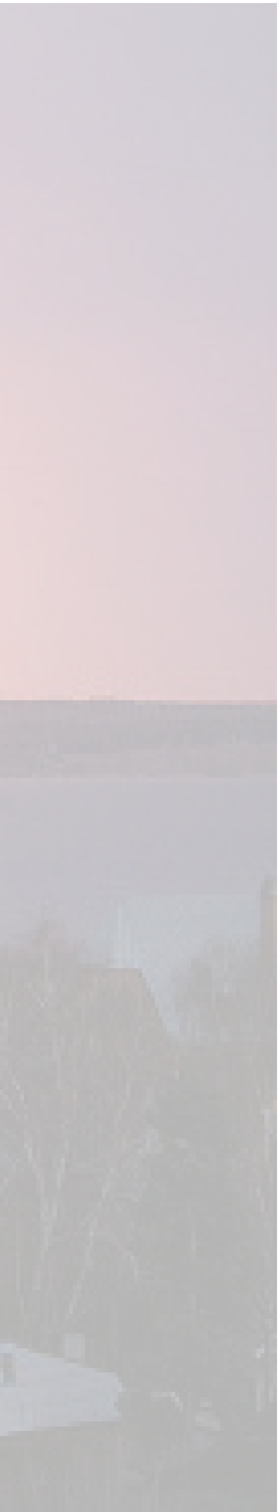
FRENCH MINISTRY FOR ECOLOGY, ENERGY, SUSTAINABLE DEVELOPMENT AND THE SEA

DESTRUCTION OF PYROTECHNIC WASTE ACCIDENT ANALYSIS



The destruction of pyrotechnic waste remains a hazardous activity; in France, this activity alone accounts for 15% of all accidents arising within the pyrotechnics industry, as catalogued in the ARIA database[1]. Waste treatment steps are carried out on materials that in many cases are more highly sensitive or whose hazards are more minimally characterised. This waste may stem from scrap, defective or expired products or «stimulated» materials capable of triggering sudden fires, deflagrations or detonations. Therefore, the steps focusing on such materials require extreme caution and attention.

The summary contained herein relies on an analysis of 150 accidents that occurred in France and elsewhere, as extracted from the ARIA base[2], that involve classified facilities. Given the data available, this synthesis is not intended to provide actual statistical findings, but should still allow for drawing lessons on the risks related to these destruction operations, presented via three major stages: pyrotechnic waste collection and transport (27 accidents), storage (19 accidents), and treatment (104 accidents).

Burning zone dedicated to a specific waste type
Source : Titanobel (D.R.)

* *« Stimulus: Any external stimulus of a thermal, mechanical, electrical, electromagnetic, chemical or combined nature, to which the product is exposed and which might or might not be considered part of normal and regulatory use conditions »* [3]

[1] Though data collection efforts began on January 1st, 1992 (launch date of the ARIA database), some 30 prior events could also be listed in the base thanks to information recorded over many years by France's Directorate of Ordnance for Powders and Explosives (IPE) [1]

[2] The ARIA reference numbers included in the body of this report correspond to a non-exhaustive selection of accidents used to illustrate the points made in this report. Summaries of accidents with an ARIA reference number underlined in the text have been included either at the end of the document or as an insert. The complete list of the summaries for the 150 events (including the 26 abroad) used in conducting this study can be found in French on the site www.aria.developpement-durable.gouv.fr, under the heading «Syntheses and lessons».

Accident analyses relative to the destruction of pyrotechnic waste have examined a total of 150 accidents (124 occurring in France and 26 elsewhere). Except when otherwise indicated, **all of the data presented herewith pertain exclusively to the French accidents.**

As opposed to other sectors of activity[1], a breakdown of events inventoried yields 64% in the explosions category for just 40% fires and 6% accidental discharges of hazardous or polluting substances, with several typologies possible for the same event. The high proportion of explosions is directly correlated with the type of materials under consideration, given their purpose as products ultimately designed to be explosive.

These destruction steps are seldom «automated». As is the case with many phases that require actual staff involvement, the organisational or human factor has been identified in this sector as a direct or indirect cause of 85% of all accidents catalogued, whether as a lone cause or in association with equipment malfunction (applicable in 27% of events). Personnel exposed to these hazards pay a heavy price at the time of a serious event; associated with the 124 French accidents on record are 15 deaths (from 8 accidents) and 68 injured, 24 of whom seriously. All victims of accidents recorded in the database were technicians.

The trend in the human consequences of accidents between the end of the 1980's and the beginning of the 21st century is indicated in the following table:

Period	No of accidents	No od death	Serious injuries	Slight injuries
Janv 1985 - dec 1992	37	6	7	3
Janv 1993 - dec 2002*	44	2*	10*	18*
Janv 2003 - dec 2009	45	3	3	5

** not including the «special» case of an explosion of ordnance scheduled for destruction aboard a ship, which caused the vessel to sink, accounting for 5 deaths and 17 injured (8 of which serious) (ARIA 23063).*

Destruction methods:

- **Burning** consists of incinerating the pyrotechnic waste at a designated destruction zone isolated from any areas with potentially serious impacts on neighbouring facilities. This incineration step can take place either in the open air or within an enclosure (i.e. incinerator).
- **Blasting or «bursting»** (through detonation) consists of destroying an explosive by means of a detonable charge placed in direct contact with the object.
- **Dissolution** consists of immersing compounds that contain water-soluble ingredients (e.g. nitrates, chlorates, perchlorates) for the purpose of destroying them. The dilution step entails a comparable principle that calls for reducing the concentration of the explosive compound in another diluting agent. The liquid residue from such operations may then be either burned should the pyrotechnic hazard remain unabated or treated biologically at a dedicated treatment plant (e.g. compound propellants derived from perchlorates).
- **Chemical destruction** involves controlled reactions between the pyrotechnic material and one or several added chemical reagents (e.g. soda for nitramines).

In some cases, a **mechanical dismantling** or disassembly of objects (e.g. cut-out by machining, laser, shear, water jet, linear shaped charge, cryogenics) serves to release from confinement or separate into pieces the objects or materials to be destroyed; the energetic materials are then processed according to the aforementioned processes.
Moreover, the terms phlegmatization and desensitisation are sometimes employed to convey «actions intended to reduce the sensitivity of a given pyrotechnic material or system by means of adding a compound or desensitizing agent or by any other process»[3]. Water is often used.

Choosing the most appropriate destruction process depends on the type of explosive material (or object), its quantities, packaging, state (deteriorated, expired, etc.), the type and location of the destruction site, and lastly the potential transport conditions. [1, 5, 6, 8]

[1] See the «Inventory of Technological Accidents», 2009 [10]

The pyrotechnics industry has existed for quite some time, as gunpowder facilities date back several centuries. Since the lessons learned from the 1794 Grenelle Gunpowder Factory explosion killing 1,000 persons in Paris, France's pyrotechnic sites have been relatively isolated from residential areas or other businesses, in particular out of respect for regulatory requirements. One positive outcome of such measures directed at this industry is that property damage in the event of an accident is now often confined to the installation itself; for activities involving pyrotechnic destruction, just a single case of broken windows outside the perimeter of a site has been recorded among the 124 French accidents.

