

# Claus unit

## Tail gas treatment catalysts

RESEARCH | TECHNOLOGY | CATALYSTS





The TK catalyst family

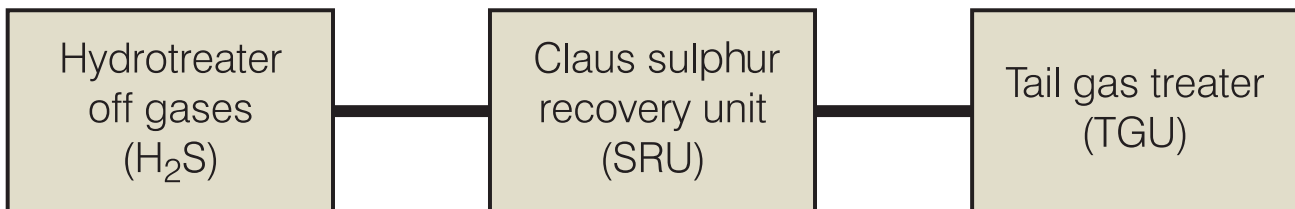


Figure 1: Sulphur recovery flow scheme

## Tail gas treatment catalysts

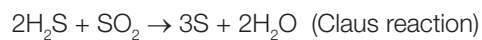
In the refining industry today, sulphur recovery is an extremely important issue that often does not get the attention it deserves. Sulphur is one of the dominant contaminants in petroleum fractions, and legislation limits not only the sulphur content of finished products, but also refinery emissions to the atmosphere. Therefore, sulphur removal and recovery is a vital process for refineries and gas plant operations. In most locations, the sulphur is hydrotreated and thus converted to hydrogen sulphide ( $\text{H}_2\text{S}$ ) which is easily scrubbed from the various liquid and gas streams. The  $\text{H}_2\text{S}$  collected from the hydrotreaters and/or gas plants is then treated by the Claus or a similar process (Figure 1).

## The Claus process

The Claus process utilises a combination of thermal and catalytic process steps. Initially, the acid gas is enriched with sufficient oxygen to convert some of the  $\text{H}_2\text{S}$  in the gas to  $\text{SO}_2$  according to the following reaction:



The mixture of  $\text{H}_2\text{S}$  and  $\text{SO}_2$  reacts according to the Claus reaction given below. At this stage, approximately 70% of liquid sulphur is recovered. The remaining gases are then fed to the catalytic reaction section, where the following reaction occurs:



The remaining effluent called Claus tail gas, apart from combustible gases, also consists of  $\text{H}_2\text{S}$ ,  $\text{H}_2$ ,  $\text{CO}$ ,  $\text{CS}_2$ ,  $\text{SO}_2$ , and  $\text{COS}$ . In order to meet the sulphur emission target Claus units often have a tail gas treater for final sulphur removal of the gases.

## Tail gas treating

The tail gas hydrotreating unit works through a relatively simple process. Because the sulphur compounds that need to be converted are relatively easy to treat, catalyst activity is not a primary requirement.

Due to the nature of the process, we can summarise and prioritise the desired catalyst properties as follows:

- low pressure drop
- physical strength
- thermal stability
- longevity
- HDS activity

For tail gas hydrotreating operations, catalysts are typically of the CoMo type.

## Catalysts

Haldor Topsøe has developed three catalysts for tail gas treating applications covering a wide range of operating conditions and plant configurations.

These are:



TK-220, 1/10" AQL



TK-222, 1/8" Ring



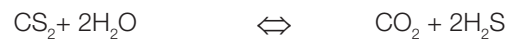
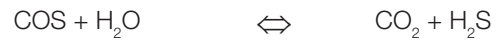
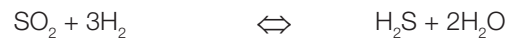
TK-224, 1/6" Sphere

	Topsøe TK-220	Topsøe TK-222	Topsøe TK-224
Shape	Quadralobe	Ring	Sphere
Nominal size, mm (in)	2.5 (1/10)	3.2 (1/8)	4.0 (1/6)
CoMo oxide, % wt	~14	~18	~12
Attrition index	>98	>97	>98
Sock loading density, kg/m <sup>3</sup> (lb/ft <sup>3</sup> )	400 (25)	500 (31)	700 (44)

Table 1: Typical catalyst properties

## Reactions

Sulphur compounds present in Claus tail gas are hydrotreated with a CoMo catalyst to H<sub>2</sub>S at a temperature level of 250-275°C (480-525°F) in the tail gas unit according to:



All of these reactions will reach equilibrium in the tail gas unit when applying any of Topsøe's three CoMo type catalysts.

