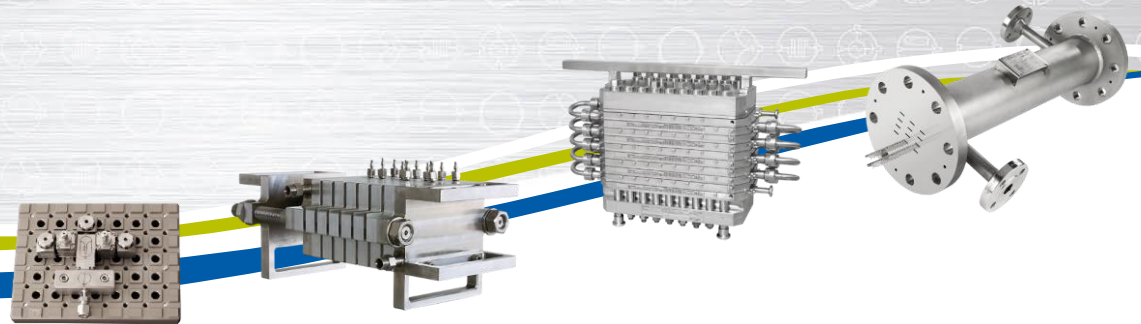


Micro Reaction Technology with Macro Process Efficiencies – Multi-Ton Production Millireactor substitutes a traditional Batch Process



ChemSpec - Basel, Switzerland, 26th of June, 2019
Dr.-Ing. Rafael Kuwertz, Project Manager



EHRFELD
Mikrotechnik

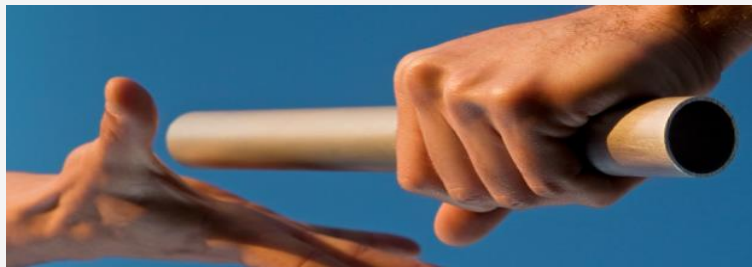
Microreaction Technology – First Steps in 1995

First Industrial consortium at IMM Mainz – Prof. Ehrfeld

- Evaluation of potentials of microreactors for technical relevant chemical reaction.
- › Participants e.g. BASF, Daimler Benz, Degussa, DuPont, Hoechst, Hüls, Merck, Rhone Poulenc.
- › Significant increase of yield of Andrussow reaction by using a micro mixer for pre-mixing of reactants.



**Prof. Ehrfeld takes over the baton as pioneer for
microreaction technology**



Microreaction Technology – 1997-2000

First conference on Microreaction Technology 1997 – extract preface – IMRET

- › Rising interest of leading companies and research institutes
- › Tremendous possibilities of microreactor concepts with huge economic potential
- › Initiation of worldwide research and development activities

Microreaction Technology – Integral part of Process Intensification

- › Radically innovative principles (paradigm shift) in process and equipment design
- › Huge Benefits in process and chain efficiency, capital and operating expenses, quality, waste, process safety and more.

Microreaction Technology – 2001 - present

Raising of interest worldwide:

- › Different suppliers of flow equipment raise their businesses
 - Chemtrix, Corning, Vapourtec, Thales Nano etc.
- › Different suppliers of peripherie adjust their product portefolio to flow equipment
 - HNP Mikrosysteme, Huber, HiTec Zang etc.
- › Chemical and pharmaceutical companies ask for real production units above the lab and pilot scale



Continuous Flow with Microstructures – Benefits

Continuous flow + Micro- / Milli-structured channels

Rapid mixing



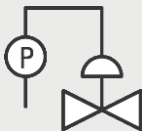
Rapid heat exchange (no “hot spots”)



Well defined residence time



Short response time



Challenges for Establishing the Technology Platform Micro-/Millireactors

→ Competition against established technologies in process industries

- › Paradigm change batch-/conti
- › In R&D predominantly use of batch reactors for synthesis of new molecules
- › Infrastructures of production plants /-logistics predominantly aligned to batch processes

→ Calculation of risk difficult for new technology platforms

- › Missing or not published references in production scale
- › Missing knowledge about attractive applications as well as design basics
- › Adequate robustness for demands of production plants
- › Risk of investment

Challenges for Establishing the Technology Platform Micro-/Millireactors

→ Critical success factors

- › Visible references in production scale
- › Demonstration of sufficient robustness for production application
- › Strong performance increase
- › Know how about attractive applications/market segments

- › Readiness for stepping in into innovative technology platform micro-/millireactors in China more pronounced than in Europe and US because of long track record of process industries in Europe and US.

