

BASF

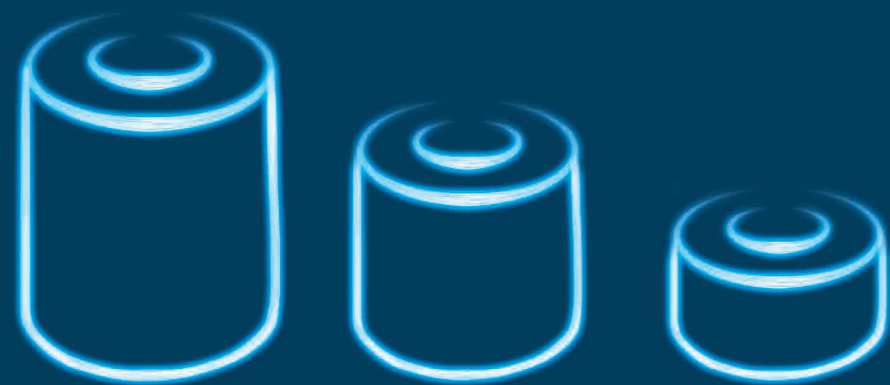
We create chemistry

The highest performance maleic anhydride (MA) catalysts by the world's leading MA producer



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BASF Catalysts Introduction

<p>Agricultural Solutions</p> <p>Petrochemicals Intermediates</p>		<p>BASF – We create Chemistry</p> <ul style="list-style-type: none"> Our chemistry is used in almost all industries. We combine economic success, social responsibility and environmental protection. Sales 2020: €59.1 billion EBIT before special items 2020: €3.6 billion Employees (as of December 31, 2020): 110,302 6 Verbund sites and 241 other production sites Around 90,000 customers from various sectors in almost every country in the world 	
	<p>Materials</p> <p>Performance Materials Monomers</p>		
	<p>Chemicals</p> <p>Petrochemicals Intermediates</p>	<p>Industrial Solutions</p> <p>Dispersions & Pigments Performance Chemicals</p>	
<p>Surface Technologies</p> <p>Catalysts Coatings</p>		<p>Nutrition & Care</p> <p>Care Chemicals Nutrition & Health</p>	

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

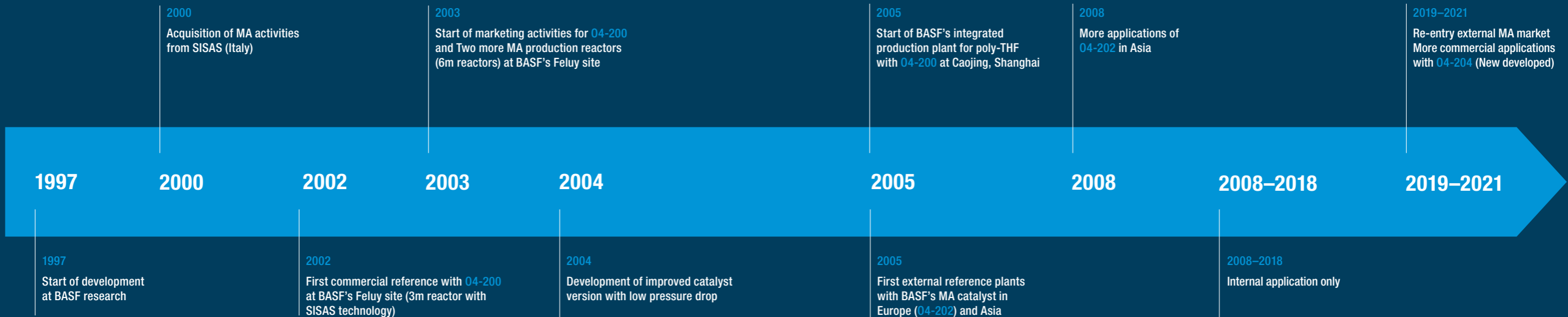
- Own Catalyst R&D with lab and pilot scale production including performance testing at Ludwigshafen, Germany
- Own MA catalyst production at Ludwigshafen, Germany
- Own MA reference plants under different operation conditions (e.g., single pass, recycle mode)
- The excellent technical service from BASF 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 I_{n-C4} /t^h
- 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 malic, fumaric polyaspartic acids
- Lubricating oil additive
- Polybutylene succinate (PBS), biodegradable aliphatic polyester
- Others, such as engineering plastics, fine chemicals, pharmaceuticals



