Fire in an aromatic extraction unit in a refinery

21 April, 2006

Notre-Dame de Gravenchon – [Haute-Normandie] – France

Refinery
Aromatic extraction unit
Distillates (vacuum)
Thermcouple well
Works
Sub-contracting
Safety management system
Communication

THE INSTALLATIONS IN QUESTION

The site;

For more than 60 years, the refinery has been located on the banks of the Seine in the Port-Jérôme industrial estate, within the commune of Notre-Dame de Gravenchon. The plant transforms crude oil into fuel (LPG, petrol, diesel fuel and kerosene), heating oils, bitumen and oils. The establishment includes all the conventional petroleum processing units (atmospheric distillation, vacuum distillation, catalytic cracker, catalytic reforming, isomerisation, and alkylation).

The unit concerned:

The unit involved in the accident is an aromatic extraction unit which uses NMP solvent (N-methyl-2-pyrrolidone, formula: C_5H_9NO). It is an oil processing unit based on vacuum distillation (distillates). The oils are processed oils with solvent in order to selectively extract certain compounds and thereby improve viscosity, colour, oxidation resistance and the lubricants' emulsion tendency.

The contact between the distillate and the solvent takes place in a counter current circulation system in a liquid/liquid extraction column in proportions and at a temperature which varies according to the nature of the distillate and the desired viscosity index. Two non-miscible phases form by gravity in the extraction tower: the "mixed raffinate", paraffin-based by nature and containing a small amount of solvent (10 to 20%), collected at the top of the column; "mixed extract", rich in solvent (85 to 95%) containing components that are eliminated and collected at the base of the tower.

After extraction and prior to storage, the raffinate and the extract are stripped of nitrogen to eliminate any traces of solvent.

The section of the unit involved in the incident is that involved in stripping the raffinate.

THE ACCIDENT, ITS BEHAVIOUR, EFFECTS AND CONSEQUENCES

Context:

After a major shutdown for regulatory inspection and work, the extraction unit was placed back into service on Tuesday, April 19th, 2006. Before being placed back into production, the unit was in recirculation phase and up to temperature (320℃ / 3.5 bar) when the fire broke out.

The accident:

April 21, 2006 at 10.15 am: a fire was reported by an employee of an external company working in a structure of the extraction unit.

At 10.20 am: The unit's fixed firefighting means were manned by the operators pending the arrival of the mobile units: cooling and protection of the structures.

From 10.22 to 10.52 am: The mobile and fixed firefighting resources on the extraction unit were put into action (foam truck, foam nozzles, …).

At 10.40 am: The Internal Contingency Plan is put into motion.

At 10.56 am: The extraction tower and ancillary units decompressed and liquid inventories reduced to a minimum.

At 11.00 am: The fire was put out but structural cooling operations continued.

At 12.20 pm: The product leak is located (bottom line of the raffinate stripping tower) and continued spraying of the product leak.

At 1.25 pm: The internal contingency plan is lifted (prevention ensured by operators with the portable water canon).

At 3.00 pm: End of operations.

The fire was not sustained and remained localised in the raffinate stripping tower. The flames were quite high (in the order of 15 m), followed by decreasing and recovery periods.

Consequences:

The accident had no human consequences. The environmental impact was limited to smoke released by the fire. The liquid effluents generated by the firefighting operations (firefighting water, foam blanket…) were directed to a catch tank and no increase in pollution was noted in the Seine on the day of the incident. The release standards were respected.

On the equipment level, the following was established after the fire:

- Several main circuits were exposed to the flames, notably:
  - the bottom line of the raffinate stripping tower,
  - the transfer line between one of the two extract reheating ovens and the first nitrogen stripping column,
  - the line supporting the raffinate supply control valve from the extraction tower to the raffinate stripping column.
- The fire-resistant concrete protecting the skirts around the stripping and extraction towers received only superficial damage.
- The framework elements trapped in the fire were not deformed, except for two supporting beams.
- The aluminium sheeting covering the heat insulation of certain circuits were partially melted.
- Approximately 70 electrical and instrumentation cables were damaged by the fire.
- The junction boxes were not harmed in the fire (paint still intact).
- The heat lagging protected the metal enclosures of the equipment and piping from the fire.
- The scaffolding installed in the zone and engulfed in the flames remained intact, except for a single element whose tubing was seriously deformed and whose wood planks fuelled the fire.

It should be noted that the property damage remained essentially within the unit.

European scale of industrial accidents:

By applying the rating rules of the 18 parameters of the scale made official in February 1994 by the Committee of Competent Authorities of the Member States which oversees the application of the 'SEVESO' directive, the accident can be characterised by the following 4 indices, based on the information available.

