# INVESTIGATION OF ACCIDENTS AND SHARING INFORMATION : AN EXPERT POINT OF VIEW

Frédéric MASSON - Jean-Philippe PINEAU
INERIS - Parc Technologique Alata - B.P. 2 - 60550 VERNEUIL EN HALATTE - France

## SUMMARY

Accidents are taken into account in risk assessment and shall be a basis for knowledge to be considered for improving the safety level at the design and operation stages in various industries and activities. Unfortunately, in many cases, detailed data are difficult to be accessed. Lessons learnt from French accidents in plants and transportation will be developed. In summaries of accidents issued after analysis, emphasis will be given on the need to consider product(s), process, causes, circumstances, evolution and consequences. Examples will be detailed on involved materials and products, on accidental phenomenon, on the general design of a plant or transportation system, on the reliability of safety related equipment, on procedures and on operator's role.

## INTRODUCTION

For long, very large accidents occurred in explosive factories. Later, accidents were reported in flour mills (end of 18th century), in mines (coal dust and firedamp explosions), in chemical plants, during the transportation of dangerous goods such as fertilizers, explosives ... or even with very common substances such as fuels or grain.

In all cases, the consequences could be more or less extended : thermal effects from fire, toxic gas and fire fumes releases, toxic spills in soil and water.

Especially, when the extension of damage was large and when people died, various enquiries were undertaken :

- at the company level for a better understanding of the deficiencies of plant design and operation including human factor, management and maintenance
- at competent authorities level for investigating the causes and for improving the existing regulation
- at the insurance company level for defining the extent of the damages to be paid and for reevaluating the insurance premium for a given plant, industrial field or technical system ...

Thus, investigations to be carried out have various goals, but the methodology could be the same. This paper is given as an attempt to summarize the experience gained by INERIS (and formerly CERCHAR) experts when accidents occurring with dangerous substances took place in a variety of plants and systems.

In general, this experience is based on direct investigation and analysis of accidents.

## PREVIOUS EXPERIENCE IN THE DOMAIN

Existing data could be collected from press dispatches, general and technical newspapers, official reports ...

The reports on accidents are rarely published when the investigation is done by insurance companies or the operator of the plant in which the accident occurred. As regards the competent authorities, efforts were made for long to draw statistics and make detailed data available. The Directory of existing databases prepared by ESReDA could be considered as an attempt for networking the databases operators and users. Other initiatives are currently in progress : a special group of European Process Safety Center (EPSC) dealing with accident, the networking of data related to dangerous substances under the aegis of EPA in USA. Data collection forms were prepared by OECD and UN/ECE, by MARS databases operators and by many databases operators. The differences alreading existing should be made as minor as possible to ease the exchange and use of information.

However, for data exchange, there is a need to be sure that the analysis of the accident was reliably undertaken.

This lecture will present the various steps of the investigation of an accident and the lessons learnt from various accidents.

## INVESTIGATION OF ACCIDENTS

Logical steps for investigating and analysing an accident are the following :

1. characteristics of the plant or system in which the accident occurred,
2. collection of data on damages, testimonies, analysis of samples,
3. definition of the operation when accident occurred,
4. consideration of all possible accident scenarios,
5. plausibility of a scenario.

<u>Characteristics of the plant or system</u>

Any information about the exact location of the plant (system) involved, other plants, buildings and communication routes in the vicinity, the operation procedures when the accident occured, the types of products involved (if relevant), the presence and location of operators or other persons, are to be collected. At this stage, preventive and protective measures, existing regulations and codes of practices, emergency response should also be reported. In many instances, emergency response data collected can give valuable information about the development of an accident, the effectiveness of preventive and protective measures, but can also explain some major modifications of the plant system before the investigation by experts.

Data on damages and testimonies, sampling

Observation of damages is to be done as soon as possible, and if possible during the development of the phenomenon.

Any injury and its consequences (immediate, mid- or long-term effects), fatalities and ecological effects, are to be reported clearly including the locations and the exact dates. Photos, video films, witnesses interviews, distribution of fall-outs and missiles, plumes distribution after releases shall be collected to be considered later.

