



Explosion in an HMX plant

- SAFEX Closed Day Incident Session -

Martin Held

**XVII SAFEX Congress
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What happened and consequences

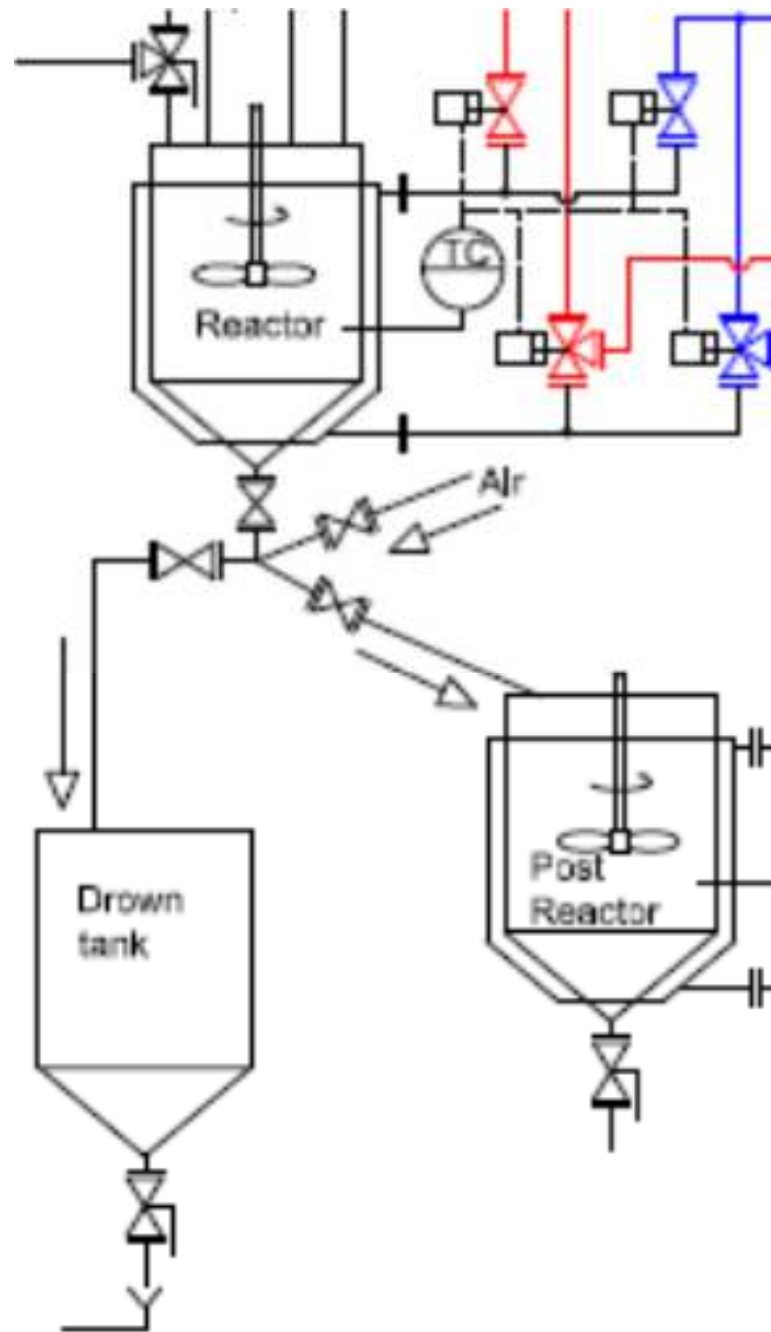
- **Where?** APA Rafaela/Santa Fe/Argentina
- **When?** June 1st, 2009 @ 7:00 am
- **What?** Explosion of a small amount of material during manufacture of HMX
Limited plant damage, no propagation
- **Who?** 1 operator seriously injured by shrapnel/1 operator minor injuries

