Bayferrox® New Red
A new generation of red iron oxide pigments

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Agenda

1. The Iron Oxide Industry in Transition
2. LANXESS IPG’s New Plant in Ningbo/China
3. The Ningbo Process
4. Bayferrox® New Reds
The iron oxide industry in transition
Sustainability main driver for drastic changes in landscape
Synthetic iron oxide pigments – Global market overview
By color / by region / by application

Market for synthetic iron oxide pigments in 2015 (kt in %)

Demand by color
- Red 43%
- Yellow 29%
- Black 23%
- Blends 5%

Demand by region
- Americas 26%
- EMEA 34%
- APAC 40%

Demand by application
- Construction 48%
- Coatings 26%
- Plastics 5%
- Paper 3%
- Other 18%

Source: LANXESS Inorganic Pigments
Iron oxide demand – Urbanization and increasing per-capita income have been the main drivers for growing pigment demand globally.

More people live inside the circle than outside.

Number of global megacities is set to rise.

Development of Urban Population

While synthetic iron oxide production plants are spread all over the world, there are only two real centers of capacities globally – Germany & China.
Tightening environmental regulations in China are a major driver for the consolidation of the iron oxide industry in China and thus, globally.

Sustainability is the key challenge for producers in China

- China is the largest producer of iron oxide pigments
- Traditional Penniman process with bad input-output ratio and extreme environmental issues
- ~20 closures of production plants in China since 2012 due to strict environmental protection enforcement measures

Source: Thomson Reuters Foundation, Ministry of Environmental Protection of China, Ministry of Land and Resources of China
The task of building an ecological civilization has been included for the first time into the 13th Five-Year Plan. In China, we will implement the most stringent environmental protection system. Enterprises who fail to meet the standards will be shut down or regulated to reorganize.

Wenchao Zang, Ministry of Environmental Protection (MEP), China
2nd Pigments Symposium, Nov 2015

China is the largest producer of pigments and paints in the world BUT:

- Manufacturing scale is generally small
- Industry concentration is low
- Technological innovation strength is relatively weak
- Mostly low quality and low price
- High emissions with harmful environmental influence

“China’s current industrial structure is irrational because low-output industries with high input, high energy consumption and high emissions still account for a large percentage of the overall national economic structure.

……I think this will have an extremely important significance for the future of pigment production in China, and it has a very important role in promoting the closure of outdated production facilities in China.”

Xu Shufan
Ministry of Environmental Protection (MEP), China
1st Pigments Symposium, Nov 2013

“The task of building an ecological civilization has been included for the first time into the 13th Five-Year Plan. In China, we will implement the most stringent environmental protection system. Enterprises who fail to meet the standards will be shut down or regulated to reorganize.”

Wenchao Zang, Ministry of Environmental Protection (MEP), China
2nd Pigments Symposium, Nov 2015

Update - 3rd Pigment Symposium to take place January 2017 in Las Vegas, USA
The LANXESS IPG Ningbo Process
A breakthrough in iron oxide red technology
Traditionally four primary industrial processes were used for the production of synthetic iron oxide red pigments.
Chinese producers primarily have been using the Penniman Red Process for the production of synthetic iron oxide red.

The waste water of the Penniman red process contains ammonium nitrate, which is a very potent fertilizer.

- Discharging of ammonium nitrate into rivers and lakes leads to eutrophication and thereby to fish mortality and shortage of drinking water supply.

Untreated waste water can cause eutrophication.
The traditional Penniman Red Process offers a range of very attractive bright red pigments, but it is challenging due to extreme environmental issues.

### Penniman Process

- **HNO₃**
  - 1. Iron nitrate

- **Fe**
  - 2. Seed

- **Air**
  - 3. Penniman-Reaction

- **Steam**

- **Filtration, Washing**

- **Drying (and Milling)**

- **Red Pigment**

### Waste gas emission

- The waste gas from the process consists of toxic nitric oxides (NO, NO₂) and laughing gas (N₂O)

### Laughing gas

- is a strong greenhouse gas with a 310 times higher impact than carbon dioxide
- is also a very potent ozone-depleting substance leading to holes in the stratospheric ozone layer
- is one of the biggest threats to the ozone layer, which protects the earth from UVB radiation
Summary: the traditional Penniman Red Process – produces attractive red shades but toxic nitrogen oxides, laughing gas and ammonium nitrate are emitted.
Our Challenge for Ningbo: To supply the global market with the required bright red pigments but to do this in the most sustainable way

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<td>Recycling of by-products to save raw materials</td>
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<td>Catalytic decomposition of waste gases</td>
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<td>Reduced demand for process water</td>
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<td>Efficient water purification to remove ammonium nitrate</td>
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<td>Re-use of purified waste water in the process (internal recycling)</td>
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<td>Reduced energy demand by recipe and process optimization</td>
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<td>Recovery of energy by e.g. applying heat exchanger</td>
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The LANXESS solution: The new Ningbo Process offers successful control and reduction of waste gas emissions, including laughing gas

**Reduction of emissions**

- Nitric oxides and laughing gas are formed in all three steps of the Penniman red process but especially in the seed formation and the Penniman reaction.

