

## **BADOTHERM successfully developed Reliable Pressure, Level and delta-P Measurements with Diaphragm Seals for All UREA Plant Technologies**

### **Summary**

Measuring pressures, levels and delta-P's in UREA plants is a real challenge. Crystallization, erosion and corrosion risks have to be taken care of. Typically diaphragm (or membrane) type of measurements are applied nowadays but its lifetime is typically limited (e.g. max one year). After this period, these diaphragms face corrosion problems and mostly needs to be replaced. This means the UREA plant needs to shut down mostly unexpected leading to significant costs in production loss. More and more UREA plants target continuous running periods between planned turnarounds of two, four to even six years. Sometimes one is able to keep the plant in operation but one needs to operate the plant under non-optimum process conditions. Such a situation also leads to a significant negative financial impact as illustrated in this paper. BADOTHERM is a well-known manufacturer of reliable diaphragm seal type pressure, level and delta-P measurements suitable for all UREA process technologies. Significant costs can be avoided and additional profits can be gained with the BADOTHERM Diaphragm Seals mounted to Pressure Transmitters, for pressure, level or delta-P measurements. Badotherm has several designs and materials available meeting the specific requirements of the UREA industry.

### **Overview of the current challenges**

Carbamate and UREA easily crystallizes when temperatures become too low. In the early days, flushes were installed at the transmitter legs to avoid crystallization, however its reliability was very limited and a lot of attention and maintenance was required. Moreover, these measurements introduced certain safety risks. Nowadays extended diaphragm seals are applied, which do not require any flushes anymore, as the diaphragm is now flush with the process. However, in case of any damage of the diaphragm, the plant many times needs to shut down and this happens mostly unexpectedly. This leads to production loss and related significant costs. One day unplanned shut down costs easily half a million US\$ in a world scale UREA plant.

The thin diaphragm of these pressures-, level and delta-P transmitters are sensitive for erosion, corrosion and mechanical stresses. In addition, the transmitter diaphragms are not available in these materials and cannot withstand the process conditions (temperature) as such, diaphragm seals are required. This offers more flexibility in materials, and protect the vulnerable transmitter-measuring cell.

For UREA applications, several materials have been considered to meet these challenges, however many materials only offer a limited lifetime. For example Hastelloy C 276: however, this is not a good option in UREA plants as within less than one year the complete diaphragm was dissolved (refer to the Figure 1). Hastelloy C276 does not provide a corrosion resistant material for carbamate solutions present in UREA plants.



**Figure 1: Hastelloy C276 diaphragm disappeared within one-year operation**



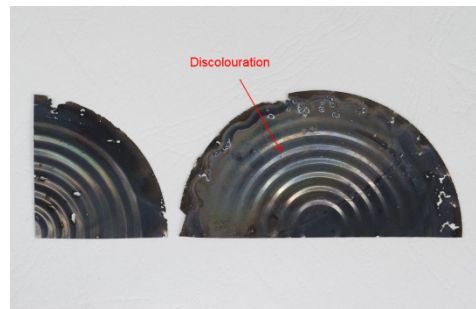
Using an AISI 316 Stainless Steel diaphragm gives a slightly better performance but still within the first year on stream time the thin diaphragm is severely damaged, also possibly contributed to condensation corrosion of ammonium carbamate when tracing and insulation are not perfect (refer to the Figure 2).

Other material such as 316L Urea Grade or 25.22.2 are often considered and in several occasions do offer a more durable solution, however under high pressure synthesis process conditions these materials still fail within a limited operating period.

**Figure 2: 316 Stainless Steel diaphragm severely damaged within the first year operation.**

Titanium is corrosion resistant in carbamate containing streams but too soft.

Zirconium or Tantalum are very corrosion resistant in carbamate containing streams even under high pressure synthesis process conditions, so in principle these are perfect materials to apply in UREA plants. However welding such a thin diaphragm to a stainless steel body is not a good idea, as it will cause mechanical stresses and deterioration of carbamate corrosion resistance. Also then maximum on stream times are limited to about one year. Refer to the Figures 3 & 4.



