Meeting IMPEL / ICPE Inspectors

on industrial accidents

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Thanks

We do thank the participants to the meeting for their presentations and their contribution in the validation process of the following synthesis.

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Summary

- Explosion of a grain silo
  Semabla in Blaye (33 - Gironde)
  August 20th, 1997

- Sinking and rescue of the sailing vessel "KRONENBURG"
  Ijsselmeer near URK (the Netherlands)
  March 5th, 1999

- Atmospheric pollution generated by a refinery
  Couronnaise de raffinage in Petit Couronne (76 – Seine-Maritime)
  September 16th, 1998

- Pollution of the river ENNS following a leakage from a hydrocarbon storage tank
  Downstream from the City of STEYR (Austria)
  May 31st, 1998

- Explosion and fire in a warehouse containing phytosanitary products.
  CAPL Company in Sorgues (84 - Vaucluse),
  September 11, 1998

- Explosion in a bark silo
  Aussedat Rey in Saillat sur Vienne (87 – Haute Vienne)
  June 9th, 1997

- Leak on a LPG storage tank in an asphalt production facility
  Baden Württemberg (Germany)
  January 26th, 1998

Feedback: what is at stake?

Marie-Claude DUPUIS

Manager of the Industrial Environment Department
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I would like to begin by saying that I take great pleasure in opening this fifth annual meeting dedicated to accidents and feedback. This year, since we will be focusing on the framework of the European IMPEL programme, I am particularly pleased to welcome our European counterparts who have decided to participate and share their experience with us. I am convinced that our discussions will prove to be a very rich learning experience for everyone.

Firstly, on behalf of the French Inspectors, I should like to briefly outline the IMPEL programme.

The network known as IMPEL, which stands for the "European Union Network for the Implementation and Enforcement of Environmental Law", was created in 1992 in order to encourage the exchange of information and the comparison of personal experience, and to facilitate a more coherent approach as regards the implementation, application and monitoring of environmental law.

The network functions with two plenary meetings per year, and is supported by work conducted by thematic workgroups. Some of the work undertaken by these groups has been published in synthesis documents concerning, in particular, the frequency of inspections, self-monitoring and minimum inspection criteria. It should be noted that the document relating to minimum inspection criteria was embraced by the European Council, which anticipates making a recommendation following consultations which are currently taking place. It should be adopted next June. This example clearly illustrates the new direction being taken by IMPEL, in which, according to the wishes of the European Council, it will play an important role in the various stages of the regulatory process, particularly where a contribution concerning practical experience is required.

A concrete example of the exchanges made within the IMPEL framework took place on February 4th, when the Alsace branch of the D.R.I.R.E. welcomed a group of highly experienced European inspectors who came to observe our inspectorate in operation.

This brief outline of IMPEL could certainly be complemented by the exchanges which, I sincerely hope, will develop with our European colleagues. Annick Bonneville, who replaced Pierre Beauchaud within my department a few months ago, is responsible for the IMPEL programme in particular. She is available to provide you with further details, and will probably approach many of you on this very subject.

To begin our discussions, I would like to emphasise what exactly is at stake with regard to the strictly organised practice of feedback and then briefly reiterate the French plan of action implemented in this field. Finally, I will mention a few of the difficulties encountered.

The stakes involved can be grouped together around five main themes.

1 – The improvement of prevention equipment and organisations

For certain types of activity, extremely detailed safety studies can be made. This is particularly the case for activities in which the value added is relatively high (for example, in the nuclear and aerospace industries) or where a large quantity of identical equipment could benefit from the studies (for example, aeronautics or armament). However, in the majority of cases involving classical industrial installations, **systematic assessment of the installation's safety very quickly reveals both economic and technical limits. The examination of past accidents is therefore a preferable method for determining which equipment is the most vulnerable, which operations are the most dangerous, and which preventive actions are the most efficient.**

2 – Evaluation of the consequences of potential accidents

The models used to represent toxic releases in the air or water, whether full-scale or modelled tracing, and the methods used to predict the effects of explosions... provide an increasingly large range of possibilities for evaluating the consequences of accidents.

Nevertheless, **there always remains a large margin of doubt** and it is often difficult to base decisions which imply significant economic constraints solely on theoretical prediction models. Although it is rarely possible to conduct full-scale experiments, they are generally considered to be more conclusive although rarely possible.

For this reason, **despite their limited character** and the fact that they are often specific to a particular installation, location, or meteorological situation... **past accidents provide invaluable elements for assessing risks and establishing theories.**

3 – Strategies to combat accidents

As with the prediction of the consequences of accidents, the strategies for combating accidents and the theoretical means which are needed to deal with them warrant permanent testing in real situations. **Exercises, which are essential for the training of intervention teams** and for the fine tuning of procedures, **will never be able to simulate the stress and difficulties which those teams will encounter** during an accident. Once again, it is important to learn as much as possible from past accidents.

4 – Defining priorities and identifying new weak spots

Production and transportation are economic activities which most often involve **a residual risk which cannot be technically overcome.** There is a limit to the human and financial resources which can be devoted to safety either by the government, by companies, or by the general public. **We must therefore mobilise the necessary means as efficiently as possible, thus directing them towards the priorities defined in the most rational way possible.**

Apart from some very rare cases, it is impossible to make a true estimate of the probability of a complex technological accident occurring: the causes involved are multiple, and their identification alone already poses difficulties. For this reason, the systematic inventory of accidents, pollution and significant incidents remains a pragmatic approach which enables the definition of priorities and the hierarchy of dangerous activities to be defined.

Furthermore, feedback enables emphasis to be placed on **"new weak spots"** ensuing from the evolution of technologies and production practices, or resulting from the use of new materials or chemical products.

5 – Estimating the cost of accidents

The best possible evaluation of the cost and the probability of occurrence of potential accidents, as well as the decrease in risk which could reasonably be attributed to preventive measures, are parameters **which directly influence the strategy of insurance companies and the decisions made in individual cases (in other words, determination of the premium that the operator must pay to the insurance company to cover the risk).** In this respect, the study of the cost of past accidents forms an essential element, even if the collection of corresponding information can often prove to be difficult.

I now turn to our own practice of feedback as implemented for the classic industries in France, beginning with a look back into recent history concerning the matter.

Like the majority of occidental countries, our policy concerning the prevention of technological risks was marked by a few major accidents. For France, this was notably the case regarding the explosion of two spheres which occurred on January 4th, 1966, just a few kilometres from here at the FEYZIN refinery, resulting in 18 deaths.

As a result of these deaths, the rules applicable to petroleum facilities were modified. The main lessons learned from this catastrophe in terms of installation design and the organisation of emergency procedures were incorporated into our legislation and regulations in 1972.

In terms of the organisation of governmental services, dangerous installation inspection structures were subjected to thorough revamping as early as 1968. This, in my opinion, was the most valuable lesson learned from the FEYZIN catastrophe, as it resulted in the building of the regulated installation inspection department for environmental protection, as we know it today.

It was also largely on the basis of these unfortunate events that a coherent policy of technological risk prevention and environmental protection was founded, resulting in the Act of July

19th, 1976 relative to regulated installations for environmental protection which forms the primary foundation on which the inspectorate is built.

Although analysis of major accidents was, of course, performed within the scope of this policy, the gathering of information and their systematic processing were not performed, contrary to the practice of our friends of the HSE or TNO, for example.

It was only in January 1992 that we created the Bureau for Risk and Industrial Pollution Analysis (B.A.R.P.I.). The majority of you are familiar with our operations, but I would like to briefly summarise a few characteristics as, within my department, the B.A.R.P.I. plays an essential role in the subject that interests us today: feedback.

Firstly, in accordance with the main industrial unions concerned, we intentionally situated this new structure within our regulated facility inspection organisation. This is why the B.A.R.P.I. is one of the offices of the Industrial Environment Department, a department which, as part of the Ministry of the Environment, directs and implements the policy of the Risk and Pollution Prevention Directorate. Three main reasons led to this decision.

1. On the one hand, the inspectors have all legitimate powers necessary, as the law requires industrial operators to immediately notify the Inspectorate in the case of accidents or incidents which could jeopardise public health or safety or the environment. Subject to the limitations which could be imposed following a judicial inquiry, the Inspectorate which conducts the administrative inquiry has extensive investigative powers which allow it, in particular, to make evaluations and implement the necessary remedies prescribed by the French Prefect.

2. On the other hand, the Inspectorate's main prerogatives are associated with a well-recognised collective and individual competence, moderation, and an independence of judgement. This "culture" which distinguishes the Inspectorate is backed up by the guarantees provided by the law as regards maintaining professional secrecy, thus forming two conditions which are essential for the effective participation of the operators in a veritable feedback policy.

3. Finally, the Inspectorate benefits from good local implantation, and its knowledge of the industrial, artisan and agricultural environment make it a privileged player in the diffusion of information gathered from the analysis of accidents and pollution. The work on the projects and their critical analysis, together with the drawing up of technical instructions for authorisation orders are excellent opportunities to informally diffuse the lessons learned and also the recommendations resulting from feedback.

With regard to this last point, I would like to mention that, in 1998, the B.A.R.P.I. responded to approximately 500 consultations initiated by companies or consulting firms within the scope of the danger assessment of new installations or major modifications.

In closing I would like to make two observations concerning the voluntary and rigorous practice of feedback which I wish to pursue and reinforce, if possible.

My first comment concerns the difficulty of grouping information together.

The collection of information relative to the accidents, which is the first phase of an organised feedback policy, is undeniably the keystone of the entire programme. The quality of the analyses which will be conducted at a later stage, and the pertinence of the resulting recommendations, depend directly on the quality of the initial data collection phase. The widest possible coverage must be sought, particularly for major accidents which, by their nature, are not very frequent. This requirement is clearly stated in international texts such as the Helsinki Convention on the Transborder Effects of Industrial Accidents, signed on March 17th, 1992 and, of course, the SEVESO 1 and SEVESO 2 directives which form the foundation of our European policy on the subject.

I would also like to stress that version 2 of the SEVESO directive will require us to significantly increase the number of accidents reported to the Commission. In the vast majority of cases this concerns major accidents into which the Inspectorate investigates, although increased rigor in our internal information procedures will most likely also be necessary. Thus, SEVESO 2 not only confirms the basic obligations and principles which were already contained in its 1st version, it also provides a much more explicit definition of the accidents which must be reported in its Appendix VI. Taking much of its inspiration from the severity scale which was established in 1992, it retains the thresholds which make notification obligatory for 4 types of criteria: the type and quantity of the substances involved, the damage to people and property, the immediate harm to the environment and material damages.

Notification is also systematically mandatory in the case of accidents in which a dangerous substance is directly involved in effects outside the territory of the member State concerned.

Finally, for the accidents and "near accidents", it is the member States' responsibility to assess whether to report the event, depending on the technical interest that it represents with regard to the prevention of future accidents.

In parallel with the mandatory notification procedures, some informal voluntary procedures were also developed, not only between the various database managers of the main occidental countries, as a matter of course, but also at the level of the OECD. within the scope of the chemical accident programme. They are often more efficient and rapid than the "official" procedures and demonstrate the operation of a network operation which I feel also inspired the IMPEL programme.

Although the need for exchange of information about the causes, circumstances and consequences of accidents is an objective admitted by all security players, it is also an objective which comes up against several difficulties;

An initial reflex of protection might lead the individuals or the company in question to conceal all or part of the information, in order to avoid admitting the error or to avoid the risk of being implicated and any possible sanctions. For the company, the fear of seeing its "image" tarnished is often one reason for their reservations As I have already pointed out, a minimum of confidence and rules are required to get companies to actively participate in a feedback programme.

It is then up to the inspectors to assess the location as quickly as possible, collect witnesses and conduct technical investigations. In practice this is not always easy to achieve, given an overloaded and fragmented work schedule, especially since the very information that we get is often incomplete and highly inaccurate.

As regards serious accidents in which human lives are involved, (and we will discuss a few of those during these two days) the initiation of legal proceedings and the requirements of the inquiry could also deprive the inspectorate and the company in question of precious information which is vital for determining the causes of the accident and for defining the means needed to prevent it from happening again.

Finally, the secret which normally surrounds the compensation of victims by insurance companies, exclusive of the legal proceedings, makes it difficult to judge the true economic cost of the accidents.

My second comment concerns the need to demonstrate our vigilance.

It is not uncommon for very similar accidents to occur in identical installations, or even in the same installation, within a few months of each other. On a more subtle level, several "near accidents" may have preceded the accident, and these can be seen as "precursors" which a rigorous practice of feedback should have detected and analysed. In the face of such a situation, it is always possible, for a manager, to explain that the causes of the initial accident had been identified but that technical difficulties or high costs made it impossible for the additional necessary measures to be taken. On the other hand, the absence of feedback and the lack of means dedicated to the analysis of past accidents will worsen any crisis of the type "nothing was done to avoid this type of accident from reoccurring", or "safety is not given any importance" etc... Our collective credibility is at stake and we must be particularly careful about this kind of thing getting out of hand.

In conclusion, I would particularly like to thank our foreign colleagues for their participation, and also our own French Inspectors who agreed to take time out from their busy schedule to present an accident that they have investigated.

Feedback is primarily the sharing of experience and, if I might add, the modesty to which we should all aspire when we read the list of accidents which could have been avoided.

Marie-Claude DUPUIS

Lyon, April 27th, 1999

Explosion and fire in a pharmaceutical production facility
Hoechst Marion Roussel in Neuville / Saône (69 - Rhône)
November 6th, 1998.

The HOECHST MARION ROUSSEL plant, located in Neuville-sur-Saône north of Lyons and on the banks of the Saône river, synthesises active pharmaceutical materials:

- corticoids (from bovine bile up until 1998, and since by synthesis of soy sterols),
- antibiotics (ketolide),
- insecticides (deltamethrine).

The company employs 1,000 individuals and is certified by the SEVESO directive (2nd amendment). In its environment, two 400 and 600m urbanisation control zones were implemented, due to the presence of an ammonia storage facility, and a PPI ("Plan Particulier d'Intervention", emergency response plan) perimeter of 2,100m.

THE FACILITY AND THE MANUFACTURING ACTIVITY CONCERNED BY THE ACCIDENT

The building involved in the accident was used for the synthesis of corticoids from bovine bile. It has been vacant since 1988. It now houses the partial synthesis of a promising antibiotic: KETOLIDE. The clinical tests on small quantities are terminated and the need to continue with product qualification tests, performed on industrial installations, justified the overhaul of the building.

KETOLIDE is synthesised in 9 steps followed by a distillate treatment to remove an odorous component, dimethylsulphide; the residue is then packaged for destruction. This treatment does not enter into the fabrication cycle and the operation is conducted in a 8m^3 reactor (GG01), by oxidising the dimethylsulphide with hydrogen peroxide in an acidic environment. The explosion occurred in this reactor. The plant must handle numerous odour problems and the resulting complaints from neighbouring residents.

