Untimely injection of foam into a warehouse containing phytosanitary products

30 April 2012

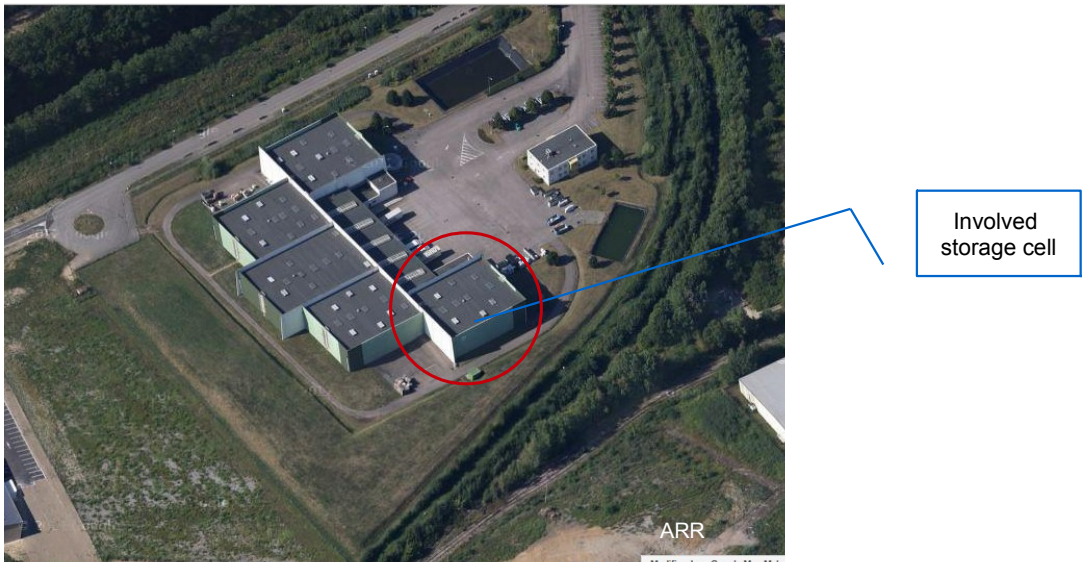
Ludres (Meurthe-et-Moselle)

France

Communication
Warehousing
Automatic extinction
Internal Emergency Plan
Emergency response

THE FACILITIES INVOLVED

The site:



This subsidiary of a major farm cooperative group is specialised in the provision of agricultural services, primarily in the areas of plant health and hybrid seeds (R&D, logistics, technical and administrative support services).

The Ludres site is a logistics platform for phytosanitary products and seeds with a "Seveso upper tier" rating. Its authorised storage capacities consist of:

- 3000 tonnes of environmentally hazardous products, known to be toxic or highly toxic for aquatic organisms;
- 200 tonnes of products known to be toxic for humans;
- 14 tonnes of products known to be highly toxic for humans;
- 4000 m^3 of flammable liquids divided into various categories, for an equivalent of 2000 m^3.

The site only stores products that fit into small containers, to be directly used by the end consumer; it handles the operations (like picking) involved in palletising the various products ordered by clients. The containers are not opened on-site, except in the event of an accidental burst.

The warehouse is composed of 7 storage cells ranging from 60 to 1250 m² with a 10 m height (3 m for the 60 sq. m² cells), each one of which is assigned to specific hazardous substances (see Fig. 1). The cell walls have a fire resistance rating of 120 minutes. Cell doors have been fitted with automatic closing devices, while the cells themselves are protected against fire by means of an automatic extinction system that relies on foam flooding.

The automatic foam extinction system features a 5000 litre emulsifier reserve plus a 120 m^3 autonomous reserve of anti-freeze fluid. The system was designed to fill a cell in less than 5 minutes and flood 2 cells simultaneously. The warehouse was also equipped with ancillary facilities: boiler room, shipping dock, workshop for charging vehicle accumulators, shipping administration offices, and a few refrigerators for storing refrigerated products.

