The highest performance maleic anhydride (MA) catalysts by the world’s leading MA producer
**BASF MA Catalysts Development**

**History**

**BASF Quality and Reputation are Unmatched**

BASF’s Chemical Catalysts combine the strength of BASF – with the experience and expertise of our chemists and engineers. Our maleic anhydride catalysts are valued components of the oxidation process for worldwide chemical manufacturing companies. BASF’s commitment to the maleic anhydride process and butane oxidation to maleic anhydride catalysts results in products and services that meet and surpass customer expectations and requirements.

BASF is the only major producer of MA catalysts with

- Own Catalyst R&D with lab and pilot scale production including performance testing at Ludwigshafen, Germany
- Own MA catalyst production at Ludwigshafen, Germany
- Own MA reference plants under different operation conditions (e.g., single pass, recycle mode)
- The excellent technical service from BASF is well known in the market from phthalic anhydride (PA) catalyst filling, start-up and customer contacts during operation.

Additionally, BASF further developed the new MA filling machines and ΔP measurement devices.

BASF’s MA Catalyst is designed for

- High performance with n-butane loads up to 44 lₙ⁴/cath
- Optimized high MA product yield and high operating flexibility
- Low pressure drop, constant over total lifetime
- Long catalyst lifetime due to low deactivation rate
- Dedicated low by-product level

The main uses of MA include

- Unsaturated polyester resin (UPR)
- 1,4-butanediol (BDO)
- Specialty acid, such as maleic, fumaric polyaspartic acids
- Lubricating oil additive
- Polybutylene succinate (PBS), biodegradable aliphatic polyester
- Others, such as engineering plastics, fine chemicals, pharmaceuticals

**BASF’s MA Catalyst Development History**

- **2004**
  - Development of improved catalyst version with low pressure drop

- **2003**
  - Start of marketing activities for O4-200 and two more MA production reactors (6m reactors) at BASF’s Feluy site

- **2000**
  - First commercial reference with O4-200 at BASF’s Feluy site (3m reactor with SISAS technology)

- **2002**
  - First external reference plants with BASF’s MA catalyst in Europe (O4-200) and Asia

- **2005**
  - Start of BASF’s integrated production plant for poly-THF with O4-200 at Caojing, Shanghai

- **2008**
  - More applications of O4-202 in Asia

- **2008–2018**
  - Internal application only

- **2019–2021**
  - Re-entry external MA market
  - More commercial applications with O4-204 (New developed)
Maleic anhydride can be produced by passing a C4 stream containing n-butane mixed with a large excess of air into a fixed-bed tubular reactor, where the butanes are oxidized to maleic anhydride with BASF maleic anhydride catalysts.
Resource-efficient solutions and business models to decouple growth from the consumption of finite resources.

Our success factors:
- Customer focus
- Digitalization
- Creativity
- Efficiency
- Collaboration with external partners

Full-scale pilot reactors for MA catalysts technology:
- Best possible quality control
- Most accurate performance measurements for new developments
- Directly measure real scale effects

Global expenditures for research and development over €2 billion, world leader in chemical industry
Approximately 10,000 employees world-wide involved in research and development
Around 950 new patents filed in 2020
Global Know-how Verbund with external partners

North America
- Iselin
  - Refining Catalysts
  - Emerging Technologies
- Iselin / Beachwood / Vidalia
  - Process Catalysts Research North America

Europe
- Ludwigshafen
  - Custom Catalysts and Scale Up
  - Catalysts for Monomers, Intermediates and Fine Chemicals
  - Oxidation Catalysts
  - New Technologies in Process Catalysts

Asia
- Shanghai
  - Process Catalysts Research Asia
  - Emerging Technologies

BASF Research & Development

Innovation – New Processes, Technologies and Products for a Sustainable Future

Pilot-Scale Testing…
…the Key to Success

Catalyst Research Organizational Set-up
Shanghai BASF Process Catalysis R&D Center

- Grand opening in 2019, dedicated R&D center for process catalysts and adsorbents research
- Development of catalysts and adsorbent solutions mainly for Asian Market
- Fast and timely support to our local customers, including BASF MA catalyst customers
  - Catalysts characterization: ICP-OES, XRF, XRD, SEM/TEM, BET, XPS
  - MA composition analysis: PMA, CMA, light ends, heavy ends analysis, through GC, GC-MS
  - Raw material analysis: n-butane analysis through GC, GC-MS, AAS, CHNS/O analyzer
  - MA production simulation and optimization

Investing in innovation:
BASF expanded its research activities with the new R&D center in Shanghai
BASF Maleic Anhydride Catalyst

