JM

Steam reforming catalysts

Natural gas, associated gas and LPG
Catalysts for optimum plant performance

KATALCO 23-series, **KATALCO** 25-series, **KATALCO** 57-series

Johnson Matthey
Inspiring science, enhancing life

Contents

Introduction 4

KATALCO catalyst selector 5

Catalyst characteristics 7

Advantages of choosing **KATALCO** 10

Additional capability with **KATALCO** PERFORMANCE 14

Our solution

The technology

Steam reforming catalysts and support for the optimum operation of the most critical operating unit in ammonia, methanol, hydrogen and GTL production trains.

Value delivered

Reduced operating costs and carbon footprint, increased production, the ability to plan with confidence, maintain efficiency and meet sustainability targets.

Benefit

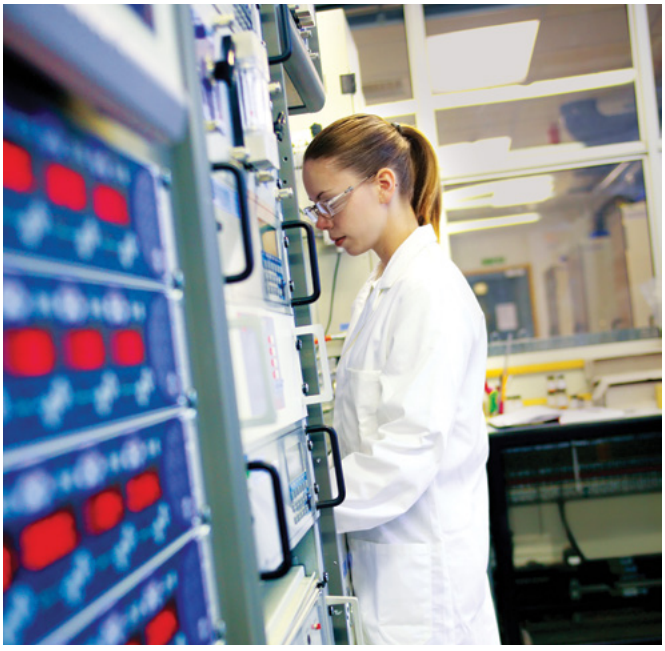
Improved heat transfer, low pressure drop across the campaign, reduced risk, lower trim fuel requirements, savings in compressor energy and reduction in CO_2 are realised through optimised pellet design, unique manufacturing and proven supply chain, robust quality, established ceramic supports and catalyst formulations.

Introduction

Steam reforming is the key process in the formation of synthesis gas (syngas) for ammonia, methanol, hydrogen and hydrogen/carbon monoxide (HyCO) production. The reformer is the largest and most expensive piece of equipment on these plants, and efficient and reliable operation is key to the performance of the whole plant and its environmental impact.

The choice of steam reforming catalyst is extremely important and has a significant effect on the reformer and efficiency. Choosing the correct catalyst has a direct impact on plant rate, tube life, methane slip, energy consumption and the formation of carbon, which can have a significant and detrimental impact on the reformer performance, operation and the carbon emissions associated with production.

Johnson Matthey (JM) is the world leader in steam reforming catalysts with **KATALCO**™ and **KATALCO PERFORMANCE** products.



Our expertise is the result of our fundamental understanding of the steam methane reforming process and what our customers value. This has allowed us to develop market leading sustainable steam reforming catalysts that provide:

- Improved heat transfer for reduced operating costs and carbon footprint and longer tube lives.
- Low pressure drop across the campaign, while retaining excellent activity and heat transfer properties, requiring less compression energy. This results in reduced OPEX and increased production
- Precise loading of nickel to make the most sustainable use of limited natural resources to deliver optimal performance
- Reduced risk so that you can plan with confidence
- Less trace ammonia produced to help maintain efficiency
- Progressive solutions to enable you to meet your sustainability targets
- And leading technical support so when you hit a problem you can get quickly back on track.

Our catalysts have a longer life cycle due to high activity, resistance to carbon formation and poisoning, and low sintering, which keeps operations running longer with fewer bed change-outs, meaning less down time, less costs of catalyst changes and turnaround services, less waste and less consumption of energy and precious natural resources.

