

Explosion

During high pressure water cleaning

May 5-6 2022

Westlake

Process Safety Conference 2026

May 13 2026/CPvB

Sharing the event....

It's



not about

blame

It's

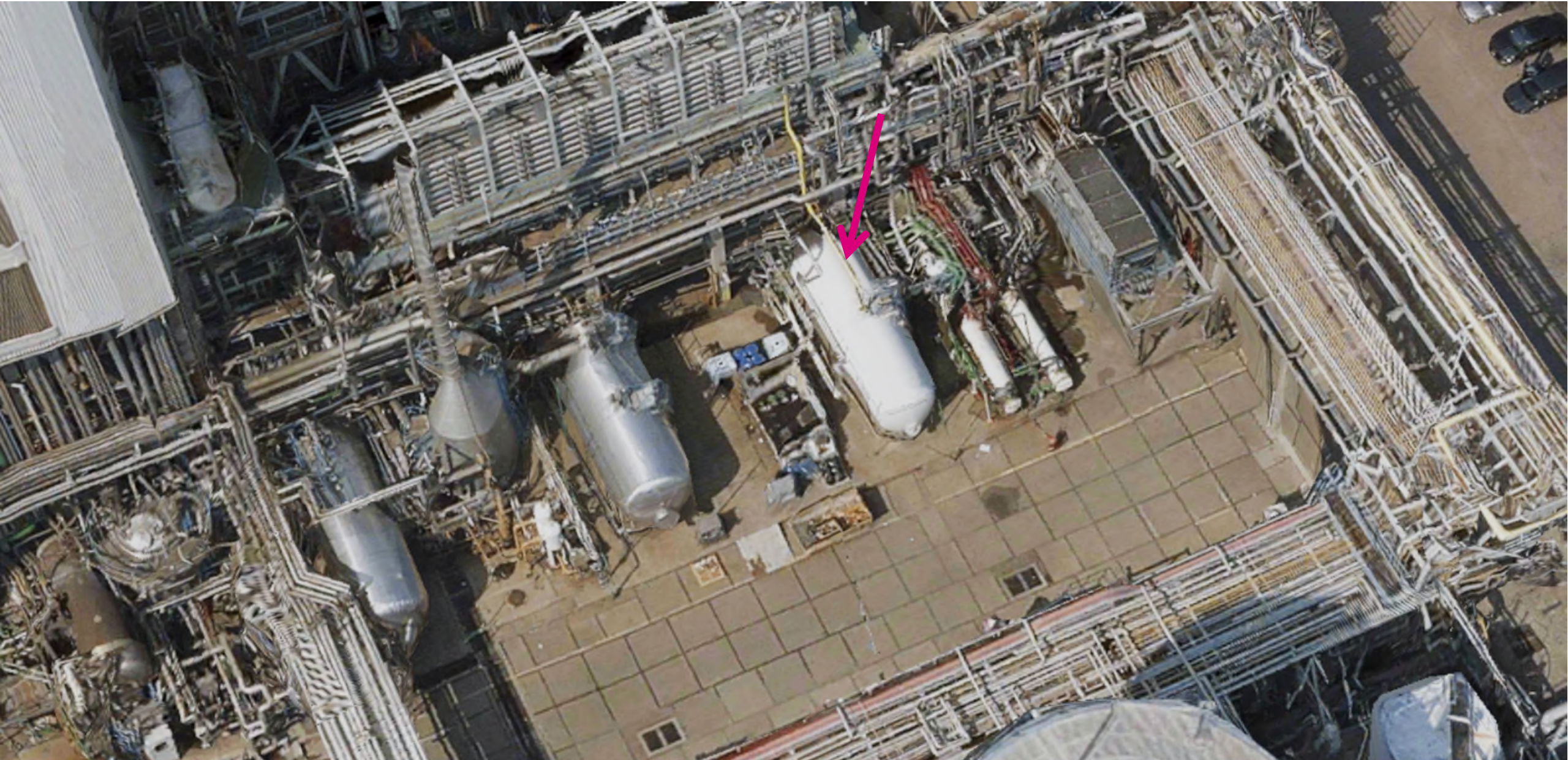


about

learning



