ATEX directives : practical concerns

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ATEX DIRECTIVES : PRACTICAL CONCERNS

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1. ABSTRACT

The ATEX directives 94/9/CE & 99/92/CE require the industry sector to identify and evaluate hazards and risks associated with combustion explosions of dusts, gas and mists. They require employers to assess the risks of explosions and to provide appropriate worker protection against explosions. Explosions involved in runaway reactions or solvent expansions (ex steam explosions) are not strictly speaking covered by these pieces of regulation but depend on general health & safety at work, chemical substances, or major hazard control (i.e. Seveso) regulations. As a result, workers exposure to explosions and their protection are only partially dealt within the "Explosion protection document" (99/92/CE, art 8).
Practical harmonization of regulation and associated governance aspects should involve several national bodies of competent authorities with respective fields of applications. Borderlines between these fields remains somewhat fuzzy making it prone to loopholes that can have serious impacts on workers. New mitigating action is being developed by some EC members. For example, the French silo legislation aiming at regrouping the SEVESO Directive and the Explosive Atmosphere directive (ATEX 137) is being revisited. Similarly, a new piece of legislation regrouping the Chemical Dangerous Agents Directive (CAD) and the ATEX 137 directive, coined as the DSEAR legislation, is being discussed in the UK.

2. INTRODUCTION

The ATEX directives 94/9/CE & 99/92/CE recently required the industry sector to identify and evaluate hazards associated with combustion explosions (dust, gas and vapor combustion). Explosion phenomena involved in runaway reactions or steam expansions are indeed not covered by this new piece of regulation but depend on general health & safety at work or major hazard control regulations. As such, workers exposure to explosions and their effects is only partially dealt within the "Explosion protection document" (99/92/CE, art 8). Further, statistics show that steam explosions account for more than 5% of accidental explosions that is to say as much as dust explosions. Steam expansion accounts for about 10%. In comparison, gas or vapor explosion accounts for about 60%.

Unfortunately, the use of water in the process industry is so common that we do not tend to consider it as a hazard. However, the effects of steam explosions also differ from those of chemical ones. Steam explosions are dependent on the confinement mode of water: explosions from enclosed pressurized water do not involve the same mechanisms as explosions caused by the pouring of a melt in cold water. Consequently the catastrophic sequences causing these events are different.

Few cases of explosion accidents are reviewed in this paper: In particular, the sudden vaporization of water during its contact with a high temperature reactional aqueous bath, the steam explosion from a smoke tube boiler, the steam explosion in an MMWW (Molten Material With Water), small BLEVES from metallic bottles treated in incinerators. These cases are not covered by the above directives. In this sense, it is important that workers and/or their company représentants be aware that such types of explosion are not systematically addressed by the required documents mandated by the regulations.
By the same token, this article is meant to warn workers/ engineers of the potential dangers they may be facing on work sites. More integrated and harmonized regulations are becoming necessary. In this perspective, new legislation development trends are illustrated in the example of the French revisited silo storage regulation.

3. EXPLOSIONS: BACKGROUND

Classical explosions are defined as rapid reactions where two compounds (the combustible and the comburant) mix and are subject to ignition sources. The type of ignition sources usually considered are either thermal or electrostatic sources. The most important explosion parameters are the expansion ratio and the overpressure. The commonly adopted values of the pressure, temperature or volume ratios vary between 5 and 8, while it can reach 1700 for steam explosion. Hence , the apparently innocuous use of water in a process may turn out to be very destructive in some cases, letting sometimes operators in a frantic mood when such accidents happen. An other misleading aspect of some these accidents (see below) is the time delay it can take between the contact of the water and the hot source and the pressure build-up and resulting outcome. The water needs to be first heated to produce enough vapor and pressure. The kinetics of this process is more insidious as it will not directly react to the initiating event as it is in the explosion of ATEX which take place within a few hundred milliseconds.

Similarly, we also note that rapid chemical runways with production of gases, leading to pressure build-ups are not expressly covered by the ATEX directives since they may not involve air as the comburant. They may nevertheless be the central initiating event that can trigger potential operator fatalities.

4 REVIEW OF SOME ACCIDENTS (BARPI)

4.1 Common domestic heater: Mooney reports a steam explosion of a 19 liters electrical hot water heater due to the conjunction of a defective pressure-temperature safety valve and a corroded drum. Fortunately there was no other damage than a blasted wall.

