Urea Reactor Height Extension to Increase Capacity

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Summary

A discussion of the extension of the Yara Belle Plaine Urea reactor as part of a recent revamp of the plant to increase capacity of the plant. Although the reason for the work was related entirely to expansion of capacity, the procedure could also be applicable to lifetime extension for reactors where the vapor section has reached its minimum safe thickness due to condensation corrosion.

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Starting as Saskferco in 1992 the company had a nominal 1500 t/day Uhde ammonia plant and a 2000 t/day Stamicarbon/ Hydro Agri urea plant. The company was bought in 2008 by Yara and became known as Yara Belle Plaine. In 1997 the plant was upgraded to 1820 t/day of ammonia and 2850 t/day of urea with the urea expansion being accomplished by the addition of a second High Pressure (HP) stripper and a parallel, smaller recirculation section. In 2008 a decision was made to further expand the plants to 2130 t/day of ammonia and 3300 t/day of urea.

This decision was based on the development of the Medium Pressure (MP) Add On process by Stamicarbon and it seemed a very good fit for the plant since it required no additional HP CO_2 Compressor, HP Stripper, and HP Carbamate Condenser, Low Pressure (LP) Recirculation or Evaporation capacity. Instead a new MP section was added in which an MP (18 bar) decomposer is used to handle a slip stream (about 800 t/day urea equivalent).

The vapors from the decomposer are partially condensed against urea solution in a new pre-evaporator with the balance of condensation being done in a new MP Carbamate Condenser. The temperature level is high enough that spent cooling water can be used as the heat sink from a conditioned cooling water loop and in that way little additional cooling water is required-an important consideration for the plant. The liquor from the MP decomposer is stripped adiabatically in a packed bed using CO_2 at 18 bar and the stripper vapors join the vapors from the MP Decomposer. The LP carbamate at 30% water is the source of water to assist in condensation, which dilutes the MP Carbamate Condenser carbamate stream down to 20% water. The carbamate is pumped to HP synthesis as was the case before, but in greater quantity due to the additional CO_2 and NH_3 that have been condensed.

Because the plant would now operate at 165% of nominal design rate, reactor capacity became an issue.

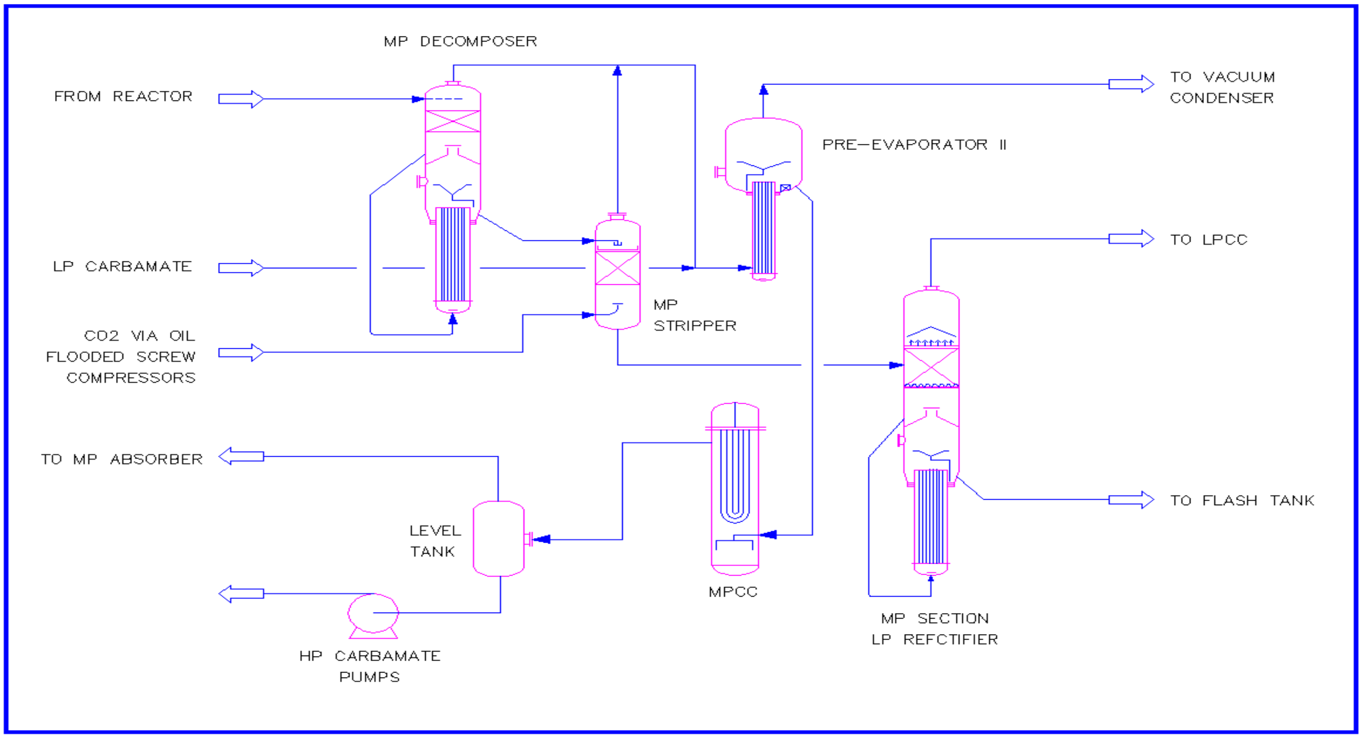

Figure – 1: New MP section added to the Exisiteng Urea Production Process

The increase in capacity required could be achieved in different ways:

- To replace the reactor by a bigger one
- To add an additional reactor
- To increase the efficiency by new tray design
- To add volume to the existing reactor

Reviewing all aspects together with Stamicarbon it was decided to add volume to the existing reactor by adding 5 meters of height to the reactor in order to meet the specifications.