Organization of the Maleic Anhydride Catalyst Business

AMERICAS

Iselin, New Jersey

- Catalysts Division Headquarters
- Regional Sales
- Regional Customer Service and Supply Chain

Sao Paulo, Brazil

- Sales Office

EMEA

Dubai, United Arab Emirates

- Sales Office

Ludwigshafen, Germany

- Catalyst Production
- Catalyst Research
- Regional Sales
- Technical Service

Al-Khobar, Saudi Arabia

- Sales Office

ASIA

Shanghai, China

- Oxidation and Dehydrogenation Catalysts Global Business Management
- Regional Sales
- Technical Service
- Regional Customer Service and Supply Chain

Seoul, South Korea

- Sales Office

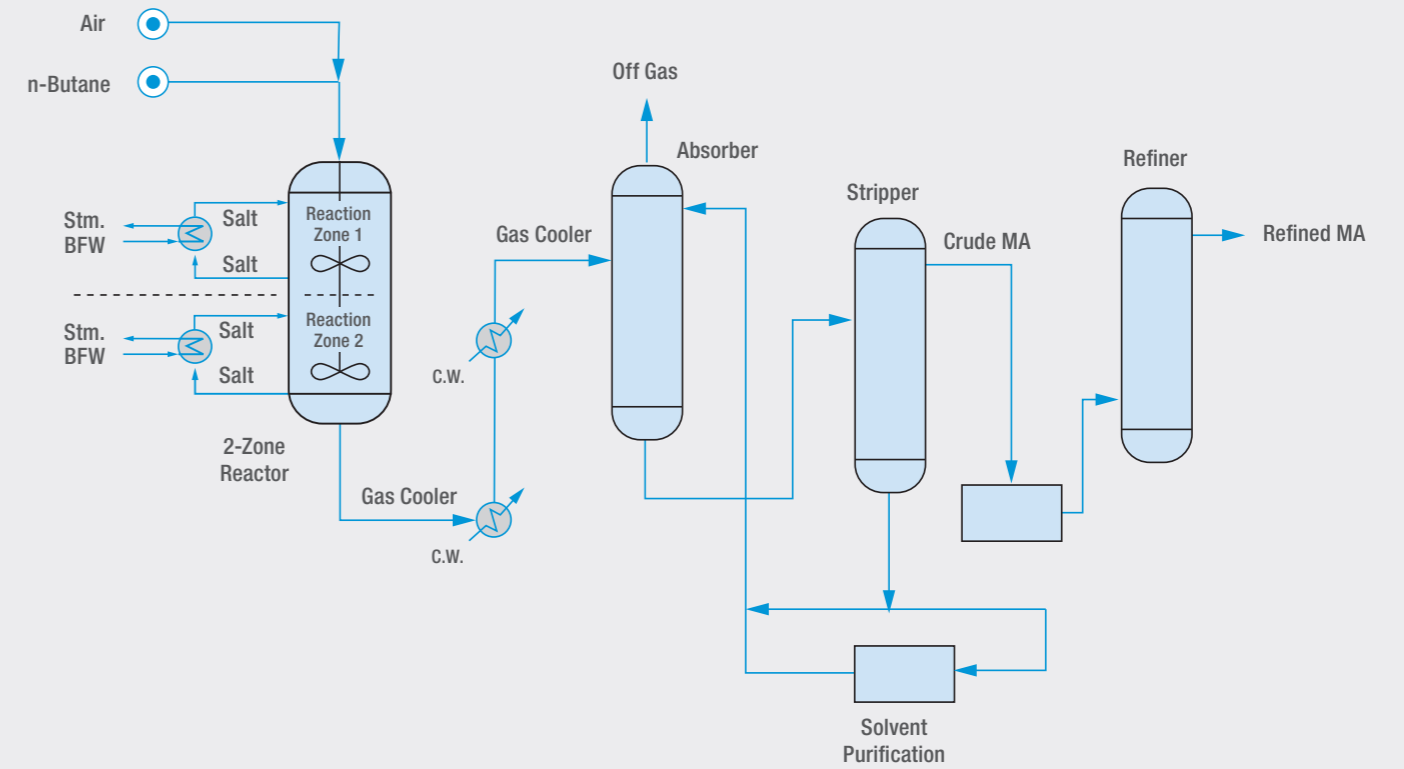