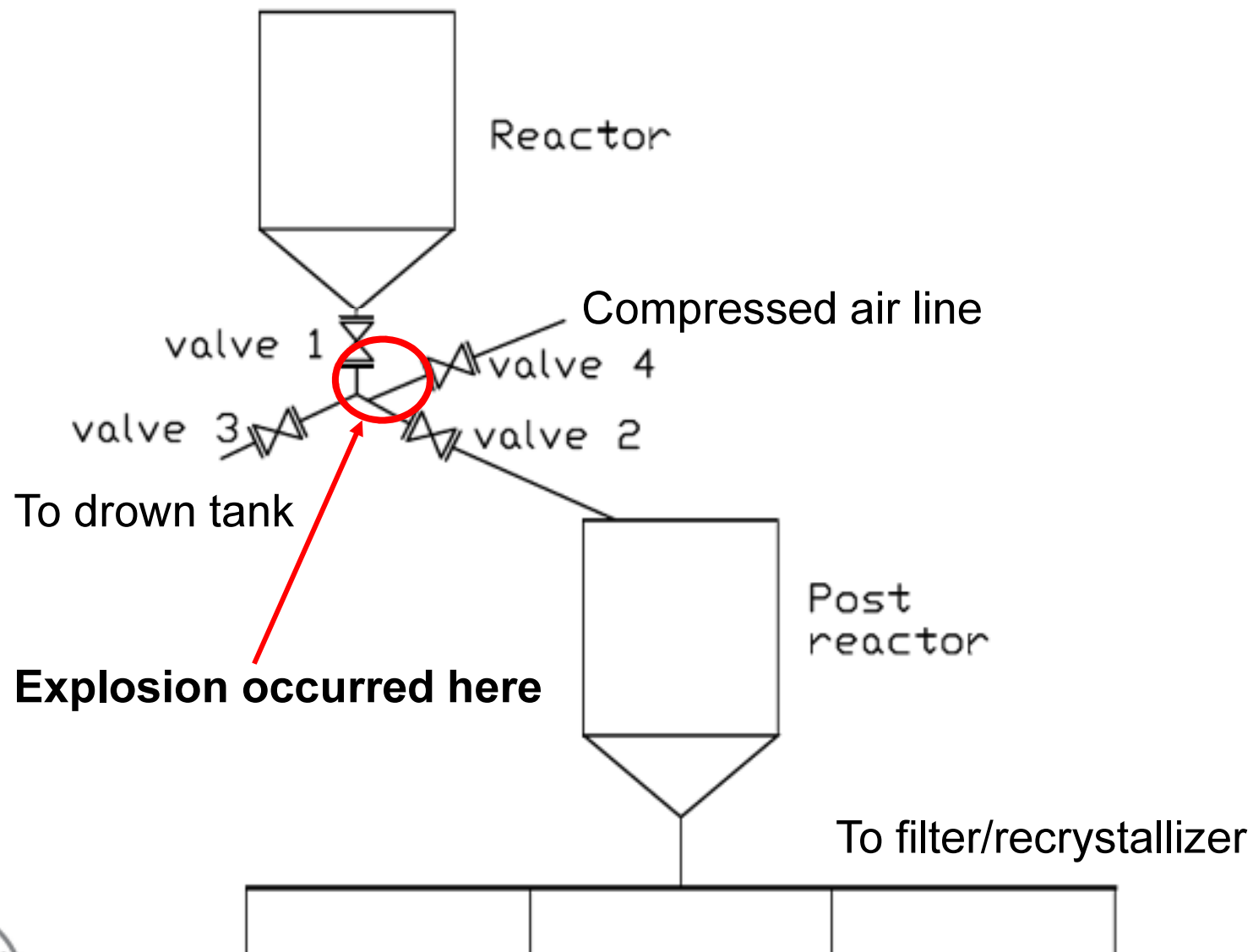


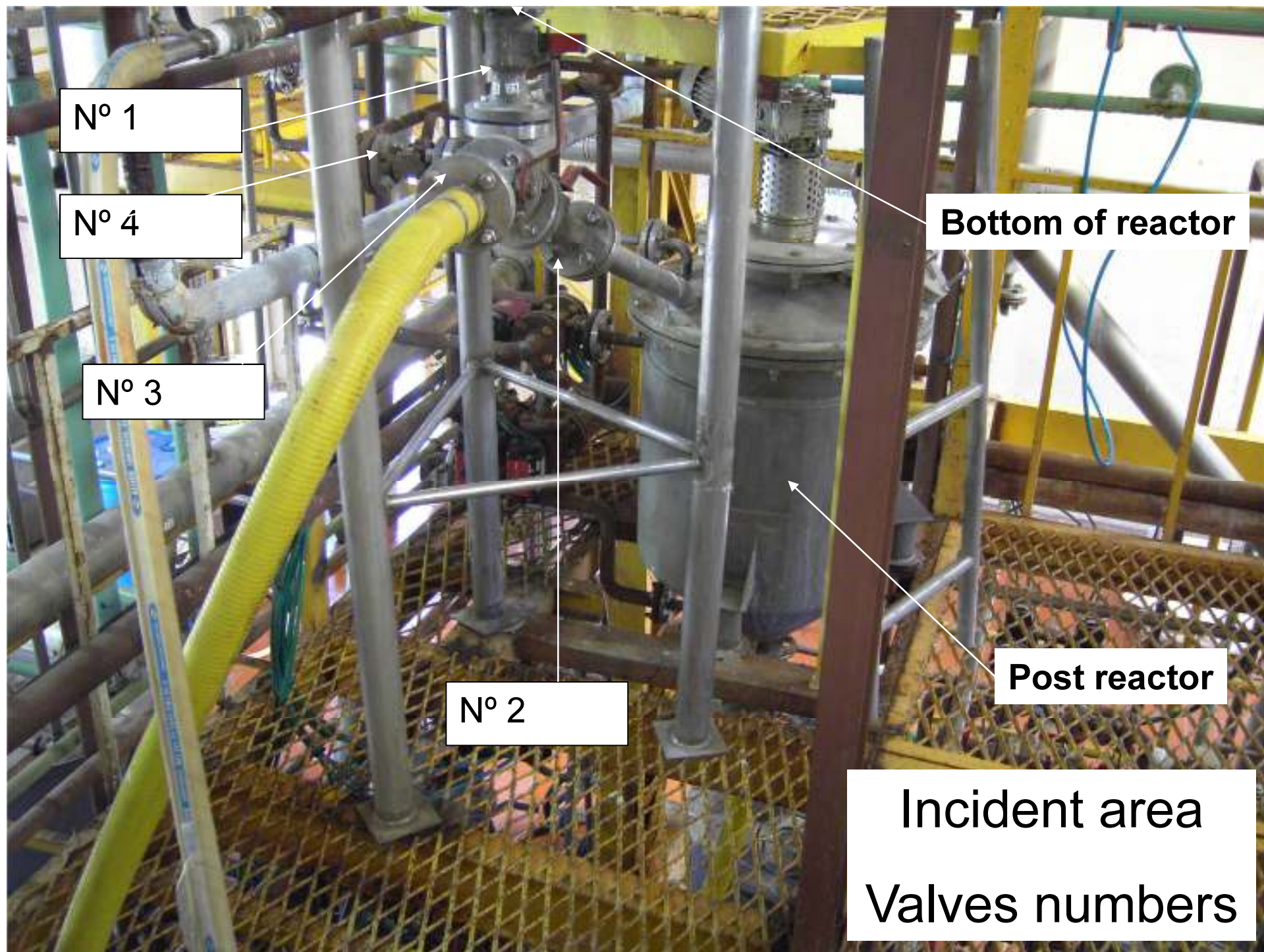
What was happening at the time of the incident?

- Batch process – complex chemical reactions involving hexamine, acetic acid, acetic anhydride, nitric acid and ammonium nitrate.
- Reaction vessel is a water jacketed vertically mounted reactor with a vertical stirrer. Reaction T around 44 °C.
- Upon completion the reactor is discharged by gravity through a series of hand operated valves to another vessel.
- Lines are purged by compressed air after each discharge.
- Several batches already produced that day.
- Nothing unusual observed.
- Appears that explosion coincided with the valve on a compressed air line being opened manually.









