

□ - BASF

We create chemistry

Do you want to combine experience with innovation?

BASF Phthalic Anhydride Catalysts are the market
leading solution for your oxidation process.



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BASF Catalysts Introduction

BASF – We create Chemistry

As the world's leading chemical company, BASF:

- Offers intelligent solutions and high-quality products for most industrial challenges
- Uses new technologies to optimize additional market opportunities
- Combines added value with environmental protection and social responsibility

BASF at a Glance

At BASF, we create chemistry for a sustainable future. We combine economic success with environmental protection and social responsibility. More than 117,000 employees in the BASF Group work on contributing to the success of our customers in nearly all sectors and almost every country in the world. Our portfolio is organized into six segments: Chemicals, Materials, Industrial Solutions, Surface Technologies, Nutrition & Care and Agricultural Solutions.

BASF has companies in more than 90 countries. We operate six Verbund sites and 361 additional production sites worldwide. Our Verbund site in Ludwigshafen, Germany, is the world's largest chemical complex owned by a single company that was developed as an integrated network. This was where the Verbund principle was originally established and continuously optimized before being implemented at additional sites.

BASF's Catalysts division, headquartered in Iselin, New Jersey, is the world's leading supplier of environmental and process catalysts. The group employs more than 5,000, with over 30 manufacturing sites worldwide.

As a global division of BASF SE, Ludwigshafen, Germany, Catalysts 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 its industry-leading research and development (R&D) platforms, passion for innovation and deep knowledge of precious metals, BASF's Catalysts division develops unique, proprietary catalyst and adsorbent solutions that drive customer success.



