PREVENTION OF SECOND-STAGE EVAPORATOR FOULING

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Long-Term Prevention of Second-Stage Evaporator Fouling in Urea Plant: Root Cause, Operational Mitigation, and Sustained Validation

Abstract

This paper presents a comprehensive operational case study from a STAMI-design urea plant, addressing chronic fouling in the second-stage evaporator (S-402) of the vacuum section. Following a start-up failure and significant production loss event in April 2024, a detailed investigation was carried out to understand why the incident occurred, how it was managed operationally, what corrective and preventive actions were implemented, and how recurrence was avoided. Particular emphasis is placed on the controlled application of urea melt flushing and the management of its associated operational challenges. The effectiveness of the adopted strategy was validated through approximately 1.5 years of continuous operation, culminating in an internal inspection during November 2025 that confirmed a completely clean second-stage evaporator. The study demonstrates that disciplined adherence to design-intent flushing practices can eliminate chronic fouling, reduce turnaround cleaning effort, and significantly enhance long-term vacuum section reliability.

1. Introduction

Fatima Fertilizer Company Limited is a major Pakistani fertilizer manufacturer company headquartered in Lahore, Pakistan. It was incorporated in **2003** as a *joint venture* between two prominent business groups — **Fatima Group** and **Arif Habib Group**.

The company produces, imports, exports, and sells a range of fertilizers and related chemicals. Its integrated production facilities manufacture intermediate products like **ammonia** and **nitric acid**, and several final products including **Urea**, **Calcium Ammonium Nitrate (CAN)**, and **Nitro Phosphate (NP)**, primarily serving Pakistan's agricultural sector.

The Urea plant is part of the **fully integrated fertilizer complex** of Fatima Fertilizer Company Limited located near **Sadiqabad, in Rahim Yar Khan District, Pakistan**. This complex was established as a *greenfield project.*

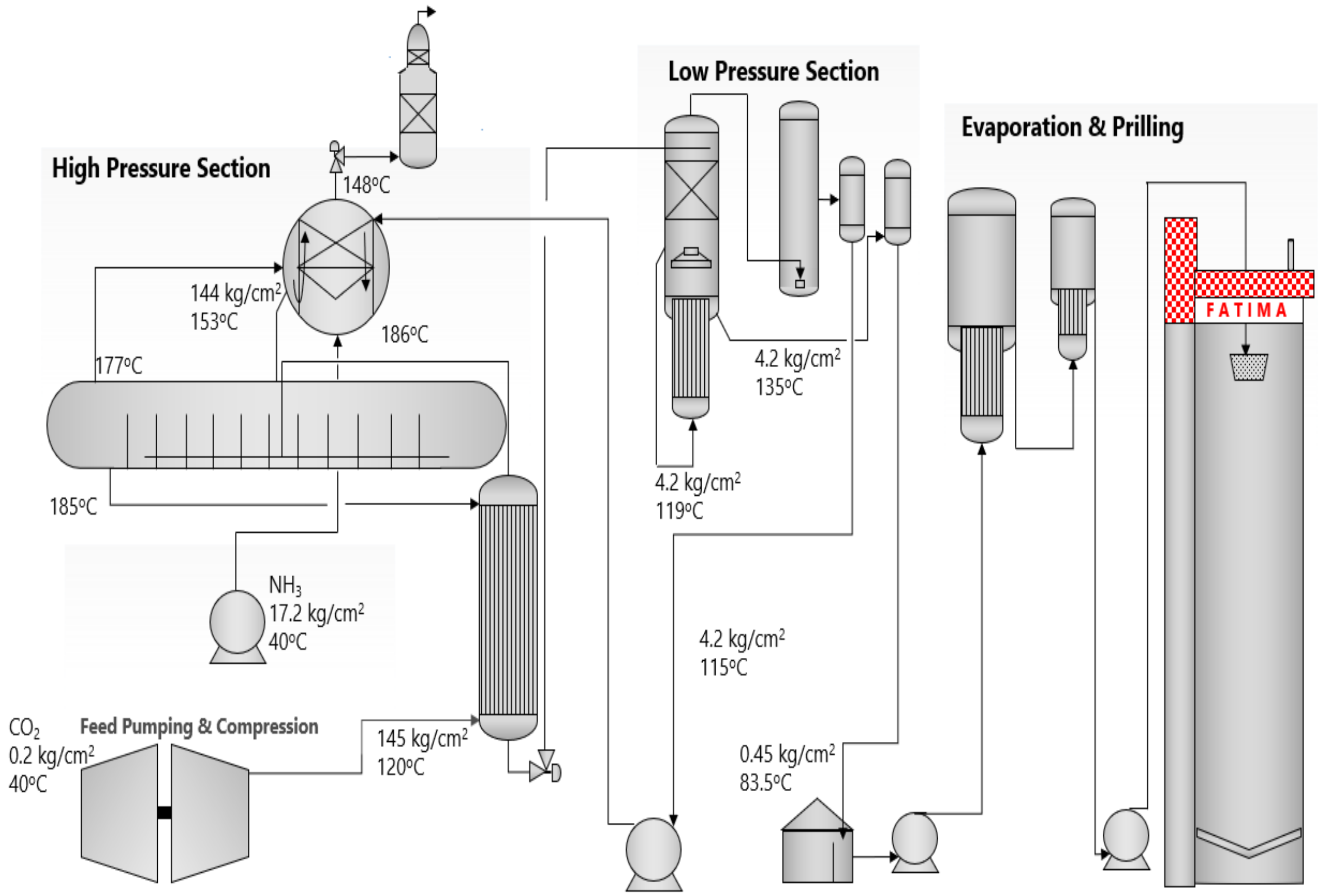
Urea Plant is designed on **STAMICARBON 2000+ Pool reactor technology** with basic and detailed engineering made by Kawasaki plant systems Ltd Japan. This plant has 1500 MTPD Capacity & it was commissioned in 2010.

