Risk Assessment of a Urea Reactor

**VS 24 July 2017**

**Assumptions:** 316L UG liner and only tubes outside the insulation as leak detection system.

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### Hazard Analysis

<table>
<thead>
<tr>
<th>Hazard &amp; Initiating Event</th>
<th>Consequence</th>
<th>Project phase</th>
<th>Equipment part</th>
<th>Hazard-reduction measures</th>
<th>Risk Ranking (1/5)</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>An active leak detection system with a reliable and accurate ammonia detector, which is in operation since the first start up minimizes time that ammonium carbamate is in contact with carbon steel and minimizes the risk of clogging of the leak detection tubes</td>
<td>Catastrophic</td>
<td>after Prevention</td>
<td>Leak Detection System</td>
<td>Perform corrosion inspections during commissioning, before operation and after major upset events</td>
<td>High likelyhood</td>
<td>Recommendation #12</td>
</tr>
</tbody>
</table>

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### Risk Ranking

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<tr>
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### Risk Ranking before Prevention

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### Risk Ranking after Prevention

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### Project Post-Step

- Project Post-Step (1): Add air during heating up procedure with steam and add pressure measurement with vacuum pressure range (Recommendation #12).
- Project Post-Step (2): Never flush behind the liner (Recommendation #2).
- Project Post-Step (3): Always assure proper connection and leak tightness during field welding (Recommendation #2).
- Project Post-Step (4): Never use carbon steel welding electrodes on stainless steel (Recommendation #3).
- Project Post-Step (5): Never use carbon steel welding electrodes on stainless steel (Recommendation #3).
- Project Post-Step (6): Always assure proper connection and leak tightness during field welding (Recommendation #2).
- Project Post-Step (7): Never use carbon steel welding electrodes on stainless steel (Recommendation #3).
- Project Post-Step (8): Always ensure air tightness of the liner during commissioning (Recommendation #2).
- Project Post-Step (9): Never use carbon steel welding electrodes on stainless steel (Recommendation #3).
- Project Post-Step (10): Always ensure air tightness of the liner during commissioning (Recommendation #2).
- Project Post-Step (11): Never use carbon steel welding electrodes on stainless steel (Recommendation #3).
- Project Post-Step (12): Always ensure air tightness of the liner during commissioning (Recommendation #2).

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### Incident 94-001

- **Project phase:** Construction
- **Equipment part:** Protective layer
- **Hazard-reduction measures:**
  - Remove old liner when a relining job is due, so one is able to assess the integrity of the carbon steel pressure bearing wall (Recommendation #12).
  - Make use of qualified and experienced welding engineers and technicians, who are able to assess the integrity of the carbon steel pressure bearing wall (Recommendation #12).
  - Always use inspection, such as non-destructive testing, to ensure the integrity of the carbon steel pressure bearing wall (Recommendation #12).

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### Incident 10-005, 05-001, 04-001, 96-001, 95-005

- **Project phase:** Operation
- **Equipment part:** Protective layer
- **Hazard-reduction measures:**
  - An active leak detection system with a reliable and accurate ammonia detector, which is in operation since the first start up, minimizes time that ammonium carbamate is in contact with carbon steel and minimizes the risk of clogging of the leak detection tubes (Recommendation #1).
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### Incident 100-001

- **Project phase:** Operational
- **Equipment part:** Protective layer
- **Hazard-reduction measures:**
  - An active leak detection system with a reliable and accurate ammonia detector, which is in operation since the first start up, minimizes time that ammonium carbamate is in contact with carbon steel and minimizes the risk of clogging of the leak detection tubes (Recommendation #1).
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### Incident 100-002

- **Project phase:** Commissioning
- **Equipment part:** Protective layer
- **Hazard-reduction measures:**
  - An active leak detection system with a reliable and accurate ammonia detector, which is in operation since the first start up, minimizes time that ammonium carbamate is in contact with carbon steel and minimizes the risk of clogging of the leak detection tubes (Recommendation #1).
  - An active leak detection system with a reliable and accurate ammonia detector, which is in operation since the first start up, minimizes time that ammonium carbamate is in contact with carbon steel and minimizes the risk of clogging of the leak detection tubes (Recommendation #1).
  - An active leak detection system with a reliable and accurate ammonia detector, which is in operation since the first start up, minimizes time that ammonium carbamate is in contact with carbon steel and minimizes the risk of clogging of the leak detection tubes (Recommendation #1).

