

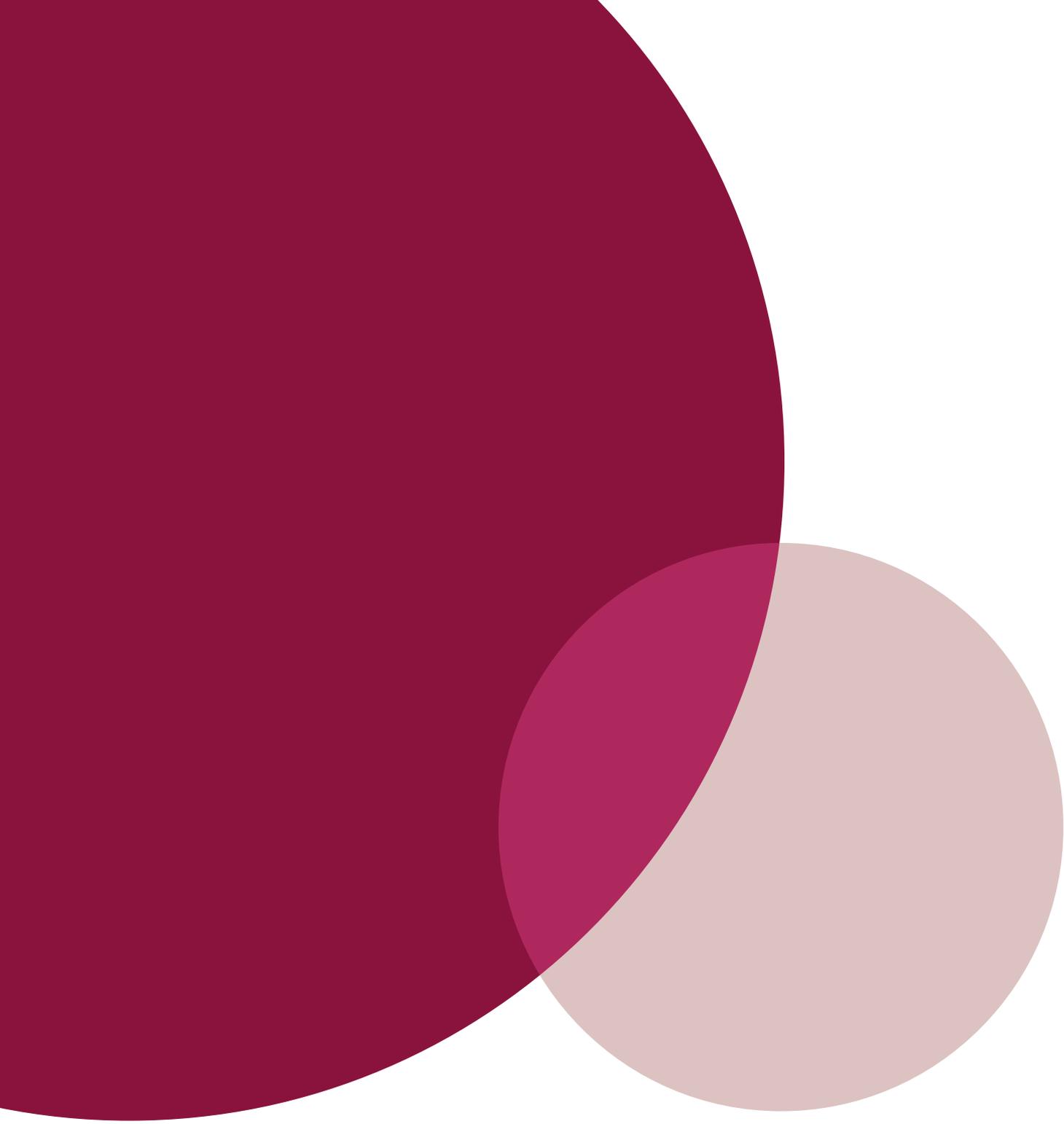
Delivering world class ammonia plant performance



Johnson Matthey
Process Technologies



Katalco^{JM}
Activate your potential



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KATALCO_{JM} a commitment to excellence

The world relies on ammonia derived fertilizers for food production so manufacturing these as efficiently as possible is of critical importance.