4.2 Industrial Boiler:

- In France (1984), the explosion of a water-tube boiler used to produce 100 t/h of steam at 82 bar and 475°C resulted from the rupture of its tubing. Postmortem analysis explained the incident as a "conjunction of generalized corrosion to many tubes in the same part, followed by erosion and intense mechanical solicitation applied to the whole weakened tubing as a chain reaction following the break-through or the rupture of a first tube". The boiler was severely damaged, pipes and refractories were projected around at 100 m. A worker resulted injured by one of these missiles.

- In France (1994), the explosion of a smoke-tube boiler killed three workers and injured two others: the body of the boiler engineer was blasted at 150 m away with debris and two other people working in a neighboring plant were buried away by its downfall. Firebox and burner were thrown at 165 m on one side, while the main part of the boiler was stopped by trees at 100 m on the opposite side. Many parts of the boiler, e.g. a 1500 L. hot water tank, were projected at some tens or even hundreds meters. No overpressure damage like glass or tile breakage was reported.

4.3 Maintenance default: reports the case of workers that added a spool in which a steam valve coming from a high pressure boiler began to leak. Since the crew left for the weekend, steam condensed inside what behaved like an enclosure. On Monday, the team began to weld without draining the spool. The welding arc heated the molten weld puddle up to 1540°C and, locally, the spool to the temperature of hot white steel. Weakened hot steel in conjunction with condensate flashed to steam drove a steam explosion that threw molten metal and steam, causing serious injuries to the welder and his helper.

5.INERIS RECENTLY TREATED ACCIDENTS:

5.1 First Example: Explosion in a metal etching tank

In this example, a rapid explosion occurred after having let the tank heated during the weekend. The bath contained an aqueous solution of salt loaded with metallic residues. After evaporation, the bath temperature reached a very high value. As the operator introduced the make-up water to compensate for the evaporated water, a strong explosion occurred three minutes after the introduction of the water. The explosion displaced the 3 ton tank, blasting away the 300 Kg cover latch and producing a 5 meter high column of hot liquid springing from the tank. . The operator was partially burnt and lost 30 % of his hearing due to the explosion pressure wave.

A schematic drawing explains what happened during this accident.

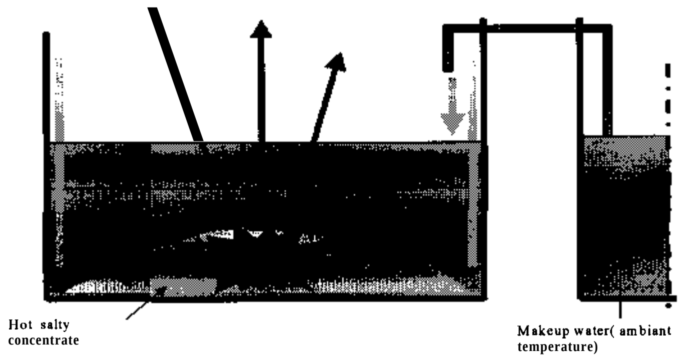


Figure 1 : Schematic illustrating the explosion in the etching tank

A simulated situation was made using the calorimeter C 80 which allows mixing a given quantity of water with the salty solution used in the process . In a typical run at room temperature, water is added after 6 hours of sample stabilization. The resulting thermogram is shown in Figure 2 . It shows that the mixing enthalpy is about 113 J/g . Such liberated energy could produce an equivalent pressure of 60 bar with the previously mentioned consequences.