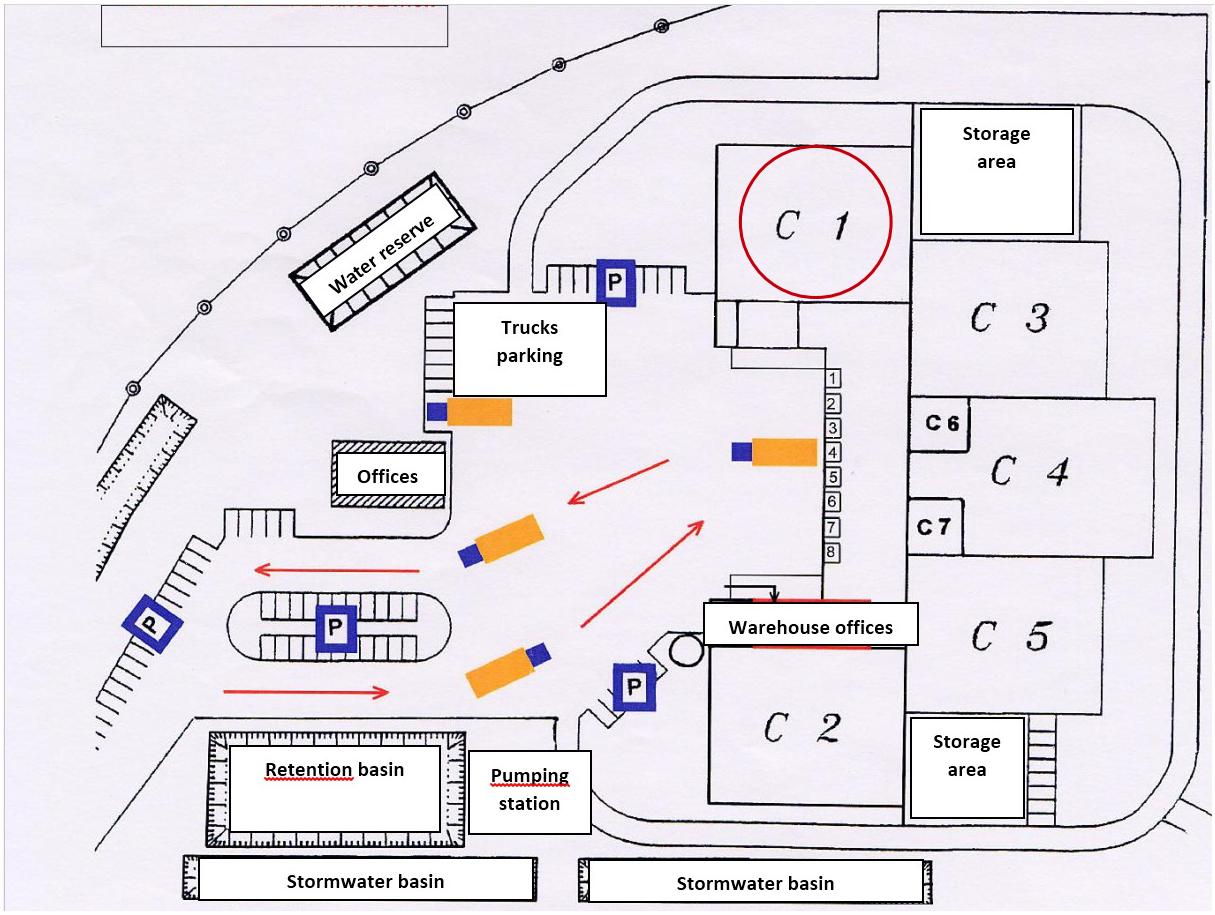


Figure 1 : Layout of the logistics platform (ARR)

The involved unit:

Cell 1, laid out over a 1000 sq. m² floor area and 10 m high, stored flammable and/or toxic or highly toxic substances for humans (Fig. 2). Like the other cells, it had been fitted with metal storage racks.

