EXPLOSION IN NITROESTERS STORE BUILDING.

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DATE AND TIME OF INCIDENT : March 13, 2013. Hours: 07:05:28 a.m.

INCIDENT LOCATION : NITROERG S.A. – KGHM Polska Miedź S.A. Capital Group Dynamites Manufacturing Plant in Bieruń, Poland, Upper Silesia region.

PROCESS OUTLINE :

General

The plant manufactured dynamites in accordance with standard technologies, using technical equipment that is typical for the manufacturing of dynamites. The blend of nitroesters (NE) (nitroglycerin/nitroglycol) mixed with water was transferred by pipelines to the main store or directly to the intermediate store. The mix from the intermediate store was transferred, as a water emulsion, to the batching room (separator + scales) within the dynamite mixer facility, where the nitroesters are separated from the water. The organizational scheme of nitroesters transportation system is shown on the Figure No. 1.

The actual layout of manufacturing facilities is shown on the map – Figure No. 2.

All operations of opening/closing valves and of starting/stopping pumps were executed in automatic mode according to a definite algorithmic routine charged to the controller. All starting/stopping operations were done remotely from the control room located inside the mixer facility. The store was operating in unattended mode, i.e. no operator was needed to be inside the store in operation. All rooms pertaining to this group of facilities were monitored by a CCTV System, ensuring 45-day storage of camera images in the recorder's memory.

Description of facilities and technical equipment:

The NE store within the facility N-9 was built as a reinforced steel structure embanked with earth. Three walls of this facility were made of reinforced concrete, while the fourth one (the face wall) was made of wood. The ceiling was made of ferroconcrete slabs. Three sides of the building including the ceiling were embanked by earth, while in front of the face wall there was a vestibule with a communication tunnel, broken at 90 degrees. In the front of the exit from the tunnel there was an earth embankment to ensure the function of a retaining wall.

Installations and equipment installed in the building N-9 (Figure No. 3):

* NE Separator, receiving the emulsion of nitro esters/water coming from the production or from the Main Store, and the transporting water, previously separated from nitro esters in the mixer facility – pos. (1).
* NE Tank,of capacity 1300 dm^3, receiving nitro esters (by bottom pass), and water or emulsion (by middle pass) – pos. (2). This tank was equipped with a NE level meter. The NE was drawn in from the bottom part of the tank by the NE transfer injector – pos. (3), and then transferred to the batching room inside the dynamite mixer facility.

* Two decanters for transportation water, connected in a cascade system – pos. (4) and (7). The first one received the water flowing down from the upper part of the NE tank.
* Two pumps to ensure the feeding of NE transfer injectors (of capacity 2,5 m^3/h, delivery head 55 meters of water column) – pos. (9/1) and (9/2). These pumps were installed on the second decanter. They were operating in alternating mode, and were used to feed the primary NE transfer injector and the auxiliary injectors. One of these pumps was used to pump NE from store tanks in the Main Store to the N-9 store.
* NE transfer injector – pos. (3) for Tellex mixer facility, offering the capacity of 1500 kg/h, and the delivery head of 10 meters of water column.
*Auxiliary injectors used for the first emptying of various tanks with NE – pos. (5), (6) and (8).
*Remotely controlled pneumatic diaphragm valves.
*Control glasses.

Process interlocks

The system of NE transfer from the Warehouse N-9 to the Tellex mixer was operated by the controller which ensures the proper sequence of various operations, and to prevent any risk of transient states occurring in the plant. There was no possibility to operate the plant without the controller or by-passing the functions that it controlled. The controller enabled for instance the shut-down of NE transfer process in following situations:
* Exceeding maximal NE level in the separator's tank before the batching scales in the building of Tellex mixer.
* Pressure of transportation water dropping or raising beyond the range 300 - 660 kPa
* Water flow through transfer injector decreases below 1500 dm^3/h, this condition being, however, subject to a 10s delay.
Moreover, pressure meters were installed on discharge flanges of the both pumps to ensure the pumps' switching off in case of transportation water pressures dropping or raising beyond the acceptable range of 300 - 660 kPa. Additionally, on the pressure pipeline of the transportation water from the both pumps there was a spring safety valve installed to switch the transportation water to the decanter No. 2 – Figure No 3, pos. (7) if the pressure exceeds a definite value.