## Catalyst activity

Topsøe's tail gas treating catalysts are offered in different shapes and sizes due to pressure drop considerations. Furthermore, they are designed with different porosities, average pore sizes, and consequently different bulk densities to optimise the HDS activity for tail gas operation.

Pilot plant testing confirms that all three of Topsøe's tail gas treating catalysts will provide the refiner with the maximum sulphur conversion at the prevailing process conditions. This is shown in Figure 2.

All three catalysts will ensure the refiner a long and stable performance in the tail gas unit. In fact, end-of-run for any of our tail gas catalysts is typically caused by an operational upset such as burner operation issues causing soot formation or a temperature runaway, rather than the gradual loss of catalytic activity.

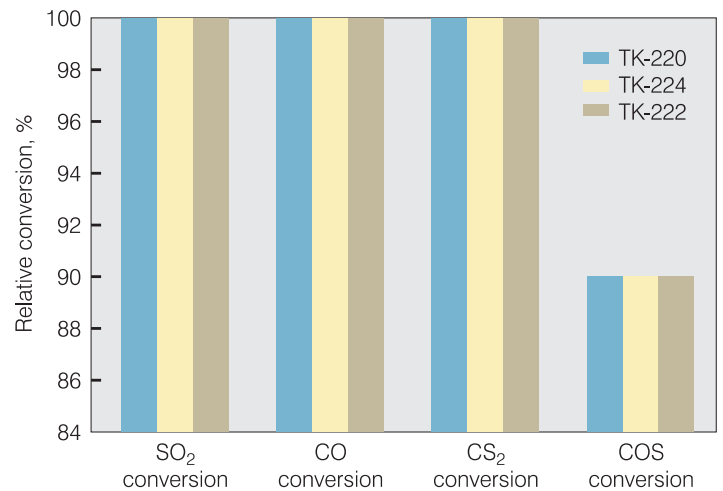


Figure 2: Performance of Topsøe's tail gas catalyst at an inlet temperature of 250°C (480°F)

## Pressure drop

The requirements for catalysts in tail gas treaters are quite different from conventional hydrotreating applications. A very important consideration is the pressure drop across the catalyst bed, as the unit operates at almost ambient pressure, and the blower is the only force pushing the feed through the reactor. This is the reason that tail gas unit reactors are designed with a very large cross-sectional area and shallow bed depth. A typical reactor loading is shown in Figure 3.

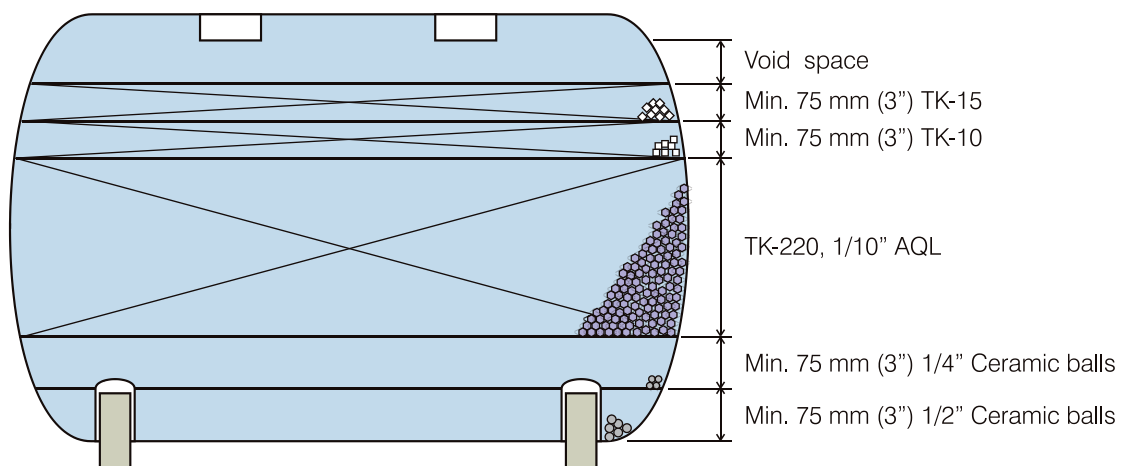


Figure 3: Reactor loading diagramme

Since the reactor pressure drop is ultimately determined by the shape and size of the catalyst particle, we have the opportunity to influence the very important start-of-run (clean bed) pressure drop across the reactor.