THE ACCIDENT AND ITS CONSEQUENCES

On November 6th, the treatment of the cyclohexane-rich distillate was almost finished following oxidation in a nitrogen atmosphere, neutralisation of the reactive environment, final inspection, then clearing of the lines with nitrogen. At 6:15pm, not long after the nitrogen valve was opened, an explosion occurred. Audible over several kilometres, the explosion shattered reactor equipment (blowout diaphragm, manifolds, etc.) and the windows of the 500m² facility.

The POI ("Plan d'Organisation Interne", internal contingency plan) was initiated. The internal fire-fighters manage to control an incipient fire in 15 minutes. An operator serious injured by a falling electrical cabinet died a few hours later, and 2 employees were injured (ankle burns and eardrum trauma) and 12 other individuals indirectly injured were examined as a precaution. Despite the noise of the explosion, no consequential damage to the environment was observed.

CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

The implementation of a new manufacturing process in the existing facility required certain modifications to be done. These modifications were carried out during the summer of 1998 and concerned primarily the connection of the equipment in place to fluid pipe networks and notably the nitrogen networks. In this respect, the factory has 2 networks, the first operating under 3.8 bar for reactor inerting and, the second, referred to as "purge nitrogen" operating under 3 bar. It is the latter that was to be used, for the first time, to purge the reactor where the accident occurred.

During the legal inquiry, the expert, upon following the pipelines, discovered that the connection had not been made on the "purge nitrogen" factory network, located on a rack outside the facility, but to the compressed air network.

The accident occurred during the rinsing of the tank containing cyclohexane (combustible), after the blowoff valve connected to the compressed air network (oxygen carrier) had been opened. The hypothesis proposed is that the energy required for ignition was provided by the agitation or the transfer of 2 non-miscible liquids (cyclohexane and water), one of which is inflammable and non-conducting and thus easily charged with static electricity (Klinkenberg experiment).

ACTION TAKEN

Suites techniques

The operator took the following measures after the accident:

- ➔ withdrawal of the deodorising treatment,
- ➔ organisation of a workgroup to determine the deficiencies in the qualification procedures and to improve them,
- ➔ better identification of pipework (all plant pipelines are painted),
- ➔ analytic inspection of the absence of oxygen (oxygen meter).

Administrative actions

The regulated activities practised in the new fabrication process were identical to those for which the facility had already received authorisation and the volumes involved were similar if not less. In terms of regulations, the new fabrication process was thus placed under the jurisdiction of article 20. The day of the accident, the operator had not completed its modification dossier, and thus it had not been submitted to the Prefecture. The Inspectorate drew up a report. The dossier has since been submitted and the facility has been in limited operation since March, under coverage of an additional prefectorial decree.

LESSONS LEARNED AND CONCLUSIONS

The proper execution of modification operations performed by an external company must be checked by 2 procedures:

- ➔ The first, entitled "qualification of installations or IQ" consists in a dry-run acceptance testing, to check that the modification is in compliance with the specifications of the reference dossier. This verification was conducted by the sub-contractor who did not detect the connection error (pipes on the rack not colour-coded).
- ➔ The second, entitled "operational qualification" in the presence of the fluids which will actually be used. This verification was conducted by the factory. Care was taken to ensure that the reactor's purge nitrogen connection was under pressure, although the fluid type was not verified.

The accident is thus the result of insufficient verification of the proper execution of works.

Leak and ignition of toluene in a pharmaceutical production facility
Orgamol in St. Vulbas (01 - Ain), France
December 3rd, 1998.

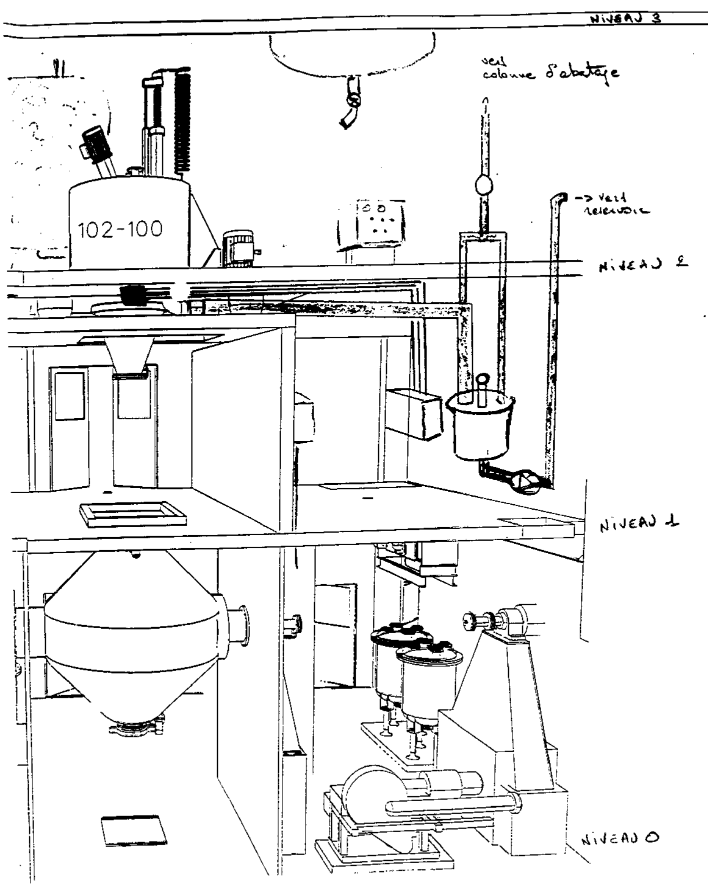
The ORGAMOL plant is located in Saint Vulbas in the *département* of Ain. It was commissioned in 1993 and has since undergone 2 extensions. It synthesises active pharmaceutical materials and employs 80 people.

The establishment, operating under a quality assurance program, features 2 production shops, including:

- ➔ 27 2,500 to 6,300-liter reactors,
- ➔ 22 multi-purpose devices in which standard chemical reactions are performed (esterification, hydrogenation, amination, halogenation, etc.),
- ➔ 5 reactors reserved for phosgenations,
- ➔ a phosgene production unit (30 to 600 kg/h),
- ➔ several dangerous product storage areas (hydrogen, chlorine, carbon monoxide, alcohols, solvents, acids and bases, etc.).

THE INSTALLATION IN QUESTION

The installation which is associated with the manufacturing reactors includes a dryer (3,000 l) connected by pipe with hydraulic seal to a plastic 300-liter solvent collection tank located 2 metres below in a room without a retention system and for which the electrical equipment are explosion-proof. The collection tank, designed to resist a pressure of around 45 mb, is fitted with a cover (60 to 70cm in diameter) and a high level sensor which is slaved to a transfer pump. The solvent (sea water) is stored in a container prior to evaporation and recycling or disposal.



The new equipment was received 12 days earlier in the presence of the various intervening parties (operator, constructor, engineers, etc.). Several anomalies were found during the qualification procedure. As a consequence, during the "lack of inerting pressure" emergency shut-down tests, leaks were reported on the cover which was secured by 4 bolts. The pressure of 45 mb could not be obtained. The decision was made to add an additional 4 bolts.

THE ACCIDENT AND ITS CONSEQUENCES

The accident occurred on December 3rd at 9 am while the installation was in its toluene cleaning phase. The solvent (the temperature of which is near ambient temperature) filled the collection tank and the pipework (hydraulic seal included), began to leak at the level of the cover's seal and burst into flames. The flash and the resulting overpressure blew the shop's doors open. The plant engages its POI. Approximately twelve employees are slightly burned. The individual with the worse injuries (3 days sick-leave) was located near the collection tank at the time of the accident.

ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

The accident occurred during the 1st fabrication operation. Due to an electrical malfunction on a terminal strip (lug poorly tightened), the tank's drainage pump did not start and thus lead to the overfilling of the tank. The tank's hydrostatic pressure resistance was insufficient (cover not leakproof). The vapours most certainly self-ignited due the toluene's dielectric characteristics.

The unit which had just been received exhibits several design defects:

- a collection tank too small in relation to that of the centrifuge implicating numerous pump starts, lacking retention and a too low resistance level in relation to the maximum possible hydraulic load (at least 150g),
- the presence of a single high level sensor (no backup),
- a questionable choice in terms of the materials used for the tank and its pipelines (plastic poorly adapted to the dielectric characteristics of toluene).

In other respects, the Inspectorate noted the following during a visit of the installations:

- the presence of 7 bolts instead of the original 4; the location for an 8th bolt is provided but is replaced by a clamp. The fastening system had been modified at the time of installation acceptance (qualification). The pressure of 45 mb could not be reached (leaks at tank cover), the centrifuge could not start; the cover mounting system was reinforced to improve the tightness of the assembly (a missing bolt was replaced by a clamp). The fabrication process was launched 12 days later, with the temporary repair having been forgotten...
- anomalies in unit operation. The procedure during the accident dictated that the operator make a log entry (time – action taken). The log was completed in advance up to 10 am (centrifuging and sampling considered as completed), even though the accident occurred at 8 am.

ACTION TAKEN

Manufacturing operations were immediately stopped (emergency shutdown). Upon the Inspectorate's request, a third expert conducted a two-week long audit of the site and proposed approximately fifty recommendations. Apart from the damaged installation, a general comment was made on the lack of level measurement equipment for stored products. Procurement management was based on automatic monitoring and operator vigilance. The weakness of certain pipelines in relation to the pressure was also highlighted.

The operator corrected the anomalies reported:

- ➔ changes made in certain operating sequences,
- ➔ holding under pressure and instrumentation of centrifuge drainage tanks,
- ➔ improvement of the explosive atmosphere detection system,
- ➔ overflow prevention during automated delivery of solvents via the storage yard,
- ➔ by-pass of the mobile safety valve on the reactor supply line.
- ➔ by-pass de la vanne mobile de sécurité sur l'alimentation des réacteurs.

LESSONS LEARNED AND CONCLUSIONS

This accident is the 4th that occurred in the installation for the last four years. This situation demonstrates not only material discrepancies but also definite lacks in the safety management:

- ➔ the design defects of an installation associated with insufficient risk analysis (specifications insufficient for the collection tank, a level sensor used as the sole safety device, lack of explosive atmosphere detection equipment in the facility),
- ➔ anomalies in the commissioning conditions of a potentially dangerous unit associated with an insufficiently rigorous qualification protocol (oriented only on the production equipment to be received, tightness achieved under precarious conditions),
- ➔ poor management of modifications (temporary clamping of the cover maintained during commissioning, drawings not updated),
- ➔ unacceptable derivation in the operation of installation (operations log poorly kept),
- ➔ poorly adapted alert methods (numerous comings and goings of individuals more or less well informed in the area after the toluene leak is reported and slightly before its ignition, facility evacuation order given late, etc.) and the disrespect for individual protection instructions,
- ➔ easy co-operation of the Inspectorate with the judicial expert (necessity for a quick diagnostic due to the commercial stakes involved).

Ravaging fire in an industrial pork processing plant Charcuteries du Bugey in Ambérieu-en-Bugey (01 - Ain) June 9th, 1998.

The Charcuteries du Bugey Company have been located, near a residential district, in the industrial and commercial activity park in Ambérieu-en-Bugey in the *département* of Ain since 1981. The establishment, which was expanded in 1986 and modified in 1992 and 1995-1996, has a production capacity of 15,000 tonnes/year or 300 tonnes/week and employed 270 salaried employees in 1996 when it was taken over by a major food industry group. The plant was restructured in 1997 and 1998 (2x4MF), and since then has increased its workforce to 140 and its production to 30 t/day. It is currently undergoing administrative regularisation.

THE INSTALLATIONS CONCERNED BY THE ACCIDENT

The establishment includes a 1,500 m² two-story building, offices and break room for the employees. A second building (15,000 m²)is used for receiving, storage, fabrication and shipment of raw materials and finished products. This building consists of a structural steelwork frame, columns and framework support elements (made of reinforced concrete up until 1992, and steel thereafter) and partitions made from polyurethane foam-based insulating panels. Concrete block walls insulate the technical and administrative buildings as well as certain specific facilities (boiler room, etc.) Part of the roof is made of asphalt-coated profiled steel sheeting and a 2nd level exists in certain zones (machinery room, clean rooms, etc.).

THE ACCIDENT AND ITS CONSEQUENCES

On June 19th at approximately 1:25 pm, a fire was reported in the processing plant. The alarm was raised and the fire brigade arrived 7 minutes later, but the fire had already had time to spread significantly. Within 17 minutes, 4,000 m² of the plant was engulfed in flames (sandwich panels) and thick smoke bellowed from the premises.

Despite the progressive stream of reinforcements, the 15,000 m² of the processing building and the refrigeration units (F22) were destroyed in less than 2 hours. The fire brigade confirmed several factors which explain why fire spread so rapidly and the difficulties experienced in fighting it:

- A delay in sounding the alarm (call to 18) due to the lack of an audible alarm, following late detection of the fire (lunchtime) and an inadequate means of communication (telephone of work areas without outside access, switchboard closed).
- The construction principle retained, a box (sandwich panels) within another box (siding and roofs), without a smoke exhaust system, initially confined

the heat and radiation inside the double enclosure and restricted the evacuation of hot gases.

- Insufficient, even non-existent, partitioning with the extensive use of polyurethane foam-based sandwich panels (walls and ceilings). These panels are M1 fire-rated although cannot withstand temperatures above 300° C and thus increased the thermal load and generated dangerous gases and volatile materials which fed the flames and spread through the walls "like blow torches".
- The metal elements of the structural steelwork collapse in fire and the use of a asphalt-coated steel sheeting on the roof causes the bitumen to melt, run and burn.
- Inaccessible false ceilings in certain areas insulating large volumes under the roof and freezing chamber of very large volume worsening factors.
- Combustible loads are highly variable (packaging materials, etc.) and the ignition of frozen merchandise is promoted by the low temperature which dries the contents. A significant storage factor leaves little chance for development and the stacking of racks creates a "chimney" effect.
- The thick smoke made it difficult to accurately locate the fire source, although the refrigerants, glycol water and R22 in this case, were without impact.
- Furthermore, the destruction during the fire of plastic rain water downpipes which were not reinforced by a metal sleeve tube may have allowed fire prevention water to return directly to the water table via the rain water network when it is connected to a percolation well.

Despite the progressive stream of reinforcements arriving to the scene, the 15,000 m² of the processing building and the refrigeration units (F22) were destroyed in less than 2 hours. At the most intense firefighting periods, 450 m^3/h of water was necessary. The fire was brought under control at 3:30pm and extinguished at 8:00am the next morning. The rescue operations were finished Sunday at 3:00pm.

The fire was responsible for 3 deaths (a welding technician from an outside firm, found in a hallway, and 2 employees, found on the mezzanine above the cold rooms, died from asphyxiation). Eight individuals were slightly injured. A firewall saved the administrative offices, although the plant was destroyed. The material damages were evaluated at more than 40 MF and 120 employees were laid off. The management announced the definitive closure of the establishment a year and a half later.

LESSONS LEARNED AND CONCLUSIONS

The exact cause of the fire is not known. However, the installations, which had undergone repeated revision, were being worked on the day of the accident. The accident occurred during a period of reduced activity (lunchtime).

