## High value in use solutions powered by Umicore's Process Excellence Model

### How innovation & technology as our main drivers do help key industries to substantially save resources

Umicore's business unit Platinum Engineered Materials (PEM) applies a total system approach to provide solutions based on innovation and technology predominantly to the chemical and special glass industries. Our Life Cycle Management approach to work in closed loops and with complementary competencies provides tailor-made, single-source engineered solutions of high economic and technological value. By perfectly synchronizing our customers' process boundary conditions with the PGM component a status can be reached that meets the maximum economic value in use: this is what we call Process Excellence. Hence Process Excellence translates as much into substantial total cost reduction as into efficiency, stability, and security for our customers.

### Physical modeling for the special glass industry

*Temperature homogenization, redistribution and chemical mixing by stirring is one of the key mechanisms in the glass production process. Physical simulation is a sound basis to give highest potential for the development of stirrer geometry and stirring efficiency. In combination with our unique single-source portfolio this leads to highly functional stirring systems and saves resources during glass manufacturing.*

Physical modeling is a method that can provide reasonable findings on glass homogenization, for non steady state processes. It can provide information about flow patterns in mixing areas and hence enables to conclude on the glass quality. There is no exact standard for glass homogeneity and it's impossible to scale homogenization performance. However, it is possible to compare various homogenization systems and find the best one. Following evaluation criteria approaches are possible:

1. Glass homogenization efficiency: The stirring effect is evaluated by time required for disappearing of the defined - usually colored - inhomogeneity introduced into the mixed liquid. The process of inhomogeneity disappearing is monitored visually.
2. Head losses of stirrer system: The stirrers have a body resistance which creates (without reference to rotation or not) the liquid level difference in front and behind the stirrers cells. It is possible to measure this liquid level step. Model head losses are recalculated by scale to real data.
3. Torque moment of stirrers: Torque moment is recalculated from model data to real data.

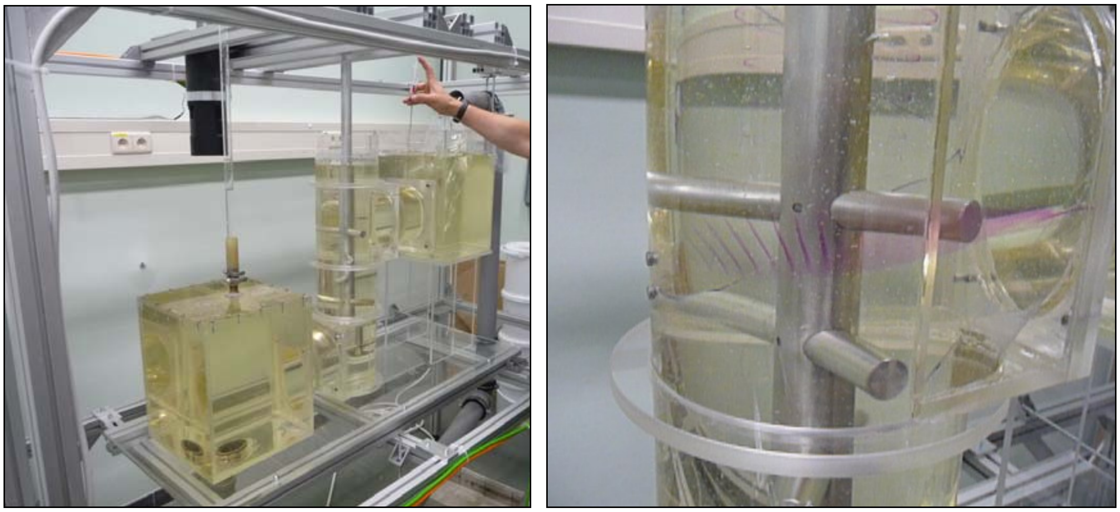

Figure 1: Umicore R&D – Model set-up and visualisation of tracer model liquid during stirring

In the following steps the model is scaled with data and designed according to defined parameters. Finally various stirrer designs & geometries are analysed by means of visualisation of flow pattern to understand which stirrer design provides the best process performance. Based on these findings we then apply our single-source portfolio of tools (material choice, engineering, manufacturing technologies, periphery considerations, and so forth) to come up with the most cost-efficient solution. Continuous fine-tuning of the stirrer design can hence lead to Process Excellence.