The inclusion of feedback in organisational strategy has undoubtedly contributed to reducing onsite property damage; any such damage seems to be more heavily restricted to the actual workstations, or eventually to the building, but very seldom beyond.

The characteristic features of accident causes will be discussed in detail over the following sections, but a few key figures can already be presented:

- Equipment defects are involved in approximately 27% of all accidents.
- The presence of «ongoing works / maintenance» is hardly represented in these accident statistics: two accidents listed in the base (ARIA 25389, 28707) took place at the time of installation dismantling or relate to derelict buildings; their inclusion in this study pertains more to poor handling of residue («waste collection» from a broader perspective) than to an accident arising during the material destruction step itself.
- Among the organisational causes, 20% relate directly to the human factor: individual error in manipulation or inappropriate action, lack of vigilance, overzealousness, etc. In almost all cases, an organisational flaw must also be sought at the level of the business entity (inaccurate guidelines, poor ergonomics, lack of control, etc.).
- Lastly, external causes (wind, frost or extremely high temperatures) were responsible, at least in part, for 5 of the 150 recorded accidents: ARIA 24877, 32222, 36880, 37091 and 37179.

ARIA 37776 (see p 6) Explosion in the Steingletscher underground storage (Switzerland)
Source : Bienz, Kummer and Partner AG (R.R.)

Transport vehicule for pyrotechnic waste
Source : Lacroix (R.R.)

When counting the accidents due to oversight errors during the collection of so-called «inert» waste prior to its destruction, 20 French events took place at the time of waste collection, assembly, sorting or transport on pyrotechnic sites, while 4 others occurred on non-pyrotechnic sites processing metals.

These events reveal the importance of being able to trace the products or materials to be processed once the waste is generated, and subsequently at all levels of the treatment chain. The waste producer is responsible for product identification and required to provide safety-related information on the given pyrotechnic product (components, hazards, etc.) to the party assigned the destruction operation, for example by means of a tracking file (even if the waste is only being circulated in-house and destroyed inside the place of production). Nonetheless, verifications are necessary at all stages, including inside the facility certified to destroy its own wastes, especially before burning packaging that in some cases has erroneously been considered as inert (e.g. ARIA 24911, 33536, 35597, 35906, 36528, 37117…)

This traceability (e.g. via an inerting report) takes on even greater importance should the initially inert waste be subsequently transferred to other businesses, such as metal recovery plants or steel mills for recycling purposes. Indeed, these destination businesses do not possess the specific knowledge of the pyrotechnic substances involved (ARIA 33042, 34585, 35491, 36819, 37234).

Waste collection is a pyrotechnic operation that can only be conducted by well-trained technicians, since a cleanup team not fully versed in the corresponding risks might, due to inattention, combine waste containers with incompatible contents (ARIA 22496). These collection and destruction teams must limit their intervention to identified wastes and, in turn, ensure that the traceability chain remains intact. Should doubt arise over a given object, the object must be treated as if it were an active agent (ARIA 33536, 35606, 36862).

An analysis of risks related to pyrotechnic waste collection and transport serves to designate the appropriate containers adapted to each type of waste, as well as suitable conditions for handling (36821, 36448, 19145) and internal or external transport (36801). Under all circumstances, it is recommended to regularly dispose of wastes in order to limit the quantities accumulated and those generated by the batches being transported.

Moreover, it is advisable to plan and prioritise waste collection and destruction with respect to all other pyrotechnic operations so as to avoid any intermediate storage, which generates additional risks (37079 - see Part 3).

Pyrotechnic waste container
Source : Lacroix (R.R.)

Nota : The ARIA database contains records of several accidents related to «product disposal» by individuals at dumpsites or improperly discarded with the rubbish, and that consequently become the cause of incidents, particularly those arising at municipal solid waste incinerators (MSWI). Without examining these cases in detail (a step that lies outside the scope of this synthesis on «industrial» wastes), the concern here nonetheless pertains to the collection of pyrotechnic products used by individuals (e.g. fireworks, flares, hunting bullets): ARIA 174, 27700, 31678, 36384…

In Précigné (72), in 2006, an explosion occurred at 4:05 pm inside one of the burning tunnels of a munitions dismantling facility,, composed of a 2-m wide concrete block and closed by gratings on three sides.
Empty crates were engulfed in flames; the detonation happened 10 minutes after the crates ignited. These supposedly empty crates originated from a workshop dedicated to removing explosive charges on anti-tank mines and had been stored for two years adjacent to the workshop.
This type of crate is used for containing hexolite residue present on the machine when the explosive is separated from the body of the mine. Such crates allow «shuttling» material between the shop area and the burner.
A crate containing explosive residue had inadvertently been palletised at the same time as the empty crates. 15 kg of the product exploded; the grates on the burner landed 50 metres away.
The site operator modified the handling protocol: empty crates were no longer left idle in the charge removal zone. To avoid any confusion, empty crates were palletised upside down and without a cover before being filmed in black and identified. (**ARIA 35597**)

Depending on the type and duration of pyrotechnic waste storage, two situations can be distinguished: production wastes directly associated with the workstation (including shorter intermediate storage periods), and longer-term storage.

a) At the workstation

At the level of the workstation, a strict waste management policy is required: it is essential for the pyrotechnic waste to be precisely identified both qualitatively and quantitatively. Moreover, the waste needs to be isolated from other pyrotechnic products in order to avoid triggering accidents (36899: ignition of a waste tank temporarily stored next to a nitration reactor) or exacerbating their consequences (28356: transmission of a fire to the wood chip and dust recovery system; 37035: spreading of a workstation fire to waste boxes).

To the greatest extent possible, it is recommended to store this type of waste in small quantities and for the shortest of durations (e.g. 24877: ignition of aluminised sludge stored for a long time while exposed to heat; 36874: explosion of a glass waste tank; 37079: self-ignition of powder released at an intermediate storage site).

b) Specific installations

The accident analysis exposes the hazards associated with «older products», which tend to be poorly identified and whose characteristics are not sufficiently known. Furthermore, such products might have undergone gradual changes in their chemical composition, thus reducing their stability (self-ignition of powder ARIA 11753, 33533, 36073, 37079) and/or raising their sensitivity to external loadings (19124, 24877…).

Pyrotechnic waste storage before destruction
Source : Titanobel (R.R.)

Periodic inspections of pyrotechnic products (e.g. munitions, powder batches) are essential, as is monitoring of the proportion of stabilisers, as a means of predicting their elimination within a reasonable period of time, before the product has time to evolve and become unstable, e.g. due to a total loss of stabiliser (ARIA 11753, 24901…).