Organization of the Phthalic Anhydride Catalyst Business

AMERICAS

Iselin, New Jersey

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

Sao Paulo, Brazil

- Sales Office

EMEA

Ludwigshafen, Germany

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

De Meern, Netherlands

- Sales Office
- Regional Customer Service and Supply Chain

Moscow, Russia

- 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

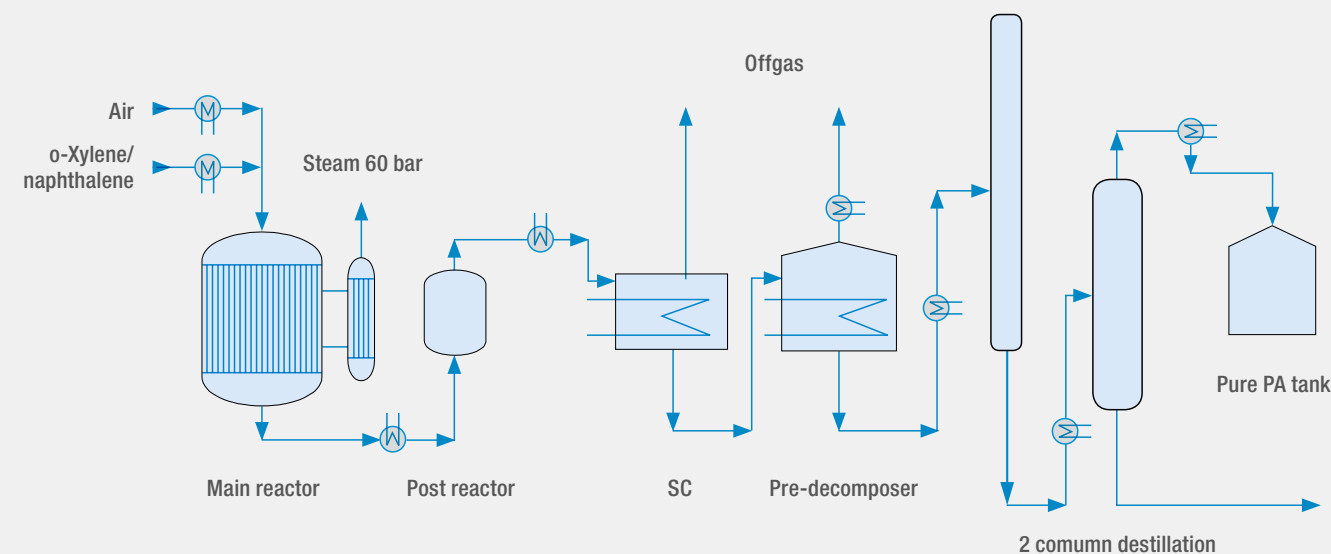
Mumbai, India

- Sales Office

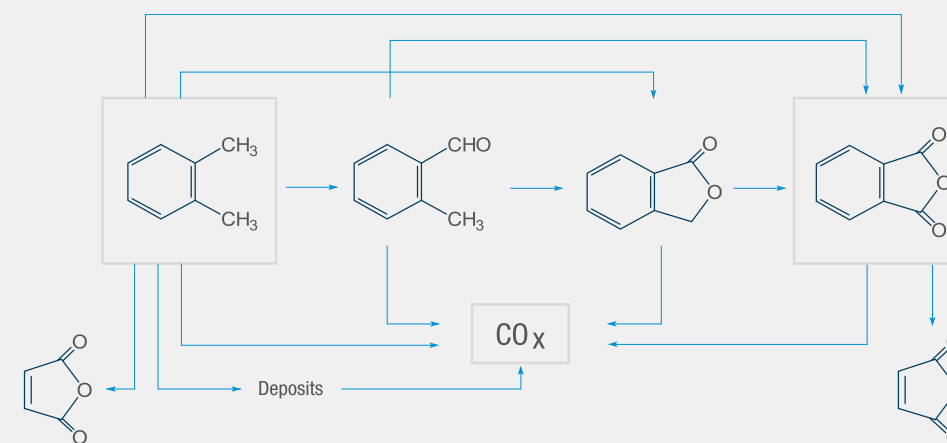


Phthalic Anhydride Process

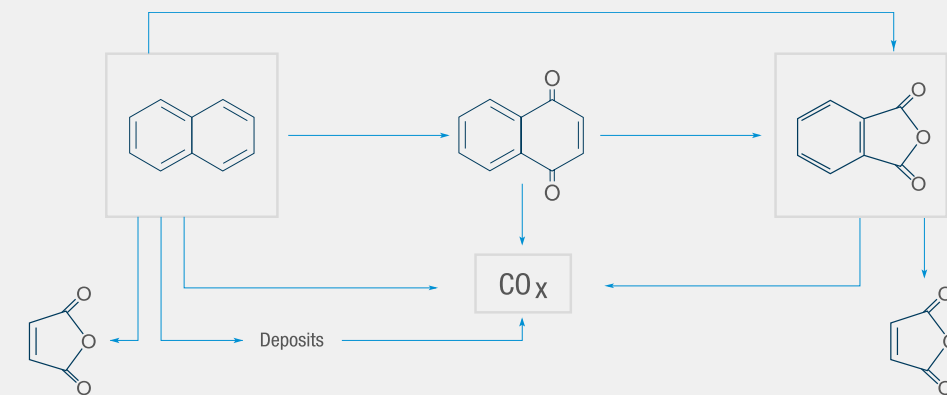
Permanent Improvement of Process and Catalyst



From o-Xylene to Phthalic Anhydride



From Naphthalene to Phthalic Anhydride



Advantages of BASF as a Phthalic Anhydride Catalyst Supplier

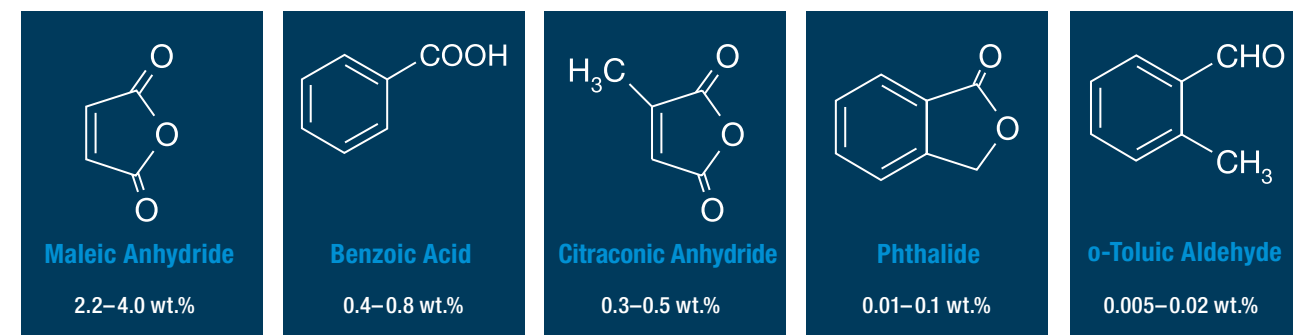
BASF offers over 140 years experience in Phthalic Anhydride (PA) production and 120 years in PA catalysts research. This legacy forms a strong foundation for continuous innovation and product improvement. Products and services are continually reviewed for alignment with our customers' needs through regular BASF Phthalic Anhydride Customer Forum meetings. Delivery of our product to the customer site is just the beginning of our offering. BASF stands behind its products and, through our technical service representatives in Asia, Europe and America, ensures that our products perform and deliver value. We innovate to make our customers successful.