V2008 location



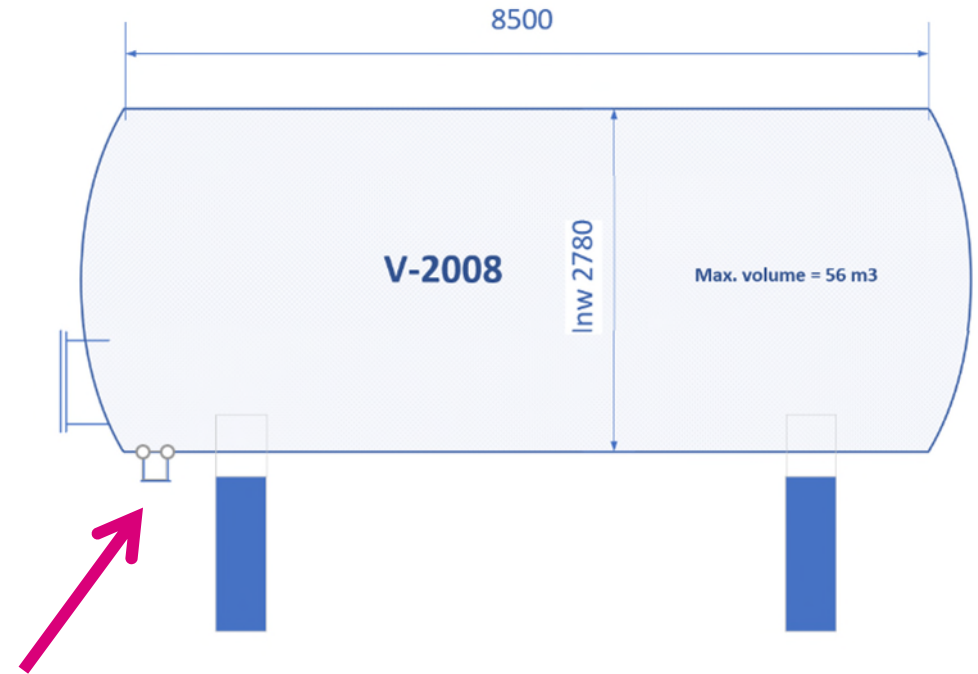
IPE vessel V2008

Properties

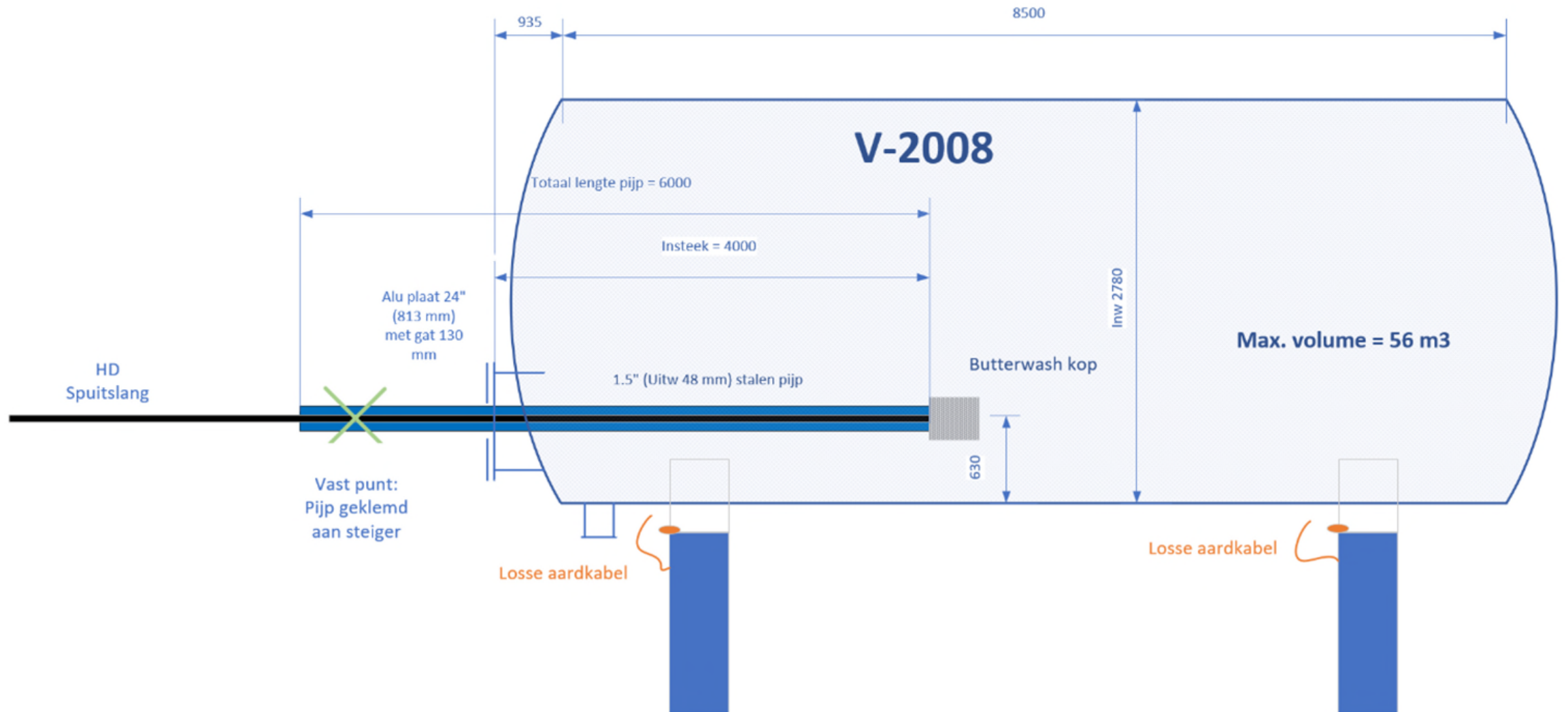
- Purpose : Buffering and separation of Isopropyl ether/water
- Volume : 56 m³
- Design pressure : 3.5 bar(g)