**Rhodium free bushing solutions for the fiber glass industry**

*The bushing is the device to form glass fibers by attenuation of liquid glass through a big number of nozzles. Bushings are usually made of Platinum alloys with up to 25% of Rhodium to maintain mechanical stability during operation. Based on our different FKS material grades we have designed bushing solutions that can be made of pure Platinum without any disadvantage regarding process performance: a tremendous potential economic saving.*

Stabilisation of Platinum by means of Rhodium is only one possibility to increase alloy performance, stabilisation by means of oxidic dispersions is a much more powerful option. Not only does this enable to reduce the Rhodium content of an alloy, it even means that Rhodium content can be completely removed.

Umicore's FKS materials have meanwhile been successfully introduced to the fiber glass industry and could demonstrate their high performance in selected E-glass applications. By slightly adapting given standard alloy bushing designs to FKS material based Rhodium-free bushings, the desired bushing performance in the fiber attenuation process could at least be equalized – without any usage of Rhodium (except for some grams of Rhodium that are still needed in the thermocouples, of course).

Let's take an example: Conversion of a given bushing design made of cast PtRh10 alloy (overall weight of about 4 kg, performing with a service time of 300 days) into a FKS Pt bushing solution performing at the same level. Taking into account the 5-year average prices of Platinum (1.257 USD/oz.) and Rhodium (4.197 USD/oz.), a total annual cost reduction per bushing of about 10% can easily be achieved. This calculation does already take into account different fabrication cost for such bushings and a slightly increased weight of a Rhodium-free solution due to the higher physical density of Platinum compared with that of Rhodium.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Currency and prices** | | **Umicore** | | | **Reference** | | |
| Currency for pricing | | USD | | | USD | | |
| | USD @ | 1,30 | EUR | USD @ | 1,30 | EUR | |
| | Pt / g @ | 40,41 | USD | Pt / g @ | 40,41 | USD | |
| | Rh / g @ | 134,93 | USD | Rh / g @ | 134,93 | USD | |
| **Total Cost Calculation per year** | | **Umicore** | | | **Reference** | | **Annual Saving** |
| **Fabrication** | | Cost F. | | | Cost F. | | Cost Delta F. |
| **Maintenance** | | Cost M. | | | Cost M. | | Cost Delta M. |
| **Application** | | Cost A. | | | Cost A. | | Cost Delta A. |
| **Energy** | | Cost E. | | | Cost E. | | Cost Delta E. |
| **Refining** | | Cost R. | | | Cost R. | | Cost Delta R. |
| **PGM** | | Cost PGM | | | Cost PGM | | Cost Delta PGM |
| **Total cost per bushing per year** | | **Total Cost** | | | **Total Cost** | | **Total: -10%** |
| **Number of bushings** | | **Umicore** | | | **Reference** | | |
| Number of bushings | | 50 | pcs | | 50 | pcs | |
| **Alloy** | | **Umicore** | | | **Reference** | | |
| Bushing Base-Plate | | Pt | FKS | | PtRh10 | | |
| Bushing Upper-Structure | | Pt | FKS | | PtRh10 | | |
| Bushing Tips | | Pt | FKS | | PtRh10 | | |
| Bushing Terminals | | Pt | | | PtRh10 | | |
| **Bushing weight proportion** | | **Umicore** | | | **Reference** | | |
| Delivery weight | | **4.175** | g | | **4.000** | g | |
| **Bushing Lifetime** | | **Umicore** | | | **Reference** | | |
| Lifetime | | 300 | days | | 300 | days | |