In Urea plants, the vacuum evaporation section plays a critical role in achieving the desired urea concentration prior to prilling. The second-stage evaporator operates under high temperature and absolute vacuum conditions, making it particularly susceptible to choking by urea, biuret, and poly-urea deposits. While the Stamicarbon process design includes preventive measures such as steam condensate, process condensate and Urea melt flushing but their effectiveness is highly dependent on consistent operational discipline.

Experience across the fertilizer industry indicates that choking-related issues often remain latent during steady-state operation and become apparent only during transient conditions such as shutdowns and start-ups. This paper highlights an actual operating experience in which long-term deviation from preventive practices resulted in a severe start-up disruption. More importantly, it demonstrates how reinstatement and controlled management of these practices led to sustained, fouling-free operation without mechanical intervention, with running plant conditions.

2. Process and Design Overview

In studied Urea plant, urea solution produced in Pool Reactor is concentrated in HP and LP section up to 72%. An intermediate storage (V-302) is available to store 72% concentrated solution before vacuum Section. In vacuum section its concentration is further increased from 72% to 99.1% in two stage vacuum section. Vacuum section consists of two stage evaporation and separation process followed by prilling of 99.1% concentrated Urea melt. Both stages are connected via seal leg maintaining vacuum of 0.36kg/cm2A and 0.04 kg/cm2A in respective stages. Urea melt of 99.1% concentration is then pumped through Urea melt pump (P-401A/B) towards prilling tower top and prilling is performed through prilling bucket. We have 2 type of buckets installed. One is conventional bucket installed as per original design and other one is Vibro priller installed later to achieve even better & uniform Prill size.