Work: Repair bottom nozzle -> Preparation for cleaning V2008

- Remove insulation locally
- Pump out content
- Apply LOTO
- Flush and steam out
- Remove connected piping



Cleaning setup



Incident Event

Sequence of cleaning preparation activities

- Manhole blind flange opened (Vessel bottom nozzle (3") was already open)
- High pressure water truck and Vacuum truck located at work spot, including facilities
- Butterwash unit installed
- Drain drums put under vessel
- Suction/cleaning hose put in drum
- Butterwash started

Moment of explosion

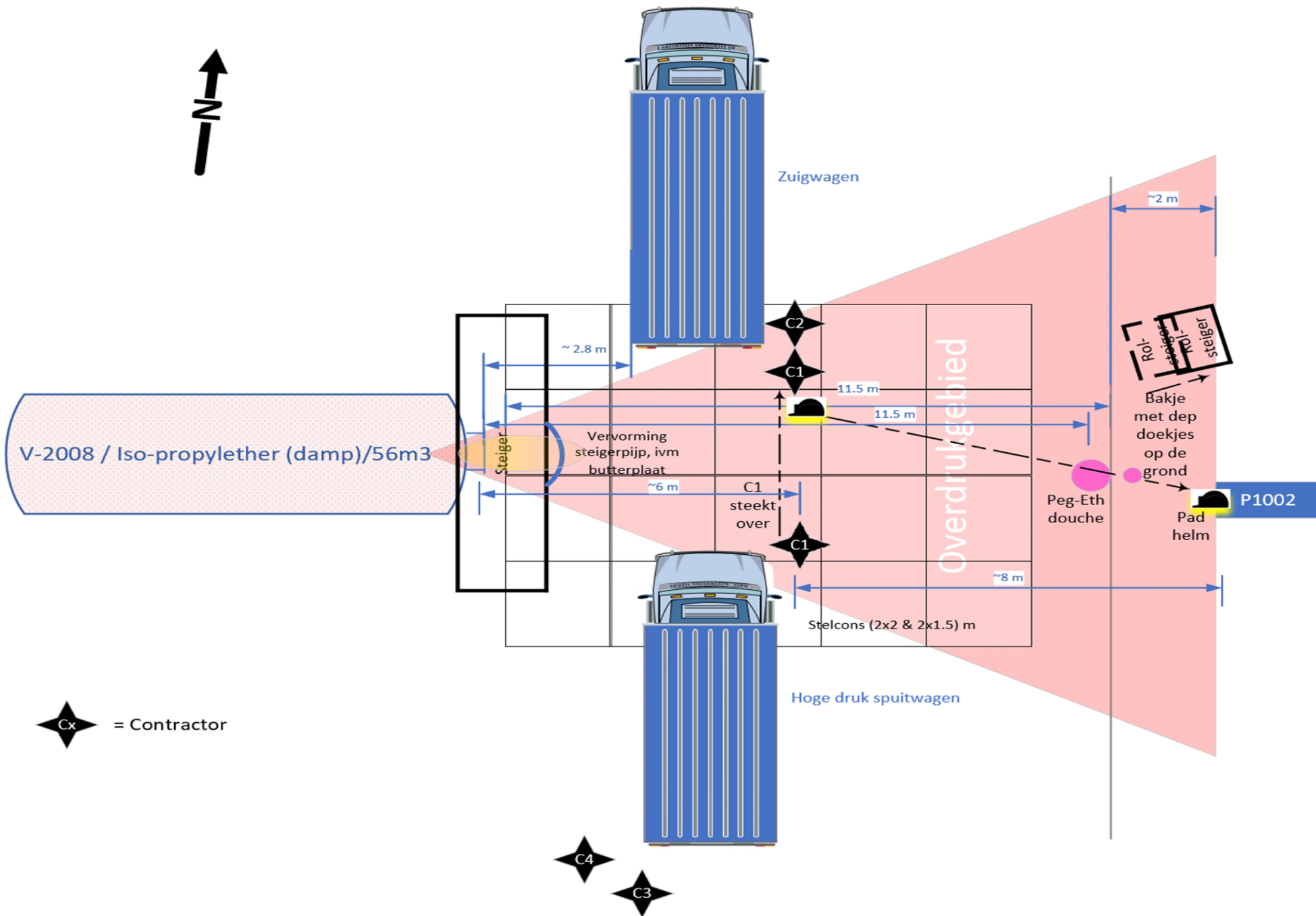
- After 15 minutes loud 'bang'
- Flame of 4-5 meter was seen
- Butterwash pipe was bent
- Splash plate fully bent over scaffolding pipe
- Hard hat blown from head contractor
- Two PE drain drums under nozzle fell down/blew away
- Rolling scaffold damaged pipe insulation



