Assessment of NOx Fugitive Emission Incidents at Chemifloc Shannon

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Executive Summary

Liam Tolton of Second Sight Technical was engaged to carry out an independent assessment and report on three incidents of fugitive emissions of NOx gases which arose at the Chemifloc Shannon facility since 2018.
The incidents which are the subject of this assessment are:

- INCI014587 - Operator Error during Metal Addition to Ferric Nitrate Reactor - 6th June 2018
- INCI18620 - Failure of Reactor Exhaust Isolation Valve - 28th April 2020
- INCI19623 - Scrubber Fan Failure - 16th September 2020

In each case the incidents were investigated by the technical and managerial personnel at the facility and comprehensive reports were prepared for the Environmental Protection Agency in relation to each of the incidents. These reports included formal Root Cause Analysis using the Ishikawa Process[1] and the preparation of formal Incident Reports and the subsequent Corrective Action Preventive Action (CAPA) Reports for the Agency.

An extensive review of all three incidents was undertaken which is described in detail in this report. I carried out two side visits to the Smithstown Industrial Estate facility. Two site visits were also completed.

Each incident is separately assessed using the following structured approach:

1. Review of the documentation including the Chemifloc Incident Reports, details of correspondence with the Agency and EPA Site Visit Reports.
2. Review of the status of close out of the recommendations arising from each investigation.
3. Assessment of the adequacy and completeness of each Incident Report.
4. Identifying recommendations for action and opportunities for further improvement following this Review process.

It is my opinion that in the case of INCI01487 that the root cause was correctly identified as human error, the investigation was thorough and complete and that the corrective actions taken were adequate to significantly reduce the risk of a similar incident recurring in the future.

It is my opinion that in the case of INCI1820 that the root cause was correctly identified as a failure of the main exhaust isolation butterfly valve on Ferric Nitrate Reactor 2 causing a partial closure of the valve which impacted the ability of the scrubbing system to fully convey the NO_x gases evolved in the process out of the vessel. The investigation was thorough and complete. The primary corrective action, replacement of the worn valve with one of superior design, was adequate to prevent recurrence.

In the case of INCI19623 it is my opinion that the root cause of the incident was not fully determined during the initial investigation. This arose as a result of a lapse in communications between personnel taking part in the immediate corrective action and the investigation team. I have recommended that the Root Cause Analysis be revised to clarify the reason for the initial fan failure and to include a recommendation on the improvement of the incident investigation process. The revised Root Cause Analysis is appended to this Report.

[1] The Ishikawa Process is a structured process used for the identification of root cause in incident investigation. It is sometimes referred to as a 'Fishbone Diagram'.

During my investigation, I received full co-operation from the technical and managerial staff at the facility and I can conclude that the plant personnel are fully committed to ensuring that the facility always operates within its licence conditions. The plant personnel are open to additional action to further reduce the risk of similar incidents arising in the future and have demonstrated that they are willing to consider any practical technical improvements identified.

1.0 Introduction

Liam Tolton of Second Sight Technical was engaged to carry out an independent assessment and report on three incidents of fugitive emissions of NO_x gases which arose at the Chemifloc Shannon facility since 2018.

The request from the Agency was for "*an Independent Engineers Report that reviews recent incidents (INCI019623, INCI018620 and INC018620) and recommends a final solution to eliminate the risk of visible NO_x plumes emanating from the site*".

I note that in the Agency request one incident (18620) was referenced twice. Discussion with the site personnel clarified that this was likely to have been a reference to an earlier incident dating back to 2018 (INCI014587) involving a NO_x plume emission. The report is therefore based on the following three incidents:

- INCI014587 - Operator Error during Metal Addition to Ferric Nitrate Reactor - 6th June 2018
- INCI18620 - Failure of Reactor Exhaust Isolation Valve - 28th April 2020
- INCI19623 - Scrubber Fan Failure - 16th September 2020

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This report includes the following sections:

A separate review of the Scrubber system capacity and performance is also being undertaken by the author as part of an EPA Licence Review process. I carried out an initial site visit in connection with the performance assessment on 8th September 2020. I completed a second site visit with a specific focus on the subject of this report on 26th November 2020. I met with Mr.