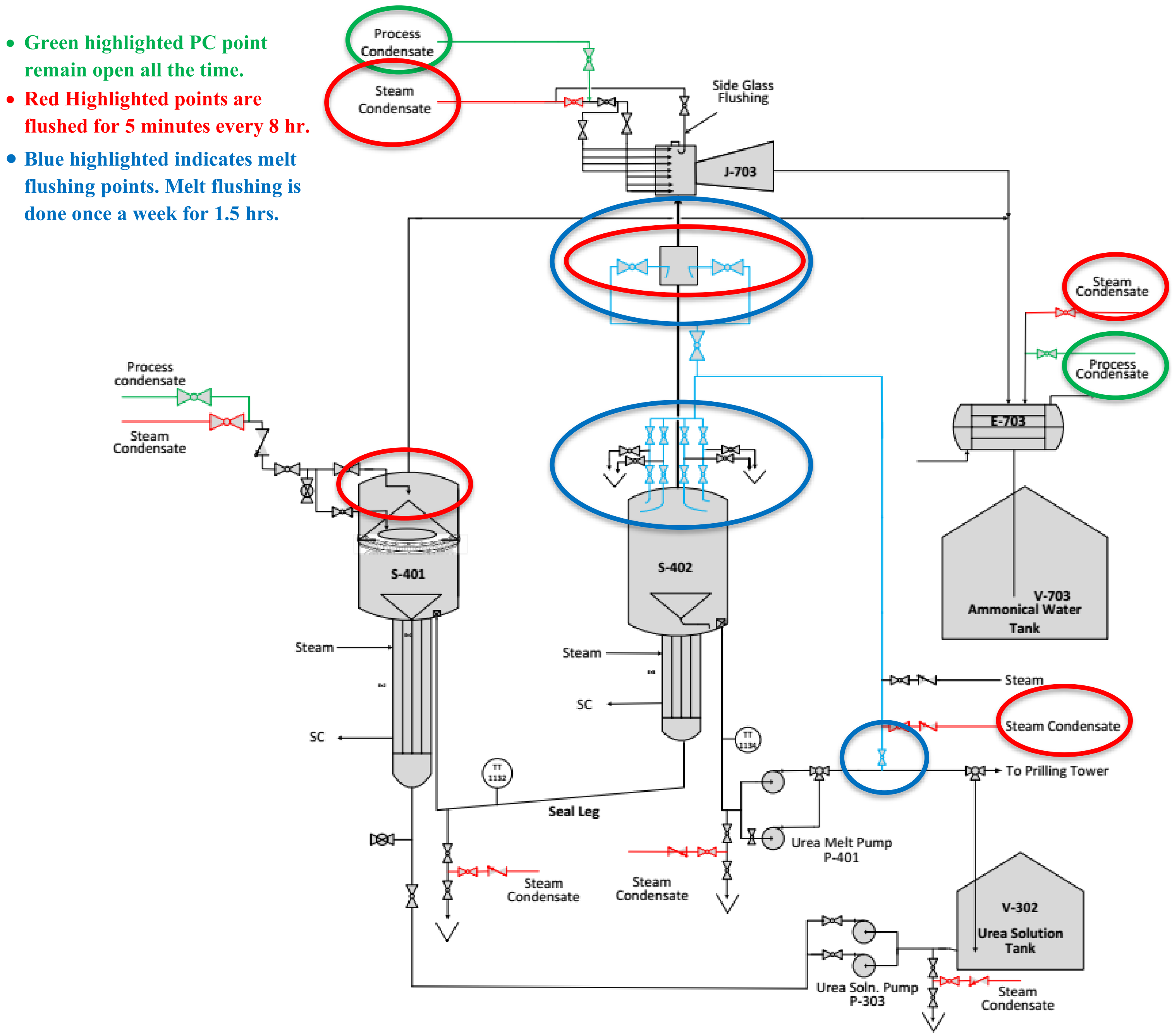
To mitigate choking, the original design provides steam condensate, Process condensate and melt flushing at different locations of vacuum section. A periodic/continuous flushing regime keep walls and equipment free from Urea deposits and lump formation. As per routine flushing sequence, following flushing regime is available.

- First stage separator (S-401) is flushed with steam condensate from top as illustrated in below P&ID for 3-5 minutes every 8 hrs.
- Second stage separator (S-402) vapor line is flushed with steam condensate as illustrated in below P&ID for 3-5 minutes every 8 hrs.
- Second stage vapor line bend towards first ejector (J-703) is flushed with steam condensate as illustrated in below P&ID for 3-5 minutes every 8 hrs.
- Second stage separator first ejector (J-703) is flushed with steam condensate as illustrated in below P&ID for 3-5 minutes every 8 hrs.
- Vapors Condenser after Second stage separator is also flushed with steam condensate for 3-5 minutes every 8 hr.

