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Nitrous Oxide Trailer Rupture July 2, 2001

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General background information

Medical gas plant in Eindhoven, The Netherlands

Filling of oxygen, nitrous oxide in cylinders

**Storage of nitrous oxide, filling in trailers
(no nitrous oxide production)**

General background information

Nitrous oxide storage tank:

- built in 1991
- upright tank, height 8 m
- capacity 40 m³
- max filling weight 36000 kg
- design pressure 24 / 32 bar
- design temperature - 80 ...- 15 °C
- foam insulated
- refrigeration unit

General background information

Nitrous oxide trailer:

- **built in 1989**
- **capacity 7600 litre**
- **maximum filling ratio 90 %**
- **maximum filling weight 7500 kg**
- **maximum working pressure 23 bar**
- **minimum working temperature - 40 °C**
- **material TStE 355**
- **foam insulation**
- **equipped with two pumps (SiHi, type ASHE 4108)**

General background information

Pump:

- **horizontal, self-aspirating, multistage centrifugal pump**
- **open impellers, lateral channel**
- **capacity 7,5 m³/h**
- **wattage 15 kW (pump was driven hydraulically)**

Situation just prior to the incident

Trailer ready to be filled from the storage tank.

Two hose filling system connected (gas return).

Condition of the storage tank:

- **content 18000 kg N₂O**
- **pressure 18,5 bar**
- **temperature - 20 °C**

Situation just prior to the incident

Condition of the trailer:

- residual content N_2O in equilibrium state:
250 kg liquid, 350 kg gaseous
- pressure 18 bar
- temperature - 21 °C

Situation just prior to the incident

Valves in position “Filling from the top with one pump and gas return”.

Pump switched on without cooling down !!!

Driver left his place at the trailer (this offended against the work instruction, but saved his life).

Five minutes after initiation of filling process the trailer exploded.

Consequences

Ten persons inside and out of the plant slightly injured by glass and metal splinters.

Trailer tank: Man hole cover torn off, tank shattered in two big fragments which were thrown away by 50 meters or 400 meters respectively.

Storage tank: Pushed away by 3 meters but stayed in its upright position, piping torn off, whole content spilled.

Consequences

Strong fire developed, fed mainly by diesel fuel, promoted by nitrous oxide and oxygen which was set free from bursting cylinders.

Hundreds of gas cylinders, heated by the fire, partly ruptured and molten.

Plant buildings and technical equipment destroyed by blast wave and fire.

Damage at foreign buildings in the neighbourhood.

Pumps and piping of the trailer



Fragments of the trailer



Fire in the filling hall



N₂O storage tank on the right hand side



Prior to the incident the N₂O tank was in straight line with the other tanks

Driver cabin of the trailer



Fragment of the ruptured tank



Causes

Following possible causes could be excluded:

- inadmissible overpressure due to overfilling
- explosion of flammable gas/nitrous oxide mixture
- inadmissible overpressure due to heating by external fire
- material defect of the tank

Decomposition

The only reasonable explanation of the incident is explosive decomposition of nitrous oxide.

The “explosive atmosphere”:

- **Nitrous oxide in the liquid/gaseous state of equilibrium can decompose explosively, if the pressure exceeds 5,7 bar and if an ignition source is present (Lit. 1).**
- **The pressure in the trailer was 18 bar, so that pressure condition of decomposition was fulfilled.**

Ignition source

Experiences from the literature:

Nitrous oxide can decompose by auto-ignition, if it is heated to a certain temperature.

Decomposition of nitrous oxide is possible at 21,4 bar and 325 °C (Lit. 2).

According to other experiments the auto-ignition temperature of nitrous oxide is 565 °C, pressure not noted (Lit. 3).

Ignition source

Experiences from investigation of the pump:

- The pump was not cooled down. It was running dry.
- The end of the pump shaft at the pressure side had significant annealing colour, generated by heat.
- The bearing box at the pressure side had blisters in the lacquer coating, generated by heat.
- Several of the bearing bushes, made of carbon, were damaged and - possibly - particles of it were burnt.

Conclusion regarding the causes

The pump was running dry and became hot.

This resulted in auto-ignition and

explosive decomposition of nitrous oxide in the trailer.

Corrective actions

Organisation:

- **Filling procedure of nitrous oxide tanks shall be regulated in a written work instruction.**
- **The filling instruction shall regulate, among other things, cooling down and prevention of dry running of the pump.**
- **The employees shall be trained on the work instruction.**

Corrective actions

Technics:

Nitrous oxide pumps shall be equipped with dry running protection, e. g. by control of temperature, differential pressure and/or engine power.

Moreover:

A nitrous oxide guideline shall be established which shall set specifications for nitrous oxide equipment.

Literature

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