*Position
Contractor
personnel*

*Pressure wave ext.
(between ~1-25
mbarg)*

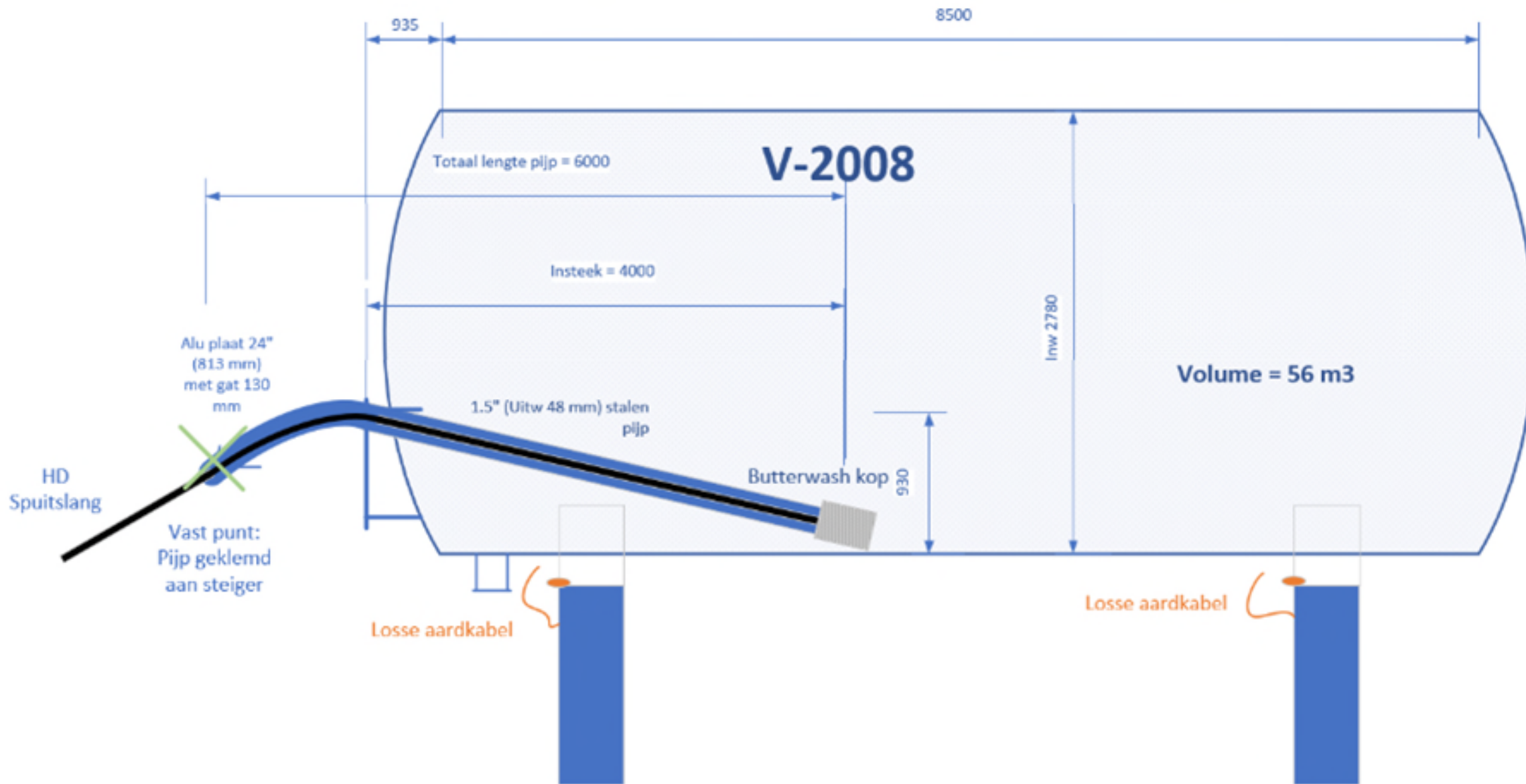