**Figure 3 & 4: Within one year the Tantalum diaphragm is severely damaged due to loss of corrosion resistance due to welding.**

### **For UREA High Pressure Synthesis applications, Tantalum or Zirconium is the best choice**

When one produces UREA on a commercial scale ammonia and carbon-dioxide is used as feedstock and UREA is produced at high pressures (140-200 bars) and high temperatures (160-190 °C). The intermediate product formed is ammonium carbamate, which has under UREA synthesis conditions extremely corrosive properties. Ammonium carbamate splits into carbamic acid, which acts as a strong Brönsted acid with the ammonium ion  $\text{NH}_4^+$  as the solvated proton similar to sulphuric acid with hydronium ion  $\text{H}_3\text{O}^+$ . The corrosion behavior of Zirconium under UREA synthesis conditions appears to be perfect. Already for decades, Saipem has successfully applied Zirconium in their bi-metallic and Omega-Bond High Pressure strippers, where temperatures can go up to 210 °C.

### BADOTHERM Solution #1: Extended full Zirconium Diaphragm Seals Transmitter

For many applications, an extended diaphragm seal type (Badotherm indicates this with EXT) is required. BADOTHERM developed a reliable solution to solve the above challenges. Applying a Zirconium diaphragm together with a Zirconium body avoids welding of the thin diaphragm to a different material such as 316 stainless steel causing corrosion problems in the weld area. With all wetted parts being Zirconium including the weld, the construction is extremely corrosion resistant against carbamate corrosion. Refer to Figure 5.

Tantalum is NOT recommended for extended diaphragm seals (EXT) as these require a tantalum-to-tantalum weld, which results in a brittle tantalum whereby the diaphragm is torn off after maximum one year of operation.

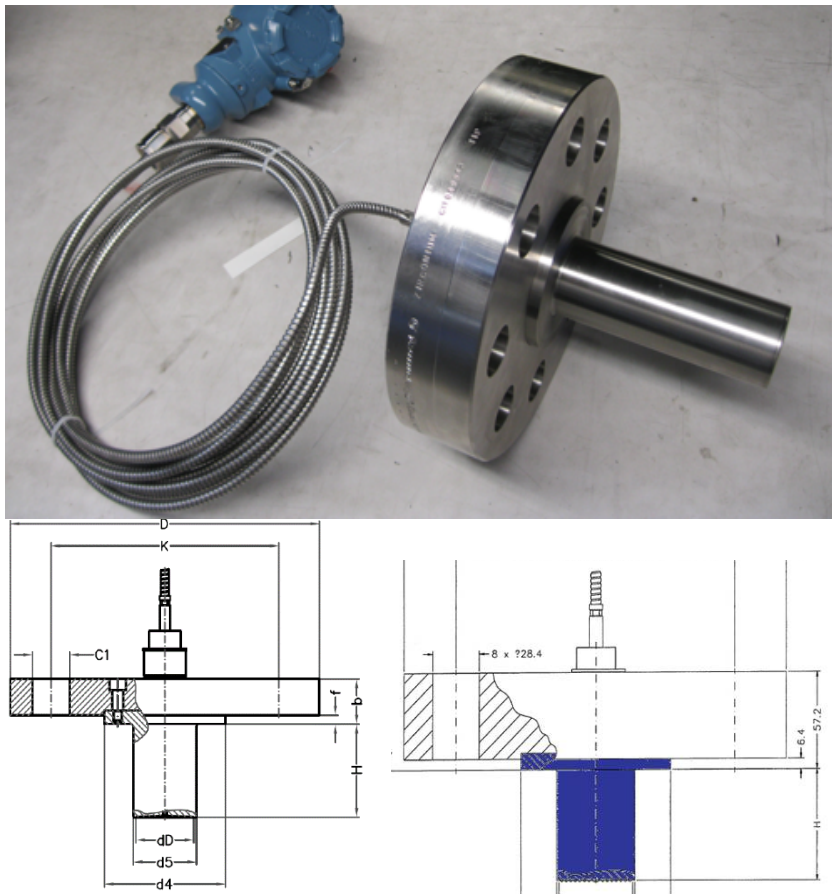
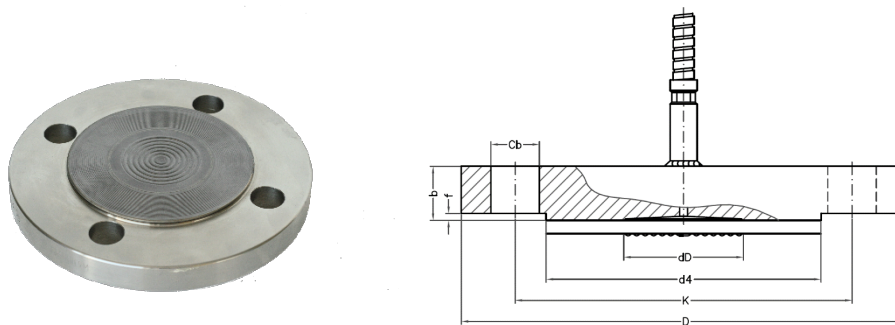