It is similarly recommended to limit the storage period for products in the destruction process (ARIA 11753, 19124, 24877, 37079…). While underwater storage of deteriorated propellants prevents against self-ignition, it is necessary to allow for the possibility of natural degassing and plan around an aerated storage zone to avoid creating or helping the confinement of nitrous vapours or other toxic gases, hydrogen, etc. (ARIA 22506)

In Rillieux la Pape (69), in 2003, a fire spontaneously broke out inside a room housing 100 litres of aluminised sludge waste stemming from the washing water used for tanks that had contained a pyrotechnic formula (i.e. a barium nitrate and aluminium-based compound) in fireworks factory. The factory watchman noticed smoke rising inside the building and sounded the alarm.
This particular waste was being stored in 30-litre plastic buckets that had dried and warmed due to the summertime heat. […] Factory scheduling was revised in order to compress the sludge storage time between production and destruction steps by a subcontracted company. Periodic inspections served to verify the actual water evaporation level, and the accessibility to operational machinery was improved. Experts stressed the importance of training for both fire-fighters and response teams as well as the quality of information disseminated during onsite response. **(ARIA 24877)**

In Bellerive sur Allier (03), in 2006, a fire broke out mid-morning on 5 tonnes of older propellants containing nitrocellulose and scheduled for destruction at an ammunition production plant in the process of being closed definitively […].
Given the age of some of the powders involved, the hypothesis of a major loss of chemical stability in one of the powders present was considered the most plausible […]. **(ARIA 35533)**

In Switzerland, in 1992, six people were killed around 4:10 pm by the explosion of nearly 300 tonnes of expired munitions and production wastes inside the underground depot at Steingletscher, located on the slope of the Susten Peak. The explosion, whose TNT equivalent was rated at 200 tonnes and a magnitude 3.7 on the Richter scale, caused the part of the mountainside overlooking the storage zone to slide; huge blocks of rock and pieces of the storage facility were blast over 600 m […]. (**ARIA 37776** [10])

a) Preparation of the destruction operation

In the 150-accident sample, 25 accidents (of which 6 were fatal) occurred during the preparation phase for the destruction operation, with one of these events happening abroad.

Preparing the material or object for its destruction constitutes the most vulnerable phase; technicians are either positioned in the immediate vicinity or come into direct contact with the material. Despite the safety measures adopted and training offered to personnel, an outbreak of fire can still arise, due to the phenomena of: static electricity (ARIA 19124, 37100, 37105), friction or rubbing on highly-reactive products (ARIA 7079, 24902, 32086, 36884, 37067…), shock / mechanical aggression (ARIA 37024, 37034, 37094,…) and even a direct product reaction (ARIA 36873 explosion of an shaken product, 37083 self-ignition of a powder trail)...

ARIA 32086 - Incendie lors de la préparation d'un brûlage

The good working order of the processing zone, its cleanliness (combustion slag, residual products) after each destruction session and compliance with the minimum wait time between operations are all essential, especially when it comes to ensuring sufficient cooling of the combustion area prior to the subsequent spreading step, thereby avoiding uncontrolled fire outbreaks (24902, 37024…).

Several accidents occurred at sites that had not completed a work safety report or that had deliberately associated destruction operations with other safety reports, without even performing a complementary risk analysis: ARIA 7079, 8886, 17152, 22518, 28352, 36417. Imprecisely stipulated operations lead to compromised safety and inadequate technician protection, with potentially fatal consequences (ARIA 17152 , 24915, 36417). When an «unexpected» situation arises, it is essential to refer to a hierarchical superior to proceed with a necessary situational analysis (17152 unauthorised handling leading to detonation, 36881 a technician noticed that wastes should have been placed underwater, an explosion was set off as he was remedying the problem).

For operations based on a proper safety report, compliance with the ensuing guidelines proves critical: wearing appropriate individual protective gear (ARIA 24915, 17152), installation of planned fire protection systems (32086), presence of specialised certified personnel (32086), respect of quantity limitations, etc. to ensure that the destruction step does not «degenerate» (see section b).

Individual Protective Gear …

The basic equipment for staff assigned to position and ignite the products to be destroyed is determined from both the type of waste involved and ergonomic conditions; the set of gear chosen may contain some of the elements presented below depending on the exposed hazard:

- gloves able to resist the anticipated effects;
- fire-retardant hood or head covering;
- fire-retardant suit that does not build up a static electric charge;
- safety glasses resistant to the anticipated effects;
- safety boots;
- hearing protection, if necessary. [4, 5]

Individual protective gear for a destruction technician
Source : Lacroix (R.R.)

In Mazères (09), in 1989, a fire broke out during the preparation of a destruction session as a follow-up to the morning session. Two technicians placed a wire mesh cage above those products considered capable of becoming airborne. Contact of the cage with the pyrotechnic compound trail intended to be ignited initiated the combustion. The technicians were not injured, but the tarpaulin covering the trailer used to transport the products to their destruction destination was completely demolished.
The operator specified a new set of operating procedures featuring:
- the pyrotechnic compound trail is to be prepared only once the wire mesh cage had been installed,
- the equipment used for the destruction step is not to be reused without first being cooled in water or for at least 24h,
- transport vehicles are to be immediately removed from the site following their unloading. (**ARIA 37024**)

b) During destruction

74 of the accidents in the sample occurred during the actual destruction phase. Quite «impressive» at times, particularly by the noise generated during the transition from rapid combustion to detonation, these accidents on the whole caused fewer deaths and injuries, with onsite technicians positioned in shelters and the destruction zones more heavily protected (safety distances, barricades, etc.).

Nearly a third of the accidents occurring «during the destruction operation» involve transitions from combustion to deflagration or to detonation, as induced by confinement (ARIA 19132, 36854, 37119…) or that arise when exceeding the critical explosion height or authorised combustion quantities (ARIA 7043, 21313, 23049, 23479, 27709, 33538, 35898, 36387…) or that stem from poor material packing (ARIA 22530, 37026, 37056, 37092…). Inadequate homogeneity, phlegmatization or lacking knowledge of the wastes to be destroyed have been documented as the cause of around ten accidents (ARIA 28350, 35829, 36490, 36831, 36854, 36879, 37062…)

Runaway chemical reactions are the source of 3 incidents (26456, 36880 et 37093), a powerful reminder that this type of destruction operation cannot be considered banal, since the exothermal nature of the reaction creates «hot spots» that directly alter the pyrotechnic substances.

All waste mixes are to be forbidden as a means of avoiding any eventual incompatibilities (ARIA 20499, 35898, 36816, 37026). In a similar vein, no waste should be added once the treatment step has been initiated (ARIA 20499, 31283).