The extent and the rapid spread of the fire coupled with the fear of toxic gases complicated the co-ordination of rescue efforts.

Following the fire, several days were required to collect and remove 500 tonnes of buried under the debris (odours detected far away, irruption of insects and rats, the risk of polluting the ground water table, etc.), primarily due to the necessary legal proceedings and expert appraisals.

Several preventive or curative actions were recommended:

At the building design level

- ➔ Integrate fire protection as early in the design phase,
- ➔ Firestop the various spaces (separating walls, M0 fibreglass or rockwool panels, etc.),
- ➔ Insulate rooms at risk or having a high calorific potential (machinery room, boiler room, fuel storage areas, etc.),
- ➔ Protect electrical installations (fire-resistant cabinets, etc.), avoid the passage of electrical conductors through sandwich panels, isolate cables in conduits, space light fixtures away from walls, etc.,
- ➔ Place sprinklers in sensitive areas,
- ➔ Install a detection system (excluding the negative cold room).

Materials used and the layout of the establishment

- ➔ Number and location of hose reels (sufficient pressure),
- ➔ Fire-resistant framework and structural work ("fire retardant" steel or reinforced concrete) for concrete, coating of reinforcements (at least 4cm), exterior cellular concrete "walls" or metal siding with M_0-rated insulating core.
- ➔ Smoke/heat vent + sectioning of smoke ejection.

Personnel and the operation of workshops

- ➔ Sensitise, inform and train employees (safety measures include: internal exercises, exercises with rescue services, etc.),
- ➔ Use the burning permit procedure during projects,
- ➔ Install audible and visible alarms (flashing lights, etc.),
- ➔ Enable workshops direct access to 18 (emergency assistance).

Curative measures:

- ➔ Favour the evacuation of people by the early triggering of the alarm, facilitate the evacuation of work areas, as well as conduits and false ceilings (toward the roof when made of concrete and downward in other cases),

- ➔ Ensure communication with the emergency services (contact with the officer co-ordinating rescue efforts, up-to-date drawing of buildings indicating fire hydrants, hose reels, etc.),
- ➔ Protection of the natural environment (fate of fire-fighting water, rapid decontamination of damaged premises, etc.).

Ammonia leak in a urea production facility Grand Paroisse in Toulouse (31 – Haute Garonne), March 27th, 1998.

The Grande Paroisse chemical factory in Toulouse (31) employs 515 people and synthesises basic products (ammonia: 1,000 tonnes/day; nitric acid: 750 tonnes/day) and fertiliser (calcium ammonium nitrate: 800 tonnes/day; urea: 1,000 tonnes/day; nitrogenous solution: 600 tonnes/day; and industrial ammonium nitrate in solution or granulates: 2,250 tonnes/day), as well as various other substances (melanin, cyanuric acid, resins, adhesives, etc.). The establishment is SEVESO rated for the usage of chlorine and the storage of ammonia, ammonium nitrate and various chlorinated products.

THE ACCIDENT AND ITS CONSEQUENCES

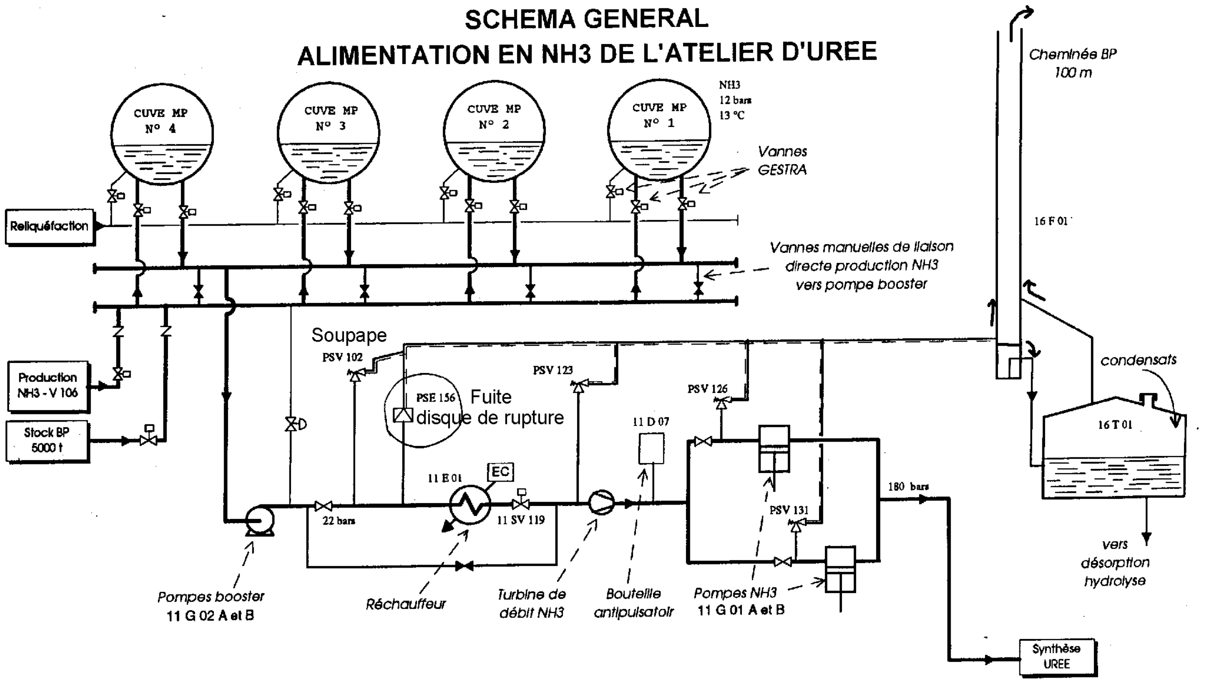
In the morning of March 27th, 1998, the inhabitants of Toulouse perceive a strong ammonia odour in many regions of the city. The fire brigade and the police begin recording complaints as early as 7:40 am, and other organisation are then submerged with calls until 9:30 am. Very unfavourable meteorological conditions (low wind and temperature inversion) amplify the effects. The fire brigade measures ammonia concentrations near the olfactory threshold (5 ppm) in several areas around the city. The population is requested not to drive in the city for a few hours until the odorous cloud is totally dispersed.

The plant management, aware the seriousness of the accident only upon arrival of the emergency intervention team and following numerous telephone calls, establishes a POI type crisis unit at 8:00 am and begins its search. The probable hypotheses of the accident cannot be made until 10:30 am: an ammonia leak occurred between 4:50 am and 6:25 am on a liquid ammonia line located between the medium pressure storage tanks (315 tonnes distributed in 7 tanks under 12 bar) and the urea synthesis workshop. A press release is established at 11 o'clock. The exact origin of the leak, the rupture of a bursting disc, is confirmed only at 1:30 pm. During the day, the plant estimates that 1 tonne of ammonia was released into the environment over a period of 1½ hour via a 100-metre high stack. The true quantity released, in the order of 10 tonnes, was known only a few days later.

THE ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

At 4:50 am, a decrease in the ammonium flow occurred on the supply line of the urea synthesis unit following an alarm on the normally open contacts of 2 GESTRA valves located at the low point of the low pressure liquid ammonia tanks. After a quick inspection, the Watch Officer decided to open the manual direct supply valve to re-establish the flow which reached a minimum level one minute later. A new round at 5 am, slightly before the end of the night watch, did not signal any anomaly.

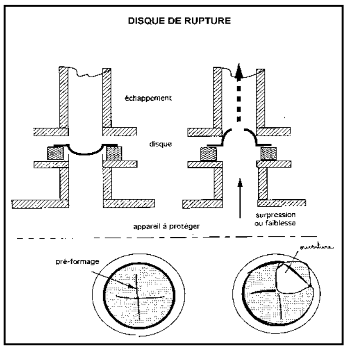
At 5:03 am, a hammering noise is heard coming from the reservoir's seal cover (ammonia water tank) which collects the condensates at the stack's low point. The noise is heard 4 times up until 6:20 am. At 5:13 am, an ammonia alarm which sounded in the plant for a period of



15 minutes is interpreted as the result of an excessive drop in the level of the ammonia water tank. The other ammonia detectors at the site and including those at the property line were never triggered.

At 5:20 am, a watchman reported the formation of frost (a sign of an ammonia leak) downstream from a valve at the output of a NH3 pump which feeds the urea production unit. The equipment is located on the exhaust manifold common with the various valves equipping the installations and connected to the base of the stack. The leak is considered to be small and resulting from the re-establishment of the NH3 circuit after the direct passages were opened. A vapour heating unit is installed on the valve to defrost it.

From 5:50 to 6:25 am, after the arrival of the shop's engineer in charge and discovery that the reheating of the pump was inefficient, the heat exchanger located downstream from the NH3 pump is isolated with its pump.



As the unit's supply seems to be correct the hypothesis of a ruptured bursting disk is proposed then abandoned in favour of the hypothesis that the valve was not tight following its opening as a result of the disturbance caused by the operation of the GESTRA valves.

ACTION TAKEN

The operator performed a thorough technical analysis of the accident and the installations were modified (removal of the bursting disk, installation of sensors and automatic shut-down devices). A safety assessment was conducted on all of the site's ammonia circuits.

The Inspectorate drew up a report for the disrespect of the prefectorial authorisation decree and a formal prefectorial order was established against the operator. The DRIRE established a new organisation and a site emergency file on the occasion of the world soccer championship. The Prefecture decided to activate a crisis response team for all accidents having a significant media impact.

LESSONS LEARNED AND CONCLUSIONS

The leak (10 tonnes of NH3 in one and a half hours) occurred during stable operation of the unit, and was a result of the operators incorrectly interpreting several alarms. The accident resulted from a series of equipment and human failures.

Organisational and operational faults:

- Decisions made without prior analysis, lack of verifications,
- Lack of written procedures (closure of safety valves),
- Lack of information in the control room,
- No alarm procedure between the manufacturer and the local air quality measurement network (ORAMIP).

Equipment design and reliability faults:

- No ammonia leak detection on the stack,
- No malfunction detectors,
- Defective valve,
- Poor design of the bursting disk and the system,
- Safety valves poorly adjusted.

Explosion and fire in a paint manufacturing plant Peinture Maestria in Pamiers (09 - Ariège), September 7th, 1998

LES PEINTURES MESTRIA company in PAMIERS (09) is a family-owned company which was founded in 1963 and has a workforce of 190. It is specialised in the fabrication of acrylic, polyurethane or epoxy paints in solvent medium for the building industry, anti-corrosion paint, paint for floors and roads and special coatings. It produces roughly 20,000 tonnes/year and has a turnover of 190 MF (1997).

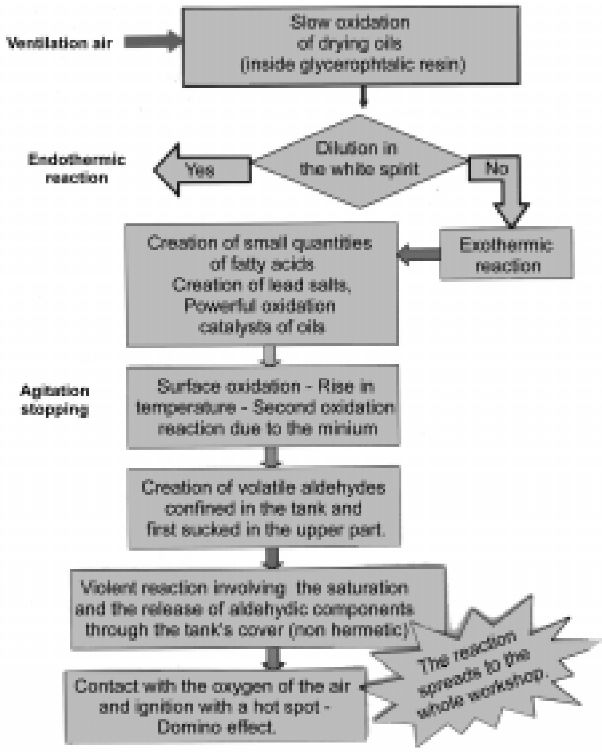
The establishment operates installations which require authorisation (prefectorial decree of 26/07/94): storage of inflammable liquids, including 300 t overhead and grinding of vegetal substances.

THE INSTALLATIONS CONCERNED BY THE ACCIDENT

The damaged installations are located in the main large-quantity paint manufacturing facility which also houses a mixing shop, part of the raw materials storage area, and the research and inspection laboratories. The installation directly concerned is a 2,600-liter tank with removable rotor.

THE ACCIDENT AND ITS CONSEQUENCES

The fabrication of a new batch of paint began at 6 am and had to be interrupted due to the lack of white-spirit. The agitation of the mixer which contains a mixture of minium (lead oxide) and glycerophthalic resin, is suspended until 9:30 am until the solvent is delivered. During a routine inspection, overheating of the reactor is noted at 4 pm; the tank is sprayed with water to cool it down. At 8 pm, the mixer wall had returned to 40° C and specific monitoring instructions were given to 2 individuals working the night shift. No other anomaly was reported until 11 pm, when the explosion occurred. The resulting fire destroyed the workshops and the laboratories and resulted in the employees being laid off for technical reasons.



The rescue efforts of the fire brigade nevertheless limited the consequences of the accident which could have reached an overhead glycerophthalic resin depot located 15 m from the main workshop. A retirement home is also located just 70 m from the establishment's property line and at 120 m from the fire.

The installation of sand dykes around the factory and the blockage of the rain water networks avoided pollution of surface waters. The next morning, a specialised company evacuated the firefighting water confined within the site. Infiltration into a cesspool polluted the ground water.

Paint fabrication was stopped and the production buildings of the main facility must be demolished and rebuilt. The material damages were evaluated at 25 MFF, raw material losses at 5 MFF and the subcontracting of certain product production for several months at 5 MFF.

ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

The accident may have resulted from a series of exothermic chemical reactions associated with the composition of the minium / glycerophthalic resin mixture.

The drying oils contained in the resin may have oxidised due to the action of the ventilation air. The slightly exothermic reaction was normally controlled by the endothermic reaction of dilution in the white-spirit. In the absence of this dilution, the rise in temperature created small quantities of fatty acids which promoted the formation of lead salt, powerful oxidation catalysts of oils. Stopping the agitation promoted the continuance of the oxidation reaction on the surface of the mixture and localised temperature rise.

A second oxidation reaction attributable to the oxidising properties of the minium may have developed, forming low-flash point volatile aldehydes which remained confined in the tank and initially sucked into its upper part.

A violent reaction of this release would have saturated the intake and promoted the release of aldehydic components though the tanks non-hermetic cover. The contact with the oxygen in the air and a hot spot would have produced the 1st explosion. The fire would have then quickly spread to the other inflammable products stocked in the building.

ACTION TAKEN

Following this accident, a rapidly initiated prefectorial order (article 6 of the Act of 76) suspended all paint fabrication activities.

The operator must take all measures necessary to maintain the damaged facility under permanent security, to prevent the consequences of the fire from having an adverse effect on the environment and to remove the waste and polluted water generated to authorised installations. As such, the rain water leaching the waste is collected in a retaining trap so that it can be collected and transferred to authorised treatment centres.

