We create chemistry that makes demanding customers love house specials

Sulphuric Acid Catalysts

BASF’s specialty oxidation catalysts ensure high-yield sulphuric acid production. They are used by the world’s most demanding customers, including BASF. Select the house special for your sulphuric acid production. At BASF – we create chemistry.

www.catalysts.basf.com
Oxidation Catalysts' Role in Manufacturing Sulphuric Acid

Sulphuric acid is an important industrial chemical; in fact, some view sulphuric acid production as a key indicator of a nation’s manufacturing strength. The manufacturers that use sulphuric acid produce:

- Fertilizers
- Chemicals
- Detergents
- Dyes
- Pigments
- Pharmaceuticals
- Refined
- Process
- Steel
- Iron

BASF Specialty Oxidation Catalysts for Sulphuric Acid Production

At BASF, we utilize our vast experience, in-depth industry knowledge, and latest technologies to produce catalysts of superior performance. Our technical capabilities extend to the research, design, and processing of specialty oxidation catalysts for sulphuric acid production.

When you choose BASF, not only will you be choosing the finest catalysts, you will also receive our industry-recognized customer support that combines our dedication to service with our extensive experience in:

- Conversion evaluation
- Performance optimization
- Technical assistance
- Customer sample analysis
- On-site plant support
- Spent catalyst disposal assistance
- Process performance evaluation

---

**History of Sulphuric Acid Production and Sulphuric Acid Catalysts in BASF**

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1865</td>
<td>Founding of BASF in Ludwigshafen, Germany</td>
</tr>
<tr>
<td>1866</td>
<td>Start up of first sulphuric acid plant in BASF</td>
</tr>
<tr>
<td>1888</td>
<td>Implementation of the Contact Process developed by Rudolf Knietsch (initially platinum on asbestos)</td>
</tr>
<tr>
<td>1913</td>
<td>Sulphuric acid catalyst patents (\text{V}_2\text{O}_5 / \text{K}_2\text{O} / \text{SiO}_2) is granted to BASF</td>
</tr>
<tr>
<td>1914</td>
<td>BASF’s sulphuric acid production capacity reaches 120 kt/a</td>
</tr>
</tbody>
</table>
Sulphuric Acid Production Reactions

BASF’s specialty oxidation catalysts are used to ensure high-yield sulphuric acid production. For years, businesses have trusted us to provide catalysts that promote effective reactions in the sulphuric acid production cycle, as illustrated below:

<table>
<thead>
<tr>
<th>Reaction</th>
<th>ΔHₜ</th>
</tr>
</thead>
<tbody>
<tr>
<td>S + O₂ → SO₂</td>
<td>-297 kJ/kmol</td>
</tr>
<tr>
<td>2 SO₂ + O₂ → 2 SO₃</td>
<td>-196 kJ/kmol</td>
</tr>
<tr>
<td>SO₃ + H₂O → H₂SO₄</td>
<td>-132 kJ/kmol</td>
</tr>
</tbody>
</table>

2001
- Continuous improvement in catalyst development

2005
- Launch of dust protection catalyst O4-110 SR18x7

2010
- Launch of new high Cs high V catalyst O4-116 SS11x4

2016
- Launch of new Cs catalyst O4-115 Quattro

Today
- Sulphuric acid catalyst production continues to leverage BASF’s technical innovations
BASF Specialty Oxidation Catalysts
Product Portfolio

