high-boiling tars processing section upstream the introduction of chemical reagents in the process; the performance of all foreseen test procedures on equipment and piping subject to maintenance was audited, and adequate training of the operative plant personnel was verified with specific checklists.
The implementation of the procedures contained in the operative manual was verified with a particular focus on the safety standards.

Updating of the operative manual
The entire operative manual of the department was revised, not only with regards to the high-boiling tars treatment section, which was the main reason of the revision, but also for all departments of the plant.

Management of change (MoC)
All technical or procedural changes have to be assessed through a MoC procedure analysing the consequences of the change with specific checklists with the participation of all roles involved.

LESSONS LEARNED

The accident put in evidence some SMS issues that, even if general and already identified in other cases, still had an important role in the event occurred.
They are showed on a specific format (table 2) used in the Italian approach, which makes reference to a check list of SMS elements (see Annex 1), consistent with the main articulation given for the SMS by the Annex III of "Seveso II" Directive.
An analysis of the actual accident pointed out the faults in SMS, as illustrated in Table 2.

Table 2 - Accidental Causes: analysis of plant and management factors

		Title: Explosion of a tank in a TDI production unit of a chemical plant

Accident occurred in section TD5 of the plant, aimed to high-boiling TDI compounds treatment. At 7.40 p.m. an internal overheating (T up to 230°C) of one storage tank of the compounds – D528/2 – caused by a runaway reaction between chlorinated tars and TDI, led to tank explosion, after the operators have tried to unload the same tank, without success. Vapour cloud released ignited after 5 minutes causing a fire, which burned almost 10-20 tons of toluene and high-boiling tars. Fire involved equipments in sight, with domino effect on a 2nd tank – D528/1 – which exploded after 1 hour, due to external radiation and internal overpressure. Overpressure wave from the 2nd explosion switched off the fire in course. A toxic cloud was formed, and four operator, injured for inhalation, were recovered. The explosions damaged different equipments and structure inside the unit. Internal and external emergency plans were immediately activated. Fire plumes caused suspected impact to the atmosphere and to the groundwater, monitored continuously by the regional agency for the protection of the environment.

3.i **3.iii**	Identification of substances and processes hazards; definition of safety requirements and criteria. Planning and updating of technical and/or managerial solutions for the reduction of risks	Inadequate re-examination of safety criteria and requirements for critical equipments. Tank D522 (for cooling impure TDI mixing) could be subject to inadequate thermal regulation, because of the presence of cooling-coils inside manually regulated, and due to the delicacy of the necessary controls. In the same way, tars storage tanks D528 could be subject to inadequate unloading, because of the peculiarity of the mixture treated (viscosity) and of the discontinuous process for transferring the product to the concentrator.	
3.ii	Identification of possible accidental events, safety analysis and residual risk	An adequate risk assessment could put in evidence the possibility of abnormal temperature increase inside the tars storage tanks D528, and the consequent exothermic reaction between TDI and tars	
4.i	Identification of plants and equipment to be subject to inspection plans	Inadequate identification of all equipments and elements subject to verify planning. Control instrumentation, safety systems (rupture disc) and mixer had to be submit to maintenance and periodic control, furthermore they had to be available during normal plant process. Instead: the mixer of D522 was under maintenance, the TI of D522 was broken (it always set bottom scale value) so it was no possible to determine the temperature value; the LI of D528/2 was out of use, the rupture disc of D525 was broken by time	

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3.iii	Planning and updating of technical and/or managerial solutions for the reduction of risks	Considering the possibility of T increase inside the tanks, and the hazardous mixture treated, it was needful to provide for an automatic alarm/lock-out	
4.iii **6.iv**	Operating procedures and instructions in normal, abnormal and emergency conditions Alarm and communication systems and support to the external intervention	Operating procedures in abnormal conditions had to include the necessary operations in the case of high-temperature (instead the operators appeared inactive during failure of mixer and instrumentation). Alarm systems not adequate. Delay in the communication of the event to the external authorities (from the first failure detection, at 2.00 p.m., to the last explosion, at 9.00 p.m., 7 hours passed).	

Annex 1: Elements of SMS check-list

1. The document on prevention policy

1.i Definition of prevention policy
1.ii Verification of the SMS structure and its integration with the establishment organization
1.iii Policy Document Contents

2. Organisation and personnel

2.i Definition of responsibilities, resources and planning of activities
2.ii Information activity
2.iii Training and formation activities
2.iv Human factors, operator/plant interfaces

3. Evaluation and identification of major hazards

3.i Identification of substances and processes hazards; definition of safety requirements and criteria.
3.ii Identification of possible accidental events, safety analysis and residual risk
3.iii Planning and updating of technical and/or managerial solutions for the reduction of risks

4. Operational control

4.i Identification of plants and equipment to be subject to inspection plans
4.ii Process documentation
4.iii Operating procedures and instructions in normal, abnormal and emergency conditions
4.iv Maintenance procedures
4.vi Materials and services procurement

5. Management of change

5.i Technical and organizational plant modifications
5.ii Documentation updating

6. Emergency planning

6.i Accident analysis, planning and documentation
6.ii Roles and responsibilities
6.iii Controls and verifications of the management of emergency situations
6.iv Alarm and communication systems and support to the external intervention

7. Monitoring performance

7.ii Performance evaluation
7.ii Accident and near-accident analysis

8. Audit and review

8.i Safety audits
8.ii Review of safety policy and of Safety Management System.

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.

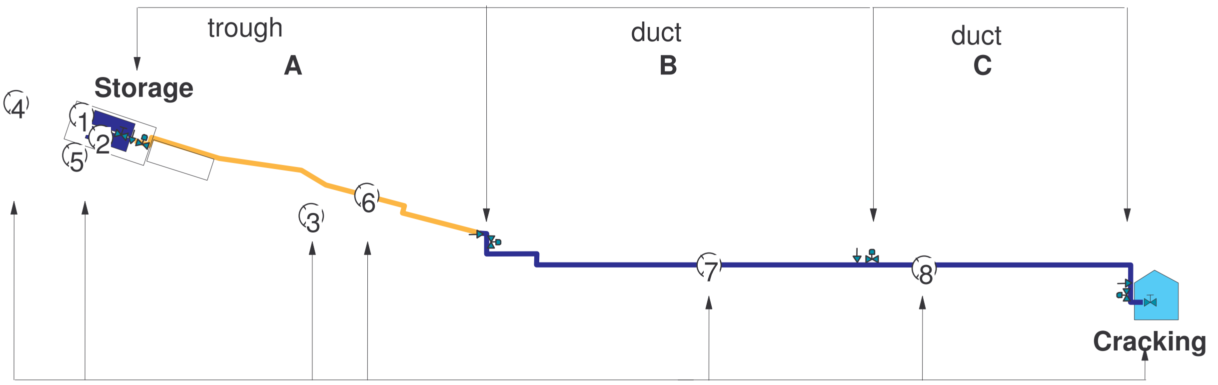


Fig. 2. Ammonia pipe equipment and diagram

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.

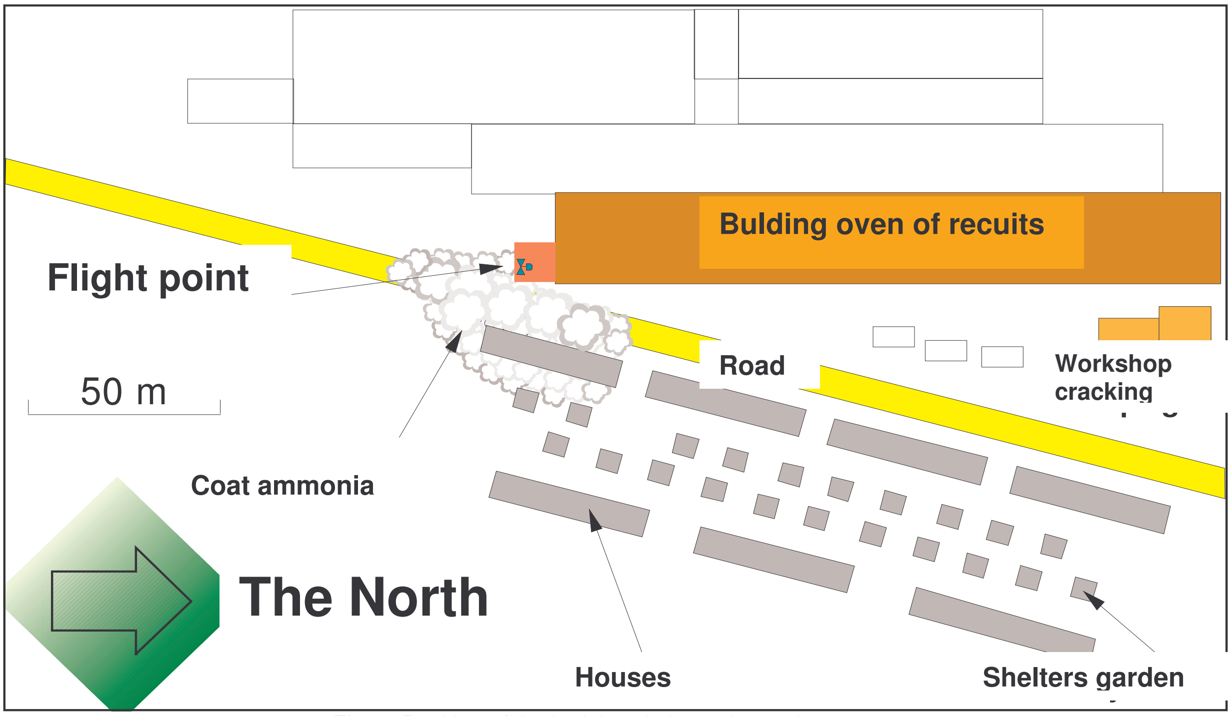


Fig. 3. Position of the leak in relation to its environment

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.

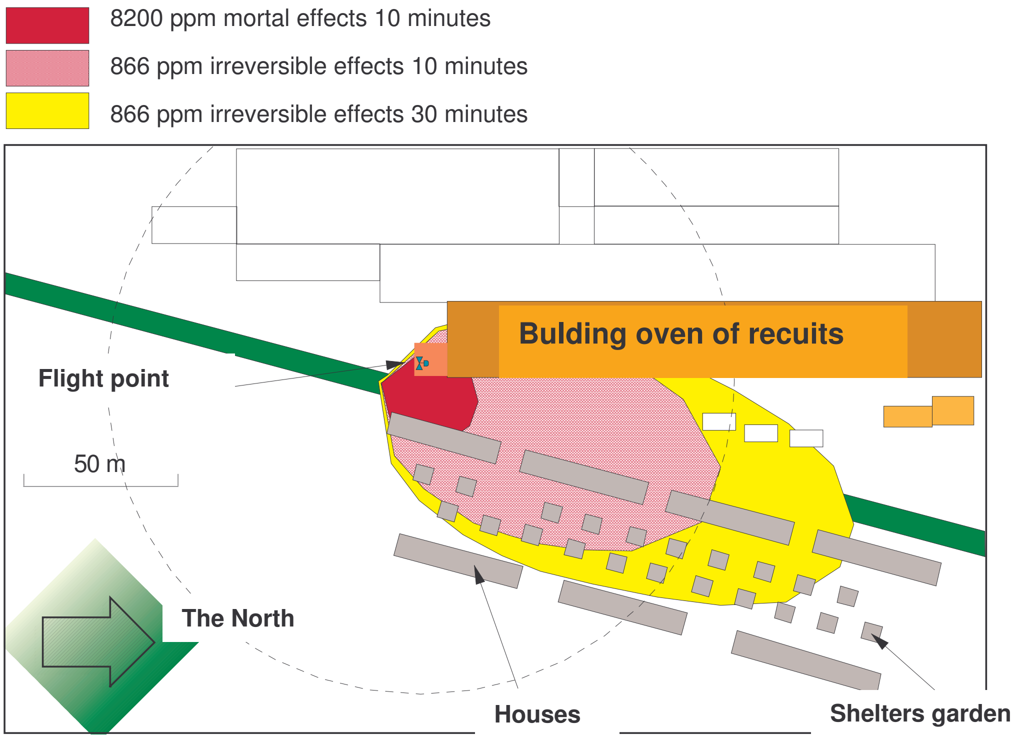


Fig. 4. Probable path of the toxic cloud

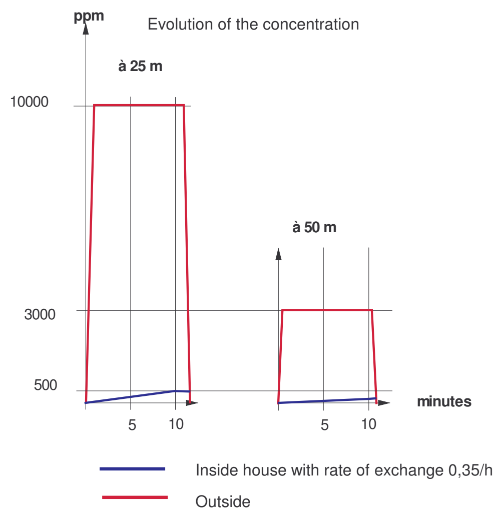


Fig. 5. Development of the concentration at specific distances

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.

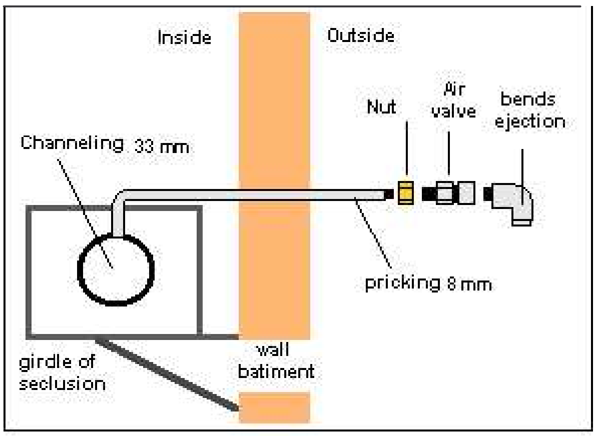


Fig. 6. cut prinking lid

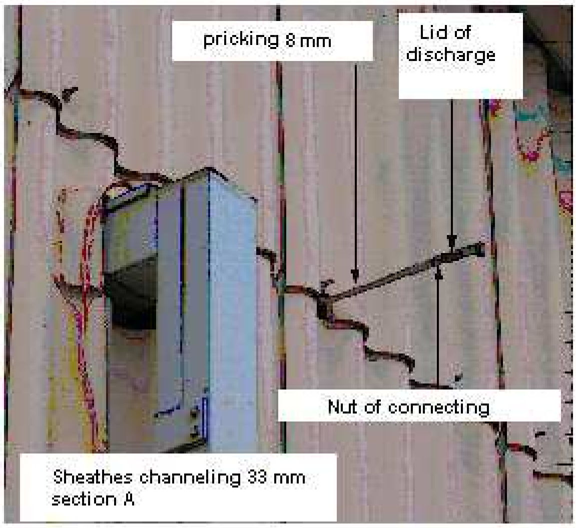


Fig. 7. Valve outlet on building facade

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

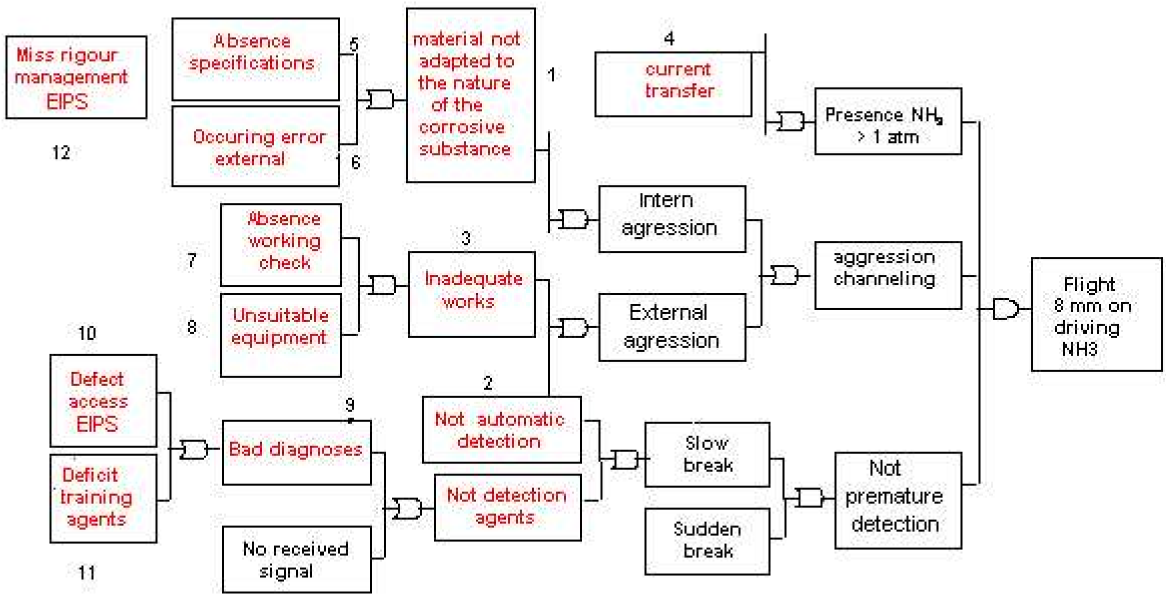


Fig. 9. Summary of faults that led to the branch connection rupture

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.

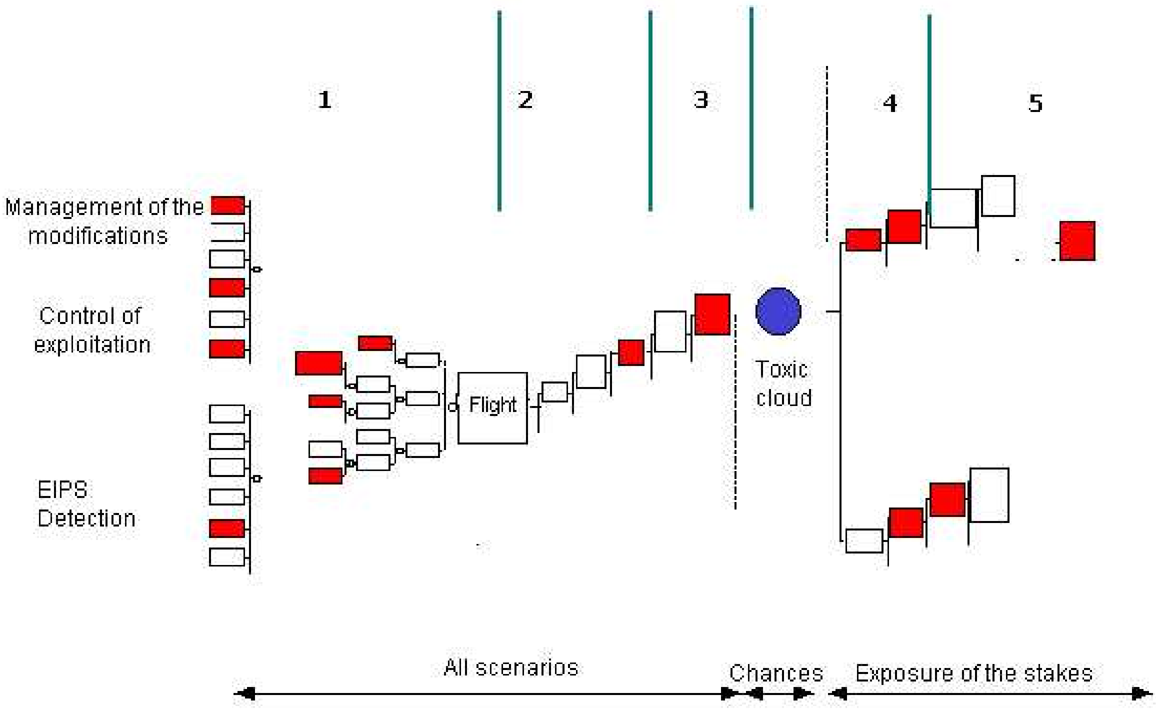
Thus, the search to assess the sufficiency of the measurements taken highlighted a flaw in the system's overall design.

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

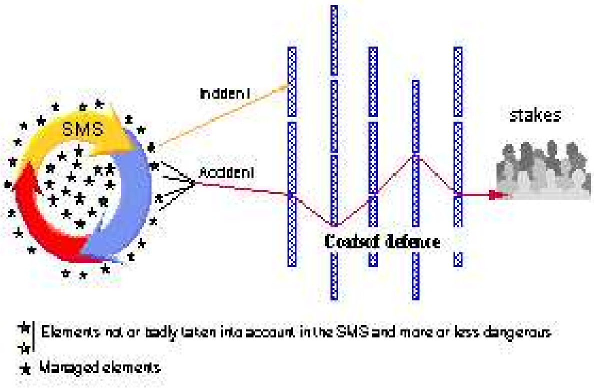


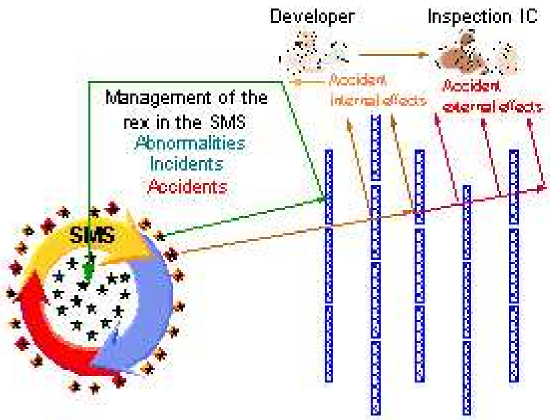
1. Primary confinement (ammonia tanks + piping).
2. Limitation of quantities released in the event of a leak.
3. Secondary confinement.
4. Distancing of the stakes involved.
5. Protection of interests (housing - siren and instructions for local residents).

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.

Fire in an electrical service room in a chemical plant and release of toxic gas

October 25, 2004

Lannemezan - [Hautes-Pyrénées] France

Hydrazine

Electrical failure

Ammonia
Monitoring & Control

THE INSTALLATIONS IN QUESTION

The site

The site is classified AS for the use, storage and manufacture of very toxic, toxic and flammable products.

The establishment essentially produces hydrazine (15,000 tons per year). One of the largest applications of this product is anti-corrosion protection of industrial boilers, thermal and nuclear power stations.

Part of this production is used at the site to produce hydrazine hydrate "derivatives" which are then used in a variety of activity sectors such as agrochemical, pharmaceutical, and chemical synthesis.

The unit concerned

The hydrazine unit's electrical substation consists of:

- a 13kV/380V transformer, in a separate building,
- an intermediate switchboard C3 which includes certain hydrazine outgoing feeders, the 2 UPS supply lines, the incoming generator line and its tripping device, the outgoing line to the back-up C2 switchboard. All this equipment is located in the same building, but in separate rooms.
- an electric switchboard C2, in a room adjacent to the control room and the hydrazine technical room, which supplies the majority of the hydrazine outgoing lines made up of a normal C2 switchboard and a backup C2 switchboard (supplied from station C3)

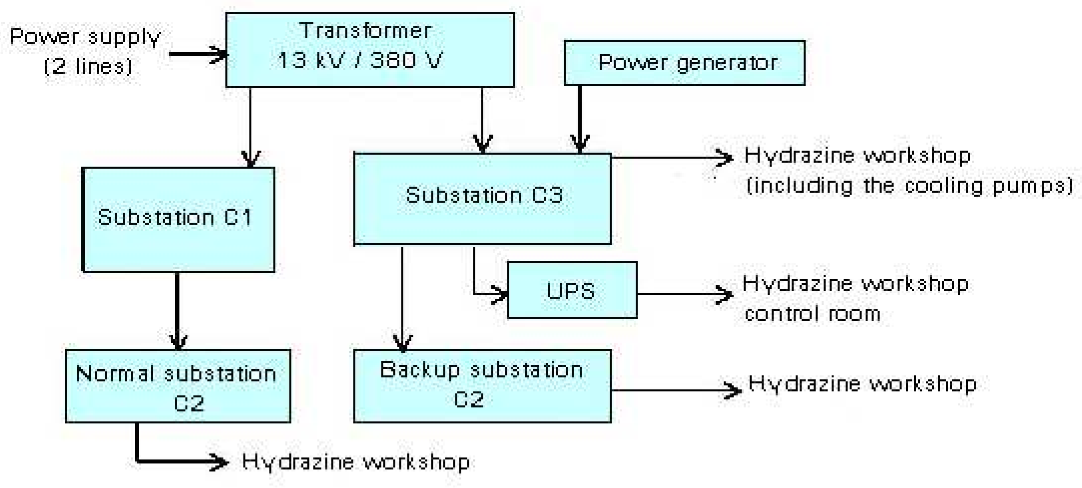


Figure 1 - Workshop electrical supply circuit

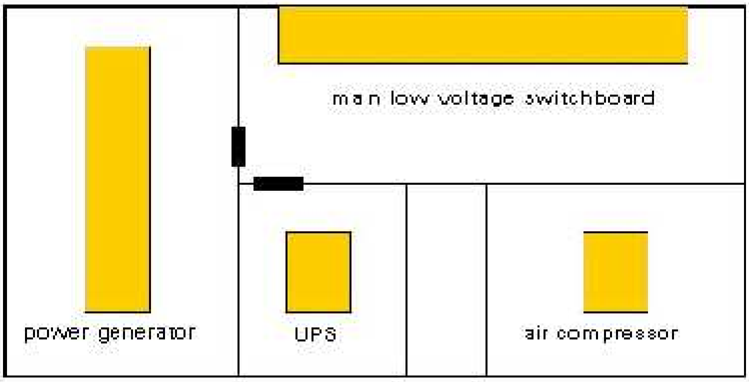


Figure 2 - Electrical service room C3

The electric power generator is shut down in a normal operating situation. It starts automatically if the normal electrical network is lost and allows the "backup" motors to start in order to safely shut down the workshop.

THE ACCIDENT, ITS BEHAVIOUR, EFFECTS AND CONSEQUENCES

The accident of October 25, 2004

12.59 pm: an electrical fault appears on one of the pumps in the hydrazine unit's cooling system. A fault on a UPS appears in the control room appears at the same time. An operator goes to station C3 and reports smoke.

1.00 pm: the fire alarm is triggered in room C3.

1.02 pm: **complete electrical disconnection on the hydrazine unit and control room**. When the power is cut, the valves of the hydrazine unit move to secure position. The Internal Contingency Plan/External Special Intervention Plan siren becomes inoperative as there is no monitoring and control.

1.03 pm: the Internal Contingency Plan is put into motion.

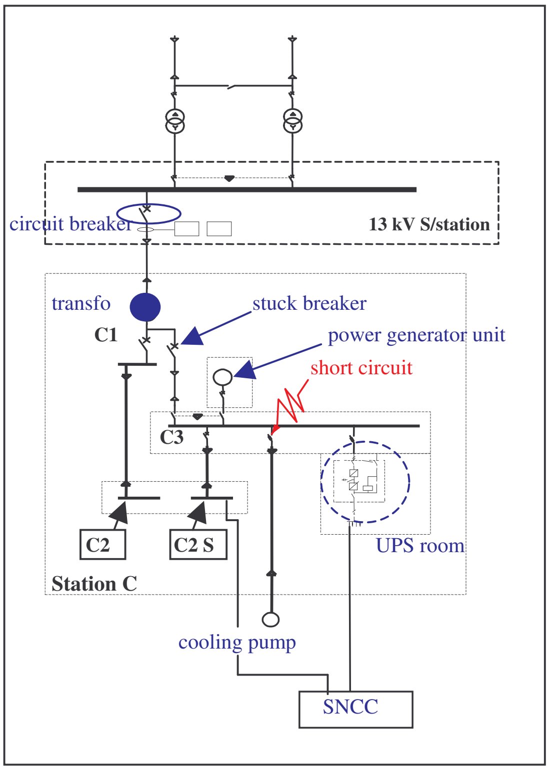
1.10 pm: an operator enters the 13 kV station and reports that the circuit breaker is open.

1.20 pm: the plant firefighters intervene at station C3 with CO_2 extinguishers.

1.50 pm: the fire is brought under control at station C3. Plant access is closed to all external personnel.

2.10 pm: **a valve on the hydrazine unit opens and releases the ammonia**. The unit's reaction section is cooled down by spraying.

2.15 pm: a water curtain is set up to combat the emissions. The Special Intervention Plan panels on the road in front of the plant are activated. Ammonia measurements are taken at the site's borders, down wind, by the site's HSE (Hygiene, Safety, Environment) department to see if the Special Intervention Plan must be initiated.



2.30 pm - 3.15 pm: the town halls of the neighbouring communities and companies are informed of the incident.

2.40 pm: **the burst disk opens** (0.5 bar) on the hydrazine unit's vent treatment tower. Water curtains are installed around the tower and a mobile cannon is set up to combat the ammonia release exiting the tower's vent.

15.40 pm: releases stop.

Consequences

The electrical column where the short circuit took place was destroyed by the fire and the entire electrical switchboard C3 was badly damaged.

During the incident, approximately 280 kg of ammonia was released, a large portion of which was brought to the ground by spraying set up by the plant's firefighters. The water used to combat the releases was collected in the shop's retaining basin. Measurements conducted in the site's environment showed very low ammonia levels (3 ppm).

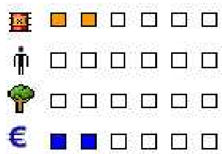
It cost 430 k€ to rebuild the electrical substation. The plant was shut down for a week: operating losses were in the thousands of euros.

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.

The parameters which 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

Quantities of dangerous substances
Human and social consequences
Environmental consequences
Economic consequences



The 280 kg of ammonia released represents 0.14 % of the corresponding Seveso threshold (200 tons - toxic), which equals level 2 of the "quantities of dangerous materials" index according to parameter Q1 (Q1 between 0.1% and 1%).

Two parameters are involved in determining the level of the "Economic consequences" rating: €15 and €16.

- Level 1 of the parameter €15 characterises the 430 k€ corresponding to the cost of rebuilding the substation (€15 between 0.1 M€ and 0.5 M€).
- The parameter €16 reaches level 2: as the operator had estimated production losses between 0.5 and 2 M€.

As a result, the overall "Environmental consequences" rating is 2.

ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

The electrical fault on one of the hydrazine unit's cooling pumps led to a short circuit on one of the columns of the switchboard C3 and started a fire. The fire then spread to all columns of table C3 via the sub-floor (electrical cables).

The circuit breaker upline from the switchboard did not function as it was "stuck".. The electrical problem then shifted to the transformer.

The 13kV/380V transformer caused a homopolar fault which shut off power to all C substations.

The electrical generator started, but the switchover to the "backup" switchboard couldn't take place as the electrical cables had been damaged in the fire. The hydrazine unit then secured itself as a result of the loss of electrical power.

As the smoke from the fire had entered the room via the open door and the sub-floor, the UPS, located in the neighbouring room, switched to standby (as soon as T=40°C), disconnecting the power of the SNCC ("Système Numérique de Contrôle Commande", digital monitoring and control system) and the programmable safety controllers. Electricity was lost in 4 minutes time.