In addition, the order specifies that the reopening of the facilities not touched by the fire is contingent on the submittal of a study including the analysis of the exact causes and circumstances of the fire, the measures taken to avoid it happening again and to continue the operation in good safety conditions, as well as a study of the safety of buildings which are to be reused and a safety analysis relative to the operation of the activity with the implantation of the recommended safety measures. The reopening of the destroyed facility depends on the submittal of the complete dossier.

The following points were also stipulated in addition to the fulfilment of the recommendations proposed in the safety study:

- the usage of highly inflammable liquids is forbidden in the workshop and the quantity of inflammable liquids in said workshop is limited to 8m^3.

- prior to fabrication, the stocks of prime materials required for the day's production must be checked line by line. A second inspection shall be performed upon the operator's order,
- the rotor heads must be maintained in high position outside the tanks after usage of the pasting-mixing arms,
- only mobile tanks will be used for fabrication operations. They must be cleaned in a special outside station after immediate evacuation of finished products,
- procurements must only be assured for the required raw materials, the products being identified for the operator in terms of safety, flammability, and reactivity,
- tanks shall be cooled and their temperature regularly checked. All tank having an abnormal temperature rise hall be cooled and evacuated,
- procedures must be drawn up to define the operator qualifications, the operation of handing and transport equipment, the maintaining of permanent ventilation and the covering of tanks in the final stages of completion,
- minimum ventilation must be provided, the conformity of the electrical installations checked and fire extinguishing equipment installed.

LESSONS LEARNED AND CONCLUSIONS

The cause of the accident can be attributed to the poor control of the manufacturing process, at first sight relatively simple (the mixing of various products), although which presents certain well identified risks. A new batch is launched, then placed on standby for lack of a raw material. The product in question, namely a solvent, also plays a major role in the heat balance of the mixing operation; this factor was underestimated the day of the accident.

The warming of the mixer is detected and initially controlled by the operators, although the monitoring procedure defined and transmitted to the night crew did not enable a new problem to occur in the batch placed on standby.

The operator must reinforce the safety of its installations, and establish or modify the instructions and procedures currently in force within its establishment.

NH3 leak in a slaughterhouse
Bigard SA in Cuiseaux (71 – Saône-et-Loire)
June 7th, 1997

The BIGARD Company's slaughterhouse in Cuiseaux (71) is an establishment of recent design, partially commissioned in 1996. The last extension completed, an ammonia storage area, was authorised January 9th, 1997. The installations process 150 tonnes of meat/day (slaughter and vacuum packing of meat, frozen ground beef, frozen or fresh cuts of meat), for a slaughter capacity of 450 to 500 head of cattle.

THE INSTALLATION CONCERNED BY THE ACCIDENT

The establishment uses refrigeration installations which employ ammonia as refrigerant (negative cold) and a glycol water production unit cooled by the same fluid (positive cold).

The installations which were directly or indirectly implicated in the accident were progressively commissioned (slaughter / cutting floor and other positive cold facilities) on January 1st 1997, the negative cold chamber on March 1st and the ground beef quick freezers on May 1st.

THE ACCIDENT AND ITS CONSEQUENCES

On June 11th, 1997 at roughly 12:30 pm, an ammonia leak occurred in the technical space in the roof of the shop where the ground beef quick freezer was located. A characteristic odour spread through the building which is rapidly followed by a cloud of toxic gas. Telephone calls are made to warn the shop supervisors. The maintenance crew cut the electrical power supply and the personnel is evacuated in a general panic.

The fire brigade is summoned at 1:25 pm, approximately one hour after the start of the accident. An inspection is performed to check that no one remained in the buildings. A CMIC ("Cellule mobile d'intervention chimique", chemical accident response taskforce) arrived at the scene at 2:20pm, and the evacuation of the buildings is completely checked again. A defective valve is located 10 minutes later. Approximately twenty firemen fight the toxic cloud with a curtain of water.

Ammonia concentrations grater than 70 ppm are measured in the building. At 5 pm, the rescue team note that this concentration is not lowering and decide to re-establish the electrical supply and activate the building's mechanical ventilation system. Despite the measures taken, the ammonia concentration level remains the same 2 hours later. The rescue team propose various hypotheses (poor extraction, another leak?) and at 8:30pm, decide not to restart the ammonia circuit, to close down the site and ventilate the building throughout the night.

At the high-point of the rescue efforts, 40 residents are restricted within a security perimeter of 500m. The facilities are ventilated for 30 hours. Ammonia odours are detected 1 km away from the site. A technician affected by the fumes is hospitalised.

The next morning at 9 am, a slight decrease in the ammonia concentration is observed in certain rooms. An additional force extraction system is set up. At 2 pm, the concentration of toxic gas is finally lowered and the evaluation of the stored merchandise can begin.

The material damages (products in contact with the ammonia or altered by the break in the cold chain, transport costs of frozen goods, etc.) are evaluated at 3.9 mFF and operating losses at 0.6 MFF.

ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

The leak, which is evaluated at 2.2 tonnes of liquid ammoniac over a period of 1' 45", occurred on a solenoid valve of the low pressure supply circuit of the ground beef quick freezer, placed into service a month earlier. The entire installation contains 8.5 tonnes of NH3. The damage automatic valve (ND 150) is without socket joint and features a flat gasket and secured by 8 bolts. At the level of the faulty seal, measurements taken with a torque wrench show that 2 bolts were not properly tightened (poor initial torque or progressive loosening following hammering or associated with the temperature or pressure variations ?); the experts recommend that the assembly be blocked with locknuts. The seal itself, of new type, was used instead of an asbestos seal, the use of which is now forbidden.

The cause of the accident is not known (hidden defect, nonconformity, poor execution of design or construction operations?). The expert assessments also show that the alarms were not slaved to the detectors set on 2 levels (300 and 2,000 ppm), as well as a lack of co-ordination in terms of responsibility.

The quantity of ammoniac released is significant despite the presence, both upline and downline from the defective valve, of positive electrically-controlled safety valves, slaved to the detection system although which can be manually forced into open or closed position and which should have closed during a leak. If these valves had operated normally, the ammoniac leak would have corresponded at the most to the quantity of refrigerant present in the ground beef quick freezer, i.e. 450 kg. The estimates formulated by the experts, much higher although compatible with the quantity of ammoniac replaced into the unit (2.2 tonnes) indicate that the leak had been supplied. The experts consider the hypothesis of the manual opening of the valve located upline prior to the accident, which subsequently may not have been completely closed, thus limiting the positive safety effect. No explanation was proposed concerning the opening of this valve which must only be manoeuvred at the time of system commissioning (operation performed in early May '97). While the operator does not consider this a possibility, subsequent manipulation of the valve cannot be excluded.

The inquiry finally revealed that the extraction vents enabling the release of ammoniac from the building did not operate due to an incorrect electrical connection. A debate between the various intervening parties concerns the role of the prime contractor (SOGELERG). The latter had apparently proposed several dates for the final testing which had be repeatedly postponed by the contracting authority (Bigard). As a result, at the time of the accident, these tests had still not been conducted while the various sections of the site had progressively been commissioned.

ACTION TAKEN

Several clauses in the Authorisation Order of January 9th, 1997 were not respected:

- the internal contingency plan was not validated by the SDIS ("Service départemental d'incendie et de secours", fire department) and the existing project did not include written instructions concerning the implementation of intervention means, evacuation of personnel and the call for external emergency assistance.

- the general audible alarm is not slaved to the NH3 detectors,
- the study which defined the quantity and location of NH3 detectors did not lead to a satisfactory detection system in terms of life safety,
- personal protective equipment is insufficient,,
- personnel NH3 safety training is insufficient.

On June 18th, 1997, a Prefectorial Order restricted the use of ammoniac to one single zone within the establishment and ordered a complete inspection of the NH3 system. The site reopened operations 5 days later.

LESSONS LEARNED AND CONCLUSIONS

The accident provides several lessons from both the technical and organisational points of view:

- the need for a reliable installation with proper operational design (a sufficient number of strategically located detectors, alarm slaved to the detectors, operational extractors),
- the need to have an operational internal contingency plan (training of personnel, adapted protective equipment and in sufficient quantities, precise drawings of systems and valves, repeated emergency evacuation drills in order to establish the necessary automatic reactions, co-ordination of intervening parties).

Chlorine leak in a chemical plant
Rhodia in Clamecy (58 - Nièvre)
December 24th, 1998

The RHODIA chemical plant in CLAMECY (58) employs 160 people and synthesises basic organic chemical products (acids and various organic anhydrides).

The plant is regulated by a prefectorial order of 7/12/88. I has been using chlorine since 1930 and operates a confined 52 tonne storage area built in 1980. This storage area, subject to the SEVESO directive, formed the subject of a safety study in 1988 and a schedule of work to be completed.

THE INSTALLATIONS CONCERNED

The confined storage facility consists of three tanks each with a capacity of $21m^3$ (26t), an atomiser and the transfer compressor. Two tanks are used, while the third is maintain under vacuum under chlorine vapour as a backup. The rail transfer station, also confined, is adjacent to the depot to the North and a neutralisation column to the South ensures the safety of the entire assembly.

THE ACCIDENT

The accident occurred on December 24th during the annual shutdown of the chlorine installation, in accordance with the following chronology:

08:00 Start of the atomiser degassing operation. Using a set of valves, the chlorine is directed to the neutralisation tower,

12:00 the operator checks that the operation is continuing,

12:40 the foreman notices the presence of chlorine in the confinement facility,

12:45 the foreman sound the internal alarm by telephone,

13:00 the alarm's automatic network on the chlorine detector is triggered (concentration of 2 ppm in the facility,

13:10 closure of the radio-controlled valve (No. 20) on the tank's output and located on the atomiser's supply line, as well as the manual safety valve (valve No. 39) situated upline from the atomiser,

13:15 leak of C12 to the atmosphere from the neutralisation tower's stack. The external emergency authorities are advised,

13:20 end of chlorine release to the atmosphere.

ORIGIN, CAUSES, AND CIRCUMSTANCES OF THE ACCIDENT

On 24/12/98, only the regeneration workshop of the catalysers was consuming chlorine. As the need to empty the evaporator was insufficient, the gas was directed to the neutralisation tower thereby ensuring the safety of the depot. The degassing of the 100kg of C12 contained in the evaporator was to last a maximum of 2 hours. The operator showed no concern even though the operation had not terminated 4 hours later.

At 12:45pm, the 1,500kg of the column's neutralisation capacity were saturated. Foaming of the solution causes the exhauster on the column's outlet to become less efficient and chlorine gas enters the storage facility via the vapour suction pipework.

The operator forgot to close the radio-controlled valve on the chlorine outlet of tank No. 2 (valve No. 20) and the radio-controlled valve 38 (allowing the atomiser on the liquid chlorine side to be isolated) began to leak. Upon closure of manual valve No. 39, upline from the atomiser (which backs up valve 38) and valve No. 20 or simply by the restart of suction after foaming had lowered, part of the chlorine escaped via the stack.

Numerous anomalies are observed:

- a standard degassing operation is performed on equipment intended to ensure safety,
- the operator checks neither that the valves are closed using a check-list, nor the coherence between the volume present in the unit and the neutralisation time,
- the controlled valves are of flat seat type, a foreign body could jeopardise valve tightness (cone seated and knife-gate valves exist which are less prone to this phenomenon),
- no check valve was installed on the suction pipework in the depot facility or in the transfer area,
- the neutralisation tower is not fitted with an efficiency monitoring system with alarm (pH-meter on the sodium solution, C12 detector on the stack's outlet, etc.),
- the neutralising solution cannot be renewed without shutting down the tower.

Following the accident, the situation of the installation was examined from the viewpoint of the Ministerial Order of July 23rd, 1997 relative to the storage of pressurised liquefied chlorine gas.

During the meetings with the Inspectorate, the operator stated that the installation of a device to measure chlorine concentration at the outlet of the neutralisation tower and flow gauge to check clogging were to be installed. An update of the dangers study was to be conducted in early 1999 following the completion of various modifications during the annual summer shut-down period:

- changing of the depot's atmosphere monitoring system,
- installation of a gamma probe tank level indicator,
- installation of a chlorine measurement device on the output of the neutralisation tower with emergency shut-down.

During an on-site inspection a few days later, the Inspector noted that the depot was being worked on, that tank No. 1 was degassed, plug removed and that the level float was seized.

ACTION TAKEN

In addition to the measures to be taken in order to comply with the Ministerial Order of July 23rd, 1997, the operator is required to modify its installations and operating procedures:

- the degassing of equipment shall be performed under normal conditions on one of the plant's chlorination reactors. The neutralisation tower shall be maintained in safety configuration,

- valve 37 can be opened only if the storage facility's outgoing valves are closed,
- a check-list of the operations to be performed shall be implemented,
- the flat-seat valves shall be progressively replaced with knife-gate valves.

In order define additional measures, the Inspectorate is waiting for the completion of the safety assessment imposed by the Ministerial Order of 23/07/97 and which must be submitted prior to 29/01/99.

CONCLUSIONS

The accident can be attributed to a series of failures: inappropriate procedures (routine degassing performed on safety equipment), design faults (presence of an unsealed remote-controlled seat valve, absence of check valves and pH monitoring equipment for the sodium solution in the tower, C12 detection at stack outlet, sodium not being able to be replaced without shutting down the tower, etc.) and human errors (atomiser C12 supply valve left open, degassing time significantly exceeded without the operator showing any concern).

The accident demonstrates the measures stipulated by the Ministerial Order of 23/07/97 concerning the monitoring of releases from the neutralisation tower are fully justified. Several recommendations could be formulated:

- ➔ continuous monitoring of the pH of the neutralising solution with a threshold alarm,
- ➔ the possibility to renew this solution without shutting down the tower,
- ➔ install check-valves on the tower's suction lines and thus avoiding the untimely reflux into the depot facility or the transfer station.

Explosion of a grain silo
Semabla in Blaye (33 - Gironde)
August 20th, 1997

INSTALLATION DESCRIPTION

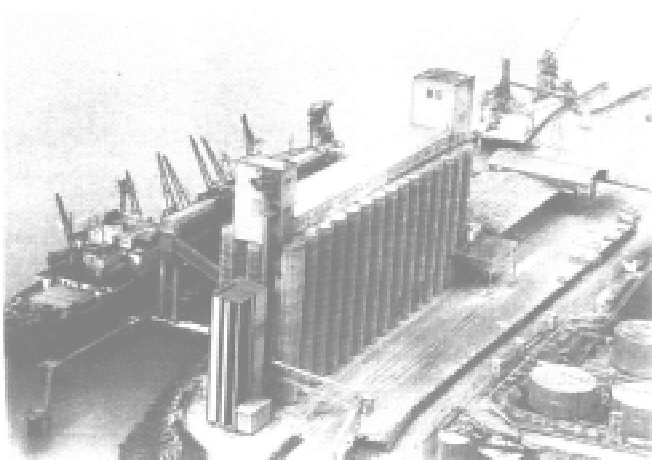
The SEMABLA site and its environment

The facilities of SEMABLA are located within the port district of the City of Blaye, on the right bank of the Gironde estuary and comprise one of the largest grain storage complexes in the *départment* of Gironde. The total storage capacity is 130,000 tonnes of grain, including 90,000 tonnes in flat storage in warehouses and 40,000 tonnes in a vertical silo. The site employees 21 people.

