MINISTRY FOR AN ECOLOGICAL AND SOLIDARY TRANSITION

Accidents related to incorrect circuit positioning

Understanding causation to prevent re-occurrence

- May 2018 -

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Contents

Summary

Fluid transfer is a common industrial operation. However, the incorrect positioning of transfer circuit during such operations, also referred to as poor alignment, is the cause of many accidents. This study, based on 372 events in the ARIA database, presents their characteristics and lessons learnt.

What are we talking about? In 92% of the accidents encountered, an alignment error leads to loss of containment and the release of hazardous materials: directly (an open valve) or indirectly (pressure build-up and leakage). Chemical, food processing and refining industries account for half of the cases, but a great number of sectors of activity are affected. Accidents occur at any point in an installation's service life: operation, works, tests, etc. Frontline employees: the number of accidents with victims exceeds the database average by 11%.

What happened? An initial analysis shows that inappropriate human interventions are responsible in ¾ of the events: drain left open, a forgotten lockout operation, connection or programming error, etc. But beyond that, organisational failures are also identified in 90% of the cases. Working conditions unfavourable to accomplishing these operations safely were noted in half of the accidents. A lack of robustness in the risk management process is a breeding ground for accidents.

What can be done? Without claiming to offer a miracle solution, a deeper analysis of these accidents makes it possible to identify elements of feedback, including:

- ✓ training of the interveners, their knowledge of the installations and the dangers involved, and operating methods;
- ✓ relevance of the procedures in order to inspire adoption and confidence among technicians;
- ✓ ergonomics of the field installations and monitoring & control systems;
- ✓ rigour of the organisation of activities, within the production and maintenance crews;
- ✓ management of permanent or temporary changes;
- ✓ risk analysis of each work situation;
- ✓ safety culture, reflecting an organisation's commitment to effectively manage its safety.

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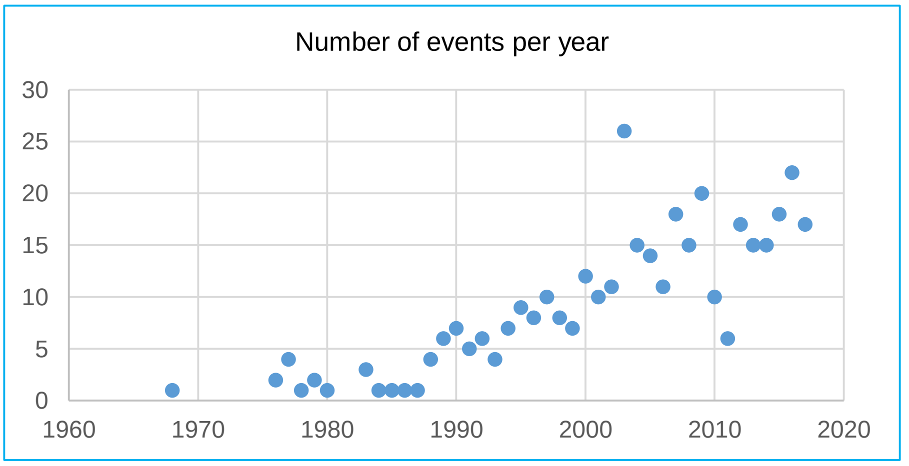
Foreword

As of 30/04/18, the ARIA database contains a large number of reports on accident attributed to errors in alignment. This task involves manipulating valves to operate equipment or put a system into service. A review was conducted on 372 of these events, each selected for their interest in terms of feedback and includes 51 accidents that occurred abroad. Any event resulting from the positioning of an element, manual or automatic, that is different from the expected configuration, is considered an alignment error: e.g., a leak from an open bleedoff, a rise in pressure due to a closed vent valve or a mixture of incompatible products due to the improper positioning of a 3-way valve.

Increasing frequency

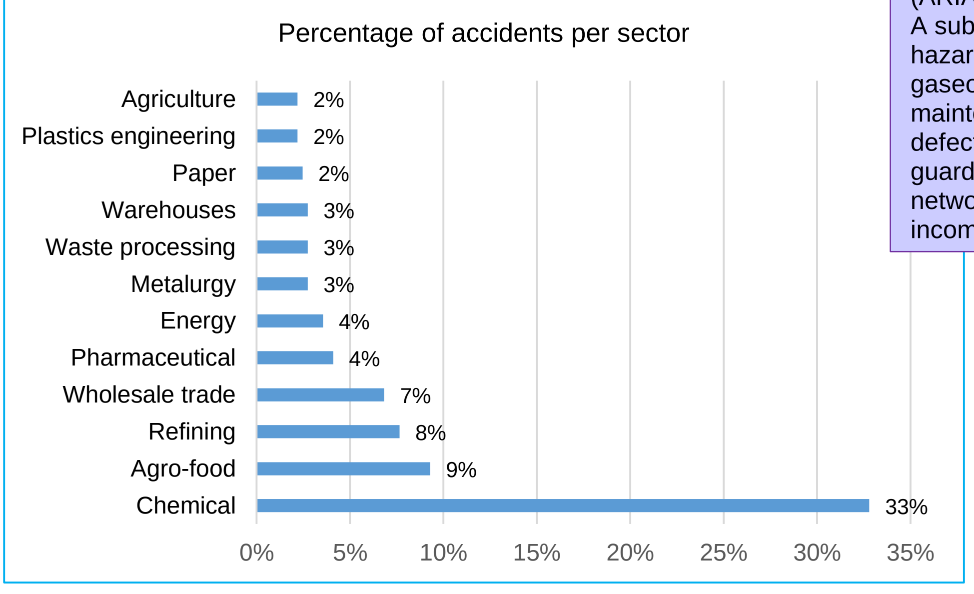
The graph below shows the number of accidents per year in the study sample. When the upward trend is clear, it is partly explained by greater accuracy of the information received by BARPI. This obviously makes it easier to identify accidents that are the result of poor alignment.

Explosion of a gas cloud
(ARIA 891)
In a polyethylene plant, a cloud of gas, escaping from a reactor under construction, exploded. Twenty-three people were killed, and 314 injured. A shut-off valve was opened because its compressed air supply was inverted. Contrary to safety standards, the intervention procedure did not include a shut-off device consisting of a double valve or a blind flange.