Fergal Gallagher and Dr. Ed Roycroft who provided me with clarification in relation to the incidents and the documentation. I inspected the reactor systems and the air emissions abatement systems during this visit.

Further analysis and assessment of the scrubber operations will be completed as part of the overall system performance assessment and additional recommendations are likely to be made arising from that review. The overall objective of both this report and the ongoing review of the abatement system is to further enhance the overall performance and reliability of the reaction and air emissions treatment systems at the Chemifloc facility and thereby minimise any risk of recurrence of fugitive emissions from the facility.

2.0 **Review of Incident INCI014587**

2.1 Review of Documentation

I examined the following documentation / CCTV footage as part of this review:

- Chemifloc Ltd. (P0076-01) Response to Environmental Complaint (COM007504) & Update for INCI014587.
- CCTV footage of the incident.
- Incident INCI014587 for Chemifloc Limited Licence (P0076-01) Notification No: INCI014587 from the EPA EDEN system.
- EPA Site Visit Report SVI 15681.

2.2 Review of the Status of Close Out of Corrective and Preventative Actions

Table 1 shows the status of the corrective and preventative actions made as part of the original investigation of this incident.

Table 1 INCI014587 Status of Close Out of Corrective and Preventative Actions

Corrective Action	Status	Assessment	Comment
All Ferric Nitrate production stopped until investigation complete.	Completed	Appropriate & Adequate.	No further action required.
All Ferric Nitrate production limited to day shift hours until engineering modifications completed.	Completed	Appropriate & Adequate.	No further action required.
All relevant personnel have been retrained on appropriate SOPs for Ferric Nitrate production.	Completed	Training records available to confirm completion.	No further action required.
Retrain all employees on HS01 (Accident/Incident Near-Miss Reporting Procedure).	Completed	Training records available to confirm completion. I confirmed the understanding of the metal addition system with the duty operator during my visit.	Ongoing refresher training is carried out as part of the normal on-site training programme.
A disciplinary/HR process is ongoing with respect to GO-1.	Completed	Appropriate & Adequate.	No further action required.

Corrective Action	Status	Assessment	Comment
Add physical interlock to dual Knife Valve system so that one valve is always closed.	Completed	Completed and operation confirmed during site visit.	No further action required.
Review air handling capability and extraction system from Ferric Nitrate production vessels.	Completed	This was completed by site technical personnel by reference to ongoing air emissions analysis which met the requirements of the EPA licence.	A formal review was commissioned as part of the current licence review. This is currently ongoing and will provide a documented assessment of the system performance.
Add a daily workflow for review of ex. day shift CCTV footage for emissions (complete).	Completed	An SOP HS/17, A1 Emission Stack daily Closed-Circuit Television (CCTV) Review Procedure was drafted and A log of A1 Emission Stack daily Closed-Circuit Television (CCTV) Reviews is maintained in form HS/17/F1.	No further action required.
A notification of the incident to the EPA has been made through EDEN (complete).	Completed	Reviewed as part of this assessment.	No further action required.
INCIDENT: INSTRUCTION from EPA included 10 items for action.	Completed	A full response was provided to the Agency based on the EPA Incident Instruction. I assessed this response, and it was appropriate and adequate.	No further action required.

2.3 Assessment of the Overall Close out

The corrective and preventive actions arising from this incident have been effectively closed out and appear adequate to prevent recurrence of a similar incident. As in the cases of all human error incidents, there is always some risk of recurrence, however in this case an interlock was added to the knife valves to ensure that these cannot both be opened at the same time. This will ensure that the reactor is not open to the atmosphere during or immediately after the metal drop is carried out and thereby mitigate the risk of recurrence due to this type of human error. Ongoing training of existing personnel and any new personnel is important to ensure that in the case of a manual operation such as this one, that the likelihood of human errors is minimised.