Even though the valves stopped the input of raw materials automatically, the excess of the materials introduced allowed the reaction to continue for a moment inside the reactor. As the reaction was exothermic and the cooling inoperative, the reaction heat could not be dissipated. The pressure in the reactor increased to the valve's adjustment pressure, then the opening pressure of the burst disc placed on the vent treatment tower resulted in the release of the ammonia mixture and steam to the atmosphere.

ACTION TAKEN

The plant was shut down after the accident. The Classified Installations Inspectorate, located near the site, arrived around 3.30 pm. The Inspectorate sent a letter to the operator on October 26, 2004 requesting that a detailed report of the accident be submitted (analysis of the circumstances and the causes, possible environmental impacts, measures taken immediately and those foreseen for the near future) before the plant be restarted. An update was also requested of the danger study, the Internal Contingency Plan and the Safety Management System with consideration of the lessons learned from the accident.

The various studies were conducted within the company to analyse the accident, identify the causes and propose solutions:

- An expert assessment was conducted shortly after the accident,

- A fault tree was drawn up,

- In order to restart the installations, a temporary switchboard was installed to replace panel C3, in a room geographically separated from the UPS and power generator rooms. The UPS was replaced, the power generator cleaned and the circuit breaker overhauled,

- Definitive replacement of switchboard C3 was programmed for the plant's major shutdown in April 2005. This operation was preceded by a study bearing on the reliability of the power supply and how the common modes, insulation of the UPS / power generator /switchboard rooms are handled, the opportunity of a dual UPS power supply, and the connection of MV Bucchols transformer safety devices.

LESSONS LEARNED

The operator shed light on four essential points:

1. **The digital monitoring and control system (SNCC) must be able to remain operational at least during the first ½ hour** to ensure that the unit itself is sufficiently secured should common modes fail on the electrical circuit supplied by the main substation. In this manner, a second independent electrical network can take over and supply the SNCC.

The UPS is kept in the existing room, physically separated from the substation (door closed and hermetic sub-floor) and its backup power supply (2nd network) rendered independent from that of the hydrazine workshop.

2. **Heating faults must be eliminated** (the cause of the short circuit) and improve selectivity. The new substation thus includes:

   - A panel capable of performing an IR thermography IR (panel in front of the rack open) of all active parts during their operation,
   - Installation of fail safe racks in the table to test and maintain the '"sensitive" circuit breakers in operation,
   - The use of Bucchols safety devices with the transformers (low voltage),
   - Minimise cable lengths and potential hazards (heating, short circuit…),
   - Study of the installation of a charging bench to regularly test the electrical generator,
   - More balanced distribution of motor outputs on the switchboards.

3. **The organisation,** particularly relative to the maintenance operations, **must be improved** by:
   - Bolstering preventive maintenance of protective devices and switchboards,
   - Performing a regular technical inspection/audit of the electrical installations,
   - Organising technical discussion meetings between electrical installation specialists (sharing of experience, regulatory and technical watch).

4. **The securing conditions and certain characteristics of the reaction** must **be reviewed** by:
   - Maintaining the reactor cooling process: installation of 2 independent available water sources to cool the reaction down,
   - Revaluating the reaction heat that was underestimated when the workshop was designed. Laboratory testing conducted by the operator showed that the calorific potential of the reaction was underestimated by 50%.

Fire in a hydrodesulfuration unit of a refinery

June 26, 2004

Feyzin – [Rhône]

France

Furnace
Detection
Intervention
Communication
Inspection plan

THE INSTALLATIONS IN QUESTION

The refinery was commissioned in 1964 to provide the Rhône-Alpes region with a variety of fuels.

It produces a full range of conventional petroleum products (LPG, kerosene, petrol, diesel fuel, domestic heating fuel oil, …) and also has a significant petrochemical activity (including the production of ethylene and propylene).

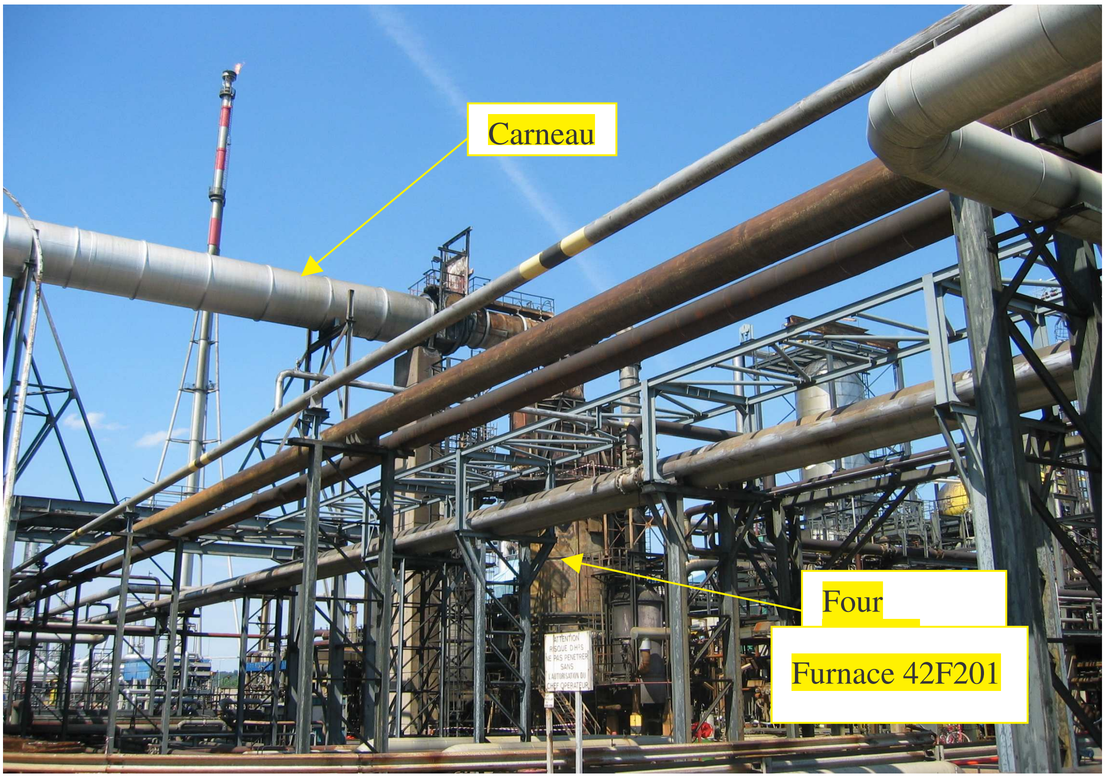
It produces roughly 6 million tons per year and has a storage capacity of 1 million m^3 for liquids and 34,000 m^3 for liquefied gases.

The plant employs approximately 600 people, including 150 for the petrochemical sector.

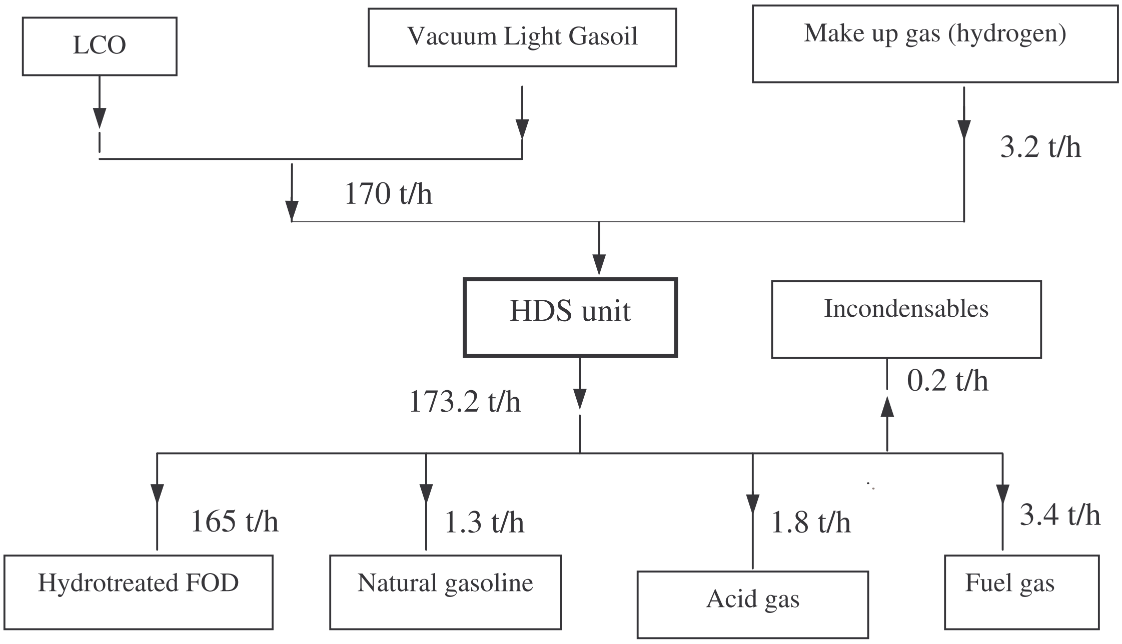
The refinery is located to the south of Lyons in "Chemical Valley" on a narrow site covering 143 hectares. It is bordered to the west by the Rhône Canal and to the east by the A7 motorway (except for the loading zone located on the other side of the A7), the Lyons/Marseilles rail line, the Sibelin railroad yard and an urbanized zone.

This establishment is governed by the SEVESO II Directive (High Level). In addition, an inspection department for pressurized equipment at the site was "recognized" by the DRIRE in 1995.

The fire occurred on the load preheating furnace (42F201) of the hydrodesulfuration (HDS) unit located on 5,300 m^2, to the southeast of the zone dedicated to the refining units.



Overall view of the HDS unit (after the fire)

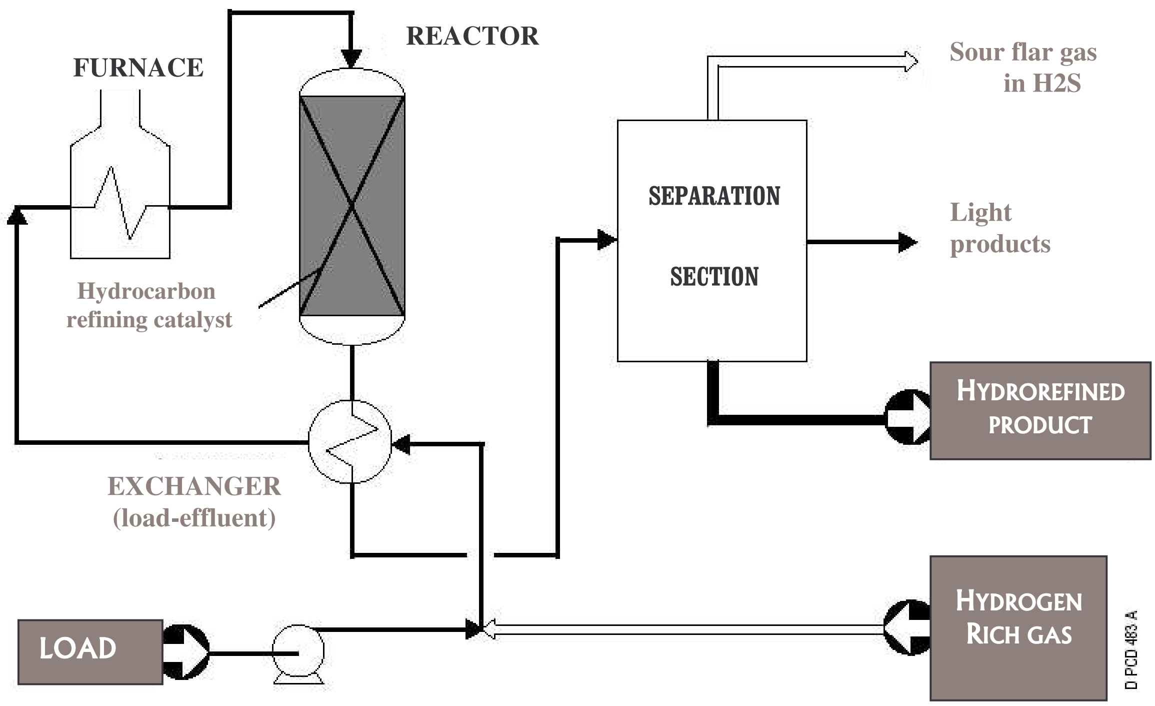


Material assessment of the HDS unit in domestic fuel oil operation

The HDS unit primarily processes fractions intended for the fabrication of diesel fuels and fuel oils. It is designed to reduce the sulphur concentration of intermediate products in order to produce combustibles and fuels that respect sulphur specifications required by environmental legislation.

Desulphuration takes place by hydrogenation in the presence of a catalyst, with the hydrogen being supplied by a gaseous mixture coming from the reformer and the steam cracker. The reaction produces hydrogen sulphide (H_2S) which the unit retransforms into sulphur (see the flow diagram below).

Sulphide loads + Hydrogen			>>>>>>>	Cleaned loads + Sulphur-containing gaseous effluent
Sulphur-containing gaseous effluents			>>>>>>>	Fuel Gas + Hydrogen sulphide
Hydrogen sulphide	>>>	Claus reaction	>>>	Liquid sulphur
Fuel Gas	>>>	Combustion	>>>	Refinery energy



HDS unit flow diagram

Characteristics of furnace 42F201:

The furnace was commissioned in 1974 and is used to desulphurize diesel fuel, distillates and domestic fuel oil.

Specifications:

- Nominal pressure: 56.9 bar,
- Maximum operating pressure: 42 bar,
- Nominal temperature: 425°C,
- Usual operating temperature around 410°C-420°C depending on the products to be desulphurize.

It is essentially made up of 6"-diameter tubes (ND 150) and elbows made of austenitic A 312 TP 347 stainless steel, selected for its resistance to the main type of corrosion in this type of furnace, which is sulphuration.

It consists of a lower radiation part where the vertical tubes are normally accessible, lapped by the flame, and an upper convention part where the horizontal tubes in superimposed and tight layers are thus not subjected to the action of the flame. Only the lower layer of convention tubes is visible, as well as the peripheral junction elbows between the layers.

On the convection part, the tubes in place were the originals while in the radiation part; several tube replacements had already taken place (1 tube was replaced in 2001 and 16 tubes were replaced during the last shut down of 2002, prior to the ten-year testing). The reasons for this were accidental overheating during a restarting operation for the tube replaced in 2001 and overheating zones due to the maladjustment of burners in 2001 for the 16 tubes.

View of furnace 42F201 (after the fire)

THE ACCIDENT, ITS BEHAVIOUR, EFFECTS AND CONSEQUENCES

The accident:

A fire broke out on furnace 42F201 on June 26, 2004 at 4.38 pm. Flames engulfed the furnace (the metal of the convection section was red hot) and black smoke was released.

The fire was not preceded by an explosion although witnesses noticed a suspicious noise, described as a whistling noise (like a valve) which became louder and louder, followed by a "mechanical" noise.

Personnel working at a neighbouring site were able to rapidly sound the alarm and manually opened part of the water curtains before the fire brigade arrived to the site. The operator stopped supplying the unit (load and hydrogen) and began decompressing via the flare stack, which rapidly reduced the combustion. The furnace's load-bearing structures, subjected to an intense thermal flux, were cooled down.

The external fire was brought under control in 30 minutes using the refinery's internal resources. The external firefighting means dispatched to the site did not have to intervene.

The ignition of the products coming from the reaction loop (reactor 42R202) continued intensely for a few hours in the furnace's convection chambers and flue exits.

Intermittent flames were observed for several minutes at the outlet of the common stack that collects the atmospheric releases from the HDS units, atmospheric distillation No. 2 (DA2) and removal of aromatics (hydrotreating section No. 2 - HDT2) and a significant plume of smoke.

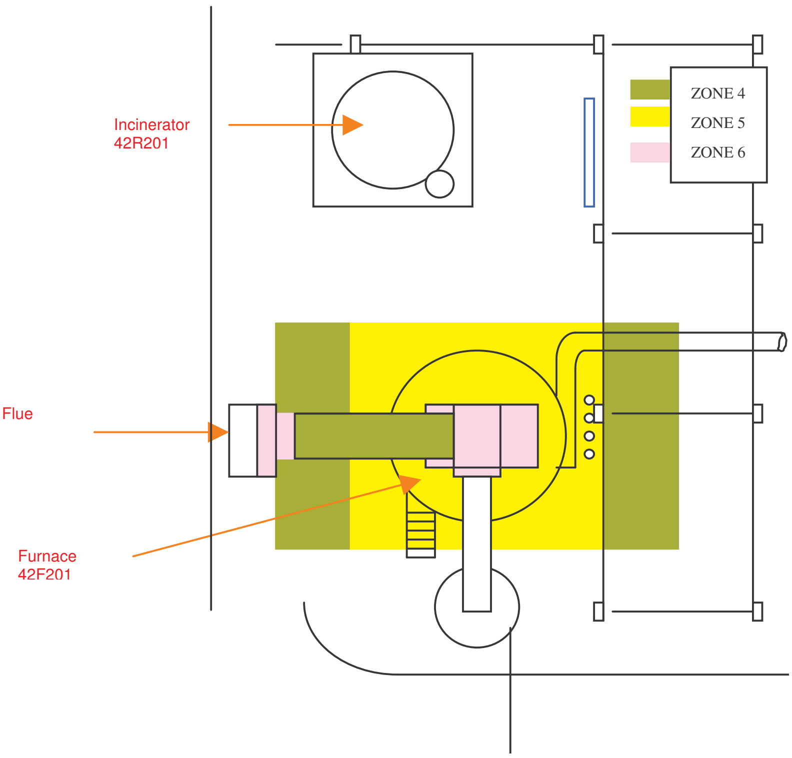
None of the H_2S detectors on the unit triggered the alarm. Most likely, however, a certain quantity of H_2S was released through the flare stack.

Among the pollutants continuously monitored by the sensors in the refinery's environment (including a network of air quality measurements in the Lyons community), the amount of sulphur dioxide and particles in suspension is likely to be high in the event of an incident of this type. The concentrations measured did not increase significantly (they remained below the information and recommendation threshold for sensitive individuals).

The consequences:

Property damage:

✓ The detailed evaluation of the damage to pressurised equipment involved in the accident was conducted according to API 579 methodology which consists in determining the temperatures reached during the fire, including spatial classification of the 6 corresponding zones and the definition of an acceptance or replacement criterion depending on the zone concerned.



Classification of zones	Description
1	Ambient temperature, no exposure to the fire
2	Temperature below 70 °C, smoke and fire protection water
3	Temperature below 200 °C, slight exposure to the heat
4	Temperature between 200 and 430 °C, moderate exposure to the heat
5	Temperature between 400 and 700 °C, high exposure to the heat
6	Temperature above 700 °C, very intense exposure to the heat

Classification of the temperature levels reached
(zones between elevations 8 m and 25 m)

Partial view of furnace 42F201 after the fire and dismantling for inspection

✓ Furnace 42F201 underwent the most extensive damage:

- Total destruction of the convection array (fusion of the upper levels of the convection, only the lower layer had tubes that were not melted, including a burst tube) (see photo below),
- Fusion and vitrification of the refractory material on the convection part (see photo below),
- Overheating of the radiation array,
- Damage or deformation of convection and radiation wall and structural elements,
- Degradation of support columns,
- Deformation of the first section of the flue.

View of the lower convection layer (after the fire)

✓ The support columns of incinerator 42F502, located near furnace 42F201, were damaged (lagging concrete damaged). According to the operator, this damage was the result of ageing of the heat lagging. Supporting documents were requested on this point.

✓ The following equipment was damaged by the accident:

- Piping in zones 5 and 6, primarily the fuel supply lines and furnace utilities,
- Electric wiring and measuring channels,
- 3 water curtains for furnaces 42F201 and 42F501, and
- Certain gas detectors.

✓ The furnace loading and transfer lines located in zone 5, as well as the set of pipes on the East rack and at ground level were not metallurgically affected by the accident owing to their heat lagging,

✓ The metal ladder on furnace 42F201 was twisted, and the wall (concrete) supporting the flue that connects the HDS unit to the stack common to the HDS, DA2 and HDT2 units was also damaged,

✓ Flames were observed for several minutes at the outlet of the chimney shared by the HDS, DA2 and HDT2 units, indicating that the structure may have been damaged (notably the refractory material),

✓ At the effluent monitoring platform of this chimney, a temperature peak of at least 500 °C (upper detection limit) was recorded, further recording was impossible as the sensor had been damaged.

Environmental consequences:

The resulting environmental consequences were described and evaluated:

- Type, quantities, composition, and toxicity of atmospheric releases (H_2S, SO_2, dusts, …),
- Type and quantities of the waste and polluted water, as well as the possible clean-up options.

The evaluations at this point were as follows:

- The quantity of hydrocarbons involved in the fire was estimated at 45 tons, which represents approximately 1 ton of SO_2 released into the atmosphere.
- While emissions of H_2S were noted in the site's environment, the fixed detectors of the HDS unit did not detect the presence of this pollutant.
- The quantity of dust from unburnt particles was not determined,
- In late September 2004, the overall quantity of waste was estimated at approximately 240 tons,
- The internal treatment station treated approximately 3,000 m^3 of water from firefighting operations.

Economic consequences:

The economic consequences were estimated to be approximately 28 million €, notably with:

- 250,000 €/day in operating losses (the facility being out of operation for 3 months),
- 6 M€ dedicated to unit refurbishing operations, including 2 M€ required to rebuild the furnace.

Human consequences:

Two operators were slightly injured during the fire extinguishing operations (from falls resulting from irregularities in the slabs of the HDS unit covered by foam).

According to the public emergency services, 600 people were temporarily evacuated from a neighbourhood in Feyzin (including the swimming pool and stadium). As a precautionary measure and due to a lack of precise information from the refinery, the law enforcement agencies decided to temporarily block the A7 motorway.

Seveso II Directive – Appendix VI

The accident was considered “major” according to the following criteria of Appendix VI of the Directive:

- "property damage inside the establishment": approximately 6 million € for a threshold set at 2 million €,

- "evacuation or confinement of individuals for more than 2 hours" (people x hours): 600 people temporarily evacuated (for more than 2 hours) for a threshold set at 500.

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.

The parameters, which 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*

Quantities of dangerous substances	■ ■ □ □ □ □
Human and social consequences	■ ■ ■ □ □ □
Environmental consequences	□ □ □ □ □ □
Economic consequences	■ ■ ■ ■ □ □

The index relative to the quantities of dangerous materials is equal to 3 owing to the release of 1 ton of SO_2 into the atmosphere. Level 3 for the human and social consequences is the result of the evacuation of 600 people. The index relative to the economic consequences is rated level 4 due to the production losses that were evaluated at 22 M€.

ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

Furnace 42F201 inspection plan:

The furnace inspection plan in force at the time of the accident offers the possibility to extend the periodic inspection intervals to 6 years and periodic requalifications to 12 years depending on a scheme approved by the DRIRE November 8, 2001, in terms of the regulations governing pressurised equipment.

With this goal in mind, the refinery's inspection department established inspection plans for the unit's pressurised equipment according to the RBI (Risk-Based Inspection) method, in compliance with the UFIP (Union Française des Industries Pétrolières) of February 2000, and recognized by the administration per DM-T/P No. 31 538 of October 20, 2000.

The implementation of the RBI method relies on "RBeye" software used within the Group, which automates the search of degradation modes according to fluid, equipment material, pressure and temperature data.

The furnace has undergone periodic inspections since its installation, with triennial verifications up to 1997, and ten-year testing. The last successful periodic requalification with performance testing took place in April 2002. It had thus been in service for 27 months at the time of the accident.

The HDS unit was inspected during the plant shutdown of 2002 ("metal" shutdown) and was shutdown in 2003 for a simple catalyst replacement operation.

The non-destructive testing conducted since the initial installation consisted in ultrasonic thickness measurements, and dimensional inspections to check for creep along the radiation portion of the furnace as the inspection department considered that it was the most exposed. Since 1993, metallographic replicas on the radiation tubes were taken and showed the initiation of stainless steel sensitisation (incipient corrosion which could modify the mechanical characteristics). The inspection department nevertheless determined it to be acceptable due to the lack of cleavage or microcracking.

On the convection part, only thickness measurements were conducted on the peripheral elbows (see photo below), and no anomaly was recorded.

View of a peripheral elbow on the convection chamber (after the fire)

The inspection report of the periodic requalification operations conducted in 2002 show that, for the convection part, the visual examination performed by the inspection department on the lower layer showed no signs of anomaly. Furthermore, the history of the thickness measurements on the radiation tubes and convection elbows since 1993 showed no abnormal decrease in thickness.

For obvious design reasons, verification operations cannot be conducted inside the tubes.

Periodic requalification is accompanied by hydraulic testing at 85.5 bar.

Condition of the HDS unit prior to the fire:

Since the day prior to the fire, the HDS unit had been in "domestic fuel oil" (FOD) operation. This operating mode is considered as moderate. It was fed by a mixture of light distillate coming from vacuum distillation unit No. 2 and LCO (light cycle oil) from the catalytic cracking unit. The load's sulphur content was estimated at 1.16%.

It should be noted that prior to introduction into furnace 42F201, the load is injected with hydrogen which contributes to the desulfuration reaction.

According to the recordings, the skin temperature of furnace 42F201 was stable at around approximately 373 °C, with a maximum allowable temperature of 392 °C (setpoint temperature).

Origin of the fire:

It appears that the tubes which make up the lower convection layer were not melted due to the fact that they were being supplied all the way to the end by the load and thus "cooled".

Among them, a tube that was found ruptured (a clean rupture 500 mm in length), was then determined to be the cause of the fire (see photo below).

Views of the ruptured tube

Expert assessments:

Two expert assessments were conducted; one by an external expert, and the other by the Group's research centre.

Assessment of the external expert:

The assessment was performed on 2 tubes (the ruptured tube and the tube next to it) based on a geometric, fractographic and metallurgical analysis of the ruptured tube as well as mechanical tests and X-ray diffraction analyses.

It appears that the rupture was the result of four types of damage which combined their effects and reduced the thickness of the tube to the point where it could no longer resist the operating pressure.

The damage:

✓ **presumed corrosion from polythionic acids:** these acids form when the load's sulphur compounds come in contact with oxygen. This situation cannot occur during normal operation, as the load does not contain oxygen. It is encountered during shutdown periods and hydraulic testing operations. To avoid this phenomenon, a passivation operation is performed during the shutdown period (the procedure was formalised in 1985). It appears that the attack may have happened some time ago as the passivation operation has been performed since 1980. It appears to be the result of localised formation of ruts on the inside of the furnace tubes.

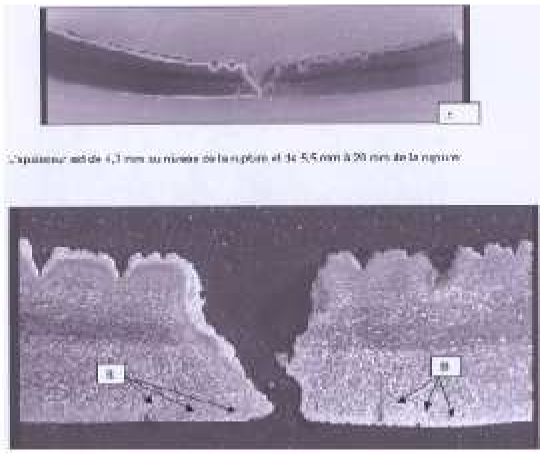
✓ **decreased thickness by oxidation/sulfuration**: in the ruts formed by the polythionic acid corrosion, the material (austenitic stainless steel) lost its corrosion-resisting properties, resulting in reduced thickness through corrosion.

✓ **presence of sigma phase** (intermetallic compound causing highly marked brittleness of the metal) in small proportion which may have facilitated the development and penetration of the intergranular corrosion.

✓ **intergranular cleavage leading to slow creep** which eventually generates cracks on the outer skin of the tubes: this phenomenon could be explained by poor heat exchange due to a coke deposit inside the tube. This external tube damage was not visible with the naked eye.

Assessment by the Group's research centre:

This assessment, conducted on another tube, revealed none of the internal intergranular corrosion patterns found on the ruptured tube. However, cleavage due to creep on the outside and dense sigma phase on the inside were noted. The assessment concluded that the defects were localised.



Microscopic view of the break and its two edges readjusted (burst tube)

Decrease in thickness through oxidation/sulfuration (internal skin), presence of sigma phase (internal skin), intergranular cleavage (internal skin) and cracking (external skin).

ACTION TAKEN

DRIRE intervention:

The DRIRE began an administrative inquiry June 26, 2004. The main contacts with the operator were was follows:

✓ visit on June 26, 2004 by the Classified Installations Inspectorate in order to conduct the first reports and to collect the first testimonies,

✓ visit on June 28, 2004 by the Classified Installations Inspectorate,; this visit continued that of June 26, 2004,

✓ working meeting and visit of the furnace on July 8, 2004 by agents in charge of monitoring pressurised equipment and the inspection of classified installations. The goal of this meeting was to collect the first elements concerning the furnace and draw up an initial progress report concerning the prefectorial order outlining the emergency measures of June 30, 2004 (see infra),

✓ participation by the Classified Installation's Inspectorate in extraordinary meetings by the CHSCT (Comité d'Hygiène, de Sécurité et des Conditions de Travail), July 19 and August 26, 2004 relative to the fire which took place on June 26, 2004,

✓ working meeting of September 2, 2004 of agents in charge of monitoring pressure equipment and the Classified Installations Inspectorate; this meeting was a follow-up to the meeting held July 8, 2004,

✓ working meeting and visitation of the furnace and neighbouring equipment on September 23, 2004 by agents in charge of monitoring pressurised equipment and the Classified Installations Inspectorate following documents submitted by the operator September 8 and 14, 2004.

In order to identify the causes of this accident and to implement the provisions required for safe restart of the HDS unit, the operator was issued a prefectorial order on June 30, 2004, outlining emergency measures proposed by the DRIRE.

Analysis of failures and causes:

The examination of event chronology (recordings of alarms, sensors, valve movements, etc.), the description of possible precursors and the list of special operations performed during the day were presented.

The following points were determined:

✓ the analysis of the HDS unit's operating parameters showed no derivation of the process parameters prior to the accident and no pre-incident indicators,

✓ no malfunction of the control and safety PLCs (independent systems) was reported.

An internal multi-disciplinary task force conducted the failure and cause analysis. An individual skilled in the fault tree method, and not concerned by the management of the accident in question conducted the work session.

Equipment:

✓ Checks and inspections were conducted on the equipment of the reaction loop downline from the furnace (reactor 42R202, exchangers 42E201 and 42E202A/B) which underwent rapid decompression when the furnace tube ruptured although normal operation calls for the application of a very progressive depressurisation procedure. For this reason, the cladded internal lining (covered by an internal skin of welded strips) or stainless steel liner may have underwent a separation phenomenon (disbonding by hydrogen). No anomaly of this type was recorded.

✓ The chimney, from which flames were seen exiting for several minutes, was subjected to thermographic inspections, visual inspections of the chimney cap with a telescope and verticality checks. It appears that the condition of the concrete structure and its internal lining (refractory bricks) are satisfactory and in compliance with construction specifications.