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### Incident 100-003

- **Project phase:** Construction
- **Equipment part:** Protective layer
- **Hazard-reduction measures:**
  - An active leak detection system with a reliable and accurate ammonia detector, which is in operation since the first start up, minimizes time that ammonium carbamate is in contact with carbon steel and minimizes the risk of clogging of the leak detection tubes (Recommendation #1).
  - An active leak detection system with a reliable and accurate ammonia detector, which is in operation since the first start up, minimizes time that ammonium carbamate is in contact with carbon steel and minimizes the risk of clogging of the leak detection tubes (Recommendation #1).
  - An active leak detection system with a reliable and accurate ammonia detector, which is in operation since the first start up, minimizes time that ammonium carbamate is in contact with carbon steel and minimizes the risk of clogging of the leak detection tubes (Recommendation #1).

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### Incident 100-004

- **Project phase:** Construction
- **Equipment part:** Protective layer
- **Hazard-reduction measures:**
  - An active leak detection system with a reliable and accurate ammonia detector, which is in operation since the first start up, minimizes time that ammonium carbamate is in contact with carbon steel and minimizes the risk of clogging of the leak detection tubes (Recommendation #1).
  - An active leak detection system with a reliable and accurate ammonia detector, which is in operation since the first start up, minimizes time that ammonium carbamate is in contact with carbon steel and minimizes the risk of clogging of the leak detection tubes (Recommendation #1).
  - An active leak detection system with a reliable and accurate ammonia detector, which is in operation since the first start up, minimizes time that ammonium carbamate is in contact with carbon steel and minimizes the risk of clogging of the leak detection tubes (Recommendation #1).
### 1. Corrosion in carbon steel on outside, which can harm the mechanical integrity of the vessel

**Operational**

**Recommendation #8**

Performing corrosion inspections by qualified and experienced inspectors during turnarounds by qualified and experienced inspectors with a frequency depending on age of reactor and previous inspection findings. [Recommendation #15].

**Moderate likelihood (5)**

Catastrophic consequence

### 2. Lower conversion figures in synthesis as reactor inlet liquid pressure bearing wall leading to potentially high corrosion rates (1000 mm/year). This can threaten the mechanical integrity of the reactor.

**Operational**

**Recommendation #2**

Look for defects in liner welds. [Recommendation #22].

**Moderate likelihood (5)**

Catastrophic consequence

### 3. Ammonium carbamate will be in contact with carbon steel on outside, which can harm the mechanical integrity of the vessel.

**Operational**

**Recommendation #18**

Measure wall thickness of trays. [Recommendation #16].

**Insignificant consequence**

**Light likelihood (11)**

Insignificant consequence

### 4. Ammonium carbamate is in contact with carbon steel and minimizes the risk of clogging of the leak detection tubes.

**Operational**

**Recommendation #1**

An active leak detection system with a reliable and accurate ammonia detector, which is in operation since the first start up, minimizes time that ammonium carbamate is in contact with carbon steel and minimizes the risk of clogging of the leak detection tubes. [Recommendation #17].

**Moderate likelihood (5)**

Catastrophic consequence

### 5. Weld decay or knife line attack in Heat Liner during turnarounds by qualified and experienced inspectors.

**Operational**

**Recommendation #21**

Measure wall thickness of liner and overlay weld at same location at regular time intervals. [Recommendation #15].

**Major consequence**

**High likelihood (11)**

Catastrophic consequence

### 6. Risk of clogging of the leak detection tubes is likely to occur.

**Operational**

**Recommendation #19**

Apply proper installation and tightening procedures for flange connections. [Recommendation #9].

**Insignificant consequence**

**Light likelihood (11)**

Insignificant consequence

### 7. Urea reactor vessel. As leaking liquid in a urea reactor contains also urea, clogging of the leak detection tubes is likely to occur.

**Operational**

**Recommendation #4**

An active leak detection system with a reliable and accurate ammonia detector, which is in operation since the first start up, minimizes time that ammonium carbamate is in contact with carbon steel and minimizes the risk of clogging of the leak detection tubes. [Recommendation #17].