Many sectors of activity affected

While the process industry sectors are the first concerned, alignment errors occur in nearly all the fields represented in the database. Twelve sectors make up 80% of the accidents. The percentage of accidents that occurred in each of these sectors is represented in the table below.



Ignition of a gaseous mixture
(ARIA 49472)
A subcontractor was burnt in a hazardous waste centre when a gaseous mixture ignited during a maintenance operation. Design defects were identified; hydraulic guards were absent on a sewer network common to potentially incompatible waste.

A third of alignment errors, therefore, occur in the chemical sector. By way of comparison, this sector's share of all accidents in the database is only 9.5%.

Main dangerous phenomenon: release

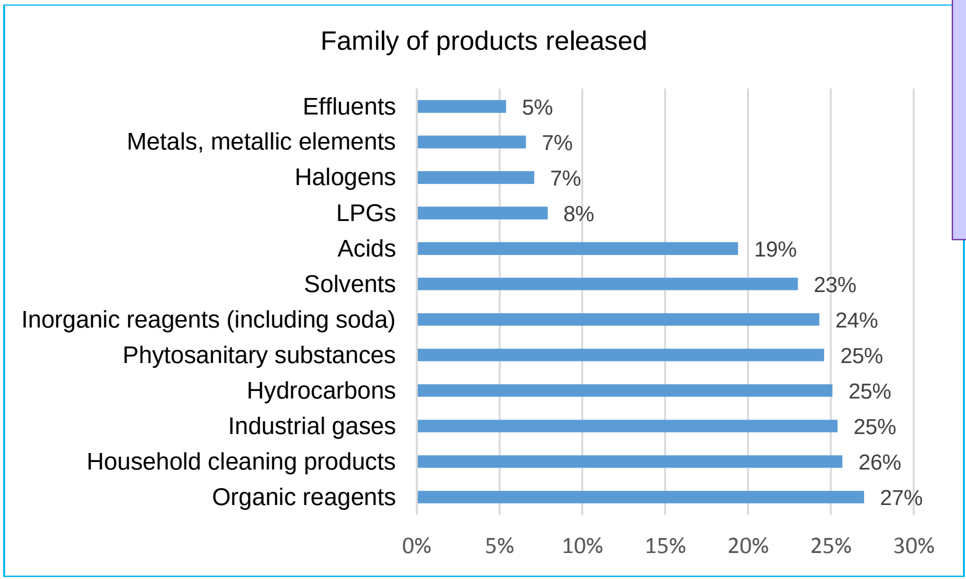

ARIA 48178 © BARPI

As shown in the table below, poor alignment is by far the greatest cause of a loss of containment with a release of materials. Compared with the database as a whole, fires are significantly less frequent.

Phenomenon	Alignment events (372 cases)	Total ARIA (49,306 cases)
Explosion	12%	12%
Fire	15%	48%
Release of hazardous materials/pollutants	92%	54%
Other	4%	7%

The hazardous materials involved are just as varied as the sectors of activity. The main families of materials are shown below, along with the percentage of accidents in which they are involved.

Oil leak (ARIA 49806)
An oil leak at 275 °C occurred when a sensor was removed from a boiler: a shut-off valve had remained open. This valve, not being properly marked, was barely identifiable. Moreover, the intervention procedure only manages lockouts, not tagouts.



Mobilisation of internal response teams


ARIA 46216 © BARPI

The events involve such a diversity of installations and materials that a review of the intervention techniques or difficulties is of no interest here. However, as can be seen from the table below, these accidents are more frequently controlled internally by the facility operator than is the case for the average of accidents within Installations Classified for the Protection of the Environment (ICPE).

Intervention	Alignment events (372 cases)	Total ICPE (35,068 cases)
Intervention by company personnel	42%	17%
Intervention by the establishment's first response teams	12%	5%
Activation of an emergency plan (internal emergency plan, etc.)	13%	4%
Public emergency call by the facility operator	36%	52%

Release of NOx (ARIA 48831)
Nitrous oxide vapours escaped from a fertiliser plant. Pneumatic valve controls had been erroneously locked out. The technicians were slow to understand because their synoptic did not display the actual position of the valves. The facility operator compiled a quick reference card/emergency instruction sheet for the control of critical parameters in accident situations.

As a reminder, compared to the average of accidents in the database, a greater proportion of these accidents occur in process industries. It can, therefore, be assumed that the training of such technicians to manage these types of accidents allows them to intervene with greater autonomy than the average ICPE facility operator.

In addition to the dangerousness/toxicity of the released materials, certain complications in event management stem from difficulties for control technicians to understand the accident scenario (ARIA 48831, 48384, 29213).

Numerous victims

The consequences of the accidents caused by poor alignment are presented in this table:

Type of consequences	Alignment events (372 cases)	Total ARIA (49,306 cases)
Human consequences, including:	33%	22%
--> fatal accident	6,1%	5,7%
--> injured, including:	30%	20%
--> seriously injured	7%	5%
Economic consequences, including:	49%	70%
--> internal property damage	38%	67%
--> external property damage	6%	6%
--> internal operating losses	24%	21%
Social consequences, including:	17%	28%
--> safety perimeter	12%	18%
--> technical unemployment	1%	7%
--> population confined or evacuated	8%	11%
--> interruption of traffic	4%	6%
Environmental consequences, including:	52%	33%
--> air pollution	22%	12%
--> water pollution	26%	17%
--> soil pollution	13%	6%
--> harm to wild flora or fauna	6%	5%

Explosion and fire on a cracking plant (ARIA 6189)
The overfilling of a separator during the restart of a refinery resulted in an explosion and a fire. One technician died and seven were injured. The supply valve failed to close automatically when the high-level threshold was exceeded in the separator, as the alarm had been disconnected for a number of years. The technicians, believing the level indicator to be faulty, no longer relied on it.

The human and environmental consequences are significantly more serious than the average of the accidents in the database, but the economic consequences are lower. These results correlate with the elements previously developed:

- ✓ the loss of containment is much greater, placing the personnel in immediate danger (all the more so in the sectors of activity concerned, given the dangerousness of the materials involved) and the environment;
- ✓ fires are rarer, although they are a dangerous phenomenon that often results in far-reaching material consequences.