While commercial ammonia production can be traced back more than 100 years, the ammonia process as we know it today was initially developed in the 1960s. Since that time, Johnson Matthey (formally as ICI) has invested enormous resources in research and development to ensure that ammonia catalysts have been adapted to meet your needs. **KATALCO_{JM}TM** ammonia plant catalysts are more active, more selective and more robust to give you the highest plant rates, longer run times and exceptional value for money.

The selection of catalysts and technology for your ammonia plant is just the start of the process. At Johnson Matthey we seek to develop close working relationships with all users of our catalysts to gain a good understanding of your operations. This allows our engineers to provide the best advice on the operation of the catalysts within the ammonia process. **KATALCO_{JM} PERFORMANCE** is a suite of value adding services to enhance the operation of **KATALCO_{JM}** catalysts, designed to address plant operational issues including efficiency, reliability, throughput, environment and safety. Our knowledge is further underpinned by operating experience in ammonia plants, allowing us to better understand your needs as a plant operator.

Within the fertilizer industry, Johnson Matthey is seen as the world-leader and has the greatest depth and breadth of knowledge providing catalysts used in ammonia, nitric acid and urea production. This position has been developed through our own technology, partnerships with leading technology providers such as ThyssenKrupp Industrial Solutions GmbH, catalyst development and the large number of plants that use our technology and catalysts. **KATALCO_{JM}** catalysts are at the heart of the world's largest ammonia plants, operating with the Udhe Dual Pressure Process at rates above 3,300tpd. The flowsheet is specifically designed to take advantage of the **KATALCO_{JM}** catalyst range.

Our focus is delivering the best plant performance in the world. We have ongoing development programmes producing new and better catalysts and improving the process technology for the ammonia industry.

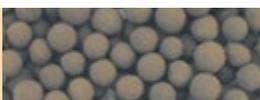
KATALCO_{JM} PERFORMANCE enables the best performance to be achieved from these products. The overall impact of Johnson Matthey catalysts and technology can improve ammonia plant costs by millions of dollars every year.

Through **KATALCO_{JM} PERFORMANCE**, Johnson Matthey can offer services including:

- energy audits
- safety studies and consultancy
- asset management studies
- full plant revamp studies
- equipment inspection
- catalyst loading techniques
- specialist measurement
- computation fluid dynamics
- catalyst handling and disposal.



Purification feed and syngas

PURASPEC_{JM} 1156		Mercury removal absorbent
KATALCO_{JM} 41-6T		Organic sulphur removal - HDS
KATALCO_{JM} 61-1T		Organic sulphur removal - HDS
KATALCO_{JM} 33-1		3-in-1 sulphur removal
KATALCO_{JM} 59-3		Chloride removal
KATALCO_{JM} 32-4/ 32-5		Zinc oxide based H ₂ S removal absorbent
PURASPEC_{JM} 2084		Ultrapurification
PURASPEC_{JM} 2020		Syngas purification

Johnson Matthey offers our **KATALCO_{JM}** range of purification absorbents and catalysts, allowing us to deliver optimized systems for meeting individual plant purification requirements. In addition, through our range of **PURASPEC_{JM}**™ catalysts and absorbents, we can provide mercury removal down to ppb levels, low temperature H₂S removal absorbents and ultrapurification down to ppb levels of sulphur to protect even the most sensitive of downstream catalysts, including pre-reforming catalysts.

For ammonia plants using a coal feedstock and gasification technology, we can again offer **PURASPEC_{JM}** purification solutions to remove impurities such as chloride and sulphur after the **RECTISOL™** or **SELEXOL™** acid gas removal system.

KATALCO_{JM} 33-1 is the latest addition to our purification range. It is a 3-in-1 total sulphur removal product, which combines the functionality of organic sulphur conversion, high capacity sulphur removal, and low level sulphur polishing (ultrapurification) in a single product. The versatility of **KATALCO_{JM}** 33-1 allows it to be deployed in ammonia plants in numerous ways, as a single product or in conjunction with conventional purification products.

By using **KATALCO_{JM} 33-1**, the total catalyst volume can be reduced while still achieving the required life. Further savings are also realized from much easier loading and discharge, and no requirement for pre-sulphiding of the HDS catalyst or reduction of the ultrapurification catalyst.