Samples shall be collected for further investigations about toxicity, combustibility, explosivity ... even modified substances or construction materials can be interesting as a proof of the fire development, thermal effects, involved materials ...

Definition of the operation of the system when accident occurred

A lot of accident investigations proved that the system was neither designed nor operated in the conditions in which it was supposed to be. Any investigation must consider the exact design and operation of the system, the maintenance, the training of operator, the application of operating procedures and the management system, the possible interaction of third parties (passengers in transport systems), the staff actions, the exact nature of products (if relevant), the monitoring system (human or technical) and shall lead to a definition of the state of the system (with existing uncertainties) and should be related to the other data collected.

All possible accident scenarios

At this stage, no consideration is to be paid to the likelihood of occurrence of the sequence of events which constitute the possible accident scenarios.

The possible scenarios may be chosen from a preexisting list based on the possible phenomena related to the use of hazardous substances, or to the materials present in buildings or transportation vehicles. Mechanical effects from pressure vessels or containers under pressure, from operation of plant, should also be considered as potential scenarios : collision, derailment, sudden engulfment by fires or by fire fumes in a building. Only the main characteristics of scenarios are to be taken into consideration. In a further step, the causes and sequences of events related to these scenarios will be reported, checked and evaluated.

Some damages and testimonies can prove the likelihood of a scenario (bursting of a vessel or building for explosion, thermal effects with flame for fire, visible colored smoke for releases). At this stage, the collection of data from past accidents and incidents in the plant (system) or in similar plants and/or with similar products, can induce some ideas about the sequence of events.

For further investigations, an event tree for the considered damage or for a given phenomenon can be established.

Two examples are given thereafter (figures 1 and 2) in which damages from pressure effects were obtained.

In such event trees, comparison with facts and damages, operation conditions, products involved can focus the attention on the most logical and plausible scenarios.

Plausibility of a scenario

In the two previous examples of explosion, the characteristics of products involved, the modelling of the phenomenon for defining the pressure levels are to be considered. In other cases, the thermal effects for fires, the gas or liquid releases flow calculations, and the dispersion effects can explain the extent of damages.

When results of tests or modelling are obtained, they shall be compared with data collected. Such analysis is examplified in the summary reports of two recent accidents (see annexes 1 and 2).

## LESSONS LEARNT FROM ACCIDENTS

INERIS experts were directly involved in the following field investigations :

- an unconfined vapour cloud explosion (UVCE) in a fuel depot at St Herblain, October 7, 1991 (J.F. Lechaudel et al., 1995) with one fatality and extensive damages outside the depot premises
- another major UVCE in the TOTAL refinery's fluid catalytic cracking unit at La Mède (November 9, 1992) (P. Michaelis et al., 1995) with 6 fatalities and 2 billion francs damage
- confined explosion in a grain silo, Blaye in 1997, 11 fatalities, 1 injured and extensive damages (F. Masson, 1998)
- confined gas explosion in a plant connected to a flare stack (J.F. Lechaudel et al., 1998)
- a fire in a fuel depot at St Ouen, June 1991, with 15 fire fighters injured and the evacuation of 1.000 persons
- ammoniac accident release (30 tons) in a chemical plant at Mazingarbe when unloading a railtank (December 16, 1994) (J.F. Lechaudel et al., 1998)
- fire and explosion following derailment of unleaded fuel railtanks on August 13, 1993 in La Voulte. 1.000 persons evacuated
- fire in a NPK ternary fertilizer storage, Nantes, in 1987. 30.000 persons evacuated.

Most of these investigations were carried out at the request of French competent authorities, the rest directly for industrial firms.

Further details on other accidents investigated, either in chemical industries or in other industries are given elsewhere (J.P. Pineau et al., 1993).

From these accidents, many lessons can be drawn, either for the general design or the operation of the system, or on the efficacy of existing safety measures.

These field investigations allowed to draw some general assumptions.

The accidents at St Herblain (fuel depot) and La Mède (refinery) pointed out the influence of the location of ignition sources when flammable gases can be released and the absolute requisite of the definition of dangerous areas for choosing the adapted equipment.

