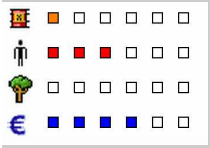
Bringing gas-powered installations back online

Explosion of a superheater within a steam-cracking unit

ARIA 36496 - 15/07/2009 - 57 - Saint-Avold

20.14 - Manufacturing of other basic organic chemical products



Superheater "A" on steam cracker no. 1 at a petrochemical platform exploded around 3 pm. Of the 8 staff present onsite, 2 were killed and the other 6 all injured. Projectiles, composed for the most part of refractory materials, were sent distances of some 100 metres, with some pieces nearly 50 cm in size landing immediately adjacent to the superheater; a dust cloud formed vertically above the site.

The Internal Emergency Plan was activated, resulting in the evacuation of plant personnel and the arrival of 70 fire-fighters. Of the 6 injured workers (2 of whom were subcontracted personnel), 5 would return home the same evening. No property damage or other impacts were recorded offsite, outside of noise caused by the deflagration. Continuous air quality measurements taken on the aerated zone did not reveal any anomaly. Both the Minister of Industry and the Secretary of State for Ecology visited the site.

Cylindrical in shape, with a diameter of 5 m and some 20 m high, this water vapour superheater, connected to a chimney of the same height via a connecting cone, was holding no toxic products. The explosion was not followed by fire.

Subsequent to violent storm activity during the night of July 13th to 14th, involving water infiltration that affected a utility room and disturbed the Digital Command and Control System (DCCS), steam cracking line no. 1 had been shut down and placed in safe mode.

The start-up procedure for this line had been initiated the morning prior to the accident; this procedure took a long time, as sections were brought back online incrementally.

On July 15th, superheater "A" was reset around 3 pm with the intention of proceeding by a manual restart. A technician arrived carrying an adjustable pole in order to switch on the pilots when the superheater exploded. The bodies of both this technician and a second employee would be found amidst the rubble, due in large part to collapse of the superheater floor.

According to the site operator, two distinct causes were responsible:

- an accumulation of inflammable gas below the flammability limit: the investigations conducted favoured the hypothesis of gas flow in the direction of the burner during both the start-up phase and the actual operation of restoring power;

- ignition of the dust cloud by the adjustable pole or a hotspot located within the superheater's convection zone.

Other ignition sources could be foreseen as well (electric spark, static electricity, etc.), although the two sources cited above would appear the most plausible. Certain circumstances facilitated the occurrence of this accident whose serious consequences were due to the presence of personnel in the vicinity as the superheater was being powered up; among these circumstances are:

- failure to proceed with a vapour cleaning of the superheater prior to restart, in violation of the operating protocol;

- gas inlet via a burner in the absence of a flame on the corresponding pilot;

- the technical safety barrier, according to which it is prohibited to supply burners without a visible flame on the pilot, was not operational. This barrier was composed of an automated mechanism that closed the gas feed valves if the flame detector has not signalled the presence of a flame 10 seconds after valve opening. Following a number of uncontrolled detection alerts shortly after installation, this automated detector mechanism would have been deactivated due to the limited number of shutdowns / restarts planned for the unit over its operating cycle.

Emergency measures were imposed upon the operator, as a precondition of restarting the vapour cracking line, including: submission of the accident report, update of the safety study relative to this part of the steam cracker, certificates of the good state of repair of all potentially affected equipment by a certified inspection body. The operator introduced a servo-controlled, automated function to ensure completion of all restart steps (vapour sweeping, pilot and burner ignition) along with a control panel for initiating the ignition sequence remotely.

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An explosion at the time of restarting a gas-powered thermal installation can take a dramatic turn, as was the case for the superheater in Saint Avold (ARIA 36496) and its 2 fatalities. Blast, thermal shock, structural collapse, projections of equipment or sizeable quantities of building fragments and materials, as well as broken windows in the vicinity, are the cause of many fatal accidents and/or injuries sustained inside the affected installation (ARIA 164, 5132, 6082, 6189, 9878, 26252, 36496) or its immediate environment (ARIA 5132 / child killed in an adjacent building).

