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One Hundred Years of Gauze Innovation

Platinum gauzes for nitric acid manufacture celebrate a centenary

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In the century since the first platinum gauze for nitric acid production was made by Johnson Matthey, the demand for nitric acid has increased considerably with its vast number of applications: from fertiliser production to mining explosives and gold extraction. Throughout the significant changes in the industry over the past 100 years, there has been continual development in Johnson Matthey's gauze technology to meet the changing needs of customers: improving efficiency, increasing campaign length, reducing metal losses and reducing harmful nitrous oxide emissions. This article reviews the progress in gauze development over the past century and looks at recent developments.

Introduction

Johnson Matthey Plc recently celebrated a centenary since making its first platinum gauze pack (**Figure 1**), sold to the UK Munitions Invention Department in October 1916 for £25 to make nitric acid for explosives during the First World War. The two 4″ × 6″ (approximately 101 × 152 mm) woven gauzes were made with 0.065 mm diameter wire, woven in a square mesh with 80 meshes per linear inch.

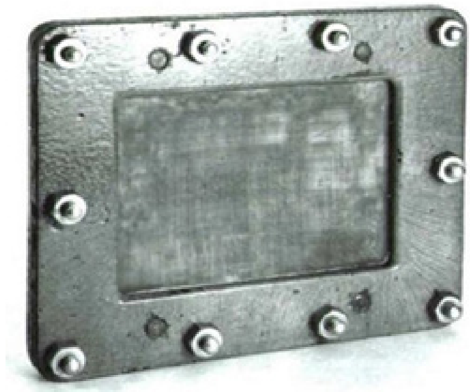

Fig. 1. Johnson Matthey's first woven gauze

In the 1930s small amounts of rhodium began to be included in the gauzes to prevent losses of platinum while increasing the strength and conversion efficiency.

Palladium catchment gauzes were introduced in the 1960s for platinum recovery, offering economic benefits. These were initially palladium-gold, but as the price of gold increased it was replaced by nickel.

1996 saw the invention of knitted gauzes (**Figures 2** to **4**), which allowed a diverse range of structures and alloys to be used in the gauze packs, giving a better metal distribution and contact area. This considerably improved conversion efficiency and overall plant performance while also reducing manufacturing time compared to woven gauzes. This technology, pioneered by Johnson Matthey, became the industry standard.

A few years later gauze packs were developed with Johnson Matthey's proprietary Advanced Coating

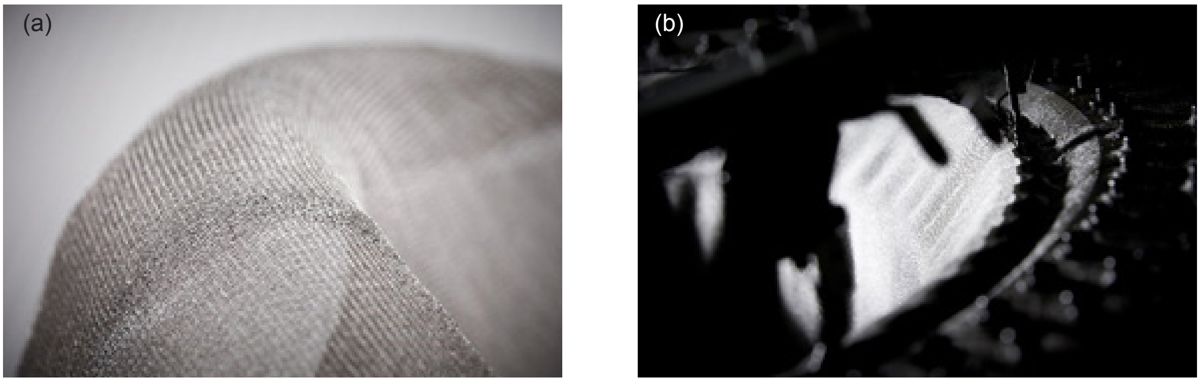

Fig. 2. (a) The structure of a knitted gauze; (b) a gauze knitting machine

Fig. 3. HICON corrugated gauze

Technology (ACT™), reducing the time required to reach maximum production. Later in 2006 the company partnered with Yara International ASA, Norway, to supply its abatement catalyst to minimise harmful nitrous oxide emissions released during nitric acid production.