- Due to efficient process control, we are able to reduce NOx and N₂O emissions significantly.

- Furthermore, our optimized Ningbo Process gives a steady NOx emission during the growth reaction which make the recycling scrubber systems more efficient.
The Ningbo Process – laughing gas and toxic nitric oxides are treated to only emit naturally occurring air components

Catalytic decomposition of nitrogen oxides

- Despite an efficient recycling scrubber system to recycle nitric acid, Ningbo waste gas still contains laughing gas (N₂O) and smaller amounts of nitric oxides (NO/NO₂)

- These are converted in a multi stage catalytic converter into naturally occurring nitrogen gas (N₂), oxygen (O₂) and water (H₂O)
The Ningbo Process – optimized process reduces energy demand by approximately 80%, relative to traditional Penniman production

- The Penniman red growth reaction requires large amounts of energy, particularly with regard to steam stripping during the growth reaction

- Due to the unique Ningbo Process and special aeration techniques, energy demand in the growth reaction is reduced by 80%
The Ningbo Process – production process water is exhaustively purified and re-used in the process

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<th>Recycling of process water</th>
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<tr>
<td>▪ Due to a higher solids content in our process steps, we have reduced the required water amount considerably</td>
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<td>▪ Used water is subsequently purified in our state-of-the-art water treatment plant by:</td>
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<td>o Sedimentation tanks</td>
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<td>o Biological denitrification process</td>
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<td>o Ultrafiltration and reverse osmosis (RO)</td>
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<td>▪ By reverse osmosis, sulfate-enriched water is a valuable raw material and can be employed back in the process</td>
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<th>Principles of reverse osmosis</th>
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<td>membrane</td>
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<tr>
<td>pressure</td>
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<td>Purified water</td>
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Principles of reverse osmosis

The Ningbo Process – production process water is exhaustively purified and re-used in the process
The patented Ningbo Process – a breakthrough in iron oxide red technology

- **Raw materials**
  - Nitric acid
  - Energy
  - Iron
  - Air
  - Water
  - Sulfate

- **Products & by-products**
  - Recycling of nitric acid
  - Heat recovery
  - Nitric oxides (NO/NO₂)
  - Laughing gas (N₂O)
  - Ammonium nitrate (NH₄NO₃)
  - Recycling of process water

- **Environmental load**
  - ~100% waste gas removal
  - ~100% waste water treatment
LANXESS IPG New Reds
A new generation of red iron oxide pigments
LANXESS Ningbo – three important product streams; New Reds will access new business outside the current color space of our existing Laux grades

**Additional Demand**
Bayferrox® 4100 types

Additional red raw material capacity to satisfy growing market demand for existing products and eliminate the need for any outsourcing.

**New Competitor Alternatives**
Bayferrox® 500 types

New Bayferrox® quality, sustainable, bright, yellow-shade reds, as alternatives to competitor grades.

**New Unique Products**
Bayferrox® 500 types

Unique new reds in a color space previously unavailable from any other iron oxide producer.
The new Ningbo facility enables LANXESS to further extend what is already the broadest range of red iron oxides in the market.

- Flexible, innovative and sustainable production processes enable both traditional Penniman and completely new color space to be achieved.
- Proven Bayferrox® quality with the possibility to open the door to new market opportunities.
- All grades will comply with existing high Bayferrox® quality standards.
New Red properties – Color development can be extended to reach highest chromaticity – products which have never been produced before!

Extended development curve with the Ningbo Process

Traditional development curve of pigment growth according to the traditional Penniman process

Electron micrograph of New Red pigment
A number of key factors are tightly controlled to ensure that Ningbo products are sustainable and meet Bayferrox® quality standards.
Targeted intermediate grades will be processed to produce the Bayferrox® 500 series; end products will offer both competitor and completely new color space.
Route for synthesis and desired color

Synthesis

Bayferrox TP LNP 1

Bayferrox TP LNP 2

Bayferrox TP LNP 3

Sieving & washing

Sieving & Washing

Combination

Combination of clinker materials for color adjustment

Milling

Milling step to achieve micronization

Specification

Specification adjustment
Bayferrox TP LNP 1 with superior coloristic in comparison to market hematite alternative

Resin binder: mid oil alkyd
Film thickness: 150µm

Left: Bright hematite
Right: Bayferrox TP LNP 1
New Red Ningbo pigments with high chromaticity

- The chromaticity values $C^*$ of selected red iron oxides were determined in a long oil alkyd system.

- In both full shade and reduction (1 : 5 with TiO$_2$), the newly developed iron oxide reds from the Ningbo process show the highest chromaticity value $C^*$.

- It is noticeable that pigments from the different manufacturing processes do not show consistent $C^*$ values in full shade and reduction.
Summary – Outstanding color and outstanding performance in modern coating systems

- A range of products made to Bayferrox® quality standards in Ningbo, China using the patented Ningbo Process
- Excellent dispersibility and viscosity behavior in paint and coating systems
- Uniformly shaped particles
- Very narrow particle size distribution
- Further extending what is already the broadest range of red iron oxides in the market
- Including competitor alternatives and highly innovative bright, yellow-shade reds which have never been produced before