FACT SHEET

Pyrotechnics: Why did the technician fail to follow the procedure?

In the pyrotechnics sector, 12% of accidents are associated with inappropriate human handling, primarily failure to follow procedures (since the ARIA database was created, 132 accidents fall into this category out of a total sample of 1076). This number sparks interest, especially given the likelihood that the actual number is even higher since the causes of a large proportion of accidents remain unknown. The recurrence of situations involving procedural non-compliance in pyrotechnic activities is all the more surprising knowing that this sector imposes lengthy procedures due to the potential fatal consequences for the most minor of infringements. These rules and guidelines are thus in place to protect technicians' lives!
Several types of procedural non-compliance can be distinguished: those due to error (unintentional actions) and those due to deliberate action, i.e. violations. The first ones (oversight, clumsiness, confusion, etc.) are by far the most common. However, the two accidents presented during the "Pyrotechnics" session at the IMPEL 2015 seminar illustrate the second aspect, namely wilful procedural infraction (proceeding with an unscheduled action to cut away a contaminated pipe; non-secured actions taken when transferring pyrotechnic products). Such actions are the focus of the present fact sheet.
Based on actual case studies, the objective is first to present typical set-ups in which technicians wind up knowingly circumventing procedures and then investigate the associated underlying causes across the range of context described.

1. Three typical situations involving procedural violation

When committing a violation, the technician is knowingly breaking a rule, i.e. he is fully aware of engaging in an unauthorised action at the very point in time he is undertaking such an initiative. We therefore exclude those cases where the procedural non-compliance occurs subsequent to an unintentional manoeuvre (oversight, handling error, interpretation error, confusion, clumsiness).
A procedural violation may take several forms:

- The non execution of a required action, such as inserting bags of pyrotechnic wastes into anoven without first opening and inspecting their contents;

- The incorrect execution of a required action, such as placing an excessive quantity of explosives into burn-out kilns, or a handling step conducted by a single technician instead of two during normal operations resulting in a dropped vessel;

- The execution of a non-required action, such as the forced restart of equipment that had been considered faulty, or the completion of an unscheduled operation.

Based on findings from accident studies, three typical configurations arise in which a pyrotechnic installation technician may be led to circumvent procedures:

1. To facilitate his task; the objective might be to save time in order to complete an assignment more quickly, e.g. by exceeding product quantities specified for a given workstation, or else to avoid confrontation with a supervisor. According to this configuration, the technician does things "his way" and places other concerns above compliance with safety rules.

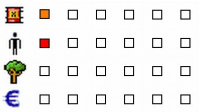
2. To seek problem resolution, often in acting alone and sometimes in the place of others, instead of securing the installation and notifying the supervisor. In all these cases, the technician is indeed taking his job seriously (i.e. trying to resolve an abnormal situation as quickly as possible), but the outcome of his initiative fails to meet expectations. Rather than producing the anticipated remedial effect, the technician's improvised action causes an accidental drift, in many instances by bringing mechanical energy in the presence of highly reactive products (e.g. the technician opening a machine that has stopped and pulling on some parts in order to restart it).

3. To respond to demands imposed by the organisation, which most frequently call for respecting time constraints or meeting objectives.

Behind the violations themselves, which constitute the initial accident symptoms, are deeper root causes. They may be related to the technician and his physical state (e.g. fatigue, overconfidence) but also to his affiliated organisation (working conditions, risk management). In general, a combination of these two factors is at play, whereby an inappropriate organisational procedure sets the stage for a technician to break an operating rule.

2. Case of a technician looking to take shortcuts, call his own shots

Example of an accident corresponding to this case



ARIA 22504 - 18 May 2001 - 09 - MAZERES

In a fireworks factory, a potassium nitrate and aluminium-based pyrotechnic compound under study exploded as it was being destroyed. Chemical instability caused an exothermic decomposition and explosion. The accident resulted in 3 slight injuries (burns and auditory trauma), yet the consequences could have been much worse.

Even though the technician was experienced (10 years in the trade) and the operating protocols tried and tested for 20 years, several procedural errors and compliance breaches have been reported, namely:

1) Water, which undermines compound stability, was used as a wetting agent instead of a water/alcohol mix.

2) The procedure called for immediate destruction of all study compounds: delaying this action increased the likelihood of an accident (compound decomposition time).

3) 10 kg of compound were prepared for destruction, whereas the procedure had stipulated fractioning into 2.5 kg jars. This breach exacerbated the accident effects and consequences.