2.4 Additional Opportunities for Improvement

As part of my assessment of this incident I noted that since the incident additional buckets are available which allows the operator to pre-batch the metal drops and thereby reduces the likelihood of error due to the operator forgetting whether he

has charged the correct amount of metal at each drop. Consideration should also be given to the provision of a whiteboard at the reactor platform opposite each reactor with each drop pre-numbered where the operator would note on the board the time of each drop. This can then be confirmed on the batch record sheet at the control room providing a cross check of the operation at the point of charging. A separate cross check such as this carried out in separate locations will reduce the risk of human error in relation to over-charging of metal to the reactors. This is particularly important when both reactors are in operation. A timer has also been fitted to the system to prevent the knife valves being operated within a shorter timeframe than the permissible 30-minute interval between metal drops.

3.0 Review of Incident INCI18620

3.1 Review of Documentation

I examined the following documentation/CCTV footage as part of this review:

- Chemifloc Ltd. (P0076-01) Incident Notification Report (INCI018620) v1.1.
- Chemifloc Ltd. (P0076-01) Corrective/Preventive Action Report (INCI018620) 20/07/20.
- CCTV footage of the incident.
- Incident INCI018620 for Chemifloc Limited Licence (P0076-01) Notification No: INCI018620 from the EPA EDEN system.
- EPA Site Visit Report SV19272.

3.2 Review of the Status of Close Out of Corrective and Preventative Actions

Table 2 shows the status of the recommendations made as part of the original investigation of this incident.

Table 2 INCI018620 Status of Close Out of Corrective and Preventative Actions

Corrective Action	Status	Assessment	Comment
All Ferric Nitrate production stopped until investigation complete (complete).	Completed	Appropriate & Adequate.	No further action required.
Replace failed valve with new valve on 30/04/20.	Completed	A new design of butterfly valve has been fitted which eliminates the possibility of a gravity induced opening of the valve.	No further action required.
Inspect Ferric Nitrate Reactor 1 valve for potential similar wear and tear and replace if necessary.	Completed	I completed an inspection of the exhaust valve on Reactor 1. The valve handle lock is functional. The true horizontal orientation will ensure even in the event of a lock failure partial or complete valve closure is very unlikely.	A complete spare valve of the new design is available in stores and will be fitted in the event of any deterioration observed during routine inspections of the Reactor 1 exhaust valve.

Corrective Action	Status	Assessment	Comment
Ensure that the Ferric Nitrate Reactor 1 & 2 exhaust valves are maintained in a locked open position under normal operating conditions and update relevant SOP if required.	Completed	SOP OP11, Production of Ferric Nitrate - revised to provide clear instruction regarding the operation of both exhaust valves and exhaust fan-set. Revised to Rev. 3 on 25/05/2020. Snippet from SOP below. Section 7.7 The Operator shall check that both Gas/Exhaust Outlet Valves (3-VL-15 & 16) on the reactors are OPEN and that the Ferric Nitrate Exhaust Fan is OPERATING. Any issue with either must be reported immediately.	The new design of valve on Reactor 2 does not require a separate lock as it is a rotary handwheel operation. The locking handle on the Reactor 1 valve is functioning correctly and a separate lock is not required to ensure it remains open. These valves are only closed during Lock Out Tag Out activities and their normal state is OPEN. The reactor systems are not designed to operate under pressure condition as the normal process is under slight negative pressure from the scrubber system fans.
Knife valves can be interlocked with the extractor fan to ensure knife valves cannot be opened unless extractor fan is operational.	Completed	This interlock has been installed via electrical modification on 5/06/2020.	No further action required.
Require all relevant ferric nitrate production staff to complete refresher training on SOP OP11 and any other relevant SOPs including specific reference to this incident.	Completed	Refresher training completed.	No further action required.
Consider sealing agitator ports.	Completed	This was originally considered in response to this incident. However, it was considered that the ingress of air at the agitator was a positive contribution to the overall safety and effectiveness of the abatement system as air would be drawn inwards at these points and promote the oxidation process in the abatement system.	The agitator ports have since been sealed and alternative air ingress points have been added to the abatement system. This is a superior arrangement and will eliminate fugitive emissions from the area of the agitator shaft.
Install automation of Scrubbing Tower pumps (currently manually turned on/off).	Completed	Operation of the scrubbing towers has been relocated to the Ferric Control Room. Visual and audible alarms have been installed to alert Ferric Operator if either the Scrubbing Towers or Ferric Nitrate Fan-set go into fault.	No further action required.
Install automation of Ferric Nitrate Reactor 1 and Reactor 2 air sparges and agitators (currently manually turned on/off).	Completed	Operation of Reactor 1 & 2 agitators and air-sparges has been relocated to the Ferric Control Room.	This will ensure that they can be operated remotely if required.