Value Added Customer Service

From order placement through invoicing, BASF's Customer Service functions as the customer's voice by:

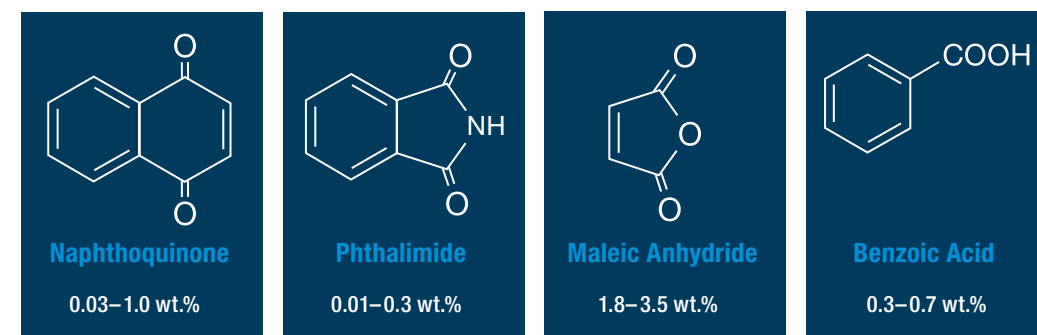
- Assigning a primary customer service representative
- Providing a Customer Service Network with 3 central hubs
- Addressing customer concerns in the language of the customer

Main By-Products in Reaction Gas (o-Xylene feed)



Typical concentrations in reactor outlet gas (ROG) at 100 g/Nm³ for o-Xylene feed.

Main By-Products in Reaction Gas (naphthalene feed)



Typical concentrations in reactor outlet gas (ROG) at 80 g/Nm³ for naphthalene feed.

Expert Technical Service

Our technical service staff has extensive professional experience in Phthalic Anhydride catalysts, including hands on operational expertise in the areas of supervision, start up assistance and catalyst performance optimization. BASF has more than 80 years of experience in the loading and start up supervision of Phthalic Anhydride catalysts.

- o-Xylene and naphthalene/mixed feed oxidation in fixed bed process
- o-Xylene loadings up to 100 g/Nm³
- Supply of complete catalyst filling and measurement equipment on loan basis, including 5-tube, 10-tube and 20-tube catalyst filling machines
- Optimization of catalyst operation condition using portable CO_x analyzers
- Verification of air flow measurements by total combustion