Conventional purification catalyst loading



Simplified catalyst loading with **KATALCO_{JM} 33-1**

Pre-reforming catalysts

CRG LHR



CRG LHCR



Johnson Matthey has been associated with pre-reforming catalysts since the 1960s and together with Johnson Matthey Davy Technologies (JM Davy) offers the **CRG** series of catalysts which have been demonstrated to be the most active and robust commercially available products. In ammonia plants, operating on natural gas feeds, the use of high pre-reformer inlet temperatures allows the maximum amount of heat recovery from the steam reformer flue duct giving an economic benefit through improved thermal efficiency of the process. In addition, by transferring the maximum amount of reforming duty into the pre-reformer, the size of the primary reformer is reduced which results in a lower capital cost.

CRG LHR is a precipitated catalyst with nickel as the active component. The catalyst is supplied in the pre-reduced and stabilized form. The oxidized form, **CRG LH**, is available as a special order.

CRG LHR pre-reforming catalyst is specially formulated to deliver good performance at high pre-reformer inlet temperatures (>500°C), which cannot be attained with many other catalysts. This allows the maximum amount of heat recovery from the steam reformer flue duct and hence increases the economic benefits that can be obtained from the pre-reformer.

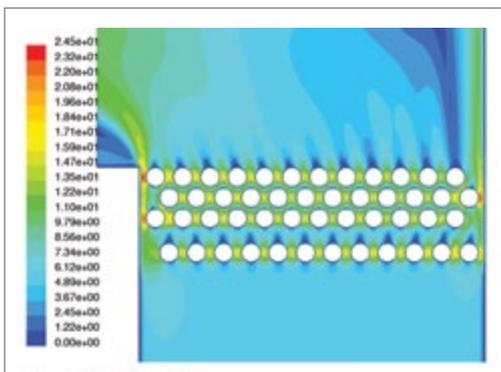
CRG LHR is available in two distinctive shapes. The exceptionally high geometric surface area that is produced by the small standard cylindrical pellet delivers outstanding catalytic activity and allows the construction of relatively small pre-reforming reactors. However, where pressure drop must be minimized, the unique microcloverleaf shape, **CRG LHCR** provides low pressure drop characteristics in combination with high pre-reforming activity.

CRG pre-reforming technology delivered increased production and lower energy consumption on a conventional Kellogg ammonia plant.

Johnson Matthey offered the most effective combination of **CRG** LHCR catalyst supply and engineering capability to deliver a 15% increase in capacity and a 5% reduction in energy consumption.

An element of engineering capability used was CFD, as the new pre-reformer reheat coil needed to be installed within an existing convection section, adjacent to a 90° bend in the fluegas duct.

Johnson Matthey CFD modelling quickly showed that the coil would work as designed.



Contours of Velocity Magnitude (m/s)



Primary reforming

KATALCO_{JM} 23-4 series		Nickel oxide on alpha alumina
KATALCO_{JM} 57-4 series		Nickel oxide on calcium aluminate
KATALCO_{JM} 25-4 series		Lightly alkalized version of 57-4 series

Johnson Matthey manufactures three main catalysts for use in primary reformers using a natural gas feedstock:

KATALCO_{JM} 23-series, 57-series and 25-series catalysts. They are made in a range of sizes, allowing optimum reformer loading for each individual plant.

Selecting the right catalyst for your application is essential for good reformer performance. Johnson Matthey will make recommendations on the correct catalyst loading based on your plant operating conditions.

When recommended, **KATALCO_{JM}** 25-series catalyst should be installed in the top 40–50% of the primary reformer tube to ensure that the carbon forming potential is minimized.

The choice of catalysts is unique with the ability to reform efficiently the full range of feedstocks used in modern steam reformers.

In this critical operating unit of the ammonia production train, the **KATALCO_{JM} PERFORMANCE** combination of catalysts and services ensures optimal operation at all times.

Reformer services

Through **KATALCO_{JM} PERFORMANCE** we want you to get the most from our catalysts. We optimize each application using our world-leading modelling capability and support the operation of your reformers with a wide range of services including process consultancy, mechanical design consultancy and other engineering services that are used to help solve customer problems.