KATALCO catalysts provide the flexibility to respond to operating constraints and overcome shortcomings while allowing operators to process a wide range of feedstocks, extend turnaround cycles and prolong reformer tube lives.

At the same time operators have the reassurance that the product can recover from both poisoning and carbon formation incidents due to its resistance to steaming. **KATALCO** catalysts are the product of choice for plants with highly stressed, uprated operating plants. Our product range also allows us to offer tailored solutions and customised loadings.

JM's customers recognise that having the right catalyst installed is only part of what makes plant operations successful and value our exceptional support, which is delivered through our global network of technical experts. These experts, along with our Research, Development and Engineering functions based in the UK, are able to deliver an unparalleled range of reformer based services.

In successfully developing **KATALCO** catalysts and services, we have also focused our knowledge to meet specific customer operational needs for all types of steam reformer from top fired to terraced, side fired, compact and gas heated reformers.

KATALCO catalyst selector

JM manufactures three main catalysts for use in steam reformers using lighter hydrocarbon feedstocks ranging from refinery off gas, natural gas to lighter LPG.

KATALCO 23-series

This catalyst is nickel oxide on an alpha alumina support.

KATALCO 57-series

This catalyst is nickel oxide on a calcium aluminate support.

KATALCO 25-series

This catalyst is a lightly alkalised nickel oxide catalyst on a calcium aluminate support.

These catalysts 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 steam reformer performance. JM will make detailed recommendations based upon your individual operating conditions. However, some generic guidelines are given below.

Typical catalyst loadings depend on the product being produced and the reformer type; however, some generalisations can be made to allow the operator to determine the optimal catalyst loading for a reformer. In general, it is necessary to use **KATALCO** 25-series catalyst in the inlet 40 - 50 % of the steam reformer tube where conditions are more conducive to carbon formation. This can be where the steam to carbon ratio is low, heat flux is high or there is a higher content of C_2+ hydrocarbons. In these cases, the **KATALCO** 25-series catalyst will be loaded with either **KATALCO** 23 or **KATALCO** 57-series catalyst in the remainder of the steam reformer tubes. At less severe conditions, these catalysts will be used throughout the steam reformer tube.

Ammonia plants

Feedstock type	**KATALCO** PERFORMANCE catalyst recommendation
High methane content gas, design plant rates	57 or 23-series
Feedstock with significant levels of higher hydrocarbons	A combination of 25-series with 57/23-series
Low steam to carbon ratio, high methane content gas	A combination of 25-series with 57/23-series
Plant limitation	**Recommendation**
High pressure drop (high plant rates)	XQ, GQ and Q size combination
High tube wall temperatures	MQ and Q size combination
High methane slip	MQ and Q size combination

Methanol plants

Feedstock type	**KATALCO** PERFORMANCE catalyst recommendation
High methane content gas, design plant rates	A combination of 25-series with 57/23-series
Feedstock with significant levels of higher hydrocarbons	A combination of 25-series with 57/23-series
Low steam to carbon ratio, high methane content gas	A combination of 25-series with 57/23-series
Plant limitation	**Recommendation**
High pressure drop (high plant rates)	XQ, GQ and Q size combination
High tube wall temperatures	MQ and Q size combination

Hydrogen and HyCO plants

Feedstock type	**KATALCO** PERFORMANCE catalyst recommendation
Refinery off gas and high methane content gas, design plant rates	57 or 23-series
Natural gas with significant levels of higher hydrocarbons	A combination of 25-series with 57/23-series
Pre-reformed feedstock	57 or 23-series, optionally with 25-series for additional operability
LPG feedstock with high C_3 content and/or high steam to carbon ratio	A combination of 25-series with 57/23-series
HyCO production from natural gas or pre-reformed feedstock	A combination of 25-series with 57/23-series
Plant limitation	**Recommendation**
High pressure drop (high plant rates)	XQ, GQ and Q size combination
High tube wall temperatures	MQ and Q size combination

Catalyst characteristics

KATALCO 23-series

nickel oxide on an alpha alumina support

3 options available:

KATALCO 23-4MQ
KATALCO 23-4GQ
KATALCO 23-4Q

Physical properties (typical)

Catalyst	23-4Q	23-4MQ	23-4GQ
Form (**QUADRALOBE**™)	4-hole cylinders with 4 flutes and domed edges	4-hole cylinders with 4 flutes and domed edges	4-hole cylinders with 4 flutes and domed edges
Length (mm)	17	13	20
Outer diameter (mm)	13	10.5	16
Inner diameter (mm)	3.5	2.7	4.4
Typical loaded density (kg/m^3 / lb/ft^3)	1090 / 69	1140 / 73	1050 / 67

Important note

The loaded density values are typical values. Depending on reformer type, loading technique etc, actual achieved density may be different from these values. Also, if alternative shapes are provided by special arrangement, the density values may differ significantly and should be confirmed.

Catalyst characteristics

KATALCO 57-series

nickel oxide catalyst on a calcium aluminate support

Options available:

KATALCO 57-4MQ
KATALCO 57-4Q
KATALCO 57-4GQ
KATALCO 57-4XQ
KATALCO 57-6Q
KATALCO 57-6GQ
KATALCO 57-6XQ

Physical properties (typical)

Catalyst	57-4Q	57-4MQ	57-4GQ	57-4XQ	57-6Q	57-6GQ	57-6XQ
Form (**QUADRALOBE**)	4-hole cylinders with 4 flutes and domed edges	4-hole cylinders with 4 flutes and domed edges	4-hole cylinders with 4 flutes and domed edges	4-hole cylinders with 4 flutes and domed edges	4-hole cylinders with 4 flutes and domed edges	4-hole cylinders with 4 flutes and domed edges	4-hole cylinders with 4 flutes and domed edges
Length (mm)	17	13	20	20	17	20	20
Outer diameter (mm)	13	10.5	16	19.7	13	16	19.7
Inner diameter (mm)	3.5	2.7	4.4	5.5	3.5	4.4	5.5
Typical loaded density (kg/m^3 / lb/ft^3)	880 / 55	900 / 57	780 / 49	780 / 49	737 / 46	673 / 42	700/44

Important note

The loaded density values are typical values. Depending on reformer type, loading technique etc., actual achieved density may be different from these values. Also, if alternative shapes are provided by special arrangement, the density values may differ significantly and should be confirmed.

Catalyst characteristics

KATALCO 25-series

lightly alkalised nickel oxide on a calcium aluminate support

Options available:

KATALCO 25-4MQ
KATALCO 25-4Q
KATALCO 25-4GQ

Extra high activity versions enhanced nickel loaded versions of 25-4 series the 25-4 H range is also available for maximum protection from carbon and longest run lengths.

Physical properties (typical)

Catalyst	25-4Q	25-4MQ	25-4GQ
Form (**QUADRALOBE**)	4-hole cylinders with 4 flutes and domed edges	4-hole cylinders with 4 flutes and domed edges	4-hole cylinders with 4 flutes and domed edges
Length (mm)	17	13	20
Outer diameter (mm)	13	10.5	16
Inner diameter (mm)	3.5	2.7	4.4
Typical loaded density (kg/m^3 / lb/ft^3)	870 / 55	950 / 60	790 / 50

Important note

The loaded density values are typical values. Depending on reformer type, loading technique etc., actual achieved density may be different from these values. Also, if alternative shapes are provided by special arrangement, the density values may differ significantly and should be confirmed.

Advantages of choosing **KATALCO**

Catalyst selection for plant optimisation

JM is the world leader in steam reforming technology for the production of ammonia, methanol, hydrogen and HyCO for a very good reason. Our focus is the delivery of the best plant performance on behalf of our customers. You can have confidence in your plant with Johnson Matthey's cutting-edge catalyst technology, vast experience and unique technical support and services capabilities.