- Urea Melt flushing of second stage separator and vapor line is done for 1.5 hours every Monday.

While process condensate flushing remains continuously open at Second stage separator first ejector (J-703) and Second stage separator first condenser.

Deviation from these practices can compromise vacuum section operation.



3. Incident Description – What actually happened?

On 03 April 2024, Urea plant was stopped due to unplanned shutdown of ammonia plant. After ammonia production was restored, Urea plant start-up was initiated on 04 April 2024 at 1710 hrs. During this start-up, prilling could not be resumed due to repeated loss of urea melt flow at the suction line of Urea melt pump P-401 after intermediate storages were filled.

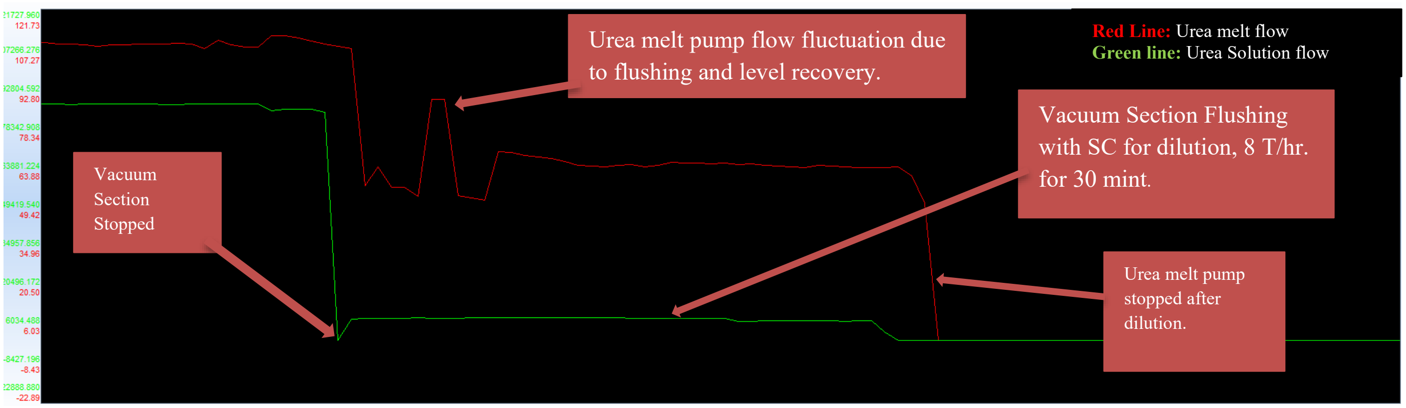
4. Incident Management – Detail Sequence of Event.

03-April-2024; 19:21 hrs.

Urea plant stopped and CO_2 feed cut as per SOP due to ammonia plant back-end shutdown.

03-April-2024; 19:27:02 hrs.

Urea solution pump (P-303 A/B) suction flushing opened and vacuum section flushing started, Flow also ensured at Urea solution line flow transmitter FT-1133 and steam condensate FT at SC header during flushing of vacuum section as per below Trend-1.



Trend 1 Urea Vacuum Section flushing trend during shutdown (FV-1133 – flow from P-303 to E-401)

After ammonia production resumed 04th April-24 @ 17:10 hrs., Urea plant start-up activities initiated as per SOP