BASF Research & Development

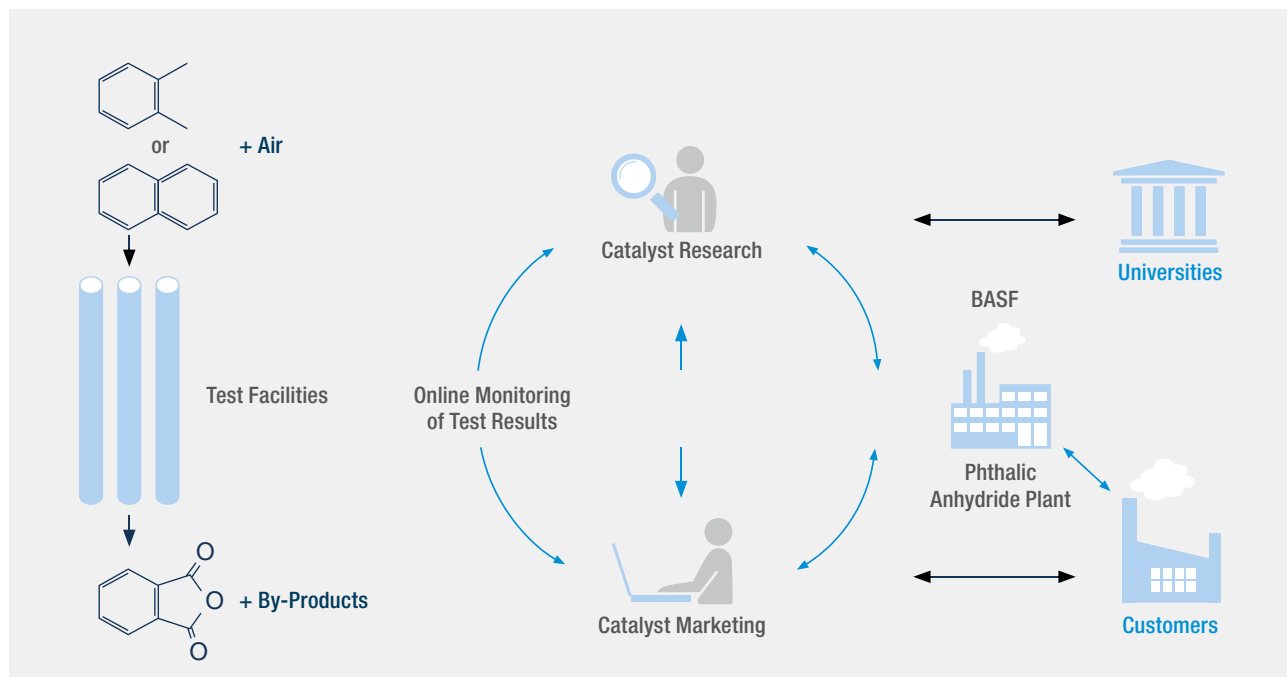
With research and development, we shape the future and develop profitable growth. In 2018, we generated sales of around € 9 billion with products launched on the market in the past five years that stemmed from research and development activities. Optimized processes and intelligent system solutions, along with new and innovative products, make key contributions to the long-term success of our customers as well as ourselves. At BASF, more than 11,000 employees are working worldwide in research and development at approximately 70 locations.

BASF's Research Verbund covers the central technology platforms, the research and development units in our operating divisions worldwide and at group companies, as well as affiliated companies. In addition, we are currently involved in more than 1,900 collaborative partnerships worldwide with leading universities, research institutes, startup companies, and industrial partners, which add momentum to our research activities around the world.

- BASF leads the world's chemical industry in expenditures for R&D with more than 2 billion € in investments.
- As the strongest innovation power in the chemical industry, BASF is ranked first in the Patent Asset Index™.
- BASF filed 1,000 new patents in 2019.



BASF Phthalic Anhydride Catalyst Research



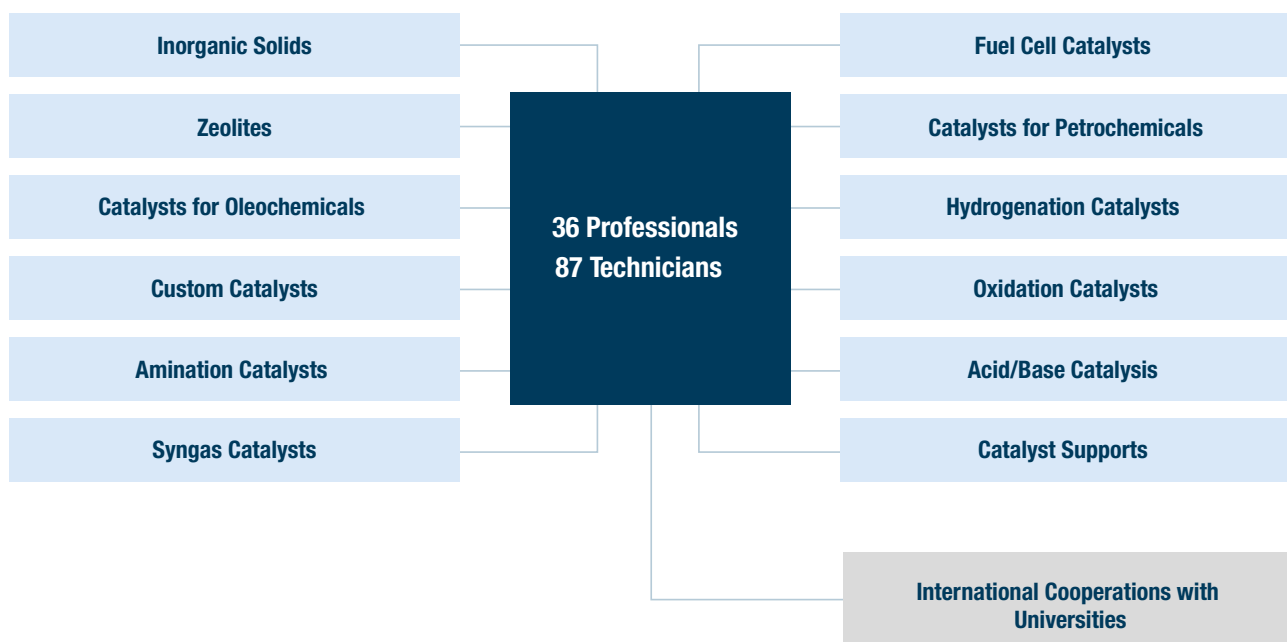
Shanghai BASF Process Catalysis R&D Center