China goes ahead with first visible reference in production scale

Attractive Market Segments & Applications

Peroxides	<ul style="list-style-type: none">• Explosive reactions• Highly exothermic reactions
Alcoxylation / Sulphonation	<ul style="list-style-type: none">• Very fast reactions• Liquefied gas reactions
Active Ingredients	<ul style="list-style-type: none">• Fast reactions• Multi-step synthesis
Precipitation	<ul style="list-style-type: none">• Fast mixing• Uniform conditions

Examples on lab scale

Hydride reduction using RedAl

Batch:

Temp: 0 °C
Retention time: 8 hours
Yield: 80...90%

Conti:

Temp: 10...20 °C
Retention time: 40 seconds
Yield: 95...98%

Output:

0,7 kg/hour of isolated product

Grignard Reaction

Batch:

Temp: 50 °C
Retention time: few min
Yield: 80...90%

Conti:

Temp: 50 °C
Retention time: 100 sec
Yield: 98%

Output: 0,5 kg/hour
of isolated product

And many more...



Lithiation Reaction

Batch:

Temp: -40 °C
Retention time: 4 h
Yield: 80%

By-product formation
time-dependent

Conti:

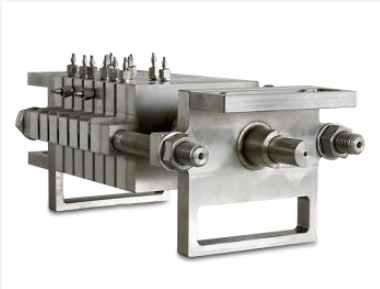
Temp: -10 °C
Retention time: 45-90 sec
Yield: 96,5%