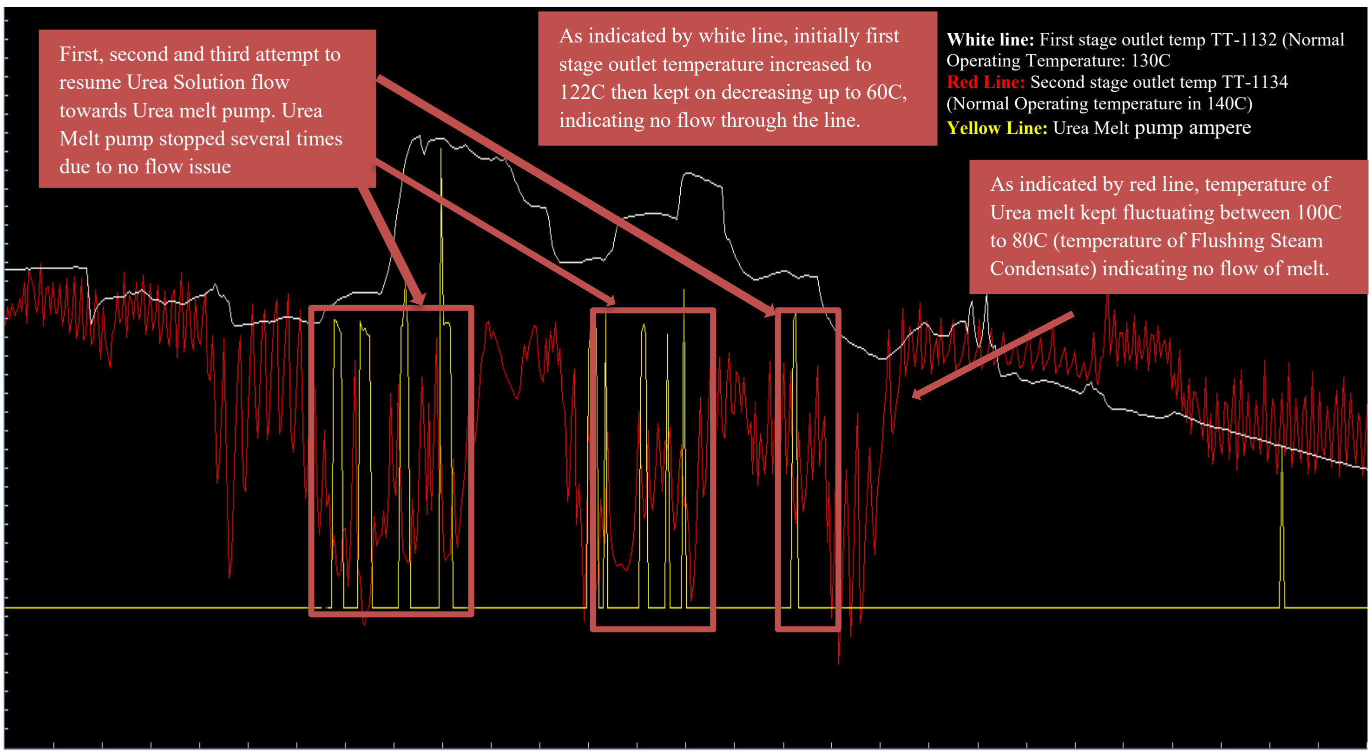
04-April-2024; 19:20:06 hrs.

Urea solution transfer pump P-303 taken into service for start-up of vacuum section after solution started to build up in Urea Solution tank V-302 from LP section.

Startup sequence of vacuum section: First Urea Solution P-303A/B is started and steam in first evaporator is lined up. This solution when reaches to seal leg between first and second stage, rise in temperature on transmitter TT-1132 (at seal leg) indicates that solution has reached this point. Then Steam in second evaporator is opened. Once after evaporation liquid starts to build up at Urea melt pump suction line, a level starts to appear on sight glass. Once the level in sight glass is full then Urea melt pump is started and flow of it is kept towards Urea Solution tank V-302 through divert valve till Urea melt concentration is achieved.

During this event **after P-303 start-up,** initially temperatures at outlet of first stage separator started to increase indicating flow has reached in seal leg but then it dropped & urea melt level was not observed in sight glass at urea melt pump (P-401) suction line. So, flushing was opened in seal leg, suction of urea melt pump P-401 & On top of second stage separator S-402.

Immediately level started to build due to flushing water and when Urea melt pump P-401 was started it immediately transferred the level and started to cavitate and also level in suction sight glass disappeared so it was stopped. Multiple similar attempts were made but issue persisted. Urea solution pump (P-303) was also stopped and started multiple times in order to establish the urea solution flow but it was of no use.



After some time, level of Ammonia water tank (V-703) started to increase showing that Urea Solution is overflowing from First stage to condenser and eventually into ammonia water tank V-703. After multiple attempts, it was decided to initiate the plant shutdown because Urea solution tank (V-302) and ammonia water tank (V-703) levels increased above 70% as plant was in operation except vacuum section.