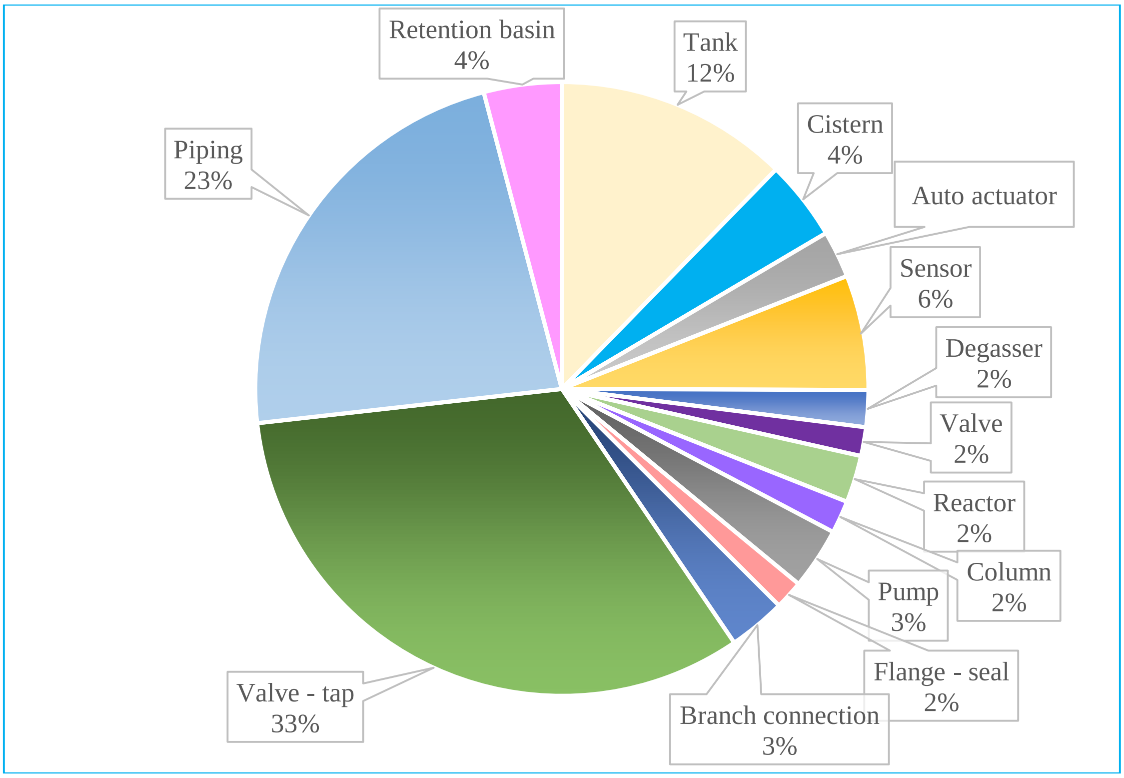

ARIA 48039 © BARPI

As the table shows, 6.1% of the accidents in the sample (41 events) were fatal. They were responsible for 49 deaths, two of which occurred outside the original site. Twenty-three employees were killed in the same event (ARIA 891 - Explosion of a gas cloud in a chemical plant during a maintenance operation in an operating unit: 40 t of gas were released via a shut-off valve that remained open due to the inversion of the connections on the compressed air supply hoses actuating it). However, over the last 10 years, only one fatal accident has occurred in France (ARIA 46729: death of an employee when the cooling system of an ingot mould in a foundry exploded: the lack of communication between production and maintenance following an intervention led to the ingot mould unit being returned to service, even though its cooling system had not been tagged out).

Equipment involved

The components of the transfer systems, including piping and valves, naturally represent more than half of the equipment identified as being involved in accidents. Many other pieces of equipment are also involved, as shown in the graph below which details the proportion of events where the type of equipment is identified.

Release of hydrochloric acid
(ARIA 40319)
In an additive manufacturing plant, an uncontrolled reaction resulted in the release of HCl vapours. An excess of reagent, coming from a manual valve left open, was at the origin of the accident. Without a position indicator, its condition was difficult to control. Specific procedures were identified in the hazard study to control this risk.



In the beginning, human intervention or a component defect …

In 22% of the accidents, an unnecessary human intervention in the normal course of the process underway is identified. These actions may be voluntarily violations of the rules by facility personnel (ARIA 49172, 48177, 43955) with, in certain situations, an intent to harm the company (ARIA 47919, 38027).

Hydrochloric acid leak (ARIA 48177)
In a chemical plant, 1 m³ of HCl spilled onto the ground during a maintenance operation. Violations of intervention procedures were noted. The procedures for issuing work permits were reviewed: overly general sentences, which do not provide specific prevention measures, were withdrawn.

On the other hand, 10% of the accidents resulted from actions not taken, even though they had been ticked on the checklist in the procedure used (ARIA 37478). And 43% of the cases correspond to required actions but which were not carried out in accordance with the procedures (ARIA 49950, 45279, 44919, 36310, 35300…).

It may also be due to a problem with the subcontractor supervision procedure (ARIA 42229). These actions may be performed out of habit (such as closing the air inlet on a pneumatic valve instead of using the stop command: ARIA 36165).

Component defects were noted in 39% of the accidents. These are differences, or imperfections, between the actual and expected state of a component. The following are illustrations of these causes:
- ✓ a solenoid valve blocked by soda crystals (ARIA 48384);
- ✓ a "dead man" switch that did not close (ARIA 51260, 50686);
- ✓ pressure sensor and high-level sensor malfunctions (ARIA 37915);
- ✓ short-circuiting of a remote control left out in the rain (ARIA 50440);
- ✓ reversal of valve controls following a wiring error during an electrical intervention (ARIA 46089) or reversal of compressed air hoses (ARIA 7069).

Latent hazards are identified in 9% of accidents resulting from poor alignment. These are underlying safety threats that require a trigger to materialise as a dangerous phenomenon, for example, the unexpected presence of residual chemicals in equipment (ARIA 50424, 48639) or in rainwater systems (ARIA 47919, 46089).