Our **KATALCO** 23-series and **KATALCO** 57-series catalysts are non-alkalised high activity steam reforming catalysts suitable for light hydrocarbon feeds. **KATALCO** 25-series are lightly alkalised steam reforming catalysts, widely used to achieve longer life in problem plants with feedstocks containing higher hydrocarbons or operating under severe conditions. **KATALCO** 25-series are typically used in combination with non-alkalised catalysts for steam reforming natural gas. Whether we recommend a combination of alkalised and non-alkalised catalysts or a variety of catalyst sizes.

Not only is **KATALCO** the best commercially available range of steam reforming catalysts, but **KATALCO PERFORMANCE**, a range of services to optimise your plant performance, is tailored for each plant on an individual basis to meet the operator's specific requirements.

JM has decades of experience in reformer simulation dating back to the ICI naphtha steam reforming process in the 1960s. Our world-class reformer simulation programme, **REFORM**™, has been developed from this heritage and refined over decades to allow us to accurately predict the exact performance of any given catalyst combination.

Although many plants may have the same design conditions, the operation of each plant is unique, and depends on a variety of factors including the gas feed, the plant rate, steam to carbon ratio and operating pressure and temperature. These differences in plant performance are critical when it comes to the selection of a steam reforming catalyst, and a detailed understanding of the heat transfer and activity contributions to the performance is key.

Reliability

You will see improved heat transfer properties and reduced feed and fuel requirements, enhanced tube life and reducing operating costs with **KATALCO** steam reforming catalysts. Our catalysts are physically strong to withstand plant upsets and have a well-earned

reputation for delivering the world's most reliable reformer operation. The high activity, optimised pellet design of **QUADRALOBE** provides better packing characteristics and fluid flow dynamics, plus the tailored use of potash delivers carbon free operation in the most highly loaded plants. If carbon is formed the ability to remove it is greatly enhanced by the resistance of **KATALCO QUADRALOBE** catalysts to steaming and the acceleration of carbon removal by the potash promotion.

Feedstock versatility

When flexibility is key JM steam reforming catalysts operate with every normal feedstock processed using steam reforming technology. These include refinery off-gas containing hydrogen, natural gas, associated gas, LPG and naphtha. Feedstocks may also include recycled carbon dioxide.

KATALCO 23-series and **KATALCO** 57-series catalysts are designed for use on natural gas or hydrogen rich feeds. For more severe duties such as high reforming heat flux, low steam to carbon ratio, or heavier hydrocarbons feeds, catalysts must be selected with a higher resistance to carbon laydown. In these situations, the alkalised **KATALCO** 25-series catalysts are used in the upper part of the steam reformer tubes in conjunction with **KATALCO** 23-series or **KATALCO** 57-series unless the hydrocarbon feedstock is butane or heavier in which case alternative catalysts from the JM range are required.

Sustainability

KATALCO steam reforming catalysts provide a progressive solution to meet your sustainability targets. Our catalyst technologies have a longer life cycle due to high activity and robust design and require lower temperatures. JM catalysts are designed to optimise process and feedstock efficiency to reduce energy use and waste generation.

Using JM's expertise in loading nickel onto alumina supports, **KATALCO** 57-6 catalyst offers precise distribution of nickel onto the pellet surface. This delivers nickel in the location where it can provide the most value, make the most efficient use of natural resources and help you meet sustainable purchasing targets without compromising the reformer performance.

Long catalyst lives

KATALCO QUADRALOBE catalysts have delivered lives in excess of eight to ten years. A longer life cycle due to high activity, resistance to carbon formation and poisoning, and low sintering keeps operations running longer with less bed change-outs, meaning less down time, less waste and less consumption of precious natural resources. Long catalyst lives are achieved through formulations that deliver high stable activity and the ability to recover from plant upsets. High activity is required at the top of the tubes to prevent carbon formation and at the bottom of the tubes (along with high heat transfer) to keep tube wall temperatures within acceptable limits. **KATALCO** catalysts are designed to maintain a high activity in steam reforming applications. Catalyst activity is unaffected by periods of prolonged steaming during plant upsets or frequent start-up or shutdown procedures. Low temperature activity is stable and ensures maximum reaction at the top of the tubes to minimise tube wall temperature in top fired furnaces.

The alkali in **KATALCO** 25-series increases the margin against carbon formation and accelerates its removal during operation and steaming.