The factory operator disciplined the technician for failing to follow instructions. He conducted a review of breakdowns in both the safety management system and the ability to keep technicians in a state of "permanent vigilance". The quarterly awareness session attended by technicians, as imposed by the regulation and implemented on-site, was incapable, in this specific case, to avoid the occurrence of a phenomenon of habituation.

Analysis of root causes

The technician who decides to ignore procedures when executing an assigned task is frequently unsatisfied about imposed working conditions. Indeed, problems involving workstation ergonomics, directly associated with a suboptimal selection of equipment and processes, commonly instigate inappropriate behaviour. For example, an installation set-up that complicates cleaning could promptly assigned personnel to do a hasty job in order to avoid all the extra effort required.

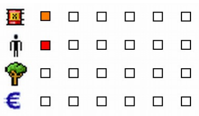
The organisation implemented in terms of guidelines and procedures might also be blamed. Existing procedures, whose content still seems to be relevant, may be applied inadequately or ignored altogether by technicians for various reasons. Accident studies reveal situations in which procedures are perceived as too burdensome and restrictive. Other cases point difficulties in procedural implementation due to instructions unavailable in the technicians' mother language, or only provided orally or else posted in the wrong zone. Procedural simplification and the creation of more "practical" tools, e.g. instituting a checklist of verifications to be carried out before start-up, are some actions designed to remedy this problem. A coordination process might also be introduced to optimise procedures and facilitate technician acceptance.
Inadequate training is another frequently cited cause, since technicians with little awareness of the sensitivity of products being handled might circumvent rules without realising the seriousness of their action and its potential consequences. However, when the training offered technicians is substandard, this tends to reflect that the global host organisation's safety culture is severely lacking. It must then be considered that the corrective action of "reminding staff to follow instructions" or "improve their awareness", as often practiced by facility operators, will only be effective if accompanied by a wholesale change in attitude among the entire organisation.

On the other hand, it is important to ensure that habits specific to an individual do not undermine the efforts expended by the whole organisation as regards risk-related training. A seemingly rigorous training process (with regular refresher courses) and the existence of proven procedures actually fall short of preventing rule violations by technicians if the "human factor" has not been fully taken into account. As displayed in ARIA accident 22504 above, an experienced technician's overconfidence can lead to taking liberties with posted instructions and executing actions not specifically stated in the company's operating rules.
This context obviously highlights issues of workplace organisation and supervision. The accident described above reveals the drifts arising from insufficient oversight. Such management problems are also illustrated in ARIA accident 45545 presented at the IMPEL 2015 seminar: the absence on the day of the accident of several supervisors, who would have been able to validate the protocol, was probably one of the factors resulting in technicians undertaking an ill-advised initiative.
These shortcomings in workplace organisation and supervision go hand in hand with flawed verification procedures. A verification policy that is poorly designed or not adapted to the existing risks acts as a disincentive for technicians to follow the rules. As an example, the inability to ensure that quantities used

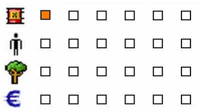
match workstation authorisations might lead technicians, as in the case above, to pay scant attention to the indicated values, no matter how critical they may be when working in contact with pyrotechnic substances.

3. Case of a technician who takes it upon himself to solve a problem

Examples of accidents corresponding to this case



ARIA 31905 - 24 February 2005 - 45 - LA FERTE-SAINT-AUBIN
In an explosives factory, a production technician was periodically cleaning the crimping devices of detonators using a rag soaked in alcohol. During this operation and the follow-up visual inspection, he noticed a number of metal burrs on the punch. **Remembering how the explosives expert and adjuster handled this situation, he disassembled the punch-holder unit using dedicated cleaning equipment. A pop (detonation) occurred when removing the metal parts.** Friction had caused the reaction when cleaning metal burrs fouled by a primary explosive (detonators containing 25 mg of dextrinated lead azide and 50 mg of reinforcing compound). The technician escaped with just a few slight wounds to the face and finger since he was wearing safety glasses and ear plugs. **Despite the instructions, operating protocol, training and his experience, this technician still performed an unplanned task without assessing the hazard.** Usually, such operations are carried out alone behind a screen by either the adjuster or explosives specialist, and only after foreman approval and chemical neutralisation of the explosive.



ARIA 24923 - 26 September 2002 - 65 - TARBES
During initiator loading with a potassium perchlorate and zirconium-based pyrotechnic compound, 110 g of compound reacted in the hopper. The hopper's cover pin was ejected in blasting off the cover.
The automatic cycle of the machine was stopped after detecting a settling defect. **The technician, believing that the storage cell had not been filled properly, restarted the cycle, which led to a double filling.** The friction generated by this overfilling of the cell triggered the initiation. Subsequent analysis revealed that the compressive force control sensor had been inoperable since a prior incident (ARIA 24922).
The plant operator modified the machine and informed personnel about the need to warn supervisors whenever an anomaly is detected, in order to analyse the situation before any resumption of activity. The operator also implemented an inspection procedure for safety devices like sensors after each reported incident.