Beyond the human casualties and property damage within the particular plant or workplace, neighbouring installations may also be affected (ARIA 1466, 26252 / tanks containing inflammable substances, liquefaction units), as well as area dwellings and the overall environment (ARIA 6189 / explosion of low-pressure separator inside a refinery evaluated at the equivalent of 90 kg of TNT, perceptible within a 30-km radius, 26252 / broken windows on adjacent buildings and shops).

While focusing on just explosion-related phenomena, events recorded in the ARIA database originate primarily from the presence of an explosive atmosphere containing combustible gas within a confined space, in the same busilding that basically houses the installation or combustion chamber, combined with its sudden ignition in contact with a hotspot.

- **An accidental gas accumulation in a confined space** may be the consequence of a number of deficiencies:
  - organisational and human:
    - procedures not respected and a gas feed line remaining open (ARIA 164);
    - insufficient vapour sweeping of combustible gases (ARIA 36496);
    - inappropriate valve opening manipulations (ARIA 3212, 6189);
    - maintenance flaws (ARIA 6343, 6560, 14666);
    - inadequate torque on the flanges (ARIA 32174);
    - incomplete installation modifications or failure to follow the acceptance procedure (ARIA 3212);
    - non-operational control and safety devices (ARIA 6343).
  - equipment:
    - relief valve (ARIA 6323), solenoid valves (ARIA 3212…), electronic fuel regulation components (ARIA 6537);
    - pipelines in open air (ARIA 6343);
    - joints (ARIA 6560);
    - defective weld or corrosion phenomena (ARIA 1015, 14666);
    - control devices and automated mechanisms (ARIA 6343, 32798, 36496);
    - poorly-designed safety accessories (ARIA 32817 / safety valves).
- **Ignition difficulties** can facilitate the appearance of some of the following:
  - pre-ventilation defects (ARIA 6538);
  - excessively low gas pressure at the fuel injectors (ARIA 6347);
  - flame detachment during ignition and multiple starts (ARIA 5132, 6323, 28389, 32175, 36496).

Other types of events have also been recorded such as the sudden vaporisation of heat conductor fluid subsequent to cracks or breaks on heat exchanger bundles inside vapour generators (ARIA 6082, 25754).

Accident records also underscore the imperative nature of personnel training regarding the specific risks related to installation start-up (ARIA 6189, 6343, 6538, 24354 / technicians' reliance on a "simplified procedure"), the existence of control procedures and guidelines adapted to this transient phase of installation operations (ARIA 32798) include: the creation of an organised monitoring programme for operational deficiencies and preventive/remedial equipment maintenance (ARIA 6189), completion of inspection audits (ARIA 6189), and the improvement of circuit sealant controls and safety accessories (ARIA 32817).

Following the explosion at the Courbevoie boiler room (ARIA 5132) and in taking the known accident history into account, a group of experts conducted a study on feedback specific to the safety of gas-powered boilers. This group's main recommendations and suggestions pertained to several technical and organizational issues, namely:

- installation design and construction (equipment location, assembly quality, placement of cut-off elements, gas detection instruments, etc.);
- installation operations, during normal periods or transient phases, and maintenance (technician awareness of the specificity of risks associated with system restart, strict written procedures and guidelines with close monitoring and control of their narrow field application, practical training and exercises).

The use of supervisory, detection and alarm resources appropriate to the kinetics associated with potential operational glitches, or the blocking or shutdown of sensitive controls, as well as mitigation devices in order to limit accident consequences are also of the kind to limit risks.

Additional references (both detailed reports and summary reports):

- ARIA 5132: Explosion of the Courbevoie boiler room
- ARIA 24354: Explosion of a gas-fired furnace
- Accident data on gas-powered heating installations may be downloaded from the Website www.aria.developpement-durable.gouv.fr - September 2008.