Investigation

Side view



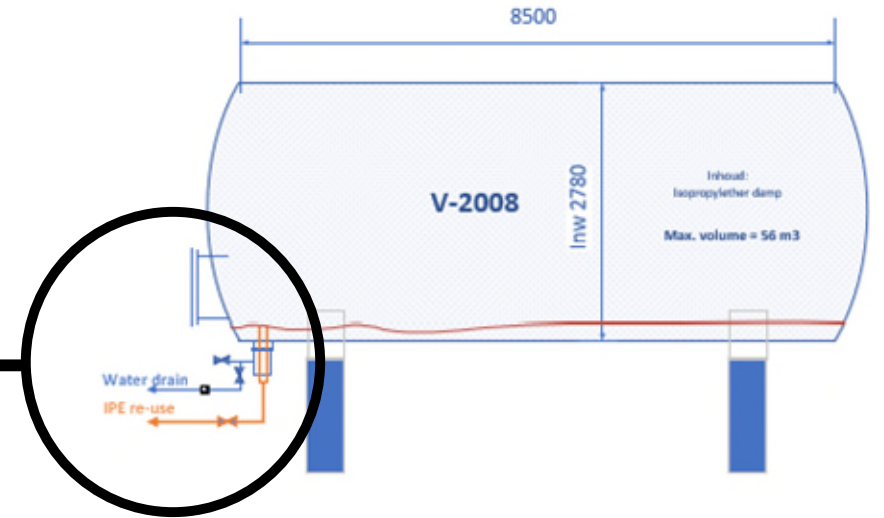
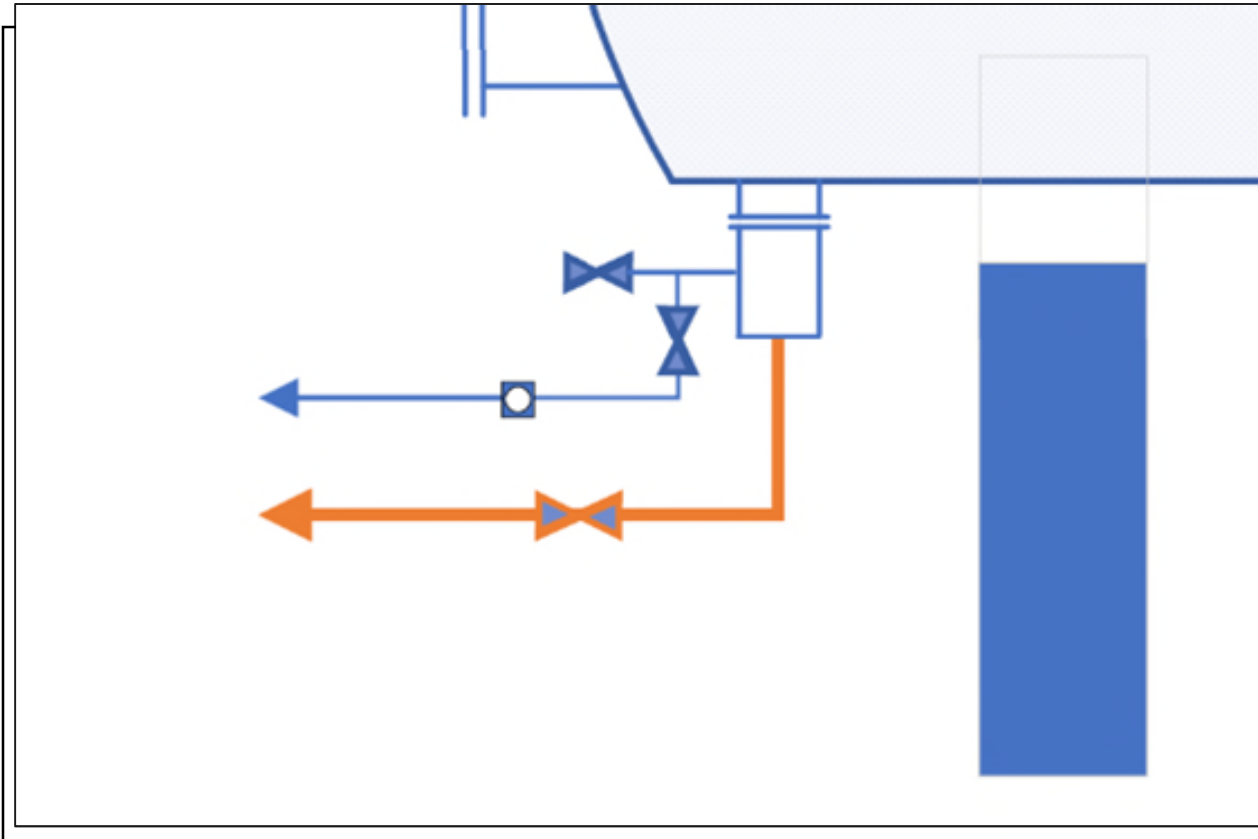