… and fire protection

In addition to the individual protective gear worn by technicians, these waste destruction operations must incite adoption of appropriate fire protection equipment: extinguishers, portable burn showers, fire smothering blankets, and other site protection devices (pump truck stationed during burning operations, fire hydrants, etc.) [4, 5, 7]

ARIA 35829 - Explosions during ammunition burning (Photo DGA - R.R.)

Lastly, as for all processing steps, compliance with guidelines proves essential: waste verification (quantities, packaging, etc.); compliance with the limits imposed on destruction quantities (19126) and in operating protocols; up-to-date maintenance of the burning zones (36360), with emphasis on the floors since their deformation could lead to local noncompliance with the critical explosion height (23045, 27709, 35893), wearing of individual protective gear; state of cleanliness; etc. A regular recall of the risks and guidelines ensures that the personnel is always ready to intervene appropriately. Technicians, in spite of their credentials and demonstrated competences, could become complacent and «fall into the routine» (ARIA 19126, 22504, 30732, 32086, 35708…) or, on the other hand, be startled by operations carried out on only rare occasions (ARIA 23045). It is advisable for special procedures to be planned when such steps are repeated less than once a year. Such measures are intended to ensure that the destruction zone always remains well adapted, personnel training programmes always pertinent, the information contained in safety reports always valid, and the production and safety guidelines still applicable.

In Saint Martin de Crau (13), in 2004, an explosion occurred while materials were being destroyed by means of burning in an explosives production plant. The substance involved, pentrite (which contains 25% water), exploded 12 min after burning had started on the floor in the presence of a solvent (toluene). Both the floor and gutter sustained irreparable damage, while the protective screens, initially installed to avoid a chain detonation across the 10 floors of the burning zone, were blasted out. Exceeding the critical height and explosion temperature, as a result of floor deformation and the solvent loading process, would have caused this accident. The site operator subsequently introduced periodic inspections of floor deformations and modified the floor loads based on their relief (deformation). (**ARIA 27709**)

In Germany, in 1992, an explosion occurred during the destruction of metal parts that had been polluted by explosive substances. The burning of 342 kg of nitrocellulose, 8.8 kg of cyclonite (cyclo trinitromethyl trinitrosamine) and 11 kg of black powder was prepared on 3 wooden pallets within the combustion zone. A fire protection station was installed 20 m away, with a reinforced concrete wall cover. A few seconds following ignition, a blast occurred injuring two. A building was totally dilapidated, while another sustained damage. The use of 350 kg of explosive powder instead of 100 kg was most likely responsible for transforming the combustion reaction into a detonation. (**ARIA 5791**)

It should be noted that some burning procedures have given rise to bush fires, either a result of operations conducted under windy conditions (ARIA 9183, 32222), or as a consequence of flying debris (ARIA 7043, 32052, 37119…). In any event, destruction operations can only be undertaken provided favourable climatic and meteorological conditions (with threshold values for wind velocity and direction potentially written into the operating guidelines) and with the proper extinction equipment available nearby to control any fire outbreak (32086). Brush removal over a good distance (at least 100 m) around the destruction zone allows minimising the risk of vegetation catching fire.

Among the accidents occurring while the destruction step is ongoing, roughly fifteen involve the «decomposition» of munitions in accordance with a stipulated industrial process (underwater or fluid sawing, cryogenics, cutting charge with cord, etc.). The hazards inherent in these activities are targeted as the integral part of the process, with the energy release provided «directly» by the sawing, compression or cord capable of inducing material reactions with a relatively high probability. These incidents have caused a certain amount of property damage at the workstation (walls blown out, damaged machinery, etc.), yet without resulting in any bodily injury since these operations are typically carried out remotely (35562, 35564, 37229, 37230, 37233…).

ARIA 37507 - Fire and explosions in an ammunition depot (Russia) Source : MSIAC (R.R.)

c) Regeneration

Used production reagents or some specific powders may be regenerated; 4 accidents in the database more specifically concern these product regeneration operations (acids, powders or chemical munitions).
Even for a widely «known» product such as nitroglycerin, risks may be underestimated when responses involve process by-products (37091: detonation while unblocking a pipe conveying spent acid using a blowtorch).

Finely-divided products, like certain powders or substances with pyrophoric characteristics, may also lie at the origin of accidents during their reprocessing steps (21315: ignition of phosphorus transmitted through washing water following a circuit design error; 36515: explosion once the recovery process for old powders has been completed, by means of distillation subsequent to fines accumulation); special attention is also required during these treatment phases.

In 1985, during a plant operation intended to destroy 500 g of pyrotechnic materials, the combustion mode transitioned to detonation, causing the metal basket (underneath which the products to be destroyed had been placed) to unhinge and be projected. The confinement of such products would have caused this transition to detonation. Flying debris in turn sparked bush fires in the vicinity, but these could be quickly extinguished by personnel thanks to the onsite presence of a fire truck involved in burning operations. The operator replaced the protective basket with an anti-spattering system attached to the burning zone and furthermore adopted measures to avoid the confinement of materials scheduled for destruction.(**ARIA 37119**).

In Oulianovsk (Russia), in 2009, a fire, coupled with a series of violent explosions, destroyed a Russian marine munitions depot: 3,000 people had to be evacuated within a radius of 7 km around the storage facility. Two military fire-fighters were killed while combating the blaze; a total of 60 injured were reported. An officer indicated that 3 railcars containing artillery shells (weighing approximately 100 tonnes) were stockpiled on the site; of these, some 40 tonnes exploded. In addition, two railcars containing gunpowder were consumed during the fire, which was eventually extinguished following the intervention of over 400 emergency personnel. Buildings adjacent to the site were also damaged (shattered window panes), including 9 schools and 20 children's playgrounds; in all, 105 residents were forced to leave their homes and be temporarily lodged in hotels.
According to a federal safety agency, the fire was initiated by the onsite munitions disposal activities. The press indicated that the poor state of local infrastructure as well as noncompliance with safety rules were the causes of many accidents of this type - fires, explosions - every year in Russia. The munitions left unexploded during this accident would, 10 days later, trigger a fatal explosion when loaded onto a railcar for their ultimate destruction. (**ARIA 37507**)

Without delving into details on the set of regulations applicable to the range of pyrotechnic activities, it goes without saying that regulatory compliance is a «mandatory» condition of pyrotechnic safety. Due to their longstanding existence, these regulations display the unique feature of imposing specific prescriptions, such as limiting the number of workstation personnel, safety distances between installations, systematic safety studies, and extending to the inclusion of waste generated (in terms of quantity, conservation, etc.) into the actual guidelines. The regulatory framework also incorporates considerable feedback from accidents with consequences of varying severity.

Given the strong probabilities of reactions between substances and often more highly unstable pyrotechnic waste, a more detailed workplace safety report becomes a prerequisite for any operation involving the waste, including: collection, packaging, transport and treatment.

First of all, a stringent identification of the materials to be eliminated along with their exact history as of the generation stage is critical, as is an in-depth knowledge of the appropriate destruction methods when given their characteristics. Should such a characterisation step prove impossible or should doubts persist, it is necessary to follow a specific set of procedures based on preventing the most significant risks.

