



JM

Hydrogen plant performance

Delivering world class hydrogen plant performance



Johnson Matthey
Inspiring science, enhancing life

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KATALCO a commitment to excellence

The world that we live in today is constantly changing; 50 years from now it will be unrecognizable. We live during a period of significant population growth, with increasing urbanization and increasing wealth. The population is not only increasing, it is also getting older, and it demands better health and nutrition. There are increasing constraints on our natural resources, with energy security, resource efficiency, alternative energy and recycling becoming global issues. And we face an increasingly diverse set of environmental factors as a result of climate change and ever tightening regulation. All of these factors impact on our industries to a greater or lesser extent.

On-purpose hydrogen production is an essential component of many industrial processes and the growth in this industry is driven by a variety of these global changes. For some, such as industrial gas companies, hydrogen gas is a product, whilst for others, such as oil refineries, it is considered to be a utility. On downstream chemical plants it is a critical feedstock in polymer production and for chemical intermediates such as aldehydes, alcohols, cyclohexane and polyurethanes as well as various hydrogenation reactions. Hydrogen rich gas is also required in processes such as glass making, direct reduction of metals and Towns Gas manufacture. Johnson Matthey is a world leading supplier of hydrogen plant catalysts to these industries.

Refinery hydrogen production

In oil refineries, hydrogen is predominately used in oil refinery processes including hydrotreating, hydrocracking, dearomatization and isomerization. Across the world, "on-purpose" hydrogen capacity in refineries is increasing due to tighter fuel specifications, the processing of heavier and sourer crudes, increasing need for lighter crude oil products and strong demand for chemical intermediates.

Estimates suggest growth of 6% to 8% in the hydrogen market over the next five years as demand for hydrogen increases, particularly in Asia. Reliable operation is the key requirement for a refinery hydrogen plant.

Industrial gas hydrogen

Reliability and efficiency are key to the successful operation of industrial gas hydrogen plants. Within the industrial gas industry, Johnson Matthey is seen as having the greatest depth and breadth of knowledge for catalysts used in hydrogen production. This position has been developed through our history and experience in the more established syngas industries of ammonia and methanol, including catalyst and technology development and the operation and maintenance of a large number of plants that use our technology and catalysts.

Hydrogen for the chemical industry

In the chemical industry, hydrogen plant requirements vary from very small scale up to large scale hydrogen and HyCO production. The products and knowledge which Johnson Matthey makes available to the refinery and industrial gas sectors and the wider syngas industries is therefore available to operators within the chemical hydrogen industry.

Direct reduction of iron

Demand for iron and steel is strong and continues to grow due to the development in the BRIC (Brazil, Russia, India, China) and related economies. Where natural gas is abundant, direct reduced iron (DRI) is made from iron ore and a reduction gas derived by reforming natural gas. Reliable reducing gas delivery is critical. Johnson Matthey reforming catalysts and upstream natural gas purification products make an invaluable contribution to DRI operations supported by the specialist technical support and troubleshooting.

Towns Gas and SNG

Towns Gas and SNG production is making a resurgence in economies lacking indigenous natural gas supply but with abundant resources such as coal, driven by the need for energy security and the need to support economic development. Johnson Matthey offer CRG process technology and catalysts for the Towns Gas and SNG sectors giving Johnson Matthey unrivalled technical depth in these operations.





As a direct result of the different industrial demands for hydrogen, on-purpose hydrogen production plants vary in size from just 1 Nm³/h (900 SCFD) to more than 275 kNm³/h (250 MMSCFD). However, whatever your industry or reason for producing hydrogen, being able to produce it reliably and efficiently should not be underestimated.

Johnson Matthey is the supplier of high quality catalysts for hydrogen production via steam reforming. Our **KATALCO™** product range is suitable for hydrogen production using a range of feedstocks, from natural gas and refinery off-gas to LPG and naphthas.