- 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 PA catalysts customer
 - Catalysts characterization: ICP-OES, XRF, XRD, SEM/TEM, BET, XPS
 - PA composition analysis: PPA, CPA, ROG, light ends, heavy ends analysis, through GC, GC-MS
 - Raw material analysis: o-Xylene and naphthalene analysis through GC, GC-MS, AAS, CHNS/O analyzer

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



Catalyst Research Ludwigshafen



Shanghai R&D center

Phthalic Anhydride Catalyst Portfolio

Catalyst Portfolio for o-Xylene Oxidation

Phthalic Anhydride Catalyst	O4-68	O4-66	O4-88	O4-888
Application	Gas phase Oxidation of o-Xylene to PA			
Composition	V ₂ O ₅ , TiO ₂ and Promotors on Ceramic Rings			
Shape [mm]	Rings, 7*7*4			
Filling Density [kg/l]	approx. 0.93 in 25 mm ID tube			
Air max. [Nm ³ /h/tube]	4.0			
Thermal Stability [°C]	up to 500			
Load [g/Nm ³]	max. 80	max. 100	max. 100	max. 100
Layers	4	4	5	5
Filling Height [m]	2.2*–3.4	3.0–3.7	3.0–3.7	3.0–3.7
Initial Salt Bath temperature [°C]	350–355	345–350	343–348	342–347
PA-Yield (Reactor Gas) [wt.-%]	114–115	114–115	115–116	115.5–116.5
Phthalide (Reactor Gas) [wt.-%]	0.02–0.07	0.02–0.1	0.02–0.1	0.02–0.08
Aromatics (In Off Gas) [mg/m ³]	20–40	20–40	20–40	20–40
Start-Up time [day]				
To 80 g/Nm ³	18	28	34	34
To 100 g/Nm ³	–	55	62	62
Restart Time [day]				
To 80 g/Nm ³	1	1	1	1
To 100 g/Nm ³	–	1–2	1–2	1–2

* in combination with post reactor

Expected Quality of Pure PA by BASF o-x Feed PA Catalysts

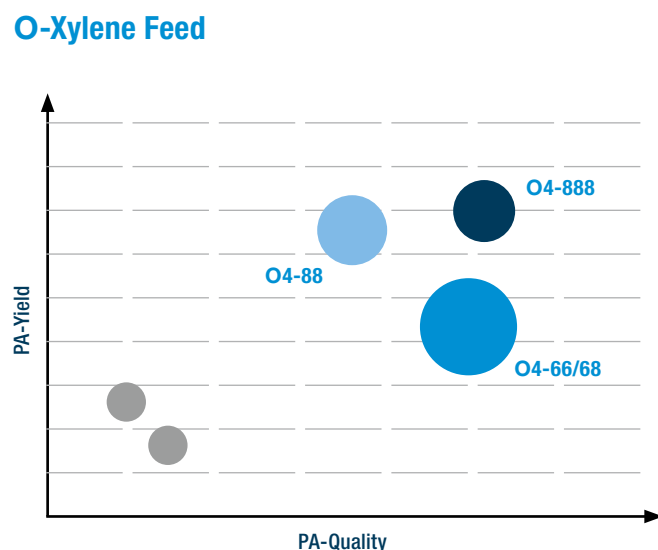
Purity [wt.-%]	> 99.9
Solidification Point [°C]	> 131.0
Color (Hazen) [APHA]	5–10
Heat Stability [APHA] (90 min, 250°C)	15–30