Corrective Action	Status	Assessment	Comment
Install high level alarms for liquid phase of all Scrubbing Towers.	Completed	All scrubbing tower liquid level gauges have been modified to enable automatic optimal liquid level control of the liquid phase of all towers. This allows for passive control of the gas/liquid phases of the scrubbing process. This is a safer and more robust configuration that automatically prevents overfilling of the scrubbing tower reservoirs thus preventing any potential blockages. Accordingly, the installation of high-level alarms are not required.	This is an inherently safer design. No further action required.
INCIDENT INSTRUCTION:INCI018620 from EPA included 19 items for action.	Completed	A full close out CAPA report was submitted to the Agency. I have reviewed this, and it addresses the root cause and the corrective and preventive actions adequately.	No further action required.

3.3 Assessment of the Overall Close out

The corrective and preventive actions arising from this incident have been effectively closed out and appear adequate to prevent recurrence of a similar incident. The new design of isolation valve fitted is not subject to accidental closure under gravity so it eminently suitable for this service.

The corresponding valve on Reactor 1 is mounted in the fully horizontal orientation and the locking handle is functioning correctly. Therefore, there is no immediate requirement to replace this valve unless future maintenance inspections determine that its replacement is warranted. A spare valve is available should this be deemed necessary.

3.4 *Additional Opportunities for Improvement*

The operation of the exhaust isolation valves is an infrequent event. It is therefore recommended that these valves be exercised to ensure they are operational as part of a quarterly preventive maintenance procedure to confirm that they continue to be serviceable.

4.0 Review of Incident INCI19623

4.*1 Review of Documentation*

I examined the following documentation / CCTV footage as part of this review:

- Chemifloc Ltd. (P0076-01) Incident Notification Report (INCI019623).
- CCTV footage of the incident.
- Incident INCI19623 for Chemifloc Limited Licence (P0076-01). Notification No: INCI19623 from the EPA EDEN system.

4.2 Site Visit

I visited the site on 26th November 2020 with a particular focus on understanding the root cause of this incident. I discussed the incident with the technical and managerial personnel on site. The abatement system is quite complex and comprises an integrated system which serves the following operations:

- Ferric Nitrate Reaction System.
- Aluminium Sulphate Reaction System.
- Tank Farm Nitric Acid Storage Tanks.
- Tank Farm Nitric Acid Bulk Offloading system.

It became clear that the original Root Cause Analysis did not fully consider the complex interactions of these systems and was therefore not sufficiently comprehensive to allow the completion of this assessment at that time of the site visit.

I therefore recommended that the Root Cause Analysis be revised. I took part in this exercise to ensure that the interactions noted above were fully considered in the revised RCA.

The results of the revised Root Cause Analysis are shown in Appendix 1.

The basis for this Assessment is the now the revised Root Cause Analysis.