Output: 1.0 kg/hour of isolated product

Production – Analogy to well established equipment

Origin:
Plate HEx

Lonza FlowPlate®
MicroReactors



ART®
Plate Reactors



Origin:
Tube Bundle
HEX

Miprowa®
Reactors



Scale-up Strategy – From micro to millimeter dimensions

R&D and Kilo Lab Scale

0.05 – 10 L/h

Pilot Scale

10 – 100 L/h

Production Scale

40 – 10000 L/h

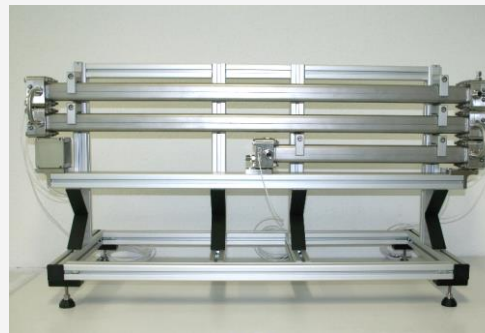
Optimization

Validation

Production



- ✓ Transfer batch-to-conti
- ✓ Optimizing your processes and products

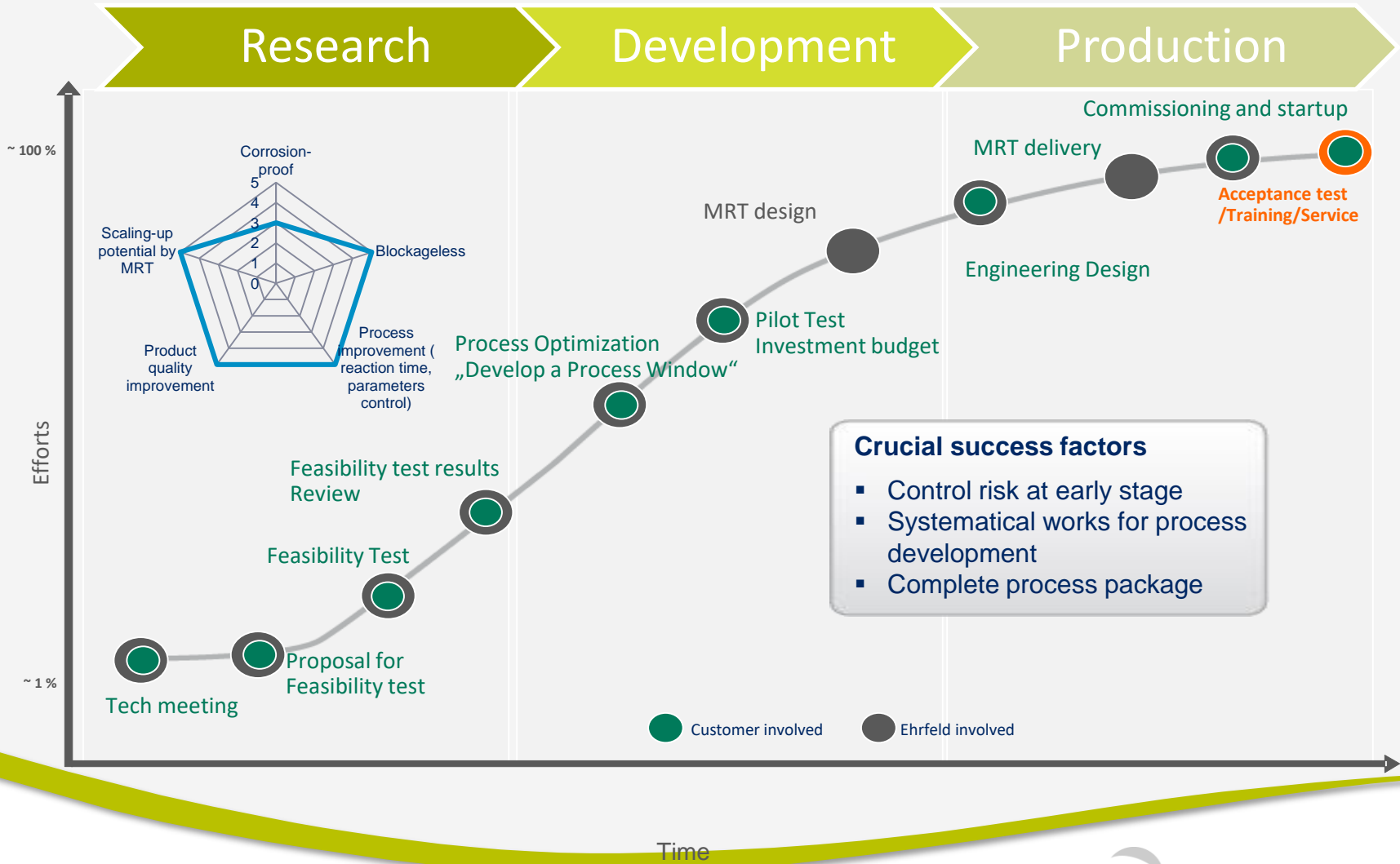


- ✓ Mastering your personalized scale-up



- ✓ Yielding your product as efficient as possible

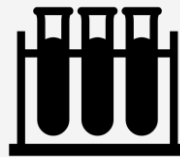
Pathway for implementation – Full Customer Support