Product Overview

<table>
<thead>
<tr>
<th>Shape and size</th>
<th>O4-110</th>
<th>O4-111</th>
<th>O4-115</th>
<th>O4-116</th>
</tr>
</thead>
<tbody>
<tr>
<td>S6 Extrudates 6 mm</td>
<td>S6 Extrudates 6 mm</td>
<td>S6 Extrudates 6 mm</td>
<td>SS11x4 Star Ring</td>
<td></td>
</tr>
<tr>
<td>SR10x5 Ring</td>
<td>SR10x5 Ring</td>
<td>SR10x5 Ring</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SS11x4 Star Ring</td>
<td>SS11x4 Star Ring</td>
<td>SS11x4 Star Ring</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR18x7 Ring(^a)</td>
<td>Quattro (^\text{NEW})</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ignition temperature</th>
<th>O4-110</th>
<th>O4-111</th>
<th>O4-115</th>
<th>O4-116</th>
</tr>
</thead>
<tbody>
<tr>
<td>380˚C(^a)</td>
<td>360˚C(^a)</td>
<td>340˚C(^a)</td>
<td>330˚C(^a)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Operating temperatures</th>
<th>O4-110</th>
<th>O4-111</th>
<th>O4-115</th>
<th>O4-116</th>
</tr>
</thead>
<tbody>
<tr>
<td>415 – 630˚C(^a)</td>
<td>400 – 600˚C(^a)</td>
<td>380 – 630˚C(^a)</td>
<td>370 – 600˚C(^a)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thermal stability</th>
<th>O4-110</th>
<th>O4-111</th>
<th>O4-115</th>
<th>O4-116</th>
</tr>
</thead>
<tbody>
<tr>
<td>630˚C(^a)</td>
<td>600˚C</td>
<td>630˚C</td>
<td>630˚C</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Packaging</th>
<th>O4-110</th>
<th>O4-111</th>
<th>O4-115</th>
<th>O4-116</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 l drum</td>
<td>200 l drum</td>
<td>200 l drum</td>
<td>200 l drum</td>
<td></td>
</tr>
<tr>
<td>1,000 l big bag</td>
<td>1,000 l big bag</td>
<td>1,000 l big bag</td>
<td>1,000 l big bag</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Typical applications</th>
<th>O4-110</th>
<th>O4-111</th>
<th>O4-115</th>
<th>O4-116</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Bed</td>
<td>Second to Fourth or Fifth Bed</td>
<td>First Bed</td>
<td>After intermediate absorption</td>
<td></td>
</tr>
<tr>
<td>Second Bed possible</td>
<td>Fourth or Fifth Bed</td>
<td>Fourth or Fifth Bed</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other Beds Possible</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) The SR18x7 Ring will only be delivered in a 200 l drum
\(^\text{NEW}\)\(^a\) Depending upon gas composition
\(^\text{Continous operation peaks up to 650˚C}\)

World Class Catalysts for Sulphuric Acid Production

Be confident in your choice of BASF selective oxidation catalysts. Our state-of-the-art catalysts are the result of decades of research and ongoing development based on industry experience gained from working in manufacturing plants all over the world.

BASF sulfuric acid catalysts provide world class performance in combination with superior mechanical strength.

BASF offers full systems design for:

- Performance reliability from planning through all phases of plant operation
- Simulations of plant operations
- Converter design calculations
- Highest conversion requirements
- Capital investment optimization
- SO\(_2\) emission reduction
- Environmental protection maximization
O4-110

- Primarily for use in the first converter bed
- Suitable for sulfur combustion gases, waste gases from metallurgical plants or H₂S ("wet") combustion
- 380°C ignition temperature\(^7\)
- 415 – 630°C operating temperature range\(^2\)
- 650°C short term peak temperature
- Ideally suited for high SO₂ contents of up to 13%
- Ultra low screening loss due to high mechanical strength.

\(^7\) In continuous operations generally 30 – 50°C higher
\(^2\) Depending upon gas composition

Special Application of O4-110 SR18x7 (Dust Protection)

Advantages of Dust Protection

- Increase of catalytically active mass in volume restricted beds
- Superb dust filtering properties
- Extended periods between screening
O4-111

- Superior activity
- Close approach to thermodynamic equilibrium
- Very high SO₂ conversion rates when combined with low inlet temperatures in the last bed
- 360°C ignition temperature
- 400 – 600°C operating temperature range
- Highly active for beds after first converter bed

⁹ In continuous operations generally 30 – 50°C higher
⁰ Depending upon gas composition

Advantages

- Outstanding mechanical properties
- High activity
- Superior cutting hardness
O4-115