… which result in organisational failures

The accidents in this study were selected for their teachings, which explains why there are far more elements of causal understanding than for the average ICPE events in the database. Thus, the causes are identified in 90% of the accidents in this study, whereas this rate is only 53% for all ICPEs. Nearly all these causes stem from organisational factors. Human deficiency factors, i.e. elements that disrupt an employee's physical/cognitive/mental abilities and that are not the responsibility of the organisation, were identified in only one accident. All the organisational factors, together with the percentage of accidents to which they contributed, are shown in the table below.

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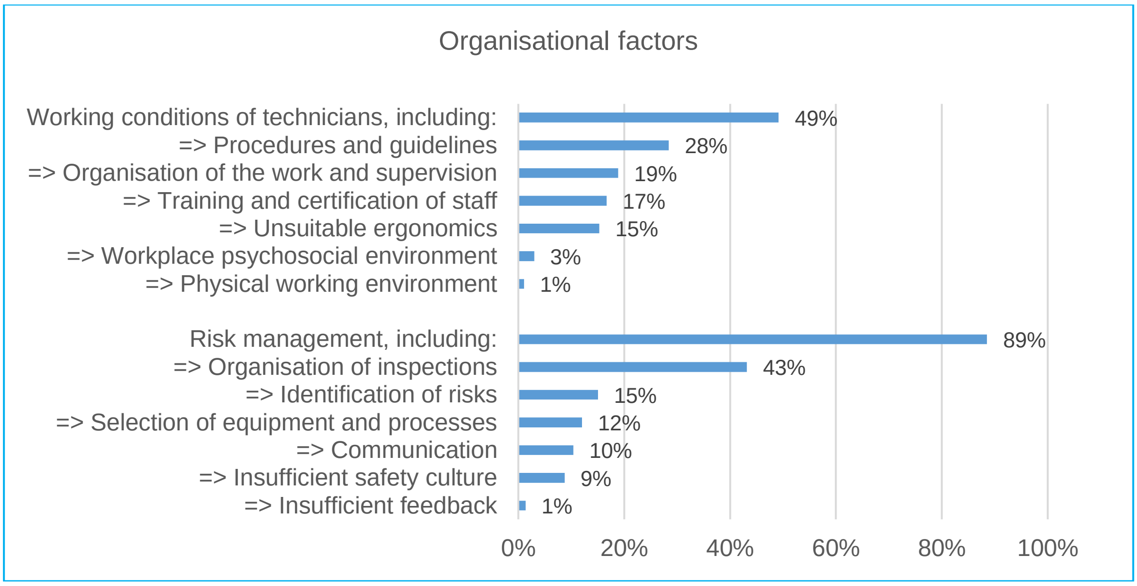
Ammonia leak (ARIA 46817)
Three employees were hospitalised, intoxicated by a release of NH3 in an industrial pastry factory. A handling error of a valve by a boilermaker was at cause. As the operation was not initially planned, he was unaware of the simultaneous intervention being performed by a refrigeration engineer. In addition, two valves, located side-by-side, had opposite operating directions.



Inadequate working conditions

Obstacles in the technicians' working environment were noted in half of the accidents.

Operational procedures

As an integral part of alignment operations, procedures were at the head of the list of organisational failures. The following situations may be noted:

Leak of boron trifluoride (ARIA 51230)
Five employees were hospitalised following the release of 15 kg of BF_3 during the restart of a petrochemical site. A valve had remained open during a leak test performed the previous day. The operating procedure did not specify the position of the valve (not identified in the DCS) upon completion of the test.

- ✓ no procedure (ARIA 49806, 46216, 44988, 39759, 35165) or only oral transmission of rules (ARIA 44813, 37516);
- ✓ the minimisation of certain operations considered too simple to be described in a procedure, such as draining test water (ARIA 48178, 45535), a nitrogen leak test (ARIA 51230) or the purge of equipment (ARIA 29213, e.g.: the absence of pipe purging caused an uncontrolled reaction when it was put back into service => sudden increase in temperature => outside the pressure vessel's P/T operating range => ripping below the valve opening threshold);
- ✓ lack of precision: responsibilities were not identified during manual intervention by several technicians (ARIA 49382) or checks conducted by several persons (ARIA 31227), vague distribution of tasks between the operator and the carrier during an unloading operation (ARIA 38625);
- ✓ inappropriate form: a collection of good practices that do not allow operational implementation, unlike a checklist (ARIA 47726);
- ✓ excessively dense content, which increases the risk of steps being forgotten: a single work authorisation for all the opening/closing operations of a pipe (ARIA 33393);
- ✓ an invalid procedure, which had not been updated after recent modifications (ARIA 21516).

Organisation of work

Failures in the organisation of work, in the distribution of tasks and responsibilities or inadequate resources for the workload and the complexity of the activity, were present in many events. We note the following examples:

- ✓ a lack of consultation and appropriate planning between the players involved:
  - ❖ co-activities on raw material lines used by several units of an industrial site (ARIA 50422);

❖ simultaneous interventions by two subcontractors on the same ammonia line => unexpected change in the installation's condition (ARIA 46817, 46185);
❖ performing tests on the digital control-and-command system (DCS) directly impacting ongoing production operations (ARIA 42746).

Ammonia leak (ARIA 41059)
When a service provider was filling a tank, 2.1 m³ of NH3 was released via a drain. The day before, the technician preparing the operation was interrupted to take an urgent sample. The service provider's procedures did not provide for an inspection of the installation.

✓ diverting a technician's attention: interrupting a technician in the middle of a task by requesting an additional activity due to production workload (ARIA 48073, 41059), several monitoring missions to be performed at the same time (ARIA 36531);
✓ loss of information transmitted orally between shift changes: in the absence of a "non-usable" status label, commissioning of a non-functional ingot mould (ARIA 46429), an unreported out-of-service condition on a transfer station in "works" configuration for an intervention to be performed the following day (ARIA 49132);


ARIA 5132 © BARPI

✓ operations performed in haste during periods when units are nearing the end of their shutdown periods: tagging out of large elements while certain lockouts must be maintained (ARIA 47926) or when the intervention is not completed (ARIA 44070);
✓ long-term retention of situations intended to be temporary:
❖ a connection system that was intended only for restart phases (ARIA 28545);
❖ a valve left open caused an increase in pressure that was not detected by the referent sensor, disconnected for years. A practice on one sensor, deviating from standard practices for pressure monitoring, had become widely used (ARIA 6189).