Accidents whose ARIA number has not been underlined are described on the Website:

www.aria.developpement-durable.gouv.fr

ARIA 164 – 27/04/1989 - 39 - TAVAUX

20.13 - Manufacturing of other basic inorganic chemical products

Inside a chemical plant, an electrostatic filter for removing dust, containing 696 plates sized 17.5 m x 7.5 m x 18 m on a 116-MW coal-fired boiler, exploded. The accident occurred during a restart procedure after a two-week shutdown for maintenance; it resulted from the accumulation of 440 m³ of gas inside the boiler following failure to close the backup burner feed line (300 m³/hr), which had been opened 1 hour and 20 minutes before the accident and which was discovered 90 minutes after the accident. One manual valve and two automatic gate valves stayed open (no visual control of valve position, automated shutoff of gate valves while continuing to inject compressed air, warning message ignored). The explosion caused 1 death and 8 injuries among the technician staff. Shattered window panes and projectiles were observed up to 250 m away. Total property damage was estimated at 20 MF.

ARIA 1015 – 20/07/1989 - 13 - MARTIGUES

20.14 - Manufacturing of other basic organic chemical products

A boiler built in 1962 that was producing 100 tonnes/hr of vapour at 82 bar and 475℃ exploded 3 days after restart following a 3-month shutdown for maintenance. The energy created cut 23 tubes out of the 470 present on the installation (A37 steel, diameter: 63 to 76 mm, thickness: 4-5 mm) less than 20 mm from the lower and upper drums. The screen burst open and was moved. Tube debris and refractory masonry were ejected a distance of 100 m and slightly injured a technician. This accident might have been caused by the simultaneous bursting of several corroded tubes (2-mm diameter) due to acid deposits (composed of metal sulphates), within a heterogeneous overlapping zone, followed by erosion as a result of a perforated tube. The cost of repairs was valued at 15 MF.

ARIA 3212 – 08/04/1991 - 71 - LE CREUSOT

25.30 - Manufacturing of steam generators, excluding boilers for central heating systems

Fitted with an automated regulation system and continuously operated without supervision since 8 February, 1991, an overheated water boiler (19.2 MW, 160℃, 11 bar) exploded during a manual control phase upon attempting to transition to a boiler with less capacity. The accident was caused by gas accumulation inside the firebox following the untimely opening of 2 solenoid valves in series, responsible for controlling the burner feed line. An electrical short tied to a previous cabling configuration, retained unexpectedly when installing the automated control system, wound up triggering a control relay switch common to both valves. No victims were reported; property damage, though significant, remained confined to the unit in question.

ARIA 5132 – 30/03/1994 - 92 - COURBEVOIE

35.30 - Production and distribution of steam and air conditioning

An explosion occurred at 1:30 am inside an urban heating plant (500 MW, 6,000 m² floor area), with the energy dissipated into the ground estimated at the equivalent of a 50 kg charge of TNT. Operational since 1987, this heating unit comprised 5 boilers (2 coal-fired, 2 fuelled by a coal/gas mix, and 1 gas-powered). During the previous shift, several attempts to start up one of the mixed fuel boilers failed. Unable to restart the equipment and with the gas inlet pressure gauges indicating zero pressure, the foreman of the night shift ordered opening both valves a quarter turn towards shutting off the gas inlet on the main circuit. Since the indicated pressure remained at zero, the shift foreman requested the boiler technician to open a blowout preventer and then a butterfly control valve to feed the mixed fuel boiler with gas. This operation resulted in a major gas leak. A gas boiler underwent emergency shutdown, and 2 technicians exited the unit to cut the general gas supply at the regulator station, 110 m from the building, when the explosion happened.

One of the 5 employees was killed on the spot. A girl 10 years old living 40 m from the plant died 4 days later due to the injuries she sustained; 59 other neighbours were also hurt. The installation was devastated and nearby districts severely damaged. A total of 600 personnel from local businesses had to be laid off temporarily and 250 residents were displaced from their homes. While awaiting hook-ups to neighbouring utility lines, some 140,000 users and 2.2 million m² of office space had no heating or hot water service. Operations of large-scale computer networks that relied on the plant for cooling, were disturbed. Total damages were valued at 544 MF (or €83 million). Investigation results indicated that 3,750 normal m^3 of gas would have been released until the gas utility company was able to cut the supply line 30 min after the explosion.