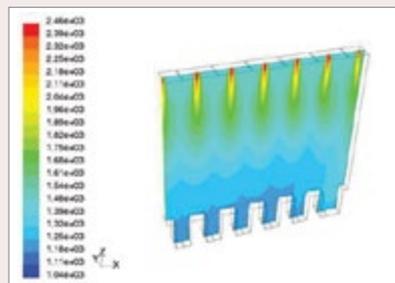
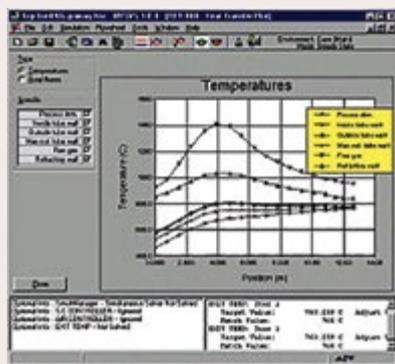
Reformer modelling expertise is one of our key skills. By using HYSYS™ for Ammonia, which includes our PRIMARY reformer model, we can determine the full impact of changing reformer conditions within a complete plant flowsheet. This is typically used for:

- revamp studies and revamp implementation
- retube studies
- reformer surveys
- operational audits.

Results are immediately available allowing rapid assessment of variations in conditions.

Other reforming services from Johnson Matthey include:

- UNIDENSE™ reformer loading technique
- LOTIS™ laser optical tube inspection system
- reformer surveys and operational audits
- catalyst tube temperature measurement
- managing the life cycle of reformer catalyst tubes
- reformer consultancy
- pressure drop measurement
- combustion systems advice.



Secondary reforming

KATALCO_{JM} 23-8 series



Nickel oxide on
alpha alumina

KATALCO_{JM} 54-8 series



Nickel oxide on
calcium aluminate

The mechanical and physical requirements of a secondary reformer are the most arduous in the plant. Johnson Matthey combines sophisticated Computational Fluid Dynamic techniques and process modelling, calibrated against data generated in our reforming pilot plant, to ensure the best performance from our state of the art range of catalysts. Johnson Matthey can also offer secondary reformer technology including proven burner designs.

KATALCO_{JM} 23-series is a nickel on alumina catalyst and **KATALCO_{JM}** 54-series is a nickel on calcium aluminate catalyst. These provide both high stability and high activity, allowing Johnson Matthey to offer the best mix of activity, pressure drop and high temperature stability for your application.

KATALCO_{JM} 89-6Q is a catalyst designed for use in the top of secondary reformers where both temperature and steam partial pressure are high; a combination that can lead to unacceptably fast volatilisation of alumina and the problems associated with this and its subsequent condensation on downstream equipment such as waste heat boilers. This catalyst utilizes a refractory metal as the active component on a stabilized high temperature ceramic support.



Ruby formation

Secondary reformer services

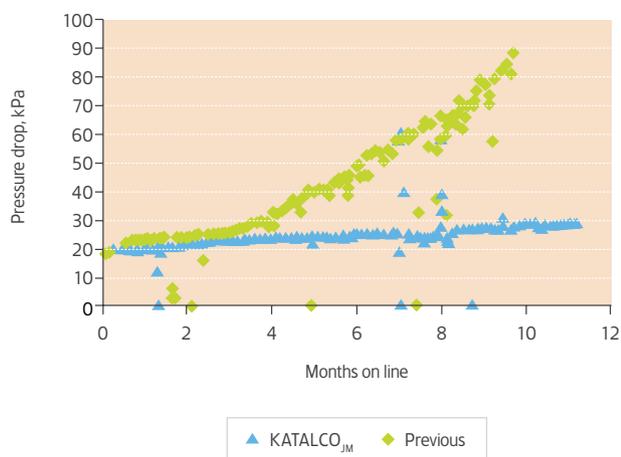
The performance of a secondary reformer is related not just to the catalyst performance but also the burner and the mixing space above the catalyst bed as well as the integrity of the refractory lining system of the reformer.

We have the right combination of expertise and practical experience to help our customers determine the cause of any under performance to develop reliable systems.

Johnson Matthey has expertise including the **KATALCO_{JM}** high intensity ring burner offering efficient combustion and mixing in a reliable design.