Training and certification

In addition to inappropriate human intervention, the lack of training provided to workers, employees or subcontractors, is frequently identified as a source of risk (ARIA 47456, 42489). Below are some examples:
✓ technicians not trained to perform the task at hand (ARIA 46121, 37516), particularly during the summer period (ARIA 27120) or during night-shift operations on utilities in the absence of dedicated day-shift crews (ARIA 51230, 47253);
✓ insufficient training in relation to the complexity of manual operations (ARIA 19471);
✓ a last-minute replacement by a maintenance subcontractor who had not been provided with the safety instructions (ARIA 46817);
✓ a lack of training leading to the repetition of incorrect practices becoming routine, in the absence of procedure (ARIA 50452);
✓ lack of awareness as to the dangerousness of an effluent: unreported release of toxic wash effluent into the environment (ARIA 48536);
✓ training deficiencies that lead to inappropriate physical positioning of the technicians: a technician was facing the drain when it was opened and was blasted in the face with propylene (ARIA 48073), or improper operation because it was performed at arm's length (ARIA 34067).


ARIA 26363 © BARPI

Ergonomics of the installations

Difficulties related to accessibility or inappropriate configurations (components, software, workstations) are often detected. In these failures related to the ergonomics of the installations, the following can be noted:
✓ the lack of identification of the components: incorrect marking (ARIA 47628), incomplete marking (ARIA 48831 lockout error due to the pneumatic valves not being properly marked at the remote compressed air outlets) or missing marking (ARIA 49139 no indication that a manual valve was locked open);
✓ difficulties in determining the position of valves: position not identifiable (ARIA 49806, 42489) or inaccessible (ARIA 47456, 37915);

Overflow of a diesel tank
(ARIA 40584)
1,000 m³ of diesel fuel flowed into a refinery's retention basin. This was caused by incorrect valve marking. The high-level sensor in the retention basin triggered an alarm on the DCS but was not taken into account as new sensors were triggering many false alarms.

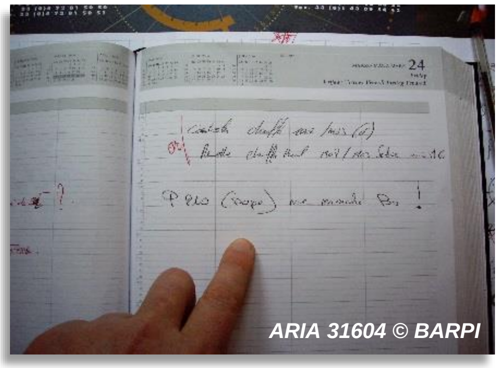
✓ complex configurations: two valves, side-by-side, that operate in opposite directions (ARIA 46817), valve not equipped with coded pins unlike the other valves in the unit (ARIA 44813);
✓ cramped working conditions: involuntary manoeuvre by the foot (ARIA 36310) or resulting from an impact during work on other equipment nearby (ARIA 32965, 9904);
✓ DCS interface:
❖ the diagram shows the position order attributed to a pneumatic valve and not the actual position (ARIA 48831) or an undefined operating mode (ARIA 41300);
❖ visual overloading of alarms on the control screens (ARIA 40584).

Communication

Communication problems are also highlighted in the study. These problems can occur at any level:

- ✓ between the facility operator and the fire brigade during the response: a misunderstanding about the responsibility for the containment of extinguishing water (ARIA 46675);
- ✓ between the maintenance department and the production crews: control technicians, uninformed of tests, deactivating alarms (ARIA 45692), operation in progress on a valve (ARIA 41300) or the unavailability of a piece of equipment (ARIA 35300 lockout status deleted from a table);
- ✓ between the facility operator and a subcontractor in charge of tagouts (ARIA 44070);
- ✓ within the production crews:
  - ❖ incorrect setpoint passage on the alignment of a system (ARIA 35863);
  - ❖ report of a defect lost after two shift changes: loss of hardcopy instructions on the 1st shift, then deletion of the computer file on the second shift (ARIA 40091);
  - ❖ a technician, returning from holiday, uninformed about an urgent change in practice that occurred while he/she was on holiday (ARIA 22104).

Kerosene release (ARIA 31227)
In an oil depot, 32 m3 of kerosene flowed from a buried tank. Causes: valve operating errors (frequent operations, succession of technicians, “blind” confidence in a colleague's verification), and malfunction of the tank's high-level sensor, known to be in a bad state of repair.


ARIA 31604 © BARPI

Deficient risk management

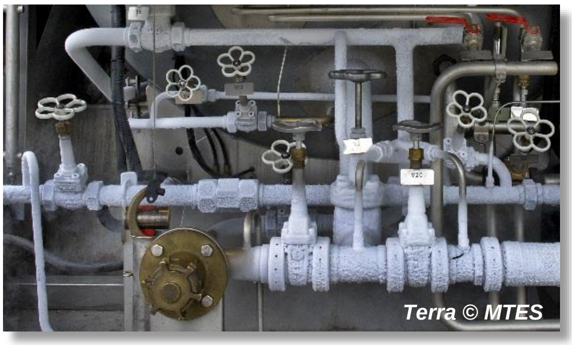
Well before the alignment action itself, an analysis of the risks present on the installation is essential, as for each operating situation. As the graph at the top of this chapter indicates, defects of this nature are frequent. Weaknesses in risk analysis are observed at different levels:

- ✓ analysis not performed as it was not deemed necessary:
  - ❖ for an operation, qualified as being as simple as managing washing water (ARIA 24726);
  - ❖ for a temporary change of operating mode (ARIA 35863);
  - ❖ on peripheral elements such as gaseous effluents: the unidentified interconnection of different units by the vent system (ARIA 49472);
- ✓ accident scenarios not taken into account:
  - ❖ due to underestimation of potential effects (ARIA 44988, 38601);
  - ❖ because a countermeasure (controlling the closing of the valve) is in place, even though it has been proven not to be robust (ARIA 35145);
  - ❖ due to omission; no gas leak scenario had been studied in a gas-fired power plant (ARIA 5132);
- ✓ inadequate management of anomalies or degraded situations:
  - ❖ unreported (ARIA 37094, 34067);
  - ❖ known but untreated situations: broken handle not replaced (ARIA 41027), sensor left unrepaired (ARIA 31227);
  - ❖ a countermeasure is put in place, but as it is not permanent, it disappears over time (ARIA 46556) or is not efficient (ARIA 44813, 42125);
  - ❖ obsolete equipment is inadvertently returned to service since it was not properly locked out (ARIA 42229, 32877);
- ✓ risk not identified or analysis incomplete:
  - ❖ automatic lockdown of the process, though the sequencing did not take into account the risk associated with the collection of reagents (ARIA 48501);
  - ❖ DCS programming errors (ARIA 50235, 47813, 22206);
  - ❖ inadequate lockout procedure: shut-off by only one pneumatic valve whereas the group's standard calls for two shut-off valves or a blind flange (ARIA 891 which resulted in 23 deaths);
- ✓ disregard for alarms (ARIA 46087) or weak signals, occurring on frequent incidents but without consequences (ARIA 49950, 45244).

Release of chlorine (ARIA 48830)
≈ 100 kg of chlorine was released from a vent valve in a Seveso-rated manufacturing plant. Failures in the risk analysis were detected: the leak check did not highlight the opening of this valve because it was excluded and the safety thresholds were not signalled in the event of liquid chlorine present in the vents.

Finally, it can be noted that certain alignment errors led to accidents because they occurred in poorly designed installations.

- ✓ choice of a piping material incompatible with the fluid conveyed resulted in its embrittlement by corrosion, and its rupture during sudden pressure stress (ARIA 22231);
- ✓ inappropriate sensor locations (ARIA 49983) or no alarm triggered (ARIA 39759) in the event of an abnormal pressure increase;
- ✓ design defects on valves (ARIA 48384, 42408, 36599), containment systems (ARIA 35145) or gaseous effluent systems (ARIA 35310) that no longer perform their containment function when used outside the standard operating ranges.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Corrective and preventive measures

Following accidents, corrective or preventive actions of various kinds were implemented to prevent them from reoccurring. In three cases, disciplinary proceedings were initiated against the workers (ARIA 48177, 22941), including dismissal (ARIA 46156).

Technical provisions

The following technical measures were identified in the study:

- ✓ installation of additional equipment:
  - ❖ shut-off valve (ARIA 31015), notably inter-connected (ARIA 51178, 46156, 24727);
  - ❖ backflow preventer on the inlet of the public drinking water system (ARIA 25610);
  - ❖ drain to depressurise the piping in case of error (ARIA 36312);
  - ❖ plugs on unconnected valves (ARIA 36102);
  - ❖ emergency stop (ARIA 33063);
  - ❖ gas (ARIA 46156, 36165, 22231) or hydrocarbon detectors (ARIA 46089);
  - ❖ temperature alarm (ARIA 48501);
  - ❖ limit switches on a valve (ARIA 46574, 25057);
  - ❖ high-level detector in a recovery pit and servocontrol of motorised valves (ARIA 46089);

Leak of hydrofluoric acid (ARIA 46556)
In a chemical plant, the increase in pressure in a reactor resulted in a release of HF: a vent valve had been closed the day before following a suspected leak. Installed when the vent systems were modified, it had to remain open, with the handle removed. However, this handle was put back in place during recent work.

- ✓ modifications of existing facilities:
  - ❖ addition of valve identification information (ARIA 49760, 42489, 31015);
  - ❖ addition of visual valve position indicators (ARIA 44813);
  - ❖ a change in the type of valve: “dead man” valve installed in place of a standard valve (ARIA 36310), automatic valves in place of manual valves (ARIA 38601, 32642), inflatable bladder instead of guillotine valve (ARIA 48384);
  - ❖ removal of all manual valves upstream of the safety valves (ARIA 22987);
  - ❖ improved ergonomics of the transfer facilities (ARIA 48354);
  - ❖ transfer of audible alarms to areas where personnel are permanently present (ARIA 47926, 32841);
  - ❖ removal of entrapment configurations: installation of blind flanges on unnecessary openings (ARIA 47726), removal of unnecessary valves (ARIA 43753, 42346);
  - ❖ replacement of a mobile hydrogen unit by a distribution rack (ARIA 44315);
  - ❖ separation of compressed air instrumentation systems and processes (ARIA 36165);
  - ❖ separation of gaseous effluent systems of the various units (ARIA 49572);
  - ❖ a change of pump technology to improve reliability and reduce the number of interventions (ARIA 24726);

ARIA 5132 © BARPI

Release of SO3 (ARIA 35300)
An SO3 hose broke in a chemical plant. The use of locked out equipment was the origin of the accident: its lockout status had been erased from the lockout table by mistake. The facility operator has integrated a red “reactor secured” panel, which is activated and deactivated by the maintenance department.

- ✓ modification of the DCS:
  - ❖ modification of information feedback: a locked out valve is shown as being closed and not as faulty (ARIA 49983);
  - ❖ addition of an interlock between the equipment (ARIA 50422, 43271, 32806);
  - ❖ creation of an available (or unavailable) status in the PLC: the equipment is blocked until maintenance confirms its availability (ARIA 35300);
  - ❖ calculation of material inlet/outlet balance to detect leaks (ARIA 48384);

Organisational arrangements

Many facility operators are also reviewing the entire organisation to make improvements:


ARIA 44070 © BARPI

- ✓ updating the procedures for:
  - ❖ maintenance (ARIA 50426, 49472, 38413…), to impose the use of the torque wrench (ARIA 22206), by external companies (ARIA 42408);
  - ❖ lockout (ARIA 48830, 47919), requiring isolation by two valves (ARIA 50426, 29566), the mechanical blocking of manual valves (ARIA 47919), the disconnection of pneumatic valves (ARIA 24760), locking by chain and pin (ARIA 4985), removal of the spindle to lock a manual valve open (ARIA 46556), the installation of labels on open manual valves (ARIA 49132) or the display of an “unavailable” status on the control screens when the equipment is locked out (ARIA 35300);
  - ❖ unit shutdown: mandatory emptying of all equipment before intervention (ARIA 6189), prohibition of physical work on equipment during an intervention on the DCS (ARIA 50424);
  - ❖ return to service (ARIA 48830, 34451) to integrate valve position verification (ARIA 50888, 46574, 44919 42823) controlled by an agent who is specially trained for this task (ARIA 34220), providing for leakage testing of shut-off valves (ARIA 26431) or an equipment requalification inspection (ARIA 7069);
  - ❖ operation: on critical alarm management (ARIA 48639, 48501, 48384), with the drafting of a quick reference card/emergency instruction sheet for non-standard operating phases (ARIA 48831), including double verification (ARIA 29164, 21868) or on by-pass operating conditions (ARIA 36165);
  - ❖ management of degraded situations (ARIA 49760);
  - ❖ monitoring of retaining basins (ARIA 50475, 47456) or rainwater system isolation (ARIA 45087);
  - ❖ managing small operations such as rinsing (ARIA 48536);
  - ❖ security and surveillance of peripheral installations (ARIA 48178);
  - ❖ interventions, to make them understandable by everyone (ARIA 46675).

Leak of phytosanitary products (ARIA 40091)
An insecticide leak, in the form of dust, resulted in 8 intoxications. A leak on an unusable valve was the cause. The information was not transmitted to the morning crew due to the loss of the paper instructions, and the subsequent deletion of the computer file. The operator has since improved the traceability of situations.

- ✓ training of:
  - ❖ maintenance technicians (ARIA 50426, 50109, 46182,..), notably with regard to the specific risks of pressurised equipment (ARIA 14779);
  - ❖ technicians (ARIA 50426, 48831, 48639, 48536,…), notably to ensure information is passed on to the following shift (ARIA 40091);
  - ❖ subcontractors, with the establishment of a certification level (ARIA 36310);
  - ❖ implementation of a periodic check of the technician's level of training (ARIA 36165);

Chlorine leak (ARIA 36165)
25 kg of chlorine was released from the compressed air system in an industrial gases plant. This was caused by an inadequate security operation to contain a leak the day before. The operator dissociated the air systems, set up a system to periodically check the operators' training and the conditions relating to the use of secured by-passes.

- ✓ measures to improve the way in which activities are organised:
  - ❖ supply of installation drawings to the subcontractors (ARIA 77);
  - ❖ reinforcement of supervision and communication with subcontractors, through work permits (ARIA 48689);

- ❖ implementation of an operations logbook for equipment shared by several units (ARIA 50422), a lockout log (ARIA 46156, 40091) or an anomaly follow-up log (ARIA 7069);
- ❖ implementation of a Listed Establishments (ETARE) plan with the fire brigade and training of first responders (ARIA 46675);
- ❖ improvement of prevention plans before works (ARIA 36310);

✓ measures to strengthen risk management, such as:
- ❖ revision of the site's hazard study (ARIA 29337) or a risk analysis of the activity to take into account co-activities (ARIA 41059);
- ❖ modification of inspection plans (ARIA 48384, 36599);
- ❖ verification that no similar risk exists on other parts of the installation (ARIA 31793).

✓ reduction of potential hazards:
- ❖ limitation of quantities of hazardous materials present (ARIA 50319);
- ❖ modification of reagents (ARIA 48354) or elimination of activities involving excessively hazardous materials (ARIA 44988);

✓ implementation of a follow-up system with regard to failures of risk control instruments, with periodic system audits (ARIA 6199);

✓ measures for sharing feedback (ARIA 38308):
- ❖ to trigger a review in the case of conflicting information, and to avoid the tunnel effect (ARIA 47953);
- ❖ on the physical positioning of technicians in dangerous situations (ARIA 48073).

Propylene leak (ARIA 48073)
On a chemical platform, an operator was burned in the face by a propylene jet. In the absence of his work buddy, who had been called to another work position by their manager, the operator actuated a control lever in error: the group's instructions recommended that handwheels be used. The facility operator issued a news flash about the accident.

What lessons can be learned?

Upon completing the analysis of the 372 accidents included in the study, certain lessons can be drawn that will assist others in avoiding accidents attributed to incorrect alignments. As human intervention is at the heart of these operations, the training of those performing the operation is of utmost importance. Understanding the facilities and operating procedures is the basis of this. Also, understanding the dangerousness and toxicity of the materials, including effluents, is essential in order to be fully aware of the danger involved. Simple unit operations should also be covered in training. In addition, certain work situations involving specific risks, such as pressurised equipment or the transport of hazardous materials, cannot solely rely on the technicians' common sense and must be covered in specific training. In process industries, providing training to technicians on how to manage process deviations helps strengthen their resilience in the event of an accident and limit the consequences. It is beneficial to learn how to react when you deviate from established regimes, even when you don't understand the cause of the loss of control. Finally, it is important to ensure that reminders and refresher training are provided so that deviations do not become routine.

Guaranteeing the relevance of the procedures, without being limited to those related to operations, is one way to limit alignment errors. The design of a procedure requires precise characterisation of the task to be performed, its performance conditions and the profile of its users. In order to be understood, applicable and applied, a procedure must have certain characteristics: it must be accurate, legible and understandable, provide the right level of guidance to those involved (neither too much nor too little) and be tailored in its form to the situation where it applies. Finally, operational procedures must inspire confidence: be useful, validated, up-to-date and benefit from positive feedback.