From above explained scenario it was evident that flow was not transferring from first stage to second stage so to find the blockage, insulation was removed from seal leg of S-401 to S-402. Line was found choked near seal leg bend indicated by relatively no flow of flushing at that point.

So, line was dismantled and de-choked. After de-choking of seal leg vacuum section was again started but again stopped due to no flow towards suction line of Urea melt pump P-401. So, then it was suspected that choking is inside separators.

After draining of vacuum section, both S-401 & S-402 manways were opened. 1st stage evaporator separator (S-401) was found clear - see figure 1, but heavy lumps were observed in S-402 – see figure 2.

Figure 1 As found condition of S-401 (Clean)

Figure 2: As found S-402 (heavily choked)

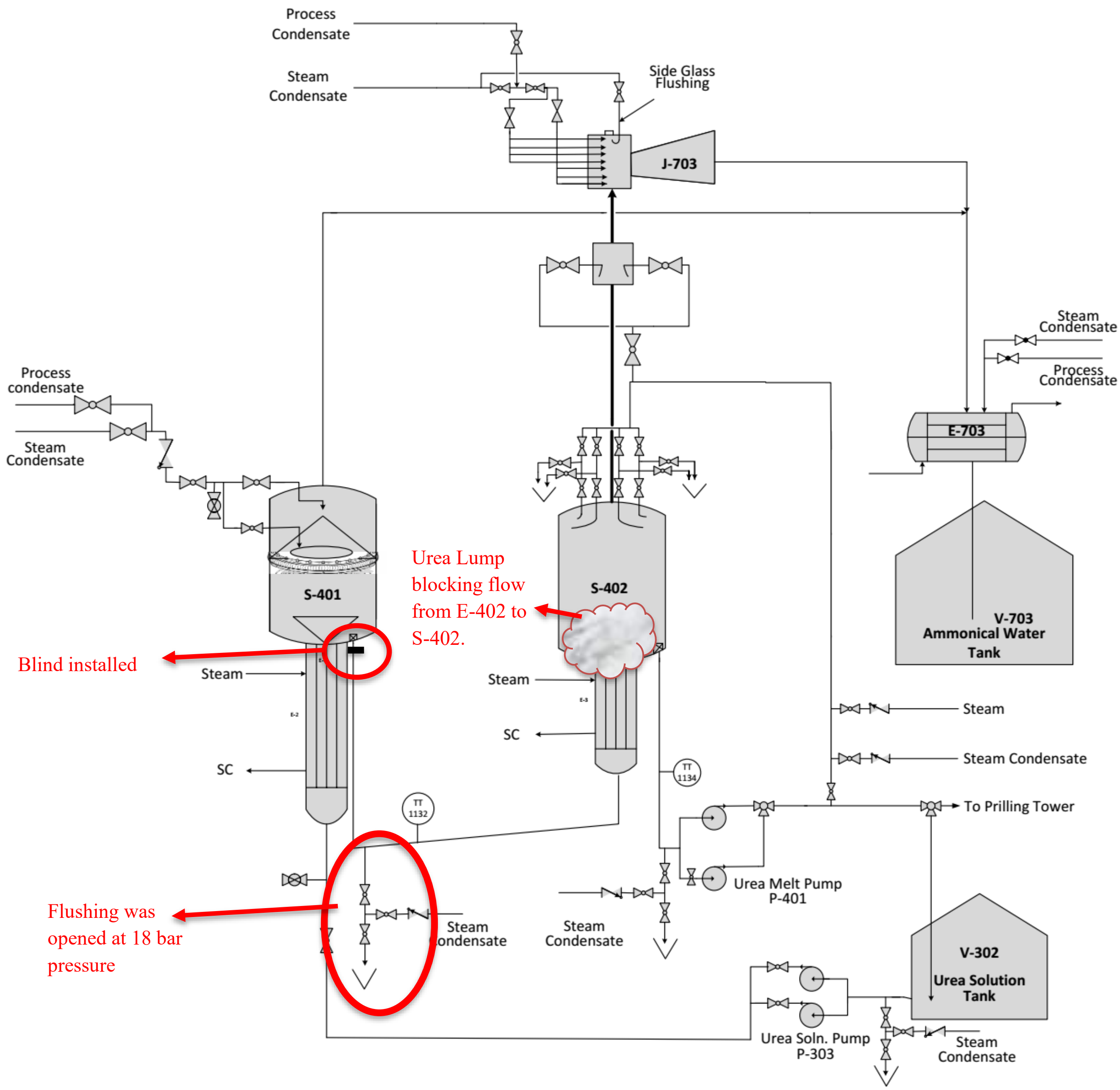
To clear the manway of Second stage separator (S-402) extensive efforts were put and huge lump was observed inside blocking the inlet of S-402 from Second stage evaporator E-402 due to which flow restriction / no flow was observed in pump P-401 suction as evident in figure three.