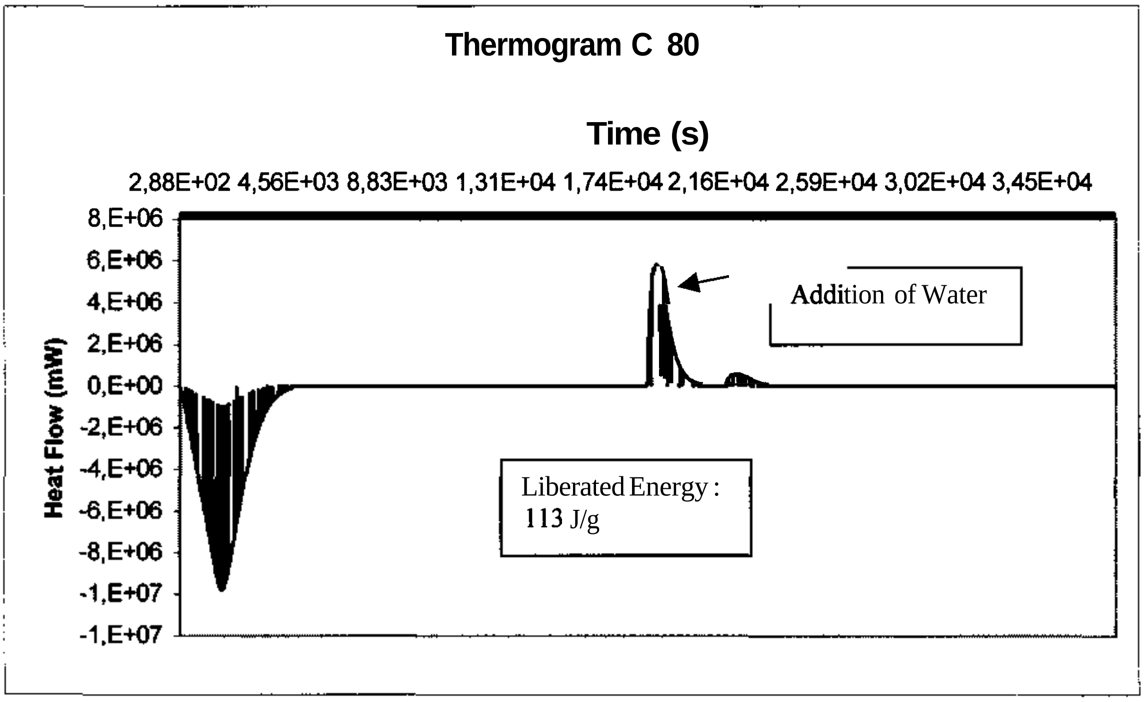


Figure 2: Typical Thermogram showing the exotherm when adding water

The analysis of this accident led to the recommendations which consisted in replacing the obsolete temperature control system of the etching tank and in providing physical barriers (equipment, glasses, gloves) to the operator.

5.2 **Second Example: Smoke Tube Boiler Explosion.**

Water circuit can be seen as one of the weakest element of the boiler. Erosion in this circuit can induce enough leakage to cause a steam explosion. Yet damages resulting from steam explosion in smoke-tube boilers are to be expected greater than those for water-tube boilers, since smoke-tube boilers parts like tanks, tubing and firebox work at high pressure.

Among external aggressions, fire is the most frequent hazard and the most dangerous in term of BLEVE : fire provides an additional source of energy that is susceptible to rise the thermodynamic state of the fluid. The energy brought by fire to the container is immediately used to evaporate more liquid, and so contributes to rise the pressure inside the vapor-space. Moreover the mechanical resistance of the vessel may drop considerably when exposed to fire. The vapor-space walls are more likely to fail since the part of the wall tank in contact with the vapor phase is more likely to suffer plasticity due to the fact that gas-solid heat transfer rates are significantly smaller than solid-liquid ones. Fire exposure also induces thermal stratification within the vessel due to buoyancy. This has been shown by Birk and Cunningham to be favorable for the resistance of vessels fitted with PRD. The upper water layer is the warmest. It controls the pressure in the vapor phase and therefore controls the PRD. Thus the PRD releases for an overpressure in the vapor that corresponds to a lower overall energy level compared with a situation where the tank has a uniform temperature. If an initial crack in the shell stops before the total collapse of the container, the liquid can play a role in the destruction of the vessel. In this case, when stratified, water will be less able to drive the tank to a BLEVE.