Long tube lives

The major cost in running a reformer is tube replacement. Tube replacement costs are typically double the catalyst cost on an annualised basis. Tube lives can be halved by a 20°C (36°F) increase in temperature so catalyst activity and heat transfer are critically important. The high stable activity of JM steam reforming catalysts keeps tube temperatures low throughout their length. The **QUADRALOBE** shapes also achieve the highest heat transfer from the tube wall to the process gas. This is particularly important towards the tube exit since in most plants this is where the maximum tube wall temperature occurs.

In reformers with very high heat flux, tube lives can be extended using **KATALCO** 25-4H series. Targeted nickel loading techniques can increase the metal content in the catalyst where it can deliver the most value via enhanced activity which reduces the tube wall temperature and increases the tube life.

High plant rates

The high activity and low pressure drop of the **QUADRALOBE** shape enables plant rate increases with little or no penalty on tube wall temperature or methane slip. The JM **REFORM** program accurately simulates all standard reformer types and enables selection of the best catalyst formulation and size combination to achieve the desired operating conditions.

Low pressure drop

Pressure drop across steam reformers is becoming increasingly important and is directly related to plant rate for many operators. Lower pressure drop across the campaign allows operators to further reduce OPEX and increase production. **KATALCO** 23-series, **KATALCO** 57-series and **KATALCO** 25-series catalysts are available in a range of different sizes and features for those plants that are pressure drop constrained. Combined with their excellent activity and heat transfer properties, this allows optimised reformer loadings to minimise pressure drop.

The high strength of **KATALCO** steam reforming catalysts minimises the pressure drop increase during the catalyst's life.

The introduction of **KATALCO** 57-4XQ offers the lowest pressure drop available.

Strength

KATALCO 25-series, **KATALCO** 23-series and **KATALCO** 57-series catalysts have high stable strength during operation and retain more than 80% of initial strength after five years of operation.

Low silica

In order to avoid all problems associated with silica migration, **KATALCO** 25-series, **KATALCO 23**-series and **KATALCO** 57-series catalysts contain the lowest possible levels of silica..

Size range

All **KATALCO QUADRALOBE** catalysts are available in a range of sizes to suit individual requirements. All steam reformers are different, therefore the catalyst requirements vary from plant to plant.

MQ, Q and GQ sizes of **QUADRALOBE** have been optimised to give the same pressure drop as our previous 4-hole product, resulting in higher activity catalysts. The XQ size has been optimised to give the same activity and thus even lower pressure drop when compared to our 4-hole G size product. Hence, the **QUADRALOBE** catalyst range offers products with the highest activity and lowest pressure drop commercially available.

Using JM's expertise in steam reforming operations and detailed modelling capability, it is possible to optimise the performance of a given steam reformer by selecting the correct size range to give the required activity, heat transfer, and pressure drop.

Ease of reduction

KATALCO 25-series, **KATALCO** 23-series and **KATALCO** 57-series catalysts are supplied with the nickel in the oxide form and so need reducing to become active. These catalysts are easily reduced in the plant using well-established procedures, advice on which is given in the appropriate JM operating manual.

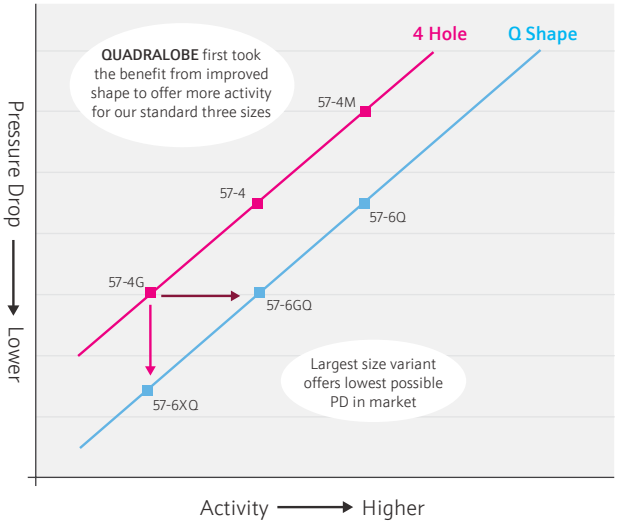
In rare cases where low reformer inlet temperature makes full reduction of the catalyst at the tube inlet difficult, catalysts can be supplied in the pre-reduced form.