4.3 Assessment of the Root Cause Analysis

The Root Cause Analysis revealed that the Ferric Fan motor tripped due to ingress of moisture at the terminal box. The fan gradually slowed down resulting in a minor loss of containment at the agitator openings as the suction draw from the fan reduced. The emission was relatively minor from an environmental perspective as was demonstrated in the Chemifloc incident report. The Alum Fan which forms part of the integrated abatement system is designed to act as a standby fan in the event of a failure of the Ferric Fan. This required the operator to operate the slide valves to allow the Alum Fan to perform the standby function. The operator was trained to make the changeover and carried out the actions within a couple of minutes thereby quickly restoring normal system operation.

4.4 Review of the Status of Close Out of Corrective and Preventative Actions

The status of the recommendations is shown in Table 3

Table 3 INCI019623 Status of Close Out of Corrective and Preventative Actions

Corrective Action	Status	Assessment	Comment
Ferric Nitrate process ceased until investigation complete.	Completed	Appropriate & Adequate.	
Opened the terminal box blanking plug and drained moisture. Dried the system and replaced the blanking plug.	Completed	Acceptable as a short-term temporary solution pending replacement of the motor & cable gland.	It was a wise precaution to avoid opening the terminal box to complete this task as it may have been difficult to adequately reseal it safely.
Investigate the potential to install alarm on current VSD or current draw controlling Ferric Fan to alert immediately should a considerable change in fan speed or electrical load be detected.	Planned completion 29/1/2021	This recommendation will require further investigation as the fan motor is currently set to operate a ca. 50 % of its maximum speed of 2880 rpm. The relatively low normal operating current may present technical challenges to providing a reliable alarm using current alone as the measured alarm parameter.	
Consider automating Stand-by Fan activation baffle valves to allow operational control from Ferric Control Room. This will form part of a wider assessment of the scrubber system performance and reliability.	Planned completion 29/1/2021	This recommendation will be further examined as part of the overall scrubber system assessment. The current physical layout of the fans and their interconnecting piping and valves is quite compact and may not lend itself to a simple and effective solution.	
Consider (based on (3) above) interlocking knife valves with extractor fan VSD alarm to ensure knife valves cannot be opened unless extractor fan is operational and operating normally.	Planned completion 29/1/2021	This will be considered as part of the overall system review.	
Increase Ferric and Alum fan-set preventive maintenance inspections to quarterly (including terminal boxes/cables).	Complete	The reliable operation of both the Ferric and Alum Fans is of critical importance to the overall operation of the integrated abatement system. Quarterly inspection should be adequate to ensure long term reliability. This should be supplemented with daily walk around checks by the system operators who should report any discernible changes in fan noise to allow these to be investigated.	Consideration should be given to developing an appropriate non-invasive inspection method to predict likely fan bearing failures in these systems. The relatively small size of the fans effectively rules out vibration analysis, but acoustic emission testing may be viable if it can economically sourced as a bought in service in the area.

Corrective Action	Status	Assessment	Comment
Replace agitator seal packing.	Complete	The reactor vessels were designed originally with stuffing boxes. These were not utilised as such due to the requirement to allow air to enter the vessel to maintain the oxidation reaction. However, the requirement for air to enter at these openings has now been superseded thereby allowing for repacking the stuffing boxes and eliminating the agitator openings as a source of fugitive emissions.	I reviewed the PTFE sealing material chosen (Klinger Topline K10 Acrylic Fibre Yarn with PTFE lubricant) and it is suitable from temperature, material compatibility, rotational velocity, and pressure for this service. Adequate spare packing is available on site and the craftsperson is experienced in repacking the stuffing boxes.
Replace the ferric fan motor, gland and re-terminate cable to ensure weatherproof seal.	Planned completion 29/1/2021	An inspection of the ferric fan motor and terminal box showed evidence of external corrosion on the fastenings of the terminal box and the cable gland. While a repair may be feasible, this may entail excessive risk that the repair may not be possible. The only prudent option is to replace the motor with a new one.	The original motor could then be overhauled at a specialist motor rewind company and retained for use as a future spare.
Ensure that for any future incident investigations a visit to the location (GEMBA) is carried out with incident investigators and the personnel involved to avoid confusion.	Planned completion 31/12/2020	There was some confusion between the maintenance personnel and the investigation as an old fan belt was found in the bund are and the Alum Fan is designed to operate with such a belt on the duty and standby motors.	Such confusion could be avoided in future by the investigation team visiting the site of the incident (Gemba) and interviewing all personnel involved not only those involved in the operational actions but also in the follow up maintenance activities which sometime can shed light on the root cause of many incidents.