The selection of catalysts and technology for your hydrogen 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 hydrogen process. **KATALCO PERFORMANCE** is a suite of value adding services to enhance the operation of **KATALCO** catalysts, designed to address plant operational issues including efficiency, reliability, throughput, feedstock flexibility, environment and safety. Through **KATALCO PERFORMANCE**, we provide the best and most innovative portfolio of support services within the industry, including hydrogen plant uprates and revamps.

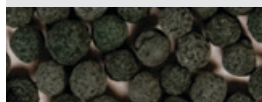
Johnson Matthey can offer services including:

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

Our focus is the delivery of the best plant performance in the world on behalf of our customers. Johnson Matthey cutting-edge catalyst technology and unique technical support and services capability will result in the most efficient and reliable delivery of hydrogen, HyCO and hydrogen-rich gases to meet the demands of the future.

Feed gas purification

PURASPEC 1156



Mercury removal absorbent

KATALCO 59-3



Chloride removal

KATALCO 41-6T



Organic sulphur removal - HDS

KATALCO 32-4/32-5



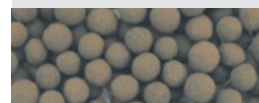
Zinc oxide based H₂S removal absorbent

KATALCO 61-1T



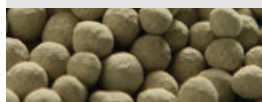
Organic sulphur removal - HDS

PURASPEC 2084



Ultrapurification

KATALCO 33-1



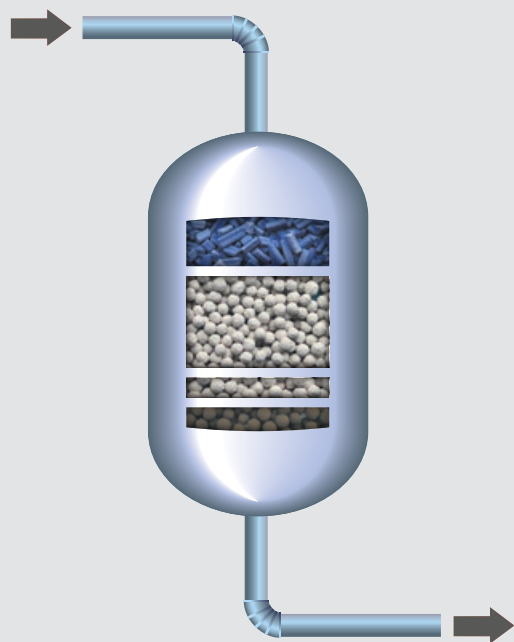
3-in-1 sulphur removal

Johnson Matthey offers our **KATALCO** 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™** 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.

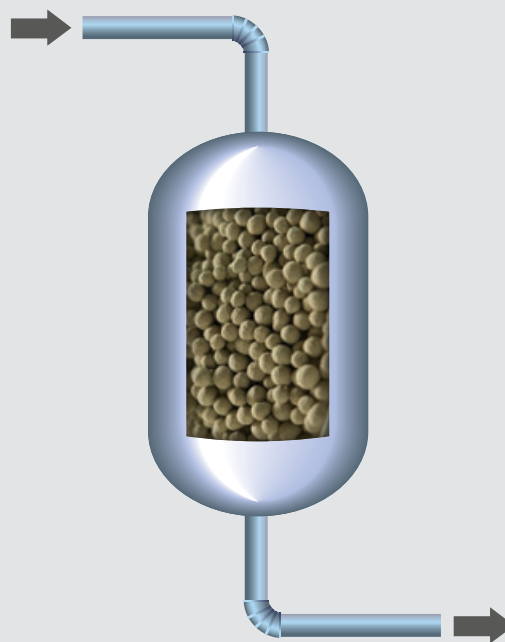
KATALCO 33-1 is the latest addition to our purification range. It is a 3-in-1 total sulphur removal product, which combines the functionality of organic sulphur conversion, high capacity sulphur removal, and low level sulphur polishing (ultrapurification) in a single product. The versatility of **KATALCO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



By using **KATALCO** 33-1, the total catalyst volume can be reduced while still achieving the required life. Further savings are also realized from the 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** 33-1

Pre-reforming

CRG LHR



pre-reforming catalyst

CRG LHCR



pre-reforming catalyst

Johnson Matthey has been associated with pre-reforming catalysts since the 1960s and offer the **CRG** series of catalysts and technology through Johnson Matthey Davy Technologies. Typical **CRG** applications in today's market place include pre-reforming, derichment and Towns Gas installations.