Gauze Development

In the same year, the catalyst and catchment were combined for the first time through Eco-Cat™ systems. This combines platinum group metal (pgm) with complex ternary alloys and knit structures. Compared to conventional gauze alloys, it uses palladium in a controlled manner to replace some of the platinum, exploiting its metal recovery properties to catch platinum that is lost from the gauze during ammonia oxidation. This system has shown an increased

Fig. 4. Installation of a gauze pack at a customer plant supplied by Paite, Johnson Matthey's Chinese licensee

performance compared to standard catalyst packs, and (subject to plant operating parameters) offers nitric acid manufacturers benefits including: extended campaign lengths by 50–100%; maintained or improved average conversion efficiency; a reduction in installed pgm weight by 40–50%; a reduction in installed platinum weight by 30–40%; reduced metal losses by approximately 30–50%; and reduced nitrous oxide emissions.

The improved performance of Eco-Cat^{TM} technology compared to standard gauze packs is demonstrated in **Table I**, showing the increase in campaign length and nitric acid production when using an Eco-Cat^{TM} system in a medium pressure plant.

Case Study: Reducing the Cost of Nitric Acid Production

Recently, Johnson Matthey worked with one customer to create a tailored Eco-Cat^{TM} system to solve its three main requirements: increasing average conversion efficiency, reducing the installed pgm content of the gauze packs and reducing metal losses. A progressive approach was taken to customising the gauze pack for the customer's specific plant conditions using in-depth analytical data.

Detailed examination of gauze samples from the first installed Eco-Cat^{TM} system uncovered an operational issue related to the plant design that was impacting the gas flow over the catalyst. Upon measuring the relative gas flow variations in the burner, it was found to be higher in certain areas. This was causing faster depletion of the gauze in these regions and therefore resulting in more platinum movement, while also adversely affecting the ammonia conversion efficiency.

The solution drew upon a vast range of gauze structures and their mechanical properties, addressing the regional flow issues in the burner while also considering one of the customer's key requirements of reducing the installed pgm content. As a result, the customer noticed an improvement in the conversion efficiency.

Analysis from previous campaigns along with the producer's data allowed the design of the catalyst to be improved through tailored wire diameters and knit structures. This optimised the reaction zone while also further reducing the installed pgm content.

As shown in **Figures 5–7**, the customised Eco-Cat^{TM} system contributed to a substantial reduction in the producer's costs per tonne of nitric acid.

Faster Light Off

A key goal for most nitric acid producers is to reduce the time required to reach peak conversion efficiency. In-house laboratory research into how peak efficiency is reached has found that platinum is volatilised during normal operation and forms cauliflower-like structures on the wire, which increases catalytic surface area. ACT^{TM} allows a thin layer of platinum to be sprayed

Table I Nitric Acid Campaign Results using a Standard Johnson Matthey Gauze Pack and Two Developments of Eco-Cat^{TM} Technology

	Standard gauze	Eco-Cat^{TM} system (Campaign 1)	Eco-Cat^{TM} system (Campaign 2)
Campaign length, days	~100	~175	~210
100% HNO_3 produced, kilotonnes equivalent	~85	~135	~160
Total mass of installed platinum, kg	~50	~40	~40
Total mass of installed rhodium, kg	~3	~2	~2
Total mass of installed palladium, kg	0	~10	~15