Corrective Action	Status	Assessment	Comment
Review tanker unloading operations and interactions with live production and abatement systems and operations to mitigate the risk of abatement system imbalance.	Planned completion 29/1/2021	It was determined that on the day before the incident that a Nitric Acid Bulk Delivery was taken. The procedure for accepting bulk deliveries of Nitric Acid is to open a large diameter (10 inch) valve which draws suction from a point in the scrubber train located between PT 5 & 6 which is much closer to the fan sets. This is to ensure that sufficient suction is available to manage the blow through of compressed air from the tanker at the end of the pressurised discharge bulk delivery. However, it is likely that this valve was not closed after that delivery thereby disturbing the pressure balance in the system as greater load was placed on the towers closest to the fans and reduced load on the largest tower PT 1.	There was no evidence that the abatement of emissions was negatively impacted by the omission to close the larger of the two tank farm valves. However, this illustrates that the abatement system is a single integrated unit. It is therefore recommended that when bulk nitric acid deliveries are being accepted that the metal drops in the reactor are suspended 30 minutes before the tanker unloading operation commences and not resumed until the scrubber configuration is returned to its normal status. This will ensure that the pressure profile on the system during process off gases abatement remains consistent. An update of the tanker unloading SOP and its integration with the Reactor Operations SOP is recommended to prevent recurrence.

4.5 Additional Opportunities for Improvement

The Root Cause Analysis has been revised and is presented in Appendix 1. The opportunities for improvement have been identified as part of that revision process. The principal additional improvements identified are around integration of the bulk tanker unloading operation with the production operations to ensure that the abatement system can perform both duties without any negative interactions between them which might result in any loss of performance of either.

5.0 Conclusions

While each of the incidents were different to some degree in their root causes (human error, mechanical failure and electrical failure) there were valuable lessons to learned from each investigation. The plant personnel carried out detailed investigations into each of the incidents and employed the expertise of external consultants to assist them in understanding the nature of the incidents and in developing appropriate corrective and preventive actions.

It is important to note that actual source of the fugitive emissions for INCI18620 and INCI19623 was the open gap between the rotating agitator shaft and the reactor lids of Ferric Nitrate Reactors 1 & 2. Historically, this gap was present to permit the introduction of air into the scrubbing tower exhaust system to assist with the abatement of NO_x. The following relevant actions been completed:

(a) dedicated air ingress points have now been installed locally within the scrubbing system to improve abatement;
(b) the production process is not completed under pressure;
(c) the agitator stuffing boxes have now been appropriately repacked and sealed.

Accordingly, it is therefore reasonable to conclude, as per the Agency's request, that the risk of future NO_x fugitive emissions from the reactor vessels has been substantially mitigated.

The recommendations from the final root cause analysis will be completed by end January 2021. In parallel with this work a comprehensive assessment of the abatement system capability is also being undertaken. Significant progress has already been made in understanding the basis of the design of the system, optimisation of process flows and additional performance testing of the main abatement elements of the system. A deeper understanding of the various duties of this integrated system is being developed. This work will lead to improved long-term performance of this important abatement system and enhanced operational reliability of the unit to perform its range of functions. It is expected that upon completion, the risk of uncontrolled visible NO_x plumes emanating from the plant as fugitive or other emissions will be eliminated as far as reasonably practicable.