CRG pre-reforming technology offers a variety of different benefits to plant operators including increased plant efficiency, feed flexibility, plant uprates and capital savings by allowing smaller and more reliable steam reformers. Over the last decade, pre-reformers have been increasingly applied to syngas plants and are finding their place in new plant flowsheets and retrofits especially for hydrogen plants.

CRG pre-reforming catalysts are highly respected amongst users, and installed in more than 150 operating plants worldwide. These products give long lives as a result of their high activity, resistance to carbon formation and poisoning, low sintering and low stable pressure drop. They have proven their superiority and resilience over many years, withstanding plant upsets and trips and have demonstrated continual robust operation at low steam ratios and with changing feedstocks.

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

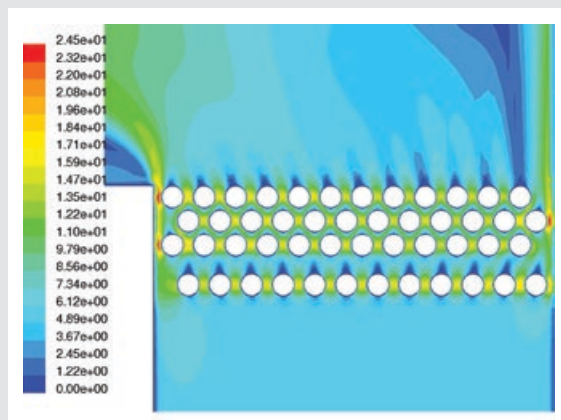


CRG pre-reforming technology delivered increased production and lower energy consumption

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)

Steam reforming

NATURAL GAS, OFF GAS AND LPG

KATALCO 23 SERIES



Nickel oxide on
alpha alumina

KATALCO 57 SERIES



Nickel oxide on
calcium aluminate

KATALCO 25 SERIES



Lightly alkalized version
of 57-series

NAPHTHAS

KATALCO 46 SERIES



Alkalised nickel oxide
calcium aluminate

Johnson Matthey manufactures three main catalysts for use in steam reformers using natural gas, off gas and LPG: **KATALCO** 23-series, 57-series and 25-series catalysts.

Selecting the right catalyst for your application is essential for reliable and optimum steam reformer performance. Johnson Matthey will make recommendations on

the optimum split of catalysts to be loaded in the reformer tubes based on your feedstocks and plant operating conditions.

If feedstocks and operating conditions require more protection from carbon formation, **KATALCO** 25-series is often recommended for the inlet portion of the tube. The optimum depth of **KATALCO** 25-series will be recommended by Johnson Matthey.

Johnson Matthey is the leading supplier of catalysts for the direct steam reforming of naphtha and other heavier feedstocks with over 50 years operating experience.

KATALCO 46-series range of catalysts are recommended where naphtha is the dedicated feed and where the feed slate features naphtha as one of the available hydrocarbon feed options.