The nearest company, the SCREG, has storage tanks that contain caustic soda, aromatic oil and molasses. The property line is located 25 meters from the silos, the nearest tank at approximately 40m and the administrative buildings at roughly 210m. The first residential dwellings are located approximately 230m from the silo.

Description of SEMABLA installations

The main activity of the SEMABLA company consists in the storage and handling of grain intended for exportation via ship; grain is received almost exclusively by truck. The company has both a vertical silo and flat storage facilities (metal framed warehouses).



The vertical silo consisted of 44 circular cells made of reinforced concrete, arranged in 3 rows and having a storage capacity of 47,240 m^3 (37,200 tonnes of wheat).

Two vertical concrete structures (53m high) are located on each end of the silo and connected by a concrete upper gallery; to the north, the handling tower, to the south: installed on top of the cells, a size grading machine and a set of two cleaners-separators. In the lower section, the set of cell shafts under the pier heads forming an under-cell space.

To the south of the vertical silo just a few meters from the last cells, a metal frame tower houses the corn dryers. Grain can also be stored in the various metal warehouses located around the site. One of these warehouses was connected to the vertical silo by two belt conveyors.

A shelter, built at the foot of the silo's vertical cells on the Gironde side, was used for the bagging operations, this site's speciality (particularly for humanitarian aid shipments).

The administrative and technical offices, including the control room in particular, are located to the north, primarily in the extension of the storage cells and the north handling tower.

Description of the vertical silo

This silo, consisting of two sets of vertical storage units, built in 1970 and 1974, formed a compact volume of approximately 100m long, 20m wide and 40m tall. Each set of storage units consisted of vertical circular concrete cells standing side by side in three rows (interior diameter 6.20m, storage height of 33m. The 2 empty sections between the walls of the cells formed storage units called intermediate stacks (storage height of 32m and a larger interior diameter of 4.20m).

The first section was made up of 20 cells and 12 intermediate stacks. The second section included 24 cells and 14 intermediate stacks.

The two intermediate stacks located at the junction of the two sections was not used for grain storage. They were open at the bottom in the under-cell space, although blocked off at the top by the floor of the upper gallery.

The cells of the second section could be ventilated by pulling air in from the bottom of the cell by means of an air extractor located at the top (except for the three cells at the silo's extreme southern end) and had a pneumatically-controlled and a manual drainage valve.

Bulk grain was received through two pits located side by side. An underground gallery, housing the chain conveyors, connected these pits and the pit of the elevators located near the north handling tower.

The north handling tower was located in the prolongation of the vertical cells and was slightly supported by them. In particular, this tower housed the vertical grain handling equipment (bucket elevators) and elements of the central dust collection system (ventilator, filter unit and dust recipient). Passageways arranged in the floors for the equipment could opened to link the tower's levels which opened, at the top, into the upper gallery and, at the bottom, in to the under-cell space.

The south tower housed a set of cleaners-separators and a sizing machine, used for green corn and barley.

The upper gallery linked the south tower and the north handling tower. It primarily housed the horizontal grain handling equipment, i.e. 4 belt conveyors (3 silaging conveyors and 1 handling conveyor for transport between the vertical silo and a warehouse).

The under-cell space primarily housed the cells' conical piers, horizontal handling equipment (10 Redler conveyors) and air blowing system at the base of the cells of section two.

Inside the silo, dust removal is performed primarily by a centralised system which sucks air at several locations on the grain circuit by means of a fan unit situated on top of the north handling tower, upstream from the bag filter (not in a cowling), the dust being recovered in a dust collector.

An automatic scanning system monitors the temperature in all of the cells. The intermediate stacks were not so equipped.

The silo was not fitted with safety equipment such as fire detectors or explosion venting. There was neither a foreign body detection or collection system at the product receiving station nor a magnetic device capable of detecting all metallic elements in the grain handling system.

Administrative situation

A Prefectorial order of June 12th, 1984 reiterated the clauses of the Ministerial Order of August 11th, 1983.

Two additional orders were issued in October 1987 and in July 1990.

An order of September 20th, 1994 authorised the operation of a 2nd dryer.

Comments: In relation to the Ministerial Order, the following points can be noted:

- the performance of electrical inspections,
- cleanliness considered correct,
- the measurement of temperatures in accordance with the legal minimum,
- the prior right of the establishment in relation to third parties,
- the lack of vents, not required by prior right,
- the lack of restriction rules for keeping personnel at a safe distance.

As a consequence, the actual conception of the silo (height ; position ; partition ; etc …) added to the prior rights presents drawbacks concerning the improvement of the safety of the installations.

Activity at the time of the accident

The explosion occurred on Wednesday, August 20th, 1997 at 10:15am.

A skip lorry with trailer was unloading corn into the receiving pit closest to the administrative and technical buildings.

The previous lorry had unloaded wheat into the other receiving pit and had just left the site. The presence of a barley and wheat mixture in a connecting conveyor with the elevator pit allows it to be assumed that it was empty at the time of the accident and that the wheat receiving operation had terminated.

In the under-cell space, two chain conveyors were carrying barley. Another conveyor was most certainly emptying a cell to transfer the barley to a warehouse and another was performing an internal bin transfer within the scope of the same operation.

Furthermore, 2 belt conveyors seemed to used for an unloading operation, consisting in the transfer of the barley from the vertical silo to a warehouse.

The silo was almost full but the storage units still empty were primarily the intermediate stacks.

DAMAGES OBSERVED AND ACCIDENT REPORTS

The inquiry lasted 8 months and involved 2 full-time INERIS inspectors, upon order of the Minister of the Environment and backed by the DRIRE (1/3 equivalent of a full-time inspector).

The method used in the inquiry was based on the collection of testimonies, the inspection of equipment and the accident site (rendered difficult by the destruction), the analysis of products recovered (grain, dust, calcine) and fault-tree studies.

Human toll

The accident claimed 11 lives (7 company employees, 3 individuals whose activity was associated with that of SEMABLA and a fisherman) and 1 injured.

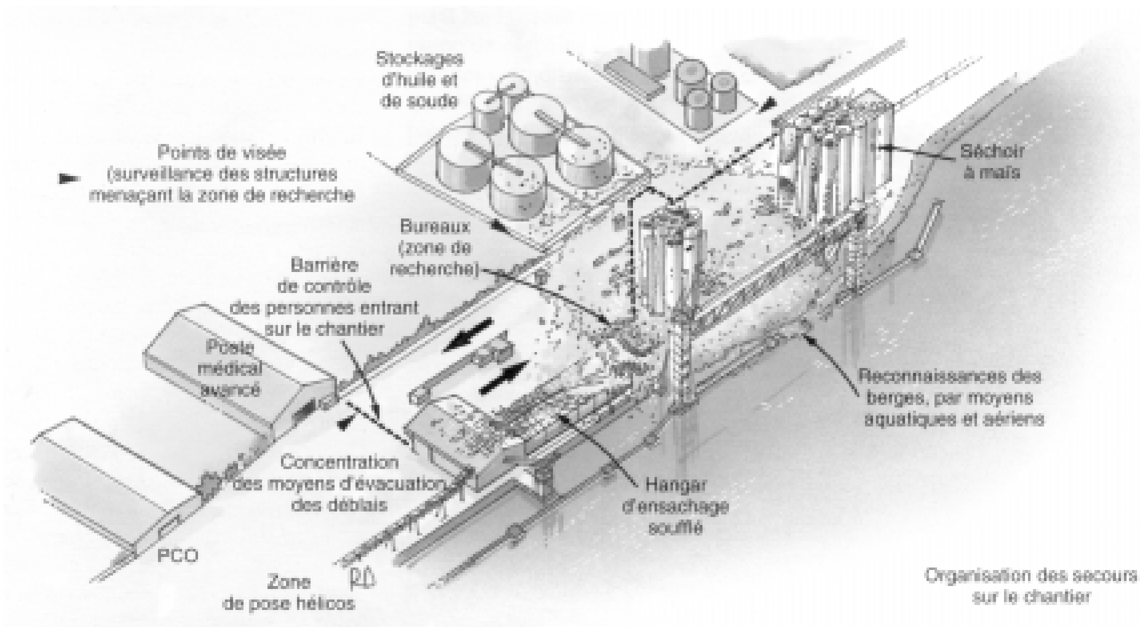
The bodies of the ten victims were found in the administrative and technical buildings located at the foot of the silo or in their immediate vicinity. The individuals located in the buildings were found at their workstations, and apparently did not have time to react (the suddenness of the accident and the probable absence of any prior warning events or identifiable downgraded situation).

The eleventh victim, the fisherman, was found several days after the other victims, buried under the rubble on the banks of the Gironde.

Material damage

a) Damage to SEMABLA installations

The vertical silo central and northern sections collapsed. The northern section buried the offices. Only 16 of the 44 cells seemed to be still in place after the accident. A characteristic of this accident is the fact that two sets of cells collapsed: a set situated to the north and adjacent the handling tower, and another set in the silo's central section (see photo).



The northern handling tower, as well as the cells immediately next to it, were nearly totally destroyed. On approximately half of its initial height, only part of this tower's curved half-shear wall, the side sections of which forming the walls of the adjacent intermediate stacks were pushed backward, onto the pit of a neighbouring cell. The fact gives evidence to an explosion in the handling tower, which would have occurred after any explosions in the neighbouring storage units.

The upper gallery was totally destroyed.

The southern tower collapsed onto the top of the cells. Cleaner-separator elements (rubber balls from the screen) found charred on the surface give evidence of flames or the expansion of burnt gases in this tower.

On the northern part of the silo, the under-cell space (primarily made up of the pit of the central cells) provides few traces which indicate the passage of flames or the expansion of burnt gases. On the other hand, underneath the compact block of the 9 cells still standing in the silo's southern zone, numerous traces of combustion were noted (plastic items melted, deposit of burnt dust, ...) particularly underneath the central cells. Furthermore, in this part of the installation, the air vent ducts at the foot of the cells were found to be disturbed, mostly being projected in the north-south direction. This bears evidence to dust accumulation in the circuit.

No trace of combustion was observed inside the elevator pit, grain receiving pits and the underground connection gallery.

As far as the grain handling equipment is concerned, the elevators' drive pulleys located in the handling tower showed no signs of slippage, the shafts of these elevators did not seem to have been seized in their bearings, the pieces of metal ductwork found were neither swollen nor exploded and the sections of the bucket loaders recovered showed no signs of combustion. Many of the upper covers of the conveyor systems were blown off. In the northern part of the silo (1st section), a conveyor showed significant signs of friction and many fins of the conveyor chain were missing.

Installation equipment, in particular elements of the centralised dust collection system which, for certain, were rather large, were not found despite the earth moving operations performed and the dragging of the Gironde.

Certain installations located near the silo were destroyed (maintenance workshop, bagging shop, ship loading crane), while others were damaged by falling debris or flying silo elements (warehouses and drying installations).

<u>b) Damage to third parties</u>

The SCREG company suffered the worst damage. Numerous projectiles struck various storage tanks. Transfer piping between the tanks and the public gangways were damaged.

Damage to residential dwellings, outside the port site, were observed up to approximately 500m from the silo, with the breakage of windows and falling plaster, in particular...

Projectiles

Significantly large projectiles (metal, concrete and glass elements) were observed at a height of 100m (2 times the height of the handling tower).

Pieces of concrete measuring several meters were found up to 50m from the silo and small-sized debris (weighing less than one kilogram) were thrown up to approximately 140m.

POSSIBLE SCENARIOS, THE SEARCH FOR CAUSES

Context of silo operation

One elevator was used for corn, the destination storage unit being unknown, although was most likely a intermediate stack. It could have been located in either the first or the second section. Owing to the handling of the corn, this first storage unit was open on the upper gallery. Inasmuch as only one lorry had come, it can be considered as being nearly empty.

At the time of the accident a second elevator was being used to empty a cell. This emptying operation seems justifiable only for the transfer of barley to a warehouse. In this case, the transit cell would also be open on the upper gallery.

A third elevator enabled the warehouse transfer operation. It would be accurate to assume that it was supplied by the emptying of a cell and by direct feed from the transit cell.

Finally, the wheat ensilage operation must have just terminated. In this case, the access trap of the cell currently being filled could have still been open on the upper gallery. The location of the destination cell cannot be specified. It nevertheless can be considered to be 2/3 empty.

Thus, 2 and possibly very temporarily 3 cells enabled the communication between the top of storage units and the upper gallery, including the transit cell (barley), in particular. The two other storage units must have been nearly empty or 2/3 empty of corn and wheat, respectively.

Behaviour of the explosion phenomenon

The testimonies gathered reveal that the initial explosion began in the handling tower, at the dust collector level. The explosion then propagated through the upper gallery, all the way to its southern extremity, certainly due to the resuspension of settled dust.

The flames resulting from this explosion, probably in the form of a jet, were able to reach the storage units which were open. They were possible 2 or 3 of these storage units.

The flame jet, penetrating into the storage units which were full of dust after the ensilage operations, created a violent explosion. The geometry of these storage units, and particular their extended shape most certainly contributed to the development of pressure effects. This remark is particularly applicable to the intermediate stack where the corn was stored. The height vs. hydraulic diameter was in the neighbourhood of 10. It is possible that this aspect, combined with the reactivity of the corn, explains, for the most part, the damage resulting in the silo's central section.