General
- Caesium catalyst promoter that enhances vanadium action
- Activates at lower temperatures than standard catalysts
- 340°C ignition temperature\(^a\)
- 380 – 630°C operating temperature range\(^a\)

First Bed
- 650°C short term peak temperature
- When used in the first bed, bed inlet temperature reduced to save energy and start-up time

After Intermediate Absorption or Final Bed
- When used in the final bed at low inlet temperatures, \(\text{SO}_2\) conversion is maximized, emissions are reduced, and production is increased

\(^a\) In continuous operations generally
- 30 – 50°C higher
- Depending upon gas composition

Advantages of the new QUATTRO shape:
- 30% percent higher active surface area in comparison to standard shape catalyst
- Higher conversion
- Lower emission level
- Capacity upgrade is possible
- Improved mechanical strength
- Low attrition level > reduced sieving loss

Advantages of Ignition Layer
- Ignition of O4-115 in the top layer already at very low temperatures
- Temperature increase in the Ignition layer due to highly exothermic reaction in the first 15 – 20 cm\(^a\) supports the operation of standard catalyst
- Ignition layer after Intermediate Absorption possible\(^a\)

\(^a\) Depending on \(\text{SO}_2\) gas concentration and gas velocity
O4-116

**Development**
- Dedicated mixture of different support materials ensure optimum pore size distribution for the low temperature application
- Best solution to achieve ultra low emission
- Improved new active phase
- No changes in handling and disposal despite new active phase

**O4-116 is Designed Especially for Passes After the Intermediate Absorption to Minimize S0₂-Emission**

![Graph showing relative activity vs temperature for O4-116, O4-115, and O4-110]

**Advantages**
- Highest activity at temperatures below 400°C
- Excellent mechanical stability
- Star Ring shape to minimize the pressure loss
“We have been using the new low temperature catalyst O4-116 in one of our sulphur combustion units at BASF SE since the fourth quarter of 2010. Up to now, I have never seen such high conversion rates in this unit before. Consequently, we will move to install O4-116 step-by-step in all of our units in Ludwigshafen.”

Dr. Thomas Bogenstätter  •  Senior Plant Manager  •  SO₂/SO₃-Verbund  •  BASF SE
The BOSS 100: BASF Optimal SO\textsubscript{2} Measurement System 100

On-site SO\textsubscript{2} Measurement Technology

BASF has developed a new, portable measurement tool to determine catalyst and plant performance: The BOSS 100 provides reliable, accurate data on SO\textsubscript{2} concentration throughout a facility in order to detect leakages and performance issues. BASF supports the customer in taking the appropriate measures to reach manufacturing excellence through our experience, technical expertise and innovative strength.

Unparalleled Technical Expertise

The Optimal SO\textsubscript{2} measurement System BOSS 100 is a technology package based on Micro GC technology enhanced by our specialists to meet the exact needs of our customers. The advantages of this tailored measurement system are:

- Ability to take SO\textsubscript{2} measurements in the presence of SO\textsubscript{3} in a wide concentration range
- Ability to analyze samples in under two minutes
- Use of a special drying agent that does not interfere with the measurement

The sophisticated system of the BOSS 100 is a combination of gas preparation, collection and analysis. In addition, it includes data processing modules and it is fully supported by the BASF Analyzing Center. This easy-to-handle system allows BASF’s customers to determine the right way to eliminate plant under-performance by providing solutions based on their specific situation.
Production performance deviations can appear for a number of reasons. As the world’s leader in catalysis, BASF has identified key issues:

- Hardware related issues, e.g. leaking/limited heat removal capacity leading to fouling, corrosion, etc.
- Operational related issues e.g. bed inlet temperatures not accurate
- Catalyst related issues e.g. insufficient activity, poisoning and channelling

The BOSS 100 offers a fast and reliable way of detecting and solving these issues.