Valve N° 1:
The sphere
was damaged

Pieces of pipe

Valve N° 3:
Dilutor tank
Minor damage



Pieces of Valve
N° 1

Valve N° 4: Air
Minor damage

Sphere from
Valve N° 2
Minor damage

Valve N° 2:
Post reactor
Minor damage



Pieces of valves and pipe

What information is in the story?

Hazard Study

Plant or process modifications

Maintenance records

Training records

Material quality

Inspection/audit reports

Who was present?

What was being done?

- *Operating instructions*
- *Production plan*
- *PTW*
- *Materials present*
- *Data recording*
- *Shift logbook*

Months or
years

Days/weeks

Very recent



The process

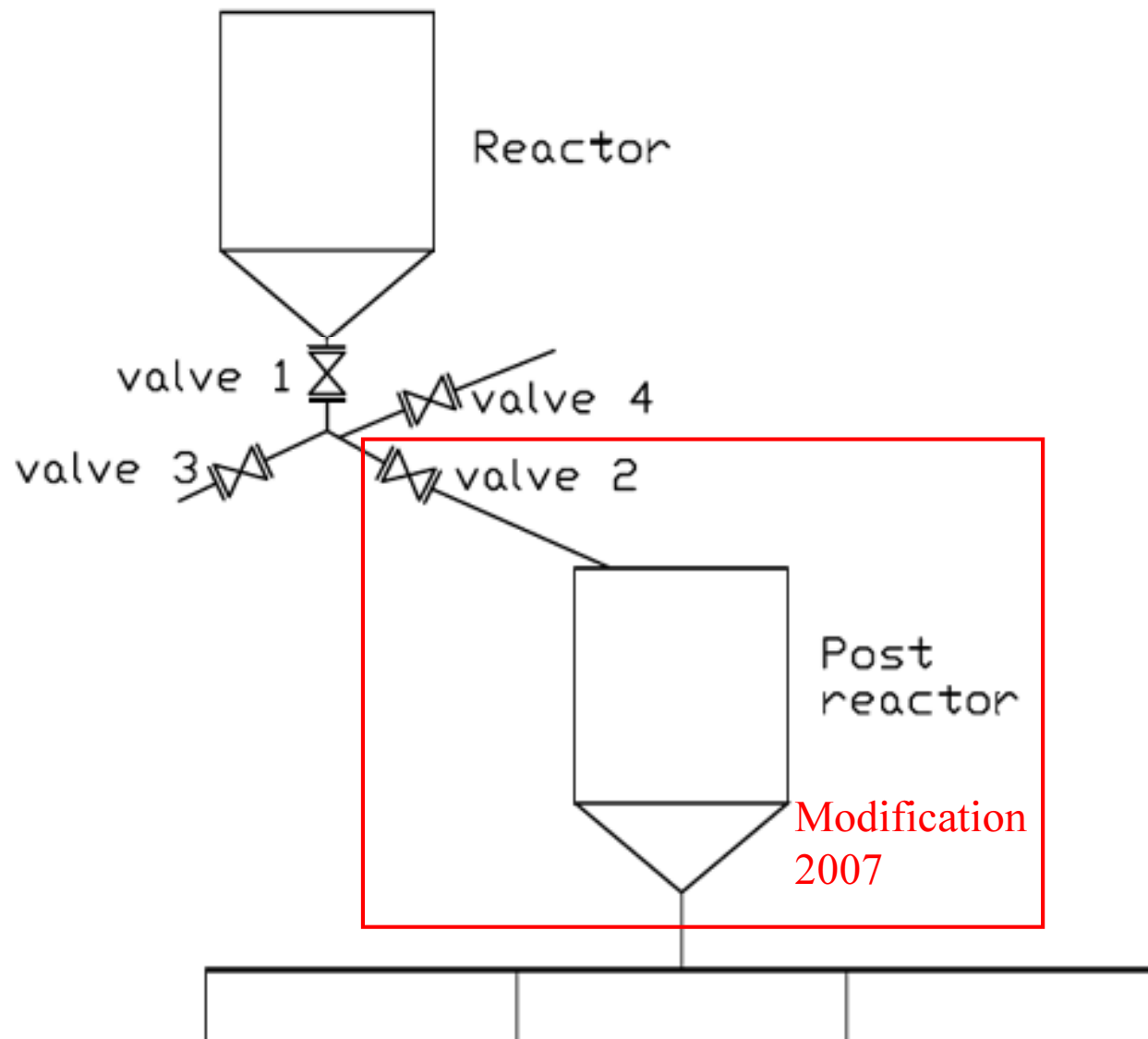
- Installed in 1990 – Modified Bachmann HMX process
- Technology based on patent literature and similar to other plants (batch process).
- Technology regarded as “state of the art”.
- Complex chemical reaction sequence.
- Incident history indicates few explosions and a “relatively safe” process.
- HMX relatively low sensitivity to friction, impact, static etc.
- However, potential for unstable intermediates and by-products (that do form in very small quantities) and hazards of these not well understood.