The defective pressure gauges might have been damaged by a pressure surge occurring sometime prior to the accident. The orders issued by the night shift foreman fell under the exclusive responsibility of the maintenance crew; in case of emergency, plant technicians should have requested intervention from the gas company. The blowout preventer had not been designed for handling within a pressurised environment, and moreover the butterfly valve upstream of the blowout preventer should have been adjusted by the boiler operator while the device had remained in the intermediate position, where it was no longer sealed since the flanges were slightly spaced. The gas cloud ignited upon contact with the coal-fired boiler, which was operating at the time of the accident. No scenario involving a leak and gas explosion had ever been assessed in any of the site's previous safety reports. The risks related to coal dust had not been addressed either. Dust particle behaviour was also likely to have contributed to the strength of this explosion.

On 5 May, 2004, the Versailles Appellate Court magistrate judging the case decided there were no grounds for prosecution.

ARIA 6082 – 08/121994 - 44 - BASSE-GOULAINE

10.13 - Preparation of meat-based products

Inside an industrial butcher shop, a smoke tube boiler set at 1 tonne/hour of steam exploded. According to its specifications, the boiler had a capacity of 2,790 litres, a heating surface area of 27 m² and was burning domestic fuel oil. Installed in 1979 to supply 5 pressure cookers, it had been rated at 10 bar. A whistling sound was heard at the level of the valve assemblies just before the explosion, which blasted the 200-m² building. Three employees were killed instantly (a body was found 250 m away along with the front boiler plate), 3 others were injured, one of whom seriously. The boiler frame (weighing 3 tonnes) was projected 150 m northward, while the firebox tube and a hot water tank landed 200 m to the south. The boiler, which had been off and drained for maintenance (relief valve, drainage tap) 3 days prior, was restarted the very same morning. One possible cause of this accident would have been the untimely and inappropriate filling of the heating unit with cold water, triggering a sudden vaporisation against the heating tube, which had already been heated to high temperature. An expert's appraisal released in 1995 indicated that partial draining of the firebox tube might have led to the observed state of damage strictly from an energy standpoint. This report however did not draw the conclusion that such draining was in fact the actual cause.

ARIA 6189 – 22/03/1987 - THE UNITED KINGDOM - GRANGEMOUTH

19.20 - Oil refining

At a refinery, a low-pressure separator exploded inside a hydrocracking unit undergoing a restart procedure. The explosion, of a charge equivalent to 90 kg of TNT, was heard and noticed up to 30 km away. The gases and inflammable liquids discharged (1 tonne of hydrogen, 400 tonnes of hydrocarbon) ignited and fuelled a fire that would cover 35,000 m². The human toll amounted to 1 fatality (a technician) and 7 injured. The missile-like effects of the explosion had threatened the safety of 200 people. Property damage was extensive, estimated at €7 million inside the site and another €7,000 outside (broken window panes, damaged roofs, etc.).

The accident occurred while the hydrocracking unit was being reset during a restart procedure subsequent to a routine shutdown. The inappropriate manual opening of a valve between the high-pressure separator (155 bar) and the low-pressure separator (9 bar) caused liquids to be transferred towards the low-pressure separator, whose relief valves had been designed solely to account for the fire risk, making these valves inadequate for the purpose of releasing excess pressure in the low-pressure separator (10 m long, 3-m diameter, 200 kg), which exploded at an estimated pressure of 50 bar. The suspected valve did not close automatically because the level alarm set very low inside the high-pressure separator had been disconnected during a modification carried out in the unit several years prior; moreover, site technicians doubted the reliability of the main level indicator, preferring instead to refer to the backup detector recording table, and it was the misreading of this recording that led them to believe that the level inside the high-pressure separator was normal.