The accumulation of wastes awaiting treatment must be prohibited; they should be eliminated, to the greatest extent possible, as they are being produced. The quantities to be destroyed upon each operation must remain limited, as need be by means of preliminarily splitting the mass of batches presented. The number of different types of products / wastes to be stored or destroyed must be simultaneously reduced, while all material mixes must be avoided. Special attention should be paid to the risk of triggering the transition: combustion / deflagration / detonation. Since the products involved are often in a degraded condition, their subpar behaviour also needs to be taken into account.

Actual implementation of the specific destruction method implies proceeding with great precaution.

It is highly recommended to conduct operations as much as possible from a remote location, in equipping technicians with adapted individual protective gear. The presence of protected workstations, free zones designated for eventual leaks and a standby emergency response to cope with burns (including showers) also contribute to personnel safety. The same applies to the preliminary onsite positioning of fire prevention resources (pump truck, protection system) to allow protecting both personnel during preparation stages and the environment during the actual burning.

Regular and sufficient cleaning of the destruction zones all around their boundaries, as well as compliance with the minimum wait time between two consecutive destruction operations, constitute key factors in preventing against uncontrolled fire outbreaks. The influence of weather conditions must also be taken into consideration; no waste destruction should be performed in the presence of strong winds, extreme heat or stormy conditions.

Waste treatment is indeed an integral part of pyrotechnic operations and can only be accomplished with certified personnel. Moreover, a regular reminder of the risks involved and heightened vigilance in ensuring procedural compliance serve to limit the rate of accident occurrence.

The various tasks to be implemented during waste treatment, from identification to destruction, necessitate a complete risk management approach dedicated to each individual stage. Such a strategy entails setting up a robust organisation with strict oversight of actual application and heavy involvement in facility management decisions. In the absence of such measures, history has shown, through accident records, that deficiencies in human organisation can lead to severe adverse consequences.

1 INSPECTION DE L'ARMEMENT POUR LES POUDRES ET EXPLOSIFS (IPE)
http://www.defense.gouv.fr/dga/votre_espace/liens/poudres_et_explosifs

2 SFEPA (Syndicat des fabricants d'explosifs, de poudre et d'artifices)
http://www.sfepa.com/

3 GTPS
Pyrotechnics Dictionary, 6th Edition, Pyrotechnics Working Group (GTPS), Publication by the French Pyrotechnics Association, ISBN2-9521621-3-1.

4 GTPS
Proceedings from the GTPS plenary session, entitled: «Treatment and elimination of explosive products», November 20, 2008, in Bordeaux.

5 GTPS / Destruction commission
"state of the art concerning the destruction of pyrotechnical waste" (to be published in 2010).

6 Best practices guide in the field of pyrotechnics, SFEPA, 2009.

7 IPE / Recommendations memorandum, No. 3004/DGA/IPE relative to emergency response measures in pyrotechnic workshops whose personnel are exposed to burns from fire, January 8, 1996.

8 FEEM (Federation of european explosives manufacturers)
Codes of good practice, http://www.feem-europe.org/

9 INERIS
Analysis of the existing industries for the collection and destruction of pyrotecnical waste – Document for the French administration. 20/10/2008.

10 BARPI
- www.aria.developpement-durable.gouv.fr
- Detailed fact sheet: Explosion during the destruction of munitions at Beine Nauroy, May 21, 1996. – ARIA 8886
- Detailed fact sheet: Fire outbreak on a burning zone at a pyrotechnics plant in Pont de Buis-les-Quimerch (29), July 28, 2006. – ARIA 32086
- Detailed fact sheet: Explosion of a shell inside a metal materials recovery company in Vierzon (18), May 14, 2008. – ARIA 34585
- Detailed fact sheet: Explosion of an underground explosives and munitions waste storage depot in Steingletscher (Switzerland), November 2, 1992. - ARIA 37776
- Inventory of technological accidents, 2009

LIST OF ILLUSTRATIVE FRENCH ACCIDENTS QUOTED IN THE TEXT

European scale of industrial accidents :

The quotation of the four criteria of the European scale is shown for each accident. It provides an indication of the seriousness of the accidents, following their detailed analysis. The scale is based on 18 parameters that are grouped into four indices, namely :

Dangerous material released	(2 parameters)
Human and social consequences	(7 parameters)
Environmental consequences	(5 parameters)
Economic consequences	(4 parameters)

The information used to determine the elementary level of each parameter is available on the site :

www.aria.developpement-durable.gouv.fr

on the « Information Tools / European scale of industrial accidents » page. For a given accident, the value of each index corresponds to the highest level of the parameters that it contains. Only some of these 18 parameters, which are designed to cover a broad variety of the possible consequences of diverse incidents, are usually of relevance when characterising an accident..

ARIA 7043 - 29/05/1995 - 13 - SAINT-MARTIN-DE-CRAU
38.32 - Recovery of sorted waste
In a pyrotechnic waste destruction facility, the burning of outdated munitions produced an explosion. The incineration furnace was completely destroyed; a fire spread and ravaged 1 hectare of vegetation. The site operator reacted by reducing the furnace filling capacity to its limit calculated upon detonation when the products targeted for destruction are capable of exploding..

ARIA 19126 - 05/11/1998 - 18 - LA CHAPELLE-SAINT-URSIN
20.51 - Production of explosives
An explosion occurred on a zone dedicated to destroying pyrotechnic products. The bags containing pyrotechnic waste (fouled packaging and rags) were planned for destruction without first being opened. They contained a quantity of explosives in excess of the designated limit, which caused shortly after ignition inside the furnace a violent reaction comparable to the detonation of 0.5-2 kg of TNT. Technicians were sheltered offsite and did not sustain any injuries. The site furnace was seriously damaged: a crater was formed in the ground, a door was thrust a distance of 40 m, roof gratings were damaged, etc. The operator verified the waste sorting procedure and provided personnel with additional training; moreover, the operating protocols for waste destruction preparation steps were all updated.

ARIA 20499 - 03/02/2000 - 95 - SURVILLIERS
20.51 - Production of explosives
In an explosives plant, a blast occurred while pyrotechnic waste was being roasted.
A technician inserted pieces of combustible wood chips into a furnace that was still turned on. Another employee used the occasion to discard into the furnace hearth a cardboard box containing two used filters from the production process for a TiPP pyrotechnic compound. The residue on the filter immediately caught on fire, creating an impressive flame. Not wearing any individual protective gear (on their heads), the two employees were slightly burned. A third person went into a state of shock. The furnace door was also damaged.
The furnace had not been designed to burn this type of compound; moreover, the objects introduced into the hearth most likely were not compatible with those that had previously been consumed in the same furnace. Lastly, the existing safety guidelines were not respected: the furnace must only be fed with fuel when shut off or via the outside and furthermore must never be opened while still operating.