Operational work prior to cleaning



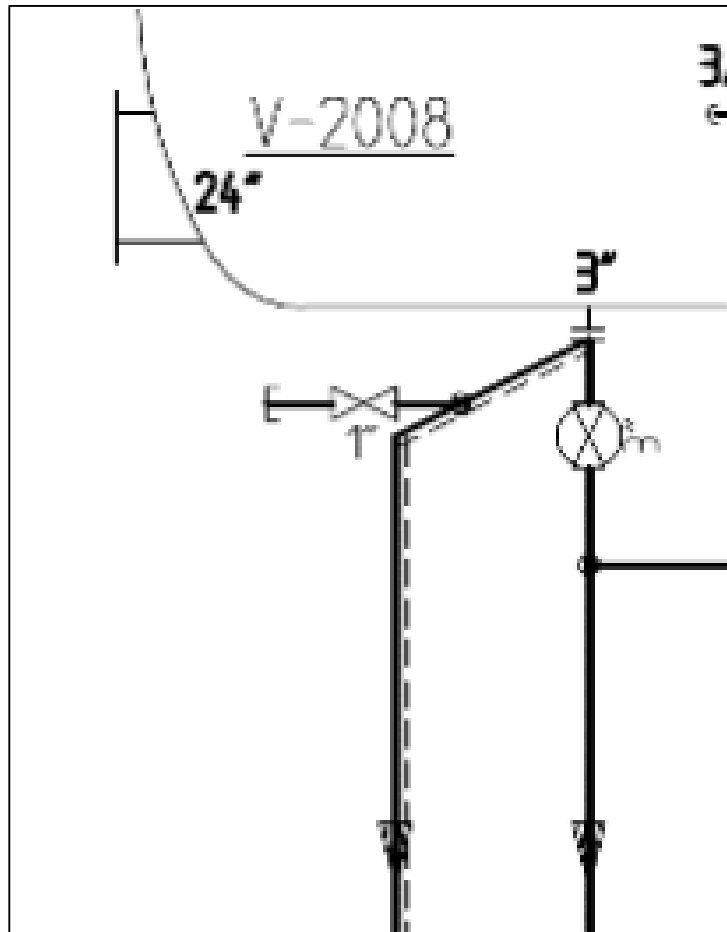
Operational work prior to cleaning

Design configuration



Initially ~2 m³ of liquid IPE remained behind, but was removed at a later stage (after steam out)

Design



Work Permit

Regular Operations

- Every job requires a separate Work Permit

TurnARound (TAR) -> possibility to use 'Consolidated Work permits' (Verzamellijst)

- Equivalent activities and risks
- Within the same unit/area
- Prior to May 5 – V2008 included (without being gas 'free')
- May 5/6 – V2008 excluded

Contractor used actual 'work lists'

Night work May 5/6 -> among other: ***Ground floor – PRIO to clean V2008***

Based on verbal communication – difference in interpretation: **thought vessel was gas 'free'**

Cleaning contractor:

'We assumed on trust that the assigned works were also permitted.'