History of the plant

- Started in 1990 and the basic reaction process was the same as today.
- 4 reactants added to the nitrator.
- Reaction is slow – requires 1 hour mixing after addition of reactants.
- Initial design required discharge of nitrator every 2 hours.
- In 2007 process modified by installation of “post reactor” to allow discharge every hour – doubled plant output.





Evaluation of possible sources of ignition

Investigation findings

1. **Fire or heat:** no issue.
2. **Sparks:** no issue.
3. **Static:** no issue.
4. **Thermal decomposition:** Unlikely, but not to be excluded. Unknown by-products may have a thermal instability. However, there was no higher temperature or peaks than usual.
5. **Pressure:** Cannot be excluded. Unknown by-products may decompose or react under pressure waves (but no high pressure peaks).
6. **Impact:** Possible. Small particles (rust, pieces of metal inside piping) accelerated by air are able to cause an ignition of by-products having higher impact sensitivity
7. **Friction:** Possible. An ignition of accumulated by-products by friction (ball valve movement) is possible.



Investigation findings

- There were no **Hazard Studies** done when the plant was erected in 1990.
- **A formal risk assessment prior to installation was not conducted.** It was probably assumed that HMX in a liquid mixture/slurry is enough insensitive to impact and friction in the range caused by the installation.
- The option to avoid blockages/obstructions by changing the outlet diameter was not evaluated and the installation of a compressed air line was easier and did not interrupt the production. **Process modification/risk assessment**



- The patent (that was referred to) drawing deviates from the plant installation showing gravity overflows from one reaction tank to the other; there were neither piping nor (ball) valves that might cause confinement and friction or impact. **Hazard study**
- Based on the experience with the 17 years running failure-free single reactor system there was confidence that process control was safe.
- Risk of more sensitive intermediates in mixture transferred from the main to the post reactor and accumulation of these in piping and valves or compressed air causing friction or impact (in accelerating small solid particles (corrosion)) not considered. **Hazard study**
- The system for **maintenance and inspection** in place was not tailored to the existing hazards.