ARIA 22496 - 12/03/2001 - 13 - SAINT-MARTIN-DE-CRAU
20.51 - Production of explosives
In a pyrotechnics plant, a deflagration followed by combustion occurred while in the process of collating laboratory waste.
Rubbish cans were normally introduced to avoid incompatible product mixes; in particular, the fuels were separated from the fuel oxidisers. A jar of crystallised parent emulsion solution containing ammonium nitrate would have reacted with just a few grams of thermite (i.e. a mix derived from aluminium, alum and copper oxide) when cleaning staff was combining the contents of rubbish containers.
The plant operator set up a colour-coded identification system for rubbish containers for the various products as a means of limiting the risk of human error as much as possible.
Based on this accident report, experts remind that the collection of pyrotechnic waste must be included in the pyrotechnic safety study and all implementation-related steps must be performed by well-trained and certified personnel. The expert assessment also insisted upon a strict traceability of wastes, with the aim of accounting for risks related to product ageing (focusing on changes in characteristics over time). .

ARIA 22504 - 18/05/2001 - 09 - MAZERES
20.51 - Production of explosives
In a fireworks factory, a pyrotechnic compound being designed based on potassium nitrate and aluminium exploded at the time of its destruction. Chemical instability caused an exothermic decomposition and the subsequent deflagration. The accident caused 3 slight injuries (burns and auditory trauma), but the consequences could indeed have been dramatic.
Though the technician had a fair amount of experience (10 years) and the operating procedures had been tried and tested for 20 years, a number of errors and instances of procedural noncompliance could still be noted:
1) Water was being used a wetting agent instead of a water/alcohol mix, leading to instability of the chemical composition.
2) The procedure called for immediate destruction of the trial compounds, yet this destruction step had been delayed in time, which increased the accident probability (greater time for the compound to decompose).
3) 10 kg of compound were prepared for destruction, even though the procedural specification stipulated splitting the amount into 2.5-kg batches; this noncompliance exacerbated the accident effects and consequences.
The operator disciplined the technician for failure to respect guidelines and proceeded with an evaluation of the failure of the safety management system, underscoring the need to «maintain permanent vigilance» on the part of technicians. Holding awareness-building sessions for technicians on a quarterly basis, as laid out in the regulations and implemented onsite, was not in this particular case able to avoid a «habituation phenomenon». .

ARIA 23045 - 10/02/1997 - NC -
20.51 - Production of explosives
In a pyrotechnics plant, an explosion occurred during the destruction by burning of 250 kg of pentrite in large rust-stained crystals. Destruction of this product represented an unusual occurrence (1st time in 10 years), and the associated combustion would typically last 20 minutes. The explosion was triggered 4 minutes after ignition. The critical product height would have exceeded the threshold in many places due to warping and overall deformation of the destruction platform floor. As per operational guidelines, the technician was in a sheltered locale 150 m from the ignition zone and was not injured. The metal burning floor was destroyed and a crater carved into the concrete slab. The operator reinforced the barricades in place around the ignition control room and replaced the window panes with an impact-resistant material.

ARIA 24911 - 07/02/2002 - 03 - BELLERIVE-SUR-ALLIER
25.40 - Production of weapons and munitions
Within a munitions plant, several detonations occurred successively during the incineration of packaging that used to contain electric detonators.
The packaging material came from a building where the detonators were being refurbished; these detonators contained 0.25 g of lead azide and 2 g of secondary explosive and were initially packaged into boxes of 30 inside individual cardboard tubes. The packing operation consisted of placing each detonator into a metal tube and then inside crates containing 25 such tubes. The empty cardboard tubes were stacked alongside the original packing boxes for subsequent destruction.
Several detonators in the cardboard tubes most likely stayed in a box that afterwards got stuffed with other empty cardboard tubes. Technicians working in the burning zone sampled a few packaging specimens to ensure they were empty before inserting them into the incinerator furnace.
The operator had informed technicians of the importance in verifying packaging contents and moreover implemented a systematic control of empty packaging within the shipping zone. The operating protocol was modified to include: breaking the cardboard tube after verifying that no contents remained inside, and the systematic folding of empty boxes into flat cardboard sheets. An element accounting sheet with the headings «incoming / outgoing / reject / return to warehouse» was also introduced.

ARIA 32086 - 28/07/2006 - 29 - PONT-DE-BUIS-LES-QUIMERCH
20.51 - Production of explosives
In a company dedicated to producing hunting ammunition, fire broke out on a pyrotechnic waste burning zone, on a day when the production facility was closed for annual holidays. A single entrance provided access to this excavated (50 x 30 m) zone, partially enclosed by a barricade and protected by a fire hydrant. To be accepted, all pyrotechnic waste required a preliminary authorisation issued by the Safety & Environment (SE) unit. Since the waste accepted from either the site itself or another company was transported in water, it was necessary for the materials to have dried to a certain extent before burning with the use of green powders. To be destroyed by burning, these waste materials needed to be laid out linearly along the foot of the excavation and typically on wood (e.g. pallets). The onsite presence of an equipped first response truck was mandatory whenever large quantities were being burned. On July 24, while the technician assigned to the particular burner since 1987 was preparing the zone using a farm tractor, the powder spontaneously ignited. Stunned by the event, the employee driving the tractor was able to leave the scene unharmed. On July 28, during the morning hours and cognisant of the extreme volatility of the wastes present onsite, the SE unit manager was assisting 2 production technicians with set-up duties, since his 2 SE employees were absent from work, in proceeding with the scheduled elimination of these unburned materials (finished, wet gunpowder for hunting rifles and graphite), by means of raking and spreading the pyrotechnic waste onto pallets to facilitate drying. At the beginning of the afternoon and without the first response truck on the scene, the onsite team distributed pallets over the layers of waste in two runs. Around 3 pm, a spontaneous fire ignited near the position of the SE manager, who was trapped by the flames and smoke. The blaze propagated throughout the zone. The other two crew members were able to escape from the zone unhurt. One of them, a volunteer fire-fighter, sounded the alarm and began to combat the fire. The SE manager, who happened to be standing 30 m from where the fire sparked at the foot of the embankment, died from his injuries in less than an hour. The fire would have been triggered by friction of the powder (dry and polluted, hence more sensitive) due to a pallet falling or skidding, or the foot movement of the deceased manager. A disposable cigarette lighter was found intact yet inoperable adjacent to the combustion zone. Facility reactivation was made contingent upon the adoption of compensatory measures. Several aspects would be treated during the implementation of new measures: soil pollution capable of arising during burning; and the typology of targeted wastes.