After the accident, several remedial measures were adopted, namely: reconstruction of the unit with correctly-designed relief valves on the low-pressure separator and improved instrumentation; implementation of procedures intended to drain the liquid present in the high-pressure separator during shutdowns; establishment of a system for monitoring flaws and maintenance needs on the equipment and appropriate personnel training; and a more frequent and stringent auditing programme.

ARIA 6323 – 29/01/1993 - 92 - CLICHY

35.30 - Production and distribution of steam and air conditioning

An operating, gas-fired water tube boiler (57 tonnes/hr, 24 bar) located in an urban heating plant stopped subsequent to an electrical power outage. The other boiler, which was also in service at the time, did not shut down. Following malfunction of the pilot valve on the spring-activated expansion device for limiting ignition circuit pressure, the technician tried 3 times to restore service before pressurisation by adjusting a tap opening and obtaining permission for activation from the control console. While shifting from start-up to normal mode, an explosion occurred shortly after opening the main feed valve. The combustion chamber was totally destroyed, and the roof along with one building wall were damaged, yet no victims were reported.

ARIA 6343 – 07/10/1994 - 69 - LYON

86.10 - Hospital activities

An explosion occurred on a gas-powered, 20.88-MW boiler operating by means of a remote monitoring system. Following the detection of an operating defect on the generator burner and its safety mechanism, an on-call technician entered the boiler room to perform verification work. The mandatory control devices, which were inoperable, made it impossible to determine the exact cause of the malfunction. The technician nonetheless reset the automated restart sequence; the explosion happened 30 sec after the pre-sweeping function had begun (air injection into the firebox). The investigation indicated the presence of a foreign body (metal and calamine particles) in both the gas filter and solenoid valves on the gas-powered boiler feed lines, with an imprint of the flap gate of the 1st valve (due to a leak?), as well as significant head losses on the pipeline exposed to the open air (22 m long, with twelve 90° elbows). These anomalies seem to have enabled gas to flow into the generator for 30 min following implementation of burner safety measures. The attempted restart by injecting air into the firebox served to reach the upper flammability limit, in turn causing the explosion to occur within the combustion chamber.

ARIA 6537 – 07/02/1973 - BELGIUM - FELUY

19.20 - Oil refining

At a steam plant, a boiler had been operating in steady state at minimum flow rate, with both gas-powered and fuel oil-powered burners running simultaneously. The mode setting was automated, yet due to a lack of reliability in the measurements of combustion air, both the gas discharge controls and blowing regime were shifted into manual operating mode in order to make adjustments to better meet demand. An electronic component malfunction on the fuel regulation system triggered the regulation valve to fully open, extinguishing combustion and generating a large quantity of unburned fuel, which blocked the flame detectors, thereby causing a general fuel oil and gas supply outage. Since the fan was still running, the unburned fuel reached the upper flammability limit and exploded.

ARIA 6538 – 15/06/1972 - Not available -

19.20 - Oil refining

In a steam plant, difficulties arose at the time of starting up a boiler. The technician repeated the start-up sequence, yet failed to ventilate the premises sufficiently ahead of time. The air-gas mix exploded upon attempting to turn the boiler back on. The technician was killed and the boiler totally destroyed.

ARIA 9878 – 04/09/1996 - 80 - HAM

24.42 - Aluminium metallurgy

An explosion occurred inside a natural gas-fired furnace used for annealing aluminium sections. While repairing an adjacent machine, a technician was killed by ejection of the furnace door (weighing 1 tonne) and an electrician sustained serious burns. The roof was partially destroyed by ejection of the upper part of the installation and debris was spread over a 50-m radius. The gas inlet was closed and no fire ensued. A judicial investigation was carried out.

ARIA 14666 – 07/06/1996 - GERMANY - GELSENKIRCHEN

19.20 - Oil refining

In an alkene manufacturing unit at a refinery, a separator exploded, causing the release of ethane, ethylene, methane and hydrogen, at the time of restarting the deep freeze installation. Other pressurised containers, pipelines, process command and control instruments and metal structures were all damaged. The emergency shutdown system was activated, and the air conditioning device at the recording station was depressurized, drained, disconnected, cleaned and drained once again. Total property damage was estimated at 3 million marks (i.e. €1.5 million).