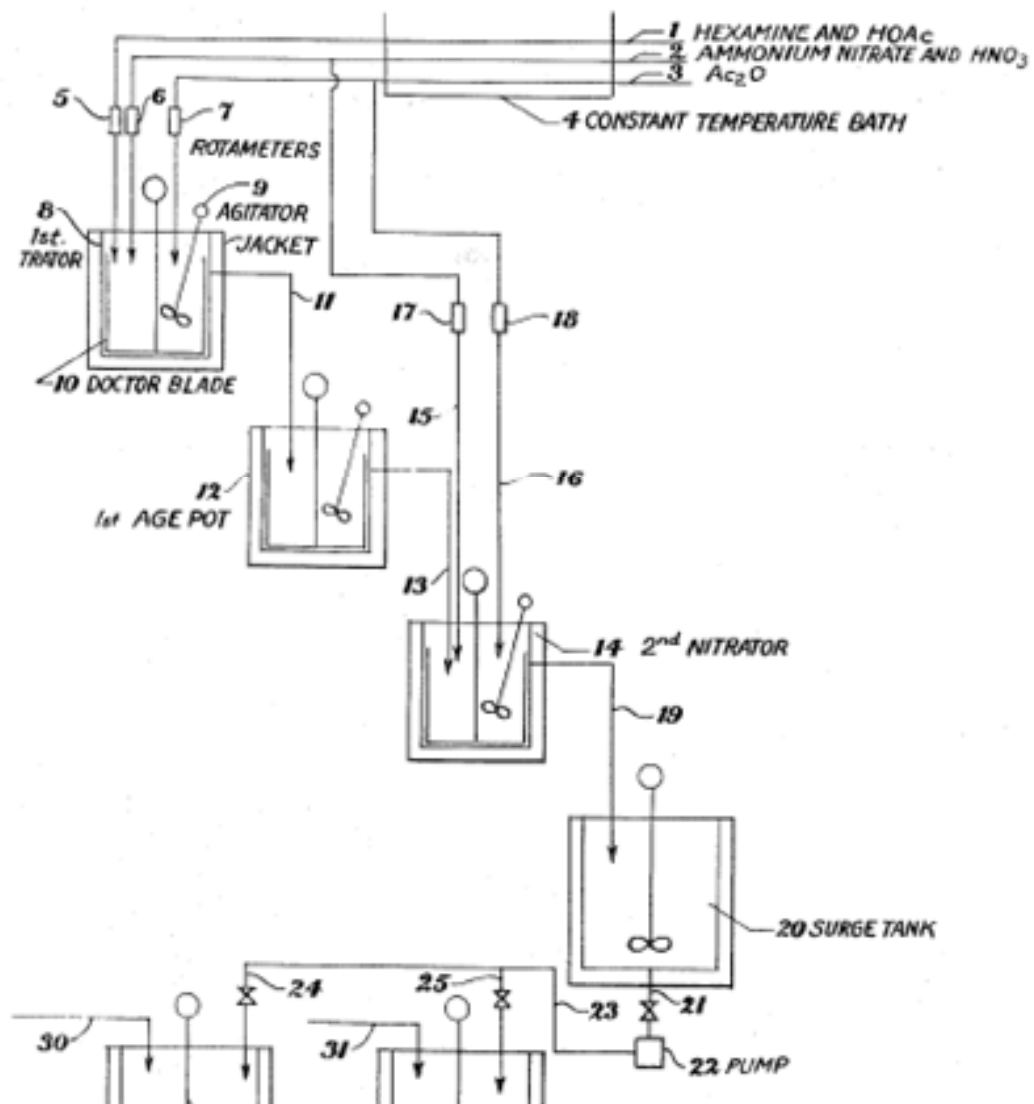
Nov. 6, 1973

R. ROBBINS ET AL

3,770,721

DIRECT PRODUCTION OF BETA-HMX

Filed Feb. 9, 1956



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Maintenance records

Training records

Material quality

Inspection/audit reports

Who was present?

What was being done?

- *Operating instructions*
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Months or
years

Days/weeks

Very recent



What information is in the story?

