CASESTUDY

CATASTROPHIC FAILURE OF A UREA REACTOR

STAMICARBON
NEXTCHEM Sustainable Technology Solutions

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SUMMARY

ABSTRACT

Operating a urea plant involves navigating the corrosive conditions of the high-pressure synthesis section, where ammonium carbamate poses a persistent threat to carbon steel pressure vessels. This paper examines a near-miss incident in a Stamicarbon CO_2 stripping urea plant in 2015, where a pinhole leak in a 316L UG liner weld—undetected due to a malfunctioning leak detection system—caused severe corrosion of the reactor's carbon steel shell, reducing its 112 mm thickness by up to 58 mm.

Disaster was averted through the alertness of a plant operator who identified crystallized urea and ammonia vapor, prompting an immediate shutdown after 21 years of service.

The investigation revealed that improper commissioning and inadequate maintenance compromised the leak detection system, allowing corrosion to progress unnoticed.

This case reinforces Stamicarbon's commitment to safe operations through robust material selection, fabrication standards, and reliable safety systems, while highlighting the critical role of human oversight when technology falters. Beyond process-side corrosion, external threats like atmospheric corrosion further underscore the need for comprehensive protective strategies in urea equipment design and maintenance.

1. INTRODUCTION

1 INTRODUCTION

In urea CO_2 stripping urea plants, the high-pressure synthesis of urea from ammonia and carbon dioxide produces ammonium carbamate, a highly corrosive intermediate that demands protective barriers to safeguard carbon steel pressure vessels.

Components exposed to this environment, whether in liquid or gas phase, rely on liners or weld overlays—historically austenitic stainless steels like 316L UG and X2CrNiMo25-22-2, now largely replaced by more resistant duplex stainless steels such as UE-Class BE.06/MS5.0.

With passivation air, these liners maintain low corrosion rates (0.05–0.1 mm/y), but its absence accelerates corrosion to 30 mm/y or higher, and breaches can expose carbon steel to rates up to 500 mm/y, risking rapid structural failure.

Stamicarbon’s rigorous standards—encompassing corrosion-resistant materials, precise welding, leak detection systems, operational protocols, and regular maintenance—aim to mitigate these hazards.

Yet, challenges persist, as demonstrated by a near-miss incident in a urea reactor in 2015, after 21 years of operation. This paper explores this event to illustrate the complexities of managing process-side corrosion and the indispensable interplay of technology and human vigilance in preventing catastrophic outcomes, while also noting external corrosion threats that further test equipment resilience.

2. NEAR MISS OF A UREA REACTOR

2 NEAR MISS OF A UREA REACTOR

This incident took place in the urea reactor of a CO_2 stripping urea plant that began operations in 1994. The reactor features a solid wall design with a 112 mm thick cylindrical section and an 8 mm thick 316L UG liner. The event occurred in 2015, after 21 years of service. A potential disaster was averted thanks to the quick response of the plant operator, despite the failure of the advanced leak detection system installed at the facility.

During a routine inspection at 08:30, the plant operator noticed crystallized white product accumulating on the insulation sheeting of the urea reactor, as shown in Figure 1. This buildup worsened rapidly over time, and the operator also detected the presence of ammonia vapor.

November 05, 08:30h, 2015

November 05, 12:30h, 2015

Figure 1: Crystalized product visible on cover sheeting insulation urea reactor

Initially, it was suspected that the leak originated from the man-way cover, as the leak detection system showed no signs of a breach. However, upon closer examination, evidence suggested a potential leak in the liner, prompting the plant to be shut down for a thorough inspection.

2.1 LEAK DETECTION SYSTEM

In 2006 a state-of-the-art leak detection system was installed to monitor all high-pressure urea synthesis equipment in this plant. The principle of the leak detection system is to circulate dry air behind the liner compartments of all connected equipment and to analyze the received air for presence of ammonia. The principle is schematically presented in figure 2. The leak monitor is connected to the DCS system in the control room.

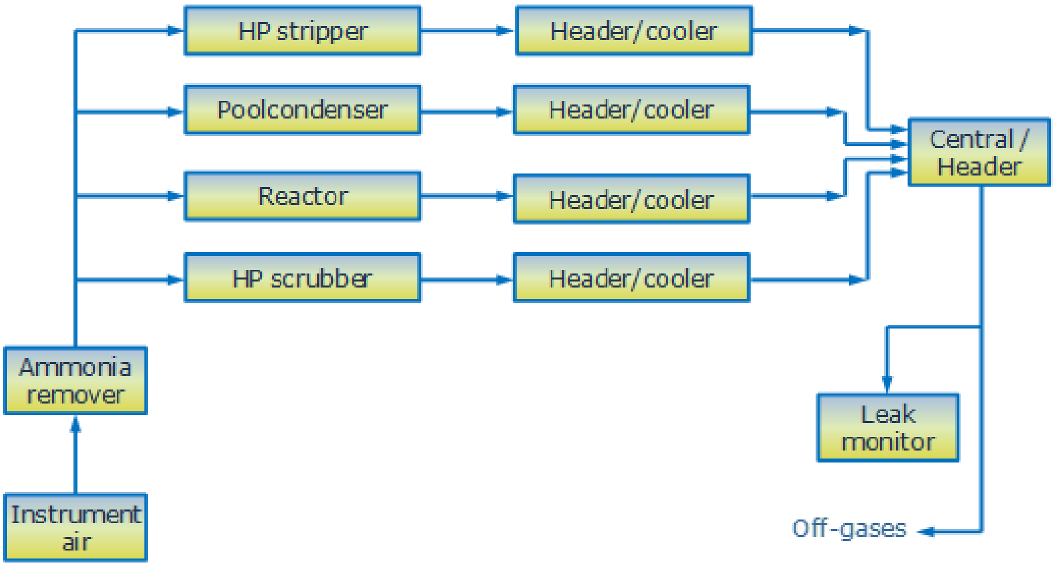

Figure 2: Principle of leak detection system, circulating dry air to all connected equipment.