The explosion resulted from an internal crack (1,600 mm) of the equipment along the weld seam (the base metal was ferritic, while the weld was made using austenitic metal). The corrosion induced by hydrogen also stemmed from start/stop cycles imposed by the production routine. Moreover, a maintenance deficiency could have been the cause as well.

ARIA 19155 – 22/10/2000 - 03 - MOULINS

35.30 - Production and distribution of steam and air conditioning

A pressure surge, most likely due to an explosion within the combustion chamber, tore off a large portion of the outer lining on a 6.9-MW boiler running on municipal gas in automated mode. The boiler room was protected by cutting the gas supply via the external valve. The fire department was called but did not have to intervene given the absence of fire and no injuries. Three days prior, following replacement of the burner, all safety tests were successfully conducted. The boiler was also being used as an auxiliary to the cogeneration system. The day before the accident, the gas-fired burner was protected following a pressure drop. The sector foreman requested that the cogeneration facility be shut down and that the boiler be allowed to operate on its own. The boiler was restarted around midnight; 2½ hours later, it had to be secured following a problem on the burner. The explosion occurred when power was restored 2 hours after that. An investigation was conducted to determine the exact causes.

ARIA 24354 – 01/04/2003 - THE NETHERLANDS - GELEEN

20.1 - Manufacturing of basic chemical products, nitrogenous products and fertilisers, basic plastics and synthetic rubber

At a chemical site producing melamine, an accidental explosion occurred during restart of an industrial furnace powered by both natural gas and the residual gas from other units. The filters clogged by residual gas were regularly cleaned, which necessitated installation shutdown and restart. The explosion blasted the cover off the furnace where a maintenance team was working. The cover as well as the personnel fell into the furnace (heated to 350°C). All 3 employees were killed. As a means of shortening this shutdown time, technicians had defined a rapid restart protocol that neglected the site's safety guidelines and indications. This rapid procedure introduced previously consisted of filling the furnace with a stoichiometric mix of gas and air. Mix ignition was likely triggered by a spark emanating from an electric fan turned on by a technician a few moments before the explosion. An investigation was launched to determine the causes of this accident. Property damage and operating losses were estimated in the several millions of Euros.

ARIA 25754 – 28/11/1984 - 76 - LE HAVRE

35.13 - Electricity distribution

An explosion occurred on a new boiler set up inside a power plant (10 tonnes of steam/hr). This auxiliary boiler had been intended to complement the provision of steam required to reheat the heavy fuel oil used in the Unit 3 burner storage and cooling areas. This was a corrugated firebox tube boiler with 3 exhaust paths. Combustion gases were directed to the back of the boiler and then channelled towards the front via the lower smoke tubes before being conveyed to the chimney located in back via the upper tubes. This boiler was designed to function in a buffer capacity on the network, in parallel with another boiler of the same type (which had been shut down on the day of the accident) and with a set of steam transformers producing the tapping steam on the turbo alternators. The accident happened at the end of a series of boiler start-up tests that were being overseen by 1 technician employed by the product manufacturer assisted by 2 boiler room technicians. At the time of the accident, a firebox tube end broke apart from the tubular plate in creating an opening on the back surface of the boiler. The water contained inside the boiler, exposed to the action of instantaneous vaporisation of the pressurised steam (approx. 13 bar), escaped through this opening. The boiler was projected by the ensuing reaction some ten metres backwards, causing it to become entangled in the scraper of a 250-MW boiler. The steam escaping from the boiler crossed the material handling bay, blasted the mechanical workshop wall and then, by vaporising partially under atmospheric pressure, filled a much larger volume, causing burns to workshop personnel. The human toll of this explosion amounted to 1 death and 17 injured; all victims were working in the same mechanical shop. Even though for some design computation codes the characteristics of this boiler were not acceptable, nonetheless it was still compliant with ISO code rules and French Standard NFE 32.104.