**Portfolio**

<table>
<thead>
<tr>
<th>Catalyst</th>
<th>04-204</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>Oxidation of n-butane to maleic anhydride (fixed bed)</td>
</tr>
<tr>
<td>Catalyst Composition</td>
<td>Vanadyl-pyrophosphate (VO)(_2)P(_2)O(_7) doped with additives</td>
</tr>
<tr>
<td>Catalyst Shape &amp; Size</td>
<td>Rings 6.5x5.0x3.7 mm, 5.5x3.0x3.0 mm</td>
</tr>
<tr>
<td>Synthesis</td>
<td>Chloride free</td>
</tr>
<tr>
<td>Delivery State</td>
<td>Activated</td>
</tr>
</tbody>
</table>

**Typical BASF Maleic Anhydride Catalyst Operation Conditions**

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>n-Butane Feed Rate</td>
<td>Up to 2.2 vol.%</td>
</tr>
<tr>
<td>n-Butane Conversion</td>
<td>82–87 %</td>
</tr>
<tr>
<td>Gas Flow Rate</td>
<td>GHSV up to 2,200 hr(^{-1})</td>
</tr>
<tr>
<td>Hot Spot Temperature</td>
<td>420 °C–450 °C, or as discussed and agreed with BASF as hot spots arise</td>
</tr>
<tr>
<td>P-Dosage</td>
<td>Necessary for stable operation</td>
</tr>
<tr>
<td>Humidity</td>
<td>Referably adjusted with steam to 2.0–3.0%</td>
</tr>
</tbody>
</table>

**BASF Maleic Anhydride Catalyst Typical Reactor Condition**

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Tubes</td>
<td>5,000 up to 50,000</td>
</tr>
<tr>
<td>Inner Diameter of Tube</td>
<td>21–25 mm</td>
</tr>
<tr>
<td>Tube Length</td>
<td>2,500–7,000 mm</td>
</tr>
</tbody>
</table>

**Expected Quality of Pure MA**

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color Number</td>
<td>Max 20 (APHA)</td>
</tr>
<tr>
<td>Crystallizing Point</td>
<td>52.6–52.8 °C</td>
</tr>
<tr>
<td>Stability to Heat (2 hrs @ 140 °C)</td>
<td>Max 40 apha (=HAZEN)</td>
</tr>
<tr>
<td>Assay</td>
<td>Min. 99.5%</td>
</tr>
</tbody>
</table>

**BASF MA Catalysts Global Reference List**

**Internal BASF Reference List**
- Belgium
- Feluy
- China
- Caojing

**External BASF Reference List**
- Taiwan
- China
- Spain
- Bosnia
- Korea
- South Africa
- US
- Germany
Customers who utilize our catalysts are offered individualized service agreements for a wide range of technical services. BASF’s dedicated technical service team has extensive experience in oxidation and dehydrogenation catalytic behavior under a variety of operating conditions. This technical team is equipped with a full range of resources to analyze the most complex problems, and has full access to our R&D facility and dedicated R&D personnel. This comprehensive service approach provides the best possible assistance to our customers anytime and anywhere in the world.

Each region in the world is assigned a dedicated BASF technical team:

**Asia Pacific**
through our MA catalyst global business management in Shanghai

**Europe, the Middle East, and Africa (EMEA)**
through our technical service team in Ludwigshafen

**Americas**
through our technical service team in Ludwigshafen

### Features
- Catalyst selection and performance forecasting
- Loading and start-up support
- Performance evaluation and optimization of current run by using portable CO \(_2\) analyzer
- Analysis of aged catalyst
- Troubleshooting
- Lifetime calculations
- Training of production staff
- Verification of air flow measurements by total combustion
- ROG MA yield calculation

### Customer Support: BASF Maleic Anhydride Catalyst Package
BASF provides not only the fitting Maleic Anhydride catalyst. In addition, we provide top class technological expertise by our experts as well as guidelines for the catalyst’s use. We support our customers even by conducting dedicated experiments in our R&D department, in case that is necessary. Last but not least, we offer in-depth catalyst training covering the whole theoretical background of this technology.

### BASF Offers Excellent Technical Service for MA Catalysts
- Operation manual
- Catalyst loading accessories (racks, spring coils, plastic caps, filling machines, complete apparatus for measuring pressure drop, support material for filling thermowell tubes)
- Loading and startup assistance (on site supervisors for loading and experts for startup)
- Technical visits and discussion on the operating data to optimize MA yield
- Invitation to BASF’s PA/MA global and regional experience exchange meetings
- Monitoring the catalyst production by testing the produced catalyst for its performance in the mini-plant under normal reaction conditions

### All Tools for a Successful Catalyst Improvement are Available at Basf
- Operation manual
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About Us

BASF’s Catalysts division is the world’s leading supplier of environmental and process catalysts. The group offers exceptional expertise in the development of technologies that protect the air we breathe, produce the fuels that power our world and ensure efficient production of a wide variety of chemicals, plastics and other products, including advanced battery materials. By leveraging our industry-leading R&D platforms, passion for innovation and deep knowledge of precious and base metals, BASF’s Catalysts division develops unique, proprietary solutions that drive customer success.

BASF – We create chemistry

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