Figure 2 : Interior of Cell 1 (Source Operator - ARR)

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

The chronology of events during this accident was as follows:

Monday 30 April 2012:

- 6:56 pm: Fire alarm triggering foam injection relayed to the offsite surveillance firm.
- 6:57 pm: The surveillance firm called the warehouse manager, who did not answer: the firm left a voice message.
- 6:58 pm: The surveillance firm called the head of the "warehouse unloading" crew, who did not answer either, and left a voice message as well.
- 7:00 pm: The surveillance firm then called the head of the "warehouse loading" crew, who answered the phone: this employee was duly informed of the situation.
- 7:02 pm: Next, the surveillance firm called the Sales Manager, who also answered and was provided the same update of the situation.
- The internal emergency plan response sheet stipulated that the surveillance firm, after having phoned these 4 managers, was to alert fire-fighters by dialling "18" (the French national fire emergency number). On its log entry however, the firm indicated at 7:06 pm: "Contact number for fire-fighters unknown".
- Around 7:15 pm: Arrival on-site of the loading crew manager, who observed that Cell 1 was filled with foam; he closed the gas intake at the shutoff valve, located outside the boiler room and designed for this purpose.
- 7:22 pm: The warehouse manager called the surveillance firm back to request confirmation of the situation.
- 7:27 pm: The loading crew manager called both the fire department and emergency services, though he dialled the local fire station number directly instead of the "18" national fire emergency number.
- 7:31 pm: The site's "diesel fire pump fault" alarm was tripped, with relay to the surveillance firm, which immediately called the warehouse manager to inform him that the diesel pump unit was no longer available.
- Around 7:35 pm: Arrival of the warehouse manager, who turned off the site's general electricity supply.
- 7:36 pm: On its log entry, the surveillance firm indicated having received instructions from the warehouse manager to notify the fire services switchboard. Unaware of this phone number, the firm contacted the police station closest to the site, who connected them to this switchboard. The local fire department operator informed the firm that a response team was already on its way to the site.
- Around 7:40 pm: Arrival of the local fire-fighting team at the scene, followed shortly thereafter by the "unloading" crew manager, who provided fire-fighters with a current inventory status of the various storage cells from the dedicated storage pocket found in the fire protection room.
- Around 8:00 pm: Despite the absence of any visible signs of fire, fire-fighters decided to inspect Cell 1: three fire-fighters roped together wearing insulated self-breathing apparatuses penetrated into the foam that covered the adjacent premises in order to access the door to Cell 1 (Fig. 5). A few minutes later, two of them exited the cell in a state of physical exhaustion while the 3rd member was reported missing. Another reconnaissance effort found him unconscious lying on the floor in a state of cardiorespiratory arrest. He was quickly resuscitated and then transported to hospital in a critical condition.
- Around 8:20 pm: Arrival of the Sales Manager at the facility.
- Around 8:45 pm: Fire-fighters decided to open the loading dock doors, under the supervision of the "unloading" crew manager.
- Around 9:30 pm: The warehouse manager completed a round to ensure none of the surface water had been polluted (retention basin, channel).

Thursday 3 May 2012: The fire-fighter found unconscious died in hospital. The autopsy did not state the cause of death, even though the hypothesis of asphyxiation from the foam was the only plausible explanation.

The consequences of this accident:

No fire had occurred, hence no toxic fumes were released and the emergency services did not deploy any specific means of extinction. The foam was confined to the site, outside of a few packets carried by the wind.

In terms of human consequences, one fire-fighter died. No other human consequences were reported; moreover, no neighbours had to be evacuated and no water, electricity or phone services had to be cut.

The wild flora and fauna were not affected by this accident. Neither groundwater nor surface water nor any soils were polluted.