Figure 3. projected piece of a smoke tube boiler after a steam explosion

6 OTHER CASES

6.1 Third example: MMWW (Molten Material with Water): BLRB explosions

In the paper industry, black liquors containing spent pulping chemicals are burnt in a recovery boiler to capture the heating value to produce steam for the plant. A pool of molten smelt at a temperature of about 980 C is present in the bottom of the boiler. When water is introduced from external hoses or from leaking heat exchangers, violent explosions occur. A typical BLRB (Black Liquor Recovery Boiler) unit after explosion is shown in Figure 4

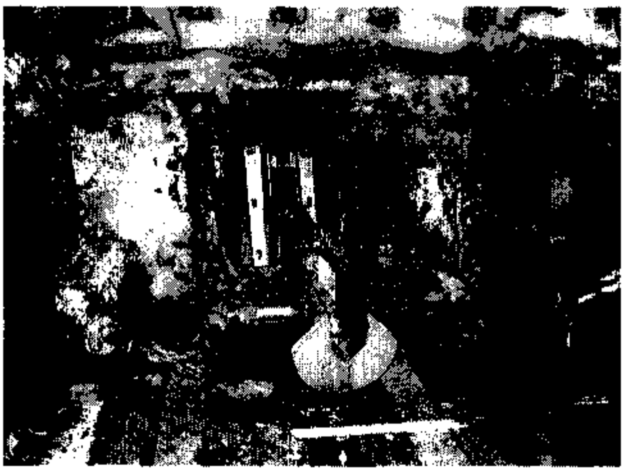


Figure 4. spout of a BLRB after explosion

In the UK, in the steel industry, 175 tons of molten from a furnace were run into a torpedo ladle. A substantial water leak was observed coming from the furnace. The water ran down the casthouse floor and entered the torpedo ladle. The explosion ejected 90 tons of metal. Eleven workers were killed and 8 injured. The water leak was probably due to heat exchanger tube bank failures.

6.2 Fourth Example: Explosions in Incinerators

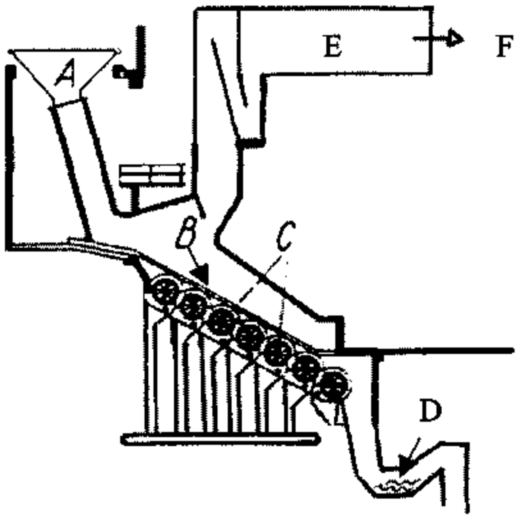


Figure 5. Side view of an incinerator

Wastes are pilled up and fed through a hopper (A). As they reach the furnace interior, they are mechanically pushed onto a mobile grid (B). This grid (sliding or rotary) conveys at slow speed the bulk of combusting waste (about 50 cm thick) from one side to the other of the furnace. Furnace temperature is about 1000°C. Hot primary fresh air (from 100 to 150°C) is fed underneath the grid and passes through the layer of combusting waste. Secondary fresh air is fed directly to the side of the furnace. This secondary air is dedicated to bum out any remaining combustible gases contained within fumes. The furnace chamber is constituted with heat resistant material. This material provides inertia to the furnace through heat retrocession. Most of the combustion takes place as wastes are travelling along the first half of the grid. Ashes fall down through the grid and are collected into a set of hoppers (C). Larger size non combustible materials (metals, clinker...) fall at the end of the grid into a water flooded conveyor (D) that cools down remaining materials.

Fumes are extracted through large heat exchanger chambers (E) which walls are made up with water filled pipes (boiler circuit). Heat is recovered as fumes are cooled down from about 1000 to 200°C. As a final stage (F) fumes are chemically and mechanically treated prior to be released to the air.

Common type of explosions in incinerators are due to the lack of quality control of wastes fed into the unit. For example the use of fertilisers fed into incinerators may produce explosive combustion leading to serious damage of the unit and injuries to the operating staff. Another type of explosion can be attributed to liquid/aerosol metallic bottles run through these units. Resulting missiles effects can promote erosion of the heat exchanger tubes located in the boiler section. The bursting of these pipes may lead to steam explosion of the boiler section where casing doors have been torn and flung away.

From the accidentology of these units, it appears that erosion/corrosion of heat exchanger tubes is a recurring event for such explosions. It is therefore important to understand particulate erosion for such processes. A great effort has been made by Bouillard and his co workers for the last 10 years to understand the under lying mechanistic phenomena of particulate erosion.