Figure 2: Total cost example

Further savings are well possible, the above example simply reveals the cost saving that is based on the Rhodium saving only. Usually conversion of designs from cast alloy based bushings to FKS material based bushings does walk hand in hand with a distinct reduction in total bushing weight, improved welding strategy and taking into account the immediate bushing

periphery for a system solution that goes beyond a mere material change.
A common prejudice in the bushing world is related to the wetting behaviour of glass in contact with Rhodium free bushings and suggests that this would have a negative impact on the glass outlet at the tips. Neither our own lab tests nor any application in reality could confirm this for typical E-glass applications. Wetting behaviour of Rhodium free systems at operating temperatures of about 1250°C did show nearly identical results in lab tests and enabled the same yields and process performance in reality.

**Improved PGM recovery systems for the nitric acid industry**

*High pressure burners for the catalytic oxidation of ammonia are particularly subject to very high PGM losses. This is partly due to the lack of an adequate catchment system which makes it increasingly difficult to operate this process profitably. Umicore's new Reconit® catchment gauze - being a three-dimensional knitted gauze - is the long needed solution for Platinum recovery in this process.*

The cost-structure of nitric acid production is threefold: raw materials (ammonia/natural gas), capital and personnel and, finally, the catalyst gauzes, which are made from precious metals (specifically Platinum Group Metals - PGM). If you look only at the PGM gauzes, again their cost structure has different components. First, and perhaps most obvious, the PGM placed inside the ammonia burners are fixed in the process and cannot be utilized elsewhere. Consequently, their financial value (which can easily add up to a few million Euros) is captive to the production process, unavailable for other use or investment. The cost of financing this fixed capital is, however, only a fraction of the total cost of PGM involved in the production process.

Of more long-term significance is the loss of PGM from the catalyst pack during the oxidation process. There are chemical and mechanical losses: Chemically, primarily platinum (Pt) is lost through oxidation, forming gaseous Pt-Oxide ($PtO_2$). Mechanically, Rhodium (Rh) losses are caused when tiny fractions are carried downstream by the gas flow (e.g. through vibrations which loosen re-crystallized Rh-Oxide at the wire surface). Although some portion of lost PGM can be recovered every few years by cleaning the plant, a significant portion of the metal is simply lost for good.

Even though the market prices of Platinum Group Metals (PGM) have plummeted after an intermediate all-time high several months ago, the long term trend will likely be toward higher prices again. It is thus reasonable to predict that it will become increasingly costly – perhaps cost-prohibitive – to continue to lose PGM in such industrial processes as the production of nitric acid. Reflecting this trend of climbing prices for raw materials, the suppliers of gauze catalyst have increased their efforts to bring down the rate of irrevocable PGM losses.

Umicore has always used long-lasting, extremely stable alloys in the manufacture of its gauzes. Another hallmark of Umicore's approach to catalyst gauze, single piece production, carries a decided advantage, making it possible to configure a specific catalyst pack by adjusting and fine-tuning each single gauze inside the pack.

Aware that precious metals are a crucial cost driver, Umicore has made significant R&D investments in an effort to bring down PGM losses over the years. Additionally it releases new product innovations which aim at decreasing losses even further, one of them being Reconit®.

High Pressure (= HP) Plants are particularly subject to very high PGM losses. This is partly due to the lack of an adequate catchment system, as well as to the process itself. HP installations are therefore becoming increasingly difficult to operate profitably.