We have also combined our catalysis, CFD and mechanical design skills to resolve secondary reformer and transfer main “hot spot” problems.

An example of this is delivering improved plant reliability to secondary reformers which have suffered from increased pressure drop due to ruby formation, leading to hot spots. Our understanding of the issue allowed us to apply leading catalysts such as **KATALCO_{JM}** 89-6Q to solve the problems eliminating ruby formation and pressure drop increase.



High temperature shift catalysts

KATALCO_{JM} 71-5/
71-6



KATALCO_{JM} 71-5M/
71-6M



The **KATALCO_{JM}** 71-5 range of high temperature shift catalysts offers high activity due to the inclusion of a patented structural promoter which improves the pore size distribution. This increases activity by reducing the diffusional limitation associated with many high temperature shift catalysts. Its pore structure also allows better water vapour release during drying after any wetting incident.

The **KATALCO_{JM}** 71-6 range has been developed specifically for highly stressed units with known waste heat boiler leakage problems and for radial flow reactors. This catalyst retains its strength and pellet size which maximizes in-situ strength, activity, and pellet integrity. This provides greater resistance to the effect of boiler leaks and minimizes gas bypassing in radial flow reactors..

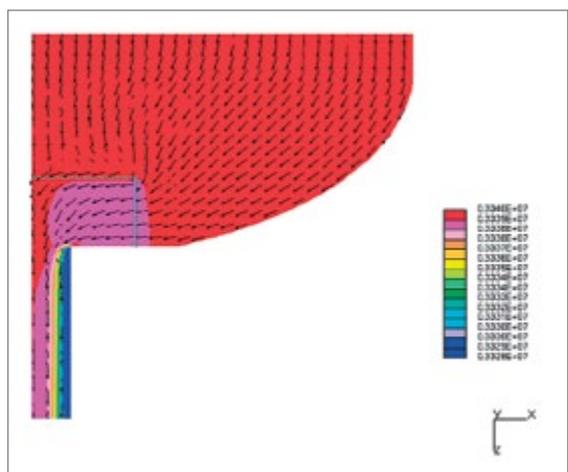
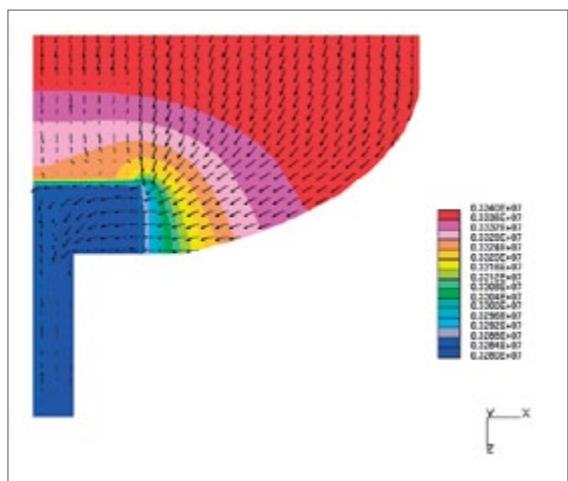
Johnson Matthey offers **SHIFTSHIELD** for installation on top of the catalyst bed. This is designed to protect the catalyst by capturing boiler solids and by preventing the impingement of liquid droplets onto the catalyst itself.

Johnson Matthey also offers the **STREAMLINE™** system for reducing pressure drop through the high temperature shift vessel.

STREAMLINE enables efficiency improvement and plant rate increases by reducing pressure drop through the shift vessels.

STREAMLINE from Johnson Matthey comprises a complete study to identify accurately all of the sources of vessel pressure drop in a converter, and a proven solution based on a novel support medium. The **STREAMLINE** low pressure drop support meets all the critical criteria for the ideal support including high voidage as a function of its shape, high strength, large particle size and low silica content.

All installations in plants worldwide are operating as predicted. Typical pressure drop savings are around 0.4bar (6psi) per vessel. A reduction in the front-end pressure drop of a syngas plant allows a reduction in compressor power requirement or an increase in throughput at a constant suction pressure.