Our portfolio offers **innovative solution**
for **every challenge in oxidation.**

Phthalic Anhydride



For PA producers, BASF's o-Xylene catalysts offer safe operation at maximum capacity up to **100 g/Nm³** feed with superior **PA quality guaranteed** by **expert technical service** and **long-term commitment in innovation** demonstrated in the **world's longest reference list** and **in-house operation**.



O4-68 Catalyst Advantages

- Higher proportion of selective layers per tube
- Hot Spot (HS) remains longer in selective layers
- Higher Phthalic Anhydride yield in 2nd operation year
- Top performance for low loading

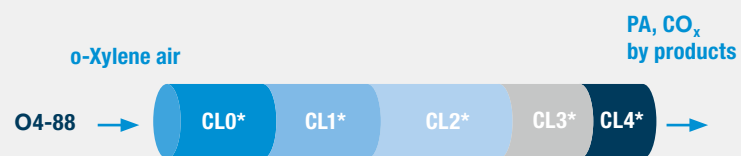
O4-66 Catalyst Advantages

- Improved 4-layer catalyst generation
- Improved stability of 1st catalyst layer
- Designed for harsh operation conditions
- Higher Phthalic Anhydride yield in 2nd and 3rd operation year



O4-88 Catalyst Advantages

- Higher yield vs. O4-66
- 3 selective layers
- Patented new active mass
- Easy start-up behavior



O4-888 Catalyst Advantages

- 5 layer catalyst system
- Improved selective layers and active layers
- Excellent product quality



* O4-88
** O4-888

Reference List

O4-66	O4-68	O4-88	O4-888
China Nan Ya Nanjing Libang Qilu Plasticizers Shandong Hongxin Shandong Lihuayi Shanghai Huayi Shijiazhuang Bailong Tongling Organic UPC Linyuan UPC Malaysia UPC Nanchong UPC Panjin UPC Zhongshan UPC Zhuhai Zhejiang GST India IG Petrochemical Thirumalai Korea Hanwha Thailand Continental Petrochemical Pakistan Nimir Japan Kawasaki Kasei Austria Atmos Belgium OBC Belarus Lida Turkey Petkim Russia Kamtex Germany BASF SE	Korea Aekyung Russia Gazprom Sweden Perstorp USA Stepan	China Nan Ya Shandong Hongxin UPC Taizhou UPC Zhenjiang Korea Aekyung India IG Petrochemical Thirumalai Germany BASF SE Lanxess Israel Gadiv Brazil Elekeiroz Petrom	China UPC Zhenjiang UPC Zhuhai Korea Aekyung Germany BASF SE Lanxess Brazil Petrom Chile Panimex Colombia Carboquimica