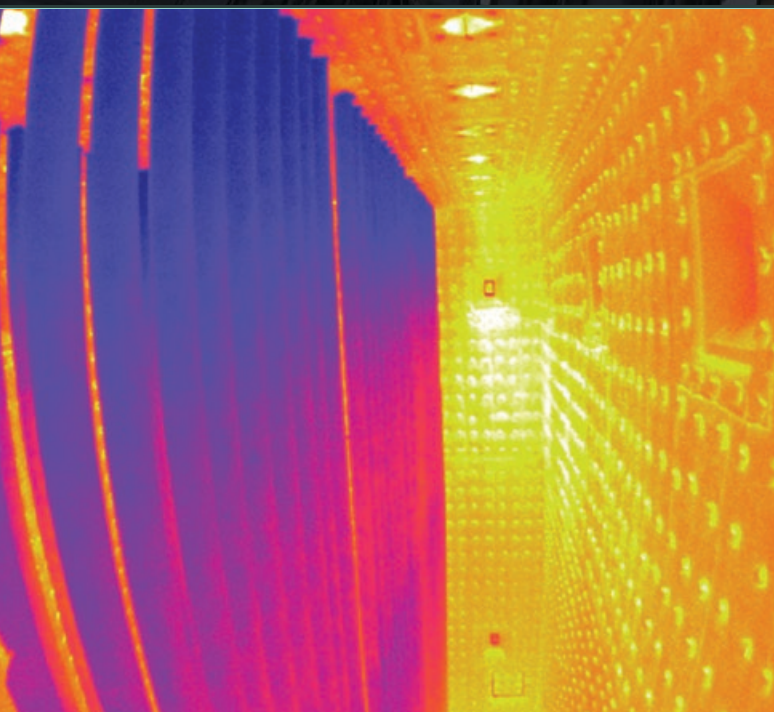
Operators often want to be able to use a range of feedstocks or a mixture of feedstocks that they may have available, often selecting the most economic feed at any point in time. Johnson Matthey can work with customers to understand their needs and provide an optimized split of **KATALCO** 46-series catalysts that will provide them with the flexibility that they require.

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 hydrogen production train, the **KATALCO PERFORMANCE** combination of catalysts and services ensures optimal operation at all times.

Steam reformer services

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.



Through **KATALCO 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 steam 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.

Steam reformer modelling expertise is one of our key skills. By using full process flowsheet modelling software, which includes our REFORM and PRIMARY reformer models, 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
- re-tube 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
- MANTIS™ and 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

High temperature shift

KATALCO 71-5



high temperature
shift catalyst

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

KATALCO 71-5M



high temperature
shift catalyst

Johnson Matthey also offers the **STREAMLINE™** system for reducing pressure drop through the high temperature shift vessel. This is a valued system when upgrading existing plants.

The **KATALCO** 71-5 range of high temperature shift catalysts offers reliable, straight forward operation through a high activity product. This is achieved through the inclusion of a patented structural promoter which improves the pore size distribution, and increases activity by reducing the diffusional limitation associated with many high temperature shift catalysts. It allows better pellet relief following wetting through ease of water vapour release during drying.

Medium temperature and isothermal shift catalysts

KATALCO 83-6



medium temperature shift catalyst

KATALCO 83-5



medium temperature shift catalyst

Hydrogen plant operators continue to look for improved efficiency on new hydrogen production units as:

- Available feedstocks increase in value in regions increasing their fuel demand.
- Refiners look for sustainable hydroprocessing technologies.
- Industrial gas companies look to improve the value of hydrogen produced.

The main approach to improving efficiency of hydrogen production is to lower the steam to carbon (S:C) ratio of the operation to less than 2.5. This S:C level creates a condition that increases byproduct formation and jeopardizes the pellet integrity of traditional high temperature shift catalysts. These low S:C levels also result in a higher CO conversion demand, creating an exotherm that challenges the thermal stability of traditional low temperature shift catalysts. Medium temperature shift and isothermal shift catalytic technologies are designed to be more thermally stable and manage the exotherm under these low S:C conditions.

KATALCO 83-6 Medium temperature shift catalysts are designed with the highest thermal stability. In addition their self-guarding capability maintains poisons, such as sulphur and chloride in the top part of the catalyst bed, even after that portion of the bed has deactivated. KatalcoJM 83-6 has established long lives, allowing alignment of lifecycles with the hydroprocessing units being fed by the hydrogen plants.