Low temperature shift catalysts

KATALCO_{JM} 83-3/
83-3X



KATALCO_{JM} 83-3M/
83-3MX



The **KATALCO_{JM}** 83-series of low temperature shift catalysts offers high activity whilst maintaining high strength to ensure physical robustness. It is available in a range of sizes to allow for optimization of pressure drop and catalyst activity. The formulation provides a self-guarding capability and maximizes sulphur retention.

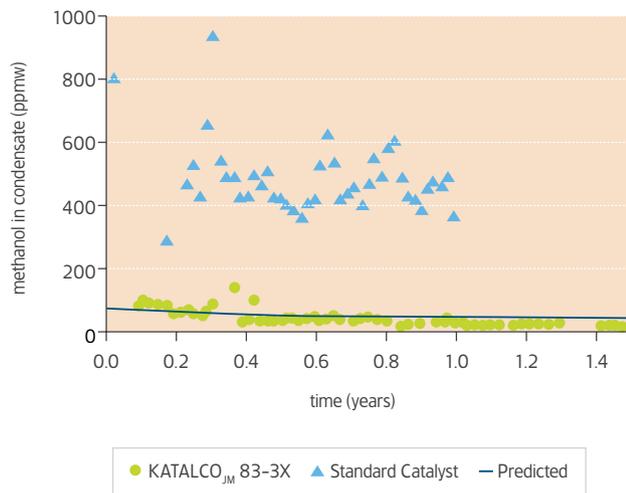
KATALCO_{JM} 83-3X is a promoted version of our standard catalyst, specifically formulated to give low levels of by-product methanol and provides enhanced chloride poison retention, eliminating the need for speciality guard catalysts.

The smaller **KATALCO_{JM}** 83-3M/83-3MX are used where maximum activity and/or enhanced poisons pick-up is required.

Johnson Matthey also offers the **STREAMLINE** system for reducing pressure drop through the low temperature shift bed.

A self-guarding catalyst offering the longest catalyst lives and the lowest by-product formation

KATALCO_{JM} 83-3X has been specifically designed to reduce methanol formation. It reduces by-product methanol by more than 80% making it the most effective low methanol, low temperature shift catalyst.



The graph shows operating data from a 1,500tpd ammonia plant in Europe which demonstrates that the methanol in the process condensate is substantially lower than with the previously installed charge.

Sour shift

KATALCO_{JM} K8-11



KATALCO_{JM} K8-11 HA



The production of syngas using gasification or partial oxidation differs considerably from that using catalytic steam reforming. Depending on the feed and process configuration, the raw syngas will have a high CO content and, it is likely that it will also have high sulphur content. This gas needs to be shifted and the excess CO₂ removed to achieve the desired hydrogen to carbon oxides ratio, and this requires the use of a sulphur tolerant shift catalyst. Johnson Matthey is the world's leading supplier of sour shift catalysts with the **KATALCO_{JM} K8-11** series of products. These catalysts are particularly robust and can withstand sharp temperature changes, high steam partial pressures and the effect of contamination from impurities in the raw gas.

The standard catalyst for sour shift is **KATALCO_{JM} K8-11**, which has been well proven in ammonia applications downstream of several different types of gasifier. Variants of this standard catalyst are available to meet specific client requirements which may place greater emphasis on pressure drop or low-temperature activity. An example of this is **KATALCO_{JM} K8-11HA** which uses a geometric shape with higher external surface and a higher packed voidage, thus lowering the pressure drop.

Johnson Matthey's experience in the application of sour shift catalyst downstream of gasifiers puts us in an ideal position to provide advice on the optimum system configuration, including the appropriate number of reaction stages, the use of bypasses, steam requirements and heat recovery options. For instance, at large plant capacities, the use of radial flow reactors may allow the use of a single reactor instead of multiple parallel axial reactors, so reducing installed plant cost. Johnson Matthey is able to provide a sour shift catalyst customized for radial flow applications (**KATALCO_{JM} K8-11R**) along with proven designs of internals for radial flow reactors.

