Incident Learning

INCIDENT TITLE: NITRATOR 02 FUME OFF

BUSINESS UNIT: AECI MINING

DATE OF INCIDENT: 22 JULY 2022

DATE OF PRESENTATION: 27 JULY 2023

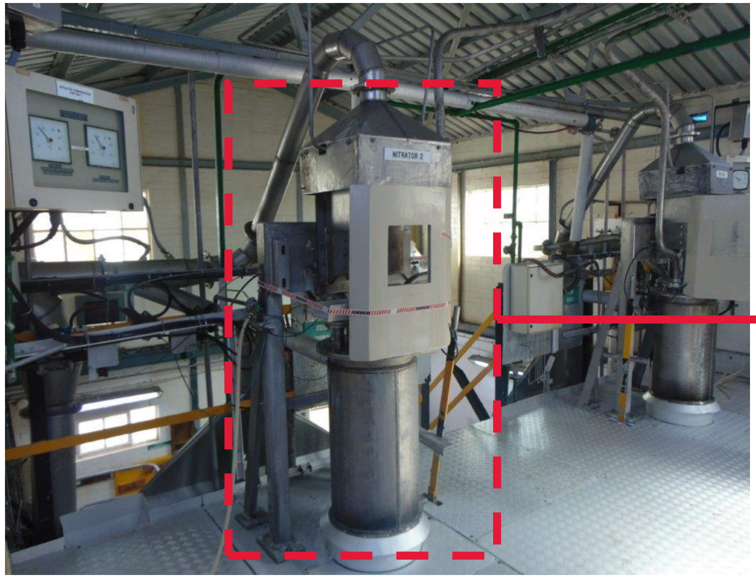
ZERO HARM

WE ASPIRE TO OPERATE SUSTAINABLY, WITHOUT HARM TO PEOPLE, THE ENVIRONMENT AND THE COMMUNITIES IN WHICH WE OPERATE.

INCIDENT RECALL

INCIDENT DESCRIPTION, CONSEQUENCES AND PHOTOGRAPHS

- The PETN Plant experienced a fume-off during the nitration process in Nitrator 02 on the 22nd of July 2022 at around 07:05 am. There was a loss of containment of acidic product due to the violent decomposition reaction that occurred within the Nitrator.
- The incident was reported as a minor process safety incident however it was classified as a high potential incident due to the possible exposure of the plant operator to the high concentration of NOx fumes as well as the potential explosion risk