Hydrocarbons heavier than water at the boiler operating temperature were present in the feed water; these hydrocarbons were then deposited onto the firebox tube. This would have caused the transition to vaporisation into film and thus a temperature rise in the metal, which had become hotter than the maximum warranty temperature relative to the type of steel used to build the boiler. The potential for polluting the vapour circuit by fuel oil during its reheating cannot be overlooked: during the recovery of vapour condensates, the fuel oil could have entered into the sumps used to supply the boiler. Since the actual operating conditions at the time of the explosion were not known with certainty, the presence of fuel oil in the feed water combined with extreme design characteristics triggered this accident.

ARIA 25923 – 18/11/2003 - 57 - HAUCONCOURT

46.71 - Wholesale of fuels and ancillary products

At an LPG filling station, around 2:15 pm, a station employee was drilling in the "automation" utility room located in a zone outside of any risk of gas presence: this room provided access to the administrative building via 3 juxtaposed electrical ducts leading into the building's crawl space. At the time of this drilling task, a flash-arc occurred and burned the employee, who was able to trip the closest emergency shutoff switch. The emergency system secured the site (shutdown of installations and automatic sprinkling of sensitive zones). Site employees quickly controlled this fire breakout. One of them raised a floor board in the room then another board before getting burned by a second flash-arc, which was quickly brought under control using powder extinguishers. Both of the injured employees had to be hospitalised (burns to their faces, hands). The utility room was damaged and the station's activity shut down for a short while. Following verifications, the safety installations were resupplied under normal conditions around 7 pm.

The accident would have been caused by a leak on the propane pipeline feeding the administrative building's heating boiler. The copper piping (diameter: 22 mm), laid aboveground from the storage tank (11.6 m³, for heating the administrative building + the filling zone, with direct feeding from the filling zone) and then run underground (diameter: 14 mm) via the crawl space, before reaching the boiler room: a screwed connection in the underground part broke, causing the leak and gas accumulation in the ground along the duct until reaching the crawl space. From this point, the combustible made its way into the electrical ducts, which were not blocked, in the direction of the automation room. The drill provided the flash point for the first flash-arc. The second time around, a hotspot smouldered and raising the floor boards created a draft that reignited the remaining gas. At the suggestion of inspection authorities, a prefectural restraining order requested the periodic verification of all pipelines, along with the monitoring of strength and seal inspections and an update of the internal emergency plan. The operator planned to implement the following measures at this site: placement of a 1.7-m³ tank dedicated to heating the administrative building, and filling of the heating tanks from a lorry. The operator also ordered all sites under his control to reference all underground pipeline segments and then undertake a program of converting these into aboveground segments, in addition to a campaign of blocking all electrical supply ducts in off-zone locations.

ARIA 26252 – 19/01/2004 - ALGERIA - SKIKDA

19.20 - Oil refining

An explosion occurred around 6:40 pm at a port petrochemical facility, located on the Algerian coast and composed of 6 gas and hydrocarbon treatment units; a total of 12,000 workers were employed on this site at the time, which was in part fuelled by gas and oil from the Sahara region.

The accident occurred inside the natural gas (LNG) treatment facility, subsequent to the explosion of a high-pressure boiler responsible for producing the vapour. Given the violence of the explosion, nearby tanks containing inflammable substances were also damaged: the resulting leaks then caused the fire to spread, with different outbreaks in turn triggering new explosions (the "domino effect"). The blast from the explosion, heard over a 10-km radius, broke building and shop windows in the vicinity. A crisis unit was set up by the operator and the Interior Minister; the prefect ("Wali" in the local administration) activated the equivalent of an external emergency plan. It took local fire-fighters around 8 hours to bring the blaze under control.

The ultimate human toll was very serious: 27 killed among the staff, including 9 security agents manning neighbouring stations, and 74 injured (43 of whom left hospital the next day after undergoing medical exams). The majority of deaths were caused by the effects of a pressure surge or the projections and collapse of structures.

The estimate of property damage rose to 800 million dollars. Three of the six liquefaction units were destroyed. Debris was ejected up to 250 m from the epicentre of the explosion, yet actual damage at the site remained limited.