Figure 5: The BADOTHERM Extended type Diaphragm Seal with all wetted parts in Zirconium

## **BADOTHERM Solution #2: Flush Mounted Flanged Diaphragm Seal with Zirconium or Tantalum wetted parts**

The Badotherm Solution #2 is for flush mounted pressure, level and delta-P measurements (Badotherm indicates this with BRF) where the tantalum or zirconium diaphragm is fixed to the body with a special resistance welding technique. The wetted parts of the flange material, typically 316(L) is now covered with the diaphragm materials, typically tantalum or zirconium. Due to the resistance weld technology, the material composition in contact with the process is not impacted. Figure 6 shows a picture of this flush-flanged solution.



**Figure 6: The BADOTHERM Solution for flush mounted pressure, level and delta-P measurements**

### **Possible UREA plant applications for BADOTHERM Diaphragm Seals**

The BADOTHERM pressure and level transmitters can be applied for several applications:

1. Pressure in the UREA synthesis section
2. Level in the High Pressure scrubber
3. Level in the High Pressure separator
4. Pressure in medium and low pressure recirculation sections
5. Level in the medium and low pressure recirculation columns
6. Level in medium and low pressure carbamate condenser level tanks
7. Pressure in hydrolyser and desorber columns
8. Level in hydrolyser and desorber columns
9. Pressure in UREA melt lines

For the High Pressure UREA synthesis section BADOTHERM recommends to use Tantalum or Zirconium as material for the wetted parts.

For the other medium and low-pressure sections, BADOTHERM suggests to use as an alternative 316L UREA Grade or 25Cr-22Ni-2Mo UREA Grade as material for the diaphragm. 25-22-2 material has lower passive ammonium carbamate corrosion rates than 316L UREA Grade or other austenitic stainless steels, it has higher mechanical properties and is less prone to condensation corrosion. 316L Urea Grade applied in a gas phase requires perfect tracing and insulation to avoid condensation corrosion risks.

Choosing the right designs and materials will significantly improve the reliability of your UREA plant as the BADOTHERM Solutions have proven.

### Case Study 1: Yara Sluiskil, the Netherlands

Most of the pressure and level applications in a UREA plant are critical and a malfunctioning critical instrument will cause either an unplanned shut down. Alternatively, a malfunctioning critical instrument can cause that one needs to operate the plant under not optimum conditions. For example with a malfunctioning level measurement in the High Pressure Scrubber in a Stamicarbon PoolCondenser plant, which caused an inert recycle over the HP ejector.<sup>1)</sup>

For three years, Yara Sluiskil in the Netherlands faced problems with the level measurement of the High Pressure (HP) scrubber in its Stamicarbon PoolCondenser UREA plant. All this time there was no level indication of the HP scrubber overflow leg. During the turnaround of 2014 this problem was solved by applying the BADOTHERM Transmitters. After controlling the level, it became clear that the synthesis overall reactor temperatures increased. It is already known for a longer period that a HP ejector is capable of circulating high amounts of vapor, including inerts as indicated in the figure below. Due to this inert recycle, the inert pressure in the top of the reactor increases and therefore the boiling temperature decreases. Because of this, the inert recycle at Sluiskil the conversion of the synthesis was significant lower than it should be. Overall, the liquid outlet temperature of the reactor is now approximately 3°C higher and the liquid outlet temperature of the HP stripper 4°C lower at 120% capacity than during the performance test at 102% capacity. This significant improvement of the performance of the UREA synthesis section leads to obvious additional financial profits in the range of millions of US\$ per year.