Mumbai, India

- Sales Office

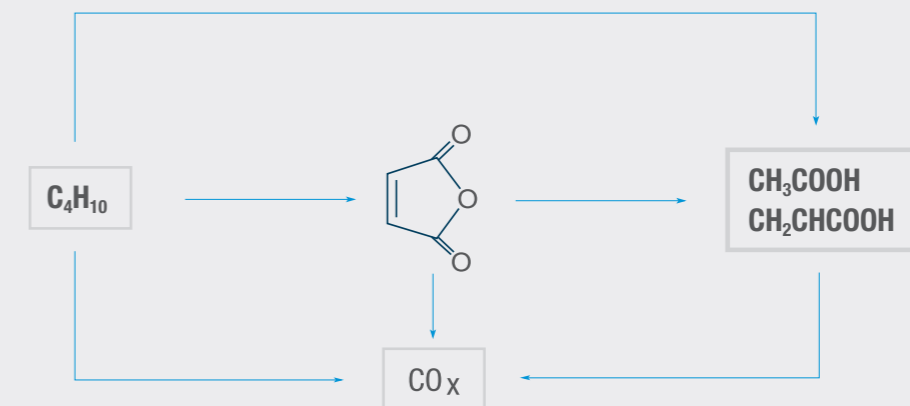


BASF's n-Butane to Maleic Anhydride Process

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.



From n-Butane to Maleic Anhydride Simplified Reaction Scheme



BASF Research & Development

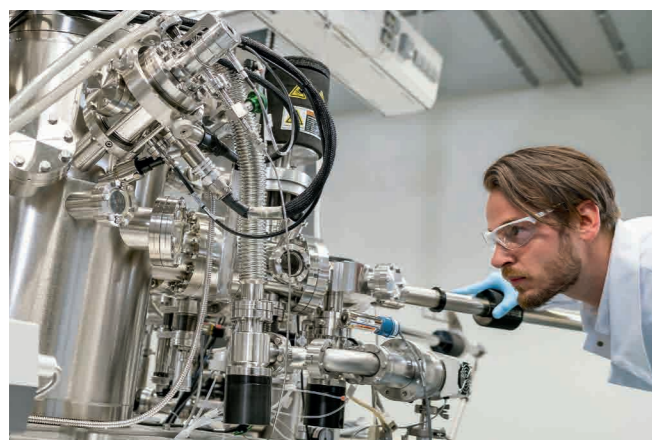
Innovation – New Processes, Technologies and Products for a Sustainable Future

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 partner

- 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

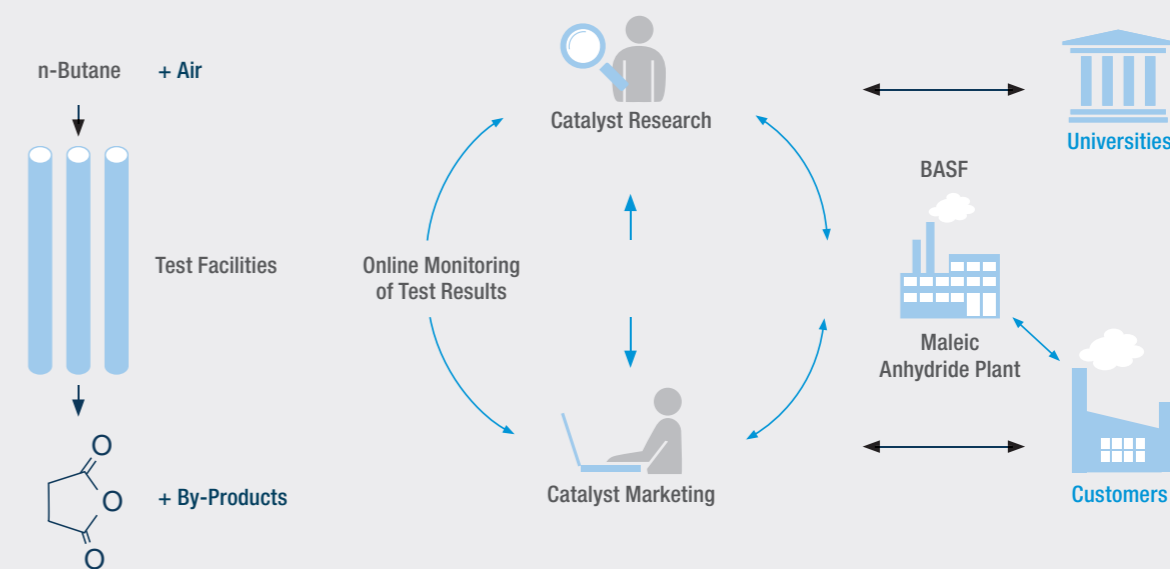


Pilot-Scale Testing... ...the Key to Success

Full-scale pilot reactors for MA catalysts technology:

- Best possible quality control
- Most accurate performance measurements for new developments
- Directly measure real scale effects

BASF Maleic Anhydride Catalyst Research



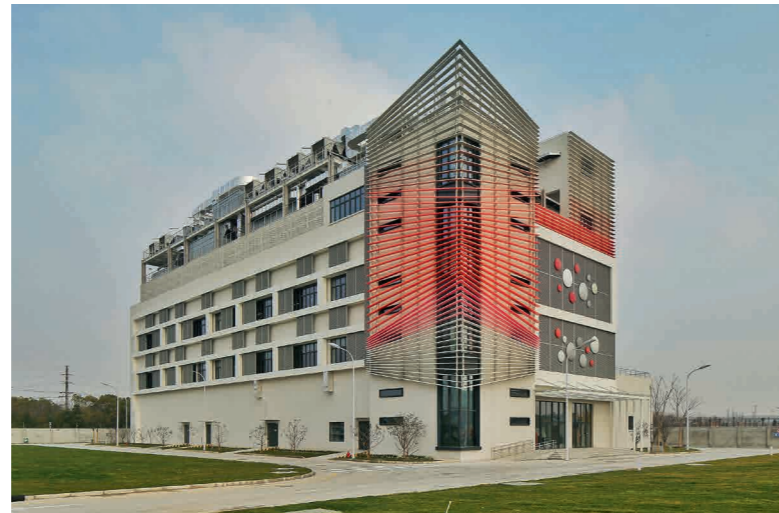
Catalyst Research Organizational Set-up

North America	Europe	Asia
Iselin <ul style="list-style-type: none"> ■ Refining Catalysts ■ Emerging Technologies 	Ludwigshafen <ul style="list-style-type: none"> ■ Custom Catalysts and Scale Up ■ Catalysis for Monomers, Intermediates and Fine Chemicals ■ Oxidation Catalysts ■ New Technologies in Process Catalysts 	Shanghai <ul style="list-style-type: none"> ■ Process Catalysts Research Asia ■ Emerging Technologies
Iselin / Beachwood / Vidalia <ul style="list-style-type: none"> ■ Process Catalysts Research North America 	Berlin <ul style="list-style-type: none"> ■ BesCat – UniCat BASF Joint Lab 	

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



Shanghai R&D center



Maleic Anhydride



BASF Maleic Anhydride Catalyst Portfolio

Catalyst	04-204
Application	Oxidation of n-butane to maleic anhydride (fixed bed)
Catalyst Composition	Vanadyl-pyrophosphate (VO) ₂ P ₂ O ₇ doped with additives
Catalyst Shape & Size	Rings 6.5x5.0x3.7 mm, 5.5x3.0x3.0 mm
Synthesis	Chloride free
Delivery State	Activated

Typical BASF Maleic Anhydride Catalyst Operation Conditions

n-Butane Feed Rate	Up to 2.2 vol.-%
n-Butane Conversion	82-87 %
Gas Flow Rate	GHSV up to 2,200 hr ⁻¹
Salt Bath Temperature	Start of run: approx. 390–410 °C, end of run: approx. 430–440 °C
Hot Spot Temperature	420 °C–450 °C, or as discussed and agreed with BASF as hot spots arise
P-Dosage	Necessary for stable operation
Humidity	Referably adjusted with steam to 2.0–3.0%

BASF Maleic Anhydride Catalyst Typical Reactor Condition

Number of Tubes	5,000 up to 50,000
Inner Diameter of Tube	21–25 mm
Tube Length	2,500–7,000 mm

Expected Quality of Pure MA

Property	Specification
Color Number	Max 20 (APHA)
Crystallizing Point	52.6–52.8 °C
Stability to Heat (2 hrs @ 140 °C)	Max 40 apha (=HAZEN)
Assay	Min. 99.5%

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



Support Technical Services

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.