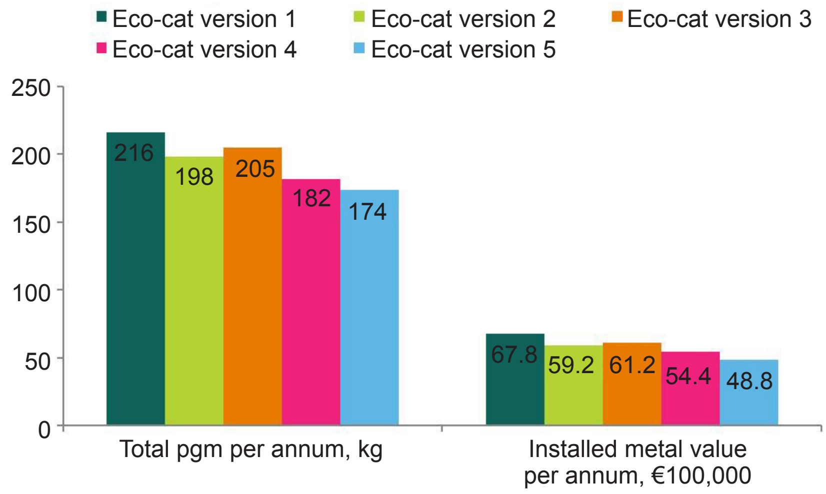

Fig. 5. The pgm content and value in developments of Eco-Cat™ packs

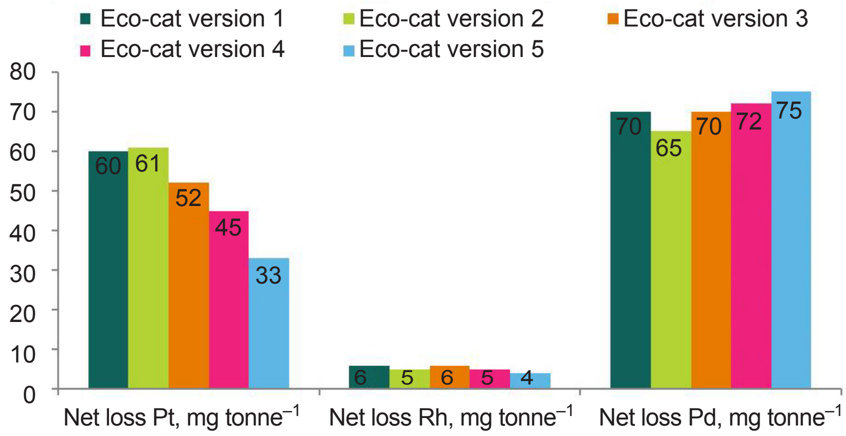

Fig. 6. The pgm losses in developments of Eco-Cat™ packs

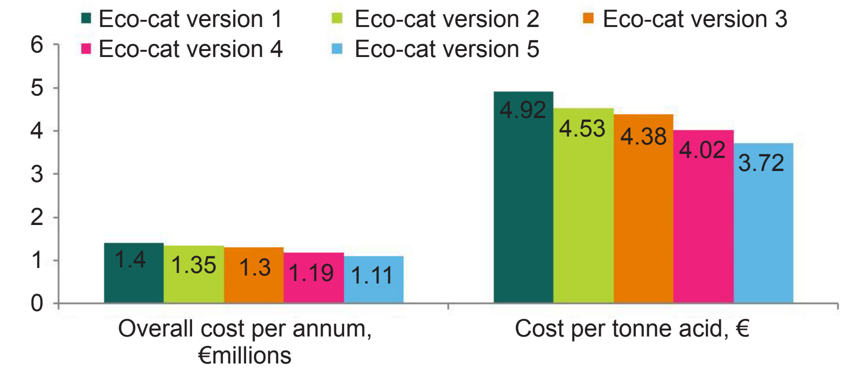

Fig. 7. Overall costs and cost per tonne of acid in various developments of Eco-Cat™ packs. (Overall cost = manufacturing cost + metal handling charge + refining assay + net metal loss)

onto the surface of selected gauze layers to improve the gauze pack's activation, resulting in faster light-off (**Figure 8**).

This technology has been shown to improve the early performance of the gauze packs in several plants when used in the top layers, but Johnson Matthey has recently been investigating how ACT™ coatings can further improve light-off and conversion efficiency.

Using the company's in-house ammonia oxidation facilities, data on light-off, selectivity and long-term performance have been analysed to improve the design of the gauze pack. Initial trials of ACT™ coated gauzes in two different knit structures (Nitro-Lok™ gauze and Hi-Lok™ gauze) both showed a 45% reduction in light-off temperature compared to the uncoated gauze (**Figure 9**).

Fig. 8. ACT™ machine

Fundamental to the design improvement is understanding how the gauze changes with time. Scanning electron microscopy (SEM) has shown the ACT™ coating forming a series of discrete islands on the gauze, each of which locally increases the surface area and becomes a focus point for light-off (**Figure 10**). Inspection of the samples from the trials has also shown the ACT™ coating restructuring (**Figure 11**) much earlier than expected; a change to the ACT™ coating placement or weight has the potential to make a significant improvement on the time taken to reach peak conversion efficiency.

This increased understanding of the mechanisms behind the coating and how this reduces the time to reach peak conversion efficiency has exciting implications for nitric acid plants, allowing the position and weight of the ACT™ coating to be tailored to minimise costs for producers.