In order to achieve this extension under the conditions as present and declared by Yara, a great deal of technical skill is required. According to the views of Stamicarbon, Schoeller-Bleckmann Nitec GmbH (SBN) the company who had previous experience with this type of jobs and after a thorough evaluation by Yara, SBN appeared to be the most adequate and attractive manufacturer to execute this modification.

After studying this reactor extension in more detail, taking into account the available down time of the plant, and considering the condition of the liner in the urea reactor it was economically the best choice not only to add an extra cylindrical section but also to renew the top hemi head and the cover.

Of course Safurex® was selected for the alloy protection for the new section. By doing so, the entire section of the reactor that is exposed to the most corrosive environment (gas phase) consists of Safurex®.

Analysis of previous reactor inspections showed that the condition of the liner in the lower reactor part was still good to achieve another ten years plus of lifetime, only the condition of the liner in the gas phase was bad due to condensation corrosion. Also Strain Induced Intergranular Cracking (SIIC) was present in the vicinity of the top circumferential weld.

The proposed modification would submerge the existing 316L-UG liner in the urea solution and will in that way extend the life time of the reactor detrimental before liner corrosion becomes an issue.

To take advantage of the extra volume in the best way, two more high efficiency trays were added, also fabricated in Safurex® The new hemi-head was designed in such a way that the leak detection system can be tied into the plants vacuum leak detection system.

Another important issue that could not be ignored was the given down time to allow this modification. For economical reasons, Yara allowed a shutdown time of maximum six weeks for the modifications.

Having ensured that the mentioned points could be met, the next point to consider was whether the existing reactor can be extended in situ. In order to prove this, the following points were reviewed:

- Type of reactor (monowall or multilayer)
- Construction material of the pressure vessel part
- The liner construction and weld details of the liners
- Can an extension be executed without a post weld heat treatment?
- Exact dimensions of the reactor (out of roundness)
- Pressure Vessel Code requirements
- The space available around and above the reactor
- The foundations (to take the extra weight)

After all the details were reviewed and positively answered a game plan was made. That game plan secured the following issues:

- The reactor extension will be done with the reactor in position
- The choice of the materials should be such that the new section will have the same wall thickness in the cylindrical part as the original reactor and the diameter will be identical.
- The new head will be made in such a way that all testing, including the hydro would be performed at the SBN facilities in Austria.
- The reactor will be cut by abrasive water cut and will be done in the circumferential weld between hemi-head and cylindrical section.
- The new cylindrical weld seam with the existing reactor will be tested by phased array method; an examination of the weld by radiography would have been quite impractical

With these starting points in place a detailed procedure and time planning was made and discussed several times discussed with all parties involved.

The works were divided in three sections:

1. The manufacturing and shipping of the new reactor part.
2. The preparation of the site (tie ins)
3. The reactor extension.

The fabrication of the new reactor head

As already stated the modification included the removal of the top hemi head, the replacement of this top head including a cylindrical section, 5,000 mm long, a new hemi-head and a new cover. The weight of these new parts amounts up to some 100 tons.

Two new high efficiency trays would be added, the down comer pipe would be extended and also the nozzle sleeve of the 10” Sch 160 nozzle N5 (liquid outlet) in the bottom head would be renewed by a 10” Sch 80 Safurex® nozzle. All these new parts would be fabricated in SBN

Ternitz, Austria. Assembly, however, would be done on site in Canada.

In order to have no delays during the field works it is of great importance that the exact dimensions of the existing urea reactor at the location of the cut are known; this means that following dimensions were taken,

- The inner diameter
- The out of roundness
- The wall thickness of the liner at the location of the cut line
- The wall thickness of the pressure bearing part

With these data available the new top head was engineered and fabricated. The cylindrical section consists of a multilayer of which the wrap layers are made from a type of Carbon steel chosen in such a way that the wall thickness of the new cylinder will be almost identical to the wall thickness of the original cylindrical shell.
The fabrication of the parts in Austria started beginning 2009 and under supervision of Stamicarbon.
The new hemi-head was equipped with a leak detection system and the surface exposed to the process fluid was protected with a 5-mm thick Safurex® liner.

The testing was done in line with the ASME code and the Stamicarbon quality requirements, typically the tests of this hemi-head were comparable with the fabrication of new equipment, and even a hydrostatic test was executed. In order to allow this hydro test, a temporary hemi-head was welded to the cylindrical section.