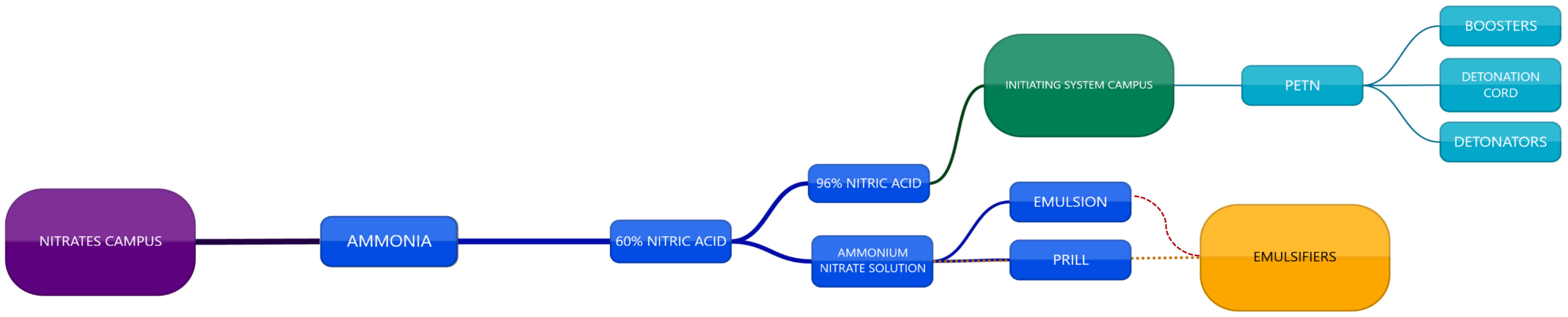


Nitrator 02

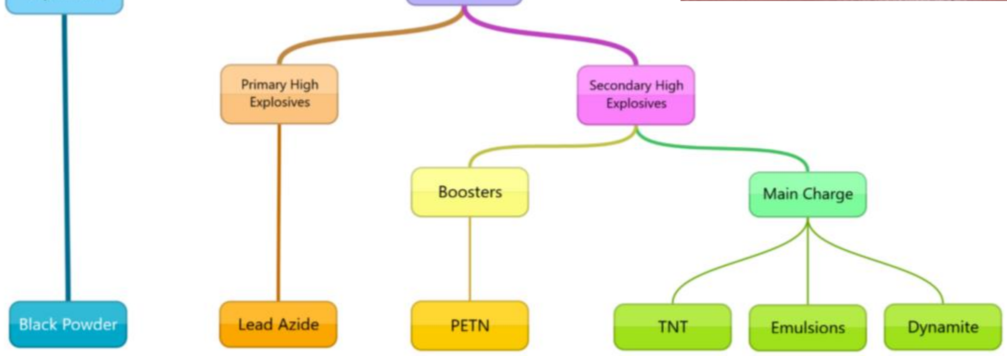
NOx fume release

INCIDENT RECALL

VALUE CHAIN



– PETN = Pentaerythritol tetranitrate
– Secondary high explosive
– One of the most powerful and brisant explosive
– White to off-white in colour
– Manufactured through the reaction between penta and 96% nitric acid (exothermic reaction)
– Powder



PETN PLANT OVERVIEW

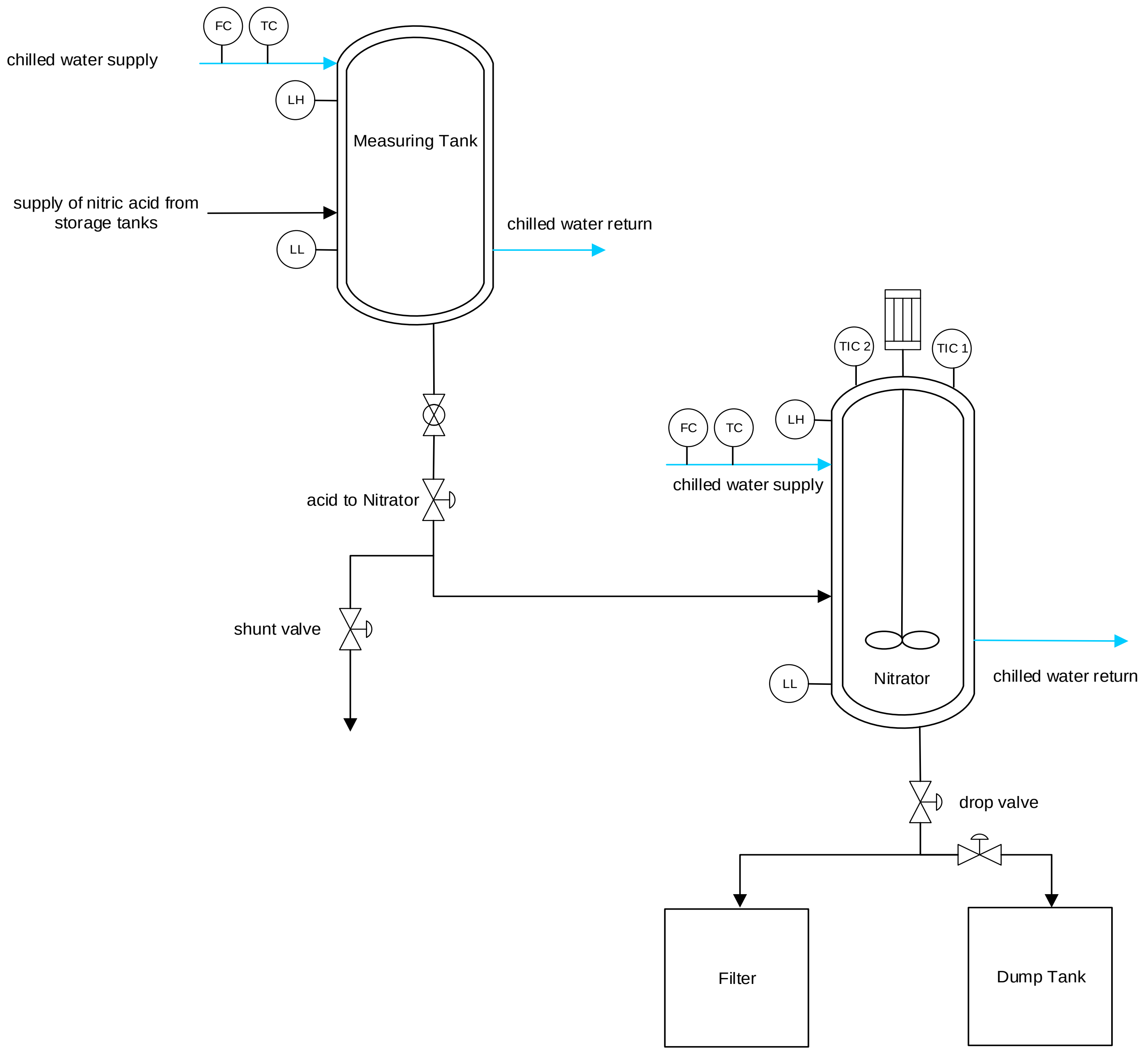
– The PETN manufacturing site is located in the Initiating Systems Campus (IS)
– Forms the backbone of IS due to its use in all the finished products
– Multiple stages once PETN is manufactured in preparation for use in detonators, detonation cord and boosters
– Spacing between process units is due to safe distances as applied by the explosives regulation