✓ 34 lines were inspected:

× the pipes in zones 5 and 6, mainly the furnace's combustible supply lines and utilities, were replaced or removed (to make room for a new furnace operating on gas fuel only),

× The furnace loading and transfer lines located in zone 5, as well as the set of pipes on the East rack and at ground level were not metallurgically affected by the accident owing to their heat lagging, The refurbishing work consisted in replacing the threaded fasteners, seals, lagging and their protective sheeting, and the spring supports,

✓ All electrical wiring and measurement channels were refurbished, and damaged equipment was replaced,

✓ All valves and pumps were overhauled,

✓ The water curtains of furnaces 42F201 and 42F501 were completely rebuilt,

✓ The gas detectors were checked and replaced as required,

✓ Considering the extent of the damage to the furnace, the decision was made to completely rebuild it, including the associated civil works structures (concrete support posts, first section of the flue). The furnace was rebuilt nearly identically, although the following improvements were made:

× 6 burners were installed instead of 4 for better distribution of the heat flux,

× installation of a remote burning ignition device,

× installation of temperature sensors on the skin of tubes on two heights in the radiation part, as well as on the lower layer of the convection part, in order to monitor any abnormal increase in temperature that may be due to coke deposits accumulating inside,

× the installation of additional inspection ports.

Inspection plan:

The furnace inspection plan was reviewed in order to consider the first lessons learned form the expert assessment and includes additional inspections, made possible by a new design:

✓ On the convection part:

- replicas and X-ray inspection of convection tubes once per cycle,
- during the next major shutdown in 2007 (after 25,000 hours of operation): thickness measurements of lower level tubes and 20% of the peripheral tubes, geometric calibration of tubes (search for creep), X-ray inspection (search for internal corrosion and the presence of coke),
- continuous monitoring of tube skin temperature.

✓ On the radiation part:

- thickness inspection on 20% of tubes and elbows during each annual shutdown (reactor catalyst change),
- on the occasion of the next major shutdown in 2007: thickness measurements of tubes and elbows, geometric calibration of tubes (search for creep), metallographic replicas on tubes at two different heights (search for sensitisation of the stainless steel),
- continuous monitoring of tube skin temperature on two heights.

The inspections and periodic requalifications include the verification of safety accessories and the requalification of a hydraulic test.

Passivation procedure:

An internal task force was created to re-examine the passivation procedure and equipment likely to be concerned. The conclusions drawn at this point were as follows:

- A procedure was drawn up in compliance with recognised trade standards,
- A few modifications were made to this procedure (including the use of a surface agent in the preparation of the carbonate solution, the addition of the pH test of the water during passivation and a decrease in the carbonate concentration from 5 to 2%).

Feedback on other equipment or other units:

The Feyzin site does not have other desulfuration furnaces exhibiting this type of corrosion.

According to the operator, polythionic acid attacks can also occur on the catalytic reformer, as well as in the HDT2 (hydrotreatment) unit where passivation cannot take place considering the geometric stresses involved. The DRIRE nevertheless requested that the operator conduct more extensive investigations on these units in order to search for any evidence of this corrosion phenomenon.

The examination of the accidentology involving these refinery furnaces (in the ARIA database established by the BARPI) revealed no other similar accident.

LESSONS LEARNED

The accident reminds us of the importance of certain problems such as detection, intervention (Internal Contingency Plan), external communication and the limits of the installations' inspection plan.

Detection and intervention:

As there was no fire detection on the HDS unit, the presence of personnel working on a neighbouring unit allowed the alarm to be raised rapidly and to operate the unit's decompression and cooling systems in the next 5 minutes.

This favourable situation cannot obscure the crucial importance of rapid detection of an accident of this type, conditioning the intervention delays of the personnel and the time required to implement the Internal Contingency Plan.

Also, faced with the drop in personnel in the immediate proximity of the installations for obvious security reasons (an ongoing construction program for new control rooms away from the units), the detection of accidental events within production units (fire, gas detection, …) and the visual and audio monitoring of installations, without detriment to the monitoring of operating parameters.

A think tank was created in order to clarify Internal Contingency Plan implementation methods. The event of June 26, 2004 gave rise to questions concerning the formal implementation of the Internal Contingency Plan.

Questions could be raised concerning whether or not the number of people assigned to operate the production units is adequate with those required to intervene in case of an accidental situation. This aspect reveals particular importance for the periods where the workforce is reduced.

Considering the human consequences of the fire on June 26, 2004, the decision was made, at the request of the CHSCT, to finish off the slab floor of the HDS unit. It would be desirable to apply this measure to the rest of the platform.

Inspection plan:

The rupture on the tube that caused the fire was the result of certain degradation modes (coke deposit, polythionic acid corrosion) that were unidentified when the inspection plan was drawn up using the Group's RBeye software. An upgrade of this tool appears necessary as a result in order to integrate the aforementioned degradation modes and to consider the age of the equipment in the criticality calculation.

Furthermore, the degradations of the tubes can also be determined during a hydraulic resistance test provided that the equipment is pushed beyond its service loading. If the initial resistance testing meets this concern for the furnace rebuilt completely, according to the provisions of the Order of December 13, 1999, it must be proven that this condition is also fulfilled for similar older equipment.

In order to verify the pertinence of these measures, it may be of interest to compare the inspection plans of such units currently in operation in French refineries.

External communication:

In the crisis management phase, the assessments provided by the operator about the extent of the accident and its consequences were considered insufficient by external organisations (including the Feyzin Town Hall, Police, Public Emergency Services, Sport Infrastructure Superintendent, etc.).

The operator felt that the decisions taken by the Authorities regarding the nature of the accidental phenomenon were disproportionate. In terms of communication, a press conference was held June 26, 2004 by the site director, the day of the accident, at 6.30 pm, nearly 2 hours after the start of the fire.

These differences in appreciation ware studied a posteriori during a debriefing meeting at the Rhône Préfecture, in which the following points were made:

✓ the organisation of crisis management must be improved between the Feyzin Town Hall, law enforcement agencies and the refinery,

✓ for the operator, the notion of an "event visible from the outside" must be formalised in the site's alert procedures, including systematic and rapid information provided to the authorities, including the absence of the implementation of an Internal Contingency Plan.

Implosion of a styrene storage tank during truck unloading operations

January 7, 2005

Tertre - Belgium

Chemistry
Unloading
Polyol
Barometric seal
Vacuum breaker

THE INSTALLATIONS IN QUESTION

The site:

The plant, located in Tertre, specialises in the fabrication and storage of:

polyether-polyols: polymerisation of propylene oxide and ethylene oxide on an alcohol, in the presence of catalysts

polymer-polyols: polymerisation of styrene and acrylonitrile on a polyether-polyol.

With this fabrication process, the company supplies one of the two main raw materials required to produce polyurethane (insulating foam, etc.).

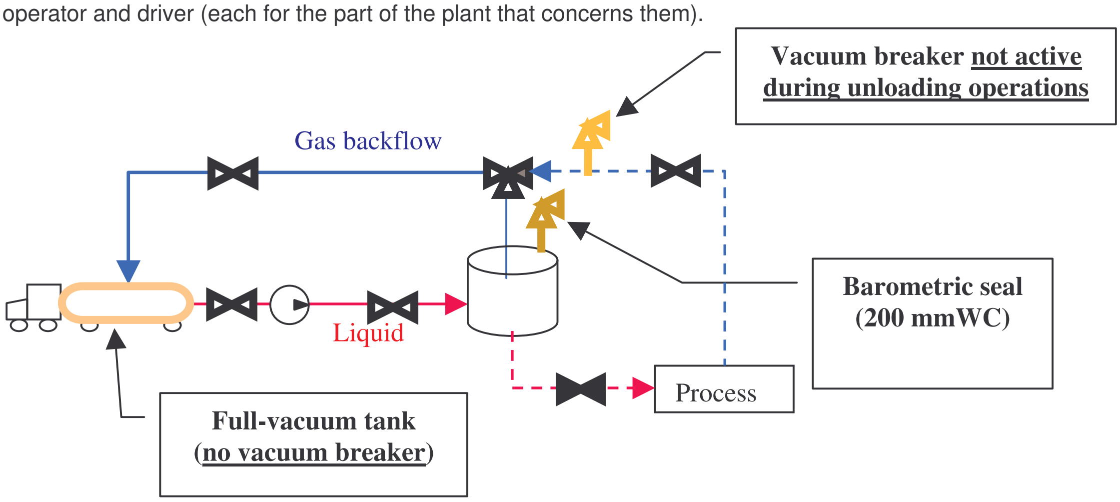
Created in 1928, the company has been producing polyols since 1964. The site currently employs 673 people, including 53 for the production of polyols.

The site is classified as "High Threshold" - Seveso.

The unit concerned:

The storage tank involved in the accident is used to store styrene (C8H8). It has a total capacity of 44 m³, of which 35 m³ is considered its "usable capacity". This represents 29 tons of product. The storage tank is equipped with a cooling system that conveys a glycol solution through a coil. It is protected against overpressure by a barometric seal calibrated at 200 mmWC. It is equipped with a pressure alarm: high level set at 150 mmWC and very high level set at 220 mmWC which shuts down the unloading pump. It also features vacuum breaker protection in case of significant draw by the process. Owing to the presence of the 3-way valve, this vacuum breaker is inactive when a truck is being unloaded. The storage tank is located in a 80 m³ retaining pit.

A truck comes to unload the styrene two times per week. Using a checklist, the alignment is ensured visually by the operator and driver (each for the part of the plant that concerns them).



The protective equipment installed on the storage tank and tanker efficiently protect the unit against the following two accident scenarios:

Incorrect alignment of the gas return during the truck unloading operation generating a vacuum in the tanker truck (vacuum breaker or "full-vacuum" tank resisting a partial vacuum) and an increase in pressure of the storage tank (valve)

Significant intake by production causing a vacuum inside the storage tank (vacuum breaker protection)

THE ACCIDENT, ITS BEHAVIOUR, EFFECTS AND CONSEQUENCES

The accident:

A truck arrived to unload 24 tons of styrene in the morning of January 7.

After connecting the lines, the unloading operation began rather quickly although the pump experienced cavitation difficulties. The pressure alarm (high level) was triggered although is not handled in the control room. When unloading operation was finished, the driver noticed that he had left a gas return valve nearly completely closed. Of his own initiative, he climbed onto the truck and opened this valve completely without first informing the operator. After the unloading operation, the truck left.

Shortly thereafter, a low level alarm on the tank's refrigeration unit (glycol solution) sounded in the control room. A slight increase in the styrene tank's level was also observed at the same time. Following an inspection on site, a styrene and glycol water leak was reported, as well as significant deformation of the storage tank.

The contingency plan was initiated (including contacting the fire department and evacuation of personnel). Without waiting for the leak run out, the operator decided to transfer the content of the storage tank to another available tank.

The consequences:

Initiation of the contingency plan (fire department notified; evacuation of the personnel),

Destruction of the storage tank (and the internal coil),

Loss of approximately 3 tons of a styrene/glycol/water mixture. This mixture was confirmed and eliminated as dangerous waste,

Production shutdown for 2.5 days.

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.

The index relative to the quantities of dangerous materials is equal to 1 as the quantity of styrene lost was less than 3 t. The operator stipulated that the index relative to the economic consequences reached level 2 owing to the property damage (parameter 15), without indicating the amount.

The parameters, which 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

ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

The accident is due to the incorrect alignment of the gas return line: the butterfly valve on the truck remained nearly completely closed throughout the entire unloading operation (forgotten by the driver).

The tanker began depressurising and, as it was "full vacuum" type, a partial vacuum was created. Upon completion of the unloading operation, the partial vacuum was estimated to be 0.6 bar. This would not have happened if the tank had been protected by a vacuum breaker, as stipulated in the operator's specifications.

At the same time, the storage tank developed a slight overpressure. The high level alarm was not managed correctly in the control room when it had sounded. As far as the very high level is concerned (causing the unloading pump to stop), it was never reached due to bubbles that were trapped in the barometric seal, which limits pressure increase inside the tank.

At the end of the unloading operation, when the driver opened the butterfly valve completely, the pressures in both the tanker truck and the storage tank were balanced out. The intake of air that followed was enough to cause the implosion and subsequent destruction of the storage tank.

ACTION TAKEN

The operator replaced the storage tank and undertook the action indicated in the following paragraph.

LESSONS LEARNED

The operator undertook the following measures to prevent an accident of this type from reoccurring:

Installation of a system to prevent the depressurisation of the storage tanks at all time (even during truck unloading operations).

Slaving of the unloading pump to the correct connection of the lines (pressure measurement).

Ensure proper communication between the driver and the operator (the driver must not initiate actions without informing the operator). Furthermore, the two individuals must be able to communicate in a common language. In this case, one spoke French and the other Dutch.

Ensure the correct configuration (set point) and management of the alarms (classification by priority).

This accident scenario must be considered in the safety studies (HAZOP analysis) and applied to other the unloading stations, where applicable.

The modifications proposed by the operator must ensure that operation take place in improved security conditions.

Vinyl chloride leak in a chemical plant

February 3, 2004

TAVAUX (Jura - 39), France

Polymerisation
Vinyl chloride
Autoclave
Batch
Valve
Manual operations
Organisation

PART OF THE PLANT CONCERNED:

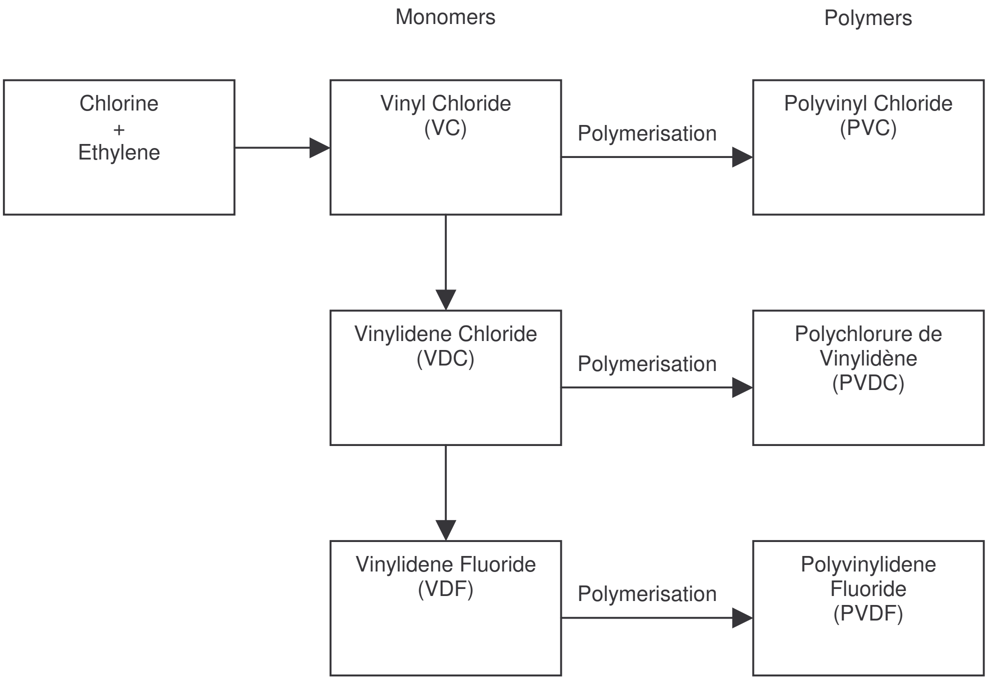
Located in Dole (Jura - 39) and created in 1930, the chemical platform is one of the largest in France and extends over 200 ha. The company employs 1,600 people at the site and approximately 700 people in external companies.

The establishment, which is governed by High Threshold Seveso regulatory requirements applicable to sites subject to authorization with public easement, includes 26 "AS" installations (for the use and storage of highly toxic and toxic liquids, manufacture, storage and use of chlorine, storage of liquefied flammable gases, and the manufacture and storage of flammable liquids…). The measures foreseen for urbanisation control around the plant apply to two circles measuring 1,000 and 1,500 m in diameter, centred on the chlorine storage facility.

For many years, the plant's activities, based on the processing and transformation of salt (essentially the production of sodium carbonate), had been developed toward high added-value productions with a strong emphasis on technology through specialisation in chemical products and plastic materials for industry.

Basic production operations are focused on polyvinyl chloride and polyvinylidene chloride (PVDC); in 2004, the tonnage of the main products was in the order of 1,250,000 t/year all products considered, including 308,000 tons of miscellaneous plastic materials (PVC, PVDC and PVDF).

These plastic materials are produced from vinyl chloride monomer (VCM), which is itself derived from the reaction of chlorine and ethylene. The manufacturing sequence of the 3 plastic materials is as follows:

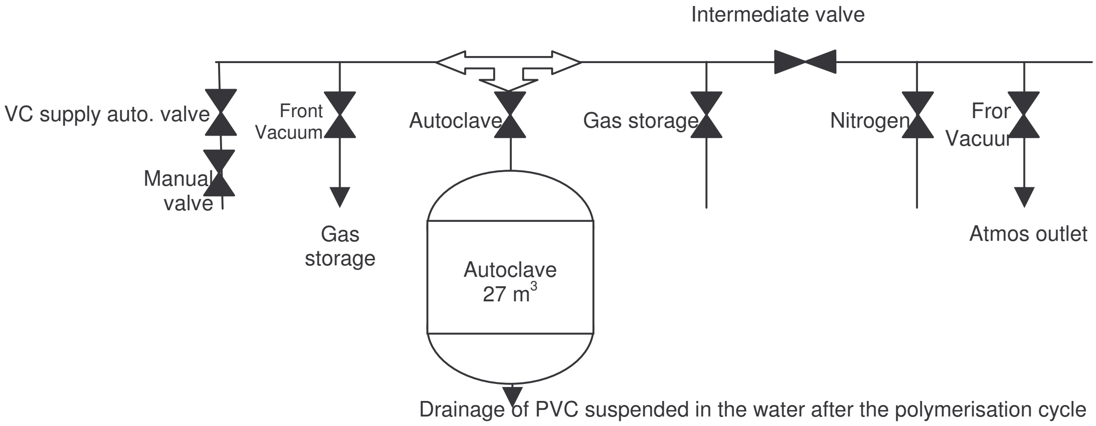


VCM is a very flammable liquefied gas (F+, R12) and a carcinogen (T, R45).

The accident took place in one of the PVC manufacturing installations (the polymerisation sector of the VCM).

The part of the installation concerned, which dates back to 1969, consists of a set of thirteen 27m³ autoclaves in which the polymerisation process is carried out according to a discontinuous "batch" process. This process requires that they be opened between 2 polymerisation operations. The installation is only slightly automated, notably in terms of the autoclave filling, drainage and cleanup processes. The accident took place between one of the VCM inlet/outlet pipes:

The system can be represented by the simplified diagram below:



Comment: The intermediate valve isolates the autoclave from any circuit not intended to convey VCM.

A series of preliminary operations are performed before the VCM is introduced:

- filling with water,
- dispersing agent and catalyst,
- degassing to the "Front Vacuum" network to remove traces of oxygen (the presence of air).

These operations are manual. Prior to the modifications made following the accident, the following functions were automated at the installation:

- Filling of VCM,
- Monitoring of the polymerisation reaction.

The personnel were certified to perform the corresponding operations. Procedures were drawn up to describe these operations, although there are no accompanying record sheets of the various steps. The preliminary operations are not subject to formal qualification prior to the authorisation of the automatic VCM introduction sequence.

THE ACCIDENT, ITS BEHAVIOUR AND CONSEQUENCES

On February 3, 2004, during the preliminary VCM filling operations of autoclave No. 11, the operator was interrupted at 5.04 am by a PLC request to immediately intervene on autoclave No. 13. The interruption took place during the preliminary degassing phase of autoclave No. 11 on the "Front Vacuum" system.

Upon returning to autoclave No. 11 at around 5.06 am, the operator neglected to close the degassing valve on the "Front Vacuum" system and authorised the filling operation, which directed part of the VCM to the "Front Vacuum" and caused its loss of confinement through a 14 m stack.

At the same time, the increase in pressure on the "Front Vacuum", following this accidental operation, resulted in the release of VCM in the polymerisation hall though another open autoclave on the same system. The alarm, raised at 5.09 am by the air chromatography monitoring network (probe activation threshold: 10 ppm), allowed the operator to detect his error after 3 minutes time, during which 1.6 t of VCM were released to the atmosphere.

For the moment, the concern was essentially to have created an explosive cloud that could reach unprotected zones in which possible sources of ignition could be located.

Evaluation of the consequences:

<u>EXTERIOR</u>:

The outside emission point was located at the top of a 14-metre stack having an outside diameter of 310 mm.
Considering the meteorological conditions, an evaluation of the cloud with the PHAST software indicated that:

- the LEL and UEL concentrations were within a parallelepiped H=3 m - W=3 m - L=17 m above the emission point located 14 m above the ground (a cloud there was no ignition source),
- the Lethal Effect Threshold (SEL) concentration is within a parallelepiped of H≤1 m - W≤1 m - L=2 m around the emission point, a zone in which the personnel cannot be exposed.

The Irreversible Effect Threshold zone (SEI) is not defined, as there is no longer a reference threshold for this substance since the last INERIS report on the subject published in 2000. Typically speaking, the zone corresponding to the No Effect Level (SER) of the VC: 8,000 ppm) was within the parallelepiped H=6 m - W=7 m - L=42 m above the emission point 14 m above the ground.

Finally, concentration measurements outside the platform were not conducted owing to the low levels reported on the chromatographic sensors nearest the VCM emission location following the rapid dissolution of the cloud.

<u>MANUFACTURING WORKSHOP:</u>

The chromatographic air-monitoring network detected the presence of VCM in the polymerisation hall. The maximum concentration recorded on a sensor was 2,763 ppm for less than 20 min. This network includes 10 sensors. Each of the sensors are read every 2 minutes, and for each of the 2 chromatographs.

The manufacturing shop was evacuated from 5.09 to 7.32 am.

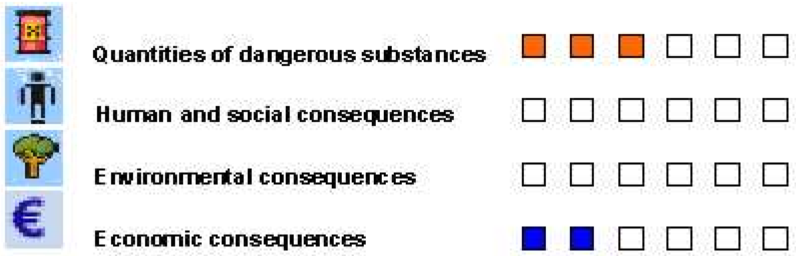
<u>OTHER WORKSHOPS:</u>

The PVDC manufacturing workshop was evacuated at 5.20 am, for 58 minutes, after VCM had been detected by the chromatographic air-monitoring network. The maximum concentration was 22 ppm for less than 20 minutes.

Given the limited characteristics of the emission, only the risks resulting from short-term exposure (acute toxicity) should be retained. The carcinogen risks associated to chronic exposure were not considered.

There were no human consequences.

EUROPEAN SCALE OF INDUSTRIAL ACCIDENTS:



The accident caused the release of 1.6 t of VCM into the atmosphere. As the Seveso threshold for this substance is 50 tons, the quantity lost corresponds to 3.2% of the threshold. The index relative to the quantities of dangerous materials for this percentage is 3 (1% ≤ Q < 10%).
The operating losses associated with the shutdown of the shop modification work was 520,000 euros and explain the index relative to the economic consequences equal to 2 (500,000 ≤ C < 2,000,000 euros).

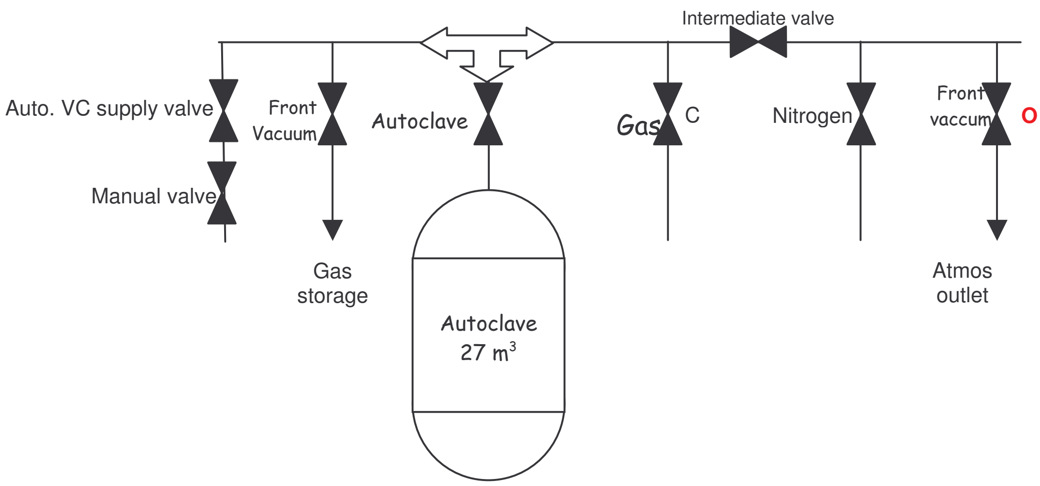
ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT:

The autoclave VCM filling sequence is managed by a PLC that ensures the following points are accomplished before authorising the fill operation:

- all the VCM supply valves of the other autoclaves are closed,
- the autoclave agitator is in operation,
- the autoclave is in a vacuum (< 0.5 bar),
- no output on the VCM supply line.

There is thus no instrumentation on the shut-off valves of the other systems (Front Vacuum, Back Vacuum, Gas storage, nitrogen, …) that is taken into consideration in the VCM loading sequence. There are procedures to check the position of these valves prior to the VCM filling operation. These procedures require that the operator allow the automatic VCM filling valve to be controlled by the PLC. However, the interruption of the operator intervening on autoclave No. 13 caused the sequence of the preliminary manoeuvres of autoclave No. 11 to be to be lost and authorised the operation when the employee returned even though the "intermediate" manual valve and the "Front Vacuum" valve were not closed.

The diagram below shows the set of shut-off valves and their position at this moment:



Causes identified:

- Cause No. 1: poorly qualified preliminary manoeuvres prior to VCM supply authorisation,
- Cause No. 2: permanent monitoring fault of the "Front Vacuum" network.

Comment: the operator performing this manoeuvre has 33 years experience in the PVC sector, including 10 years at this installation. His experience and skill enabled him to become a member of the training team for newcomers at the installation.

MEASURES TAKEN:

The DRIRE requested that the operator propose a set of immediate actions to control the preliminary operations by eliminating the identified causes and by proving the efficiency of these actions.

Secondly, owing to the polymerisation shop's low level of automation, it was requested (and reiterated by the company's committee for hygiene, safety and working conditions - CHSCT), that a working group be set up to identify all risky manual operations that could have serious health and environmental consequences, then propose the corresponding safety barriers.

Finally, inspections were conducted jointly with the DDTEFP in March, June, and December 2004 and April 2005.

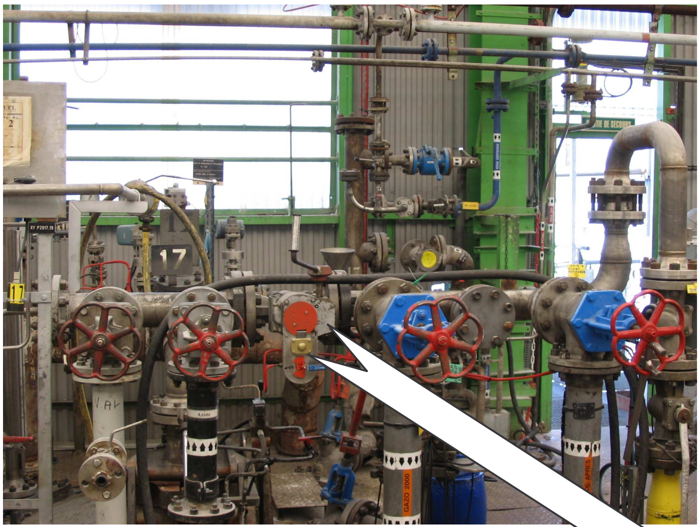
The operator immediately undertook the following action:

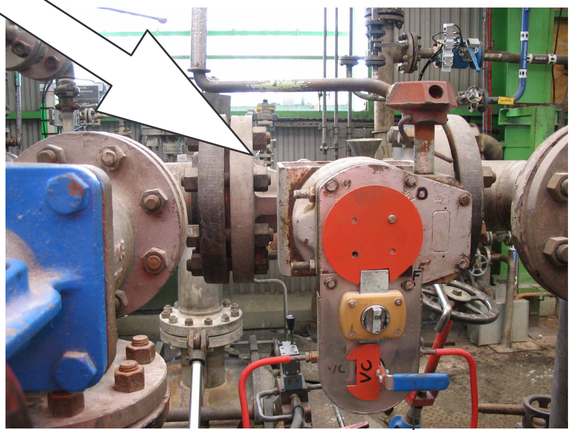
- the manual valve upline from the automatic VCM loading valve was closed and locked down with a chain and padlock (above photo). In this configuration, VCM filling is rendered impossible. In order to make this possible and enable this upline manual valve to be opened, a procedure uses this same chain to block and lock the manual "intermediate" valve closed (see previous diagram). In this configuration, the autoclave VCM filling sequence is authorised, with all expulsion rendered impossible. This control measure is limited in its objective to draw the operator's attention on the installation's configuration. It is active on all autoclaves as long as the measures taken to mitigate cause No. 2, presented below, are not implemented.

And in the short term:

- corrective action on cause No. 1: Formal documentation and recording of the qualification of preliminary autoclave start-up operations before authorising VCM filling operations. Measure established 02/12/04.
-
- corrective action on cause No. 2: study of technical measures to reinforce monitoring of the Front Vacuum network. The results of this study were submitted 02/28/04 with a lead time proposal for the 13 autoclaves:

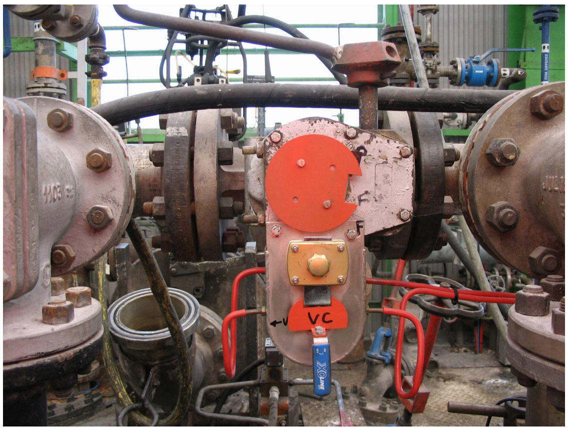
  - ❑ modification of the load control system for 04/05/04, by setting up a mechanical system which prohibits VCM from being loaded if the "intermediate" valve is not closed (see photo below):





VCM filling authorised

Valve allowing the pneumatic supply of the automatic valve of completion of CVM



VCM filling prohibited

- pressure measurement on the "front vacuum line for 03/17/04, in order to confirm the presence of VCM in the "front vacuum" network,

- fractioning of the VCM load into 2 steps: initially 200 kg, followed by a 2-minute delay before continuing the loading operation if no leak is detected. The loading operation is continued upon PLC authorisation (after the 2 min. time delay) accompanied by operator acknowledgement in the control room. The modification on the 13 autoclaves was deployed as of 04/01/04.

Cost of these corrective actions: 20,000 €, half of which was required to modify the PLC VCM load management program.

