JM

# Leading Water Gas Shift Solutions

Structure, strength and durability

Johnson Matthey
Inspiring science, enhancing life

## High and low temperature shift solutions

The water gas shift process is divided between two unit operations: a high temperature shift (HTS) and a low temperature shift (LTS). Since greater equilibrium conversion of carbon monoxide is favoured at lower temperatures, a compromise is required between achievable conversion and kinetic rate.

The water gas shift conversion is an important aspect to the economic operation of an ammonia plant as this is the key mechanism allowing catalysts to perform reliably for the desired run lengths between turnarounds. The factors that can limit this performing optimally are pressure drop increase, either due to fouling or lack of catalyst strength, and lack of conversion, due to a lack of catalyst activity.

Johnson Matthey (JM) enables efficiency improvement and plant rate increases by reducing pressure drop through the shift system with high activity, long lasting catalysts.

## High Temperature Shift

### Shape

**KATALCO**™ 71-series F shape fluted pellets are patented for use in high temperature shift processes and provide optimised pressure drop reduction.

Figure 1: **KATALCO** 71-series F shape fluted pellet design

This range of HTS catalysts offers high activity due to the inclusion of a structural promoter which improves the pore size distribution. This increases activity by reducing the diffusional limitation associated with many HTS catalysts. Its pore structure also allows better water vapour release during drying after any wetting incident.

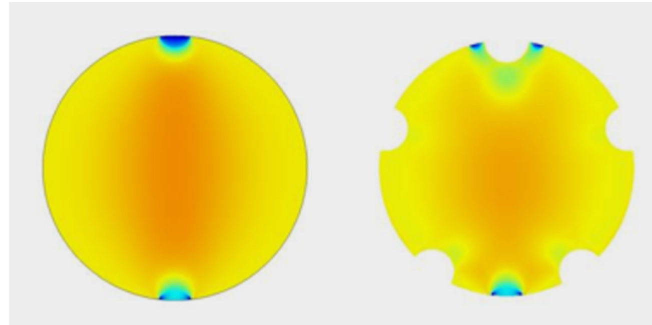

Figure 2: Stress comparison of a typical standard pellet versus the fluted design of a **KATALCO** 71-series F shape

This catalyst series design has increased strength while retaining its pellet size which maximises in-situ strength, activity, and pellet integrity. This provides greater resistance to the effect of boiler leaks and minimises gas bypassing in radial flow reactors.

### Pressure drop

Minimising the pressure drop is an important consideration in overall process economics. Pressure drop characteristics of a catalyst are dictated by the pellet design. The design of the **KATALCO** 71-series pellets optimise the aspect ratio to achieve high voidage in a packed bed to deliver the best combination of decreased pressure drop at start of run and low rates of pressure drop growth with increased strength and activity. JM can offer improved pressure drop and conversion versus typical cylindrical pellets by utilising patented developments in HTS pellet design..

The **STREAMLINE**™ technology from JM is an engineered design using shaped media to reduce pressure drop in a converter. **STREAMLINE** low pressure drop support media 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.

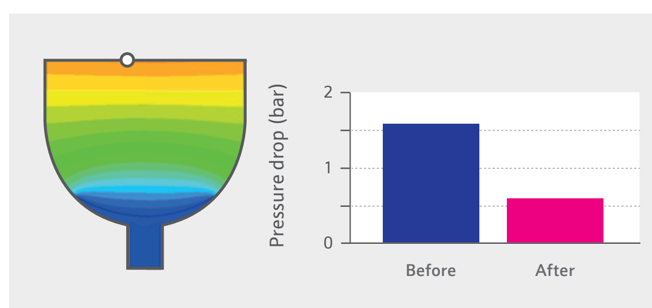


Figure 3: Pressure drop comparison of a syngas plant with **STREAMLINE** shaped media installed at the base of an HTS

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.

### Poison protection

The catalyst should be able to tolerate plant upsets and retain its low pressure drop characteristics. Unplanned events that impact the HTS are likely to be wetting incidents related to boiler leaks, which can lead to increased pressure drop from the build-up of boiler solids. Robust catalysts, like the **KATALCO** 71-series, have good strength and open pore structure to withstand rapid cycles of wetting and drying.