UNDERSTANDING THE PROCESS

- **STAGE 1: FEEDING NITRIC ACID**
  - Nitric acid received from road tanker and loaded into 2 storage tanks (acid QC'd)
  - Nitric acid is pumped from the storage tank into the measuring tank
- CRITICAL CONDITIONS:
  - High level must be initiated to ensure correct quantity is filled in the measuring tank
  - Chilled water flow and temperature measured

- **STAGE 2: BEFORE NITRATION**
  - Measure correct quantity of Penta and place in a trolley next to the Nitrator
  - Send the nitric acid from the measuring tank into the Nitrator
- CRITICAL CONDITIONS:
  - Nitrator must be low level before transferring acid
  - Stirrer must be on
  - Drop valve must be closed
  - Chilled water flow and temperature correct
  - Nitrator must be at correct cool temperature
  - Nitrator must be high level after transferring acid

- **STAGE 3: DURING NITRATION**
  - Begin loading Penta two scoops at a time and watch the temperature.
  - Control temperature at specific value – temperature control dependent on Penta addition
- CRITICAL CONDITIONS
  - Drown tank activation:
  - Temperature reaching above critical temperature
  - Stirrer stopping – malfunction, manually stopped
  - Chilled water temperature inadequate
  - Chilled water flow inadequate
  - Extraction system displacing fumes to the stack



INCIDENT RECALL

VIDEO FOOTAGE

INCIDENT RECALL

RELEVANT FACTS - TIME LINE / SEQUENCE OF EVENTS

Provide a basic timeline of the sequence of events.

20/07/2022
Problem detected with Nitrator 02 and Filter 02 with regards to nitric acid passing into the effluent system

21/07/2022
Problem was determined to be the actuator valve not opening to the recovery system but into the effluent system. Repaired

22/07/2022
In the early hours of the morning Nitrator 01 probe was reported to be malfunctioning (charged with acid)

22/07/2022
He could not determine the problem with the Nitrator 02 probe and shift handover was completed

22/07/2022
Artisan called out to evaluate. He found that the temperature probe on Nitrator 01 was broken which he replaced.

22/07/2022
Around the same time it was reported that Nitrator 02 (charged with acid) probe was also malfunctioning.