At present, several automated functions have been added to the installation:
- closing of all VCM valves on the other autoclaves,
- fractioning of the VCM filling operation: 200 kg then the remaining 10 t upon operator authorisation,
- checking that the intermediate valve is closed.

Medium and long term:
- Organization of a 7-person task force made up of workshop personnel, members of the CHSCT (committee for hygiene, safety and working conditions) and another neighbouring workshop, with the group being run by the shop supervisor. The task force's objective is to initially list all the manual operations that could create an accidental situation in which VCM is released through all possible systems, then, secondly, implement the corresponding barriers to mitigate human error on the operations identified.

The task force, which meets 2 times per month for 2½ hours, structures its approach through the AMDEC method. In its analysis, at the request of the manager, the task force also included transitory phases, particularly maintenance steps that include many manual operations.

An initial report regarding the implementation of this recurring action plan was carried out with the DRIRE on April 5, 2004, followed by 3 meetings held in conjunction with the labour inspector. In addition, the CHSCTs were kept informed of the task force's work. The inspectors of the DRIRE and the DDTEFP, recipients of the CHSCT reports, were also informed.

In all, the task force identified 39 manual sequences that could result in loss of VCM confinement. The sequences were the subject of proposals for technical barriers, possibly declared as being safety-related, and completed by organizational barriers in certain cases.

The group met 15 times and established the action plan based on the proposals retained during the AMDEC analysis. These proposals will cost approximately 150 k€ and are scheduled for 2005.

Joint Labour Inspectorate / Classified Installations Inspectorate intervention:

A joint Labour Inspectorate / Classified Installations Inspectorate study was conducted:
- owing to the nature of the accident involving a new VCM leak, categorized as carcinogen (R45), on an installation of the Tavaux platform. The previous leak, which occurred in 2002 on a different installation, had already been subject to a joint inspection operation.
- due to the operator being put aside.
- because the CHSCT rapidly requested a special meeting about this incident.

Action of the CHSCT:

A special meeting was held 03/03/04, in which the presence of the Labour Inspectorate and the DRIRE was requested. According to the members of the CHSCT, this installation had the following characteristics:
- a former job site, the shut-down of which had been announced several times,
- a significant workload for the personnel, workshop P69 had a high production load.
- personnel understaffed (with, according to management, many individuals on long-term sick leave).
- A high level of stress among the personnel, working with the fear of making a mistake,
- insufficient security, the control of the operations was based on procedure logs in which the operator must check off the operations performed one by one successively during a production cycle. The studies showed that this procedure did not guarantee the site a sufficient level of safety and, to a certain degree, places the responsibility on the personnel in case of an incident.

The CHSCT was instructed to conduct an internal assessment with the personnel*** in order to:
- analyse all tasks performed at P69 (start-up, shut-down, normal and downgraded operation),
- record all operating methods,
- identify the risks involved in the VCM atmosphere,
- analyse the impact of the workplace organization on the order in which tasks are performed,
- identify the factors which could have an influence on the personnel's working conditions.

This decision was in addition to that taken by the operator on 02/16/04 during the meeting with the DRIRE for the presentation of the short-term, medium and long-term action plan, namely, for the latter:
- record all operations in which there is a risk of VCM to the atmosphere (during operation, maintenance, downgraded operation),
- find and implement technical and organizational.

➢ An internal task force was created with the participation of the personnel concerned and certain members of the CHSCT who were particularly familiar with the P69 installation.

This task force, defined during the CHSCT meeting of 03/11/04, included:
- 1 person in charge: the PVC Suspension (PVC S) manufacturing supervisor
- 2 PVC S personnel: the P69 / P79 production manager and the P57 autoclave operator
- 4 members of the CHSCT.

The task force's specifications, defined on 03/11/04, include the complete analysis of the polymerisation operations from the start-up of the autoclave to the transfer to the final slurry tanks (obtaining of the PVC to be dried, after treatment of the excess gaseous VC), by including the operating and maintenance operations:
- to define the barriers concerning the possibilities of venting the VC to the atmosphere,
- to check that the procedures and manoeuvres are adequate with the workplace organization.

In the end, the task force held fifteen 2½-hour meetings over a period of 8 months, with:
- meeting minutes,
- regular presentations of the work to the manager and to the members of the management of the P69,
- task force progress reports during the quarterly meeting of the sector's CHSCT,
- regular presentation of the current work to the personnel of the 5 stations,
- validation of the technical solutions proposed by the STI Manager ("Sécurité Technique et Intervention", technical safety and intervention department).

➢ This demonstrates the involvement at all levels.

The STI Manager stipulated that the objective of all the technical barriers set up or to be implemented is to create new alarms designed to assist in controlling the installations. They should provide the operators a certain level of assistance and prevent them from being apprehensive about possible errors.

Furthermore, the PVC Manager, in charge of the P69 site, decided not to launch a cycle during the 15 minutes preceding a shit change (which was not the case prior to the incident).

In the end, the task force work was considered to be satisfactory with:
- operations conducted by the production foreman,
- constructive presence of the members of the CHSCT,
- the use of a finite and systematic analysis method (AMDEC),
- discussions with the sector's personnel and regular meeting with these individuals,
- implementation of solutions on an autoclave used as a prototype, prior to widespread use,
- review of procedures and rewriting of procedures, including the clarification of the shift change phase (2 people were designated in each shift to make the link, written instructions, record sheet, no batches started less than 15 minutes prior to a shift change).

Interest and success conditions of such an approach (task force + AMDEC):

- participative approach, with discussions with the personnel ⇨ involvement of the personnel, notably with regard to the respect of new procedures and new operating methods,
- finite and systematic analysis of tasks and risks (AMDEC method),
- internally-designed solutions:
    - the personnel now have a sense of security, the barriers implemented have done away with the possibility of making a mistake and the procedures were completely reworked. The personnel is now reassured.
    - a large psychological impact on the personnel from which a reduction stress and feelings of insecurity can be expected by the employees of workshop P69.

During discussions with the personnel representatives about the interest of this task force, it appears that the conditions for its success were based significantly on a particular condition. The task force was created following an incident and its work was followed very closely by members of the CHSCT, DRIRE and the Labour Inspectorate.

This context allowed the operator to become aware of the risks presented by these manual operations and to rapidly implement technical and organisational solutions.

Finally, it appears that the opinion of the Labour Inspectorate, the collaboration of DRIRE/Labour Inspectorate allows the members of the CHSCT and all employees of workshop P69, to learn more about the missions performed by DRIRE inspectors who were previously perceived as being an authority in charge of handing out sanctions.

LESSONS LEARNED:

The human factor:

- A procedure and, more generally, the organisational barriers do not by any means prevent the risk of human error and cannot alone be considered reliable safety barriers with regard to the stakes involved for both man and the environment,
- The certification of the personnel is not an end in itself and is thus a safety barrier with a low level of reliability (the operator was also a trainer),
- The task force's results show that it is advantageous to conduct a risk analysis that includes the field personnel, notably when the installation have little automation and includes manual operations that could lead to significant accidents. The involvement of the field personnel demonstrated the efficiency and complementarity in the risk analysis for the "VCM loss of confinement" event. The work will be included in the danger study that is scheduled to be updated in late 2005.
- Involving the field personnel in this project allowed the operator to tap previously unknown skills among the personnel and, as a result, was able to put them to good use. In fact, a company employee and not a technical department employee who deployed the modifications to be made on all the autoclaves. Finally, the operator will promote this example to spearhead a company innovation program.

Concerning the installation:

- When an installation's level of automation is low and includes risky manual operations, this experience shows that an installation can be secured by simple and efficient technical measures (physical or positive security measures without systematic automation). This project, which is essentially based on the implementation of technical barriers instead of organisational barriers, showed that it is possible to automate the management of safety measures without automating the operation of the installation.

Given the satisfactory results obtained, the head of the PVC department will present the platform managers the approach (advantages and drawbacks) and the solutions implemented (scheduled for late June 2005). The operator has set an objective to deploy this method on the installations where this approach is pertinent.

Chlorine leak in a liquefaction workshop of a chemical plant

January 13, 2004

Vieux-Thann – [Haut Rhin] France

Electrolysis
Liquefaction
Hydrogen
Chlorine-Iron reaction
Re-start
Confinement

THE INSTALLATIONS IN QUESTION

The site

The plant specialises in the fabrication of chlorine, and chlorinated and brominated products. It is governed by the "high threshold" of the Seveso directive. The plant is located in an urbanized zone.

Part of the chlorine produced in the manufacturing facility by mercury-cathode electrolysis (200 t/day) is used on site. The other part is liquefied and loaded into rail cars or stored in an 11-m^3 tank. The installations containing liquid chlorine are located in closed buildings equipped with a ventilation system and a neutralisation tower to process any accidental releases. A prefectorial order required the company to adopt this confinement installation in 1995.

The unit concerned:

The chlorine coming from the electrolysis facility is compressed and condensed, and then the gas and liquid phases are separated in a floatation pot-type separator. The liquid part is then directed to the storage facilities or to the loading installation. The non-condensed part (referred to as residual gases), containing gaseous chlorine and non-condensable gases (notably H_2 and air) is distributed on site. As the liquefaction rate increases, the concentration of non-condensable gases in the residual gases also increases (the enrichment factor is [$1/1-\tau$]). As such, if 50% of the chlorine is liquefied, the concentration of the non-condensable gases in the residual gases doubles, but is multiplied by 10 if the liquefaction rate is 90%.

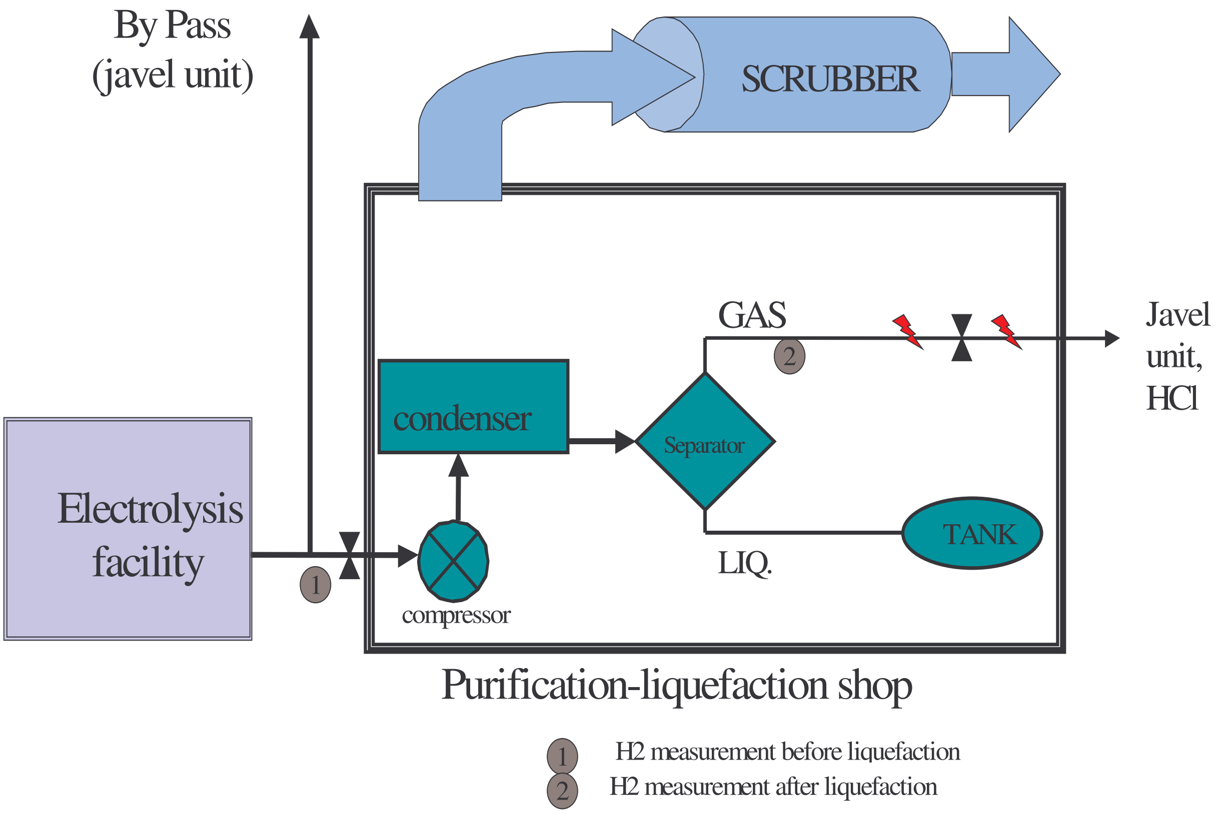
The presence of hydrogen and inert gases, inherent to the chlorine manufacturing process, is particularly important during the installation restart phases, notably after long shutdown periods.

It should be reminded that hydrogen and chlorine react violently, producing hydrochloric acid.

The presence of hydrogen in gaseous chlorine thus requires a that certain number of precautions be taken, including monitoring the changes in its concentration in the installations to ensure that it remains below the lower explosive limit (LEL). The hydrogen contents are measured at the electrolysis shop's outlet and in the gas outlet of the floating pots by means of an automatic analyser, or by manual analysis.

The company's internal procedures require that a maximum hydrogen concentration of 4.7% be respected in the residual gases. The LEL of the chlorine-hydrogen-air mixture is 5% (source: INRS).

The automatic hydrogen analyser is inoperative during the installation's start-up phases due to the excessive quantity of inert gases present. For this reason, during installation start-up operations, the operators perform manual concentration measurements (a measurement every ten minutes, according to the procedures).



THE ACCIDENT, ITS BEHAVIOUR AND CONSEQUENCES

The accident:

In the morning of January 13, 2004, the electrolysis installations were being started after having been shut down due to a lack of cooling water. During the first start-up phase, the chlorine produced is sent directly to the Javel (bleach) unit.

At 9.15 am, the concentrations measured leaving the electrolysis unit at analysis location No. 1 (1.3% H2, 80% Cl2) enabled the liquefaction part of the workshop to be put back into service in accordance with the company's internal procedures. Chlorine production was 1,600 kg/h, the output of residual gases 600 kg/h and the hydrogen concentration in the residual gases 3.3% (analysis location No. 2).

The electrolysis facility's production level was progressively increased to 2,900 kg/h. A new series of measurements at the "residual gases" outlet of the liquefaction facility at analysis location No. 2 showed an initial concentration of 4.6% hydrogen in the residual gases. The measurement conducted ten minutes later gave a value of 6.7%. Noting this value, the operator immediately performed the analysis again, which confirmed the first analysis.

The operator then decided to reduce the liquefaction rate by increasing the output of residual gases to 1,000 kg/h in order to lower the hydrogen concentration.

Immediately afterward, a leak was detected at 10.10 am by the alarm and visually in the building. The operators initiated the emergency shutdown; the confinement installations were automatically put into service and directed the majority of the leak to the neutralisation tower.

The majority of the chlorine released by the leak was neutralised in the tower. The operators secured the installations then grouped together to locate and were able to completely isolate the leak in 20 minutes.

The consequences:

No employee or resident of the area was injured. A pipe was damaged in three locations. The quantity of chlorine released into the confinement building was indirectly estimated at 600 kg. The quantity released into the environment was limited to just a few kilos while the confinement building was depressurizing. Nearly all of the chlorine leaked was treated in the neutralisation tower for accidental releases.

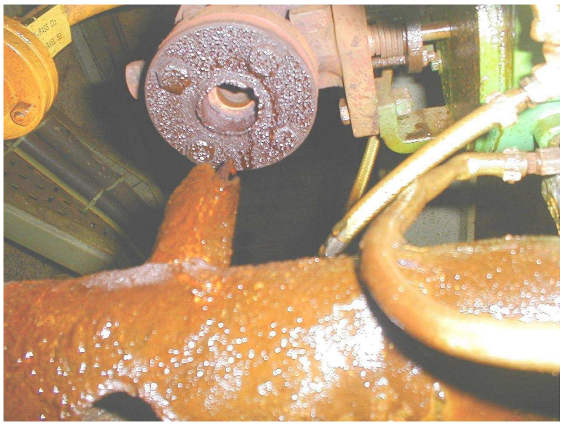
European scale of industrial accidents:

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. The parameters, which 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

Quantities of dangerous substances	■	■	■	□	□	□
Human and social consequences	□	□	□	□	□	□
Environmental consequences	□	□	□	□	□	□
Economic consequences	□	□	□	□	□	□

The 600 kg of chlorine from the leak represent 2.4% of the corresponding Seveso threshold (25 t) and result in a level 3 rating in terms of the "quantities of dangerous substances" according to parameter Q1.

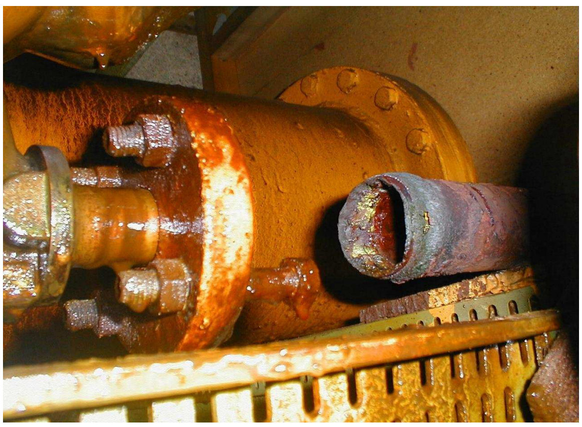
ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

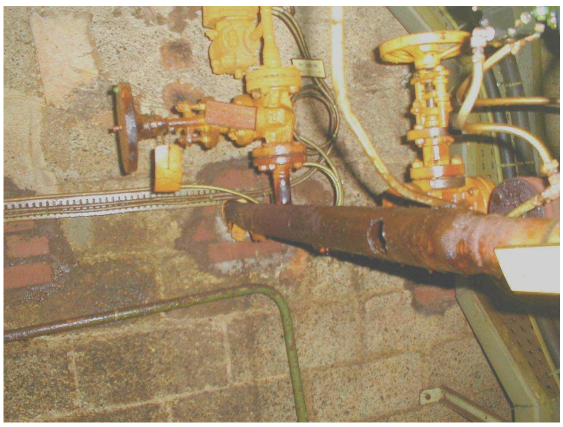


The expert assessment conducted immediately following the incident showed that the leak, located along the limit of the confined zone, resulted from the combustion of the steel in the chlorine on a pipe transporting the gaseous chlorine: at two locations (located near zones in which the pipe size was reduced: valve and venturi), the pipe had disappeared over several centimetres, including a flange. A hole of diameter equal to that of the pipe (8 cm) was created in a third location.

The combustion of steel in chlorine is a process that is initiated when the steel is brought to a temperature above 130 °C. Once this reaction begins, it is self-sustaining until all the chlorine has been consumed.

The operator identified the cause of the iron/chlorine combustion process as a hydrogen-chlorine fire whose ignition energy is sufficiently low to start spontaneously due to an output restriction or a significant flow rate. The increase in the output to 1,000 kg/h could have also supplied the ignition energy required.

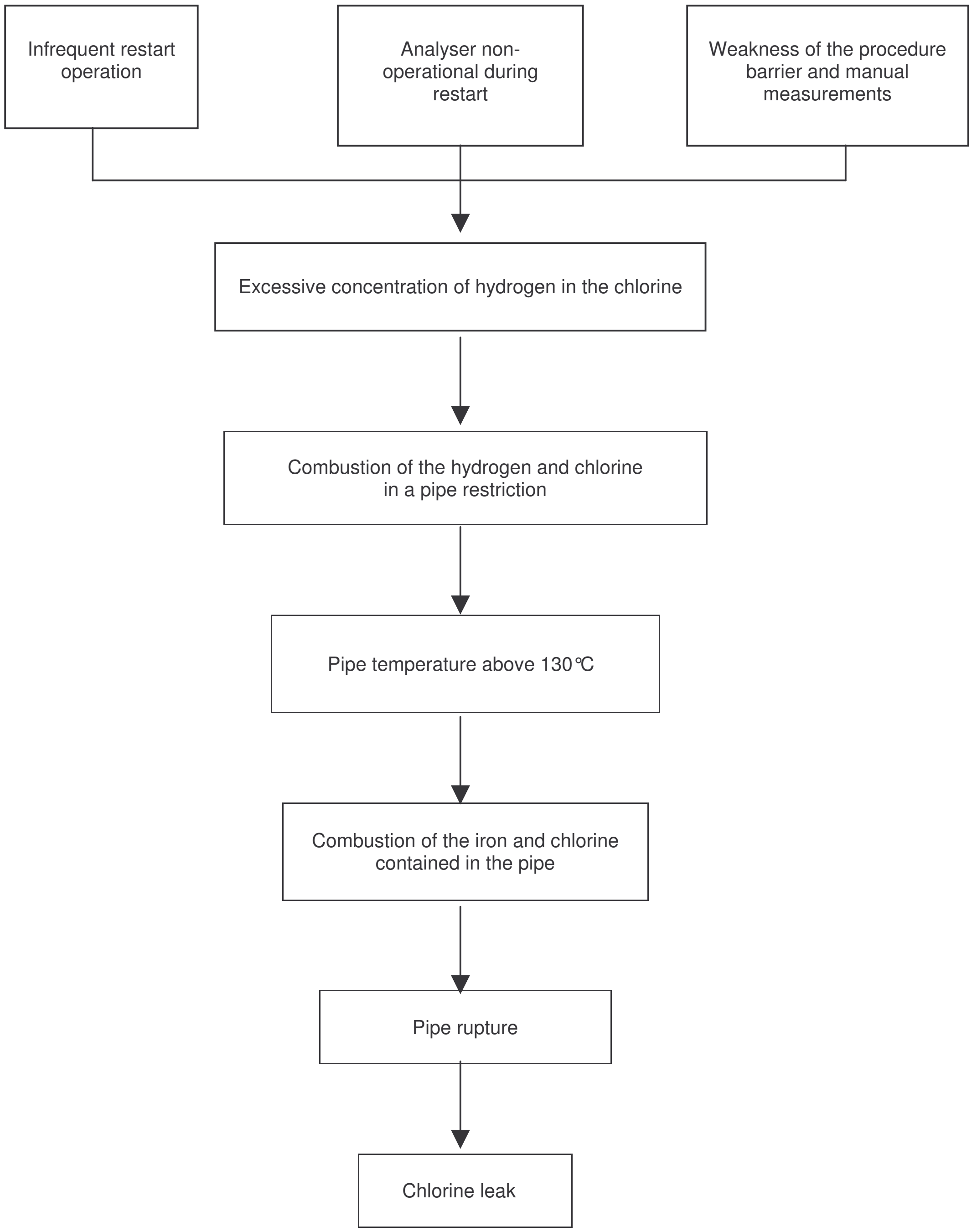




The value of the hydrogen concentration leaving the electrolysis facility and the liquefaction rate could only result in the LIE being exceeded (the hydrogen enriching factor being 5 just prior to the accident) as soon as the operator did not act immediately when he measured a concentration of 4.6%.

The non-operation of the automatic analyser and related safety devices during the start-up phases made the security of the installations rely only upon action by the operators, who are particularly busy during the rare start-up phases. This point was brought up during the last risk analysis of March and December 2003, when the operator was searching for a new analyser.

This incident can be broken down in the following manner:



ACTION TAKEN

Besides the verification of the installations and the replacement of damaged parts, several actions were implemented to prevent the incident from happening again:

- A material assessment was set up to monitor the hydrogen concentration in the residual gases according to the liquefaction rate and the hydrogen content at the electrolysis facility's outlet.
- Implementation of two continuous hydrogen analysers that can be used in the presence of inert gases (cost: 150,000 euros).
- Supervision of start-up phases by a manager.
- Modification of the instructions.
- Re-examination of post-accident actions.
- The installations are shut down if the hydrogen concentration is exceeded by more than 3.5%.

LESSONS LEARNED

The main feedback elements to remember concern:

- The correct operation of the confinement installations during an incident without the building increasing in pressure.
- The guillotine rupture scenario that is not a textbook example.
- The analysis of transitory phases and the specific security arrangement to be implemented and not neglected.
- The weakness of the operator barrier associated with the instructions that were not necessarily explicit (the number of measurements, respect of the limit concentration of hydrogen in the residual chlorine, shut down of the electrolysis facility).
- An organisation to be improved through the modification of instructions and better operator training as well as the reinforcement of the supervisors' role during delicate phases.
- The relatively significant delay in isolating the leak (20 min.) following problems relating to the intervention and locating the leak in a building in a chlorine atmosphere.
- The drainage of upline and downline chlorine systems by depressurisation, particularly concerning the 11 m^3 liquid chlorine storage tank which supplied the leak for 5 minutes until it could be isolated.
- The low ignition temperature of combustion between iron and chlorine (130°C).

Overpressure in a chemical reactor in an organic synthesis workshop

March 23, 2004

Montluçon – [Allier 03] France

Gaseous release
Chemistry
Cyanide
Pressurised equipment
Burst disc
Valve
Field of safety

THE INSTALLATIONS AND OPERATIONS CONCERNED

The chemical plant belongs to an industrial group that federates small independent structures, including 7 production sites in France. The Montluçon site, located in an urban zone, has a workforce of 56 people. It is dedicated to products for the pharmaceutical and electronics industry, which little by little are being substituted for agrochemical products. The plant has two synthesis shops called "organic synthesis shop I and II" equipped with multi-purpose equipment representing a total reactor volume of approximately 115 m^3, a finishing workshop (drying and crystallisation) and various storage facilities.

The accident took place in organic synthesis shop I. While relatively old and small (420 m², roof peak height 13 m), this multi-purpose shop houses 8 reactors and all the utilities (steam, cooling plant, neutralisation tower, fire detection and automatic extinguishing system) and conducts a large number of traditional organic chemical operations in aqueous environments or in solvents as well as physical-chemical operations.

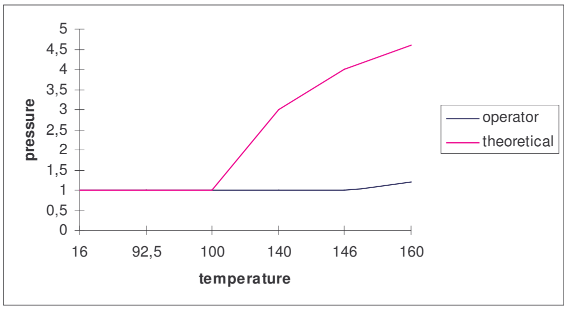
THE ACCIDENT, ITS BEHAVIOUR AND CONSEQUENCES

The accident:

On March 23, 2004 at 2 pm, the R201 reactor was loaded with the effluents from the neutralisation tower contained in the 3 tanks, for total of 4.4 m^3. A cyanide concentration of 6 ppm is analysed on one of the tanks.

At 3.40 pm, when the load was finished, the operators opened the steam circulation in the double walled reactor to heat up the environment. The operators' readings on the increased temperature of the reaction environment and the pressure indicated on the pressure gauge were as follows:

- 3.40 pm T= 16℃ P = P atmospheric
- 5.00 pm T= 95.2℃ P = P atmospheric
- 6.30 pm T= 146℃ P = 1 bar
- 7.30 pm T= 160℃ P = 1.2 bar



As the pressure setpoint had not yet been reached, the operators did not stop the steam heating of the reaction environment. As shown on the graph, they did not react to the inconsistency of the values between pressure and temperature.

During the 7.30 pm reading, just prior to the accident, an operator noted a leak on the reactor's manhole and tightened its bolts without giving any thought to this indirect alarm signal. The burst disc ruptured 3 minutes later, releasing steam into the workshop; part of the fibrocement roof was blown away.

The 3 operators present, standing about 20 metres from the reactor, evacuated the workshop after a short lapse of approximately 10 seconds due to the surprise.

It appears that the noise of the steam exiting via the ruptured disc could be heard for 2 to 3 minutes. After this period, the operators entered the workshop, secured the reactor (heating and insulation shut off) and ventilated the area (extractor).

The volume of water transformed into steam and lost in the accident was 1,350 litres.

The consequences:

Roof damage

The direct consequences are uniquely equipment:

- ✓ one rupture disc destroyed,
- ✓ some pipe jacketing was destroyed,
- ✓ a few m² of fibrocement roofing blown out (see photo).

The damage was evaluated at 8 k€.

The environmental consequences were low: the cyanides were completely destroyed (not detected in the reaction environment residue) and the measurements conducted on the gaseous atmosphere and in the environment showed no trace of hydrocyanic acid. Note: the concentration in the effluents to be treated were already low (6 ppm).

The human consequences were also low. The operators, surprised by the explosion, were shocked, but decided not to go to the hospital as the public emergency services had suggested. Retightening the manhole could have lead to much worse consequences for the operator. Despite the shop's relatively small surface area, the operators were located a distance from reactor R201 at the time of the explosion. This distance explains why they were only slightly affected.

As the explosion was perceived outside the site, the public authorities were initially alerted by calls from residents. The Montluçon firemen arrived in 11 minutes (from the time of the explosion to their arrival at the site) with considerable means: two fire trucks, a ladder truck and a chemical hazards vehicle. The Montluçon municipal police blocked the access road to the site and evacuated the neighbouring sports facility for 30 minutes, the time required for the atmospheric measurements to determine that no pollution was present. An assistant Mayor and the Montluçon Deputy-Prefect arrived at the site.

The management of the post-accident crisis aimed at controlling the media and social consequences which would have damaged the acceptance of the activity by the residents.

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.

The parameters which 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

Quantities of dangerous substances	☐	☐	☐	☐	☐	☐
Human and social consequences	☐	☐	☐	☐	☐	☐
Environmental consequences	☐	☐	☐	☐	☐	☐
Economic consequences €	☐	☐	☐	☐	☐	☐

The chemical substances at cause are not classified under terms of the SEVESO directive and the accident had no sufficiently significant consequences to be rated on the European scale for industrial accidents. The evacuation of the zone and the nearby sports facility for less than 2 hours has no impact on the 'human and social consequences' indices (criterion H7). Furthermore, the evaluation of internal property damage was less than 100 K€ (criteria €15).

ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

Circumstances:

The damaged reactor is the R201. It was new at the time and had been installed in the workshop since the summer of 2003. In compliance with the operator's specifications and according to regulations, the equipment was delivered without equipment or safety devices.

The operator is thus responsible for choosing and installing accessories.

When installed, the following safety equipment was installed on the R201 reactor:

- a valve (6.3 bar) (at this pressure, the saturated steam output is 1,800 kg/h, or approximately 30 kg/min).
- a rupture disc (6 bar, ND 150 mm) (at an operating temperature of 20°C).

They correspond to overall consideration of the protection of the reactors throughout the site against overpressures and represent a standardised technical solution.
At the time of the accident, the piping downstream from the R201's rupture disc had not yet been connected to the "crash tank" network of organic synthesis shop I. Only a tubular element measuring approximately one metre in length extended the branch connection vertically.
The establishment was granted prefectorial authorisation (AP No. 2168/93 dated May 11, 1993) which sets a daily release limit for the cyanides, in terms of concentration at 0.001 mg/l and flow at 14 g.
Before releasing wastewater that could contain cyanides into the community network, the operator analyses the concentration, and processes the water by a process that lowers the cyanide content, as required.