The fire in the St Ouen fuel depot emphasized the role of repair and maintenance works and some difficulties for closing valves during fire fighting, mainly in relationship with the design.

A grain dust explosion as in Blaye, a rare occurrence with so extended damages and fatalities is dealing with dust, a by-product in grain elevators. The extension of fatalities is related to the location of offices and to the design of confined premises in which the explosion can propagate.

The case of Nantes accident (fertilizers) is an illustration of a dangerous release of toxic fumes from a fire and the necessary emphasis to be paid to proper distribution of goods in storages and use of adapted fire fighting methods.

The railtank accident in La Voulte is dealing with a transportation accident for which the geographical location of the occurrence can play a major role : explosion in a sewage system and pollution of the drinking water system.

The emission of toxic gases as in Mazingarbe and the explosion in a plant connected to a flare stack could be considered as an illustration of accidents in which the use of safety measures was not analyzed regarding their functionality and dependability : safety systems for avoiding releases in the first case and the running of utilities in the second case had poor reliability.

Within the cases of these accidents, only technical aspects were dealt with either for the design stage or for the operation stages in which safety measures are to be used. An improvement of the situation can only be obtained if the same level of experience is shared between manufacturers and designers of equipment and the users. This could be based on a risk analysis in which the intended use of the equipment (generally included in a process or a plant) is adequately defined, as well as the potential accidental scenarios with the hazardous zones concerned and the use of safety measures (including their reliability).

But more emphasis should be paid on organisational measures (safety management) and human behaviour.

All these aspects being dealt with, they could be introduced in a database in which a summary report can be the basis for further use.

## CONCLUSION

The analysis of accidents needs an understanding of intended use and operation procedures of a system or equipment or plants. The identification of possible accidental scenarios is a prerequisite. Existing databases are helpful for risk analysis when such analysed data are collected. The structuration of data shall be the result of a process in which a plausible scenario is defined after due consideration of all facts reported during the investigation (operation conditions, witnesses reports, damages ...) to be faced to a sequence of events leading to the accident, the various sequences of phenomena being modelised and/or tested.

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Figure 1 :
Explosion in a boiler