The economic consequences for the farm cooperative warehouse were significant (i.e. €750,000), as a result of:

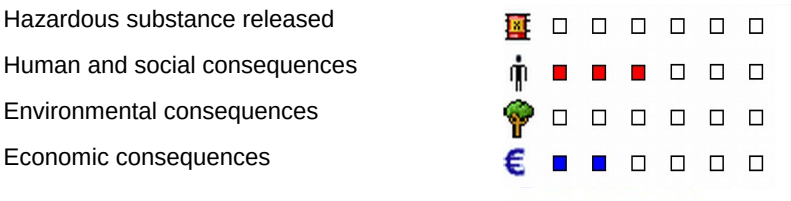
- round-the-clock (24/7) site monitoring (excluding warehouse opening hours) due to the lack of an operational automatic fire detection system for over a year;
- damage sustained by the fire extinction system (pump destroyed, emulsifier stock depleted, etc.);
- operating losses tied to reduced activity schedules imposed by administrative and judicial authorities for 6 weeks;
- the requirement to repackage a number of bottles, including the destruction of some that had become unsellable (Fig. 3).

According to the site operator, these economic losses were compensated in full by the insurance policies.

Figure 3 : Cell 1 after activating the foam extinction
(Source Operator - ARR)

European scale of industrial accidents:

By applying the rating rules applicable to the 18 parameters of the scale officially adopted in February 1994 by the Member States' Competent Authority Committee for implementing the 'SEVESO' Directive on handling hazardous substances and in light of available information, this accident can be characterised by the four following indices:



The parameters composing these indices and their rating methodology are available on the Web page: http://www.aria.developpement-durable.gouv.fr.

The "hazardous substances released" index was scored a "0" since no substance on the list referenced in Appendix I of the Seveso Directive was actually released.

The "human and social consequences" index was assigned a "3" rating due to the death of a fire-fighter directly related to his entry into the storage cell implicated in this accident.

The "environmental consequences" index could not be evaluated since no environmental impacts were recorded.

The "economic consequences" index received a "2" rating due to the cost of monitoring operations and the extent of operating losses stemming from both a decline in business activity and stock damaged by the foam.

THE ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

This accident was caused by a technical malfunction of the automatic extinction system, which under normal conditions should not have resulted in human consequences. The incident however was exacerbated by circumstances surrounding the emergency response, as well as by the type of extinction foam.

Key event: The accidental injection of foam into Cell 1

The untimely signal that had caused an automatic foam injection in the cell was due to wear on the cable connecting a manual trigger with the site's programmable safety controller. During the month following the accident, several fire detection incidents were recorded by the fire station, all of which were aberrant and stemmed from one of the two Cell 1 manual triggers, while not being able to identify precisely which one. A detailed inspection of the cables revealed wear and tear marks and on one of them, which generate a recurrent fault.

The fire safety system had been designed to limit these unscheduled injections by servo-controlling the motorised pump start-up to fire detection by means of two different detectors. In the case of the manual triggers however, just a single signal was necessary: no redundancy had been built in.

Exacerbating event: Confusion between an ICPE category number and the UN number used when transporting hazardous substances

Fire-fighters with the first response team arriving on-site asked the operator to provide them with the latest inventory status report. The operator obliged by producing a printed document, generated upon completion of the most recent work day and easily accessed from the room containing fire protection equipment. This step had been regularly performed during annual meetings held on-site between warehouse management and local emergency services. The last such meeting had actually taken place just 3 days prior to the accident. The deceased fire-fighter had been present at that meeting and, given his knowledge of the premises, volunteered to be part of the group entering the warehouse.

When fire-fighters became aware of this "printout" version of the cell's inventory, they assumed that the numbers used by the warehouse operator to classify the various stored products and their weights corresponded to the current UN numbering system for transporting hazardous substances, whereas in reality they corresponded to the French ICPE (designation for environmentally sensitive installations) category numbers associated with these products.

Among the numbers listed in the report, i.e. category no. 1510, the storage of combustible materials under the ICPE regulations was mistaken for the same UN number, which corresponded to Tetranitromethane, a toxic combustive product (see Fig. 4). Responders thus considered that, despite the absence of visible signs of ignition from the outside, a fire might have been smouldering within the foam and moreover fed by this combustive product. Accordingly, a physical investigation by a three-member team wearing self-breathing type masks was decided so as to remove this doubt.