**Moderate likelihood (5)**

Catastrophic consequence

### 8. Moderate likelyhood

### 9. Rare likelyhood (7)

### 10. Moderate likelyhood

### 11. Rare likelyhood (5)

### 12. Rare likelyhood (5)

### 13. Moderate likelyhood

### 14. Rare likelyhood (7)
Cracking accelerated rates of strain induced stress corrosion locally defects in passive Cr₂O₃ layer and Sulphur contamination on process side leading to accelerated rates of strain induced stress corrosion locally defects in passive Cr₂O₃ layer and Chloride contamination on process side leading to layer passivation leading to active corrosion with higher possible process upset conditions. Subsurface defects open up due to passive corrosion. Without an active leak detection system in operation. Liner. Condensation corrosion in gas phase part of reactor vessel. As leaking liquid in a urea reactor contains also urea, (1000 mm/year). This can threaten the mechanical integrity of the vessel. As leaking liquid in a urea reactor contains also urea, (1000 mm/year). This can threaten the mechanical integrity of the vessel. Ammonium carbamate will be in contact with carbon steel pressure bearing wall leading to potentially high corrosion rates. Ammonium carbamate can get into contact with carbon steel and minimizes the risk of clogging of the leak detection tubes. Note: Only a vacuum system guarantees a direct monitoring of at maximum 20% area also in case teen peaks are reached [Recommendation #48].

Defects in the protective layer leads that ammonium carbamate is in contact with carbon steel and minimizes the risk of clogging of the leak detection tubes [recommendation #1]. A vacuum based leak detection system detects more quickly a leak [Recommendation #8]. Performing corrosion inspections during turnarounds by qualified and experienced inspectors with a frequency depending on age of vessel and previous inspection findings [Recommendation #30]. Make use of skillful and experienced designers and fabricators also for high pressure piping systems; perform expediting services by skillful and qualified and experienced inspectors with a frequency depending on age of the plant and previous inspection findings [Recommendation #30]. Note: Only a vacuum system guarantees a direct monitoring of at maximum 20% area also in case teen peaks are reached [Recommendation #48].

An active leak detection system with a reliable and accurate ammonia detector, which is in operation since the first start up, minimizes time that ammonium carbamate is in contact with carbon steel and minimizes the risk of clogging of the leak detection tubes [recommendation #1]. Performing corrosion inspections during turnarounds by qualified and experienced inspectors with a frequency depending on age of vessel and previous inspection findings [Recommendation #30]. Make use of skillful and experienced designers and fabricators also for high pressure piping systems; perform corrosion, leak detection and repairs in accordance with relevant codes and standards. An active leak detection system with a reliable and accurate ammonia detector, which is in operation since the first start up, minimizes time that ammonium carbamate is in contact with carbon steel and minimizes the risk of clogging of the leak detection tubes [recommendation #1]. A vacuum based leak detection system detects more quickly a leak [Recommendation #8]. Ammonium carbamate can get into contact with carbon steel pressure bearing wall. Ammonium carbamate can get into contact with carbon steel pressure bearing wall. Liner. Liner. Liner. Liner. Liner. Liner. Liner. Liner.
41. Detoriation of the protective layer increases the risk that active corrosion with higher corrosion rates show up. This leads to a stripping effect of the oxygen in the liquid during blocking in leading to risks of active corrosion with higher corrosion rates (1000 mm/year). This can threaten the mechanical integrity of the reactor contains also urea, clogging of the leak detection tubes is likely to occur. Perform corrosion inspections during turnarounds by qualified and experienced inspectors with a frequency depending on age of reactor and previous inspection findings [Recommendation #2]. Make use of qualified and experienced fabricators and welders for repair jobs. Minimize welding as repair procedure. If welding is required make use of 25-25-25 filler metal [Recommendation #32].

42. Protective layer defect due to flushing in urea shortly after a reactor is in operation (in 10% of reactor operation time) [Recommendation #1]. Avoid/limit blocking in of reactor [Recommendation #33].

43. Protective layer defect due to excessive chlorides in urea shortly after a reactor is in operation (in 10% of reactor operation time) [Recommendation #1]. Never use chloride containing markers [Recommendation #39].

44. Protective layer defect due to excessive nitrites in urea shortly after a reactor is in operation (in 10% of reactor operation time) [Recommendation #1].

45. Protective layer defect due to excessive ammonia shortly after a reactor is in operation (in 10% of reactor operation time) [Recommendation #1].

46. Protective layer defect due to excessive nitrites in urea shortly after a reactor is in operation (in 10% of reactor operation time) [Recommendation #1].

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