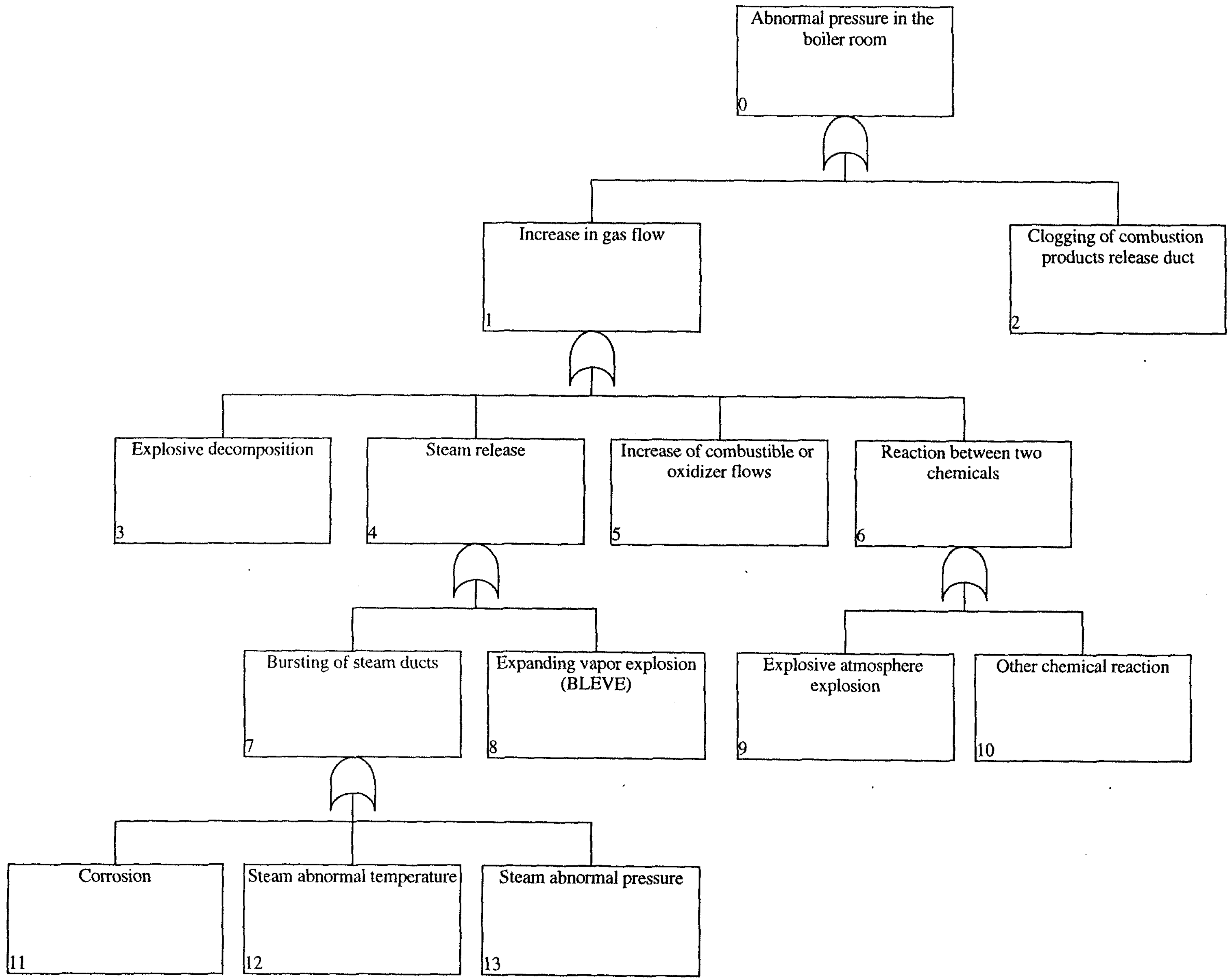
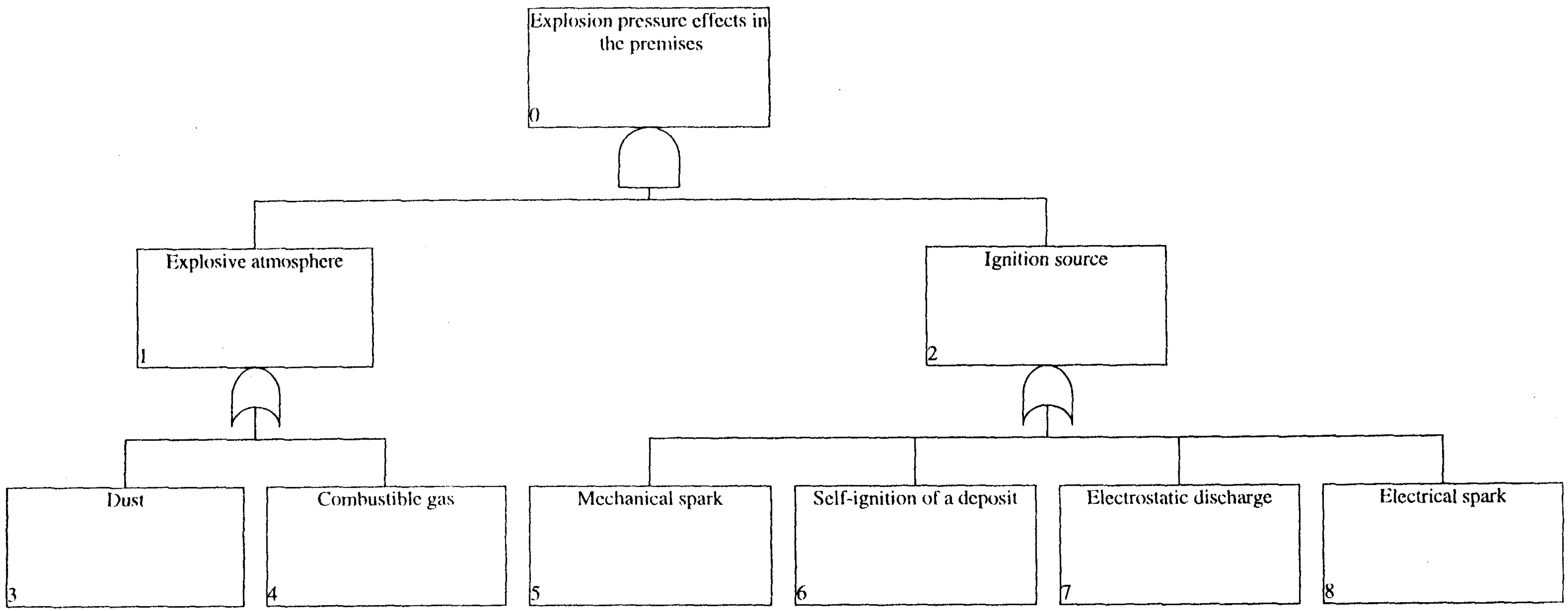


