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:

  **H₂** – 61 %
  **CO₂** – 22 %
  **H₂O** – 15 %

  **CH₄** – 0,4 %, **Ar** – 0,3 %,
  **CO** – 0,3 %, **N₂** – 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 1 period lasts about 10 seconds (according to the witnesses).
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 installation.
- 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):
  \[ \text{Fe} + \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{FeCO}_3 + \text{H}_2 \]
- Partial pressure of CO2: 0.048 MPa
- Temperature: 80°C
- 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 reoccurrence

- 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 reoccurrence

- 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 installation
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 specifying the ways of protection of control room against explosions
Measures taken in order to prevent reoccurrence

- Analysis of the possibility of changes in the design of HE’s chambers

- Identification 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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