To do this, the effluents undergo thermal treatment for a few hours in a soda environment (NaOH) in order to downgrade the cyanide radical C⋮N. The water from the neutralisation towers is introduced into a reactor with the soda, then maintained at a certain temperature for 2 hours under a pressure kept at 3 bar. This operation (required only 4 to 5 times per year) was not considered to be dangerous and no special instructions were issued.

Three operators were at their workstations in the shop at the time of the accident. The operations in progress on reactor R201 showed normal operation of the workshop, without no special aspects. However, this relatively basic operation (increase in temperature of the environment and hold for 2 hours) is not frequently performed.

Causes:

The fault tree established by the operator indicates two main causes and aggravating events:

- As the pressure gauge used by the operators to control reactor steam heating was plugged in an elbow, they did not have correct pressure information. As reactor heating was controlled from this information, the operators didn't stop the heating, letting the pressure increase in the reactor.
- As the valve was calibrated at a value greater than the burst pressure of the rupture disc, the reactor was not decompressed by the value prior to the burst disc rupturing.
- The lack of a collection pipe from the burst disc aggravated the situation.

On March 30, 2004, the Classified Installations Inspectorate and the labour inspectorate noted two question points:

1st point (technical): Reason why the valve didn't work? Possible design errors?

2nd point (organisational): why didn't the operators detect the alert signals? An hour before the accident, an operator recorded the temperature and the pressure without realizing that the two parameters were incoherent. When faced with a manhole leak, the first reflex was to tighten the screws on the lugs without checking if the manhole had been correctly closed and to determine if this leak was logical in relation to the observed low pressure of 1.2 bar.

This operator's reflex demonstrates a lack of knowledge of the hazards of pressurised equipment. By retightening the nuts, force is put on the lugs which are already under stress from the pressure inside the reactor. When a lug ruptures, the stress spreads to the remaining lugs, the entire manhole is weakened successively and may break. The risk of injury is high for the operator doing the operation. In addition, the increase in pressure was not stopped; on the contrary, as the leak output was eliminated, the pressure in the chamber continued to increase.

The safety equipment installed during the installation of reactor R 201 in late August / early September 2003 in workshop S1, included:

- a valve (6.5 bar)
- a rupture disc, 6 bar (20°C).

As the two triggering threshold values are very close, it is difficult to predict, in the case of a pressure increase, which equipment will operate first, considering the precision of the calibrations and the variations of the rupture disc thresholds with the temperature.

The design of the overpressure protection and the choice of safety devices comply with regulation requirements in terms of performance characteristics. The operator set up standard protection for its reactors without looking any further. A more detailed study and in-depth reflective thinking would have discovered this design fault.

The causal tree submitted by the manufacturer emphases only the technical problem. The joint report (drafted by the Classified Installations Inspectorate and the Technical Inspections Division), and Labour Inspectorate, which goes further in the analysis, underlines the design problem (dimensioning of overpressure safety features) and inappropriate reaction by the operators who should have reported the warning signs of the danger:

✓ A design anomaly of the safety features:

The design of the overpressure safety devices for all of the site's reactors is based on the choice of standard protection of -1/+6 bar founded on the service pressure requested by the pressurised equipment manufacturer. Generally, the syntheses are conducted at atmospheric pressure; on all the manufacturing operations listed, only 6 phases are conducted under pressure.

× The trip thresholds of both devices are close and no preventive reflective thinking about their operation was carried out, thus no clearly established defensive strategy was established.

× The trip thresholds of both devices are near 6 bar, although the nominal pressure of the reaction is two time less (3 bar).

× The rupture disc's discharge pipe must be connected to the workshop's discharge network.

✓ Faulty operational control:

× The operators controlled the rise in temperature from a faulty pressure indicator. They regularly record the temperatures and pressures in the reactor, without analysing them, and did not notice the inconsistency between the two parameters.

× The operators did not react to the alarm signals, nor to the abnormal duration of the pressure increase and the manhole leak.

ACTION TAKEN

A report from the Classified Installations Inspectorate, the Technical Inspections Division (DRIRE) and the Labour Inspectorate, dated June 21, 2004, was forwarded to the District Attorney.

The causes of the accident were clearly established, the Classified Installations Inspectorate and the Technical Inspections Division also sent the report to the operator including a letter stipulating that several actions be performed:

✓ Personnel information:

- × the report was sent to members of the CHSCT (the committee for hygiene, safety and working conditions), and the Inspectorate requested that the document be presented at a CHSCT meeting so that the entity could give its opinion.

- × the Inspectorate also requested that the personnel training programmes and the reminders designed to improve the behaviour and knowledge of the operators as a result of the feedback about this accident also be presented to the CHSCT.

✓ Reminder of pressurised equipment regulations (ministerial decree of March 15, 2000):

- × the Technical Inspection Division requested that the operator correct the lack of thoroughness in the application of the regulations concerning pressurised equipment, revealed by the accident. Article 8 establishes strict obligations: "the personnel in charge of operating pressurised equipment must be informed and competent to monitor and take all initiative required for their safe operation" and "the personnel must be deemed fit to operate pressurised equipment and periodically tested in this position".

- × the Technical Inspections Division also requested that the operator provide the Inspectorate a schedule to meet the obligations of Article 6, paragraph 5 "required measures must be taken so that the release of fluid possibly caused by their operation (Editor's note : in this case, it concerns the operation of the rupture disc) is not hazardous".

Following the incident and the meeting to establish the causal tree, the operator immediately implemented an action plan. This plan called for verification of the valve opening pressure calibration on all reactors and their verification during preventive maintenance operations, as well as an inspection of all rupture discs. This action, conducted in the following days, did not highlight any anomalies. Other actions were subsequently conducted.

- × A procedural modification introduced the monitoring of reactor operation based on two pieces of available information (pressure and temperature) and not just one (pressure). The procedures were also modified to include fail-safe verification of the reactor's pressure gauge with that of the supply line during the nitrogen leak tests prior to loading.

- × At the request of the Classified Installations Inspectorate, the operator listed all of the reaction phases performed under pressure. The operator decided to implement a fail-safe configuration to measure the pressure on all reactions identified.

- × The work enabling any fluids released by the rupture discs to be collected in a crash tank was scheduled for the summer of 2004.

Following the report by the Classified Installations Inspectorate in late June and the work performed, the operator completed its action plan by providing its operators basic training to enhance their skill levels. 30 operators should benefit from this training in 2005.

Finally, the operator undertook in-depth reflective thinking on the defensive strategy against overpressure in the reactors. As such, for reactor R201, after having analysed the operating conditions under pressure and temperature through laboratory work, the operator defined the rupture disc [bursting pressure: 6 bar at 120 °C] as the reactor's ultimate protective barrier. The valve calibration, defined at 5.3 bar, is used to discriminate the trip thresholds. The valve must thus operate first and limit the internal pressure thereby giving the operators enough time to intervene. The design work of the safety accessories thus had to be performed *a posteriori*.

Lastly, the company changed its effluent treatment method; it no longer uses the pressurised phase to destroy traces of cyanide.

LESSONS LEARNED

Although very basic, the elements of feedback to be retained should be indicated:

✓ **Design safety devices according to the safety objectives:** this means having a defined strategy, subordinate to the safety objectives. Just respecting the regulations (for the pressurised equipment in our case) is not enough. The good strategy consists in defining the equipment's field of operational safety and the objectives to be reached for the safety barriers, then and only afterwards, select and design the components of these barriers in order to reach these objectives.

✓ **The control of all dangerous operations must not rely on a single system:** systematising the fail-safe configuration on all control-related parameters or promoting the breaking down of safety barriers for defence in depth, but always consolidating its operational safety without encumbering it or putting it off balance, remains a real permanent challenge for all players.

✓ **The place of the human factor in industrial safety, from design to operation:** this incident once again shows how important the human factor can be. From the selection of safety equipment used on the reactor to the skill level and availability in the manner to run it, man is at the core of the essential decisions.

Refining

Road-tanker loading facility

LPG

Flash

Fatality

Threade-coupling loading-arm/road-tanker

Material failure

Management: periodic inspections

LPG release and flash in the LPG road-tanker Loading facility of a refinery

23rd of April, 2004

Germany

THE INSTALLATIONS IN QUESTION

The accident took place in a LPG road-tanker loading facility in a refinery. The picture gives a glance on this kind of installation.

On the site involved, for a loading operation, the LPG tanker is connected to the loading installation via a jointed loading-arm. Loading is carried out under "spray loading", in which the liquid phase is pumped through the foot valve into the vapour phase of the road-tanker's tank. No vapour phase exchange takes place.

THE ACCIDENT, ITS BEHAVIOUR, EFFECTS AND CONSEQUENCES

The event:

At 7h30, as 15 t of LPG had already been loaded, there was a spontaneous separation of the connection between the loading-arm and the vehicle at the threaded coupling. This lead to a release of LPG, which ignited and engulfed the driver. The force of the separation was sufficient to propel the loading-arm backwards until it impacted with the housing of the loading station. This lead to the activation of the "pull-away" quick release coupling and the flow of LPG from the refinery was stopped.

The fire melted the pneumatic hose for the foot valve of the road-tanker and the pneumatic valve closed, stopping the release of LPG from the tanker

The consequences :

The driver, who was engulfed by the fire, died a number of days later as a result of the injuries received. The size of the release was estimated to be about 20 litres (ca. 10 kg).

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.

The parameters which 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

Quantities of hazardous substances

Human and social consequences

Environmental consequences

Economic consequences

ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

Material failure :

The investigation carried out after the accident showed that the cause of the LPG release was the failure of the threaded coupling. A closer inspection showed that the 3¼" ACME threaded coupling was extremely badly worn. The trapezium cross-section of the thread of the threaded ring was worn so badly, that it was reduced to a triangular form. The fitting (road-tanker) was worn so that it was slightly conical. The connection was therefore extremely instable. This meant that even vibration or a slight movement of the loading-arm could have been sufficient for the connection to fail.

Examples of worn threaded coupling : road-tanker fitting and threaded ring

Practice failure :

Clearly visible on the threaded ring was the deformation caused by hammering the lugs (ears) with a hammer to tighten the coupling. This practice was common place. However hammering has a number of effects including: the thread may be worn by over-tightening or the ring may become deformed (oval).

Near to the loading-station a wrench for tightening the coupling was found on the ground, so it can probably be discounted that this driver had tightened the coupling by hammering in this case.

ACTIONS TAKEN

This accident had immediate consequences for the LPG-industry throughout the State of Baden-Württemberg. A state-wide inspection programme was immediately started. The aim was to identify all couplings and fittings which were "at risk" of being in a damaged state. All LPG distributors were inspected, as were LPG Storage tanks with a storage volume of 15 tonnes or more. LPG tanks which were known to have a frequent filling interval, where more wear could be expected were also to be inspected. All LPG road-tankers which were found were to be inspected, however most of the specialist haulage firms are based outside of Baden-Württemberg.

Due to the risk of similar events information was exchanged with a wide range of authorities and organisations. These included the State pollution control authorities and the authorities responsible for machinery safety, the German LPG trade association (DVFG), the Federal environmental agency (UBA) and the central reporting body for major accidents in Germany (ZEMA), the Federal Association of Hauliers and Storage companies (BSL), the Association of technical inspection bodies (VdTÜV), the Mineral oil trade association (MWV), and the colleagues in the local authorities across our international borders (DRIRE-Alsace, KCB-Basel-Landschaft, Sicherheitsinspektorat Basel-Stadt).

The technical regulations covering the handling of pressurised gases, in particular the technical regulation gases (TRG 402) regarding filling installations – operation of filling installations are the relevant regulations for this time of installation. Number 8.2 concerns the testing of manoeuvrable piping (hoses and jointed pipe-work). One of the most important aspects of the testing is the visual inspection of the outer-surface and as far as possible the inner surface with regard to their condition.

The Factory Inspectors who were instructed to carry out the immediate inspection programme were provided with a list of visual indicators to assess whether a potential hazard existed or not.

The thread was to be investigated with regard to the thread profile, damage to the thread (flat points, pitting, broken threads. Also damage to the lugs ("ears") of the threaded ring which indicate that the coupling had been tightened by hammering was to be identified.

In the course of the investigation and communication with the UK LPG Association a further testing possibility was discovered. The use of Go / No Go Gauges allow a quick assessment of the degree of wear of the threads of both halves of the coupling. The function is extremely simple. The gauges allow maximum 1 turn of the thread for threads which are OK, worn threads allow more than one turn. The threaded ring which was involved in the accident was so badly worn, that the gauge could travel four turns.

Initially within the inspection programme there were no clear criteria for assessing the quality of the couplings, so it was necessary to rely on the expertise of the factory inspectors.

The results of the inspection programme were as follows:

✓ In no single case was serious wear on the ACME-threads of the LPG storage tank fittings identified.

✓ In a few individual cases minor wear was identified. In these cases the fittings were replaced as a precaution by the operator.

✓ In a few cases signs of hammering could be identified on the threaded ring of the coupling, although the thread itself showed no signs of damage. The operators were required to ensure, that in future the coupling was no longer tightened using a hammer – as was common practice in the past.

However it was also reported that several operators were already informed by their LPG supplier and had already replaced the relevant fittings in their installations as a precaution. It is not possible to say afterwards, whether a fitting that has been replaced had signs of excessive wear or not.

LESSONS LEARNED

From this event, the lessons to be learnt are rather simple:

✓ to make sure that in the future, the coupling was no longer tightened using a hammer – as was common practice in the past.

- ✓ to carry out regular visual checks or testing device
- ✓ Importance of the following lessons to learn :
  - to investigation the causes of the accidents,
  - to draw up measures and consequences
  - to communicate the causes, measures and consequences widely, throughout the industries concerned, with the authorities and across national and international boarders
  - act upon the information which is received .

Whilst carrying out the investigation it was brought to Baden-Wurttemberg authority's attention, that a similar event had occurred in the UK. This event (at a third-party's depot) led to the company issuing a safety alert, dated 8 December 2000. This alert was distributed throughout the group production facilities. If this alert had been distributed throughout the whole of the LPG industry and the LPG has acted upon it then possibly the accident in 2004 could have been avoided.

As a concluding remark, the UK LP Gas Association has released a Technical Memorandum (No. 81) regarding ACME threaded couplings, dated April 2005. The group has also re-released its safety alert at the end of 2004.

ARIA Nos. 26064, 27920, 28558, 27923, 30077

A series of accidents in a chemical plant

Between 2003 and 2004

Auzouer-en-Tourraine – [Indre et Loire] - France

Chemical
Explosion
Flood
Aquatic pollution
Organisation
SMS

THE INSTALLATIONS IN QUESTION

The chemical plant employs 135 people, including 25 engineers and executives. It operates around the clock, manufacturing approximately 400 chemical products and uses numerous toxic and/or flammable substances. The company's activities are governed by the "upper" threshold of the "Seveso 2" directive, owing to the nature and quantities of the substances stored, formulated and used.

THE SUCCESSION OF ACCIDENTS: BEHAVIOUR, EFFECTS, CONSEQUENCES, ACTION TAKEN AND LESSONS LEARNED

In 2003 and 2004, five accidents or incidents were reported to the Classified Installations Inspectorate:


Faut-il fermer [redacted]

Le feu chez [redacted]

Photo : DRIRE Centre

Press articles

- **February 2, 2003:** pollution of a river as the result of a leak on a filter in a workshop;
- **December 15, 2003:** an explosion followed by a fire in a R&D building;
- **January 13 and 14, 2004**: partial flooding of the site. As the reactors were being washed during this period, the wash water mixed with the flood waters via the piping;
- **Night of February 27, 2004:** ammonia released for an hour
- **July 19, 2004:** pollution of a river. The analyses conducted at the discharge point of the plant's treatment plant indicated that the standards established under the authority of a prefectorial order had been significantly exceeded (7 times the authorised threshold for phenols, 5 times that authorised for COD, and 3 times that authorised for nitrogen). A few days after having noted this pollution, the Supreme Council for Fishing estimated that 80% of the piscifauna (approximately 400 to 500 kg of fish) had disappeared downstream from the site.

February 2, 2003: pollution of a river as the result of a leak on a filter in a workshop (ARIA No. 30077)

The accident :

On Sunday, February 2nd, between 5am and 8am, 20 m³ of an iron complex likely to contain phenols and other toxic substances were released from a filter system located in a workshop. The leak, resulting from the expulsion of an element on the upper part of the filter, resulted to the release of polluting substances into the river.

The consequences :

The liquid substance spread out over the ground and entered the wastewater network. As the 2 day pools located downs line from the station were unavailable, the polluted water did not pass through a buffer tank enabling it to be checked before being sent to the pools of the plant's treatment plant. It was thus not possible to process the polluting load.

On Monday morning, when the Inspectorate arrived at the site, the releases from the station were highly coloured and visible over approximately fifty meters.

The results of the analyses conducted on a sample taken Monday morning showed that the discharge standards had been exceeded:

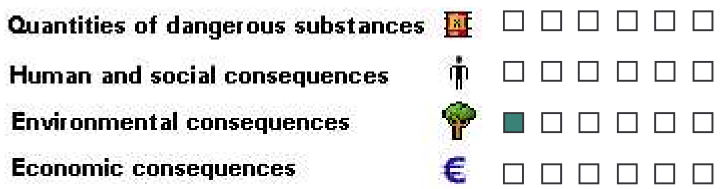
	Sample	Standard
- chemical oxygen demand (COD):	1,826 mg/l	350 mg/l
- overall nitrogen:	99.7 mg/l	32 mg/l
- iron	265 mg/l	5 mg/l

The significant flow rate of the river at the time of the release limited the environmental impact of the accident.

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 Vaily-sur-Aisne accident can be characterised by the following 4 indices, based on the information available.

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 Env12 parameter of the "environmental consequences" index is rated 1 by default, as the volume of polluted water had not been determined.

Lessons learned and action taken :

The consequences could have been reduced by the proper application of the safety instructions.

The significant quantity of substance released (20 m³ over a 3-hour period) is the result of the operator not being at his workstation for an extended period of time. The operator in question had been working in another workshop at the time of the accident. Filtration takes place without monitoring.

In addition, the malfunction was discovered Sunday morning, but the non-compliant effluent continued to flow toward the river until the following Monday.

These two elements point to a problem in the application of safety and emergency procedures.

The Classified Installations Inspectorate recorded the facts and implemented the corresponding actions.

December 15, 2003: explosion followed by a fire in a R&D building (ARIA No. 26064);

The accident :

On December 15, 2003, around 5pm, an explosion and fire was reported in a laboratory on the first floor of the research and development building.

Causes :

According to the subsequent investigations, it appears that this accident was caused by the explosion and fire of a mixture of highly flammable solvents (tetrahydrofuranne and hexane) contained in an open 15-liter container and in 2 open jars. All three of these containers were located in an operating extractor hood in the laboratory, while the laboratory technician was absent (3 to 4 min.).

It appears that the electronic heating regulator of a heating mantle (placed in the hood) caused the ignition of the solvent/air mixture that had formed in the hood. The electrical defectiveness of this regulator, not designed to be used in explosive atmospheres, was thus the cause of the accident.

Lessons learned and action taken :

In this accident, in which no one was injured but which destroyed the laboratory and blew out several windows on the first three floors of the R&D building, it appears that:

- the laboratory operators did not take all the adequate safety measures,
- the equipment that they were using was not compliant for use in areas with explosive atmospheres.

As regards the regulations, it is the operator's responsibility to define the explosive atmosphere zones and to adapt the electrical equipment to the regulatory requirements stipulated for use in these zones. In any event, this rule was not respected at the site.

The inspectorate of classified installations recorded the facts. A prefectorial order was issued to collect and process the toxic waste produced by the accident. Extensive investigations were also ordered concerning the R&D unit's workstations.

The operator was formally instructed to delineate safety zones, to bring the electrical equipment used in explosive atmospheres up to standards and to install additional firefighting equipment in the R&D buildings.

January 13 and 14, 2004: partial flooding of the site (ARIA Nos. 27920 and 28558)

The accident :

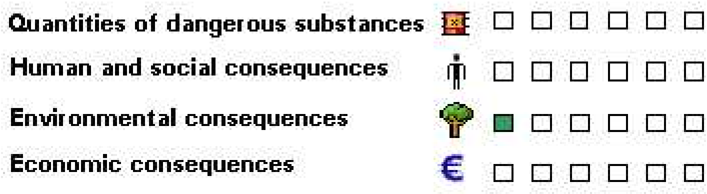
Due to the sudden rise of the river on January 13 and 14, 2004, water entered part of the site and was polluted by spreading over the ground and mixing with the wastewater in the networks. This led to further pollution of the natural environment. Traces of spillage of coloured substances, containing iron and aluminium, were noted in various locations.

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.

The parameters which 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

For accident No. 27920, the indices are as follows:



The Env12 parameter of the "environmental consequences" index is rated 1 by default, as the volume of polluted water had not been determined.

Lessons learned and action taken :

In this accident, it should be noted that the consequences of the pollution were compounded by the fact that the reactor cleaning operations were continued during this period. The wash water mixed with the floodwaters via the piping, which could have been avoided had the emergency instructions been applied.

The Classified Installations Inspectorate recorded the facts and a supplementary order of the prefect called for a study relative to the flood hazards, operations designed to insolate the site and a study relative to the origin of the spillages.

July 19, 2004: pollution of the river (ARIA No. 27923)

The accident :

On July 19, at approximately 7 pm, after having noted dead fish downstream from the plant, the Supreme Council for Fishing visited the site, accompanied by the plant operator to take a sample at the treatment plant's outlet. There were no visible signs of pollution in the area surrounding the discharge points.

On the morning of July 20, after having checked the results of the effluent sampled at the treatment plant's outlet, the manufacturer noted that they were significantly above the standards and stopped their release.

A deviation in the plant's operating procedures, primarily over the weekend of July 17/18, 2004 resulted in the releases exceeding the standards established under the authority of a prefectorial authorisation (7 times the authorised threshold for phenols, 5 times that for COD, and three times that authorised for nitrogen).

The analyses, conducted on the samples taken automatically at the station's discharge point and maintained refrigerated by the operator, provided the following results (in mg/l):

	Release of 07/16	Release of 07/17	Release of 07/19	Standard
- chemical oxygen demand (COD):	433	586	1690	350
- overall nitrogen:	26.1	35.9	110	32

In addition, analyses conducted on the sample taken at the plant's discharge point by the Supreme Council for Fishing in the evening of July 19th, confirmed the malfunction: significant Suspended Solids (SS), phenol content of 0.255 mg/l which is well above the authorised value of 0.05 mg/l.

The consequences :

The high content levels largely contributed in downgrading the receiving environment, notably its oxygen content required to sustain aquatic life.

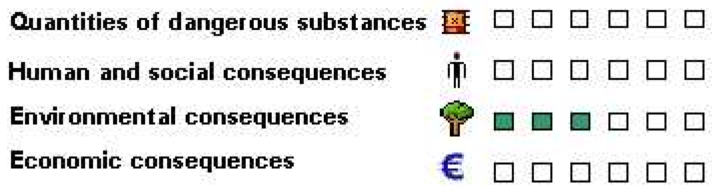
The treatment plant's malfunction killed several hundred kilos of fish over 3 to 4 km downstream from the discharge point and, according to the Supreme Council for Fishing, also destroyed a large portion of fauna along the river.

According to the operator, "fixed-term contract" and temporary personnel washed the containers used to transport chemical residues over the weekend. This washing operation may have been the origin of the malfunction.

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 Vaily-sur-Aisne accident can be characterised by the following 4 indices, based on the information available.

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



Three parameters are involved in determining the level of the "Environmental consequences" rating: Env10, Env12 and Env14.

- Level 2 of the Env10 parameter is associated with the 300 kg of fish killed in the water (Env10 between 0.1 t and1 t).
- The Env12 parameter is rated 1 by default, as the volume of polluted water had not been determined.
- Level 3 of the Env14 parameter corresponds to the river pollution over 3-4 km (Env14 between 2 km and 10 km).

As a result, overall "Environmental consequences" rating is 3.

Lessons learned and action taken :

The washing operations conducted without supervision by a foreman contributed to sending large amounts of chemical pollutants to the treatment plant, that the facility was unable to process, inasmuch as the operator did not first check the plant's ability to process the water collected in the buffer tanks located upline.

This event once again shows that there is a problem relative to the application of procedures and a lack of supervision of the personnel.

The Classified Installations Inspectorate recorded the facts and a complementary prefectorial order was issue bearing on the reinforcement of daily inspections and the implementation of specific drum cleaning procedures.

FOLLOW-UP – MEASURES TAKEN

The disregard for safety instructions, faulty or non-compliant equipment, tasks performed by insufficiently trained personnel, the installation operating without surveillance, and instructions not followed, are all causes of the accident at the site. These elements were detailed in reports made following inspection visits during which the organisation and the management of the safety management system (SMS) were regularly found to be faulty.
Some of these characteristics findings, established during the in-depth inspections conducted in 2003 and 2004, are presented below.

2003 inspection:

The main findings concentrated on the disregard of procedures related to the management of procedural modifications, the consistent delays on the inspection of certain safety-related elements owing to a lack of personnel to conduct the preventive maintenance operations, as well as the storage of an abnormally high quantity of containers outside retention facilities.

Deviations concerning the management of procedural modifications :

Certain manufacturing operations were conducted in reactors whose volumes were greater than those indicated in the safety study. The Inspectorate questioned the operator about the procedure followed to ensure that this modification did not present a hazard.

The reliability study for an operation of this type was conducted without formalisation and in the following manner:

- the reaction was carried out in the reactor of volume V1, using the quantities of product stipulated for the reactor of volume V2 (V1>V2)

- the reaction volume was progressively increased up to V1, while checking that the cooling power is sufficient for the next reaction volume.

This procedure was not compliant with the SMS which specified that the change in reaction parameters (quantity of reagent, temperature, pressure and output conditions…) must form the subject of an in-depth examination, updating of the safety studies and possibly laboratory testing.

The manufacturer must also ensure that the new reaction conditions remain safe, which requires a minimum level of investigation and validation by sufficiently-trained agents.

It was also found that certain recommendations outlined in the safety studies were not followed (notably the temperature recordings).

Deviations concerning the management maintenance operations :

During the visit of two workshop facilities, the Inspectorate wanted to check the follow-up of safety-related equipment. For the 13 instruments (thermometers, pressure switches…) declared as safety-related for these two workshops, only one had been inspected during the 12-month periodicity indicated for the inspection of safety-related elements and some had never been inspected since they had been installed.

Conversely, certain non safety-related instruments had been inspected during this period, thus demonstrating a total lack of ranking of instruments to be inspected first.

The same was true for a phosphorous trichloride (PCl_3) storage tank, a product that is highly corrosive and toxic. The danger study stipulated that the tank was to be drained and inspected on a yearly basis, and to change the bottom valve. While this operation had been performed following corrosion problems and leakage on these elements, the inspectors noted that the valve had not been replaced since1999.

2004 inspection:

The findings concentrated on the storage conditions that did not ensure a sufficient level of security.

Certain containers were outside confinement zones and the lack of passageways prevented easy access to the products stored in case of an accident. The fixed storage retention zones which were flooded two weeks earlier still held a considerable amount of water, making their capacity insufficient.

Once again, the inspection of maintenance operations was determined to be faulty. While a danger study stipulated that the high temperature alarms must be tested on a daily basis, the operator was not able to describe this test.

The equipment conditions (logging system, the crampedness of the facilities, archiving possibilities) appear to be insufficient to ensure the management and follow-up of more than 1,000 instruments, sensors or equipment.

Training programs were nevertheless conducted and programmed for maintenance crew personnel, whose workforce had been increased since the 2003 inspection.

Findings:

The inspections described above lead to numerous administrative and penal actions designed to require the operator to take corrective action.

In autumn 2004, legal action consisted of two hearings before a tribunal. IN November 2004, the company was fined 75,000 euros and the director received a 3-month suspended jail sentence and a 10,000 euro fine. The manufacturer appealed the first ruling. In late June 2005, the magistrate's court sentence the establishment's director to a 3-month suspended jail sentence and a 10,000-euro fine. The company was fined 120,000 euros. The manufacturer also appealed the second ruling. These legal cases, as well as the various accidents presented above, received significant media coverage.

PERSPECTIVES FOR IMPROVEMENT

An improvement in the situation, notably in terms of management of the site's storage facilities, was noted in the second semester of 2004.

It should be noted that following the administrative and penal actions, the manufacturer, through its CEO, undertook strong commitments with the Prefect, the DRIRE and the CHSCT to improve the situation by implementing an investment program.

The administrative actions are continuing and a complementary prefectorial order was issued on January 7, 2005. The provisions notably bear on the critical analysis of the danger study and a study of the health hazards.

In order to evaluate the pertinence and the proper application of the procedures that had been deemed faulty in the past, an external audit was also prescribed relative to the implementation of the SMS and specifically on the following:

-the personnel's knowledge of the SMS and the respect of procedures,

-the operator's ability to implement the SMS and to check that is applied properly,

-the pertinence and the efficiency of the safety organisation.

This 2½-day audit should be able to identify the organisation's weak points and the origin of the problems, on which the operator must undertake corrective actions.

In early 2005, the group's CEO expressed his desire to reduce hazards, fulfil regulatory requirements and improve the company's image, with the assistance of an external advisor.

The action plan proposed by this consulting agency was forwarded to the Classified Installations Inspectorate in April 2005. The initial actions concentrated on improving the storage areas and on the reorganisation of the HSE department.

In parallel, in April 2005, the manufacturer presented his revised multiyear investment plan, which outlines significant investments in terms of reducing risks, and proposed additional changes at the request of the labour inspectorate and the Classified Installations Inspectorate.

Ignition of a cloud of wood dust in a manufacturing facility

May 11th,2004

Allouville-Bellefosse – [Seine Maritime] France

Panels
Press
Inappropriate intervention
Lack of procedures
Banalizing of the risk
Cleaning
Training
Death
Serious burns

THE INSTALLATIONS IN QUESTION

The company is specialized in the manufacture of panels made of chipboard or flax shive.

The installations, whose capacity had been increased in 2003, are subject to prefectoral authorisation with regard to the installed power (50 MW of heat drying, 4.5 MW for the shredding of wood and nearly 2 MW of electricity for sawing and sanding). The industrial site produces 500,000 m³ of chipboard panels per year. It operates around the clock and shuts down only twice a year, in August and December.