The parameters that comprise these indices and the corresponding rating method are available at the following address: http://www.aria.ecologie.gouv.fr.

The "dangerous materials released" is ranked 1 as 1.4 tons of raffinate (easily flammable liquid as per the Seveso Directive, Appendix I, part II) was released during the accident (parameter Q1).

The "economic consequences" index is rated 2 as the economic impact of the incident was calculated to be approximately 1 million euros in production losses, with property damage being evaluated at less than 40 k€ (parameter € 16).

The accident had no human or significant environmental consequences. The liquid effluents generated during the fire were recovered and processed in one of the refinery's treatment stations (in particular, no dangerous product was released into the Seine).

ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

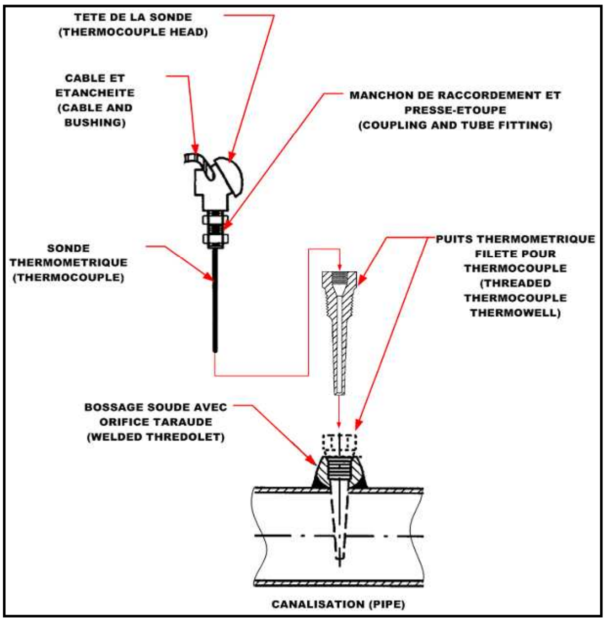
Origin and causes of the accident:

The analysis of the incident discovered that the thermocouple was improperly installed on the bottom circuit of the raffinate stripping tower. The installation was not in compliance with the construction drawing of a thermocouple well on a pipe.

A proper installation of a temperature sensor (see diagram below) adapted to the installations' service conditions would consist of the following:

1. A threaded boss on the pipe wall intended to receive the thermocouple;
2. Screwing of a "sensor pocket" on the aforementioned boss and reinforcement by means of a weld bead;
3. The thermocouple is then screwed into the pocket;
4. The wires are connected to a signal transmitter, once the cable is connected to the sensor by means of a coupling.

In this configuration, while ensuring a reliable temperature measurement, the thermowell guarantees that there will be no direct contact between the process fluid (for which we are attempting to measure the temperature) and the thermocouple. In the case of accidental rupture (contact between the process fluid and the thermocouple), the tube fitting limits/prevents the loss of confinement provided that the leak is not excessive.



Temperature sensor assembly diagram

The investigations conducted following the incident showed that the thermocouple had been installed without a "sensor pocket", thus without protection. The hot raffinate was thus in direct contact with the sensor. As the quantity of product was excessive and the fluid very hot (320 °C), the tube fitting was unable to properly maintain the seal, leading to self-ignition of the product released and in contact with the air. The equivalent diameter of the break at the pipe level is roughly 10 mm.

A pool of flame quickly spread across the ground, forming flames of 5 to 6 m. The fire reached the scaffolding planks within the structure, increasing the height of the flames up to approximately 15 m for 8 minutes. The firemen were able to put out the burning wood, allowing only the initial pool to burn.

Analysis of the fundamental causes of the incident:

1) Traceability of job site phases

The operator conducted more extensive research to determine the reasons behind the faulty thermocouple installation. During the major shutdown for regulatory inspection and work on the NMP extraction unit, the following elements were brought to light:

- The replacement of the line on which the thermocouple was installed, was planned and undertaken during the unit's major shut down.

- An initial request for work was not requested for the disassembly of the thermocouple on the button line of the raffinate's stripping tower. According to the individual managing instrumentation work, this procedure is normally performed by "Piping" crew supervisor. The "Instrumentation" organisation did not issue a permit authorising the disassembly of the thermocouple of the line to be replaced.

- No permit was issued to install a thermowell on the new bottom line of the raffinate stripping tower. No request was submitted to the "Instrumentation" organisation to provide the company working on the unit with a thermowell notably consisting of a "sensor pocket".