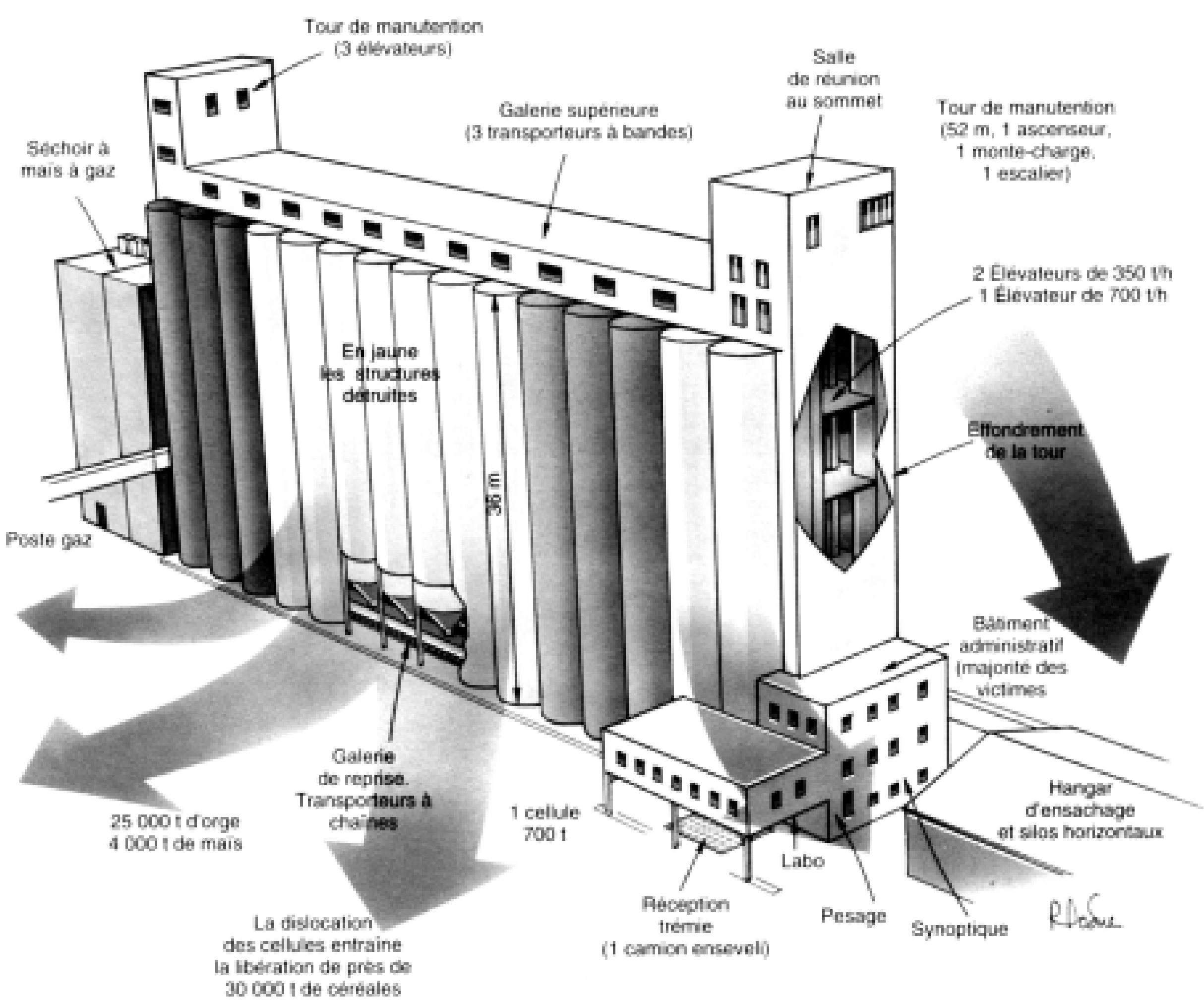
Furthermore, the destruction of the upper gallery and its floor in particular, rendered the communication between this gallery and the under-cell space possible at the intermediate stacks located at the junction of the two silo sections.

The propagation of the explosion by this opening seems possible as the space had never been cleaned. The deposit of dust on the walls of this space is this probable.

At the level of the north handling tower and accompanying the eruption of the transit cell, the explosion went from the top downward. The pressure level attained was able to be limited due to the lack of vents. As a result, the north handling tower was destroyed.

The propagation medium was neither the ducts of the elevators, nor the conduits of the centralised dust extraction system. This propagation thus occurred within the volume of the handling tower itself. The presence of possible depots could reasonably be excluded due to the fact that the area was regularly cleaned. Also, only an accidental dust spreading mechanism could have stirred up this dust from the top to the bottom of the handling tower. The only possible process which could have spread a significant quantity of dust in this manner is the rupture downline from the dust collection ventilator (the most probable hypothesis: rupture of the dust collector).

The explosion discharged in the under-cell area, either at the foot of the handling tower or, more probably, by the intermediate stacks located at the junction between the two sections. In this second hypothesis, the propagation of the explosion via the intermediate stacks would have enabled the flame to accelerate, particularly due to their geometric configuration, by inducing significant pressure effects. Under these conditions, the pressure waves emitted at the lower outlet of the intermediate stacks could be sufficiently intense to destroy the adjacent storage units and, in large part, the concrete curtain wall separating the under-cell gallery from the outside. These openings at the under-cell gallery level, slightly prior the passage of the flame, could have formed venting surfaces thereby limiting the level of overpressure reached within the under-cell gallery itself.



The destruction of the under-cell gallery's curtain walls could have thus been caused by pressure waves generated by the top to bottom propagation of the explosion or by the collapse of these structures. These series of events is coherent with the fact that the destruction of the under-cell space's concrete curtain walls occurred near the end of the explosion process, as was reported by the witnesses.

The collapse of these structures may have been facilitated by any structural weaknesses (the wall of an exterior cell had partially collapsed in 1988 being witness to an insufficient or poor positioning of concrete reinforcements on many cells). This event and falling equipment inevitably caused short-circuiting, particularly within the transformer building located on the half-story of the administrative and technical buildings. This could have been the cause of the localised fires following the explosion.

Similarly, the propagation of the flame and the explosion of burnt gases caused combustible materials to catch fire or resulted in the thermal effects on plastic materials.

The fires in the cells, noted particularly at the upper surface of the storage area, may have been caused by falling burning material after the passage of the flames.

<u>The search for the causes of the accident</u>

The two key points in determining the conditions of this accident are based on the search of conditions which may have lead to an explosive atmosphere and in the identification of the ignition source.

Concerning the formation of an explosive atmosphere: two possibilities are proposed:

- the formation of combustible gasses at the top of the storage units, caused by a downgraded situation such as, for example, spontaneous heating, fermentation or an incipient fire,
- an inflammable mixture of dust and air.

In light of the accident reports and testimonies, the first possibility can be reasonably excluded.

The second possibility corresponds to the explosion of a dust/air mixture which could have existed in certain parts of the installation. This type of explosion has been routinely encountered in other accidents. On the basis of the eyewitness testimonies and the reports made, the explosion would have started either in the dust removal system or within the silo structure itself (an origin in the "product" system can reasonably be excluded). The examination of the ignition sources, outlined below, leads us to plausible ignition sources, within the dust removal system.

The search for the ignition source was particularly delicate inasmuch as the hot point work was able to be excluded relatively quickly. The categories of the ignition sources which remained possible were as follows: mechanical sparks or heating, static electricity, electrical sparks, spontaneous combustion of dust. In this case, electrostatic sparking was not retained as an ignition source, primarily due to the relatively high baseline ignition energy of the grain dust in question.

The analysis of the various possibilities, owing to the disappearance of dust collection system elements, provides two plausible origins for the ignition which lead to the explosion:

- either mechanical impacts or friction on the dust removal system's ventilator,
- or an incipient fire caused by spontaneous heating in the dust collector.

LESSONS LEARNED FROM THE BLAYE ACCIDENT

In 1998, a specialised environmental inspection mission, requested by the Ministry of the Environment, submitted a report which highlighted the necessity to update the legislation of 1983 for application to silos built previously. The essential recommendations are:

➔ a safety assessment performed on existing installations,

➔ sufficient separation of buildings occupied by third parties,

➔ the creation of venting surfaces,

➔ the distancing of personnel not critical to silo operation.

In its expert report, the INERIS analyses the events of this accident and by considering the uncertainties that surround it, derives the major lessons to be learned for a silo whose structure is similar to that of the Blaye silo. They concern several subject areas which can be organised by following the process of the explosion itself and which are listed below by theme.

The seriousness of this accident lead to the updating of the Ministerial Order of August 11th, 1983 applicable to this type of installation, which is expressed by the Ministerial Order of July 29th, 1998. The reference to the articles of this order is mentioned in comparison with the corresponding technical recommendations which were thus reformulated in the form of regulations.

Prevention of explosive atmosphere formation:

- ➔ monitor the temperature in the intermediate stacks (article 13);
- ➔ employ video-surveillance, coupled or not with detection systems;
- ➔ determine the operational limits of the dust removal system, primarily for centralised-type systems (article 28);
- ➔ permanently monitor the suction efficiency of the centralised dust removal system by means of a vacuum measurement, for example (article 28);
- ➔ ensure that filter-bags are enclosed or install an equivalent device which would prevent the risk of spreading dust into largely closed installations. The most adequate measure would consist in installing such equipment outside a largely closed installation, i.e. outdoors (article 15);
- ➔ isolate, whenever possible, the different parts of the silo from each other (the term "parts of the silo" designates, for example, the handling tower, the upper gallery or the under-cell space) (article 11).

Removal of ignition sources:

- ➔ fit main equipment with spark detectors or equivalent devices which can shut down the equipment (approach by articles 16, 17 and 18);
- ➔ install a system to detect the abnormal temperature rise of certain equipment (bearings of the centralised dust collection system, for example).

Propagation of the explosion:

- ➔ separate the different structures in order to limit the propagation of the explosion (which also helps to limit the effect) (article 11);
- ➔ install the centralised dust collection systems, wherever possible, outside of all confined installations, i.e. outdoors (article 15).

Limitation of effects:

- ➔ install vents on the structures which house grain handling equipment and on storage units (article 12);
- ➔ determine the methods and limits for calculating vents for the long structures, during ignition by a flame jet (see safety assessment);
- ➔ forbid or limit the use of storage areas in which the length to diameter ratio is high (that is, greater than 5) and the intermediate stacks, in particular.

Limitation of consequences:

- ➔ perform a case-by-case study of the distance separating the buildings occupied by third parties. The value of 1.5 times the height of the silo is to be understood as the minimum distance (articles 7 and 8);
- ➔ remove from the silo all individuals whose activity is not critical to its direct operation (article 9).

Other lessons learned:

- ➔ install fire detectors in areas at risk due to the presence of combustible materials other than grain (article 13),
- ➔ regularly clean the ducts of the air flow system at the foot of cells (article 22);
- ➔ adapt the storage temperature alarm threshold to the outside climatic conditions, provided there is technical justification which takes into account the kinetics of the spontaneous heating phenomenon (articles 13 and 24);
- ➔ each silo must be subjected to a risk analysis within the scope of a danger assessment (article 2).

The main stake is the application of the recommendations to existing installations.

To accomplish this, the Ministerial Order of July 29th, 1998 dictates that the new recommendations are applicable immediately to modifications made to existing installations and stipulates deadlines from 1 month to 2 years for implementation in existing installations.

Sinking and rescue of the sailing vessel "KRONENBURG" Ijsselmeer near URK (the Netherlands) March 5th, 1999 ?

INSTALLATION AND ZONE CONCERNED:

The operation concerns the rescue of a ship in difficulty, the "Kronenburg", in a sensitive zone comprised of a land-locked sea, the Ijsselmeer zone.

The 85m-long ship had a transport capacity of 1,690 tonnes and was on route between Harlingen, the Netherlands and Leverkussen, Germany. 76 individuals were on board.

CIRCUMSTANCES AND CONSEQUENCES:

In the evening of March 5th, the crew sent a message indicating water in the engine room, followed by a distress call.

During the night, the crew was rescued by a private rescue organisation. The ship foundered during the same night.

The environmental risks are essentially related to the pollution to the environment due to the loss of hydrocarbons from the engine room and the increase of chlorides in the water from the barge's cargo. It should be noted that there is a drinking water station nearby, in Andijk, located opposite the zone concerned by the accident.

Unloading operations of the foundering ship were undertaken March 6-8. Operations were then suspended for 2 days due to poor meteorological and

Chlorine Measurements in mg/l on 10 march 1998 rough sea conditions.

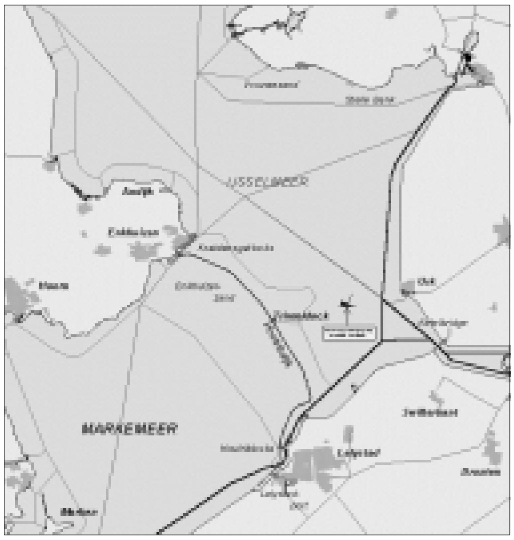
Other means were employed starting March 9th: 2 barges attempted to refloat the ship, under authority of the RWS (Public Works and Water Development Branch) and by the environmental inspectors.

Co-operative efforts were undertaken between various public and private organisations.

LESSONS AND CONCLUSIONS:

This accident, slightly different from the others presented, underlines the importance of very close co-operation between the various entities which are involved in the crisis situation.

From this point of view, the example is highly characteristic of the territorial organisation of the Netherlands: in fact, in this case, 6 provinces were concerned involving as many local authorities, 10 regional fire brigades, 10 regional police departments and 41 local authorities.



Atmospheric pollution generated by a refinery Couronnaise de raffinage in Petit Couronne (76 – Seine-Maritime) September 16th, 1998

ACTIVITIES AND LOCATION

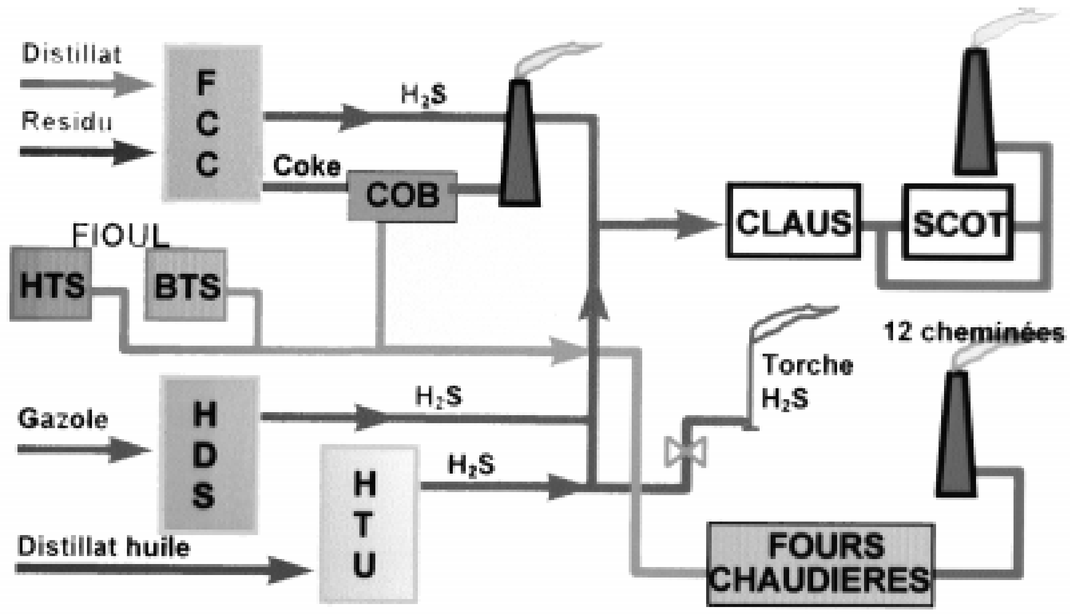
The Couronnaise de Raffinage refinery (SCR) is located within the commune of PETIT-COURONNE, in the suburbs of ROUEN. This site produces oils, bitumen, fuels, heating oil and liquefied petroleum gas (LPG). and is divided into 3 autonomous production centres. The overall workforce is 590. The production capacity is currently 7Mt of crude per year. The SCR belongs to the SHELL Group.