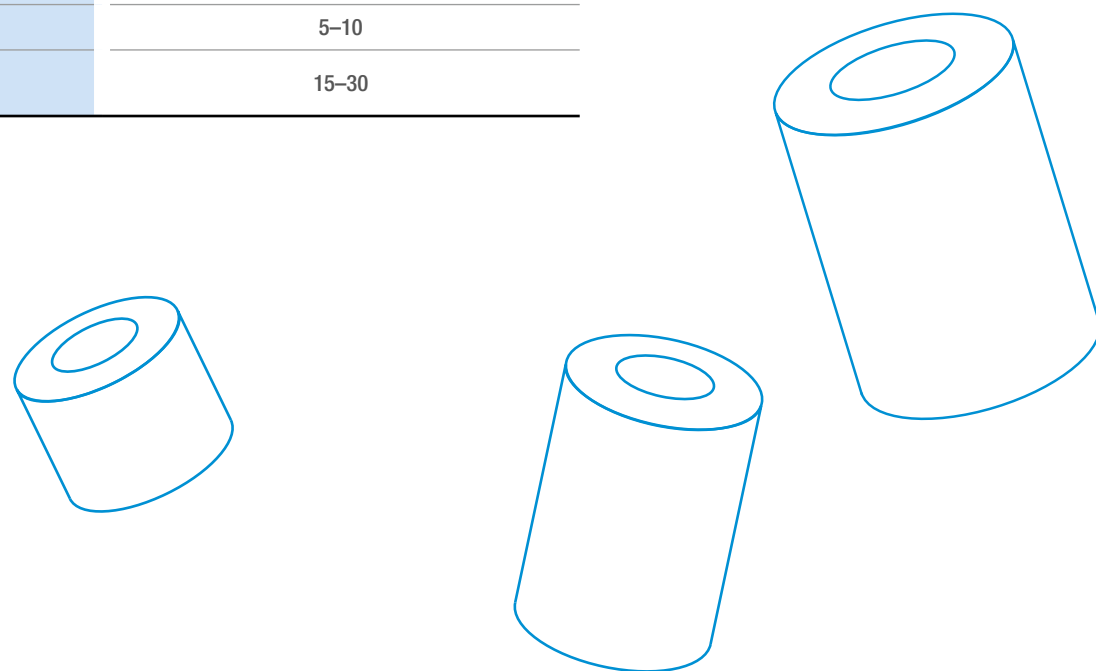


Catalyst Portfolio for Naphthalene/Mixed Feed Oxidation

Phthalic Anhydride Catalyst	O4-29 HiFlex II	O4-35
Application	Gas phase Oxidation of Naphthalene/Mixed feed to PA	
Composition	V ₂ O ₅ , TiO ₂ and Promotors on Ceramic Rings	
Air max. [Nm ³ /h]	4.0	
Thermal Stability [°C]	up to 500	
Feed (Ratio)	Naphthalene Feed: 100–35% o-Xylene: 0–65%	Naphthalene Feed: 100–50% o-Xylene: 0–50%
Load [g/Nm ³]	Naphthalene: 80 Mixed Feed: 85	Naphthalene: 85 Mixed Feed: 90
Layers	4	5
Shape [mm]	Rings, 8*6*5	CL1/CL2/CL3: Rings, 8*6*5 CL4/CL5: Rings, 7*7*4
Filling Density [kg/l]	approx. 0.88 in 25 mm ID tube	CL1/CL2/CL3: approx. 0.88 in 25 mm ID tube CL4/CL5: approx. 0.93 in 25 mm ID tube
Filling Height [m]	2.9–3.5	3.0–3.5
Initial Salt Bath Temperature [°C]	355–365	350–365
Phthalic Anhydride Yield (Reactor Gas) [wt.-%]	Naphthalene: 104.5–105.5 o-X/Naphthalene (50:50): 109.5–110.5	Naphthalene: 104–105 o-X/Naphthalene (50:50): 109–110
By-products in Reactor Gas		
Naphthoquinone [wt.-%] (100% Naphthalene Feed)	0.05–1.0	0.03–0.5
Phthalide [wt.-%] (50/50 Feed)	0–0.05	0–0.03

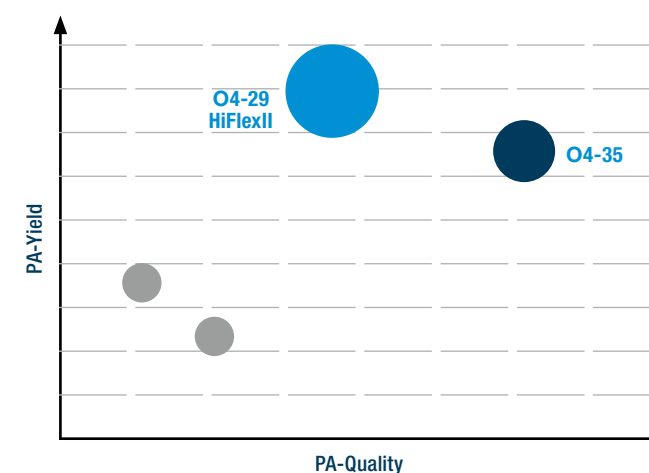
Expected Quality of Pure PA by BASF Naphthalene/Mixed Feed PA Catalysts

Purity [wt.-%]	> 99.9
Solidification Point [°C]	> 131.0
Color (Hazen) [APHA]	5–10
Heat Stability [APHA] (90 min, 250°C)	15–30



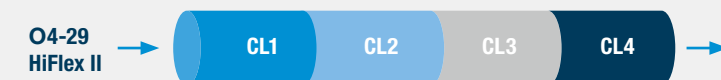
For PA producers, BASF's Naphthalene and mixed feed catalysts offer **superior PA yield** and **leading PA quality guaranteed** by **expert technical service** and **long-term commitment in innovation** demonstrated in the **world's longest reference list**.