The start-of-run reactor bed pressure drop is determined by the bed void and the particle size, and Topsøe's three different tail gas catalysts have the following pressure drop characteristics:

Catalyst	Sock loaded void fraction, %	Relative pressure drop
TK-220, 1/10" Quadralobe	48	1.00
TK-222, 1/8" Ring	53	0.15
TK-224, 1/6" Sphere	35	0.95

Table 2: Pressure drop characteristics

As can be seen from the above, Topsøe offers a number of catalyst filling options in order to meet all needs of the refiner.

For refiners who really need a lower bed pressure drop, our TK-222 1/8" ring meets this requirement. TK-222 has only 15% of the pressure drop of any of the other shapes utilised today, namely quadralobes and larger sized spheres. In fact, TK-222 has the lowest pressure drop of any commercially available catalyst applicable for tail gas service. As such, it offers refiners considerable advantages and opportunities for debottlenecking the sulphur constraints of any refinery by allowing a substantial increase in throughput.

TK-15 and TK-10 are used as topping layers to improve distribution as well as to provide the catalyst hold-down function. TK-15 has 65% void and TK-10 has 55% void, which, coupled with the fact that these layers are shallow, means that they contribute positively to the SOR pressure drop of the catalyst fill.

Tail gas feed, Vol%	
H <sub>2</sub> S	0.8
SO <sub>2</sub>	0.4
S <sub>8</sub>	0.1
CS <sub>2</sub>	0.1
COS	0.1
CO	0.3
CO <sub>2</sub>	3.0
CH <sub>4</sub>	0.1
H <sub>2</sub>	2.0
H <sub>2</sub> O	32.0
N <sub>2</sub>	61.1
Process conditions	
Typical inlet temperature	250-275°C 480-525°F
Air/Fuel Ratio	70-90% of stoichiometric
H <sub>2</sub> S/SO <sub>2</sub> Ratio	2

Table 3: Tail gas feed and operating conditions

Typical tail gas feed composition as well as operating conditions for tail gas catalysts are shown in Table 3.

For more information about our tail gas catalysts or any of our products and technologies, please contact your Haldor Topsøe representative.

# A long lasting partnership combining knowledge with business

## Your technology partner

Since 1940, Topsøe has specialised in heterogeneous catalysis, process development and engineering. A continuous focus on research and development has ensured that Topsøe's technologies and catalysts remain top of class. The many different types of process plants supplied by Topsøe promote synergy and give our clients the benefit from the experience gained from these plants.

Topsøe's product portfolio ranges from catalyst production and sales, licensing and engineering of proprietary catalytic processing units to in-house process development, project management and technical service. Proprietary knowledge of all these fields ensures clients a competent business partner.



## The Topsøe business portfolio

The firm commitment to catalysis and process technology has strengthened Topsøe's position in a wide range of additional business areas: Development and supply of catalysts and technologies for the production of ammonia, methanol and other petrochemicals, for gas conversion, oil refining and for emission control for the power and automotive industry.

Working with Topsøe, clients will benefit not only from our long-term knowledge of sulphur related processes, but also from a broad portfolio of other technologies and catalysts:

- hydroprocessing and hydrogen production in the refining and petrochemical industry
- ammonia, methanol, DME, substitute natural gas (SNG) and coal to liquid (CTL) in coal based industries

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The information and recommendations have been prepared by Topsøe specialists having a thorough knowledge of the catalysts. However, any operation instructions should be considered to be of a general nature and we cannot assume any liability for upsets or damage of the customer's plants or personnel. Nothing herein is to be construed as recommending any practice or any product in violation of any patent, law or regulation.