7. Legislation in Europe and in France

7.1 Transposed Legislation in France

The analysis of explosion accidents may fall under several legislations. A summary table of European and French Legislations is shown in Figures 8 and 9. These figures display the main European pieces of legislation for ATEX, pressure vessels, chemical agents, transport of dangerous goods and their correspondence with the transposed French texts.

From the inspection of these regulations, the reader can note that these texts do not cover directly the explosion scenarios discussed above, because these types of explosion are not depicted as the classical explosions defined in the ATEX Directives, nor are they specifically referred to by the chemical agents or the dangerous substances directives.

It is unfortunate that the required document (Directive ATEX 99) relative to the worker prevention and protection of explosions, written by the employer does not cover the early described types of explosion. It is one of the concerns of this piece of legislation. The ATEX 99 directive has been conceptually constructed and based on the premise that an explosion requires three simultaneous necessary phenomenological ingredients: 1) The presence of combustible, 2) The presence of comburant and 3) the presence of an ignition source. Unfortunately, these ingredients are not the prerequisites for the steam explosions as discussed above, and hence will not be described in the ATEX document; though such a document is meant to protect worker's lives. From the worker's point of view, it does not matter what mechanism govern the explosions, rather it is their effects on human lives that count. It is the reason why legislations should be combined or regrouped into new ones with adequate proper guidelines, so that all aspects of explosion are treated simultaneously so as to protect worker's health and safety and his environment.

Figure 8: Correspondence between European and the National French Legislation for Equipment Producers