2.2 INVESTIGATION

The leak detection pipes linked to the suspected section of the urea reactor were detached, revealing the presence of ammonia in the leak detection hole. Upon opening the reactor, the source of the leak became readily apparent. It was traced to the circumferential weld joining the original 316L UG liner (the brown surface in the lower part of Figure 3) with the X2CrNiMo25-22-2 liner (the grey upper part in Figure 3), which had been added in 2002. The relining of the reactor's top section had been required due to earlier corrosion issues.

Figure 3: Leak found in the circumferential weld between the X2CrNiMo25-22-2 relined part (top) and original 316LUG liner

To access the integrity of the c-steel pressure shell a window was cut from the liner around the leak point, see figure 4. Corrosion of the c-steel vessel wall was evident. Wall loss ranged between 10 and 30 mm. In one local area (80 x 50 mm) a maximum wall loss of 58 mm was found (remaining thickness 50 mm; original 112 mm), see figure 5.

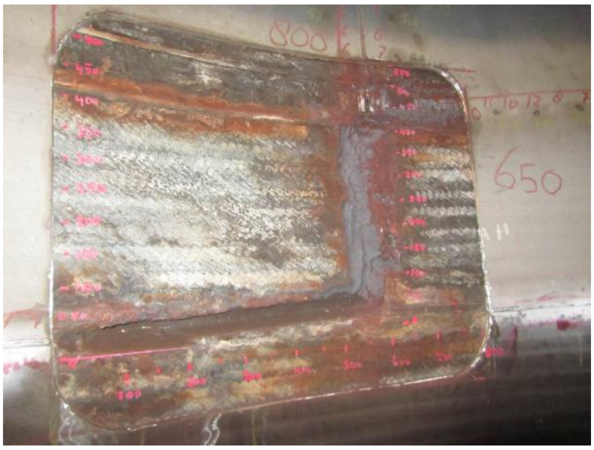

Figure 4: Corrosion of the c-steel pressure shell visible

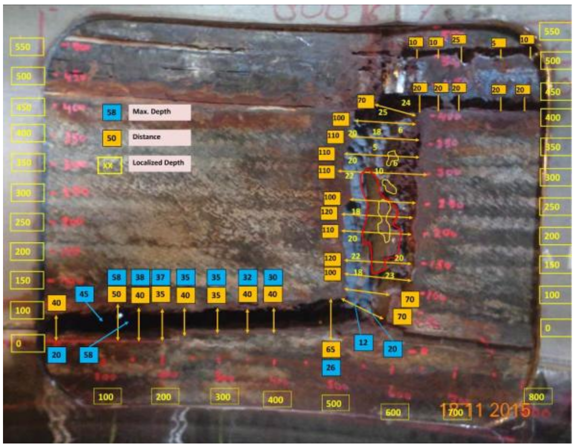

Figure 5: Maximum corrosion depth: 58 mm

It was decided to make a temporarily repair and to execute a full repair later, which was executed successfully within 1 year. The integrity of the reactor is restored again.

The pinhole leak in the liner created severe corrosion attack of the c-steel pressure shell and the reactor was put out of service just in time. The state-of-the-art leak detection however failed to indicate the leak; this was due to a combination of wrong commissioning of the system and failure of some components; thus, insufficient inspection and maintenance of the system.

The leak detection system was refurbished and made operational before start-up of the plant.

Also, an inspection and maintenance program were implemented to increase the reliability and availability of the system. All plant operators were instructed again.

3. SUMMARY & CONCLUSION

3 SUMMARY & CONCLUSION

3.1 SUMMARY

- The root cause of the near miss is a small leak in the liner weld
- The leak was not indicated by the leak detection system, since it not working properly
- Catastrophic failure was avoided by an alert action of a plant operator
- Plant management took immediately the correct decision to stop the plant
- Safe operations of the plant are only possible with a good working leak detection system

3.2 CONCLUSION

The near miss incident at the CO_2 stripping urea plant in 2015 serves as a critical reminder of the interplay between human vigilance, system reliability, and material integrity in ensuring the safe operation of high-pressure chemical reactors. The failure of the state-of-the-art leak detection system—due to improper commissioning, component degradation, and inadequate maintenance—allowed a pinhole leak in the liner weld to go undetected, resulting in severe corrosion of the carbon steel pressure shell and bringing the reactor perilously close to catastrophic failure.

The swift observation of crystallized urea and ammonia vapor by an alert plant operator, coupled with management's decisive action to shut down the facility, averted disaster after 21 years of service. The subsequent refurbishment of the leak detection system, implementation of a robust inspection and maintenance program, and retraining of operators restored the reactor's integrity and reinforced the importance of proactive safety measures.

This case underscores that while advanced technology is indispensable, its effectiveness hinges on proper upkeep and the irreplaceable role of human oversight in high-stakes industrial environments.

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