Improvements have been made in both upper and lower support media surrounding the bed to improve plant efficiency by increasing protection. Atop the bed, DYPOR media is used as SHIFTSHIELD to protect from wetting via boiler leaks.

Below the HTS bed, **PURASPEC**™ 2272 is installed as a strong chloride trapping  support that replaces previously inert support with active material. This patented technology combines strong purification expertise with the design of low pressure drop systems for shift reactors to develop this technology. Installed at the  bottom of the HTS vessel by capturing Cl it can protect the LTS from damage that can be caused by  wetting resulting in  Cl migration within the LTS catalyst bed.

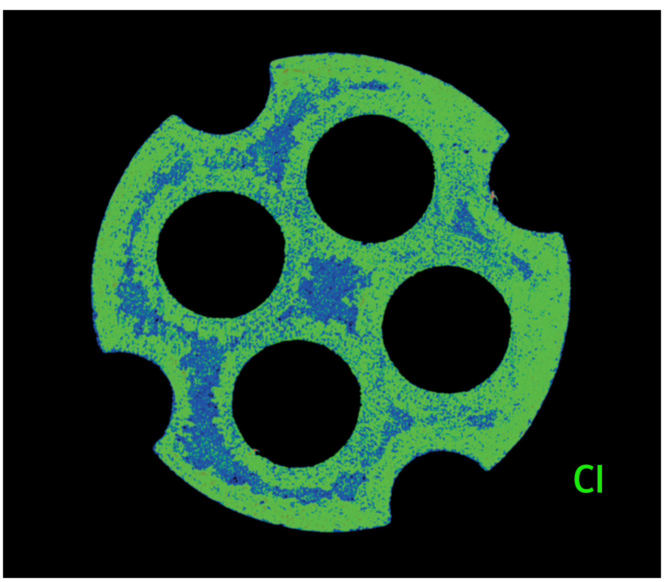


Figure 4: **PURASPEC** 2272 Cl- trap image showing how Cl is absorbed into the low pressure drop HTS support

## Low Temperature Shift

The **KATALCO** 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 optimisation of pressure drop and catalyst activity. The formulation provides a self-guarding capability and maximises sulphur retention. **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.

### Structure

Johnson Matthey's LTS catalysts contains an ideal blend of three key elements based on their interactions to optimise strength, activity, and poison protection: aluminium (Al), zinc (Zn) and copper (Cu). Physical robustness and high strength can be attributed to the interaction of Al and Zn. Activity is influenced by the copper, primarily maintaining its surface area and how it interacts with the support. Poison resistance, especially towards sulphur, is increased with interactions between Zn and Cu.

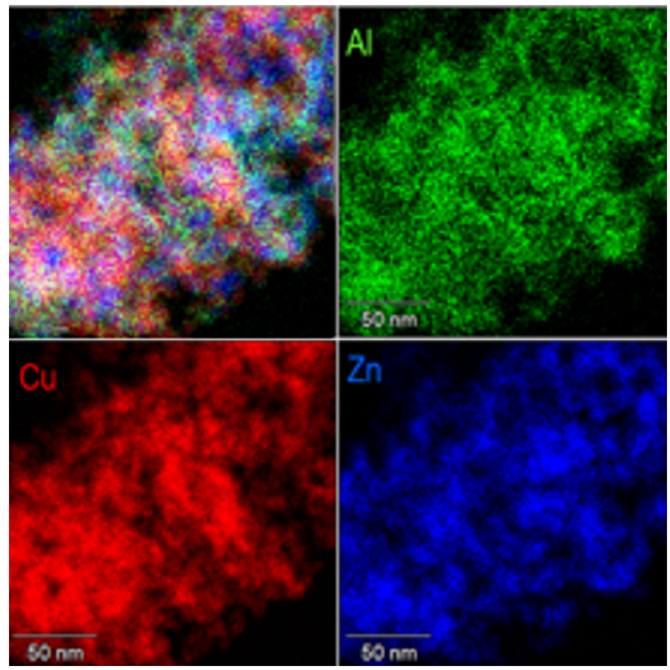


Figure 5: EDX images of individual elements (Al, Cu, Zn) and JM's LTS catalyst (top left) showing structural interactions of key components

The combination of these three key elements allows for JM to optimise the performance of its LTS catalyst, developing a reputation for stability, sturdiness, and minimal pressure drop increase in service.