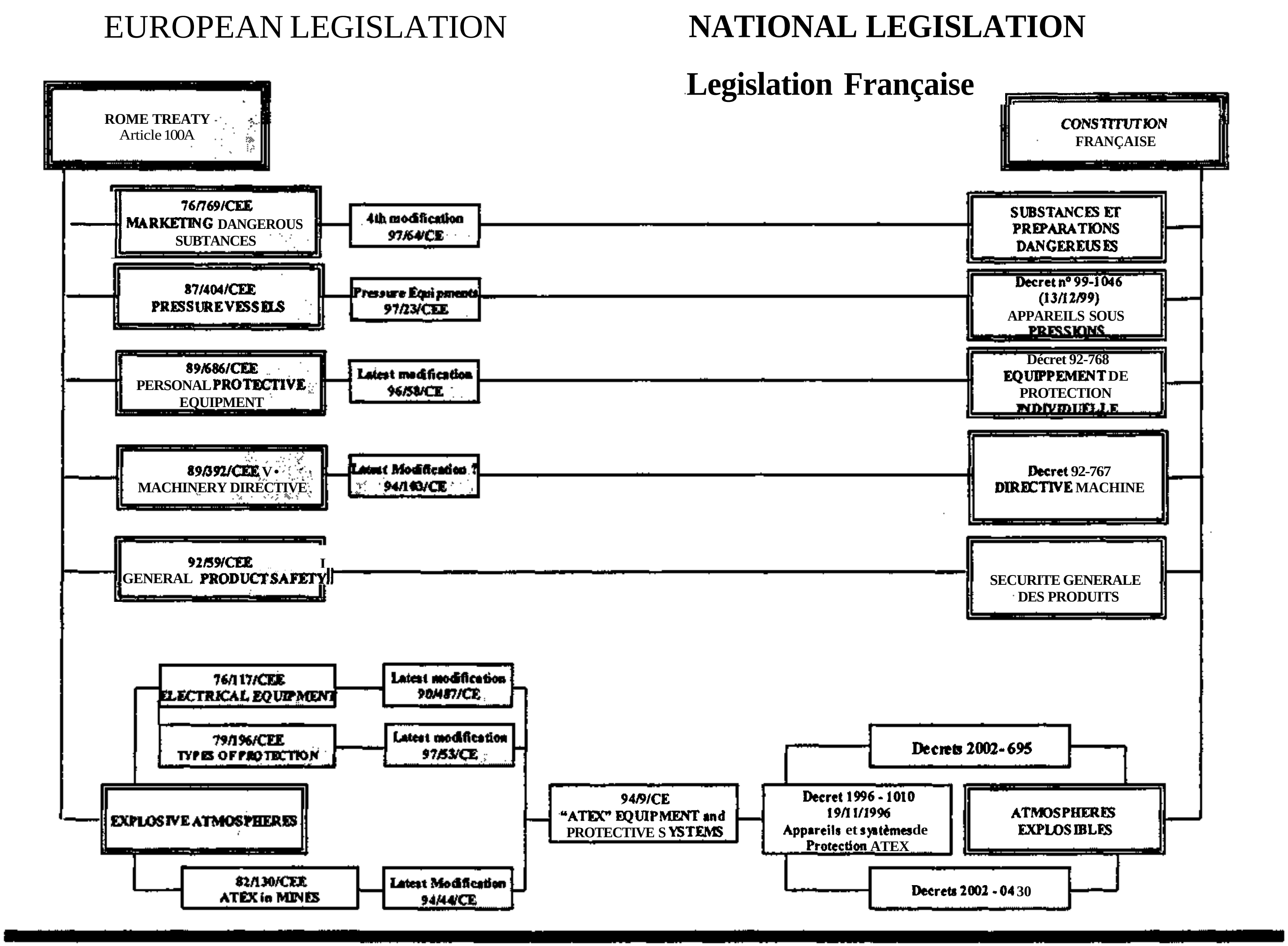
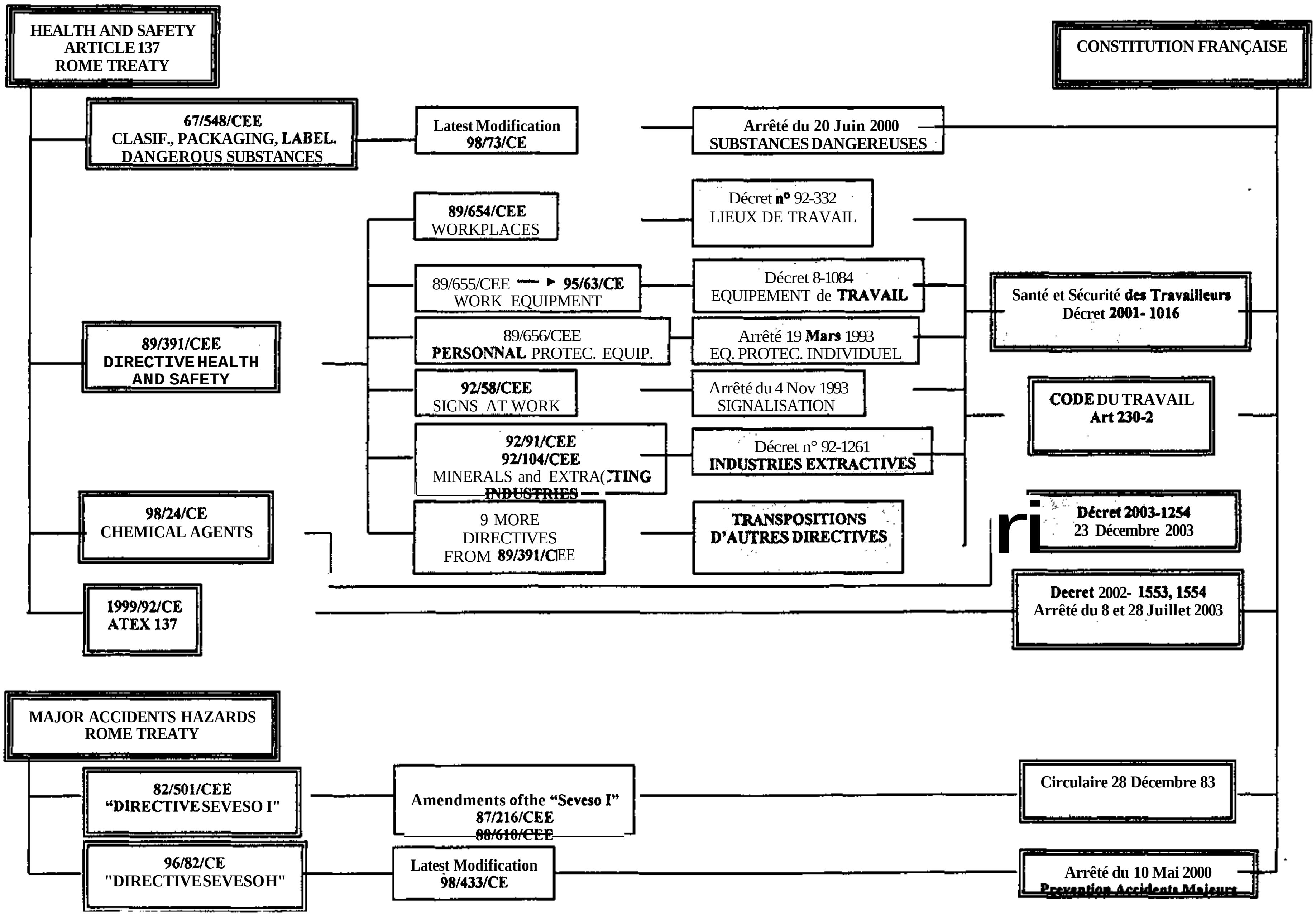