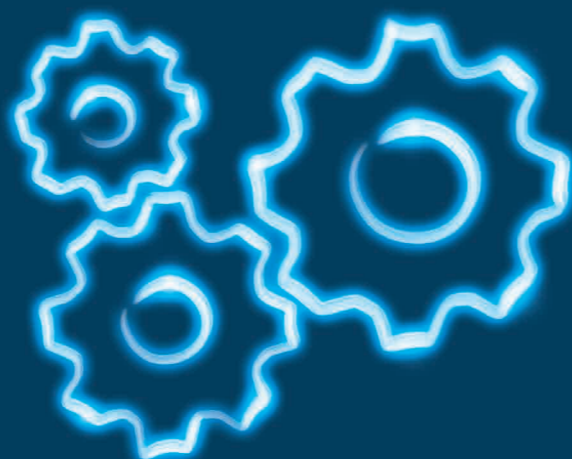
Asia Pacific
through our MA catalyst global business management in Shanghai

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_x analyzer
- Analysis of aged catalyst
- Troubleshooting
- Lifetime calculations
- Training of production staff
- Verification of air flow measurements by total combustion
- ROG MA yield calculation

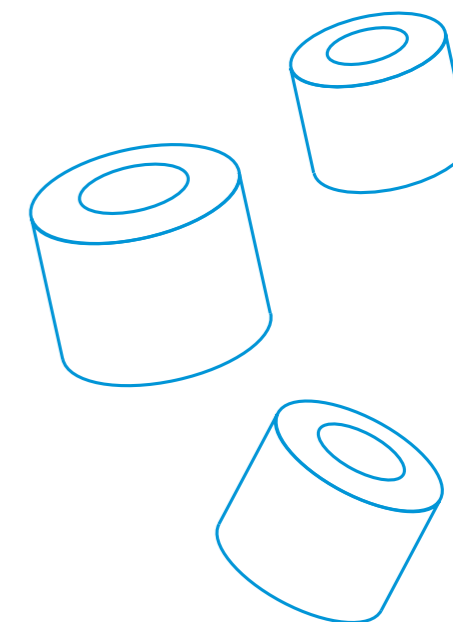


Customer Support: BASF Maleic Anhydride Catalyst Package

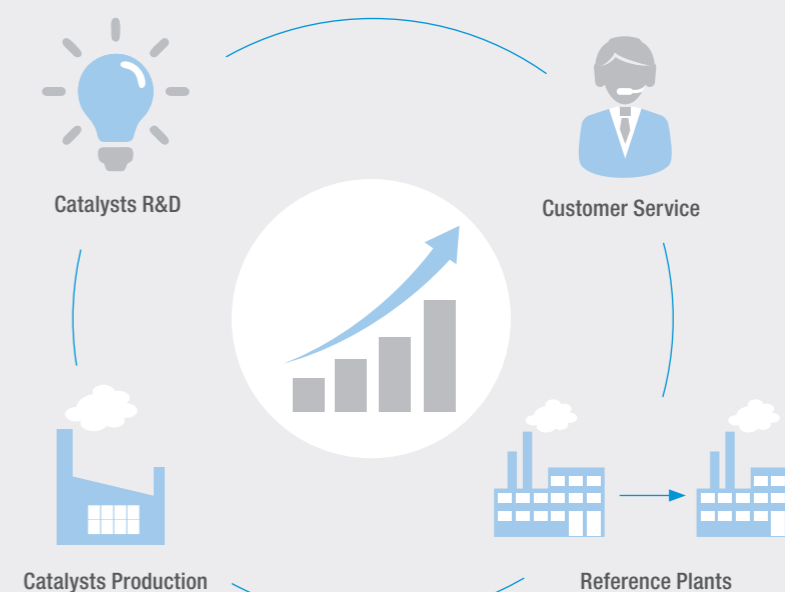
BASF provides not only the fitting Maleic Anhydride catalyst. In addition, we provide top class technological expertise by our experts as well as guidelines for the catalyst's use. We support our customers even by conducting dedicated experiments in our R&D department, in case that is necessary. Last 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





We create chemistry

Americas

BASF Corporation
25 Middlesex/Essex Turnpike
Iselin, New Jersey, 08830, USA
Tel: +1-732-205-5000
Fax: +1-732-205-7725
Email: catalysts-america@basf.com

Asia Pacific

BASF (China) Company Limited
300 Jiang Xin Sha Road
Pudong, Shanghai 200137
P.R. China
Tel: +86-21-2039 2549
Fax: +86-21-2039 4800-2549
Email: catalysts-asia@basf.com

Europe, Middle East, Africa

BASF De Meern BV Catalysts
The Netherlands
Tel: +31-30-666 9444
Email: catalysts-europe@basf.com



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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