### Strength

It is important to note that all LTS catalysts have lower in-service versus fresh strength. However due to its robust structure, JM's LTS maintains high strength while the competitor is typically seen to lose strength once in service, attributed to shrinkage and catalyst reduction.

The relevant strength of any LTS catalyst is that in the reduced state, since that is the state of the catalyst in-service. Reduced catalyst strength is important, some low temperature shift catalysts can be too weak. **KATALCO** 83-3X is the optimum choice it retains the maximum level of mechanical strength after reduction.

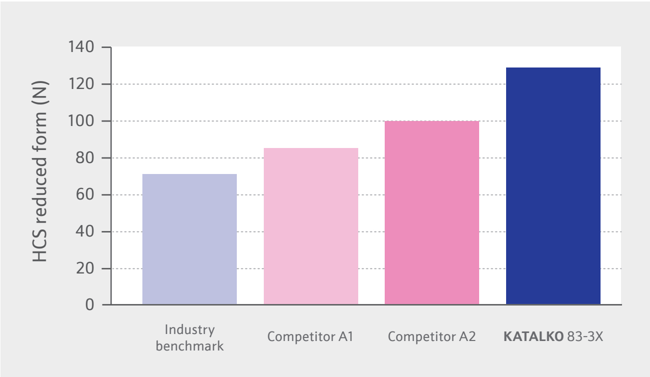


Figure 6: Graph showing the industry landscape regarding mechanical strength of the catalyst in reduced state during service

The outstanding mechanical stability of **KATALCO** 83-3 series catalysts deliver a benefit of lower pressure drop increase with time on-line and consequently a longer lifetime.

Pressure drop is an important parameter relating to the economics of the syngas generation train. Catalyst pellet design can improve the pressure drop of an LTS reactor, and catalyst strength throughout its lifetime is as important as the strength of the fresh pellet. The high strength of **KATALCO** 83-series catalysts minimises the rate of increase of pressure drop during operation, and its formulation gives high strength after reduction, steaming and any unplanned wetting events.

There is also a much lower exposure to risk of production losses caused by pressure drop where deformation of weaker pellets can lead a resistance to flow. There are many incidents in industry where weaker LTS catalysts have caused incidents causing pressure drop losses that can be measured in $1-10M's

## Poison protection

Not only was the **KATALCO** 83 series designed for high strength, but also for a higher resistance to transients including sulfur and chlorides that would cause sintering and overall decreased activity.

Poison control has more of an impact than activity in contributing to a longer lifetime. Higher activity is more limited by equilibrium earlier in life, so it will not make a considerable difference early on, whereas early poisoning in the bed would decrease activity and require early changeout.

A by-product of the water gas shift process is methanol. Methanol is undesirable since its formation consumes hydrogen that could otherwise be used for ammonia synthesis, and methanol emissions from the process can be a serious environmental concern.

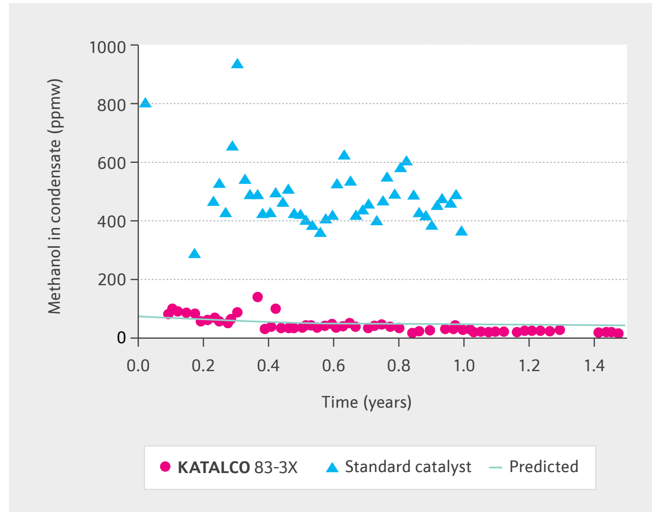


Figure 7: Methanol in condensate with **KATALCO** 83-3X installed versus a standard competitor catalyst charge

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.

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.

**Talk to JM today to find out how we can provide catalysts and technology to help you get the most out of your operations.**

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