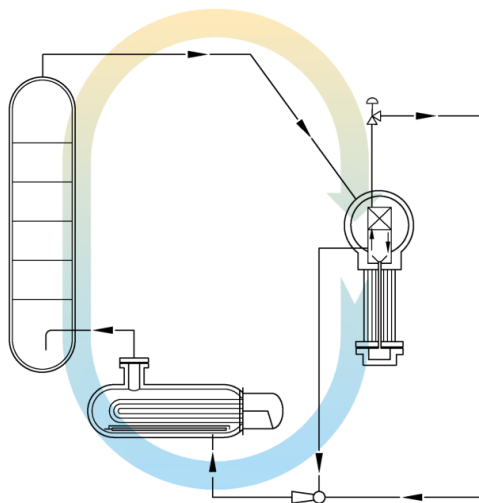


Figure 7: Inert recycle in a Stamicarbon UREA synthesis section due to malfunctioning of then level measurement of the High Pressure Scrubber

### Case Study 2: OCI Nitrogen Geleen, the Netherlands

A BADOTHERM pressure measurement has been installed in the high pressure recycle line from a melamine plant to the urea plant. The process conditions are very severe in this ammonium carbamate line as temperatures go up to 210 °C. The BADOTHERM Diaphragm seal pressure transmitter has proven to be able to withstand these very harsh conditions for a long time.



## Conclusion

In UREA industry the need for longer maintenance interval periods result in stronger demands in the materials and their required lifetimes. Selecting corrosion resistant materials for all wetted services remains critical to the reliability and durability. Also welding mixed metals needs to be avoid where possible. For UREA High Pressure Synthesis applications, Tantalum or Zirconium materials are the best choice.

## More information?

In case you are interested to receive more information about this or our other solutions, please contact any of our sales offices or the below mentioned contact:

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## References:

- 1) Maximum Load Test at A Large Scale UREA Plant In The Netherlands EELCO MOSTERT Stamicarbon B.V., The Netherlands, Nitrogen & Syngas Conference 2016, Berlin.
- 2) Corrosion Engineering Guide, Giel Notten.
- 3) Badotherm Diaphragm Seals Solutions – catalogue

### About Badotherm

Galileo Galilei once said 'measure what is measurable and make measurable what is not so.' Four hundred years later, this is exactly what we do. We are a family-owned company specialized in high quality mechanical process instrumentation. Founded back in 1957 as a production- and repair shop for thermometers, today we are a leading manufacturer of Diaphragm Seals, pressure gauges, temperature gauges, thermowells, valves and manifolds. Badotherm is headquartered in the Netherlands, and employs over 225 people in seven different countries and serve the most reputed end users on a global basis. We have offices and facilities in Europe, the Middle East, India, the Far East and Americas.



Badotherm has a strong focus on Diaphragm Seal Solutions. Diaphragm Seals, also known as remote seals, are used to separate the pressure instrument from the harsh process conditions, to protect the vulnerable measuring element. We develop, engineer and manufacture tailor-made solutions for the most challenging conditions in the field of Diaphragm Seal measurements. The patented HTDS solution for pressure measurement up to 600°C by means of Diaphragm Seals is a great example of this, just as the low gauge pressure (LGP) measurement of just 5 mbar-g. In addition, we also developed a web-based performance calculation tool 'BaseCal' for Diaphragm Seal applications, to help engineers understand the impact of Diaphragm Seals, calculated under actual process conditions. And for UREA applications, there is the full zirconium extended type of diaphragm seal that has been developed.