ARIA 34585 - 14/05/2008 - 18 - VIERZON
38.32 - Recovery of sorted waste
In a holding centre for ordinary industrial waste and metal waste, a 155-mm shell from World War I not fully inert and still containing between 2 and 4 kg of picric acid (melinite or 2,4,6-Trinitrophenol) exploded around 3:30 pm when a subcontractor punctured the shell with a blowtorch. An employee taking a break 10 m away died from the shockwave reflected off the walls, 2 workers were injured (one of whom seriously) and 2 others entered a state of shock. In addition to the subcontractor killed upon perforating the shell, two other workers employed by the same firm also sustained injuries.
Approximately 20 g of product had violently ignited: shell debris was dispersed both on the site and beyond the perimeter at distances of up to 300 m. The remainder of the picric acid spread over the ground (forming a yellow powder). Emergency rescue teams and the land mine removal service were both notified. The pile of shells was sprinkled with water. A 200-m safety perimeter was set up onsite around the stockpile containing several thousand shells presumed to be inert. The adjoining street was closed to traffic, and 30 employees from a neighbouring company's premises were evacuated.
The mine removal team conducted a site survey and ruled out any chemical risk, yet acknowledged the eventual presence of other shells still «active», though without suggesting any immediate risk. Their findings led to maintaining constant monitoring of the site during the time required to carry out further investigations. Another worker had already been slightly injured the very same morning following the explosion of a small-sized shell. A prefectural order to enact emergency measures required: defining and marking a safety perimeter around the shell stockpile, applying access restrictions inside this perimeter, controlling water quality, discharging the water trapped as a result of actions taken by the emergency services team, submitting an accident report that mentioned the circumstances and causes of the accident as well as its effects on individuals and the environment, the measures adopted or anticipated to avoid a similar accident and the actions implemented to cleanup the site.
The classified facilities inspectorate recorded the facts surrounding the accident, in addition to the noncompliance with several prescriptions set forth in the prefectural order granting authorisations to the facility, namely: onsite presence of at least one type of explosive waste, failure to procure a burning permit for operations performed using a blowtorch, lack of training and certification verification for personnel working onsite, failure to furnish accreditation for the subcontracted company, decision to pursue the activity subsequent to the explosion that took place the very same morning, without first notifying the appropriate authorities (i.e. mine removal unit or local gendarmerie), even though an explosive device had been found onsite.

ARIA 35562 - 30/10/2007 - 72 - PRECIGNE
25.40 - Production of weapons and munitions
Inside an explosives plant, a 155-mm shell with an 8.7-kg hexolite charge detonated while being cut as part of its eventual charge removal. This cutting operation on the 155-mm shells got underway the previous day using a machine equipped with a brand new saw blade; 32 shells were sawed throughout the previous day and another 27 on the day of the incident. Cutting on the 28th shell caused the explosion, which as anticipated in the workplace safety report did not cause any injuries; although the two technicians on the scene were in a state of shock. All of the walls vulnerable to a blast within the working enclosure were destroyed, as were all the tools and machinery. The roofs on adjacent premises were also damaged.
The ordnance was triggered by means of friction due to the cutting operation, despite repeated lubrication of the cutting edge. Since this practice, which had already proven its efficiency elsewhere, was normally not sufficient to initiate the hexolite, the hypothesis was therefore forwarded of a non-homogeneous explosive. Higher concentrations of cyclonite at the spots where friction was present could have triggered the explosive.
No system allowing the verification of the homogeneity of the explosive charge existed, consequently, the company ceased the process of directly sawing the hexolite.

ARIA 35898 - 04/11/2008 - 45 - LA FERTE-SAINT-AUBIN
25.40 - Production of weapons and munitions
In a weapons and munitions plant, technicians remotely lit the «cord» of explosive shavings lying underneath the explosive block scheduled for destruction by burning. After a few moments, the combustion of a portion of the explosive produced a detonation. he quantity of secondary explosives to be burned amounted to 48 kg (ten 1.4-kg blocks of hexolite + 33 kg of dust generated from machining hexolite + 940 g of hexocil shavings + 300 g of dust from machining aluminium tolite wax), i.e. nearly twice the mass authorised under the safety guideline for burning.
No human consequences were reported since both technicians were protected inside the control room at the time of burning. The burning platform was destroyed; moreover, chunks of the concrete slab were projected 4 m into the air, and 2 craters (measuring 20 cm x 30 cm x 3 cm deep) were observed at the site where the detonation occurred. The explosion also caused a polycarbonate glass sheet to be stripped from a door on a building located 100 m away as well as a light grating to fall in a building 450 m away. Several hypotheses relative to the detonation transition were imagined:
- self-confinement of melted explosive that would have flowed into a crack in the concrete zone,
- self-confinement of hexolite dust that was not sufficiently spread over the burning platform,
- reaction of the tolite wax aluminium powder with humidity of the burning platform,
- detonation of explosive particles enclosed in the slag present on the platform.

The site operator reminded technicians of the importance of initiating ignition from the shelter in addition to strict compliance with guidelines and operating procedures: safety guidelines were to be reviewed at least once a year. The operator issued this information to the entire staff as well as the Corporate Committee for Hygiene, Safety and Working Conditions (CHSCT). A tree analysis was also conducted of the accident causes and the following conservation measures were introduced in order to resume the waste destruction sessions:
- strict compliance with the maximum 25-kg quantity stipulated in the safety report and guidelines, using just a single line no more than 4 cm thick, as calibrated using a tool,
- separate burning for explosives containing metal powder,
- installation of a video recorder onto the existing camera: the objective here was to capture a view of the placement sequence followed for the products to be destroyed, with the precise position before initiation of burning, and the behavioural patterns during the destruction process,
- inspection by a hierarchical superior prior to initiating burning of the targeted explosives,
- creation of «waste orders» associated with each container (25-kg max) to improve knowledge of the total mass of explosives,
- search for a means to split the explosive blocks to be destroyed into smaller units,
- update of both the destruction and waste guidelines.

ARIA 36360 - 28/07/1995 - 21 - PONTAILLER-SUR-SAONE
20.51 - Fabrication de produits explosifs
20.51 - Production of explosives
Segments of a detonating cord exploded during destruction by burning. The well-experienced technician had visually verified the contents of the bags to be destroyed and ensured the absence of any tight knots on the detonating cord. No more than 3 bags were ever burned simultaneously. Burning was initiated by an electric lighter remotely controlled from a blockhouse. On the day of the accident, a few of the shorter detonating cord segments (70 g/m) stemming from the laboratory were burned. After a couple minutes, as the flames were starting to subside, the technician moved away from the blockhouse, protected nonetheless by the barricade all around the destruction zone. At this point, the remainder of the cord exploded, leaving a crater 2.2 m in diameter and 80 cm deep. It was possible that the aluminium covers had remained in place on a few cord ends, although the size of the crater is out of proportion with the equivalent PETN suspected: the initial detonation took place inside the cord, with transmission to products that would have infiltrated underneath the slab concrete. The burning zone was destroyed.
The operator separated burning zones depending on the type of explosive to be destroyed, with each concreted zone being installed on an impermeable layer in order to collect the burning residue and soluble products such as the oxidisers.