The liner was NH_3 leak tested and after all the tests were completed the inside of the reactor was blanketed with nitrogen and shipped to Canada.

The execution of the field works

The field works started in June 2009 and included following works:

1. Cutting hemispherical head from existing Urea Reactor
2. Machining of weld bevel
3. Lifting the new head onto existing reactor
4. Modifying the gas outlet line
5. Increasing the size of the bottom liquid outlet nozzle N5
6. Installing two additional Sieve Trays (Stamicarbon HE-trays)
7. Finalizing tie-ins for the MP Add On connection

Cutting hemispherical head from existing Urea Reactor

After the reactor was assigned to maintenance, the cut in the urea reactor was made through the circumferential weld between the existing top hemi-head and cylindrical section.
The cut was made in such a way that the multilayer wraps and the existing liner were not touched. The cut was done by abrasive hydro cutting. The cutting angle was chosen in such a way that the cut was already the weld preparation.

After cutting the following inspections were executed,

- Check the cut visual
- Reconfirm the dimensions of the inner diameter and wall thickness
- 100% PT of weld preparation and adjacent base material. preparation.

Figure 2: New top reactor shell section

Lifting the new head onto existing reactor

The lift of the new head was done with the help of a 660 tons mobile crane and went through the roof of the building.

With the help of guiding and positioning provisions the exact positioning was ensured, the orientation was important due to the presence of a nozzle in the hemi-head.

Welding was done while the Carbon steel was pre heated to some 100°C.

The circumferential weld was made by dia 4.0 mm stick electrodes. The welding of the circumferential seam took approximately 4 days and in that time 600 Kg of weld consumables were deposited.

The circumferential weld seam was NDT inspected by phased array method at intervals, after respectively 30%, 60% and after completion of the weld.

This phased array UT method used was a relative new inspection technique for this type of repair welds. The procedure was qualified with the provincial regulatory body and found to be equal or better than the standard radiography methods. This testing went without incident

After completion of the weld, the weld and its vicinity were soaked for removal of any hydrogen at 320°C for 10 hours.

After completion of the carbon steel circumferential weld the transition between the new Safurex® liner and the existing 316L-UG liner was welded with Safurex® weld consumables, The root run was made using alloy 25-22-2.

After completion of this Safurex® "overlay" weld the weld surface was checked for weld defects by PT examination.

Finally the reactor was closed

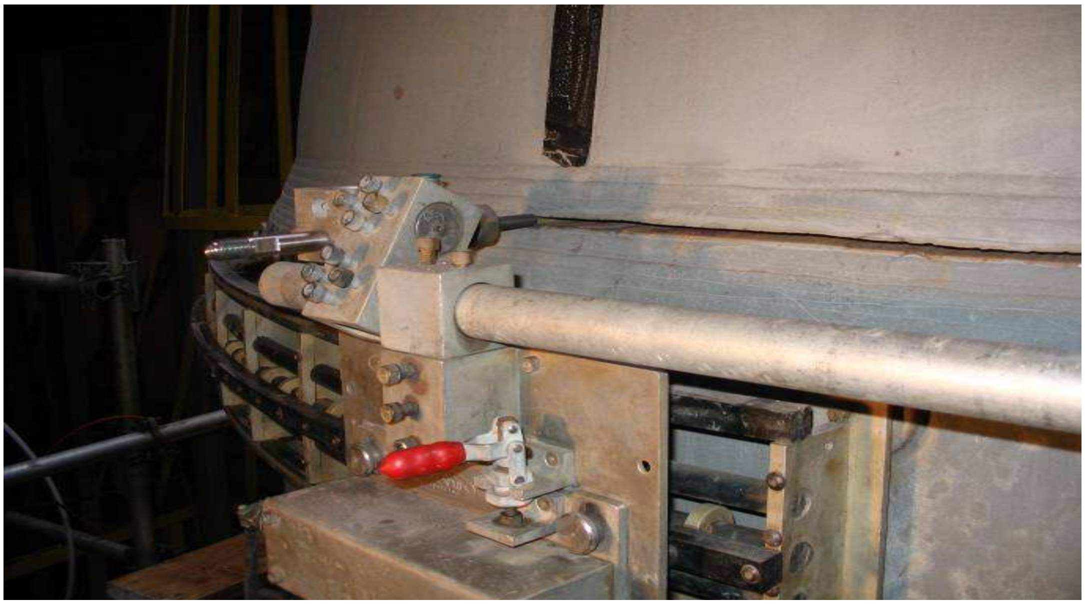

Figure 3: Cutting of the head underway using HP water-jet / abrasive cutting

Figure4: Machining of the weld preparation bevel

Figure 5: New reactor section being lifted

Conclusion

Our experience with the expanded urea plant has been very good and the present limitation is almost always CO2 availability from the ammonia plant.

The overall project and the reactor extension portion of the project were within budget and the reactor components were well ahead of scheduled delivery dates. Although in the Yara Belle Plaine case the reason for the work was related entirely to expansion of capacity, the means used to accomplish the work would also be applicable to lifetime extension for reactors where the vapor section liner has reached its minimum safe thickness due to condensation corrosion.