Methanation catalysts

KATALCO_{JM} 11-4/
11-4R



KATALCO_{JM} 11-4M/
11-4MR



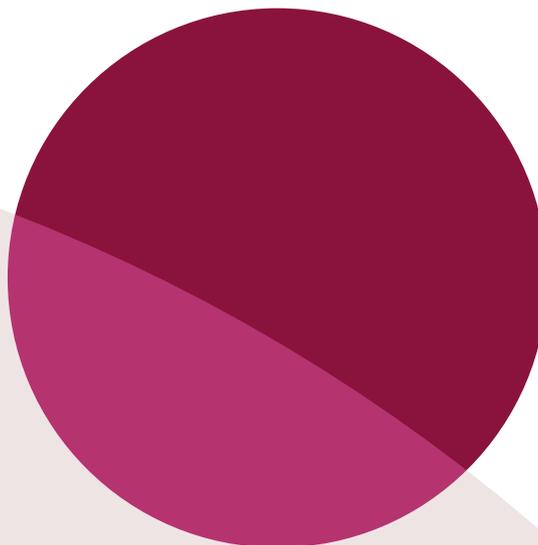
The **KATALCO_{JM}** 11-series of methanation catalysts offers a high activity and is extremely robust; for example it can be washed if fouled during an upset in the CO₂ removal system. The catalyst is also tolerant of temperature excursions. Lives of up to 20 years have been achieved. The catalyst is available in an optimized pre-reduced form to allow for fast start-ups and operation at inlet temperatures as low as 220°C (428°F).

The pre-reduced catalysts **KATALCO_{JM}** 11-4R and 11-4MR have been reduced and stabilized with an oxide layer which makes the catalyst stable in air and prevents further re-oxidation. These catalysts require no activation stage and initiate methanation at maximum activity as soon as reaction conditions are established.

The **KATALCO_{JM}** 11-series offers unrivalled dependability and stability for maximum protection of the synthesis catalyst.

KATALCO_{JM} 11-4 catalysts have the highest nickel loading and activity of any methanation catalyst commercially available and hence have been proven to operate in the most demanding low temperature duties where the highest kinetic catalyst activity is required.

As a result of using **KATALCO_{JM}** 11-4, one plant has been able to deliver an efficiency improvement of 0.15GJ/te by operating at a lower temperature and saving 5tonnes per hour of HP stream.



Ammonia synthesis catalysts

KATALCO_{JM} 35-4		Multi-promoted magnetite
KATALCO_{JM} 35-8		Pre-reduced and stabilized multi-promoted magnetite
KATALCO_{JM} 74-1		Multi-promoted magnetite
KATALCO_{JM} 74-1R		Pre-reduced and stabilized multi-promoted magnetite

The **KATALCO_{JM}** 35-series of ammonia synthesis catalysts combines long life with high activity.

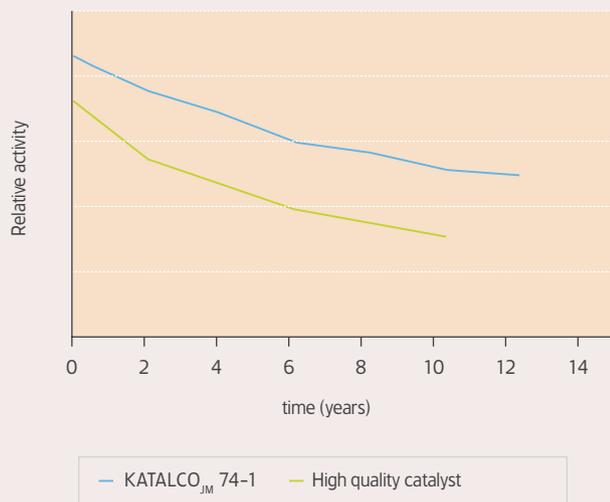
The catalysts are available in a wide range of sizes in both pre-reduced and oxidic form that are suitable for all designs and types of converter.

KATALCO_{JM} 74-series ammonia synthesis catalysts contain promoters which offer superior activity and long life at all pressures. This benefit is being particularly pronounced in the range 80-120bar (1160-1740psi). It has been proven in operation since the mid 1980s and is also used in the Uhde Dual Pressure Process.

Our ammonia synthesis catalysts are based on more than 80 years operating experience with ICI, along with more than 85 years operating experience with BASF and extensive experience of all other operating technologies. All of this experience has been further developed and improved by Johnson Matthey.