The flow chart of the manufacturing process is provided below :

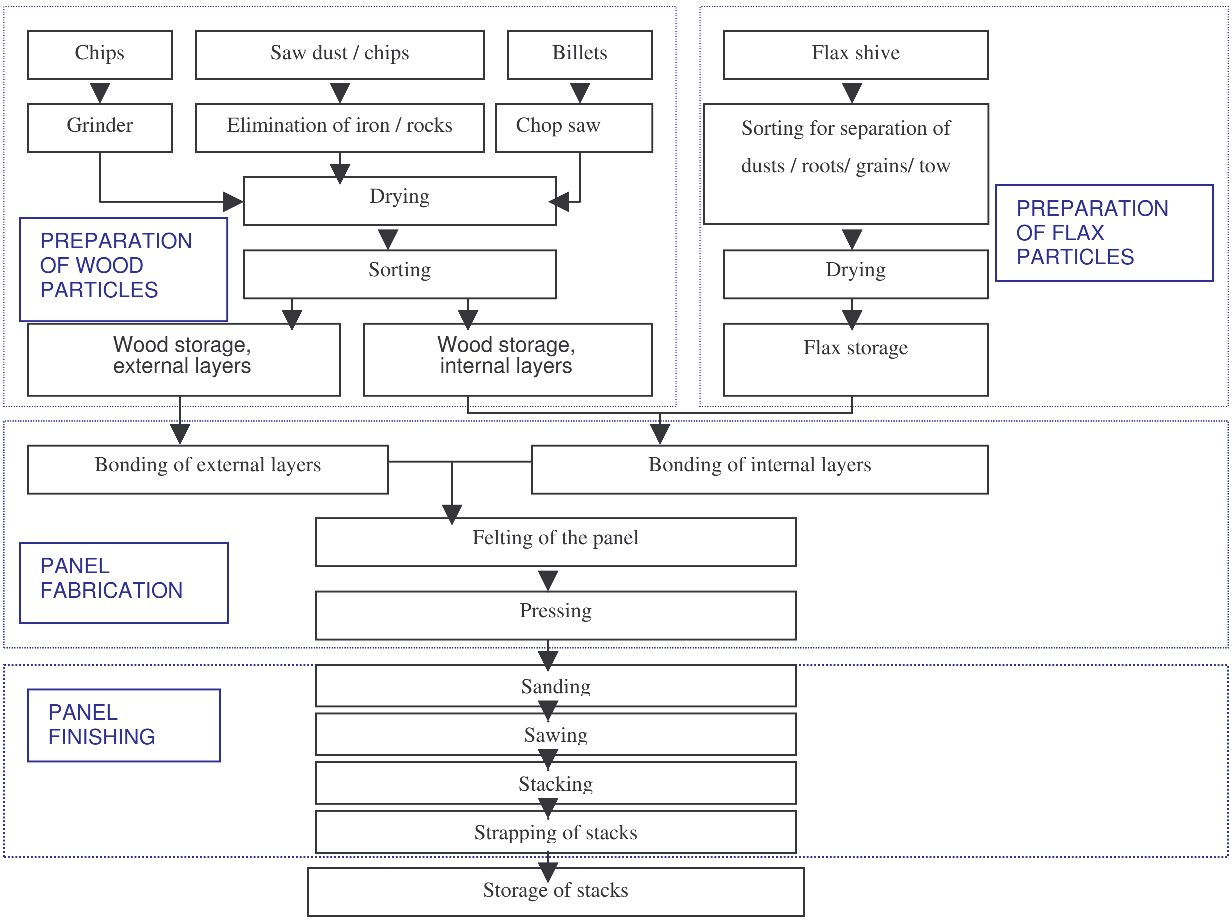


Figure 1: Flow chart of the chipboard panel manufacturing process

The panel manufacturing process can be broken down into three steps:

- gluing of particles with a urea-formaldehyde adhesive,
- felting which consists in spreading out the material to form a uniform mat on metal screens,
- pressing during which the mat is placed in a heated hydraulic press to ensure polymerisation of the adhesive.

In this case, the hydraulic press, installed 8 years ago, had been modified in 2002 in order to increase the production capacity (11 stages instead of 8). The heat is provided by mineral oil heated to 250 °C and distributed by a control circuit from 140 to 210 °C.

In essence, the process generates wood dust. For example, 60 tonnes of dust are produced on daily basis by the panel finishing operation alone.

THE ACCIDENT, ITS BEHAVIOUR AND CONSEQUENCES

The accident:

On Tuesday, May 11, 2004, a cloud of dust ignited at 6.45am above the press while two operators were attempting to extinguish a smouldering fire with a dry chemical extinguisher.

The consequences:

This accident had dramatic consequences. One operator died and another was very severely burned. At the time this report was being drawn up, the latter, who had been hospitalised for several months, had not yet returned to work.

There was limited property damage: Overpressure did not occur as the accident took place in a relatively open area. The fire was quickly brought under control by the automatic fire-extinguishing network (sprinklers). As the emergency response centre is located just a few kilometres way, firefighters were able to respond quickly on a part of the roofing. Part of the bituminous roofing material had been damaged.

Operating losses were significant (production was stopped for 10 days). Resumption of operations is contingent upon submittal of assessments prescribed by a draft order outlining "emergency measures".

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.

The unfortunate death of an employee explains the level 2 classification attained by the human and social consequences under the terms of parameter H4. In addition, as the operator had not yet indicated the actual amount of property damage and operating losses (parameters €15 and €16), the classification relative to the economic consequences could not be characterised.

The parameters, which 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

ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

Given the severity of the accident, an analysis of the accident's circumstances and the definition of the corrective and preventive actions to be implemented were requested. The company has contacted an engineering firm specialised in dust explosions to conduct an expert evaluation.

Circumstances:

On the eve of the accident, the crew working the 9pm to 5am shift detected a burnt odour in the workshop without being able to locate where it was coming from. The morning crew (5am to 1pm) located the smouldering fire on top of the press around 6am.

Using an aerial basket, a mechanic and an electrician discovered embers on the upper "counter-heating platform" of the press. After informing the foreman, the decision was made to empty the press and shut down the line prior to intervention.

The production supervisor was informed. The foreman and the electrician, wearing neoprene masks equipped with a P3 cartridge and face shield climbed to the level of the embers with a 50 kg dry chemical extinguisher. A scraper was brought in order to recover the burning material. Beforehand, one or two attempts to smother the embers were made with the extinguisher. At that moment, around 6.45am, the dust ignited immediately causing a flashover above the press. The mechanic, at ground level next to lifting device whose basket had been moved and blocked in the press' upper structure, was able to rescue the foreman, who was able to climb down by himself despite his burns. The electrician was found dead in the lift.

Origin and causes of the accident:

The eleven stages of the press, which measures approximately 9.50 m x 5.50 m are subject to high stresses in terms of both temperature and pressure. In order to compensate the possible deformation of the highest platforms, the manufacturer had installed a "counter-heating platform" above and below the press, divided into three lengthwise control zones.

When adjusting the press, the company had worked on the temperatures in these heating zones. Experience had shown that above 165 °C dust had caught on fire locally. A maximum setpoint of 140 °C had been adopted.

Transformations of the press

During the backfitting of the press (from 8 to 11 stages), the last platform was brought closer to the "counter-heating platform". For production reasons and throughout the entire adjustment period (July 2002 to January 2003), the temperature of the platforms was dropped from 190-215°C to 170-190°C.

In January 2004, when the temperature of the platforms was raised. Even in the absence of heating of the central zone of the "counter-heating platform", the temperature reached 165°C. As outbreaks of fire were again noted (these incidents, considered minor and of no consequence, were not reported to the Classified Installations Inspectorate), the company decided that the central zone would be cooled instead of heated, as the platform was supplied with coolant from the heat sink. All of the equipment (pumps, piping…) was operational during the month of April. The centre zone was set at 140 °C.

Felting line and press

Initiator

An incident was reported in the report of the crew's electrician. On the eve of the accident, at roughly 10am, the control room operator noticed excessive temperature in the "counter-heating platform" (temperature above 200 °C). The electrician and the mechanic reported that the temperature regulator was operating correctly but not the 3-way valve which remained partly open on the hot reservoir. The thus manually closed the 3-way valve and, for safety reasons, a manual valve and the zone's circulating pump.

The temperature dropped regularly. At around 4.30 pm, it is known that the temperature was around 150°C.

An expert evaluation of the 3-way value conducted later showed that its blockage may be the result of a hard spot, as the servomotor used to drive it is low-power.

An incandescent layer of dust

The press is stopped and cleaned only one or two times per year (the platform is difficult to access and the extreme temperature does not allow intervention while it is in operation). At the time of the accident of May 11th, the layer of wood dust was probably between ten and fifteen centimetres. The blast from the extinguisher blew the dust into suspension thus increasing the explosibility conditions with the presence of incandescent particles.

ACTION TAKEN

During the week following the accident, the company performed repairs and verifications of the damage equipment. It also proposed to implement temporary monitoring measures, mainly consisting of a reading with a paper printout of fluid temperatures and a procedure to be followed to handle any new rise in temperature.

As the accident had claimed victims, the Classified Installations Inspectorate acted jointly with the labour inspectorate and the CRAM ("Caisse Régionale d'Assurance Maladie", regional sickness insurance fund). The latter were able to testify regarding the difficulties encountered in how the company takes occupational hazards into account. This report limited the scope of the procedures proposed by the company for restarting the activity.

an emergency shutdown order was proposed to the Prefect, making the continuance of the activity contingent on in-depth investigations. The scope of the study concerned the press and its utilities, although the company was also asked to implement a study program bearing on the entire site. The company contracted an expert organisation, specialised in dust explosions.

Immediate measures prior to installation restart

Several pre-restart measures were defined jointly with the organisation in order to allow the installations to resume production:

✓ Temperature control:

Concerning the "counter-heating" control zone, the external zones not needing to be heated, and the heating systems were shut down.

Three temperature probes were added in a fail-safe configuration, each having indicators on the fluid and 2 alarm thresholds (1st threshold at 142 °C to indicate an anomaly and a 2nd threshold at 160 °C which stops the boiler burner).

✓ Dust limitation

In its analysis report, the expert organisation shows that, in terms of a dust deposit's self-ignition characteristics, there is a relationship that links the thickness of a dust deposit and the temperature in contact with this deposit.

In this particular case, a fire may break out at 240 °C (temperature of the coolant leaving the boiler) for a 5mm layer. This thickness is increased to 7cm at 160°C, a temperature that the operator's fail-safe temperature measurement system should prevent.

However, markers were placed at 5cm from the surface of the last platform as a preventive measure and are checked two times per week. The readings are then recorded. The press is shut down and cleaned by a vacuum system as soon as the thickness is reached (every 10 to 15 days of operation).

It is important to mention that the expert organisation stipulates that the dust thickness limits are provided only as a general indication (products need to be known better) and bears only on controlling smouldering fires. Such dust thicknesses are sufficient enough to propagate an explosion when the dust is put into suspension.

✓ Definition of procedures to be followed

According to the operator, several fires had already occurred on the installation since its commissioning. These were the result of errors of the fixed setpoint temperature on the platforms at issue. These outbreaks of fire occurred on the hot parts (lighting…), the incandescent portion had been collected with a broom or scraper and the incidents were of little consequence. Owing to a lack of written instructions regarding the procedure to be followed in the case of fire, on May 11, 2004 the employees attempted to put the fire out with a fire extinguisher.

Following this dramatic accident, written procedures were drawn up and explained to the personnel regarding what actions are to be taken in different circumstances. Namely :

- the procedure to be followed when an abnormal increase in temperature is noted,
- what actions are to be taken when a burnt odour is detected,
- the press cleaning procedure,
- the intervention procedure on smouldering fires.

✓ Prevention and protection measures on the press

Heat lagging was installed on the top of the press to insulate the hot surface from dust deposits. Should fire break out on the top of the press not protected by the sprinkler network, spray booms are installed to ensure cooling and extinguishing from the floor level.

✓ Training of personnel

Fifteen individuals were trained in the handling of fire extinguishers (i.e. 3 people per crew). This was the first time that such a training program had been given.

✓ Management's commitments

The company committed to the following points: the continuation of the studies stipulated by the expert organisation in order to define Potentially Explosive Atmospheres (ATEX), the search for collection solutions at the source of dusts and centralised cleaning by a vacuum system, the hazard training of personnel and the implementation of specific documentation (labour regulations).

Additional requirements reinforcing site safety

As a result of the measures taken, operations were resumed in the afternoon of May 22, 2004, following a fire extinguisher training for the employees. The shutdown over a period of approximately ten days was economically destabilising for the company as well as about twenty scutching operations and multiple customers upstream and downstream of the production facility (500 jobs).

The Classified Installations Inspectorate also proposed a complementary order intended to reiterate all of the palliative measures retained for resuming activities. This order, also prepared in close collaboration with the labour inspectorate and the CRAM, requires that additional studies be carried out encompassing the entire site. They aim to reduce the source of hazards presented by the installations according to the following four axes:

Mechanical transport with decoupling by screw

- identify the dust emission sources and, as required, the dust prevention measures that would reduce these emissions in the ambient air and closed spaces,
- analyse the pertinence of the cleaning procedures and methods, the means implemented (suction equipment, equipment and operator protection devices, secure access to the areas to be cleaned, human resources...) and personnel training,
- define all explosive atmospheres, identify the associated equipment and establish the adequacy program as per Directive No. 1999/92/CE (ATEX directive) transposed into French law,
- dimension and define the protective means against the effect of a possible overpressure (vents, explosion suppressor…) and accident response means.

The installations have now been modified so that dust is no longer deposited on the press. The cleaning of the facilities has been facilitated by the installation of a centralized vacuum system.

The danger study defined several modifications that should be undertaken, including moving a dust silo and resizing of overpressure vents. It also stresses the hazards presented by the sawdust transport installations via pneumatic means. The slow mechanical transport which enables an uncoupling system to be implemented must be given special consideration as it limits the effects in the event of an explosion.

It should be noted that the installations have been equipped with the risk of explosion since the beginning. In particular, spray booms slaved to spark detectors are installed along a large portion of the system. These devices record an average of 400 detections per month. This number certainly contributes to banalization of the phenomenon within the company.

A search of the accidentology in the ARIA database relative to similar installations provided to be rich in information: of the 100 accidents reported between 1999 and 2004, the main hazards identified concern fire (70 cases) and explosion (20 cases). In particular, 9 accidents involve driers, 5 cases involve silos and 4 cases concern dust connection systems.

The study relative to the adequacy of the equipment, per the requirements of the "ATEX" directive, culminates on an extensive program of additional investigations and replacements which cannot be completed prior to 2007. A difficulty arises from the fact that the manufacturers cannot commit on the compliance of the equipment sold without an expert assessment of the equipment on site and with the installation shut down. Complete replacement of the installations must sometimes be considered.

In terms of installation operation, roughly thirty procedures and instructions are implemented. Unfortunately, the inspections conducted since then show that the updating of these procedures are not in line with the modifications made to the installations. As the personnel's "risk" culture is not developed, it appears as though these tools have not been successfully adopted. This is the reason why a training program seems essential.

Finally, the company hired a safety manager.

Drier

LESSONS LEARNED

The following elements can be retained from the feedback:

✓ although exposed to dust explosion and fire hazards, the particle board manufacturing industry in the Seine-Maritime department does not appear to be prepared for the application of texts relative to the "ATEX" directive. The Classified Installations Inspectorate reiterated these requirements to all of the flax scutching plants in the department, which are subject to requirements of the same type,

✓ the measures consisting in reducing dust emissions at the source and to avoid the accumulation of dust are essential in the prevention of fire and explosion hazards. In addition, as of June 30, 2005, the concentration in the ambient air at the workstation is limited to 1 mg/m^3.

✓ changes in the behaviour of the personnel, such as the assimilation of written procedures, are difficult to obtain without appropriate training. In this respect, cooperation with the CRAM and the Labour Inspectorate allows complementarities to be found.

Explosion of a fireworks fabrication and storage facility

June 01, 2004

Villeneuve sur Lot – [Lot et Garonne] France

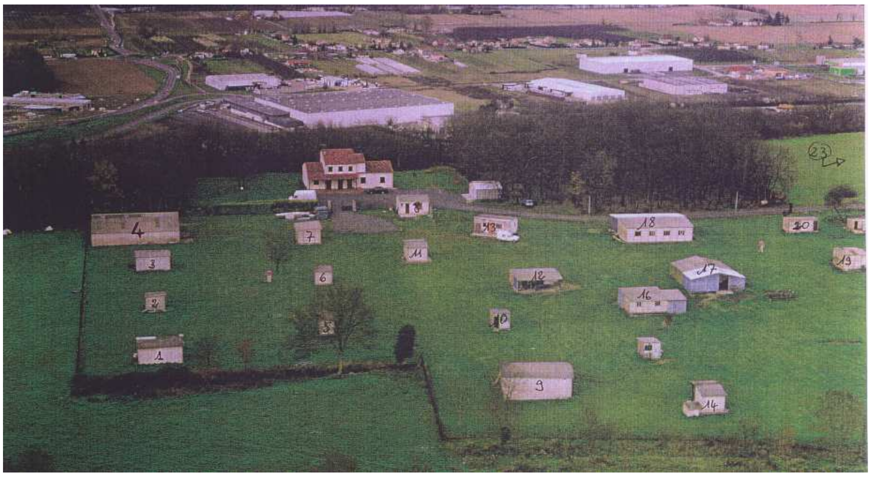
Explosives
Fireworks
Homemade

THE INSTALLATIONS IN QUESTION

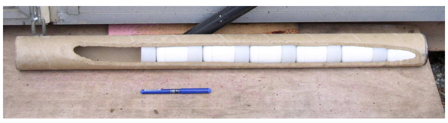
The establishment is specialised in the fabrication and storage of fireworks. The facility is located on 8 ha of land on which approximately 30 buildings have been erected. Some of the buildings have several rooms. Ten of the buildings are reserved for fabrication operations and 20 are dedicated to storage.

The establishment is classified SEVESO ("AS" high threshold with public easements) owing to the storage of explosive substances (16 t for an "AS" threshold of 10 t). In application of the French texts, which transpose the European "Seveso II" Directive, the facility is subject to the provisions concerning the "high level" Seveso threshold of said Directive.

The site has been in operation since 1976 and the current operator has been in place since 1995. On the day of the accident, 6 people were working at the site.



The establishment manufactures a wide range of homemade fireworks. The pyrotechnic materials used or manufactured essentially consist of binary mixtures of combustible products (metal powders) and combustive products (nitrates, chlorates,…).



The pyrotechnic products manufactured on site include:

✓ stars, the main components of fireworks designed to produce light effects;

✓ light-effect shells, composed of a plastic shell in which the stars and the bursting powder are located;

✓ acoustic-effect shells where the stars are replaced by a pyrotechnic composition that produces the expected effect;

✓ candles which consist of cardboard tubes of various diameters. The shells and lifting charges are stacked successively inside the candles;

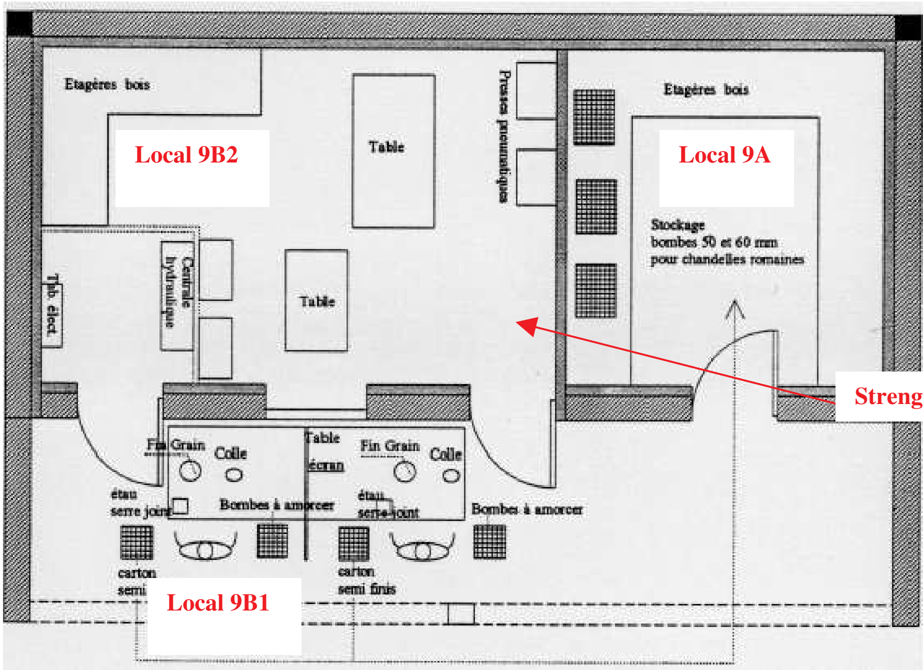
✓ Bengal lights, jets.

The workshop (building 9), involved in the accident, was dedicated to the manufacture of candles. It contained two workstations and a storage facility. Three consequential activities are performed:

✓ the shell assembly area, under the building's awning (facility 9B1). The operation consists in manually filling the lower part of the plastic shell with a bursting and star charge, and then to bond it with the upper part and arm the shell formed;

✓ intermediate storage of these products in storeroom 9A. The shells are stored in plastic boxes stacked on 5 levels on the wall separating this area and facility 9B2;

✓ the shells are loaded into the candles in facility 9B2. This operation consists in using a low-power hydraulic press to insert a series of armed shells and cups filled with powders into a cardboard tube with a closed base. The composition of these powders ensures the ejection of the shell from the tube.



The authorisation to operate this building prohibits the simultaneous shell assembly and candle loading operations. The shell storage facility was authorised to contain a maximum of 300 kg of active ingredients, characterised as non-detonating products (closed and armed shells). The maximum capacity of the two assembly and loading workshops was 5 and 2 kg of detonating products, respectively, owing to the handling of the powder.

THE ACCIDENT, ITS BEHAVIOUR AND CONSEQUENCES

The accident:

On June 1st, 2004 at 11.20 am, a series of explosions rocked building No. 9.

Two people were working in the building at the time of the accident. According to the manager, the workers had begun assembling 60 mm dia. shells under the building's awning area (9B1) in order to make a few candles.

On the day of the accident, witnesses reported that the accident took place in 2 phases. An initial explosion occurred first, followed immediately by a second, more violent explosion which generated thick white smoke.

The consequences:

Two employees were killed in the accident. Their extensively mutilated bodies were found 20 and 25 m from the epicentre of the explosion.

An employee who was in a building less than 20 m from building 9 at the time of the accident was very lightly injured even though the building was practically destroyed.

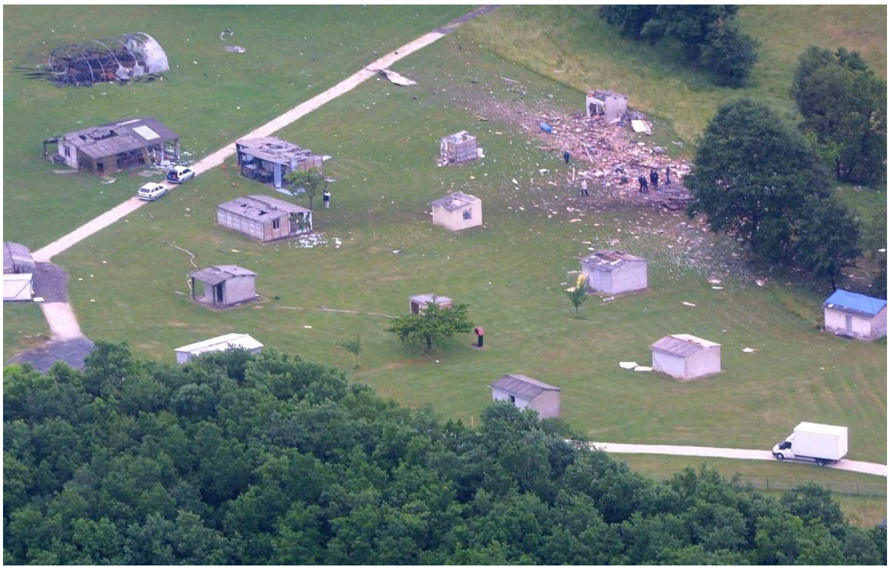
A second employee was also hospitalised for less than 24 hours for auditory problems.

Building 9 was completely destroyed. All of the walls are blown down to floor level, including the 40 cm wall anchored into the ground which had separated the 2 rooms of building 9. In the shell storeroom (room 9A), there was a crater measuring 3 m x 1.5 m and more than 50 cm deep, near the outside wall.

The explosion caused significant damage to the neighbouring buildings due to overpressure and projections. Fourteen buildings were partially or totally destroyed (structure and roof), the roofs of three additional building were damaged and the window and doors of six other buildings significantly damaged.

No domino effect was observed in the other shops or pyrotechnic stores. Only the plastic sheeting used to cover a greenhouse was partially burned owing to the stars that were launched onto it. This installation is located more than 70 m from building 9.

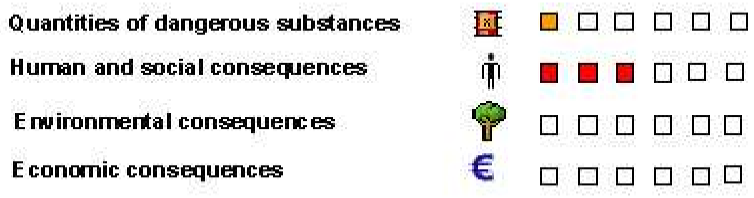
Debris was spread into four zones around building 9, in an elliptical shape. Each of the "pedals", which begin at the building's four walls, had an average length of 50 m. However, wall and roof debris was found up to 160 m away from the building.



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.

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



The level 1, for the quantities of dangerous substances released, is due to the explosion of dangerous materials (estimated to be roughly equal to 15 to 30 kg of TNT).

Level 3 for the human and social consequences is attributed to the death of 2 employees at the site.

ORIGIN, CAUSES, EFFECTS AND CIRCUMSTANCES OF THE ACCIDENT

Several inquiries into this accident are currently on going:

– a judicial inquiry (the judiciary police are being assisted by the police forensic laboratory of Toulouse);

– an administrative inquiry.

The effect of the explosion of building 9 is rather surprising. The blast exhibited a detonation phenomenon although owing to the products present in the storeroom (where detonation took place) one would have expected a rapid and very intense burning without a significant blast effect, owing to the classification "1.3" of these products as defined by current regulations governing pyrotechnic materials.

The effect zones determined by the operator in the initial danger study did not exceed 20 m for the lethal effects and 38 m for the irreversible effect zones.

Owing to the consequences of the accident, an investigating bureau concluded that the detonation was equal to 15 to 30 kg of TNT. The shock wave recalculated on the basis of this hypothesis would give the radius maximum lethal effect and irreversible effects in the order of 40 m and 70 m, respectively.

Considering the information gathered in the field, it is possible that one of the two individuals, or even both of them, were inside the candle loading facility (9B2).

It can also be considered that this operation was conducted simultaneously with the shell manufacturing operation (although this configuration was prohibited).

Hypotheses about the circumstances:

The existence of a crater inside the storage facility would prove that a significant quantity of products had detonated. The investigations took three possible causes into consideration:

✓ The risk presented by the products habitually stored in this area had been poorly evaluated (a detonation risk was not retained). In the trade, it is a recognized fact that the stars and small-diameter shells are classified as non-detonating products. As these products are not marketed "as-is", the operator did not submit these products to a certified organisation for classification testing. However, the "bulk" storage method and confined room may have played a role in the product's detonating behaviour. The question remains concerning the origin of the ignition;

✓ The products stocked may have been violently aggressed and the energy absorbed may have lead to the detonating behaviour. In this hypothesis, the origin of the aggression may have been an initial accident in one of the two adjacent workstations (9B1 and 9B2), and relayed to the storeroom (9A) through a relay mechanism. However, close examination of the concrete slab of these two facilities (9B1 and 9B2) showed no sign of explosion (no impact, no fragmentation of the concrete or burn marks). As far as the relay effect is concerned, it should be noted that, in light of the projectiles found and the testimonies collected, at the time of the accident the door of the storeroom had remained opened (although prohibited by the safety procedure) and an industrial truck may have been placed near the door. The latter could have directed projectiles from the first explosion toward the facility. Pieces of the truck were found 150 m from the building in the direction of building 9A's access door.

✓ There may have been unauthorised detonating product inside the facility and which caused the shells to detonate after catching fire. Building 9's incoming/outgoing log was examined. The log does not indicate that the storage capacity was exceeded or the presence of products other than the 50 and 60 mm shells. The analysis of debris found in the bottom of the crater may possibly give an indication as to the nature of the pyrotechnic composition that detonated.

Hypotheses on the initiator

The origin of the initial ignition as well as its location still remains unknown. The first explosion at one of the workstations had left a mark on the concrete. A problem that occurred directly in the storeroom may is possible in case of incorrect handling. This second possibility cannot be confirmed by the position of the victims' bodies.

ACTION TAKEN

On the proposal of the Registered Installations Inspectorate, the *Prefect* established an orders calling for the following emergency measures:

- ✓ the shutdown of all fireworks manufacturing activity, the restart being subject to a new authorisation procedure;
- ✓ removal of all residual pyrotechnic products from all manufacturing workshops;
- ✓ refurbishing of both storage buildings so that they can accommodate the establishment's pyrotechnic products within the limit of their proof testing and in acceptable conditions;
- ✓ grouping of intermediate products present in a third storage building;
- ✓ the separation of storage locations between the marketed products and intermediate products;
- ✓ removal of pyrotechnic products from the other storage buildings;
- ✓ maintain permanent surveillance of the site;
- ✓ definitive processing of all intermediate products, the expected behaviour of which is doubted in case of activation.

Since the accident, the operator has cleared out its stock of finished products for the 2004 summer fireworks season. The operation, involving the elimination of unmarketable intermediate products, finished with their destruction in a location designed for that purpose, located near the site and in compliance with all necessary regulations.

The future of the site is currently under deliberation. A new operator had expressed a desire to take over the site under the current authorisation conditions, namely the absence of a product fabrication facility and the limitation of product storage in the three authorised buildings.

LESSONS LEARNED

At this stage of the inquiries, feedback elements are essentially organisational in nature:

- ✓ characterise the risks associated with the products as best as possible (according to the storage and transport configuration), with special attention given to the intermediate products. As operators of small installations experience difficulties in classifying their products by standardised tests, better application of the standard rules must be sought as a minimum;
- ✓ respect the foreseen and posted safety rules. Vigilance on this point tends to drop over time and during activity peaks;
- ✓ maintain strict management of the operating conditions and the quantities of dangerous products present in the storage and manufacturing units.

These basic rules are already included in the regulations dealing with this activity.

Technically speaking, although without knowing the exact origin of the accident, several aggravating factors were raised:

- ✓ the bulk storage of shells and candles in crates, which generate a "confinement" of these products, most certainly contributed to a shift to a detonation configuration;
- ✓ the fact that the stored shells were armed may have lead to massive ignition through friction. Arming consists in bonding a layer of power onto the outside of the shells. This is to allow the flame to propagate from one shell to another inside the candles;
- ✓ the proximity of the storeroom for these products to the two fabrication shops tends to introduce a domino effect range that may be poorly controlled.

A spot inspection of 12 establishments was initiated 3 weeks after the accident in the Aquitaine region with mixed results. Administrative and penal actions were launched against 5 establishments. Complementary actions were also conducted in connection with other partners:

- ✓ Labour Inspectorate, given its involvement in the respect of texts regulating the activity;
- ✓ the mayors of the communities in the region who organise fireworks displays each year. The regulatory requirements associated with the temporary storage of fireworks near firing locations should also be reminded as well as their legal liability implicated by this operation;
- ✓ the administrative department responsible for the prevention of fraud for an establishment that has operated a fireworks manufacturing activity, without authorisation and for many years, and which has significantly exceeded the limit of its facilities;
- ✓ the police authorities to find the "hidden" storage location of a company being inspected, at the head office of which it had reported the absence of pyrotechnic products.

This operation determined that the last two fireworks manufacturers in the region did not operate in the same manner. The shells were prepared whenever they needed candles (thus no intermediate storage), or stored in a remote location and not armed.