KATALCO 83-5 isothermal shift catalysts are designed to provide thermal stability and high CO conversion activity to meet the compact, high heat transfer conditions of steam raising isothermal reactor technologies.

KATALCO 83-5 has proven experience and reliable performance for these isothermal reactors.

Low temperature shift

KATALCO 83-3/83-3X



low temperature
shift catalyst

KATALCO 83-3M/83-3MX



low temperature
shift catalyst

The **KATALCO** 83-series of low temperature shift catalysts offers a reliable, simple and sustainable option for this duty. Only one catalyst is required in the low temperature shift bed as the formulation provides self-guarding capability and maximizes sulphur retention. At the same time it demonstrates a high activity whilst maintaining high strength to ensure physical robustness. The product is also available in a range of sizes to allow optimization of pressure drop and catalyst activity.

KATALCO 83-3X is a promoted version of our standard catalyst, specifically formulated to give low levels of by-product methanol and provide enhanced chloride poison retention, eliminating the need for specialty guard catalysts.

The smaller **KATALCO** 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.

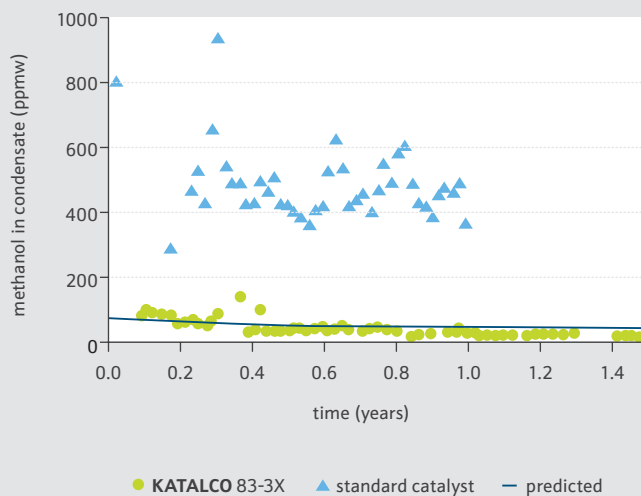
These offerings can increase the effectiveness and overall hydrogen production when retrofitting an LTS unit into an existing PSA based hydrogen plant.



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

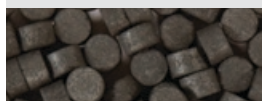
KATALCO 83-3X has been specifically designed to reduce methanol formation. It reduces by-product methanol by more than 80% making it the most effective low methanol, low temperature shift catalyst.

The graph shows operating data from a plant in Europe which demonstrates that the methanol in the process condensate is substantially lower than with the previously installed charge. This charge was operated for five years maintaining this low byproduct methanol level throughout its life. This site has continued to manage its environmental emissions using **KATALCO 83-3X**, installing three more charges of this product, each of which has given a five year life.



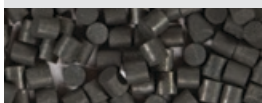
Methanation catalysts

KATALCO 11-4/11-4R



methanation catalyst

KATALCO 11-4M/11-4MR



methanation catalyst

The **KATALCO** 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** 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.