Process Modelling

Along with catalyst, catchment and abatement solutions that Johnson Matthey supplies to the nitric acid industry, complex models of the reaction system can be provided using its fundamental chemical and physical properties alongside proprietary data. Through this knowledge and modelling of the burner, more information can be found on the selectivity of ammonia conversion, in particular the extent and type of reaction.

The complex model of the burner has been built from extensive experience of gauze design along with known process conditions using spent gauze analysis,

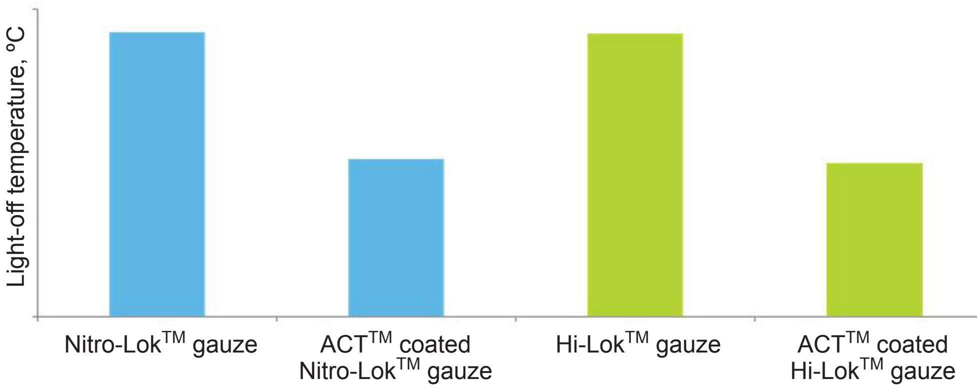

Fig. 9. Graph demonstrating a reduction in light-off temperature with ACT™ coatings

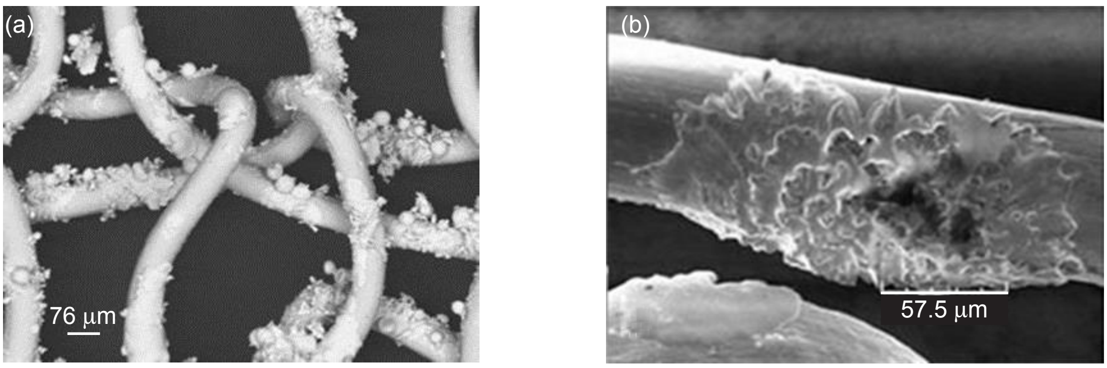

Fig. 10. Scanning electron microscopy (SEM) images of the ACT™ coated gauze

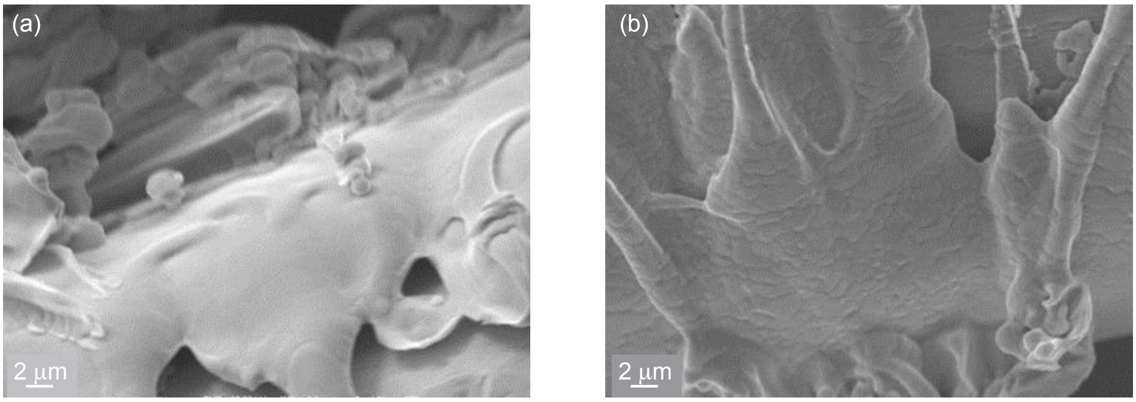

Fig. 11. SEM images of the ACT^{TM} coating: (a) before and (b) after restructuring