About the Author:

Liam Tolton holds a primary degree in Electrical Engineering from UCC majoring in Power & Mechanical Engineering and a Master's Degree from the University of Sheffield (Department of Chemical & Biological Engineering) specialising in Process Safety & Loss Prevention. I have 28 years of Industrial experience in the oil and pharmaceutical industries including the design and operation of air emission abatement systems. As a consulting engineer for 14 years, I have advised clients in process safety, HAZOP, incident investigations, abatement system design and optimisation.

Appendix 1 - Revised Root Cause Analysis for Incident INCI019623

Problem Statement

1

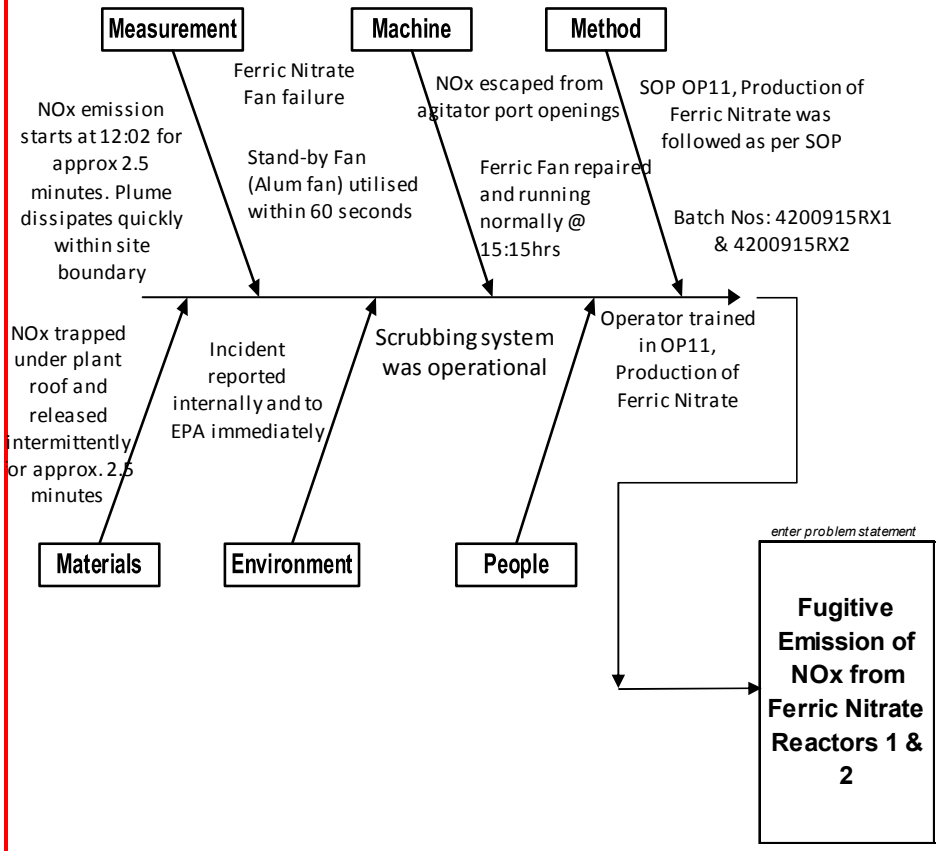
What is the problem is statement?	Fugitive Emission of NOx from Ferric Nitrate reactor 1 & 2
Date and time of problem:	16/09/2020 @ 12:02
Who witnessed the problem:	NB
List any batches impacted:	4200915RX1 & 4200915RX2
List any equipment involved:	Ferric Nitrate Fan
Investigation Team:	MM, RL, PR, FG, ER, LT (as per EPA request)
Investigation Date:	16/09/2020 - Updated 11/12/20