The pre-reduced material is only required in the inlet 1-2m (3-6ft) of the reformer tube where the operating temperature is lowest.

Stability

All **KATALCO** steam reforming catalysts will withstand typical plant problems, e.g.,

- short exposure to temperature in excess of 1000°C (1830°F)
- prolonged steaming at operating temperatures
- steaming to remove carbon deposited on the catalyst or to remove sulphur poisoning
- the effects of condensing steam



Additional capability with **KATALCO** Performance

There are a variety of factors that determine what is most important to plant operators when it comes to optimising their plant performance. From feedstock costs to market dynamics, local legislation and sustainability targets, each operating site is unique. In today's competitive landscape, companies operating inefficient plants find that they are struggling to compete with those paying much less for energy. As the world becomes more concerned with the links between energy consumption, carbon dioxide emissions and environmental impact, stringent legislation and regulations covering topics such as energy efficiency are now an important part of business. The incentive to decrease energy consumption and make the most efficient use of our planet's natural resources therefore goes beyond traditional energy costs, putting pressure on companies to reduce energy consumption, emissions and waste.

At JM we understand this, and we offer a range of services specifically designed to help you improve your plant operations, be it through higher efficiency, reliability or throughput. Our background in plant operations, together with our catalyst know- how, has made us the number one supplier of steam reforming catalysts and services world wide.

We offer a unique range of services directly related to steam reformer operation, all of which are designed to improve your plant performance. JM will recommend the relevant products from the **KATALCO PERFORMANCE** portfolio to address the specific issues on your plant.

Reformer surveys and operational audits

The optimal temperature to operate the reformer is a balance between maximising both methane conversion and the lifespan of the equipment.

JM's reformer surveys provide accurate tube wall temperature measurement – often a key performance indicator for the reformer - using the latest measurement techniques. This data is used in conjunction with detailed kinetic modelling of the reformer catalyst to check current performance versus expectations and generate future performance predictions. It can also be used to identify current or potential operational issues and provide a baseline for plant uprate studies.

JM offers several different types of reformer surveys from a quick health check of the reformer to a significantly more detailed assessment. Depending on their scope, these surveys use a JM optical pyrometer together with a gold cup contact thermocouple and/or a reformer imager (an unrivalled, portable, thermal imaging camera using near infrared temperature measurement technology).

The scope of the reformer survey is tailored to meet individual plant situations and can be extended to include the convection section heat recovery and synthesis gas cooling train. If a reformer survey concludes that more detailed investigation is needed to solve a particular problem, JM has access to a wide variety of additional techniques that can also be employed. The combination of techniques selected is tailored to the specific problems to enable a targeted and comprehensive analysis of the issues.

Steam reformer modelling - REFORM

Accurate modelling of steam reformers is critical for predicting reformer operation, reducing risk and determining the correct catalyst selection for any given plant. REFORM, the JM reformer simulation model, looks at all aspects of the steam reformer, so that you can plan with confidence.

It models the flue gas side from the flame heat release, radiation from the flame, radiation from the gas, radiation from the wall of the furnace and radiation from the coffins. As well as receiving the radiation on the tubes it considers which direction the radiation is coming from and hence the temperature distribution both axially along the tube and radially around the tube circumference.