Figure 9. Correspondence between European and the French National Legislation for Workers Health and Safety



7.2 **Particular Case of the revised French ATEX Legislation Implementation: The New Silo Storage Legislation**

Following the BLAYE explosion in France on August 20, 1997, two French Silo regulations issued through the Décrets 1998 and 2000 are being applied to the classified SEVESO sites. A new national piece of legislation is being drafted that will be taking into account at least three basic regulations: the SEVESO directives (Décret n° 77-1133 du 21 Septembre, loi n° 76-663), the ATEX directives (Arrêté du 8 Juillet 2003) and the lightening French regulations (Arrête du 28 Janvier 1993).

Figure 10 View of the BLAYE site before the accident

Figure 11 View of the cereal storing site of Blaye after the accident

This new regulation aims at protecting the population (internal and external to the site) and the nearby environment from accidents stemming from large scale storage of grains, cereals, foodstuffs and all other products susceptible of yielding combustible dusts, classified under the item 2160 of the SEVESO Directive (French Nomenclature). The employer must file a safety report in which he must show that he has carried out a risk analysis that takes into account the probability of occurrence, the kinetics and gravity of potential accidents. Furthermore, he must show that he implements adequate prevention barriers in order to reduce the probability of these accidents. The employer must nominate a site silo and safety specialist who is in charge of the site safety and in particular the safety report. The site staff must be adequately trained with the use of safety training packages that have to be regularly adapted and validated by the employer.

In terms of technical means of prevention, the revised legislation demands the following requirements:

- Loading and unloading areas must be located outside the silo; These areas must be equipped with a dust extraction system.
- Self heating of organic materials should be properly controlled
- Regular installation cleaning should be performed in order to reduce the possibilities of dust cloud explosion. Permanent dust collection systems can be used to this effect.
- Proper land planning is required on site. Nearby construction of buildings, roads or rails should be made outside a given perimeter from the silo.
- Silo cells should allow inerting capabilities in case of the development of a fire.

In terms of protection, subunits should be decoupled, adequate venting and/or pressure relief systems should be implemented, operation buildings (i.e. control rooms) should be explosion resistant and proper fire detection and extinguishing capabilities should exist and be in working order.

As can be seen, we observe the development of a specific ATEX regulation applied to silo storage of potentially explosible materials. This regulation is a step forward, going beyond the ATEX directive in the sense that it applies to major accidents legislation (SEVESO Directives). It is one illustration where the ATEX and SEVESO Directives are combined into a new piece of legislation. This text will tend to fill in the commonly acknowledged loophole application of the ATEX directive: This directive being often thought as one mainly concerned by the day-to-day local explosion prevention and protection in the work place without direct implications on major accidents.
In this new French piece of legislation, ATEX directives are to be fully integrated to the SEVESO directives.

8. Conclusions

As new regulations develop, they are increasingly becoming more harmonised, designed to integrate all aspects of explosion regulations. At the present time, past accidents have shown that seemingly innocuous water based processes can have indeed severe explosion impacts on site workers, and should therefore not be ignored.

At an European level, ATEX 99 directive requirements are being incorporated in other regulations such as the occupational health and safety (Directive 89/391) for the elaboration of the unique document . At the national French level, the ATEX 99 requirements are slowly coming forward into new pieces of legislation such as the silo storage regulation. In the same vein, the British DSEAR regulation regrouping the

Chemical Dangerous Agents Directives (CAD) and the Explosive Atmosphère Directive (ATEX 99) has been designed to accomplish similar goals. We undoubtedly assist at new trends and a willingness to combine, integrate and harmonise regulations in order to simplify the legislation body so as to converge towards a same purpose.

9 References

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