Ignition Analysis (1)

Electrostatic charge build-up & discharge (1)

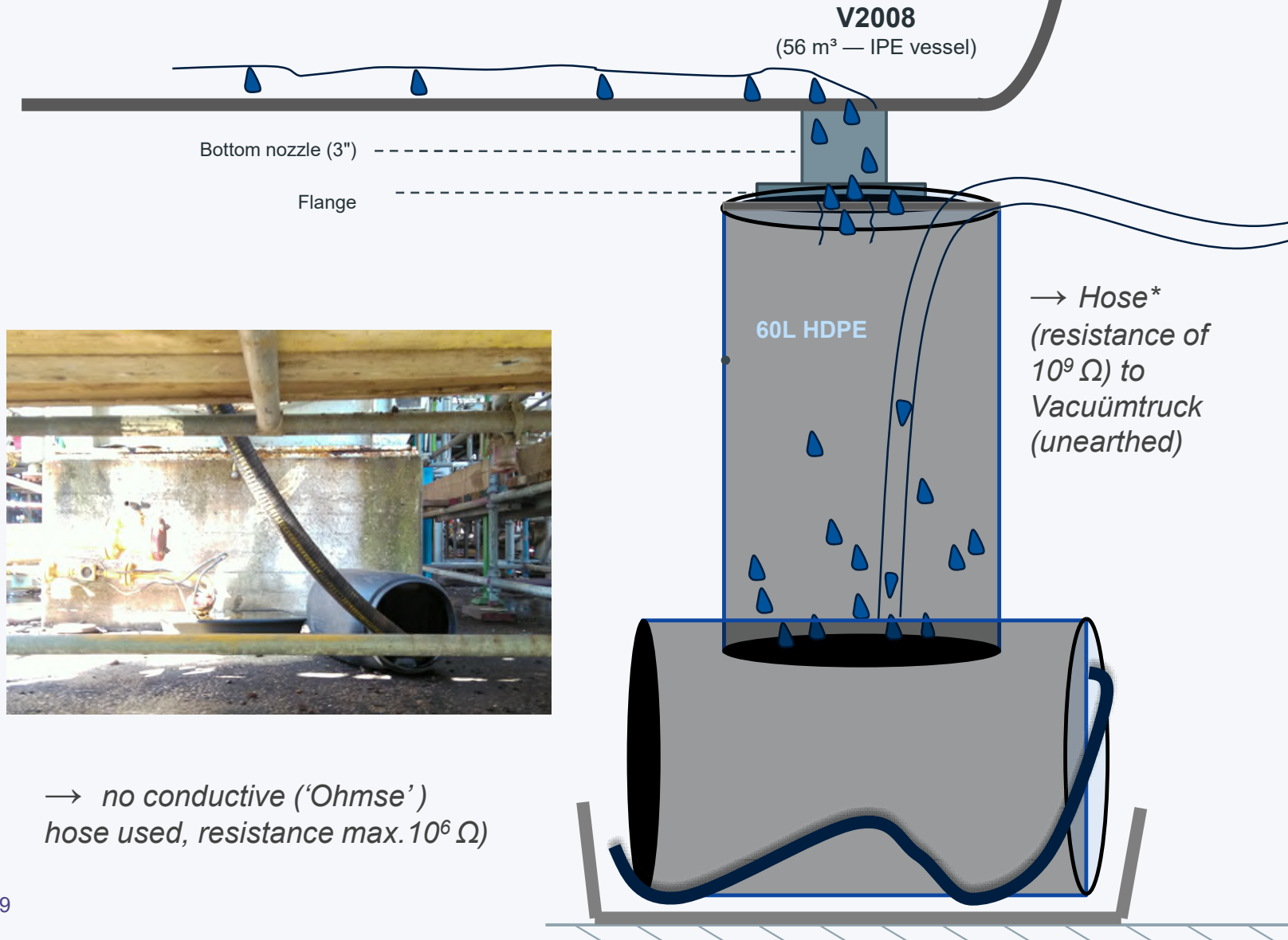
High pressure water cleaning (provided vessel and butterwash equipment are earthed)->

- **NPR-CLC-IEC/TR 60079-32-1 Explosive atmospheres – Part 32-1: Electrostatic Hazards – Guidance**
 - **Sprays could create very high charge densities and potentials in the tank during cleaning.**
 - The ignition risk for (washing) tanks which contain a flammable mixture is acceptable when:
 - Cylindrical metal container ≤ 3 m diameter
 - Spraying head pressure ≤ 500 bar(g) and flow rate of ≤ 5 l/s (300 l/min)
- Sources indicate differently for having no significant risk when vessel <1000 m³, neglected <100 m³, other say safe <30 m³
- During work in general, multiple cleaning employees, confirm seeing sparks occasionally
- Water settling: Where an immiscible component settles out in an insulating liquid (for example water in oil) high potentials can arise.

