Explosion and fire in a chemical plant

- Chemical plant; upper-tier establishment,
- Production of fertilizers,
- Ammonia production unit, heat exchanger (HE)
- Substance involved: H2

Heat exchanger

- Year of production:
  a) drum: from 1971
  b) chambers: **2011**

- Subject to Technical Office's Inspection

Process gas

- Average composition of process gas flowing into the HE:

H_2 – 61 %

CO_2 – 22 %

H_2O – 15 %

CH_4 – 0,4 %, Ar - 0,3 %,

CO – 0,3 %, N_2 – 1 %

Composition of the process gas was not different from its usual content

Parameters of work

Before HE:

- Gas temperature 146.7 °C
- Gas pressure 3.07 MPa
- Water temperature (cooling agent) 38.5 °C

After HE:

- Gas temperature 39.7 °C
- Water temperature 115.7 °C

Phase I

- Rapid expansion of the process gas with hydrogen at a pressure of approximately 3.0 MPa
- The gas stream from the ruptured cover bursts asymmetrically down the structure towards the concrete substrate at level 00.
- Process gas with a majority of hydrogen, despite very low activation energy, does not ignite and does not explode due to the accompanying water vapor and carbon dioxide (typical extinguishing agents).
- The phase I period lasts about 10 seconds (according to the witnesess).

Phase II

- Spatial hydrogen explosion in the air (characteristic flash and noise).
- Wave of overpressure of the explosion makes a loss in the radius (150 m) – smashed glass and falling out of windows.
- The detonation wave (pressure-sound) hits the nearest adjacent objects at the epicenter of the explosion.
- Estimated time of rapid linear pressure drop from 3 MPa to near atmospheric pressure is approximately 20 seconds.

Phase III

- Free, limited, jet fire of the remains of the hydrogen in the instlation
- Addition of nitrogen to gas to extinguish the "burner" which causes a gradual decrease in the burning intensity and flame length.
- Estimated volume of process gas outflow 15 000 m3, including about 10 800 m3 of hydrogen.

The consequences

- 9 injuries, no fatalities,
- Damages on site: > 2 mln Euro,
- Production stopped for 2 weeks
- The amount of the process gas released: totally app. 9 MG including 1 MG of explosive and flammable (H2, CH4)

Causes of the accident

- Two independent expert's opinions have been carried out (Technology University of Warsaw and Office of Technical Inspections)

- Direct: thinning /weakening of part of the heat exchanger's wall due to corrosion and erosion in the presence of humid/moist CO2 in the specific process conditions (in the chamber);

Corrosion processes

- Electrochemical aspect of the corrosion (general reaction):

$$Fe + CO_2 + H_2O \Rightarrow FeCO_3 + H_2$$

- Partial pressure of CO2: 0,048 MPa
- Temperature: 80^0C
- pH 4 – acid character (typical value for condensed steam saturated with CO2)

Estimated corrosion speed: 5,5 mm/yr

Loss calculation

- reconstruction of damaged equipment and equipment - EUR 2.2 million
- lost profit of the plant - EUR 2.6 million
- the value of lost production in relation to the plan - EUR 18 million

Measures taken in order to prevent reoccurence

- Updating the existing procedures/instruction on technical supervisions/checks,
- Elaboration of trainings in order to discuss the causes, course and consequences of the accident with the Staff (also management)
- Introduction of the monitoring equipment (video cameras) within the unit

Measures taken in order to prevent reoccurence

- Equipping the chemical rescue unit with the telemetric system and wireless duplex communication
- Analysis of the possibility of registration of the conversations on rescue channel
- Analysis and inclusion in the investment/action plan modernization of the DSC system (*distributed control system)* for the ammonia installtion

Measures taken in order to prevent reoccurence

- Risk re-assesment of all the posts in the ammonium unit (H&S issue)
- Analysis of possible equipping control rooms with radiotelephones with laryngophone
- Carrying out of a complex elaboration specifing the ways of protection of control room aginst explosions

Measures taken in order to prevent reoccurence

- Analysis of the possibility of changes in the design of HE's chambers
- Identitication of innovative methods of testing the technical equipment in the real operating conditions (and accepted by the authorities) allowing replacing hydraulic pressure tests

Thank you for attention

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