ARIA 36880 - 23/07/1990 - NC - NC
20.51 - Production of explosives
A detonation occurred during the destruction of detonators by chemical reaction taking place in buckets. The buckets were filled with the destruction solution, and the cooling step by means of circulating cold water was initiated. The bucket containing the (50-g) detonators exploded after about 10 minutes. The bucket, the PVC pipe responsible for feeding the destruction solution and its support were all destroyed. The adjacent buckets were moved slightly but sustained no deterioration. The workstation design (remote operations from behind a protective wall) provided an effective means of protection for the technician, who walked away from the incident completely unscathed.
A flaw in the set of working instructions caused the explosion; neither the high ambient temperature nor the heat associated with the exothermic reaction that triggered the explosion had been taken into account. The outside temperature parameter was to be incorporated into the operating procedure (during hot times of the year, waste destruction activity would take place at the beginning of the morning)..

ARIA 36899 - 06/11/1990 - NC - NC
20.51 - Production of explosives
Upon starting his shift, a nitration specialist noticed flames at the door leading to the workshop. He immediately began fighting the fire using an extinguisher and was able to put out the blaze. The day before, a technician had recovered inside the acid tank separator situated at the beginning of the residual acid pipeline leading to the nitrogen removal agent, an emulsion composed of a mix of water, acids, nitroglycerin, nitroglycol, etc. that he placed into a pitcher along with a bucket made of ebonite rubber.
Unable to immediately contact the Production Manager to show the sample, he took the initiative to temporarily store it, thinking that its destruction could wait until the next day. The normal procedure called for conducting an analysis by the laboratory, which would then make a decision regarding destruction. The wastes reacted when placed in contact with air, thus triggering the blaze.
The investigation revealed that the large quantity of waste collected stemmed from a rather rapid cooling of the residual acid tank over the four days of downtime around the first of November, given that the space heater had been removed for repairs.
The operator reset the heating system and acid tank temperature regulation system, in addition to carrying out a safety study for the waste extraction station inside the separator and offering a refresher training course to staff members assigned to handle wastes.

ARIA 37026 - 22/05/1989 - 13 - SAINT-MARTIN-DE-CRAU
20.51 - Production of explosives
Technicians responsible for waste destruction produced 6 hexolite sludge batches to burn. A mine slated for destruction was placed on top of one of these batches and the fire was then ignited. Five minutes later, one of the batches exploded, as a chain reaction due to the mine explosion. The other batches did not make the transition. A crater approximately 5 metres in diameter and 30 to 80 cm deep was created.
Subsequent burning sessions would only be conducted using products of the same type; the mines would be destroyed by blasting instead of burning.

ARIA 37079 - 25/08/1988 - NC - NC
20.51 - Production of explosives
An anomaly in setting the time for the propellant plate rolling operation caused a major loss of stabiliser; 6 kg of noncompliant powder had to be evacuated to the waste storage zone. The powders self-ignited after roughly 45 minutes. The fire spread to the other pyrotechnic waste containers, holding 40 kg of pellets and rolling wastes. The ground of the storage area was burned over a diameter of approx. 2 metres.
The rolling time regulation system was to be completed (servo-controlled?) in order to better control this rolling operation. In the event of a subsequent anomaly in the regulation process, the products were to be destroyed as quickly as possible.

ARIA 37083 - 20/09/1988 - 84 - SORGUES
20.51 - Production of explosives
Technicians assembled five batches of hexolite sludge to be destroyed by burning. The batches were connected one to the other by trails of old strip propellants. One of the batches caught on fire unexpectedly, probably as a result of the instability of powder conserved underwater.
The operator prohibited the use of strip powders in a poor state of conservation for the purpose of triggering ignition.

ARIA 37091 - 13/01/1987 - 62 - BILLY-BERCLAU
20.51 - Production of explosives
A detonation occurred during the treatment of residual acids from the production of explosive oils. These residual acids from nitrated oil fabrication were then transferred to the nitrogen removal installations via an aboveground 120-m long pipe.
On the day of the accident, the outdoor temperature was near the -15°C mark, thereby blocking the flow of fouled nitroglycerin and nitroglycol acids inside the pipeline. A maintenance team undertook the task of «defrosting» the pipe by heating it through the use of open flame devices and through disassembling some selected parts, which in turn caused a detonation. A technician died and several metres of pipe were destroyed.
The explosion took place on a portion of the pipe that had not yet been heated and where the victim was not equipped with either a heating device or any special tool. The reheating and disassembly of the frozen pipe was able to generate thermal and mechanical stresses on the stagnant and frozen explosive oil, thus causing a autocatalytic chemical decomposition of nitroglycerin.
The operating safety range of the installation was revised on the basis of temperature in order to safeguard against special risks related to periods of intense cold weather. The residual nitration acid transfer pipeline was heated to above the freezing point. .

ARIA 37105 - 15/09/1987 - NC - NC
20.51 - Production of explosives
The technician placed a zirconium-based pyrotechnic compound to be destroyed by burning in a trail. He held the metal box with both hands and backed up by slightly shaking it so as to facilitate the smooth flow of its contents. The second 200-g box of compound was nearly empty when a deflagration occurred, most likely initiated by static electricity. The technician was wearing the set of individual protective gear: goggles, boots, leather apron, and fire-retardant outfit; he sustained serious burns on his hands and had his eardrums perforated. The capacity of the compound to instantly burn was not known with any accuracy, hence the operating procedure was poorly adapted. The plant operator reinforced the measures in place to prevent static electricity build-up.

TECHNOLOGICAL ACCIDENTS ONLINE

Safety and transparency are two legitimate requirements of our society. Therefore, since June 2001 the website www.aria.developpement-durable.gouv.fr of the Ministry of ecology, energy, sustainable development and the sea has been putting lessons learnt from the analysis of technological accidents at the disposal of professionals as well as the general public. The main sections of the website are presented both in French and English.

Under the general sections, the Internet user can, for example : inquire for the state's action, access to wide extracts of the ARIA database, discover the presentation of the European scale of industrial accidents, inquire for the "dangerous substances parameter" used to complete the "communication on the spot" in case of accident or incident.

Accidents description, which is the raw material of any method of feedback, constitutes an important part of the website : when known, events, consequences, origins, circumstances, established or presumed causes, actions taken and lessons learnt are compiled.

Over a hundred detailed and illustrated technical reports present accidents selected for their particular interest. Numerous analyses sorted by technical subjects or activities are also available. The section dedicated to technical recommendations develops various topics : chemistry, explosives, surface treatment, silos, tyre storage, hot work permit, waste treatment, handling ... A multicriteria research engine enables getting information about accidents arisen in France or abroad.

The website www.aria.developpement-durable.gouv.fr develops constantly. Currently, more than 37 000 accidents are online and new topics will be regularly added.

The summaries of the accidents presented in this document are available in French at:

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