Figure 3 Condition after mechanical cleaning & steam condensate flow (Before Startup)

Only flushing flow (From S-402 vapor line and P-401 suction line) was coming towards P-401 suction that was causing temporary buildup of level, and no urea solution is travelling from S-401 to S-402 due to this choking. So, when P-401 started it took load momentarily as evident in above pumps flow graph but eventually leading to cavitation and stoppage of P-401.

5. Incident management- How was the situation managed?

- After ensuring flow of liquid from P-303 till Seal leg between S-401 and S-402, box-up of S-401 was carried out.
- Pressure blind was installed at outlet of S-401. As indicated below P&ID to route condensate flushing towards E-402 & S-402.
- Pressure from steam condensate at 18 bar was applied inside which after some jerks eventually created a passageway from E-402 towards S-402 by removing some of the fallen urea lump.
- Fire water was also applied from manway without any entry to break lump & create passageway
- Sight glass at suction of P-401 was dismantled to ensure P-401 melt line is clear & no lump should fall towards P-401 suction line during deblocking activity. After ensuring positive flow from seal leg towards P-401 suction line for several minutes and ensuring that no lump has blocked the suction line of P-401, sight glass and S-402 manway was boxed up and plant startup was initiated.
- This time again low flow issue was observed but after several attempt P-401A/B eventually took load, initially up to of 70% of its rated capacity. But slowly flow kept on increasing and within a day or two maximum possible flow was achieved.
- Management of emergency without vessel entry and mechanical intervention made it possible to bring plant back in service after 44 hours, else mechanical cleaning inside separator could take more than 10 days in blinds installation, vessel entry, mechanical cleaning and de-blinding/start up.
- There was also risk of more lumps falling during start up, future shutdown & during operation which could disrupt plant operation.


Process
Condensate
Steam
Condensate
Side Glass
Flushing
J-703
Steam
Condensate
Process
Condensate
E-703
Process
condensate
Steam
Condensate
V-703
Ammonical Water
Tank
S-401
S-402
Urea Lump
blocking flow
from E-402 to
S-402.
Blind installed
Steam
Steam
SC
SC
Steam
Steam Condensate
TT
1134
To Prilling Tower
TT
1132
Urea Melt Pump
P-401
Flushing was
opened at 18 bar
pressure
Steam
Condensate
Steam
Condensate
V-302
Urea Solution
Tank
Urea Soln. Pump
P-303
Steam
Condensate

5. Root Cause Analysis – What Actually Happened?

Subsequent investigation revealed:

1. Urea melt flushing at S-402 had been gradually discontinued after conventional bucket replacement with vibro-priller as melt flushing caused carryover of small urea lumps and choking of vibro priller mesh which cause overflow of bucket leading to product quality issues.

2. The duration of routine steam condensate flushing had also been reduced due to temperature reduction during flushing.

3. These deviations did not immediately impact steady-state operation but allowed progressive accumulation of heavy deposits within S-402. The accumulated material was dislodged during excessive flushing of vacuum section after shutdown for dilution.
4. Vacuum Section separators were inspected in Turn around 2021 & later missed in future outages to see the actual condition.

6. Corrective Actions – What Actions Were Taken?

Based on the findings of the investigation, corrective actions focused on reinstating design-intent preventive practices rather than introducing hardware modifications. Urea melt flushing at S-402 was formally reintroduced with defined frequency and duration, and the effectiveness of routine steam condensate flushing was enhanced by increasing flushing time.