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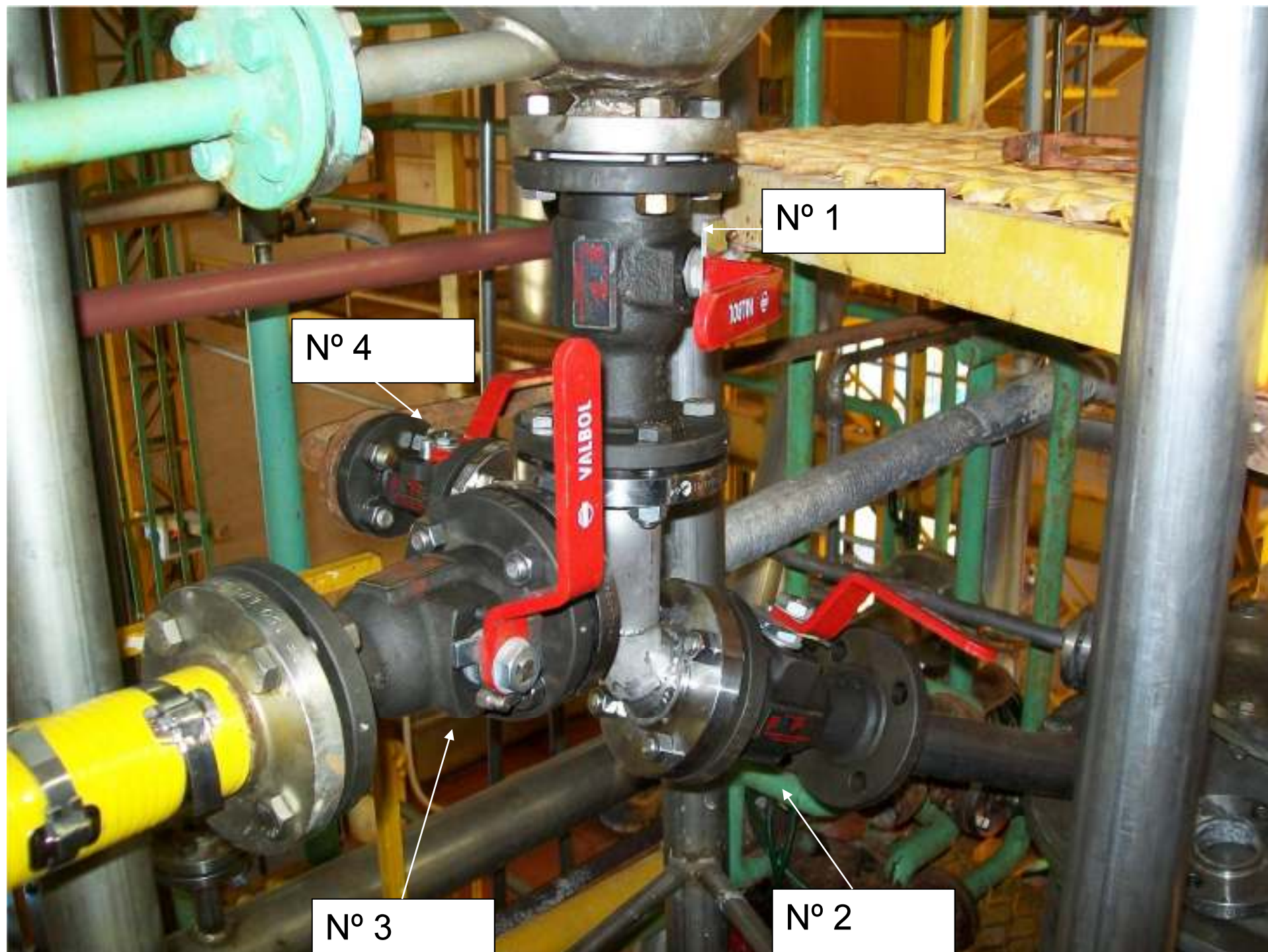
Very recent



Actions to prevent recurrence

- Process flow was studied in detail. Hazard and HAZOP studies. Other items identified that did not contribute to this incident.
- Reactor outlet enlarged and metal piping replaced with reinforced plastic hose.
- Compressed airline removed.
- Total number of valves reduced (from 4 to 1).
- Ball valves replaced with diaphragm valves.
- Improvement of maintenance plan.
- Periodic Hazard Studies in other plants on that site.







Learning points

- Wet materials (HMX and by-products) were not as insensitive as assumed
- Review processes operating for a longer period of time regularly and apply Hazard Studies and HAZOP
- BOS documentation should be reviewed regularly