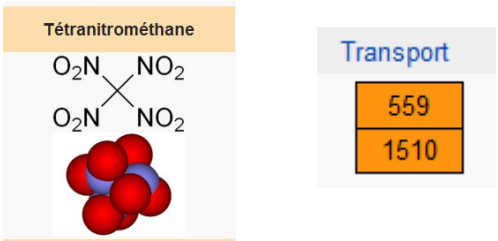


Figure 4 : Tetranitromethane and its 4-digit UN code, identical to that under the heading entitled "*Storage of combustible materials, products or substances in enclosed warehouses*" listed in the French ICPE installation nomenclature

Exacerbating event: The danger from foam being injected into the building

The two surviving fire-fighters of the three-man reconnaissance team, as well as the members of subsequent investigation parties, reported that the foam inside the buildings did not display the same consistency as that observed outside. They all complained of real difficulty in advancing into the foam, which entailed coping with a highly viscous substance that constrained any kind of movement. They also expressed that the foam had been an obstacle to vision, to such an extent that a hand placed in front of the eyes remained invisible. Similarly, the foam acted as sound insulation, thus preventing verbal exchanges (besides radio) with the other two fire-fighters in the trio. In addition, they mentioned that shortly before exiting the premises, the foam wound up penetrating inside their breathing masks. The team's progress had been slowed to a point that they were not even able to enter Cell 1 and had to turn around barely after reaching the door (red dot in Fig. 5).

The foam that had reached the building exterior, either after opening some doors or via seams in the walls, did however immediately exhibit a consistency similar to that initially applied outside.

Fire-fighters were trained in the use of insulated breathing apparatuses, including under stressful situations, and were very familiar with the time needed to empty

the bottles. Nonetheless, on the day of the accident, the assigned responders consumed air roughly twice as fast as normal and experienced an abnormal level of fatigue, nearing exhaustion.

Following the enquiry, emergency services concluded that the foam viscosity had caused both excess oxygen consumption and the formation of a film on the relief valve appended to the mask. This film in turn raised the valve's opening pressure, thus building up pressure inside the breathing mask and causing the appearance of empty spaces between the responders' faces and masks.

The hypothesis forwarded to explain these observations was that the foam, theoretically of high bulk (i.e. a foam of limited density), had transformed into a low bulk foam as a result of confinement created by the premises and pressure generated by the height of stacked foam. A rough calculation shows that 120 m^3 of water and 5 m^3 of emulsifier injected into a 10,000-m^3 cell yields an average bulk of 80 (in comparison, a bulk above 200 is considered "high" and one below 20 "low").