Naphthalene/Mixed Feed



O4-29HFII Catalyst Advantages

- Improved 4 layer catalyst generation
- Higher yield vs. O4-29HF
- Up to 65% o-Xylene in feed

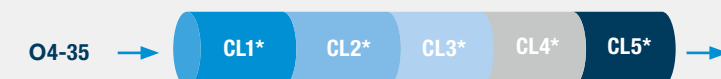


naphthalene
o-Xylene air

PA, CO_x
byproducts

O4-35 Catalyst Advantages

- Latest generation 5-layer catalyst system
- Catalyst geometry adjusted for maximum performance
- Superior PA quality



* O4-35

Reference List



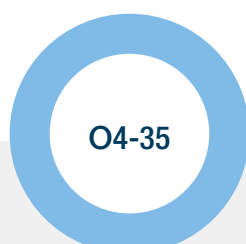
O4-29
HiFlex II

- | | |
|---|---|
| China
Cixian Sinbo
Henan Qing'an
Jining Carbon
Jiaozuo Qirui
Kaifeng Jiuhong
Qilu Plasticizers
Shandong Hongxin
Shijiazhuang Bailong
Taixing Union Zond
Tangshan Risun
Xingtai Risun
Zaozhuang JFE | Korea
OCI

Brazil
Elekerioz

USA
Koppers

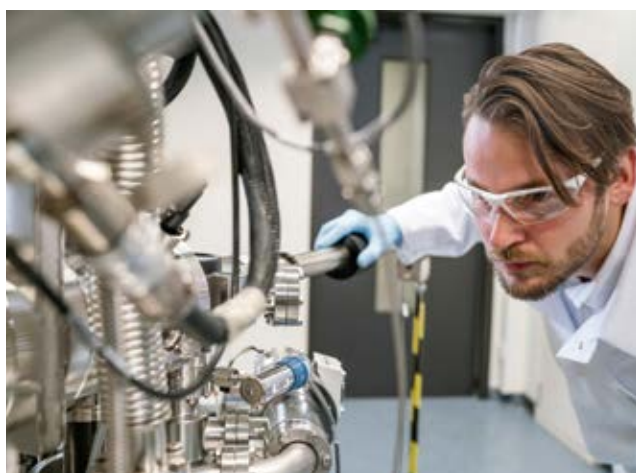
Czech Republic
Deza |
|---|---|



O4-35

- | |
|--|
| China
Huanghua Xinnuolixing

Belgium
Rain Carbon |
|--|



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 PA catalyst global business management in Shanghai

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

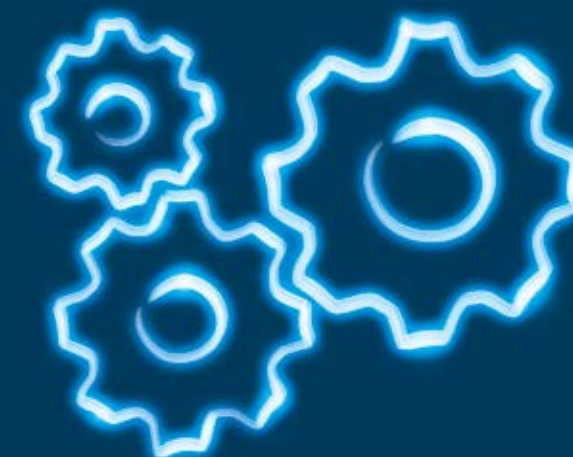
Americas
through our technical service team in Ludwigshafen

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 PA yield calculation

Customer Support: BASF Phthalic Anhydride Catalyst Package

BASF provides not only the fitting Phthalic 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.





We create chemistry

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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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