22/07/2022
The morning shift was briefed about the inaccuracy of Nitrator 02 temperature probe

22/07/2022
The plant operator began adding Penta, while the shift manager went to call the on shift artisan

22/07/2022
At 7:05 am the temperature began ot increase rapidly and a plume of brown fumes escaped from the Nitrator 02. The plant went into emergency mode

– Critical information used to build the investigation:
  - CCTV footage
  - SCADA information – process information
  - Operator interviews
  - Test reports of instruments
  - P&ID’s
  - SOP’s
  - Work instructions
  - Past test reports from maintenance
  - Product QC reports

INCIDENT RECALL

ROOT CAUSE ANALYSIS SUMMARY FROM INVESTIGATION

Direct Causes:

- Leak in the measuring tank jacket causing dilute acid
- The dilute acid caused a delayed reaction that eventually led to a runaway reaction

Underlying causes:

- Continued Penta addition

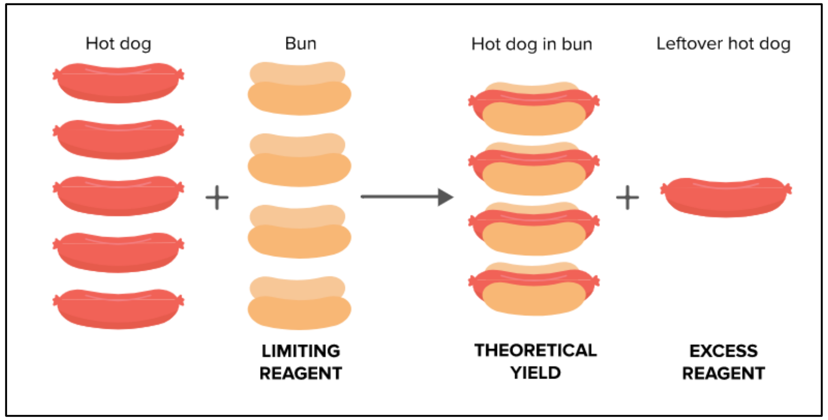
Root Causes:

- Inspection of equipment to assure integrity
- Troubleshooting methodology
- Detection of process upsets
- Training not risk related in understanding consequence of deviation

INCIDENT RECALL

RELEVANT FACTS – ANY OTHER FACTS

Chemical Reaction: $C(CH_2OH)_4 + 4\ HNO_3 \rightarrow C(CH_2ONO_2)_4 + 4H_2O$



- Add Penta gradually to safely shift that reaction to the left
- The conversion of chemical potential energy into molecular translational energy (heat)
- Diluted acid slows the reaction down but a tipping point is reached where there is enough of the two reagents to push the reaction
- Why HPI?
  - Penta reacts violently with strong oxidants and strong acids. This generates an explosion hazard
  - Exposure to NOx fumes would have overcome the plant operator

INCIDENT RECALL

CORRECTIVE ACTIONS FROM THE INVESTIGATION

CORRECTIVE ACTIONS:

<table>
<tr><th>Problem</th><th>Action</th></tr>
<tr><td rowspan="4">Chiller Water jacket pinhole leading to Nitric Acid dilution</td><td>Remove the Fresh Acid measuring vessel and seal off the pinhole.</td></tr>
<tr><td>Consider installing temperature probe to measure Fresh Acid Measuring Tank and either indicate or interlock it.</td></tr>
<tr><td>Consider a maintenance program for Nitric Acid systems with a specific view of verifying system integrity e.g. periodic inspections or replacement</td></tr>
<tr><td>Review process safety critical equipment and re-evaluate maintenance program or consider better materials of construction like titanium for Acid exposed equipment.</td></tr>
<tr><td rowspan="3">Continued Nitration in the absence of appropriate temperature responses</td><td>Consider reviewing OI to include some information as to why temperature responses are safety critical during the Nitration process and the consequences thereof.</td></tr>
<tr><td>Review process safety critical and re-evaluate control measures including periodic operator awareness</td></tr>
<tr><td>Conduct behavioural Safety audits e.g. PJO followed by engagement with PETN with view of driving positive safety culture</td></tr>
<tr><td>Troubleshooting inadequacies</td><td>Ensure subordination plan is followed especially when root causes aren’t identified after hours</td></tr>
<tr><td>Inadequate artisan competencies especially after hours</td><td>Involve Plant SME in the development of artisan training matrix and train all exposed artisans.</td></tr>
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INCIDENT RECALL