DESCRIPTION OF THE INCIDENT :

On March 13, 2013, at 07:05:28 a.m. there was an incident (explosion) in the intermediate store room N-9. This facility was used to store NE (mix of nitroglycerin and nitroglycol in proportion 60/40), in order to feed it subsequently to the Tellex dynamites mixer which is located in the neighboring facility. At the very moment of the explosion there were circa 600 kg of NE inside the tanks. After the esterification process was started, the NE emulsion with water was fed continuously from the production line to the store until the NE tank – pos. (2) was completely filled, then the excess emulsion was sent to the tanks in the Main Store. The NE was consumed by portions needed to prepare subsequent batches for particular production charges. The explosion occurred during the feeding of NE from N-9 store to the facility of Tellex mixer. In that moment the transfer of NE from the Main Store was not in operation.

EFFECTS OF THE INCIDENT :

No fatalities or injuries.
The building for the intermediate storage of nitro esters (N-9) has been totally destroyed. The detonation did not propagate to the nitroesters transfer pipelines, or to the Main Store, or to the batching room in the Tellex mixer building.
No structural damage has been caused in other production buildings in the vicinity of the N-9 store, only broken windows, damaged roofs and doors, and damaged external pipelines. The post-incident situation is shown in Figures No. 4 to 9.

LIKELY CAUSES OF THE INCIDENT :

In the first approach the following potential causes for the failure have been taken into consideration:

1. Direct or indirect human error.
2. Use of bad quality raw materials for the esterification process, which could result in a spontaneous decomposition of nitro esters.
3. Failure of transfer pumps which feed the transportation water.
4. Initiation of NE in the transfer injector caused by an impact of NE column against metal parts of the injector.
5. Discharge of static electricity.
6. Effect of a thermal impulse.
7. Impulse that was extrinsic to the manufacturing facility – explosion initiated within the fly-over used for the transportation of NE emulsion to the N-9 store.

During the investigation the following factors have been excluded as potential causes of the explosion:

1. Willful misconduct of a member of staff, or of a third person – the N-9 store was in operation in unattended mode, and at the very moment of, or immediately before the incident nobody was inside it. This was be confirmed by CCTV records (Figure No. 10).
2. Use of bad quality raw materials for the esterification process – all results of raw materials and NE tests were compliant with the requirements.
3. Failure (disintegration) of the rotor of a transportation water pump. The pump remains have been found after the incident, and the casings of rotors do not show any traces of an internal explosion (Figure No. 11).
4. Static electricity – all elements of the technical equipment within the N-9 facility were electrically earthed. A technical inspection of the facility's electric systems took place in September 2012.
5.Thermal impulse / stimulus – the only parts of the installation that could generate high temperatures were the rotors of transportation water pumps when in operation, however, they were immersed in the decanter of transportation water, and additionally cooled down by the sucked water.
6.Possible initiation of the explosion by an impulse (another explosion, fire) that was extrinsic to the manufacturing facility – no traces of a fire were found.

The most probable cause of the explosion could be an initiation of NE within, or immediately downstream the transfer injector. This could be, for instance, a result of an accidental, uncontrolled start-up of the second pump while the first one was still in operation. Such a situation should not occur because of adequate process interlocks ensured by the controller. Unfortunately the controller used for the control did not offer the possibility to record the actual "states" of various devices at the very moment of the explosion; this hypothesis cannot be neither confirmed nor excluded. However, this is the only possible explanation of a high energy that eventually has been generated up to a value that exceeded the levels needed to initiate NE. If the water was forced to the injector in double quantities in comparison to the normal conditions, that situation could result in a substantial increase of the negative pressure inside the injector, and cause a violent "detachment" of nitroesters in the suction tube with a subsequent impact of them against the injector's casing. Moreover, the system of automatic shut-down of pumps in case of an increase of water pressure did never operate, or did not operate in time.

LESSONS LEARNED :

1.All systems which require that various operations of their particular units, devices and technical elements are always executed in a strict sequence (according to definite procedures) shall be equipped with high-tech controllers. These devices shall ensure:

- Proper sequence of operations executed by plant, unit, or line.
- Record of historical data including emergency states, and the last executed operations.

2.Solutions where two different units can execute the same operation, for instance pumping water to the same pipeline, are to be avoided.

3.When selecting protective devices to protect manufacturing lines and technical equipment, their reaction times are to be known and well determined. Actual reaction times of these devices shall be periodically tested in conditions that are as close to the critical situations as it is possible.

4.It has been confirmed that the distances between various manufacturing buildings, as used for calculations in the design process, were proper (no propagation of the explosion occurred, even to the nearest manufacturing facilities).

5.It has been confirmed that the structure of the destroyed facility has prevented the propagation of the explosion to nearby installations.

6.When designing a facility, massive structural elements shall be avoided, because in case of an explosion they could be thrown far away causing serious injuries to bystanders, additional material damages, or even secondary explosions in neighboring facilities (Figure No. 12).

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