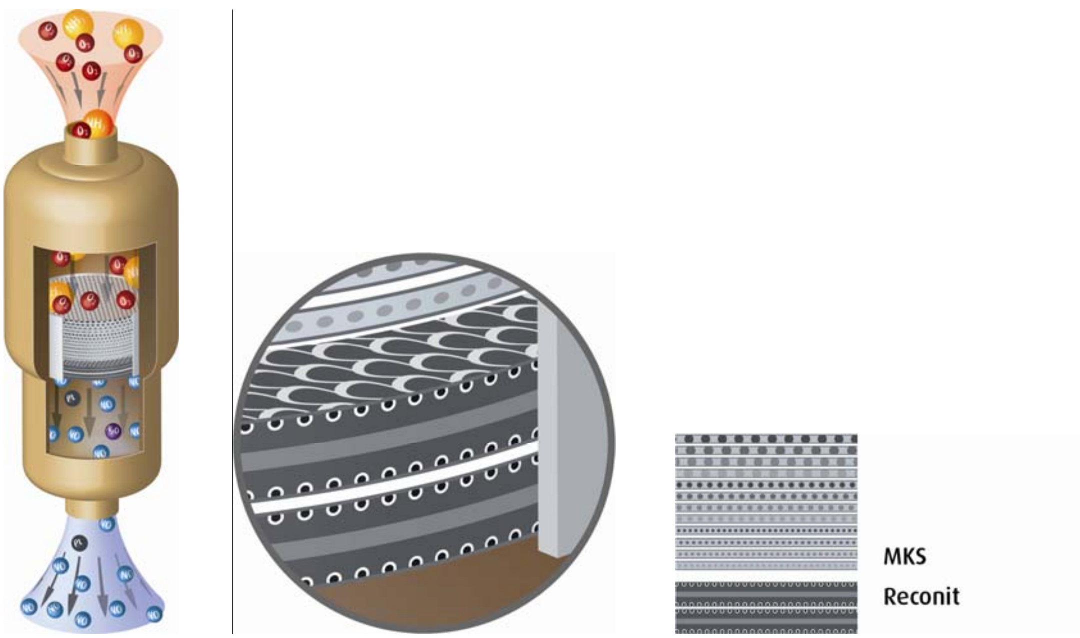


Figure 3: HP reactor with Reconit® layers below the MKS catalyst system

A seeming contradiction is the fact that HP reactors, despite their high primary losses very rarely use recovery gauzes. This is true because of the fact that conventional catchment systems can only be used a short time in installations with high primary losses. Since they consist of dense woven gauzes the spaces in-between the meshes quickly accrue and become clogged. Additionally the pressure drop rises disproportionately which leads to increased stops and downtimes of the reactor. On the other hand, when using a more wide-meshed gauze type, the recovery rate goes down and the process will no longer be economically viable.

By using the flat bed knitting technology Umicore is in the position to produce catchment gauzes, which are dense from the top view but open-structured from the side view.

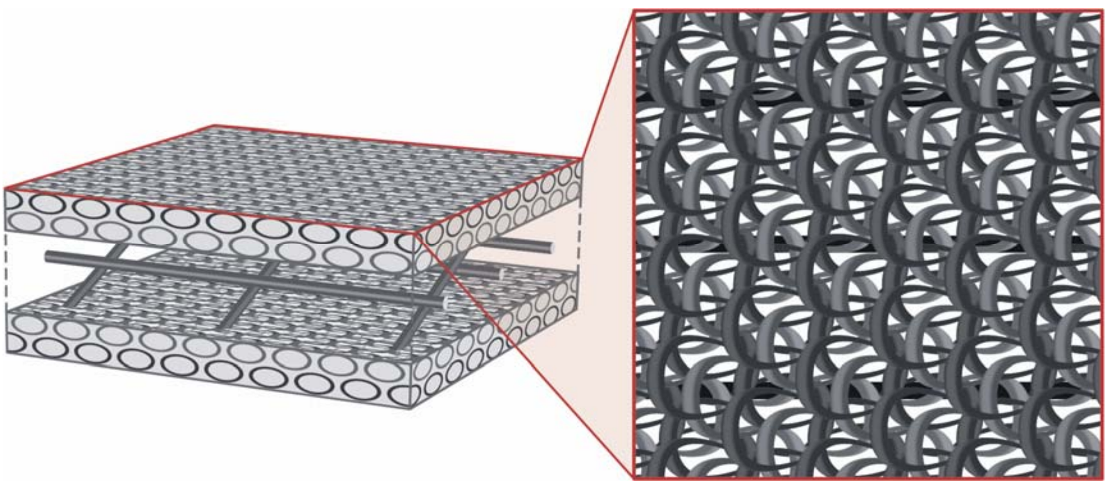

Figure 4: Reconit® gauze - side view (open) and top view (dense)