According to witnesses, strange noises corresponding to vibrations or leaks from valves were heard prior to the powerful explosion. The unit ("Train 40") where the explosion occurred seemed to display frequent operating anomalies. After a major leak notified by a maintenance agent, who would die in this explosion, a mix of air and gaseous hydrocarbons was suctioned by the air inlet of the Train 40 boiler, causing an initial explosion inside this boiler, followed by a second deflagration outside and then a fire destroying adjacent "Trains 20 and 30" separated just 60 m from one another.

ARIA 32777 – 05/02/2007 - 45 - SAINT-JEAN-DE-LA-RUELLE

35.2 - Production and distribution of gaseous fuels

A public works company, assigned to conduct earthworks using a mechanical shovel, accidentally hit the connection to natural gas-powered boilers, causing an explosion followed by fire. The pipeline was torn at the level of the station's input flange. The boiler room, juxtaposed with a building, was half sunken into the ground. The company had filed a works authorisation request with the gas utility and possessed a map of the utility network lines. A fire-fighter declared having seen flames surge forth from a duct in the boiler room. Gas would have likely spread via the PVC tube surrounding the burst pipe and diffused through a crack in the duct heading towards the boiler room. The heating unit, which relied on atmospheric burners, depended for its air supply on another duct dropping to ground level, while the upper ventilation consisted of a 2 m x 2 m chimney anchored at the level of the flat ceiling. Gas ignited when in contact with an electric motor or the flame from a burner. Six employees, including 4 members of the worksite crew, were slightly injured.

ARIA 32817 – 29/11/2006 - 77 - GRANDPUITS-BAILLY-CARROIS

20.15 - Manufacturing of nitrogenous products and fertilisers

At a chemical plant, an explosion occurred and a leak ignited at the level of a valve flange on the turbo compressor located in the ammonia (NH_3) production facility, which was in the process of being restarted. The hydrogen detectors and fire alarm notified the control room, triggering immediate shutdown of the facility. Rescue crews were quickly able to control the event. The internal emergency plan was not activated.

The accident caused no casualties, as the technician present in the vicinity was able to escape just before the explosion, after hearing the whistling sound associated with the discharge of synthetic gas, composed of 70% hydrogen (flow rate: 15,000 Nm^3/hr). Physical consequences of the turbo compressor's direct environment involved: electrical cabling, melted cladding, heavy damage to heat insulation on the pipeline. Ammonia production was shut down for more than a month.

Five days prior to the accident, a problem related to the of CO_2 absorption defect at the level of the decarbonation column in the NH_3 production facility, which was being restarted, led site technicians to open the vent downstream of the column before activating the high-temperature safety procedure. This excessive venting (due to operating error) caused a sudden drop in suctioning pressure at the NH_3 synthesis turbo compressor while triggering the facility's emergency shutdown. The valve positioned on the line between the turbo compressor and the anaerobic digestion reactor was thus placed into operation under high pressure and opened without any technicians noticing.

During the ensuing days, production resumed, yet an abnormal synthetic gas reading led the operator to conduct further investigations and discover that the previous valve placed under such pressure was no longer sealed: it was allowing gas to escape via a 47-m high chimney. The facility was stopped once again to allow replacing the suspected valve.

The unit was started once again. The anaerobic digestion reaction began at 10 pm; the synthetic gas turbo compressor started up at 1:30 am and the accident happened at 3:14 am on the flange of the newly-installed valve (diameter: 6", approx. 150 mm).

This accident was due to insufficient valve calibration; upon start-up, the valve fluttered, causing vibrations that eventually led to rapid loosening of the flange nuts, which most likely had not been tightened enough at the outset. The lack of traceability during these jointing operations (torque) was also highlighted.

As for feedback, the company assigned the valve calibration task was required to undergo certification by the plant inspection unit, resulting in an improved jointing protocol, more rigorous specifications regarding jointing, upgrades to the revised valves, and implementation of an additional pressure sensor.