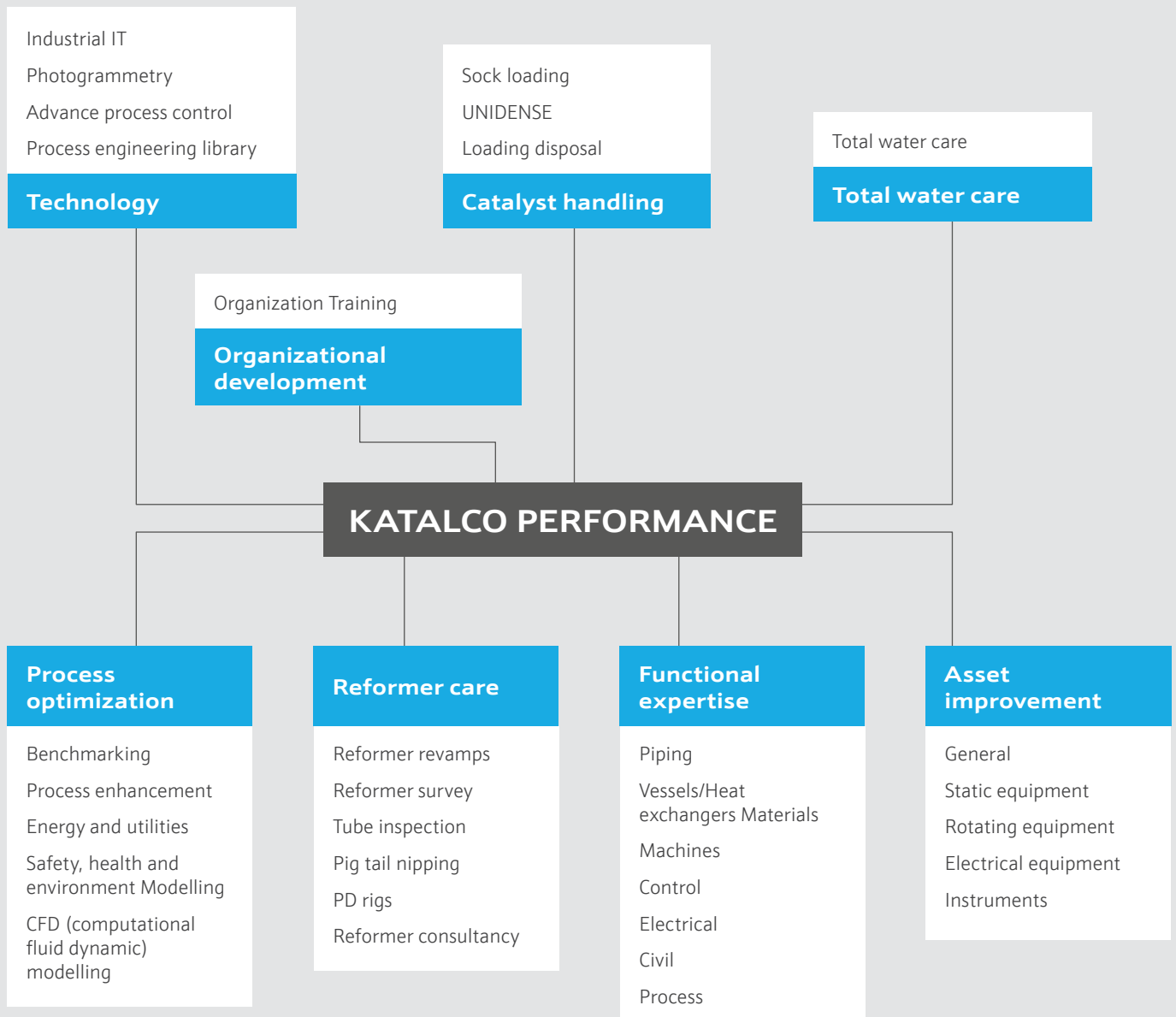
The **KATALCO** 11-series offers unrivalled dependability and stability, for maximum protection of the synthesis catalyst.

KATALCO 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** 11-4, one plant has been able to deliver an efficiency improvement of 0.15 GJ/te (65 BTU/lb) by operating at a lower temperature and saving 5 tonnes (11000 lbs) per hour of high pressure stream.

KATALCO performance

Johnson Matthey is the world-leader in steam reforming catalysis. Our superior market share and performance is a result of unbeatable catalysts backed up by unique design, optimization and service capabilities through **KATALCO PERFORMANCE**.



Product realisation: 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** and **PURASPEC** 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 catalysts go through a range of validation testing and small scale manufacturing runs as part of the commercialisation 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.





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