Operating procedures were revised to reinstate the flushing requirements during normal operation, shutdown, and start-up. Flushing activities were incorporated into operator and Boardman checklists to ensure consistent execution and accountability.

7. Management of Negative Effects of Urea Melt Flushing

While urea melt flushing is effective in dissolving deposits, it can introduce short-term operational challenges, including temporary fluctuations in urea melt pump load, disturbances in prilling and Product quality issues.

To mitigate these effects, melt flushing was performed in a controlled manner during stable operating conditions. Critical parameters including urea melt pump amperes, vacuum stability, and prilling performance were closely monitored. During melt flushing, the vibro-priller was temporarily switched over to the conventional bucket system to avoid operational disturbances. This approach ensured that the long-term benefits of melt flushing were achieved without compromising overall plant operability.

8. Results and Long-Term Validation

Following implementation of the revised flushing regime, the urea plant operated continuously for approximately 1.5 years without recurrence of vacuum section choking or abnormal pressure drop trends. No unplanned outages related to vacuum section fouling were recorded during this period.

During a planned outage in November 2025, S-402 was opened for internal inspection.

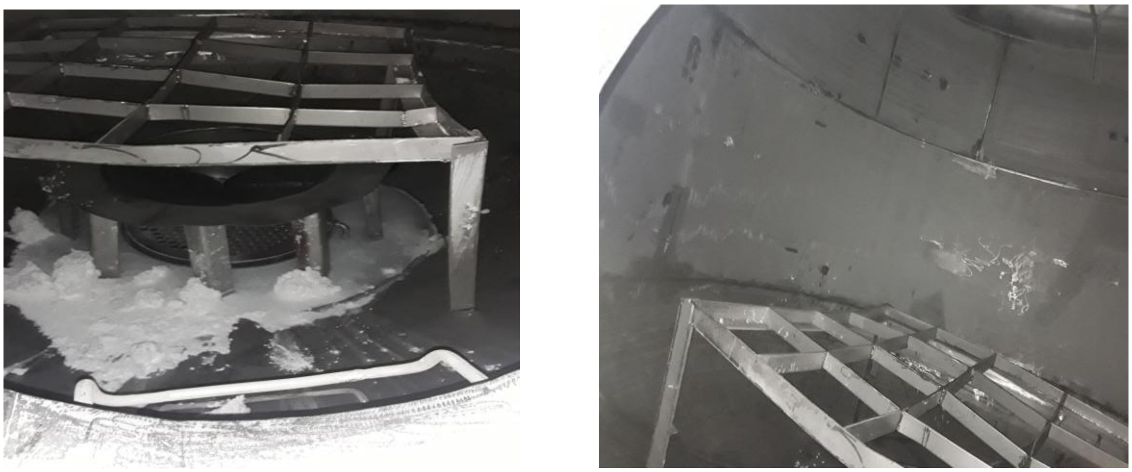


Figure 4 As found condition of S-402 after 1.5 years operation, with flushing practices

Contrary to typical findings of heavy lumps in second stage separators in Urea Plants, the separator was found completely clean and free from urea or poly-urea deposits. No mechanical cleaning was required, providing direct physical validation of melt flushing and routine flushing effectiveness as intended in Stamicarbon design.

9. Prevention of Recurrence

To ensure sustainability of the achieved performance, preventive flushing practices have been formally embedded into standard operating procedures and routine operational audits. Any deviation from design-intent flushing practices requires formal management of change.

The experience demonstrates that disciplined execution of preventive operational practices is more effective than reactive maintenance or extensive turnaround cleaning and is directly transferable to other urea plants facing similar separator choking challenges.

10. Conclusion

The April 2024 vacuum section choking incident was the consequence of long-term procedural deviation rather than inherent equipment design limitations. By reinstating and properly managing urea melt flushing and steam condensate flushing, chronic fouling was eliminated and sustained, reliable operation was achieved. Long-term validation confirms that disciplined operational practices are critical to maintaining vacuum section integrity and minimizing life cycle maintenance effort.

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