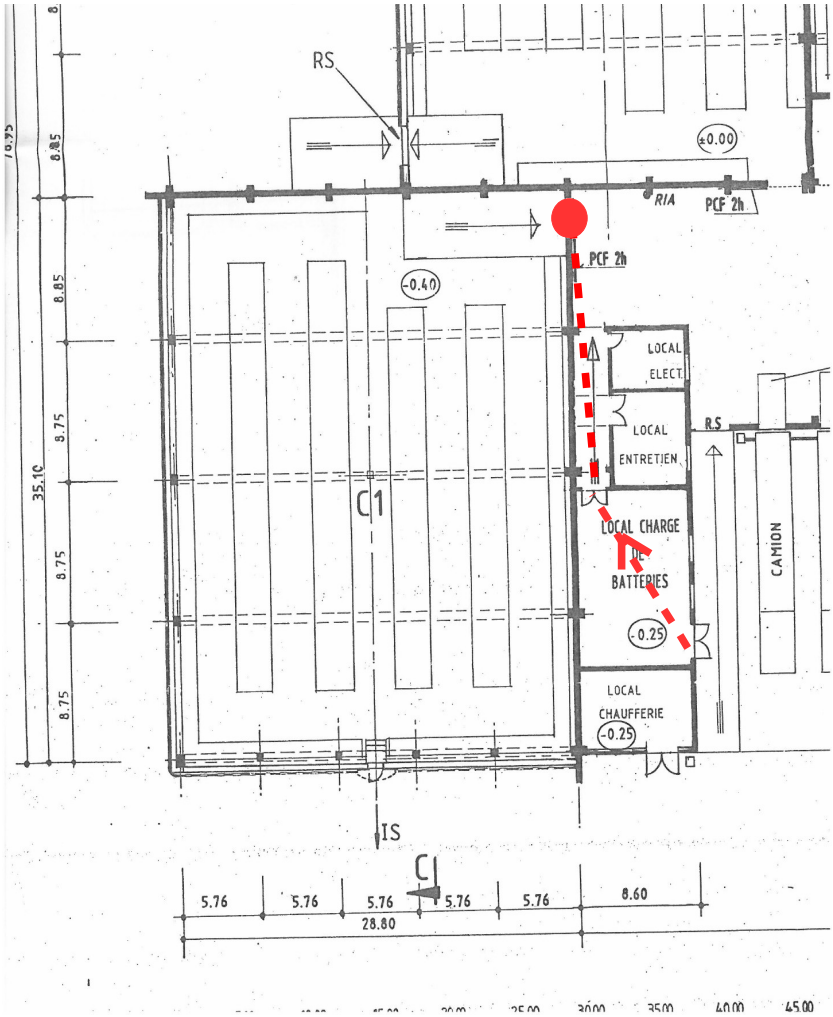
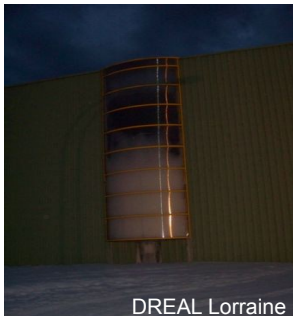


Figure 5 : Path followed by the three fire-fighter investigation team (ARR)



This hypothesis was confirmed by the fact that a glass column on the side of the cell made it possible to observe that at the time the emergency crew arrived, Cell 1 was entirely filled. An hour later however, the same glass enclosure revealed a foam height reaching about 60%: due to pressure generated by this volume of foam, the foam itself had settled, especially closer to the floor and its bulk had decreased. Moreover, the foam that filled the access corridor must have escaped from the cell through wall seams since the cell door had remained properly closed. The foam therefore had to contain the smallest bubbles, hence the lowest bulk. Even though no sampling conducted at the time could prove it, experts considered that the trio of fire-fighters on reconnaissance were indeed facing a foam displaying a bulk significantly less than 80, making it a low bulk foam.

ACTIONS TAKEN

Administrative actions

Within 72 hours, the Inspection Authorities for Classified Facilities ordered the site operator to halt all incoming deliveries of hazardous substances, given the degraded safety conditions at the warehouse. Incoming non-hazardous substances were still accepted, as were outgoing shipments of both hazardous and non-hazardous materials. The local governement issued an emergency measure requiring the operator to install a round-the-clock foam injection system in order to compensate the loss of a stationary pump. The authorisation to resume all site operations was granted to the operator 40 days later, under his full responsibility and subject to strict compliance with the following provisions:

- replenishment of the emulsifier stock;
- installation of a mobile motorised pump offering characteristics similar to the previous pump;
- ban on activating automatic injection as long as the origin of these aberrant detections remained undetermined;
- site surveillance outside of working hours to immediately initiate manual foam injection, if needed;
- special training sessions organised for both the warehouse company and surveillance firm on how to proceed with a manual foam injection response.

Authorities also sent a correspondence to all operators of "upper tier Seveso" rated facilities within the administrative area requesting them to ensure that, in the case of offsite video surveillance, the instructions furnished actually listed the local fire station emergency phone number and not only the national fire emergency number ("18").

Technical actions

Warehouse management restored the facility's safety equipment (pump replacement, replenishment of emulsifier stock, repairs to the fire detection system) and modified the set of instructions provided to the surveillance firm in specifying the local emergency fire services number (a 10-digit number and not the national fire emergency number "18"). The step was also taken to clearly note on the stock status tracking document dedicated to storage cells that the number appearing on the cover of each product family in storage was indeed the corresponding ICPE category number.