Umicore's new product Reconit® assures that a major part of the $PtO_2$-Molecules will get close enough to a Pd-wire to be caught in the alloy. Due to the very high porosity of Reconit® the likelihood of clogging up is close to zero even when a lot of PGM is already bound to its surface. Regular catchment gauzes have a porosity of 70-80%. By contrast Reconit®, with its three-dimensional structure, possesses a porosity of over 90 %. This is why it can be used over even the longest production period.

Depending on operation parameters, desired recovery rate and installed precious metal, even several Reconit® gauzes may be used to increase the recovery rate but without increasing the pressure drop significantly. It is thus possible to win back a major part of the primary losses without interfering negatively with the process itself.

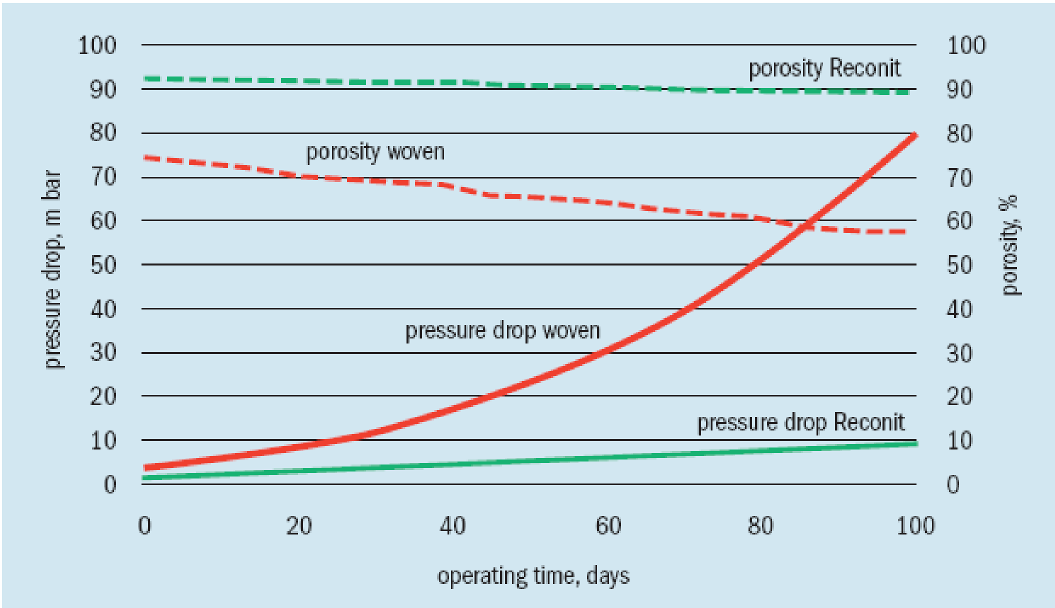


Figure 5: Reconit® during high pressure campaign in comparison with woven gauzes

To quantify the above let's take an example of a HP converter operating at 10 bar (abs.) with a contact diameter of 1.700 mm, an ammonia load of 12.500 $m^3$/hour and an operating time of 100 days. Without appropriate catchment system the converter's catalyst system shows primary losses of 16.734 g of Platinum and 470 g of Rhodium, making a total cost of 748 kUSD based on the 5-year average prices of Pt and Rh. The same converter equipped with Reconit® at a recovery rate of 50% related to the Pt and Rh primary losses will show net losses of only 8.367 g of Pt, 235 g of Rhodium, and 4.530 g of Pd, making a total cost of only 420 kUSD and hence a total cost saving of 56% with reference to the system without catchment.