THE INSTALLATIONS CONCERNED BY THE ACCIDENT

All of the units were concerned by the accident although the most implicated initially are the steam plant and its electrical supply network and the hydrodesulphurization facility.

Steam plant:

This installation generates steam at 46 bar and 450° C for the rest of the refinery and particularly the HDS (hydrodesulphurization) facility. It consists of 4 boilers and a CO burner for the cat cracker. This steam is then transformed into steam at 22 bar and steam at 3 bar, depending on the needs of the users. In this manner, the 22 bar steam is used for the flare stack and the HDS facility's steam ejector.



The refinery's electrical supply includes two 90 kV lines which are then transformed to 20 kV, then 3 kV and then 380 V. The steam plant is fed by two 380 V lines. It also is equipped with a diesel-powered back-up generator. It should be pointed out that the stations are independent, not coupled and are not used simultaneously as only one is required. The current supplies the distribution panels of the boilers with 220 V.

Hydrodesulphurization (HDS) facility:

This installation performs the desulphuration of diesel fuels to obtain a sulphur content of 0.05%. The reaction takes place in the presence of a catalyst in 2 reactors mounted in series. The sulphur contained in the diesel fuels is then transformed into gaseous H2S which is recovered and sent to the CLAUS SCOT unit. The traces of H2S remaining in the diesel fuels are subject to additional processing: vapour stripping separates them from the basic product and a vacuum drier, with a steam ejector device, separates the gas from the diesel fuel and contributes to the vacuumizing of the system.

THE ACCIDENT AND ITS CONSEQUENCES

Chronology of the accident of September 16th:

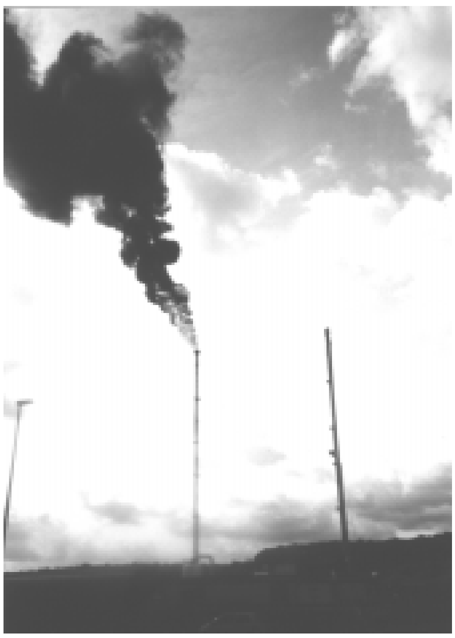
10:15 Shut-down of the steam plant's steam generators, resulting from an electrical failure. Nearly simultaneously, the installations are placed in fail-safe mode. This causes the gases present in these installations to be directed to the flare stack.

11:15 The company informs the DRIRE.

11:30 The company initiates the POI ("Plan d'Organisation Interne", internal contingency plan) and implements its operational control point. The sirens are activated to evacuate the personnel after detection of H2S.

It should be mentioned that the AIR NORMAND pollution measurement network, contacted by the DRIRE, detected nothing with its sensors at this moment. On the day of the accident, the winds were west/north-westerly.

11:45 The fire-fighters of the SDIS are advised and arrive at 12:00.



12:10 The H2S concentration measured downwind from the HDS facility, inside the refinery, is in the order of 1 to 3 ppm.

12:40 The sensors located outside the refinery still detect nothing. Flare stack emission starts to lower.

13:00 Still nothing reported by the sensors.

13:28 Restart of the steam plant.

14:15 Pressure level of the high pressure steam enables steam to be sent to the flare stack once again.

14:27 Termination of evacuation alert.

18:00 Situation normal as far as the steam is concerned.

All installations operate once again the next day.

<u>Chronology of communication between the various organisations:</u>

11:15 The company informs the DRIRE.

11:54 The DRIRE is informed of the initiation of the POI, the implementation of the operational control point and the evacuation of the personnel.

12:10 FR3 (television station crew) is on site.

13:15 Summary fax sent to the Prefecture's crisis centre, activated independently for a nuclear exercise.

13:33 First press release by the operator.

15:30 Debriefing with the site management, the personnel, the Petit-Courrone elected officials, the DRIRE and the fire brigade.

16:00 Second press release by the operator.

17:00 Interviews by FR3 of the operator and the DRIRE. Prefectorial communiqué.

CONSEQUENCES OF THE ACCIDENT

Smoke plumes were highly visible and very spectacular.

The available estimates are as follows for the releases during the entire accident:

- Dust = unestimated
- SO2 = 48 t over the 3 days (50 t/d on the 16th, 67 t/d on the 17th, and 31 t/d on the 18th)
- H2S = 100 l

For informational purposes, the authorisation order specifies the following maximum values for SO2:

- average = 45 t/d
- maximum occasional value = 70 t/d.

ORIGIN AND CAUSES OF THE ACCIDENT

During a programmed manoeuvre on the 22O V network, a power shut-off of a few seconds occurred and affected the centralised control screens one after the other. The boilers' flame detection systems were also activated causing the their shut-down and thus a lack of steam throughout the site. The lack of steam caused the site installations to shut down.

The manoeuvre does not normally cause a power shut-off as the distribution panels are backed up by battery/converters. However, the day of the accident, a circuit breaker ensuring the continuity between this assembly and the distribution panel was found open.

It should be noted that the automatic protection system, equipped with an autonomous power supply, were not affected by the power outage, which enabled the installations to enter fail-safe mode according to the normal sequence.

Furthermore, on the HDS part, due to the absence of pressurised steam at the level of the stripper and the ejector (which places the system in a vacuum under normal situations), the assembly was in a state of overpressure and the hydraulic seals were removed. In this manner, the H2S contained in the gaseous phase escaped to the outside.

Finally, it should be noted that the Air Normand sensors are located at the site and toward the west (Roumare, Val de la Haye) or the south (Grand Couronne). The smoke plume was directed toward the south-east. This explains why these sensors did not detect anything.

LESSONS LEARNED AND CONCLUSIONS

Technical aspect

- ➔ The procedure concerning the switching of 220V power supplies was modified: it includes the verification of circuit breaker position (normally placed in open position).
- ➔ A study is currently underway in light of the modifications made on the 220V power supply.
- ➔ The hydraulic seal was redesigned and modified (increase in diameters from 2" to 4").
- ➔ An additional safety assessment relative to the risks associated with H2S during the transitory phases of units, networks and flare stacks is currently underway.

Crisis management aspect

- ➔ For the administrative personnel, it is interesting to the training in crisis management and the operator's POI.
- ➔ One should carefully choose your words in a press release: in this case, a distortion appeared between the facts and the manner in which they were divulged to the media.
- ➔ In a refinery, even related equipment, such as the steam plant, as they represent a common mode of failure for the entire installation.

Pollution of the river ENNS following a leakage from a hydrocarbon storage tank
Downstream from the City of STEYR (Austria)
May 31st, 1998

THE INSTALLATION AND ZONE CONCERNED

The installation in question is a high-capacity storage tank, located on the site of an engine manufacturing company, containing hydrocarbons used for the heating system.

This tank consists of two envelopes as shown in the diagram below. The reservoir containing the product, made of steel, is housed inside another reservoir. The assembly measures approximately 22m tall and can contain approximately 1,000 m^3.

The site concerned is located on the bank of the river ENNS, a tributary of the DANUBE, and downstream from the City of STEYR. The STANING hydroelectric plant's impounding dam is also located downstream. Furthermore, within this same zone on the left bank of the river, there is a drinking water station with its extraction wells in its immediate vicinity which provides water to approximately 50,000 inhabitants.

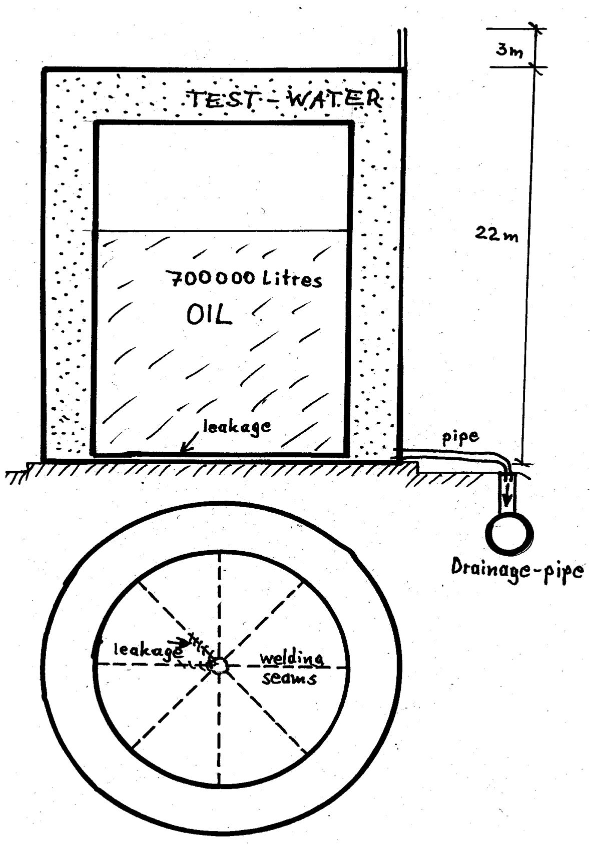
CIRCUMSTANCES AND CONSEQUENCES:

The tank is undergoing testing: the space between the two walls is thus filled with water. At this time, the "interior" tank containing the fuel contains approximately 700m^3. During the entire test, the tanks appear to be free of anomaly.

During the night, the valve at the base of the tank is opened and the test water drains toward the river via the inter-envelop drainage pipe.

In the morning, fishermen inform the police that the river is polluted. The majority of the pollution is located within the impounding lake formed by the STANING dam, thus near the drinking water well zone.

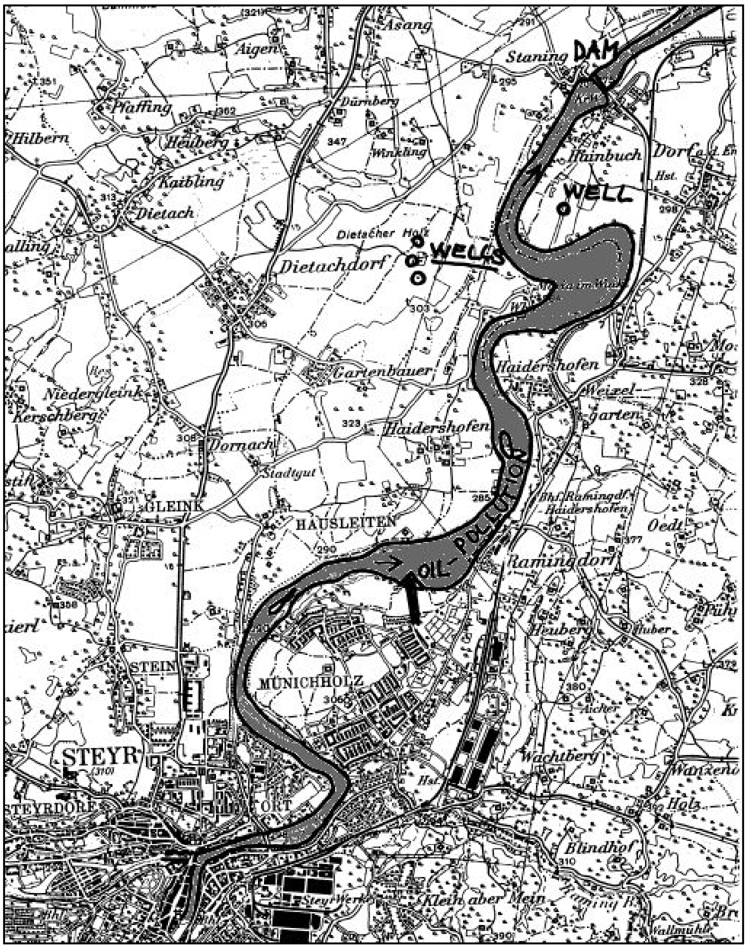
For three days and three nights, the water authorities and fire brigade worked to contain the pollution: installation of floating barriers, skimming of the surface to recover the hydrocarbons, cleaning of the surface and banks of the river, ...).



The pollution extended 35 km, affecting 3 hydroelectric dams located within this zone.

Approximately 9 weeks after the accident, the drinking water wells showed a significant level of hydrocarbon pollution. It was, however, of short duration and low concentration.

Finally, numerous wells were inspected during the 6 months following the accident.



ORIGIN AND CAUSE

During the test, no one was able to detect the crack on a section of weld seams located on the bottom of the main tank, i.e. the tank containing the hydrocarbons. As a result, approximately 70m^3 or more drained into the river.

LESSONS LEARNED AND CONCLUSIONS

The tank in question is slightly special. However, certain lessons should be learned from this type of situation:

- The drainage phenomenon was amplified by the test of the exterior tank as the leakage of hydrocarbons is assisted by the draining water.
- The installation's configuration, with a purge emptying directly to the river, is inadequate.

Explosion and fire in a warehouse containing phyto-sanitary products. CAPL Company in Sorgues (84 - Vaucluse), September 11, 1998

ACTIVITIES AND LOCATION

The company concerned is the CAPL agricultural co-operative (Coopérative agricole de Provence Languedoc). It is located in the centre of SORUGES. Miscellaneous products are stored there:

- 1,700 tonnes of phytosanitary products,
- 17 tonnes of highly toxic products,
- 150 tonnes of toxic products,
- oxidising agents, ...

Owing to its location, the establishment is subject to easements and the urbanisation around the site is controlled by the land-use plan (POS): as a result, radii of 100 and 200m were defined around the building used to store the phytosanitary products.

THE INSTALLATIONS CONCERNED BY THE ACCIDENT

The site consists of 3 warehouses: the accident began in the oldest of the three. It contained 26t of sodium chlorate, in addition to other chemicals.

THE ACCIDENT AND ITS CONSEQUENCES

At around 6pm on September 11th, when the establishment was closed, a fire broke out in one of the buildings. Approximately 10 minutes later a violent explosion occurred, followed by several smaller explosions. The fire gained momentum and the plume reached a height of 50m.