LESSONS LEARNT

This accident served to draw the following lessons:

The importance of acknowledging hazards to first responders (internal or external) by using foam

High bulk foam may create certain hazards depending on its application conditions. In a closed building with high ceilings, the foam formed by the extinction system might display significantly less bulk than expected. In turn, this low bulk can cause the following hazards for individuals present inside:

- decrease of some senses needed to carry out their action or survive in this environment (sight, hearing);
- substantial viscosity impeding all types of movement;
- excess consumption of air and penetration of foam inside the mask for those wearing insulated self-breathing apparatuses;
- formation of a film capable of asphyxiation when inhaling this foam.

The design of manual triggers for automatic extinction may prove to be vulnerable (due to a lack of redundancies)

Placing the warehouse in safe operations mode was contingent upon a simultaneous fire detection by two distinct detectors, which protects against unwanted foam injection resulting in operating losses for the warehouse. Yet this principle of detection redundancy had not been in effect for manual triggers since just a single detection with this type of trigger, even when activated by an electrical fault and not a deliberate employee manoeuvre, was sufficient to initiate the safety action sequence, including automatic foam extinction. For this type of design therefore, each manual trigger constituted a potential source of malfunction within the automatic extinction chain.

The potential risk of mistaking ICPE category numbers used by the operator with the hazardous substance transport numbers more familiar to emergency services personnel

Knowledge of ICPE regulations is a critical part of the curriculum of most local fire-fighting officers in France. Yet this content is not taught during the training program for other categories of fire-fighters, including those making up the majority of response teams, even though their education calls for an extensive coverage of regulations on transporting hazardous substances, with special emphasis on the meaning of safety plates affixed to vehicles ("RTN" module:

Technological and Natural Risks). In both of these regulations, 4-digit numbers were primarily used, often without specifying the substance name or corresponding ICPE activity (see Fig. 4, right).

As such, the ICPE category number used by an industrial operator may be interpreted by emergency services as a UN number assigned to the transport of hazardous substances. The issue here however is that the hazards associated with substances identified by the UN code and those referenced in the French ICPE activity of the same number are, most of the time, very different. In an emergency situation, this source of confusion may lead to misunderstanding, in turn prompting inappropriate actions on the part of first responders, as aptly illustrated by the accident presented herein.

The importance of providing precise instructions to offsite surveillance firms

The warehouse operator had requested his video surveillance firm, located in a different area, to notify emergency services on their own in the event of fire outbreak, by dialling the number "18", which simply relays to the call desk of the caller's local fire services.

If the surveillance firm is not based in the same area as the facility operator, which was the case here, it is not connected with the appropriate local fire service, which delays an effective response. When drafting the instructions and response sheets for emergency situations, the operator must provide the subcontractor with the actual (10-digit for France) phone number of local fire services for the site location.

In conclusion, it was recommended to:

- determine whether, in light of the safety report, it was acceptable for manual triggers to be able, in the event of simple malfunction, to activate automatic safety devices; should the answer be no, and especially if the safety of employees or first responders was at risk or economic losses deemed too extensive, then it would be necessary to back up both the manual triggers and the cables transmitting signals to the programmable safety controller;
- ban access to cells filled with foam; nonetheless, employees required to violate the ban in order to gain entry, in particular to implement measures necessary to destroy the foam, must imperatively be attached to a life line;
- ensure that inventory report documents made available to emergency services clearly underscore the fact that the numbers used are those of the environmental authority headings (if any, e.g. coloured insert on the front or upper part of the document, addition of the mention "ICPE No." in the number column). This consideration must also be regularly pointed out by the operator during interactions with local fire service representatives, e.g. when conducting joint drills or preparing / updating the external emergency plan for Seveso-rated facilities;
- verify that the instructions and emergency response sheets provided to personnel assigned to monitor the site and sound the alarm (watchman's quarters, surveillance firm and/or video monitoring unit) show the local phone number of the main fire station corresponding to the site location, Moreover, it is essential that these individuals realise the need to call this number in case of emergency and not the national (18) or European emergency number (112).