- The isometric drawing of the circuit and the list of required materials were given to the external company to perform the work on the new bottom line of the raffinate stripping tower. When the company's pipe fitter arrived at the site, the thermocouple had already been removed from the old line. He thought that it was an element reduced by ½" in diameter on the 1" dia. boss. (it was in fact a "sensor pocket" and not a ½" adapter fitting). He thus welded a 1" x ½" adapter fitting on the new section of line to have the same configuration as the old line.

- Once the welding operations were completed, the adapter fitting was equipped with a threaded plug to allow the new circuit to be tested. Once the leak test was performed, the plug was removed, thus leaving the pipe open.

- A work request was not made concerning the reinstallation of the thermocouple (normally submitted to the "Instrumentation" crew by the "Piping" crew); no permit was issued to reinstall the thermocouple on the new line.

- The piping company did not refit the thermocouple. The pipe work acceptance sheet relative to the extraction unit shows that the instrumentation was in place and reconnected just prior to restart. In the end, only three permits were granted for the following work: blinding, cold cutting, welding, grinding, testing and blind removal.

- It was not possible to establish who actually removed the thermocouple from the old line and who put it back in place on the new line.

2) Analysis of the failure of the safety bars

The piping company did not inform the operator that it had removed the adapter fitting which was not requested, nor that the thermowell indicated in the list of equipment had not been supplied.

The refinery's instrument specialists had never been involved in this operation.

The line's testing procedure had been accepted with an adapter fitting that had not been requested. The boss designed to receive the thermowell had also been plugged: it was thus impossible to identify that is was not in place.

When the line was accepted, neither the presence of the non-requested adapter fitting, nor the presence of the thermowell were identified.

The nitrogen flushing, leak testing and the introduction of cold then hot product, did not allow the well's absence to be detected prior to the incident.

ACTIONS TAKEN

The Classified Installations Inspectorate visited the facilities on the day of the incident. The Inspectorate requested that the operator provided an incident report before authorising the unit to restart. Owing to the operator's reactiveness in managing the incident and the "post-incident" measures taken, no administrative penalty was proposed.

The property damage was essentially limited to the instrumentation and pipe elements without involving all of the pressure tanks. The main work performed on the unit prior to its restart after the incident consisted of the following:

- partial or total replacement of approximately 70 instrument cables;

- the overhaul of certain control valves and various level measurement accessories;

- reworking of seals and the replacement of the threaded fasteners of parts exposed to the fire, in accordance with the inspection service's recommendations;

- the installation of a thermowell for a thermocouple on the bottom line of the raffinate stripping tower;

- the refurbishing of the analyser circuit and its support elements;

- reworking of the stuffing boxes on the valves exposed to the fire;

- replacement of destroyed or impregnated heat lagging;

- inspection of the electrical insulation of pumps and their drying;

- replacement of damaged spring boxes.

The damage to the guniting was also considered to be minor. The necessary repairs were undertaken to allow the installations to be placed back into service safely just a few days after the incident (the Classified Installations Inspectorate granted restart authorisation of the unit on April 25, 2006).

LESSONS LEARNT

In addition to the human error that resulted in significant property damage to the unit, the faulty installation on the thermocouple resulted in a **failure of the Safety Management System**:

- lack of communication between the refinery's "Piping" and "Instrumentation" departments,

- poor definition of each department's role,

- incorrect application of the procedures,

- non-compliant work acceptance,

- poor definition of the work requested of the external company.

The operator proposed to implement the following avenues of improvement with regard to the acceptance of piping work and the thermocouple installation process as defined in the Safety Management System:

1. Establish a "maintenance procedure" clearly stipulating the work to be performed by each trade (notably, "Piping" and "Instrumentation"). These procedures are developed by the refinery personnel and must be applied by the external companies. They describe the individual steps to follow regarding the inspection, repair and maintenance of technical systems. They must also display the list of spare parts required for the work to be performed and to establish the time required to perform the work.
2. Stipulate in the specific "Piping/Valves" Specifications intended for external companies, that the piping company is responsible for the installation of wells. This company must also procure the parts from the refinery's supervisory department, and so that all modification in relation to the isometric drawings must be reported to this same department.
3. Stipulate in the specific "Instrumentation" Specifications what verifications must be performed in order to ensure that a thermowell is present before installing a thermocouple.
4. Work with the platform's Inspection Department so that the lines equipped with thermowells are tested with the "sensor pockets" in place (plugging the pipe bosses intended to receive the thermowells is prohibited).
5. In the pipework acceptance phase, refuse all additional part added by the external company that does not appear on the isometric drawing.
6. Add a "thermowell" line to the "piping/valves" acceptance sheet.
7. Reinforce the message that only the refinery's instrumentation specialists are authorised to remove/install instruments.

This feedback, rich in information, was shared among other refinery units in which similar incidents could occur.