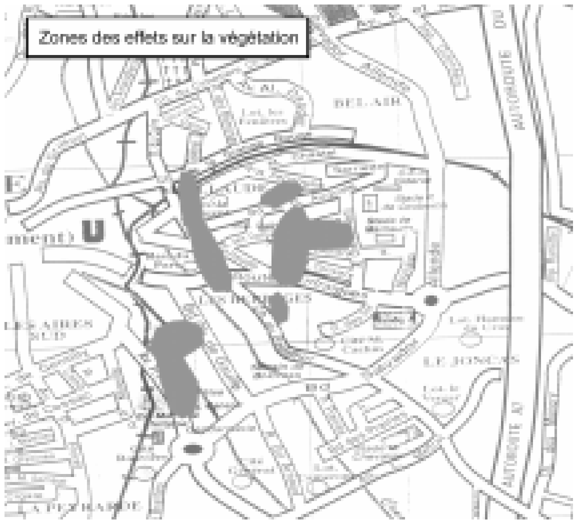
The fire brigade was arrived at the scene in 15 minutes and it took them 5 hours to bring the fire under control.

<u>Damage to installations</u>

- 20 metres of wall had been blown away,
- 1,000m² of roof destroyed,
- windows were blown out at distances up to 150m,
- barrels being projected 150m were observed.

Effects on the environment

- roofing and internal walls were damaged in the personnel dwellings located nearby,
- the population was also effected by the accident: 20 people suffered from shock, although all were released during the day or the next day. One individual, pushed to the ground by the blast, suffered a double fracture.
- the loss of vegetation in the immediate area and downwind from the blast was observed over approximately 700m. (It should be noted that, since the accident, the situation has improved in this respect).



In addition to the smoke, it should be pointed out that part of the fire protection water was left to enter the water table.

ORIGIN AND CAUSES

The sodium chlorate is considered to be at the origin of the explosion as a significant quantity was stored in the warehouse. On the other hand, the ignition source is not precisely known. Several hypotheses exist:

- wastes not correctly stored which would have reacted with the sodium chlorate,
- incompatibility of the chlorate with other products.

LESSONS LEARNED AND CONCLUSIONS

Immediate measures:

An emergency Ministerial Order was drawn up: it defined, in particular, making the site safe, the evacuation of waste following the accident, and the inspections to be performed on the water table. It also stipulated that the other warehouses on the site must be brought into compliance with regulations. A violation report was also established. The quantities stored on the site were indeed greater than the quantities authorised in the order.

Evaluation of consequences:

The analysis conducted by the INERIS studied this point and concluded that, in their estimation, the dosages received in the most unfavourable case do not exceed 1% of the dose inducing significant effects for the individuals located on the outside at the time of the accident. The percentage is 0.01 for the individuals located inside residential dwellings.

Lessons learned:

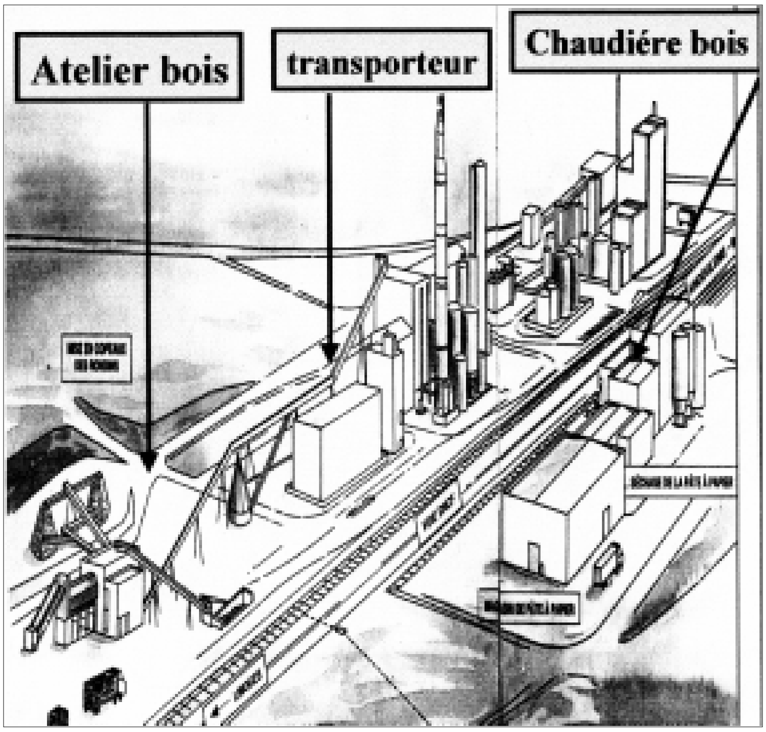
- The sodium chlorate (subject simply to declaration between 2 and 100 tonnes) may be a major accident source.
- The smoke was the most toxic during the less violent phases of the fire.
- The generation of heat promotes the dispersion of pollutants upward.

- The maximum concentration of toxic products appears at a distance of 400 to 500m from the accident.

Explosion in a bark silo
Aussedat Rey in Saillat sur Vienne (87 – Haute Vienne)
June 9th, 1997

ACTIVITIES AND LOCATION:

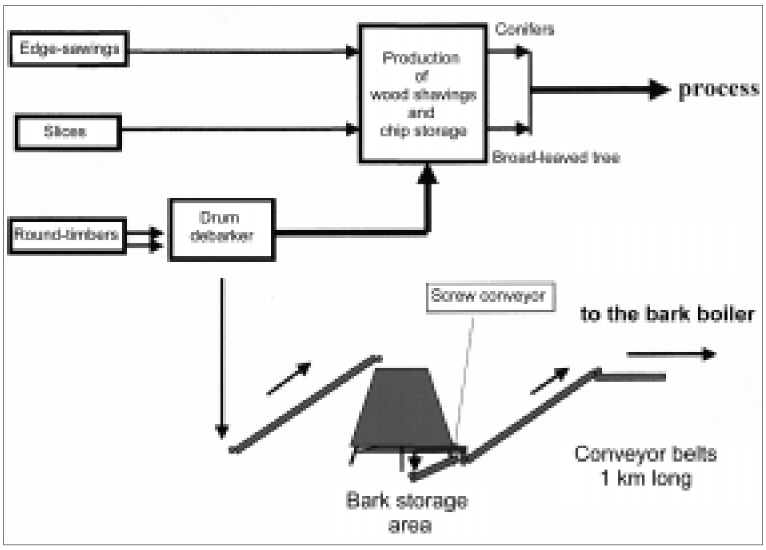
The AUSSEDAT REY Company, subsidiary of INTERNATIONAL PAPER, European leader in the white and colour reprography printing market, runs the SAILLAT-SUR-VIENNE site. This facility, initially created in 1894, was renovated in 1993. It is in fact a nearly new paper mill that was reconstructed at that time. The production capacity is 300,000 tonnes of pulp/year and 200,000 tonnes of paper/year. A total of 750 people work at the site.



THE INSTALLATIONS CONCERNED BY THE ACCIDENT:

The installation at the origin of the accident is the bark storage silo, associated with the energy recovery boiler.

The paper mill's wood zone generally includes the raw material storage zones, the transfer to the drum debarker and the grinder for the transformation into wood shavings, the chip storage area, and the bark storage area (see diagram below).



The bark storage area is in the open air, in a pile covered by a sheetmetal roof. From this pile, a screw conveyor in conjunction with a belt conveyor feeds a 100m^3 silo, which itself feeds the boiler by means of 3 extraction screw conveyors.

THE ACCIDENT AND ITS CONSEQUENCES:

The shut-down of the screw conveyor located at the open air pile is scheduled for June 9th from 8am to 5pm.

The chronology of the accident which occurred this day is as follows:

5:00	the transport of bark via the belt conveyor is stopped and at 5:30 the various belt conveyors, silos and associated equipment are empty.
8:00 to 14:00	an external company works on the screw conveyor to be repaired at the open air storage area.
17:05	the installation restarts.
17:16	the high level alarm in the silo appears and immediately, 1 minute later, the supply of bark stops. At this time, a operator goes to clean the level sensor cell (located on the upper section of the silo, on the outside). He informs the operators in the control station via walkie-talkie that the bark supply operation can continue.
17:24	the silo explodes
30" later	the conveyor sprinklers are triggered following the detection of a fire.

The human consequences were tragic as one individual, the operator who went to work on the silo, died in the explosion.

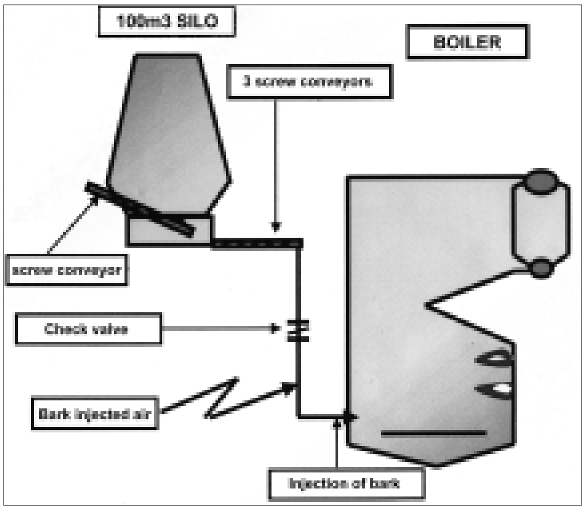
In terms of material damage, the following effects were observed:

- silo roof raised in 3 areas,
- ladder twisted,
- grating raised in various locations,
- sheetmetal cowling on belt conveyor ripped away,
- electrical wiring and conveyor partially destroyed by flames at one end.

The "wood" shop was out of operation for 6 days.

Origins and causes:

The INERIS analysed this accident: the probable cause which led to the accident was more likely due to the reactivity of dust further to their spontaneous heating in the presence of a hot air inlet, than to ignition caused by a spark. The report's quantified data provides detailed information and gives detailed concentrations of dust and dust ignition energy values in various configurations.



The possible sequence would thus be as follows:

- dust deposit attached to the inside walls of the silo,
- a return of hot air coming from the boiler enables the spontaneous heating of this deposit,
- following the restart of bark supply to the silo, the level sensor becomes dirty and the feed of bark is automatically stopped,
- the operator who went to repair the level sensor prepares to come down via the ladder,
- the deposit of dust detaches suddenly, creating a cloud of dust which ignites and explodes.

LESSONS LEARNED AND CONCLUSIONS:

Immediate measures:

Following the inquiry by the DRIRE and the INERIS inspection, the first conclusions resulted in the laying down of emergency action and the modifications to be initiated within the days following the accident.

Modifications:

The following modifications were stipulated:

- ➔ 2.4m² vents, thus larger than those already existing (on the silo),
- ➔ a CO detector (on the silo),
- ➔ 2 steam inerting taps (on the silo),
- ➔ dual check valves on the section between the silo's extraction screw conveyor and the boiler,
- ➔ 2 temperature sensors on the same section, on each side of the check valves,
- ➔ a level sensor which is undisturbed by a dust-charged atmosphere,
- ➔ a metal screen capable of protecting an eventual operator,
- ➔ regulations restricting access to the silo roof during filling operations.

Leak on a LPG storage tank in an asphalt production facility
Baden Württemberg (Germany)
January 26th, 1998

THE INSTALLATION CONCERNED BY THE ACCIDENT:

The installation in question is a tank located in an asphalt production facility. The liquefied petroleum gas (LPG) present in the tank is butane and is used to heat the bitumen during the fabrication process, in the storage containers or the mixers.

The tank is equipped with a pressure control valve. It is located on the pipework section between the tank and the burner. The excess gas passes by the valve and returns to the tank.

The section was refurbished in July 1997. The valve had been installed at this time.

The valve's operation is independent of the pressure sensor. The valve's adjustment pressure is set by a manual handwheel which compresses a spring. The envelop which surrounds the adjustment spring communicates with the outside air.

The valve is a boot valve as shown in the diagram opposite.

CIRCUMSTANCES AND CONSEQUENCES:

The accident was detected at approximately 5:30am in the morning by the owner of a neighbouring installation. He noticed a strong gas odour around the asphalt factory. He assumed that the tank had been filled that morning. As the odour persisted, he approached the tank with an electric flashlight and noticed the LPG flowing from the valve. The outside temperature was –5° C.

The police were informed immediately, around 6:45am. The police, accompanied by the fire brigade, block the traffic on the road next to the installation and measurements of the ambient air are taken. The sector's electrical power supply is also cut off due to the high risk of explosion.

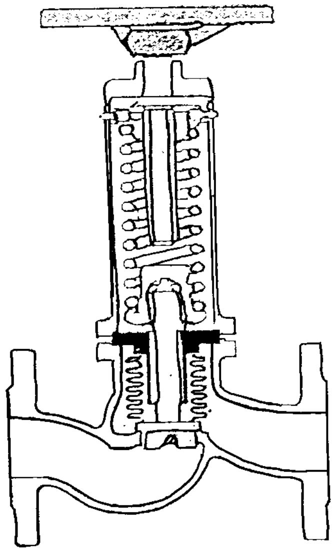
The valve is isolated, the operation being conducted by a technician of a company specialised in handling LPG. The gas remaining in the tank is burned off by means of a flare stack.

Approximately 150 litres of butane, or 90 kg, managed to flow through the crack. Owing to the factory's isolated location and the particularly low temperature that day, no one was seriously injured and there was no damage.

ORIGINS AND CAUSES:

In the case of the accident, the leak was due to a crack in the boot. As a result, there was communication between the LPG loaded section of the valve and the part connected to the atmosphere (the spring's envelop).

According to the study conducted by the TÜV, the following causes may have lead to the crack:



- local overpressure at the level of the boot,
- boot manufacturing defect or defect on the associated welds,
- mechanical stress overload due to the repetition of cyclic operations,
- corrosion,
- deformation of the boot due to the penetration of water, rain or condensation, for example, into the body of the valve, at the boot level.

On this basis, the local inspectorate conducted additional inquiries and arrived at the conclusion that the fault was caused by the formation of ice on the lower part of the boot The observation of the part showed that it buckled and was subjected to very high stresses (estimated from 80 to 100 bar). The scenario which could have occurred is as follows:

- The boot fills with water (as was seen coming from the exterior or from condensation): the water's access toward the boot was made possible by the design of this type of valve.
- The particularly cold weather caused the boot to freeze and thus the increase in the volume of water trapped inside by approximately 10%. The resulting stress on the metal caused the plastic deformation of the boot. After a thaw period, the phenomenon could have happened again which would have caused increased deformation of the various parts or the boot until a crack was created.

LESSONS LEARNED AND CONCLUSIONS:

As soon as it was established that the valve was at fault, an inspection programme initiated by the Ministry of the Environment and Land Transportation concerned. Within the framework of this programme, the inspectors of the installations concerned were required to identify the installations potentially concerned. The operators of this type of installation were asked to take the necessary corrective measures immediately, such as the modification of the valve or its replacement.

The professional LPG union was informed of this programme and also contributed to the feedback by requesting the operators to conduct the necessary inspections. In this manner, in the Land of Baden-Württemberg, 55 valves were identified as having to be either replaced or modified. Furthermore, the LPG operators took the matter very seriously and identified then replaced the defective units before being requested to do so by the authorities.

In conclusion, this type of valve is not appropriate for the storage of dangerous products. In particular, the pressure control valves must be of higher quality.

In the case of Germany, the inspection programme is the means for the authorities to respond to a specific incident. Through this type of action, targeted measures can be taken in order to prevent accidents or dangerous situations from reoccurring.