ARIA Nos. 26457, 26459, 26460, 29646 and 29661

The impact of floods on SEVESO establishments

Series of events from 1993 to 2003

Provence-Alpes-Côte d'Azur Languedoc-Roussillon

France

Warehouses
Paper mill
Explosives manufacturing plant
Floods
Dike failure
Danger study
Alert management
Property damage
Technical unemployment

FOREWORD

Flooding in the Cévennes Region in 2002

The Saint-Nicolas bridge in Uzès (Gard), submerged by flood waters - 09/09/2002

View of the bridge 5 days later

In early September 2002, intense rain beat down on the south of France for two days (Anduze: 687 mm/24h, Ners: 591 mm/24h, Alès: 514 mm/24h (*) – (Sources: Météo France). This intense rainfall lead to rising water levels from 1 to 3.5 m in an hour's time.

In the Gard, Hérault, Drôme and Vaucluse departments, the flooding resulted in 25 deaths and damage estimated at 1.2 billion euros (including 814 million euros for the Gard). 295 communities of these 4 departments were a natural disaster area.

Following these dramatic events, the local communities and certain operators of industrial facilities undertook preventive operations (construction of dikes, redimensioning of rainwater networks, maintenance of rivers and streams…) and engaged in reflective thinking on:

- ✓ the reference water levels (new cartography of flood planes according to gauge heights, river flow rates…)
- ✓ the various means of communication during a crisis (the proven efficiency of the microwave network, questions regarding satellite technology…)
- ✓ alert (creation of the SCHAPI in Toulouse: Service Central d'Hydrométéorologie et d'Appui à la Prévision des Inondations)
- ✓ the maintenance of networks (electricity, water, gas, roads...)
- ✓ enhanced consideration of the vulnerability of industrial sites in terms of flooding (inclusion of a "flooding" scenario in danger studies)

(*) For comparative purposes, Marseilles' average rainfall is 570 mm.

The flooding of industrial facilities

Flooding of Arles - December 2003

As the French drainage network extends over 280,000 km of rivers, only a few geographical regions are spared the risk of flooding. Although it can prove extremely harmful in terms of human losses and property damage, the operators of installations classified for environmental protection still do not give this type of risk sufficient consideration.

In June 2003, the DRIRE of the Provence-Alpes-Côtes d'Azur Region (PACA) created a "Natural Hazards" task force with the objective to study the natural hazards likely to have an impact on industrial installations, their intensities and associated probabilities and also to define the means required to reduce their impacts. In addition, the task force reiterates the methods applicable in terms of impact analysis.

Faced with the extensive damage caused by the Rhone and its tributaries in 2002 and 2003, the task force planned to first deal with the risk of "flooding". The DRIRE Languedoc-Roussillon ("Direction Régionale de l'Industrie, de la Recherche et de l'Environnement", Regional Industry Research and Environment Agency), DIREN PACA ("Direction Régionales de l'Environnement", Regional Environment Agency), DDE ("Direction Départementale de l'Equipement", Departmental-based Infrascructure Agencies) of the Bouches du Rhône department, the BRGM ("Bureau de Recherches Géologiques et Minières", Office for Geological and Mining Research), a departmental community, engineering firms or adjustment bureaus, manufacturers, labour unions and representatives of insurance companies all participated in this task force. The DRIRE of Upper-Normandy and Météo France also offered their support.

Several of the sites that were flooded in the Bouches du Rhône were visited within the scope of the task force's work: pesticide warehouses in Arles and Rognac, an explosives manufacturing plant in Saint Martin de Crau, and a paper mill in Tarascon... The visits in the Languedoc-Roussillon were terminated by an inquiry in an agro-pharmaceutical product warehouse in Saint Gilles (Gard). These industrial establishments were flooded by an overflowing river or canal, by the rupture of a dike or by significant volumes of run-off water.

In addition, the DRIRE agencies of the Languedoc Roussillon and PACA, in close collaboration with the CETE ("Centre d'Etudes Techniques de l'Equipement", Centre for Technical Studies on Infrastructure) of Aix and the DIREN PACA, drew up specifications for conducting "flood" hazard risk studies on the major industrial sites. This document, available on the web site of the PACA SPPPI ("Secrétariat Permanent pour la Prévention des Pollutions Industrielles", Permanent Office for the Prevention of Industrial Pollution) (SPPPI) PACA, completes simpler guides published by various organisations (insurers…) that warn of this risk in small and medium-sized companies/industries. In the PACA Region, the Aix CETE is conducting a "'vulnerability" study of SEVESO sites by taking a census of the various types of floods feared (floods, dam failures…).

- TARASCON site (Bouches du Rhône) - *(ARIA No. 26459)*

THE INSTALLATIONS IN QUESTION

The company operates a bleached paper pump production unit that uses an ECF (Elementary Chlorine Free) process. Oxygen, hydrogen peroxide and chlorine dioxide, manufactured at the site, are the bleaching agents. Black liquor, fuel oil, methanol, chlorate and several tons of wood are also stocked at the site. The plant produces approximately 250,000 tons of paper pulp per year. Since 1953, the facility, which employs 280 people, has been located to the south of the city of Tarascon, in an industrial estate bordering the Rhone River. It is subject to authorisation with public easement (AS). A reduction in the amount of dry chlorate stored on site and, used in the process, would reduce the site's classification from "high-level SEVESO" to "low-level SEVESO".

The comprehensive development area map requires that the level of the building's ground level floors be placed above water. For the factory, rebuilt in 1981, this level is defined at dimension NGF + 10.56 m (NGF: Nivellement Général de France, French vertical datum - MSL) in reference to the maximum height of the water recorded at the site during the 100-year flood of 1856. The plant's level 0 is located at + 9.36 m NGF; the floors of the workshops and offices were raised 1.2 m. Part of the stock and utilities (lifting pumps) are located below this reference level, but the majority of the heavy equipment is above this level, owing to the presence of bases and support platforms.

Prior to the floods of December 2003 (*No. ARIA 26459*), the plant had already been flooded by 60 to 70 cm of water three times between 1992 and 1994. As a few motors had been flooded at the low points, the plant had been shut down as precautionary measure.

Measurements were taken in the establishment following the 3 other floods in 2001 and 2002, when the level of the Rhone had reached the site to a level of + 10.27 m NGF:

- the "flooding" hazard was integrated into the danger study,
- instructions on site shut-down procedures were drawn up,
- production shops, black liquor boilers and turbines were raised to + 10.56 m, 15 m and 21 m NGF respectively; electrical equipment placed above the water level,
- storage facilities were equipped with retaining basins 0.7 m high and tanks were anchored,
- piping was mounted on racks (only the water conduits were buried).

THE ACCIDENT, ITS BEHAVIOUR AND CONSEQUENCES

Flooding of the Tarascon site

On December 1, 2003, firemen alerted the operator of the risks that the Rhone may breach its banks. The establishment began operations with a reduced workforce the following day.

Faced with the continually rising water, an alert procedure was implemented according to the water levels:

- at 6.4 m NGF, a 600 mm dia. bladder was installed on the piping to prevent the overflow of rainwater into acid effluents,
- at 9 m NGF, the personnel was evacuated and the site was secured by 25 employees (total shut-down of installations, moving of exposed equipment well above water level).

The intervention time allows sufficient reaction time to stop chips being sent and to shut down the black liquor boiler (6 hours are required for complete shut down). For flood protection, the installations are shut down and the boilers and the scrubber are secured.

A team of 25 individuals carries out these operations, while the other 255 employees are evacuated. The total security operation takes 8 hours. Shutting the machines down prior to flooding reduces the chance of equipment damage.

December 3 at 3.30 pm. The reference level of the 100-year flood of 1856 was thus exceeded by 0.74 m. As the site was completely flooded, a boat was used to check that the safety devices on the installations were operating properly. Water reached the following levels during the flood:

- 20 cm at the plant entrance,
- 40 cm in the workshops and offices,
- 1.5 to 1.6 m in certain offices located in low areas,
- 1.6 m in certain buildings.

The computer, electrical, telephone, fax and drinking water networks were lost during the flooding (required for the process). However, The level of the RHONE River at the site reached 10.50 m NGF on December 2 at 3 pm and 11.30 m NGF on the operator could be contacted by mobile telephone throughout the event.

The water receded in 24 hours, and the site became accessible by foot on December 4.

Power generators had to be rented until electrical power could be restored on December 12.

The plant was shut down for 1 month so that the site could be cleaned by employees, civil protection organisations and 300 individuals from external companies (including 60 electricians and 50 mechanics). Personnel from a departmental community, the Direction Régionale de l'Agriculture et de la Forêt and volunteers also provided assistance. Mixed teams (internal personnel, electricians, and mechanics) were formed to repair the damage as best they could.

The safety system implemented for the machines, which operated correctly, was checked after the flood.

The plant resumed normal activity on January 19.

Consequences

The water entered via the parking lot located on the Rhone River side, to the west of the plant. From this side, the fencing protected the tanks and various equipment from debris transported by the river. However, the relatively strong current ripped away the fencing to the northwest of the site.

The current also carried off 6,000 tons of wood (which ripped away the south-side fencing) and empty or nearly empty containers (less than 3 m³). Certain pulp batches were tipped over but not carried away. Two thousand tons of pulp bales were drenched and thus lost. The storage tank, including those not anchored, did not move due to their liquid contents. However, the empty peroxide storage container moved slightly during the flooding. The environmental impact was limited as no chemical products were spilled and due to the Rhone's significant flow rate (dilution effect).

The firefighting water network was untouched owing to the fact that it was located further downstream from the stocks of wood that were carried away by the flood. The merchandise railcars remained on their rails.

Electrical substations were flooded, as well as 400 motors that had to be disassembled and cleaned. Cryptogenics was used to dry the archives. Potholes as a result of gully erosion were observed during the site visit.

The treatment plant (located 7 m below the plant) experienced numerous malfunctions; primary settling tanks were set up to evacuate the silt.

The plant's shut down resulted in production losses of 11 million euros to which can be added property damage and the site refurbishing costs. In addition, the sale of damaged pulp at prices significantly below market value also adversely affected the company.

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 floods of the Tarascon site in December 2003 can be characterised by the following 4 indices, based on the information available.

Quantities of dangerous substances		□	□	□	□	□	□
Human and social consequences		□	□	□	□	□	□
Environmental consequences		□	□	□	□	□	□
Economic consequences	€	■	■	■	■	□	□

Production losses of 11million euros explain the **level 4** rating of the economic consequences in terms of parameter €16. The parameters that comprise these indices and the corresponding rating method are available at the following address: http://www.aria.ecologie.gouv.fr

ACTION TAKEN

The plant was designed to withstand a 100-year flood (1856). The action plan was slightly modified following the floods of 2003, and preventive measures were implemented to protect the archives and the computer servers.

As raising the height of the installations was cost prohibitive, a dike project, required by the insurance companies and the site's shareholders, was subject to a public inquiry by way of the "water police". The height of the dike will be based on the flood of 2003, which will represent the reference in terms of PHEC ("Plus Hautes Eaux Connues", highest known flood waters), with an occurrence estimated at 300 / 500 years.

ST MARTIN DE CRAU site (Bouches du Rhône) - *(ARIA No. 26460)*

THE INSTALLATIONS IN QUESTION

The company operates an explosives manufacturing plant located within the *commune* of St Martin de Crau in the township of Arles in the northwest of the Bouches du Rhône *département*. The plant is located in the heart of the Crau plane, which is a sparsely populated urban area.

The facility, which employs 63 people, is classified as high-level SEVESO under the terms of European regulations and subject to authorisation with public easement (AS) as per French regulations. The plant is not located in a flood-risk area and had never been flooded prior to December 2003.

Fifteen hectares of marshland are located near the administrative buildings to the northeast of the site. Numerous canals empty into this marshland and is subsequently used as an outlet for the overflow of water from heaths in the surrounding area. A 150 m³/h lifting pump discharges the marsh water via canal to the Chapelette marshes to the northwest.

THE ACCIDENT, ITS BEHAVIOUR AND CONSEQUENCES

The flooding of December 4, 2003 at the St Martin de Crau site

The strong rains that had continued for one week flooded the land next to the site and raised the water level in the Langlade canal on the plant's southern border by 2 m. The gates, closed for an unknown reason, were unable to drain off the canal's overflow.

Workshops

A wave of water entered the site from the southwest and flowed into the 15 ha of marshland. The 150 m³/h pump, flooded by the rapidly rising waters, was unable to prevent the site from being flooded where the water level had already reached 1.2 m. The operator had set up the 4 pumps available on the site in strategic locations.

As the water pumped from the site was discharged into a second small marshy area, it eventually flooded the northern zone of the site where a transformer was located. This transformer was not damaged. The back-up pumps, requisitioned from other industrial sites and providing a total flow rate of 2,000 m³/h, were able to control the rising waters in the marshland.

After a week of pumping, the CHAPELETTE canal returned to its normal level.

Consequences

Although the production buildings, sensitive equipment and stocked products were not damaged, a 2-week shut-down resulted in operating losses estimated at more than 100K euros.

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 floods of the St Martin de Crau site in December 2003 can be characterised by the following 4 indices, based on the information available.

Quantities of dangerous substances	☐	☐	☐	☐	☐	☐
Human and social consequences	☐	☐	☐	☐	☐	☐
Environmental consequences	☐	☐	☐	☐	☐	☐
Economic consequences	■	☐	☐	☐	☐	☐

Production losses, estimated at more than 100K euros, explain the level 1 rating of the economic consequences in terms of parameter 16. The parameters that comprise these indices and the corresponding rating method are available at the following address: http://www.aria.ecologie.gouv.fr

ACTION TAKEN

The operator added the addresses and phone numbers of companies that could provide back-up pumps in the case of an emergency to the Internal Contingency Plan. No other measure concerning the floods was taken in terms of the Internal Contingency Plan or the Danger Study.

- ROGNAC site (Bouches du Rhône) - *(ARIA No. 29646)*

THE INSTALLATIONS IN QUESTION

The facility stocks, re-labels, prepares, repackages and palletises merchandise. In 2 hangars with a total surface area of 11,000 m², it stocks pesticides, bulk products in silos, plastic materials and power generators. 37 employees are at the site during the day.

This company is no longer classified as 'low-level SEVESO' due to the limitation of its pesticide storage which had been partly transferred to another site.

Located at the base of a hill, the site is surrounded by a rail line. The elevated upstream part of this rail line forms a dike.

THE ACCIDENT, ITS BEHAVIOUR AND CONSEQUENCES

The site was subjected to 2 floods in 1993 and in 1994.

✓ The floods of September 1993 followed an intense period of rain lasting 2-3 days. The rail spur channelled the rainwater running along the hill behind the site via underground passageways, which lead to the very rapid rise in the water level.

The wave of water passed through the site and emptied through the entry gate into the avenue. The wave lasted 3 to 4 hours and flooded the offices, storage units and warehouse packaging areas under 50 cm of water.

The very sudden wave occurred around 6-7 am. As no one was at the site at the time, the flooding was reported only later in the morning. No preventive measures had been foreseen.

The damage primarily concerned the machines and the offices, as the computer network had been disconnected. Flammable pesticides, stuffed animals and life preservers were being stored when the flooding took place. Financial losses were estimated at 7 MF, in addition to a significant loss of clientele.

✓ The second floods in Oct.-Nov. 1994 were more extensive. The torrential and intense rains (lasting between 24 and 48 hours) caused an 80 cm-high wave that remained at the site for more than 10 hours. The water followed the same path as the first floods.

The flooding slightly damaged the machines, although the damage was concentrated in the offices and the merchandise stored in the cells. A second warehouse, located on higher ground, had less damage. The computer network was also disconnected during these floods.

Financial losses were evaluated at 6MF despite the measures taken following the floods of 1993.

European scale of industrial accidents

The indices are as follows for each of the establishment's floods:

Quantities of dangerous substances	□ □ □ □ □ □
Human and social consequences	□ □ □ □ □ □
Environmental consequences	□ □ □ □ □ □
Economic consequences	■ ■ □ □ □ □

Property damages of 7 and 6 MF (1.1 and 0.9M €) explain the level 2 rating relative to the economic consequences in terms of parameter 15.

ACTION TAKEN

Following the 2nd flood, the operator introduced a permanent monitoring program through a 24/7 duty cycle on the site. In case of new floods, a team of 3 or 4 people would be made up to rapidly secure the equipment and sensitive merchandise.

The *commune* built an underground canal connected to the Etang de Berre which collects water from the entire industrial area. It also created a retaining basin upstream from the industrial site designed to handle 100-year floods.

In the event of a 100-year flood, most of the surplus water would be released back into the canal. The *commune,* thus informed the operator that the site may nevertheless be flooded by 10 cm of water. The latter had 20 cm walls built in front of the emergency exits of the storage units and called for a dam arrangement with transport containers to channel the flow of water.

In most cases, industrial zones are protected only against 100-year floods. Public infrastructures generally do not protect against major floods and the operators of classified installation must undertake additional actions.

- ARLES site (Bouches du Rhône) - *(ARIA No. 26457)*

THE INSTALLATIONS IN QUESTION

The company stocks and distributes finished pesticide products, without transfer operations and does not sell to the public directly. The storage activity involves 3,600 m² and an average height of 7 m (4 levels). The facility has a maximum storage capacity of 3,000 tons, and 48% of the merchandise is governed by legislation relative to dangerous materials.

Located in the Arles industrial zone, the establishment is classified as 'high-level SEVESO' and employs 6 to 8 people. The Grand Rhone is located 750 m to the west and the Vigueirat canal is 1,100 m to the east.

Prior to the floods, the site was not registered as being in a flood-risk area as it was protected by a reliable dike. Since that time, the DDE has downgraded the zones from "protected by reliable dike" to "submersible protected by a dike".

THE ACCIDENT, ITS BEHAVIOUR AND CONSEQUENCES

Flooding of the Arles site

The flooding of the site in December 2003 resulted from a dike on the Rhone failing at Avignon.

On December 3, the flow rate of the Rhone River had increased significantly. On December 4 at 4 am, the Town Hall sent a fax to announce that the industrial zone would receive 20 cm of water. As the building's docks are 1.2 m above ground level, the facilities were considered to be above the rising water level.

Precautionary measures were nevertheless taken in the morning. From 9 am to 12 pm, while the rest of the personnel had evacuated, 2 employees used the detailed list of stored products to move sensitive merchandise onto the docks, closed the valves to prevent water from entering through the rainwater drainage network and disconnected the electricity and the foam generator.

Little by little the water rose above the loading docks and reached the storage units; 0.9 m at mid-day and 1.43 m the next day. Surveillance rounds of the facilities were conducted and the water level monitored for 14 days following the flood.

On December 17, the DRIRE proposed the Prefect to authorise the operator to pump the water contained in the cells following analysis by an external company. The establishment resumed its activities on January 5 after the facilities had been cleaned.

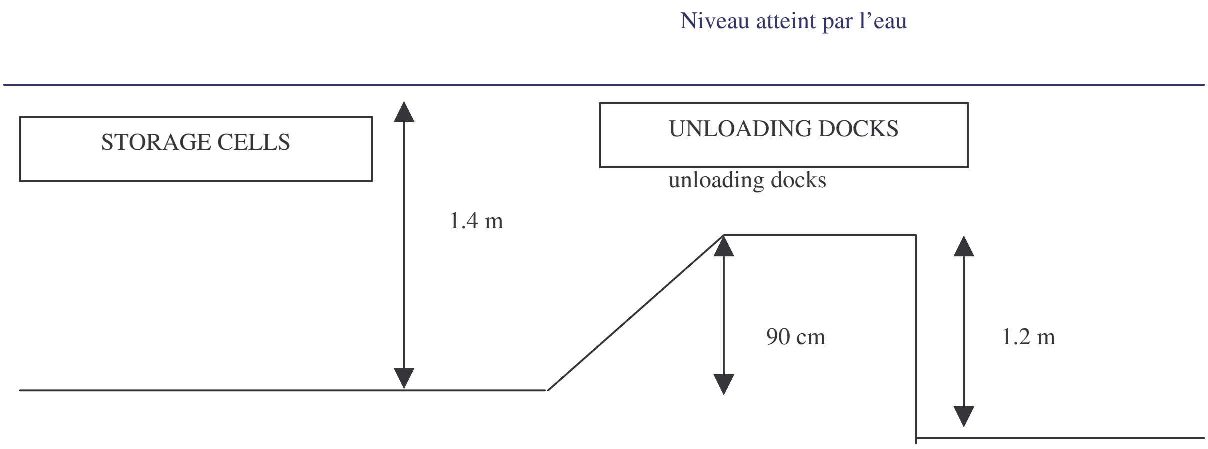


Diagram of water heights on the docks and storage cells

Consequences

Property damage was estimated at 4M euros. At the time of the flooding, 1,300 tons of merchandise were stored in the halls, including 400 t on the ground. Approximately 1/4 of the stock was saved, while the remainder was either destroyed or downgraded.

Many of the chemical products were liquid and packaged in plastic jugs, metal, aluminium or cardboard drums. The heavy-duty packaging for the dangerous materials did not suffer extensive damage. However, the Kraft drums in which the 'chlorine' tablets (DCCNa) were packed sagged, generating odours which alerted the firemen patrolling on site.

The pallets were not moved; only a few boxes were swept away by the current.

All the motors of the forklifts, parked on the dock, were flooded. Part of the archives stored in the administrative buildings was damaged.

Cracks were observed in the storage unit floor slabs. There where, however, no visible traces of impacts or deformations on the racks.

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 flooding of the pesticide product storage and distribution site in December 2003 can be characterised by the following 4 indices, based on the information available.

Quantities of dangerous substances	□ □ □ □ □ □
Human and social consequences	□ □ □ □ □ □
Environmental consequences	□ □ □ □ □ □
Economic consequences	■ ■ ■ □ □ □

The four million euros in property damage explains the level 3 rating of the economic consequences in terms of parameter 15. The parameters that comprise these indices and the corresponding rating method are available at the following address: http://www.aria.ecologie.gouv.fr

ACTION TAKEN

Following this episode, the operator included the 'flood' risk in the danger study and reviewed the site's Internal Contingency Plan.

A direct telephone line to the municipal flood-warning department was installed and a permanent monitoring program was set up for the site (in terms of an on-call system). Even in the event of a minor alert, all merchandise must be secured.

In terms of stock management, sensitive merchandise are automatically placed on level 1, only drums (metal, or jugs) can be stored at floor level.

Barriers measuring 90 cm high and guided by rails are placed on the doors of storage units and emergency exits.

- SAINT GILLES site (Gard) - *(ARIA No. 29661)*

In early December, the Rhône also flooded a pesticide products warehouse in the Gard after a dike broke. The operator implemented emergency measures similar to those taken for the Arles warehouse. Even while limited, there was significant damage owing to the lack of a 'flood risk' prevention plan.

THE INSTALLATIONS IN QUESTION

The company in question stored agro-pharmaceutical products.

One thousand tons of chemical substances can be stored in three 480-m² storage bins, each capable of holding 330 t of merchandise over an average height of 7 m (4 or 5 levels). The facility is classified as high-level SEVESO under the terms of European regulations and subject to authorisation with public easement (AS) as per French regulations.

The floor of each unit is designed to be hermetic to firefighting waters, among other things.

THE ACCIDENT, ITS BEHAVIOUR AND CONSEQUENCES

Flooding of the Saint Gilles site

In the morning of December 3, 2003, the Prefecture of the Gard department contacted the industrial sites to inform them of water rising in Saint-Gilles as a result of the heavy rain that had fallen in the region the previous days and that several dikes along the Rhone had failed. The Classified Installations Inspectorate was informed in the same manner.

As a precautionary measure, the operator of the agro-pharmaceutical products warehouse placed the most sensitive products and those with cardboard packaging at a height of 1.8 m. The products were then raised to a height of 3 m as a precaution.

The 3 employees present were working up to the time when water began to enter the storage units.

The means of communication (conventional telephone line) and the electrical installations were inoperative. In contact by mobile telephone with the operator, the rescue services were able to evacuate the employees by raft.

The operator then pumped the water retained in the storage units outside the buildings.

Consequences

Several days later, the Classified Installations Inspectorate noted that the water had risen 90 cm in the storage units and 57 cm to the level of the loading dock and offices.

Considering the relatively slow kinetics of the flood and the measures taken, no accidental pollution was noted after the water had risen in the 3 storage units.

The company was able satisfy its customers' needs from its head office, thus avoiding operating losses.

However, the cost of the damage caused to the offices (furniture, floors, walls…) and equipment (UPS, vacuum, fire detection battery…) was nearly 80,000 euros.

The damaged pesticide products (packages or labels damaged…) represented losses estimated at more than 40,000 euros.

European scale of industrial accidents

The following indices were determined for the flooding of the Saint Gilles site:

Quantities of dangerous substances	□	□	□	□	□	□
Human and social consequences	□	□	□	□	□	□
Environmental consequences	□	□	□	□	□	□
Economic consequences	■	□	□	□	□	□

The 120,000 € in property damage explains the level 1 rating of the economic consequences in terms of parameter 15.

ACTION TAKEN

As the agro-pharmaceutical product storage site at St. Gilles had never been flooded prior to December 2003, it did not have a "flood" prevention plan. Nevertheless, the measures undertaken immediately proved efficient, even without benefiting from the public rescue services that were extremely busy providing assistance to the populations in need.

The Classified Installations Inspectorate requested that the operator:

- check the electrical installations and major safety-related equipment prior to resuming any activity,
- in terms of the safety management system, implement site securing procedures for the "flooding" hazard,
- integrate the "flooding" scenario into the Internal Contingency Plan.

Furthermore, the operator:

- raised the electrical installations above the flood water level,
- modified the management of stocks in order to raise humidity-sensitive products,
- rework the sealing of the 3 storage units (with the application of resins), even though the floor was not damaged.

- Lessons learned -

National level concerns

This summary of the Provence-Alpes-Côte d'Azur and Languedoc-Roussillon regions shows that the risk of flooding can take several forms (direct overflowing of rivers or canals, trickling, dike failures…) and can take place more or less suddenly in numerous locations. This situation, however, is not specific to these regions, the flooding of the Tarn in 1999, Brittany and Somme departments in 2001… are a firm reminder. In addition, the climatic changes warn of a general increase in this type of phenomena.

A present, the PPRI ("Plans de Prévention des Risques d'Inondations", Flood Prevention Plans") define the construction standards required for local urban planning documents in terms of public easement. They generally take the level of the PHEC ("Plus Hautes Eaux Connues", highest water levels) into consideration or those of the 100-year floods by default, but the strictest criteria may be retained. The PPRI of the Yvelines region also indicates raising installations 20 cm in relation to the PHEC.

The public or private infrastructure (collective or otherwise) can have a strong influence on the risk of flooding (backfill, roadways, wastewater systems, location of industrial zones… and more generally, all structure likely to modify the flow of water). It is thus of utmost importance that the those involved in regional planning address these questions.

Consideration of the "flooding" hazard in classified installations

Detailed studies addressing the types of possible flooding, their intensity and probability of occurrence and preventively defining the means to implement in classified installations in order to limit the human, property and environmental consequences are required. In these circumstances, the use of dangerous materials or processes could have ecological and public health repercussions depending on the characteristics and quantities of products involved. These studies concern both new installations and existing sites where the prevention or protection measures can often be improved.

In this respect, the memorandum of the French Minister of Ecology and Sustainable Development of January 15, 2004 entitled 'National actions 2004' emphasized that the prevention of "flood" risks must take increased precedence in the danger studies of SEVESO sites. There are no national technical regulations that specifically address the flooding of classified installations, comparable to that of lightning or earthquake activity. Also, the analysis of this risk and developing the means of appropriate prevention and protection for each installation concerned is even more important.

The measures imposed on classified installations subject to authorisation must take the extent of the possible consequences into account on a case-by-case basis, as well as the technical and organisational measures available. It should be observed that the reference floods retained for the definition of these means are strongly influenced by the extent of the last catastrophe that occurred. As in the case of the Tarascon site, the 2003 flood corresponding to the highest flood waters known (PHEC) estimated to occur every 300 to 500 years, was taken into consideration.

The frequency and the extent of the floods in the recent past confirm the need to better analyse this type of risk and the internal measures to be adopted, at least for the danger studies of classified installations. Several general recommendations were formulated in this respect.

Firstly, the kinetics of the natural phenomenon must be considered. It particularly concerns taking into consideration the time available between this alert and the flooding in order to classify the various measures to be implemented:

- those dealing with prevention and protection that require an excessive period of time. They must be set up independently of the alert and are to be regarded as "permanent",
- intervention actions that can be reasonably implemented after the alert with a sufficient safety margin.

The measures to be implemented must also be proportioned to the extent of the stakes and interests to be protected.

Analysis could take place according to the following scenario:

- ✓ identification of the type(s) of possible floods to which the industrial site is subjected without limitation in terms of frequency,
- ✓ data collection: topography of the site, hydrogeological and hydrological data, information on floods (PHEC, flood flow rate, rate of water increase, submersion duration, warning lead times…), feedback on floods at the site or similar sites,
- ✓ characterisation of the reference flood scenario(s),
- ✓ determination of the site's zone that would be effected by floods,
- ✓ for these zones: risks for processes and products,
- ✓ detailed risk analysis, identification of major accident scenarios, safety-related elements, evaluation of the consequences by considering the "flood" risk (loss of utilities, equipment floatation and/or overturn study...),
- ✓ definition of appropriate protection, intervention and prevention measures.

Experience has shed light on permanent measures to prevent a site from being flooded or to reduce the risks and damages that it may encounter; the following examples may be cited:

- ❑ dikes around the site to be protected,
- ❑ sufficiently dimensioned rainwater storage basins,
- ❑ constructions on a crawl space, enabling the floor to be built above the reference flood level,
- ❑ implantation of a building in the direction of the current, in order to limit the obstacle effect against the flowing water,
- ❑ reinforcement of the building structure so that it can resist the forces exerted by flowing flood water and the differential settling after the water has receded,
- ❑ raising / protection of the most important or water-sensitive storage areas and equipment (at risk or with windows, for establishment operation) by low walls,
- ❑ ballasting, anchoring, sealing of tanks that could be dangerous or polluting,
- ❑ placement of electrical, telephone, computer, gas, and drinking water networks above the water level,
- ❑ creation of a refuge area for the employees above the water level
- ❑ construction of non-floodable access roads to facilitate intervention in the buildings,
- ❑ a visual identification system of electrical power supply disconnection devices or wastewater network valves,
- ❑ installation of drainage systems for flooded areas in order to reduce submersion time…

Despite all the measures that could be implemented at a site, the flood alert procedures must not be neglected. Radios, which cover the entire territory, and telephone, via simultaneous calls, are two particularly efficient means. In this respect, the actual operability of the means of communication between the operators and the organisations in charge of the alert must be frequently checked.

Furthermore, the establishment's internal contingency plant must reiterate the actions to be taken in case of a weather early-warning and flood warning, the personnel evacuation procedure and specialised rendezvous and refuge locations, the precautions to be taken depending on the nature of the products and the equipment concerned, the designation of the intervention team and the temporary measures to be taken, such as:

- shutdown of activities, securing of installations, interruption of product transfer operations,
- disconnection of power supplies (electricity, gas…),
- locking and sealing of certain openings,
- placement of sensitive or "at risk" elements above the maximum probable water level,
- moving of critical stock and equipment away from the flood zone,
- plugging of wastewater and rainwater networks,
- pumping of water to control the rising water in units running the greatest risk…

Regular monitoring of the weather forecast allows one to be regularly informed of alert messages in order to allow sufficient reaction time to implement these measures.