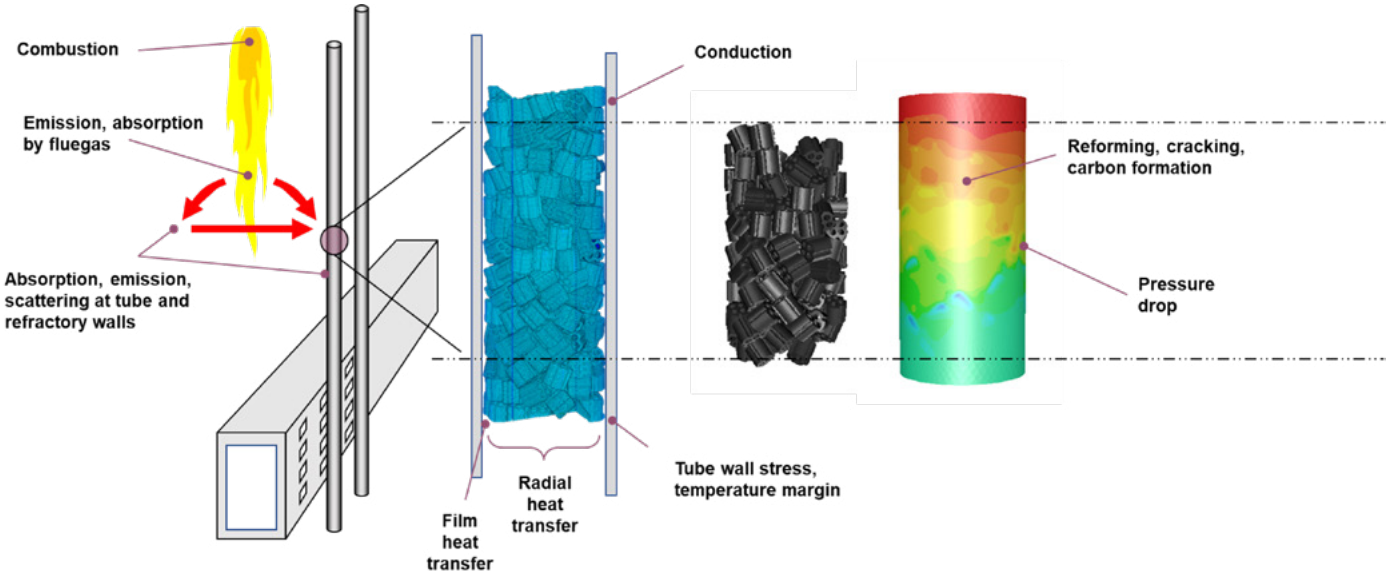
The inside of the tube is modelled by considering the heat transfer between the tube inside wall and the gas phase, the catalyst and the catalyst reactions in both an axial and a radial direction. This is then used to work out the tubes stresses very precisely. Carbon formation and detailed pressure drop through the catalyst are also calculated.

With a model of this detail we are able to precisely predict how different catalyst combinations are going to work under any given set of conditions. This allows us to recommend the optimum catalyst solution for any type of steam reformer. JM also uses this program in troubleshooting problems on steam reformers as part of our steam reforming optimisation studies.

Advanced reactor thermometry technology

Accurate temperature measurement within a catalyst bed can be crucial for understanding the performance of the catalyst, hitting targets, cost management, diagnosing operational upsets and determining remaining life. JM has formed a partnership with Daily Thermetrics to offer catalyst users the most advanced temperature tracking technology currently available – the CatTracker®.

The CatTracker® employs advanced technology and offers catalyst users the most rugged yet flexible temperature probes designed to be in direct contact with the process. Optimised for use in steam reformers, each CatTracker® probe is installed using a patented JM loading technique. The temperature sensors give temperature readings at different points in the reformer tube, giving continuous on-line monitoring of the tube temperature profile, with the profile available in real time through the plant DCS system to ensure your plant is always running as efficiently as possible.



Reformer consultancy

By collaborating and working closely together, JM's experienced engineers can assist in identifying operational problems, whether related to process operation or mechanical equipment, and in developing appropriate solutions.

Practical JM experience gained on a range of different steam reformers and other furnaces can be applied to customers with similar designed steam reformers to give them a benchmark of how they are operating against similar designs and assistance in how to improve their furnace operation.

Reformer process and mechanical design consultancy and engineering services

Through our operational experience in running large steam reformers, JM has developed design skills and knowledge that can be shared for the benefit of our catalyst customers. This includes advice on options for taking advantage of new materials for reformer tubes, reconfiguring tube support systems or replacing collection and transfer headers.

Further details on these and other services capabilities are available from JM.

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