RISK REVIEW – REFER TO THE RELEVANT RISK POSTER

1. Were the **risk management requirements** in place? If not, please elaborate.

   Design, maintain, install and/or modify process equipment using recognized and generally accepted good engineering practices, in accordance with established codes and standards

   Training

2. Which **critical controls** should have been in place for this specific risk?

   Temperature monitor on the measuring tank

   pH monitor on the measuring tank

   Improved inspection methodology on equipment such as dye pen testing, pressure testing more frequently

   Inherent safe design – removing the operator from the process. Automatic charging on Penta into the Nitrator

3. Which **critical controls** are preventive and which ones are corrective controls?

   Corrective controls = temperature exceedance led to the automatic dumping of the batch into the dump tank. Emergency alarm activated and drenching of the plant

   Preventative controls = temperature indication and control in Nitrator 02

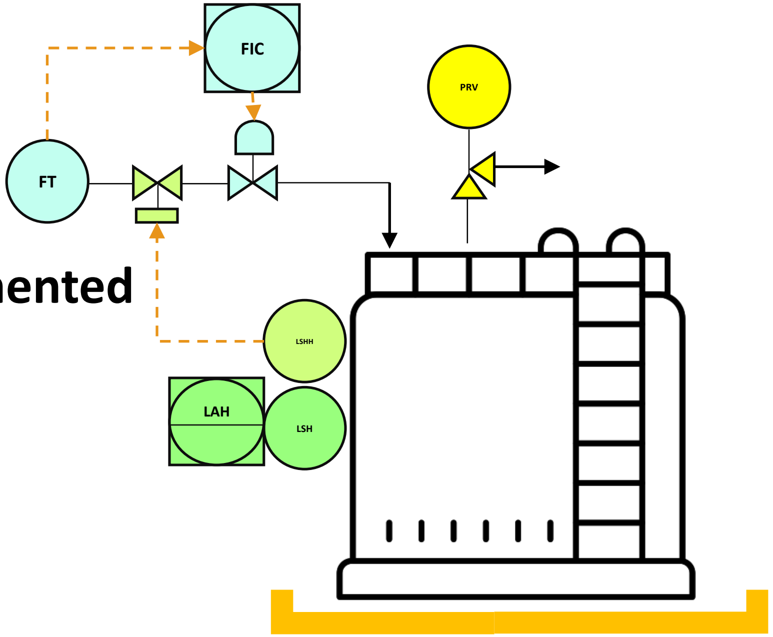
4. Which **critical controls** failed, in other words which controls were weak / absent, that lead to the **unwanted event** happening?

   Verification of acid quality is only limited to a sample from the road tanker

   The extraction system could not displace the NOx fumes fast enough

LEARNINGS AND NEXT STEPS:

RECOMMENDATIONS FROM THE RISK REVIEW FOR OTHER BUSINESSES



– Understand your layers of protection
  - **Don't blur your Basic Process Control System as being your Safety Instrumented System**
  - Output failure of the BPCS will result in the safety system failing
  - Plant integrity forms a layer of control

– Training is not simply giving someone instructions
  - **Work procedures + Cognitive skills = Skilled personnel**
  - Knowledge presented in the context of its job
  - Context provides structure on which to hang new knowledge
  - Link between the knowledge and its use

SUMMARY

The concentration of acid in the nitration process is a critical parameter – focus needs to be given to ensure this parameter does not undergo upset

Incident occurred within the context of an explosive environment but the learning transcends into any manufacturing context – the integrity of our processes must be maintained and assurance given

Inherent design thinking must be applied from design inception – in the case of brownfield inherent design can still be applied (LOPA)