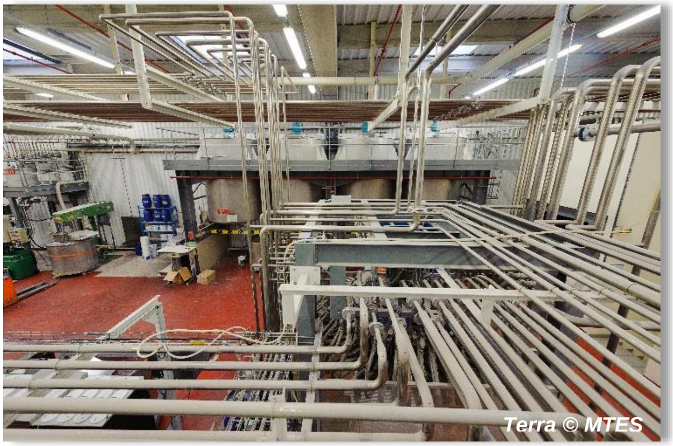
Release of nickel (ARIA 44813)
4.6 t of nickel solution flowed through a sampling tap in a chemical plant into the Rhone River. Unlike other valves, this valve did not have a cover to avoid operating errors. The ineffectiveness of the retention basin, due to a permanent bypass, was known.

The ergonomics of the installations is also crucial. Training and procedures cannot address inappropriate, dangerous or complex equipment configurations. For example, without correct marking or position indicators, alignment errors are inevitable. Moreover, these points and their homogeneity should be kept in mind as units are modified. While the physical layout of the equipment has a direct influence on its ergonomics, digital monitoring also plays a role. Increasingly automated control mimic panels are the mirrors of the production units. To best represent reality, their ergonomics must be relevant. Similarly, the number of alarms in the control room must be reasonable.

Control of alignment operations also requires rigour in the organisation of the work and its monitoring. The interface between production and maintenance teams appears to be of central importance. Responsibility for determining equipment availability and the associated securing operations, such as lockout/tagout operations, must be clearly and robustly defined. The same applies to issuing instructions at each shift change, designed to guarantee the continuity of information: the condition of equipment, anomalies, etc. It is also advisable to adapt task sequencing in order to avoid conflicts linked to co-activities on the same installation. This is applicable for the normal operation of the units, and particularly during work periods. Finally, equipment re-qualification operations performed when restarting an installation after interventions, carried out with non-hazardous fluids or at low speed, make it possible to detect any errors while limiting their consequences.

Particular attention must be paid to modifications, including in the context of installation maintenance as they are frequently responsible for alignment accidents. In particular, one should be wary of temporary or transitional situations. The risks associated with these one-time changes should not be minimised. They must undergo rigorous analysis so as to identify the necessary responses and to guarantee their robustness throughout such temporary periods (many of which end up becoming permanent). The same applies to both physical changes and the supervisory PLC (e.g. from automatic to manual control). In addition, removing equipment from service is also a modification that must be dealt with on a permanent basis (dismantling, disconnection or blanking off) to avoid its unintentional use. Finally, as soon as they are implemented, the permanent modifications must be included in the inspection drawings and the operational procedures.

Leak of butadiene (ARIA 21516)
In a refinery, butadiene leaked through a valve for 30 minutes. The leak was due to the pressurisation of the circuit as a result of incorrect alignment: recent modifications to the automated valve controls had rendered the previous operating procedures obsolete.



Risk analysis, the cornerstone of prevention, forms the basis for measures to avoid these events. Firstly, we must refuse to systematically exclude certain operations considered as harmless. Purging and cleaning actions, etc. can lead to accident-causing situations. Similarly, process analyses should not be limited to single operations at the core of the process, but also include peripheral operations involving effluents. On this point, special attention should be given to the interconnections between the various units. In addition, it should be noted that the securing of the installations, by means of an emergency stop or the control PLC, are critical phases. All the consequences must be evaluated, particularly those relating to major units opened due to a lack of air, and safe means of exiting the unit. Similarly, the DSC programming task should be analysed. Additionally, feedback from industrial accidents should ensure that scenarios are not mistakenly excluded from a hazard study.

To conclude, proper control of alignment operations is one of the positive effects of safety management by the facility operator. It reflects the strength of individual and collective values, attitudes, skills and behaviours as well as an organisation's commitment to effectively manage safety. A safety culture cannot be established in environments where violations of safety procedures at all levels are routine, where priority is given to productivity and savings, and without a commitment from management. Employees or subcontractors cannot alone compensate for the accumulation of organisational failures. For example, the same high standards and rigour should be applied to tagout operations as to lockout operations. At the end of operations, just before the equipment is put back into service, the tagout stages are particularly vulnerable to pressure for productivity, even though they play a major role in the safety of the installations.

Naphtha fire (ARIA 50452)
During a maintenance operation in a refinery, two operators opened the wrong purge. Four-hundred litres of naphtha spilled out and caught fire. The operators were not qualified to perform this task and, like 10% of their colleagues, did not follow the operating procedure. The authorities noted persistent shortcomings in the facility operator's safety culture.

TECHNOLOGICAL ACCIDENT SUMMARIES ONLINE

Safety and transparency are two legitimate demands being imposed by society. In response, since June 2001, the Ministry for an Ecological and Solidary Transition has made www.aria.developpement-durable.gouv.fr available to professionals and the general public, presenting the many lessons drawn from analyses of technological accidents. The main headings of the website are presented in both French and English. Users may, for example, obtain information on governmental actions, consult large excerpts from the ARIA database, find out about industrial accidents at the European level, and check the index of hazardous substances to round out the information provided in news bulletins and announcements in the wake of accidents or incidents.

The description of accidents, as the raw material of any feedback-driven approach, makes up a significant portion of the site's resources: the stages and consequences of an event, its origins, circumstances, identified or assumed causes, actions taken and lessons learnt.

Some 100 detailed and illustrated technical datasheets present a selection of accidents offering pertinent lessons. Many analyses by accident typology or industrial sector are also available. The heading devoted to technical recommendations is divided into various topics, e.g.: fine chemicals, pyrotechnics, surface treatments, silos, tyre warehouses, fire permits, waste processing, and material handling.

A multi-criteria search engine can be used to find information on accidents that occurred in France or abroad.

The site www.aria.developpement-durable.gouv.fr is continually expanded. There are currently about 50,000 accident reports available online, and new thematic analyses are regularly added.

The summaries of all events presented here are available on the following website:
www.aria.developpement-durable.gouv.fr

To submit a comment or suggestion, to report an accident or to obtain permission to use this data for publication purposes:
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