Figure 2 :
Explosion in a silo



Annex

**Channel Tunnel fire**
**November 1996**

The system

This tunnel consists in two running tunnels, 50 kms long. The ventilation is obtained through air injection in various locations from the service gallery.

In all cases, this service gallery is a safe haven for the evacuation of passengers and crew members. An overpressure of fresh air is always in existence in this gallery.

Facts on accident

Fire occurred in a heavy goods vehicles shuttle (HGV), induced a stop in a running tunnel and caused major damage to a section of the running tunnel and its equipment.

About 700 m long, concrete structure of the tunnel was to be rebuilt in the zone where the maximum heat flux was 350 MW ; 27 people were evacuated in the service gallery from the amenity coach where HGV drivers were locaded and from the locomotive without suffering too much influence from the fire fumes.

Immediate cause

Fire in the HGV shuttle was detected and reported by people located in the open-air premises of the tunnel, before the shuttle enters the tunnel.

Underlying causes

Underlying causes for aggravating the consequences of this fire were numerous. Among them, the following should be pointed out :

- the logics used to trigger an alarm and actions from the railway centre needed to be reconsidered
- the use of a supplementary ventilation system for the avoidance of fire fumes around the amenity coach where lorry drivers were located was rather late
- the complexity of emergency procedures.

Annex 2

**Grain dust explosion in a silo**
**August 20 th, 1997**

## Type of plant

In a grain elevator (port silo along the Gironde river), under operation (unloading grain from lorries and moving grain from a cell to another storage area through a conveyor belt), an explosion occurred.

## Facts on accident

The explosion induced the collapse of more than half the 44 silos cells (30 m high and 6 m in diameter, storing wheat, barley and maize), and of the working tower, with blow out of debris 100 m around ; 11 people were killed and 1 injured. Minor damages to neighbouring houses occurred : glass breakages.

## Immediate cause

The immediate cause of this explosion is still unknown, but reports from witnesses proved that the explosion initiated at the top of the working tower. Due to possible accidental release of dust from centralised dust collection system, it is supposed that the explosion initiated there and propagated to some cells, the working tower and other parts of the silo

The investigation proved no evidence of self heating of stored grain, excluding the formation of an explosive atmosphere of pyrolysed gas from grain stored in cells.

Extended damage does not allow to define the nature and location of the ignition source of grain dust air mixture. Friction through mechanical shocks in the ventilator upstream of the bag filters, or self ignition in the dust collection chamber are suspected. The equipment was located in the upper storeys of the working tower.

## Underlying causes

The propagation of the explosion in concrete confined structures was at the origin of their collapse of concrete structures. Location of offices in these concrete premises, too close to silo cells, was an aggravating factor and the cause of fatalities of people not directly related to the operation of the silo.

Dust was collected through bag filters collected to a dust chamber. The non enclosed bags were located at the top of the working tower. Such a device should be avoided.

Recommendation

Revision of the French legislation on grain storage (dated 1983) which will imply a risk assessment.