**Why use the BOSS 100?**

Full-loop Technical Support

The BOSS 100 is fully supported by the BASF Analyzing Center and managed by experienced catalysts experts. As a result, customers can expect full-loop service:

- On-site measurement and technical support
- Customer sample analysis
- Conversion evaluation
- Process performance evaluation
- Plant performance optimization
Measurement & Reporting

The BOSS 100 enables measurement of SO₂ in a wide range of concentrations: 50 ppmv – 15 vol. %.

Two types of measurement reports are available:
- The Thermodynamic Simulation Report
- The Analytical Measurement Report

Evaluation

You can expect results and recommendations shortly after all measurements have been executed.

The Thermodynamic Simulation Report compares a simulation for fresh catalysts to the actual performance thus helping with identifying and optimizing performance problems in particular.

The Analytical Measurement Report summarizes all analyzed parameters providing comments and recommendations with respect to data consistency.
Finding the Right Solution

On-site measurements allow for the development of customized solutions: The portable system locates leakages and other issues where they arise. Based on these results it is possible to systematically identify weak spots and to develop specific procedures to correct performance issues and improve the plant’s overall efficiency.

Like this, the BOSS 100 – as the latest generation of SO₂ conversion measurement systems – offers the key to tailored solutions for manufacturing excellence.
Research and innovation are essential for BASF to shape the future sustainably. Along with innovative products, improved processes and intelligent system solutions contribute vitally to ensuring BASF’s success and the success of its customers. In 2010, BASF spent about €1.49 billion on research and development. This represents an increase of roughly 40% in R&D expenditure since 2005.

Around the world BASF had some 9,600 research and development employees in 2010. BASF’s research Verbund is comprised of central technology platforms, global research and development units of business units and group companies, as well as subsidiaries. In addition, BASF is participating in 1,900 cooperative projects worldwide together with leading universities, research institutes, start-up companies and industry partners to gain fresh impetus from around the globe.

BASF’s key competencies in research include the preparation, testing and scale-up of new and improved heterogeneous catalysts like sulphuric acid catalysts for internal and external customers. More than 650 experts work globally in catalyst R&D at BASF. This ensures that the excellent quality of our catalysts meets our own expectations and those of our customers today, and will continue to do so in the future.

Manufacturing

For more than a century, BASF has produced its sulphuric acid catalysts in manufacturing facilities at its Ludwigshafen, Germany, Verbund site. The site is distinguished by extensive expertise, with its current employees collectively sharing more than 250 years of experience in manufacturing sulphuric acid catalysts.

The original site at Ludwigshafen became operational in 1865 and is today BASF’s most important production site. At Ludwigshafen, we use petrochemical and inorganic substances and process them into high value-added chemical products for the global market. The tightly knit network of more than 160 production facilities provides exceptionally favorable conditions for the manufacture of complex and highly refined chemicals. As the BASF Group’s technology platform and center of excellence, the Ludwigshafen site is a major source of innovation in products, methods and processes.

The central location of the site in southwest Germany, as well as its state-of-the-art logistics infrastructure with excellent rail, road and water transport links, offer ideal prerequisites for BASF to reliably supply customers all over the world. Two combined-cycle gas turbine power stations, a highly efficient wastewater treatment plant, and state-of-the-art infrastructure across the site ensure sustainable manufacturing operations.
Why BASF?

Our goal is to drive our customers’ success. We accomplish this through our commitment to excellence and our passion for innovation, which helps deliver enhanced production economics and increased productivity. We are the partner of choice in our industry, with extensive expertise in both catalysts and applications.

About Us

The BASF Group, consisting of BASF SE plus more than 100 subsidiaries, produces over 8,000 products and has operations in more than 39 countries.

BASF’s Catalysts division is comprised of main research centers in the United States and Europe, production facilities all over the world, and a worldwide marketing and technical service team with regional

Catalysts marketing and technology centers in Asia Pacific, Europe, and the Americas regions.

The Catalysts division produces more than 150 different catalysts. The majority of our portfolio is readily available on the open market. Some of these catalysts are specially developed in cooperation with our customers to meet their specific requirements.
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