The largest, the most efficient and the lowest pressure ammonia plants in the world use **KATALCO_{JM}** catalysts at the heart of their process: in the ammonia synthesis converter.

KATALCO_{JM} ammonia synthesis catalysts are also proven in operation for KAAP replacement. **KATALCO_{JM}** 35-series and 74-series catalysts coupled with Johnson Matthey's experience and expertise provides world leading performance.



Hydrogen removal

PURAVOC 73



High-purity, fully reduced platinum eggshell on alumina tablet

The urea process has a relatively limited conversion per pass and involves gas recycle. The CO_2 contains some H_2 which builds up on recycle to form a potentially explosive mixture. Oxygen is therefore added to the CO_2 stream which reacts with the H_2 over the **PURAVOC™ 73** to form water. The purified CO_2 contains some residual O_2 which offers a passivation effect to the materials of construction.

PURAVOC 73 is suitable for both high pressure (typically 140–150bar, 100–150°C) and low pressure (typically 18–24bar, 190–230°C) applications.

Proven to have long, dependable lives, with no known failures, the robust support gives excellent strength and attrition resistance for low, stable pressure drop.

Johnson Matthey can provide a complete service, including recovering and refining the platinum from spent catalyst. **PURAVOC 73** is approved for use in all technologies for urea production. This catalyst is highly dispersed platinum impregnated by a proprietary process on a robust alumina pellet.

Product realization: From the laboratory to the plant

Catalysts and processes are developed in laboratory reactors, semi-technical units and side-stream reactors specifically designed to simulate accurately the important features of operation in full scale plants. The catalysts are then finally proven at commercial scale before being incorporated into the Johnson Matthey **KATALCO_{JM}** and **PURASPEC_{JM}** sales range.

New catalysts continue to deliver significant plant improvements. Every catalyst activity improvement enables a corresponding potential increase in plant rate, and can also deliver a longer life before current end of run conditions are achieved. Lower pressure drop options enable plant rate and efficiency improvements. For steam reforming catalysts, improved heat transfer reduces the temperature of reformer tubes, extending the time between costly renewal. Better poison pick-ups extend absorbent lives and improve the performance of downstream catalysts.

Johnson Matthey has teams focusing on the catalysts for each plant reactor and targeting performance improvements driven by customers'

requirements. Each area has a dedicated team of experienced scientists. Research and development activities in Johnson Matthey's catalysis research, technology and engineering centre at Billingham, UK, benefit directly from the close interaction of chemists and physicists with engineers who have plant operations experience.



There is close co-operation between the teams involved in fundamental research, catalyst development, catalyst manufacture, and synthesis gas production. Catalyst development is supported by the most modern techniques in applied surface science.

Our new improved catalysts go through a range of validation testing and small scale manufacturing runs as part of the commercialization process. This ensures that the catalyst we make in the laboratory is exactly the same as the one supplied from full scale production. At every point along this process the key performance parameters of the catalyst are tested in our dedicated catalyst testing facilities at Billingham, UK. This guarantees that the benefits we see in small scale testing are transferred to the customers operating unit.

The elements of sustainability

Sustainability is a core part of our business strategy. It is about the way we do business – using natural resources efficiently to make products that improve the environmental performance of our customers' products and processes.

But our view of sustainability extends beyond this. It's also about the health, safety and wellbeing of the people who work for us, our customers and our communities. It means using resources efficiently, innovatively and effectively, striving to achieve the highest environmental standards in our own operations. At the same time sustainability is about delivering value to our shareholders and our customers in the most responsible way, making sustainable long-term decisions to build a company and

plan its third century of business. Sustainability is about making the right decisions for our people, our communities, our shareholders and, most significant of all, for the planet.

As we progress towards 2017, we are managing sustainability according to five elements:

- Social
- Environment
- Health and Safety
- Governance
- Financial



At least double earnings per share



Achieve carbon neutrality



Achieve zero waste to landfill



Halve key resources consumed per unit of output



Achieve a zero 'greater than three day accidents' safety target



Implement ISO 14001 at all major manufacturing sites by 2010



Reduce annual incidence of occupational illness cases by at least 30% over the five years to 2013/14

Find out how we are progressing towards Sustainability 2017 – www.matthey.com/sustainability



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