Target Condition/Goal

What is the desired outcome

To prevent an incident re-occurrence

Analyse Causes (Cause and Effect)



For each cause ask Why (5-Why Analysis)

enter the problem statement here

Fugitive Emission of NOx from Ferric Nitrate Reactors 1 & 2

Cause #1	Cause #2	Cause #3	Cause #4	Cause #5
NOx escaped from agitator openings	**Operational standby Fan (Alum fan) utilised within 60 seconds**	**Scrubber system pressure balance may not have been optimal.**	**Miscommunication between operational staff and manager regarding the initial incident cause. This was originally understood to relate to a broken fan belt.**	
Why is that?	*Why is that?*	*Why is that?*	*Why is that?*	*Why is that?*
Ferric Nitrate Fan failure - Motor Trip due to moisture ingress to the Terminal Box	**The Alum Fan is designed as the operational standby for the Ferric System by means of manually operated slide valves.**	**There are two abatement configurations from the tank farm to scrubber system which are required to be configured for (1) normal tank farm operations or (2) for tanker unloading operations. The system pressure balance is different in both**	**GEMBA incident location visit was not carried out by relevant team members.**	
Why is that?	*Why is that?*	*Why is that?*	*Why is that?*	*Why is that?*
Ingress of Moisture / Condensation due to very small gaps at the cable gland, blanking plug or terminal box cover.		**The investigation showed that a tanker delivery had been completed the previous day and the abatement configuration may have been left in the tanker unloading**		
Why is that?	*Why is that?*	*Why is that?*	*Why is that?*	*Why is that?*
Insufficienctly frequent maintenance inspections of terminal box		**The abatement system continued to perform albeit not optimally.**		
Why is that?	*Why is that?*	*Why is that?*	*Why is that?*	*Why is that?*

Improvements and priority

Brainstorm ways to fix identified root cause:

No.	Proposed Solution / action (Score1-5)	By Whom?	When	Benefit of Solution (B)	Easy Implement (E)	Total (BxE)
1	Ferric Nitrate process ceased until investigation complete	PR	Completed 15:15 hrs 16/09/2020	5	5	25
2	Opened the terminal box blanking plug and drained moisture. Dried the system and replaced the blanking plug.	MM	Completed 15:15 hrs 16/09/2020	5	5	25
3	Investigate the potential to install alarm on current VSD or current draw controlling Ferric Fan to alert immediately should a considerable change in fan speed or electrical load be detected	MM, LT	29/01/2021	4	3	12
4	Consider automating Stand-by Fan activation baffle valves to allow operational control from Ferric Control Room. This will form part of a wider assessment of the scrubber system performance and reliability.	MM, LT	29/01/2021	2	1	2
5	Consider (based on (3) above) interlocking knife valves with extractor fan VSD alarm to ensure knifevalves can't be opened unless extractor fan is operational and operating normally.	MM	29/01/2021	4	4	16
6	Increase Ferric and Alum fan-set preventive maintenance inspections to quarterly (including terminal boxes/cables).	MM	Completed 18/09/2020	4	5	20
7	Replace agitator seal packing.	MM	Completed 18/09/2020	5	4	20
8	Replace the ferric fan motor, gland and re-terminate cable to ensure weatherproof seal.	ER	29/01/2021	5	4	20
9	Ensure that for any future incident investigations a visit to the location (GEMBA) is carried out with incident investigators and the personnel involved to avoid confusion.	FG	31/12/2020	5	5	25
10	Review tanker unloading operations and interactions with live production and abatement systems and operations to mitigate the risk of abatement system imbalance.	FG	29/01/2021	5	5	25

Control and fix the problem	
Where else could cause create a problem?	Any relevant critical plant item with a terminal box vulnerable to moisture ingress.
How will we monitor if fix works?	No fugitive emission of NOx
Do we need to update the risk assessment?	The risk assessment for this system will be updated following a comprehensive review of the scrubber system operation as part of the EPA Licence Review.