test rig data and historical plant data. This provides an in-depth understanding of how gauzes change over time and how this impacts the overall conversion efficiency. It can also help to identify where efficiency losses may be occurring; once this is found different sensitivities can be investigated to optimise the process, resulting in maximum plant conversion efficiency. Compared to a process model that is theoretically derived, this model provides more accurate and valid data through the dynamic kinetic model of the burner.

The detailed kinetic model allows predictions to be made for the optimal knit structures and alloy compositions for a campaign, for example looking at the gauze restructuring which is closely linked to the catalyst performance, where an increase in active surface area can improve the conversion efficiency. The model can also relate specific plant conditions to metal losses, which can reduce costs for the producer and again improve conversion efficiency of the burner. Any findings from the model can then be compared to experimental observations from gauze analysis.

This robust gauze model overcomes difficulties producers have historically faced in directly measuring conversion efficiency and selectivity, where high gas temperatures and testing conditions of the sampling point make it challenging to obtain a representative gas sample over the gauzes. This makes it an extremely useful tool in optimising the overall plant operation.

Present Day

100 years after making the first gauze catalyst, Johnson Matthey now offers a full service package for nitric acid manufacturers: catalyst, catchment, N_2O abatement and containment engineering, technical analysis, plant cleaning to recover metal through a partnership with R S Bruce Metals and Machinery Ltd, UK, and process simulation through a partnership with ProSim SA, France. The latest additions to these services are absorption tower scanning through Tracerco and water treatment for cooling and process water through MIOX®, both part of the Johnson Matthey group.

ACT™, Eco-Cat™, Nitro-Lok™, Hi-Lok™ and MIOX® are trademarks of Johnson Matthey Plc, UK.

The Authors

Hannah Frankland joined Johnson Matthey as Marketing Specialist for the Noble Metals business unit in 2015 after previously working for the Royal Society of Chemistry, Cambridge, UK, where she was primarily involved in membership communications. With a Chemistry degree from the University of Bath, UK, she enjoys combining her technical knowledge with her passion for marketing.

Christopher Brown originally joined Johnson Matthey in 2001 as a Materials Scientist in the Noble Metals technology group after graduating from the University of Nottingham, UK. After moving into sales and marketing in 2004, Chris has worked in technical sales roles, primarily in the Nitro Technologies sector which has combined his passion for business, people and travel.

Helen Goddin is the Research Group Leader for Nitro Technologies, leading developments in ammonia oxidation products. Prior to joining Johnson Matthey two years ago, she worked at TWI, leading research projects on materials development and joining processes. She has a PhD in High Temperature Electronic Materials, from the University of Cambridge, UK.

Oliver Kay joined Johnson Matthey in 2015, from the University of Leeds, UK, where he read Chemical Engineering. Oliver is part of the Graduate Programme, originally based in Noble Metals, where he was involved in developing a service offering for the nitric acid business. Now Oliver is based in Maastricht, The Netherlands, working for Advanced Glass Technologies, where he has a varied role, ranging from New Business Development to Operational Excellence projects.

Dr Torsten W. Bünnagel began his career with Johnson Matthey in 2011 in the Technical Sales Team of Noble Metals, Royston, UK, advising nitric acid, caprolactam and hydrogen cyanide businesses around the globe on new developments in the areas of catalytic ammonia oxidation and N_2O abatement systems. In his current role as Sales Manager – Organometallics, Dr Bünnagel is commercialising novel materials utilised in various advanced chemical processes and technical applications. Prior to Johnson Matthey, he developed OLEDs for lighting applications and consumer electronics for Sumitomo Chemicals Company, Japan. He earned a Diploma Degree in Chemistry at the University of Wuppertal, Germany, and completed a PhD in Macromolecular Chemistry in the area of Organic Electronics in 2008.