- **In our case:**
 - **Diameter 2.8 meter, water flow 200 l/min), but pressure range from 200-800 bar(g)**
 - **Residual IPE floats on water**
 - **Earthing**
 - **Vessel: 2 loose earthing cables, assumed to be preparation for theft**
 - **Suction hose/vacuum truck: not earthed**

Ignition Analysis (2)

Setup: HDPE drum under bottom nozzle V2008



Ignition Analysis (Other hypotheses)

- Vibration between Aluminium Butter plate and corroded bolts -> **Thermite reaction**, which has generated heat -> no proof found



- Vessel: 2 **loose earthing cables**, assumed subject theft -> resistivity tested afterwards, not a cause
- **Peroxides**



Fuel

Isopropyl ether (IPE)

- Original content
- Despite emptying, initially still material left ($\sim 2 \text{ m}^3$), due to insert pipe
- Despite steam-out, still flammable vapor present
- Measured post event – Still 30% LEL (LEL/UEL IPE: 1.4 – 7.9%)

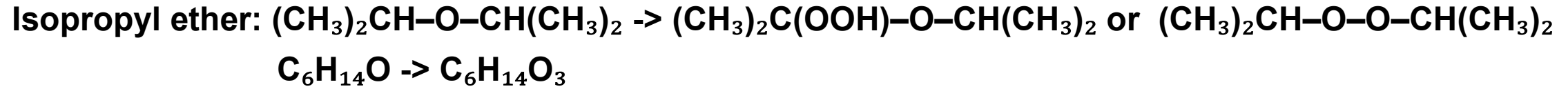
Two hours after the explosion:

- A gas test revealed 30% LEL concentration in the vessel ($\sim 4,200 \text{ ppm}$)
- 200 ppm IPE was measured in the 'wash' water
- Based on flame length ($\sim 4 \text{ m}$) it is assumed that flammable vapor was present.

Peroxides

- IPE -> Peroxides -> crystals
- Contractor: *A thin layer of residue was found in the vessel prior to butterwash, but no liquid*

Peroxide formation



Expect easy radical formation and peroxide risk, if a molecule has:

- ✓ Oxygen
 - ✓ C–H bonds next to that Oxygen
 - ✓ Secondary or tertiary carbons
- The O–O bond appears only after reaction **with oxygen (O₂) from air**. This happens via autoxidation, a radical chain process.
- High-pressure water jets (500-800 bar(g)) do not provide bond-breaking pressure directly, but they can supply
 - Mechanical shock
 - Cavitation micro-implosions
 - High-frequency vibration
 - Particle impact: The exit velocity of the water from the head is approximately 380 m/s.
 - At microscopic contact points, these create transient energy densities far higher than the average jet pressure.

IPE -> Class A – highest in range

Event from the past...

On June 3, 1998, a 165 m³ **cone roof tank** containing methyl tertiary butyl ether (MTBE) **exploded while being washed**, causing a fatality and **launching the 1.4 tonne roof a distance of 100 m.**

Initially the tank contained 27% MTBE vapor with the balance nitrogen. However, as washing proceeded **a vacuum truck was used to suck sludge, water, and residual MTBE out of the tank bottom.** As the vacuum hose lost contact with the liquid layer, the resulting negative pressure intermittently sucked air into the tank via the top manway, which held a high pressure washing device. **Turbulent mixing by the washing jets helped form a flammable mixture in the tank.** The explosion occurred during the **fourth cleaning cycle** and the fatally injured man was blown from the roof shortly after adjusting the washing device. Two “static” mechanisms considered were a **static discharge involving the water mist** and a **static discharge from an ungrounded vacuum hose.**

* Peroxide Hazard Group: Class B

Organisation & Human factors

Organization of work

- Implementation of safety management during a TAR is different and more complex than during regular operations.
 - **Less frequent**
 - **Limited available time in execution** (pre-technical period)
 - **Limited operational support (evening/night)** and **experience** (young operators)
 - Lack of clear hold points enable undesired step through
- Clear equipment (safety) status register

Human factors

- **Mixed messages and interpretations** about vessel being 'empty', 'clean', 'product-free', 'ready'
- Cleaning contractor:
 - *'We **assumed** on trust that the assigned works were also permitted'*
 - *'to avoid standing still and still do something'* job started

Measures to prevent reoccurrence

- **35 actions**
- **Strict monitoring on follow-up**

Highlights

- Adaptations Work Permit process
 - High pressure water cleaning work not per Consolidated Work Permits
 - High pressure water cleaning work: Hot work type 2
- Standard Work Instruction Flushing, including secondary improvements (e.g. after gas' free' measurement -> 5 min butterwash -> repetition of gas measuring)
- Include time-consuming safety matters in overall TAR schedule
- All activities to be supervised either by the TAR team or operations. For cleaning, a SIR-trained person is assigned to supervise these activities (including at non-daytime hours)
- Contractor set-up internal training

THANK YOU