Finally, it is useful to point out the interest that operators have in having their own flood control equipment (pumps, power generators, life rafts…) as the rescue services are often very busy during floods providing assistance to the population.

Gas oven explosion

April, 1st, 2003

Geleen – The Netherlands

Oven
Gas
Explosion
Restarting
Maintenance

THE INSTALLATIONS IN QUESTION

Chemelot site is situated in the south of the Netherlands, in the province Limburg, just north of Maastricht. It is the second largest chemical complex in the Netherlands. Chemelot consists of several production plants, producing plastics, as well as several base chemicals for the production of plastics, medicine and other products.

On the site several companies are active among which a former state owned mining company, nowadays a privately owned company which produces basic chemicals, medicine, food products and products such as high strength fibres like Dynema. The accident happened in a plant which is part of this company. This plant consists of a large industrial gas oven, fuelled by natural gas and residual gasses from other plants on the site. These residual gasses are contaminated en therefore have to be filtered before use. These filters have to be cleaned regularly, which means shutting down the oven and restarting it after cleaning the filters. This plant produces melamine.

THE ACCIDENT, ITS BEHAVIOUR, ITS EFFECTS AND CONSEQUENCES

The accident :

Shutting down and restarting the oven is a lengthy process in which the oven has to cool down, before it can be restarted. Restarting has to be done gradually, starting with the pilot burners, after which the main burners can be started.

On restarting the oven filled with a combustible mixture of gas and air, which was *probably* ignited *by an errant spark from* a ventilator *started* by an operator.

The explosion caused the lid of the oven, on which a maintenance crew was working, to be blown off. The lid fell down in the oven, together with the crew who were standing on it.

The oven before the accident

The oven after the accident

The consequences :

At *the* moment *of the accident* three people carried out maintenance work on top of the lid of the oven. The temperature in the oven was still 350˚C and all three were killed tragically.

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 characterized by the following 4 indexes, based on the information available.

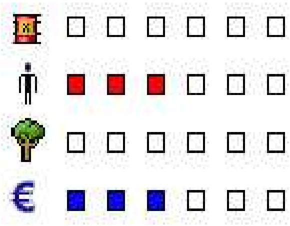
The parameters which compose these indexes and the corresponding rating method are indicated in the appendix hereto and are available at the following address: http://www.aria.ecologie.gouv.fr/

Quantities of hazardous substances

Human and social consequences

Environmental consequences

Economic consequences



The level of the human and social index is 3 because 3 workers were killed. The level of the economic consequences index is 3 because damages to the installations and production losses are estimated at several millions of euros.

ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

Safety has three components :

- The first is the 'hardware' consisting of machines, ancillaries, pipes etc., in this case the oven itself with pipes, valves, burners, ventilators, electric appliances, the switchboard etc.
- The second component is the 'software' consisting of measures, rules and regulations regarding the safe operation of machines and plants.
- The third and last component is the human factor, the people operating the switchboard and their behaviour.

The behavioural elements are the crucial factor in this case, as they often are.

As said before, stopping and restarting the oven was a lengthy procedure, taking about *24* hours. During that period production at the plant was halted, causing substantial production losses. In order to shorten the cut off time, the operators of the plant devised a faster procedure to restart the oven, thereby ignoring safety procedures prescribed.

This faster procedure, which was employed before, resulted in filling the oven with a stochiometric (explosive) mixture of gas and air. This explosive mix was ignited, probably by a freak spark coming from an electric ventilator started moments before the explosion, by an operator.

In analysing the sequence of events, it becomes clear that the fast track procedure employed in this case, resulted in bypassing the safety precautions, applied to prevent the oven filling with an explosive mixture of gas and air. It becomes clear that the explosion *probably* happened because of the ventilator, which provided the spark for the ignition, but that the roots of the accident are lying deeper.

The underlying cause consists is the use of the fast track procedure employed to restart the oven. This procedure was designed to by-pass safety measures prescribed in order to safeguard the safe restart of the oven. By doing so, explicit safety instructions were ignored.

However the root cause can be found when analysing this event. Analysing the root cause, is necessary to understand the operators, the people who run the plant and were trying to restart the oven as quickly as possible. Of course they were well-trained and experienced professionals, knowing their plant and the oven inside out, otherwise they would not have been able to devise a fast track procedure to restart the oven. Of course they were not irresponsible, incompetent, or consciously taking the risks they were taking. Nor were they undisciplined thrill seekers. On the contrary, they meant to be responsible professionals, trying to do their job properly and to a professional standard, thereby bearing in mind the primary goal of the company; to produce as much, as fast as possible, at the lowest possible costs.

It was this aim that was predominant in their decision to restart the oven using a faster procedure than prescribed. In this, their actions were in keeping with the result driven culture of the company involved, which puts economic aims first and consequently safety at a second best. A quote from one of the company's directors testifies this. In a safety audit the company scored 55%, which according to the director in case is sufficient to pass your exam at school!

The fast track starting procedure had been employed before, in that instance with good result. The accident survey revealed that in that case, neither beforehand nor afterwards, did the management of the plant check the procedure. By not checking the procedure, the quick restart of the oven was implicitly accepted by the management as good practice. So understandably the operators saw no reason not to use the fast procedure again.

As we now see, the result driven culture of the company, which puts economic results first en safety second best, supported by actions of the company's management, or rather as in this case by the lack of action in the form of control, resulted in the dangerous fast track starting procedure devised by the operators of the plant.

The conclusion is therefore that on the basic level the root cause of the accident is to be found in the company's culture.

LESSONS LEARNED

Human behaviour is crucial for safety.

Safety starts with addressing human behaviour.

Safety is produced from the top down with full commitment.

Safety responsibility starts and stops with management. This means that for a manager the working day starts and ends with safety.

Safety has to be practised by the management.

Don't be fooled by signs, posters, slogans and management jargon, search for what makes people (at all levels) act the way they do!

Storm "Gudrun" and the Swedish forest

January, the 8th, 2005

Sweden

Natural risks
Forestry industry
Timbers
Pesticides
Irrigation
Material and environmental damages
Regulation

LOCATION OF THE STORM AND LEGISLATION INVOLVED

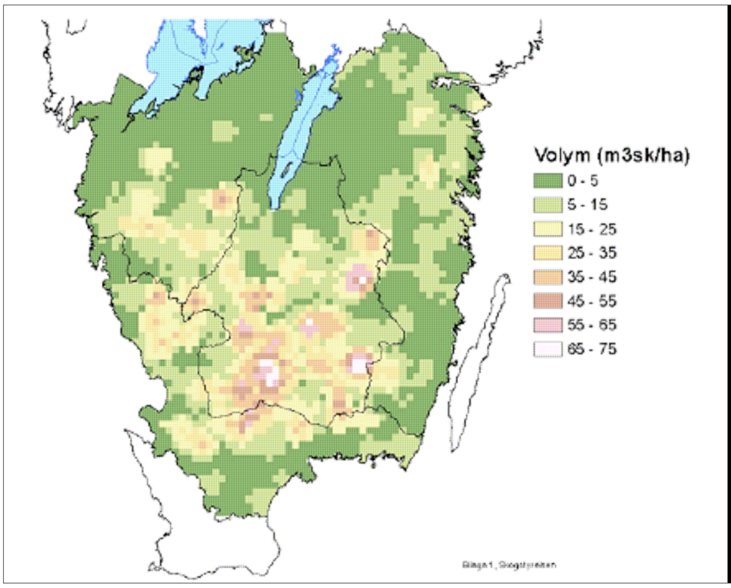
The storm mainly affected the southern parts of Sweden. In this area, the quantity of coniferous forests with spruce is large. The major effects caused by the storm consisted of fallen trees, shown in the map below illustrating the volume of timber damaged in different parts of southern Sweden (Figure 1).

This presentation will focus on the environmental issues concerning the storm.

The most important consideration after the storm was the possibilities to handle and store all of the fallen timber. Storage usually involves irrigation or even storage in lakes.

Until the storm occurred, environmentally hazardous activities like these always requested permit from the County Administrative Board (regional authority) according to an ordinance in the environmental legislation called "environmentally hazardous activities and health protection". Normally a licensing process lasts for as long as a year.

For hazardous activities with less environmental impact, a notification is made to the local authority (municipality) instead of the permit.



maged by the

Figure 1 – Volume of timber per hectare (10 000 m^2) damaged by the storm in January 2005

THE EVENT, ITS DEVELOPMENT, ITS EFFECTS AND CONSEQUENCES

The event :

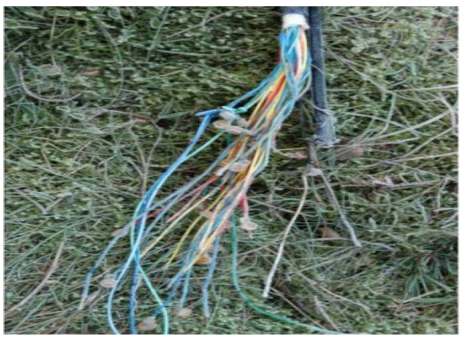
The storm called "Gudrun" struck southern Scandinavia on the night between 8th and 9th of January 2005. In Sweden, the winds first reached the west coast at storm levels. The storm grew further during the evening and spread all over the south of Sweden. In some places, even in the inland, the winds reached the strength of a hurricane (≥ 33 m/s). The storm is considered to be the worst in Sweden since September 1969.

During this storm, more than 75 million m³ of timber were damaged, compared to 35 million m³ of timber in the storm 1969. Most of it fell down, but some trees were broken like matches. The major part of the trees that fell were very old aged spruces (*Picea abies*).

The consequences :

Immediate consequences

As an effect of the large number of fallen trees, the following consequences emerged.



- ✓ At least seven persons were killed, mostly in traffic accidents with falling trees involved.
- ✓ An estimate of 410 000 households had no electricity after the storm. Even as long as a month after the storm, many households still lacked electricity.

- ✓ For at least 200 000 households, the telephone network was out of order.

- ✓ Immediately after the storm, many roads where closed due to fallen trees. As the road authority was prepared, many of the major and middle sized roads where open within a couple of days after the storm.

- ✓ As the railroads were struck harder than the roads, rail traffic was affected for a month.

- ✓ In many watercourses, the water level rose but sank again shortly after the storm had abated.

Subsequent consequences

To avoid damage of the timber by insects, fungus or dryness, it needs to be irrigated or put in water during the summer months. In the worst case, treatment with pesticides can be a possibility. Irrigation is used on timber transported to larger terminals and pesticides are used on smaller timber stacks gathered along country roads. To avoid the use of pesticides, the objective by the forest industry is to transport the timber in timber stacks to larger terminals.

✓ Irrigation and lake-storage timber lead to a leachate containing substances released by the timber. These are mainly phosphorous, toxic substances like phenols, and terpenes, and a lot of oxygen demanding organic substances. Due to organic acids, the pH-value of the leachate becomes low. The environmental impact from lake-storage is greater than from irrigation of timber. Lake-storage is also an expensive method and is nowadays not used by the forestry industry. Because of this, there are not many good places for lake-storage.

Therefore, irrigation with water in terminals is the most important method to store timber fallen in the storm. With the irrigation of several millions cubic metres of timber, the consequence will be enormous : amounts of contaminated leachate throughout the south of Sweden. Irrigation normally lasts for 12-15 hours a day during the summer months. About 3 litres of water are needed per second to irrigate 1 000 m³ timber.

✓ For the treatment of fallen timber with pesticides, only two pesticides whose effective substances are cypermetrin and deltametrin respectively, are allowed in Sweden. These chemical products are very toxic to fish and other water living organisms. Treatment with pesticides may present an interest if the forestry industry does not succeed transporting the timber gathered in timber stacks along country roads to larger terminals for irrigation.

Recently, the forestry industry suggested that the use of pesticides would be less than first expected. This is mainly due to economical reasons and that the government simplified the legal process for irrigation and lake storage of timber. The effort made by local authority (municipalities), handling the notification for irrigation and lake-storage very efficiently, is also an important factor.

ORIGIN, CAUSES AND CIRCUMSTANCES OF THE EVENT

There are many theories about why the storm caused such a large number of fallen trees. The following are the major theories.

- ✓ Mostly spruce were fallen by the storm. This is probably due to a root system that is very shallow in comparison to deciduous trees.
- ✓ In the south of Sweden, spruce is mainly planted for the forestry industry. It has been established that different ways of attendance and thinning of the forest have led to different amounts of timber fallen in the storm.
- ✓ The exposition of forests to a lot of wind had created clearings, places which are more vulnerable in case of hard winds.

ACTIONS TAKEN

By the forestry industry

The problems for the forestry industry mainly concerned the transport of timber from the forests to terminals and the industries. There was a lack of timber-lorries, which was finally solved by borrowing lorries from the north of Sweden and even from the Baltic States. The objective now is to deal with all the fallen timber within 18 months.

One of the tasks was to find appropriate locations for terminals to irrigate the timber. In order to serve as a terminal, some requirements had to be fulfilled : supply of water and electricity, being in a logistically good position. Terminals are now found mainly at industries and in harbours, and at places between forests and industries/harbours.

Although some of the timber is exported from the harbours by boat or transported by timber-lorries to the north of Sweden, the sawmills and paper mills in the south of Sweden are highly under pressure.

By the government

The legal process to get a permit to irrigate or lake-store timber in a certain location was changed by the Government. The licensing process may take up to a year, which is normal, and the processing of permit applications is done by the County Administrative Board (regional authority). With a process of this kind, there was an imminent risk that a lot of the fallen timber could be destroyed or preserved by treatment with dangerous pesticides that would be spread throughout the forests. To simplify and speed up the licensing process, the Government immediately changed the ordinance to the Environmental Code regarding “environmentally hazardous activities and health protection” to an extent : a notification to the local authority was sufficient to store fallen timber due to a storm or hurricane. It is also possible to submit a notification up to six weeks after the storage has begun at a location.

By national authorities

The Swedish Environmental Protection Agency was the authority that made the proposal to the Government about changes in the legislation. They also made the work easier for regional and local authorities by guidance and information.

Also the Swedish Chemicals Inspectorate assisted the regional and local authorities as well as the forestry industry with guidance and information concerning pesticides.

Being relieved of the procedures of irrigation and lake-storage of timber, the County Administrative Board concentrated on guidance to local authorities concerning the incoming notifications and gave status reports to the forestry industry and individual forest proprietors.

Other legislation remained. This results for example in that permit is required according to the Environmental Code for pumping water for irrigation from watercourses and lakes in case of disturbance of individual or general interests in the watercourse. The licensing process lasts a very long time and is arbitrated by the Environmental Court. Questions about the requirement for permits are handled by the County Administrative Board that was exclusively concerned, along with the forestry industry, with finding locations where permits were not needed.

Due to the high pressure on sawmills and paper mills, some of the industries now need a new permit from the County Administrative Board to produce more than they are allowed in the present permits.

By local authorities

The local authorities (municipalities) deal with the notifications. Since the other aspects of the legislation remain the same, the demands concerning the impact on the environment due to irrigation of timber also remain. It leads to rejections of some locations for irrigation of timber, for example soils such as sand and gravel drain water easily, or within protection areas of water catchments. The approval documents of the notifications are also combined with certain conditions regarding how to decrease the environmental impact from the environmentally hazardous activities.

LESSONS LEARNED

✓ Our legislation was not prepared for unexpected natural catastrophes. This knowledge can, with the help of risk assessment, be avoided in other similar unexpected situations.

✓ Better understanding is needed between forestry industry and authorities.

✓ Increased knowledge about the methods for environmental protection, preferable tot irrigation and lake storage of timber. Infiltration of leachate in soil and use of clean water for irrigation are for example a better solution than water recirculation. When you use the same water many times over the timber, it can give severe problems with growth of bacteria in the water.

✓ Several research projects have been started to study effects of the storm, for example;

- the environmental impact from irrigation and lake-storage of timber
- how to attend and thin the forest efficiently to avoid storm fallen trees
- other options than using pesticides, for example pheromone traps

✓ Deciduous forests are less likely to be affected in a storm than coniferous forests.

Seminar closing speech

Philippe Lucas
Assistant Head of the Industrial Environment Department.

Following two days of intense exchanges and debate, I would like to take this opportunity to thank all those who contributed to making this event a success. I would like to extend special thanks to:

✓ the Prefect of the Basse-Normandie Region, Mr. Cyrille Schott who welcomed us yesterday, the Basse-Normandie, DRIRE, its Director, Mr. Alain Louis Schmitt for his personal involvement and that of his team in the organisation and warm welcome, and the Barpi agents for the overall coordination and documents provided.

✓ I would particularly like to thank the various participants who accepted to share their presentations with us: the Classified Installations inspectors and labour inspectors. They presented their cases and the lessons learned in a clear and informative manner.

✓ I thank the participants in the round-table discussions:

- Mr. LECOQ, Mayor of Gonfreville,
- the DRIRE, Mr. Alain Louis Schmitt,
- Mr. GUEYDAN, Director of the Calvados Prefect's office,
- Colonel BIZET, Director of the Manche SDIS ("Service Départemental d'Incendie et de Secours", county fire and emergency service),
- Mr. PIERRAT, Assistant Director of the UIC,
- Mr. BONNEMAINS of the "Robin des Bois" Association,
- and our colleague, P. CRENN, Classified Installations Inspector in Le Havre.

✓ I would also like to thank all the participants who contributed through their questioning and personal experience.

Without reiterating all of the technical aspects presented during these two days, I feel that it would be useful to comment on a few specific points:

1. The importance of the human factor in the fundamental causes of accidents
2. How accident feedback can orient the Inspectorate's work
3. The need for greater openness as regards the public

First: **The very significant role that the human factor plays in the fundamental causes of accidents**

✓ After analysis, the wide variety of accidents reveals already well-known technical causes (exothermic reaction, tank implosion, dust explosion…) but which escaped the control of the operators.

✓ The lack, insufficiency or disregard for intervention or operating instructions and occasionally even neglect of pre-incident indicators are often at cause. These elements are not likely to be identified in the danger study, but they are frequently at the heart of accident mechanisms. Whether it is the operational phase itself, transitory phases or steps associated with operations, etc., the "human factor" does not concern the operator exclusively. The organisation plays a major role in accident mechanisms, beyond technical failures.

This point was made clear in a number of presentations, regardless of the technical aspects in question (periodic verifications of threaded connections, follow-up of instructions, loading/unloading operations or unit lock-out procedures…).

The analysis of fundamental causes often enables a reorganisation of sites and concrete improvement. Reducing the number of accidents greatly depends on this.

These observations are corroborated by the 1992-2004 study of technological accidents recently published by the DPPR.

Second: how can accident feedback orient the Inspectorate's work?

Several orientations merit further development:

- ✓ Firstly, though risk analysis and danger studies are indispensable prerequisites for improvement (to avoid common-mode electrical failures, for example), they are insufficient to provide safety throughout the life of the unit.

- ✓ Concrete elements of internal and external feedback must also be included on a regular basis in these theoretical studies. This is an experience-based continuous improvement process including the recording and analysis of incidents, the development of countermeasures and the long-term follow-up of their efficiency.

Beyond discussions with site safety officers about installation and equipment, scheduled or spot field inspections must be conducted to ensure that all those participating in the daily operations or during repair/installation work, be they salaried employees or subcontractors, respect the management requirements in terms of safety. Numerous cases presented during these two days illustrated this need.

During our inspections, we must verify the process which is meant to ensure that the pertinent information reaches the concerned operational level. Through this type of inspection, we urge the operator to create a reasonable balance between the time spent on the danger study and that reserved for management, training, information and verifications or internal audits.

This concern for balance between theoretical studies and practical applications is a fundamental element of feedback. It is certainly one of the key parameters for safety. It concerns everyone: be it the operators, management or the Inspectorate. In this respect, appendix III-6 of the order of May 10, 2000 (application order of the SEVESO directive in France), clearly emphasizes the importance of feedback management based on the analysis of incidents, the development of countermeasures and the long-term follow-up of their efficiency. This is a "continuous improvement process".

And last but not least: the need for greater openness as regards the public

The social context in which the various risk prevention players intervene must also be more closely considered.

Generally speaking, the lack of information and communication on the realities and difficulties of risk prevention exacerbates the crisis, because when an accident occurs, there is often a serious problem of comprehension among the public.

Also, it is essential to rise above the dialogue of technicians and ensure that the specialized commissions are periodically informed: the County Heath Council (CDH) which has become the County Council for the Environment and Heath and Environmental Hazards (CODERST), the Permanent Office for the Prevention of Industrial Pollution (S3PI) and the Local Information and Joint Action Committee (CLIC). We must also communicate the results and the difficulties of our actions more widely in activity reports or thematic publications. It appears that communication and information provided to the public must be developed. It also offers major leverage regarding difficult situations, as shown by several cases examined yesterday.

Of course, the role of the players in risk prevention consists of reducing the frequency and seriousness of consequences through appropriate technical and organisational measures. But it is also their role to build confidence with society as a whole and to promote the emergence of a culture that is better protected against technological risks so that the public can further participate in managing the risks to which it is exposed.

For the Inspectorate, it is clear that operators should be urged to immediately report their noteworthy incidents or those perceived outside the facility. Several examples were mentioned yesterday. They demonstrate the advantages of providing information as quickly as possible. Extensive work is required in this field: if public relations communication is systematically based on these principles and the improvements are made, a better understanding may be achieved with the local population. The nuclear example is significant in this respect; it benefits from a good public image of safety, thanks to the openness of its representatives in handling incidents.

This dialogue should be established when incidents happen, without waiting for an accident, as the public is more receptive to explanations in the absence of notable consequences that could alter their perception. A dangerous materials index was developed to complete this communication by shedding light on the source of the incident – because the terminology generally used is poorly understood by the population. This is also the general spirit of the provisions of Article L 125-2 of the environmental code which requires that the CLICs be informed of incidents or accidents.

Encouraging operators to provide information about their incidents or accidents and on the measures taken constitutes an essential element of transparency. They key principles are:

- ✓ Reveal the crisis and avoid being suspected of trying to conceal it,
- ✓ Take the initiative and thereby avoid a defensive posture of justification,
- ✓ Prevent rumours and controversies from spreading due to a lack of information.

Failing that, when the next major accident occurs (and we certainly can't "maintain the illusion that risk will be eradicated" as the Minister reminds us in the brochure), the system will be confronted with even greater difficulties stemming from the public's insufficient knowledge of technological risks. This was one of the main lessons learned from the Toulouse catastrophe. But, you may ask, what about the day-to-day concerns? It is precisely through better understanding that we can achieve a more calm and objective climate of exchange, for example as concerns consultation for authorizations or modifications.

It is an extremely important point that must be handled calmly. And I particularly appreciated the round table discussion on this theme yesterday. The collaboration of the various participants allowed us to better identify the expectations of the parties involved. The Inspectorate, often called upon in these circumstances, must learn to position itself in relation to the emergency services and to organise its efforts according to missions provided for by the law. From the practical standpoint, the "Crisis Task Force", organised within the scope of the DRIRE's quality approach, has developed guidelines for the Inspectorate in these situations. Excerpts of these guidelines are available on the BARPI website.

I would once again like to thank you all for your contributions which have enriched our seminar. I hope that our work will be able to orient the work of the Inspectorate on a daily basis. I am referring of course not only to the analysis of danger studies, but also to your other missions:

- ✓ Field examination of the concrete application of the safety management system,
- ✓ Urge operators to communicate more spontaneously in the event of an incident,
- ✓ Develop a dialog with the various parties involved in specialised CDH (CODERST), SPPPI and CLIC commissions.

They contribute to improving risk prevention and to a better public understanding of our action.

Before closing, I would like to insist on one last point. Traditionally, our seminar is an important phase in the life of the IMPEL network for European inspectors owing to the presence of colleagues from numerous countries. The tradition was again upheld this year and even improved; inspectors from 12 member states brought with them a considerable sum of experience.

An ever-growing number of foreign inspectors have asked to present accidents: 7 requests for 5 presented, but we were faced with deadline requirements for this meeting. I am hoping that we will be able to increase foreign presentations by 50% for our next seminar. So please respond promptly when the next call for papers is issued… I hope that the contacts and exchanges established during these two days will continue beyond the seminar so that the work of the Inspectorate's network will be continually improved.

European scale of industrial accidents

Graphic presentation used in France

This severity scale was made official in 1994 by the Committee of Competent Authorities of the member States which oversees the application of the 'Seveso' directive. It is based on 18 parameters designed to objectively characterise the effects or consequences of accidents: Each of these 18 parameters include 6 levels. The highest level reached by any one of the parameters determines the accident's severity level.

A new presentation of the European scale with four indices was proposed following problems that arose with the attribution of an overall rating covering the a very different range of consequences depending on the accidents (refer to the report available in the "European scale of industrial accidents" section on the internet site http://www.aria.ecologie.gouv.fr/). After having completed a large consultation of the various categories of the players concerned in 2003, this proposal was retained by the CSIC ("Conseil Supérieur des Installations Classées", Higher Council for Classified Installations). It includes the 18 parameters of the European severity scale in four uniform groups of effects or consequences:

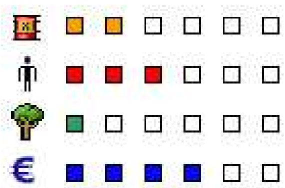
- 2 parameters concern the quantities of dangerous materials involved,
- 7 parameters bear on the human and social aspects,
- 5 concern the environmental consequences, and
- 4 refer to the financial aspects.

This presentation modifies neither the parameters nor the rating rules of the European scale.

Graphic presentation:

The graphic presentation retained for the 4 indices is as follows:

When the indices have already been explained elsewhere, a simplified presentation without the wording may be used:



European severity scale parameters

Quantities of dangerous substances		1	2	3	4	5	6
Q1	Quantity Q of substance actually lost or released in relation to the "Seveso" threshold *	Q < 0.1%	0.1% ≤ Q < 1%	1% ≤ Q < 10%	10% ≤ Q < 100%	1 to 10 times the threshold	≥ 10 times the threshold
Q2	Quantity Q of explosive substances having actually participated in the explosion (equivalent in TNT)	Q < 0.1 t	0.1 t ≤ Q < 1 t	1 t ≤ Q < 5 t	5 t ≤ Q < 50 t	50 t ≤ Q < 500 t	Q ≥ 500 t

* Use the upper thresholds of the current Seveso directive. In the event of an accident involving several specified substances, the highest level reached shall be retained.

Human and social consequences		1	2	3	4	5	6
H3	Total number of deaths: including - employees - external rescue personnel - persons of the public	- - - -	1 1 - -	2 – 5 2 – 5 1 -	6 – 19 6 – 19 2 – 5 1	20 – 49 20 – 49 6 – 19 2 – 5	≥ 50 ≥ 50 ≥ 20 ≥ 6
H4	Total number of injured with hospitalisation ≥ 24 hours: including - employees - external rescue personnel - persons of the public	1 1 1 -	2 – 5 2 – 5 2 – 5 -	6 – 19 6 – 19 6 – 19 1 – 5	20 – 49 20 – 49 20 – 49 6 – 19	50 – 199 50 – 199 50 – 199 20 – 49	≥ 200 ≥ 200 ≥ 200 ≥ 50
H5	Total number of slightly injured cared for on site or with hospitalisation < 24 hours: including - employees - external rescue personnel - persons of the public	1 – 5 1 – 5 1 – 5 -	6 – 19 6 – 19 6 – 19 1 – 5	20 – 49 20 – 49 20 – 49 6 – 19	50 – 199 50 – 199 50 – 199 20 – 49	200 – 999 200 – 999 200 – 999 50 – 199	≥ 1,000 ≥ 1,000 ≥ 1,000 ≥ 200
H6	Total number or homeless or unable to work (outbuildings and production tool damaged…)	-	1 – 5	6 – 19	20 – 99	100 – 499	≥ 500
H7	Number N of residents evacuated or confined in their home > 2 hours x nbr of hours(persons x nbr of hours)	-	N < 500	500 ≤ N < 5 000	5,000 ≤ N < 50,000	50,000 ≤ N < 500,000	N ≥ 500,000
H8	Nbr N of persons without drinking water, electricity, gas, telephone, public transport for more than 2 hours x nbr of hours (persons x hour)	-	N < 1,000	1,000 ≤ N < 10,000	10,000 ≤ N < 100,000	100,000 ≤ N < 1 million	N ≥ 1 million
H9	Number N of persons having undergone extended medical supervision (≥ 3 months after the accident)	-	N < 10	10 ≤ N < 50	50 ≤ N < 200	200 ≤ N < 1 000	N ≥ 1,000

Environmental consequences		1	2	3	4	5	6
Env10	Quantity of wild animals killed, injured or rendered unfit for human consumption t)	Q < 0.1	0.1 ≤ Q < 1	1 ≤ Q < 10	10 ≤ Q < 50	50 ≤ Q < 200	Q ≥ 200
Env11	Proportion P of rare or protected animal or vegetal species destroyed (or eliminated by biotope damage) in the zone of the accident	P < 0.1%	0.1% ≤ P < 0.5%	0.5% ≤ P < 2%	2% ≤ P < 10%	10% ≤ P < 50%	P ≥ 50%
Env12	Volume V of water polluted (in m^3) *	V < 1,000	1,000 ≤ V < 10,000	10,000 ≤ V < 0.1	0.1 million ≤ V< 1 million	0.1 million ≤ V< 1 million	V ≥ 10 million
Env13	Surface area S of soil or underground water surface requiring cleaning or specific decontamination (in ha)	0.1 ≤ S < 0.5	0.5 ≤ S < 2	2 ≤ S < 10	10 ≤ S < 50	50 ≤ S < 200	S ≥ 200
Env14	Length L of water front or water channel requiring cleaning or specific decontamination (in km)	0.1≤ L < 0.5	0.5 ≤ L < 2	2 ≤ L < 10	10 ≤ L < 50	50 ≤ L < 200	L ≥ 200

€ Economic consequences		1	2	3	4	5	6
€15	Property damage in the establishment (C expressed in millions of € - Reference 93)	0.1 ≤ C < 0.5	0.5 ≤ C < 2	2 ≤ C < 10	10 ≤ C < 50	50 ≤ C < 200	C ≥ 200
€16	The establishment's production losses (C expressed in millions of € – reference 93)	0.1 ≤ C < 0.5	0.5 ≤ C < 2	2 ≤ C < 10	10 ≤ C < 50	50 ≤ C < 200	C ≥ 200
€17	Property damage or production losses outside the establishment (C expressed in millions of € - Reference 93)	-	0.05 < C < 0.1	0.1 ≤ C < 0.5	0.5 ≤ C < 2	2 ≤ C < 10	C ≥ 10
€18	Cost of cleaning, decontamination or rehabilitation of the environment (expressed in millions of €)	0.01 ≤ C < 0.05	0.05 ≤ C < 0.2	0.2 ≤ C < 1	1 ≤ C < 5	5 ≤ C < 20	C ≥ 20

* The volume is given by the expression Q/C_{lim}, in which:

- Q is the quantity of the substance released,

C_{lim} is the maximum allowable concentration of the substance in the environment concerned, set by current European directives.

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