Analysis of root causes

When a technician takes initiative in the aim of resolving an abnormal situation on his own, he is showing a desire to "focus on the most urgent" even if it means overlooking basic safety principles. This type of phenomenon is also on display in the example of a management employee who decides to take action despite poor knowledge of the installations and a role without direct responsibility over technical operations, and finally commits an error while attempting problem resolution. Such response to exceptional situation raises questions over the extent of employee awareness about risks incurred and how risks are managed as part of the corporate culture. Has the organisation been efficient enough in its effort to build risk awareness? Are the models proposed by managers consistent with the expected safety attitude? Are some goals actually at odds with the implications of taking a more cautious approach (e.g. productive pressure)?

In building risk awareness, it must be ensured that the training offered to hands-on personnel is adapted with respect to both its content (inclusion of explanations on the behaviour to adopt when confronted with an atypical situation, e.g. malfunction, faulty classification) and its dissemination to technicians (necessity of refresher courses or regular "review sessions" to enhance assimilation of the material). The two accidents summarised above illustrate the drifts tied to inadequate training: error in identifying the type of fault occurring at an installation, failure to implement the supervisor's alarm procedure when an anomaly arises.

Organisational deficiencies in the area of risk identification are associated with incomplete procedures that give technicians too much leeway regarding the behaviour to adopt: ARIA accident 24923 reveals that, prior to this incident, no formalised procedure had required the systematic verification of key safety-related elements following an incident.
Along the same lines as the case described in Section 2 above, insufficient training and failure to identify risks may rise a technician's overconfidence or lack of risk awareness and moreover let him believe in his ability to manage a situation on his own, no matter how complex, e.g. in repeating what had been witnessed previously by fellow technicians (see ARIA accident 31905).
The two examples cited above once again reveal the effect of a poor working organisation with insufficient oversight and supervision.

4. Case of a technician under pressure

Example of an accident corresponding to this case

ARIA 20502 - 15 February 2000 - 83 - TOULON
When handling a missile launcher, a missile fell 0.6 m, yet this did not trigger any pyrotechnic activation. **The forklift operator was using an inappropriate vehicle in order to save time.** He raised the missile too high off the ground, which caused the fall. Other anomalies were also recorded: the container had not been properly marked; the crate was blue (i.e. the colour used for drill exercise equipment) despite the missile not being inert. The missile was only slightly damaged and able to be restored. The operator re-issued the operating guidelines in addition to holding quarterly information sessions, as required by the decree of 28 September 1979 related to the protection of workers in the pyrotechnics industry.

Analysis of root causes

Situations involving procedural violations by technicians subjected to pressure are commonly encountered in the realm of handling operations, as illustrated by ARIA accident 20502 above, as well as by the accident that occurred in Italy and presented at the IMPEL 2015 seminar: due to a peak in seasonal activity, employees at a fireworks plant acted hastily and without following the full set of safety rules.

A worsening psychosocial environment might also constitute a deep-rooted cause of certain procedural violations: excess workload (than can prompt a technician to assume responsibility for a task outside his assigned mission, in a move to "help colleagues", and thereby lead him to commit an error), or stress tied to extreme operating constraints or scheduling demands. Along these lines, it is worthwhile to note that an excessive workload often becomes a chronic problem, e.g. a return every July for recreational fireworks manufacturers.

While the number of known cases clearly pointing to excessive pressure on technicians as the underlying accident cause remains quite small, these cases still provide instructive value. Such a configuration is in fact likely to be present in a larger number of cases than it appears at first glance. It should nonetheless be noted that problems of psychosocial workplace conditions more often act as an exacerbating factor for other deep-rooted causes (e.g. risk identification, workplace organisation).

Conclusion

Technicians' awareness of the importance of procedural compliance is critical, if merely for their own safety: breaches like neglecting to wear individual protective gear or failure to abide by the "in case of accident" response protocols can worsen the human consequences of accidents. In the pyrotechnics industry, even more than in other sectors, anything not specifically authorised is strictly prohibited. The organisation is responsible for implementing the right resources to avoid these operational drifts via a multifaceted strategy, whereby a purely procedural and organisational dimension must be complemented by a robust "safety culture", i.e. raising risk awareness coupled with promoting a prudent and precautionary attitude in any situation on the part of technicians.