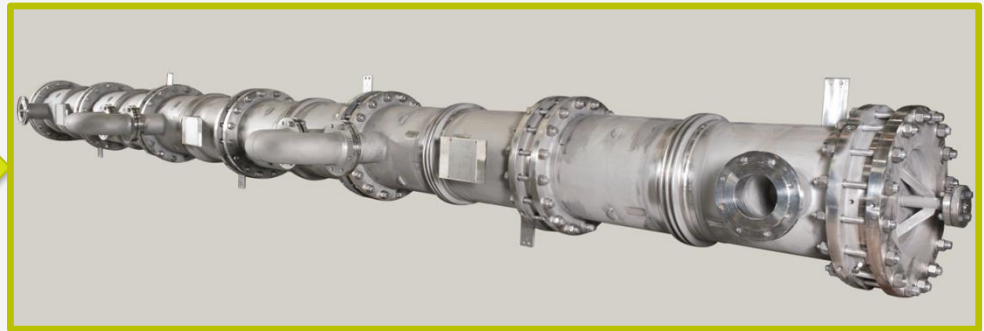
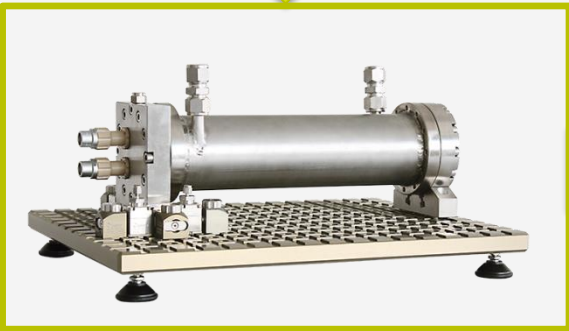
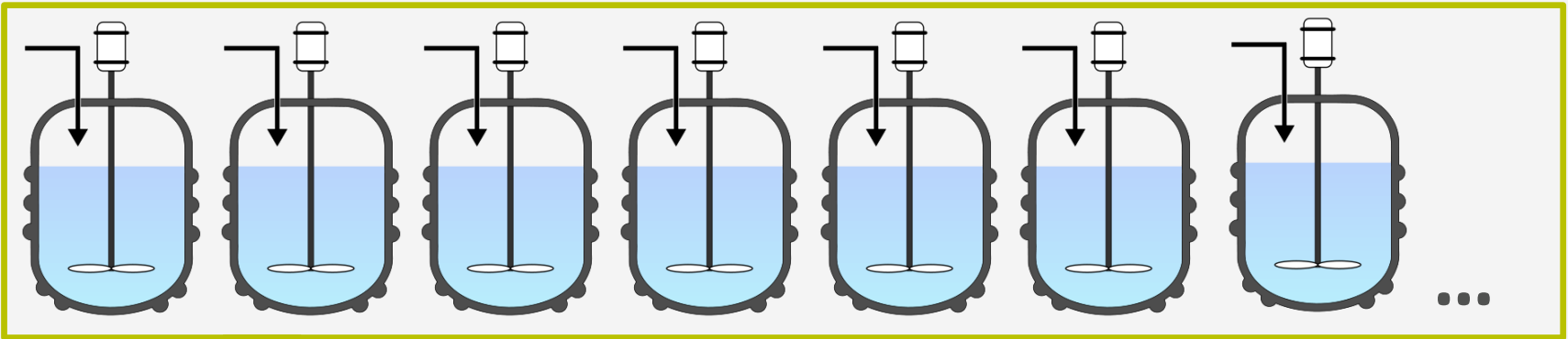
Lighthouse Project – Multi-Ton Production Millireactor

Challenges in Batch Plant:

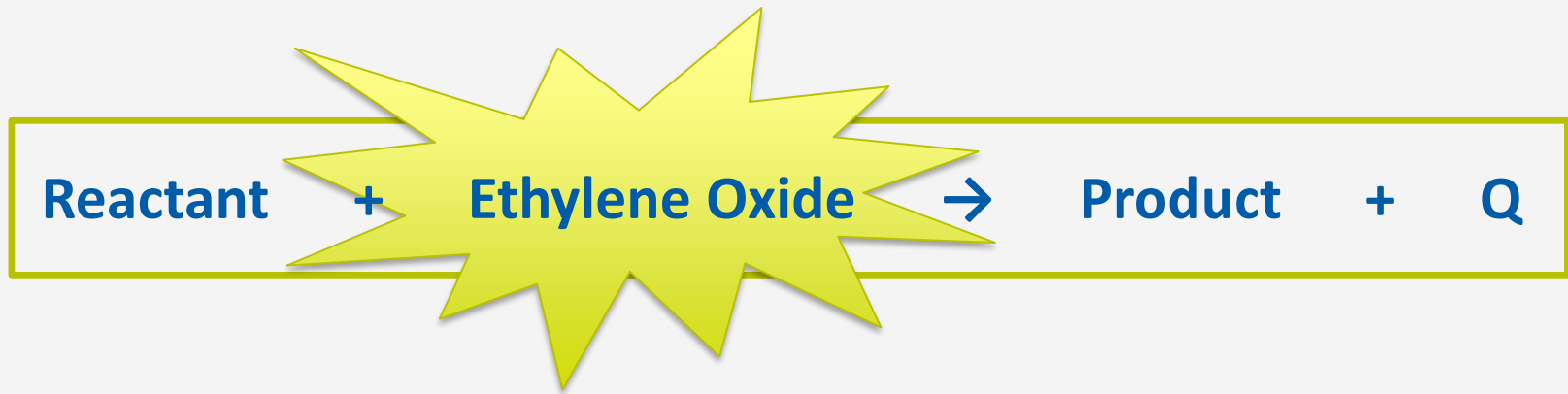
- Strong heat release
- flammable, explosive and toxic
- Long reaction time
- low efficiency
- poor safety
- uncontrollable capacity expansion



From Batch to Continuous Production



The Chemistry Behind



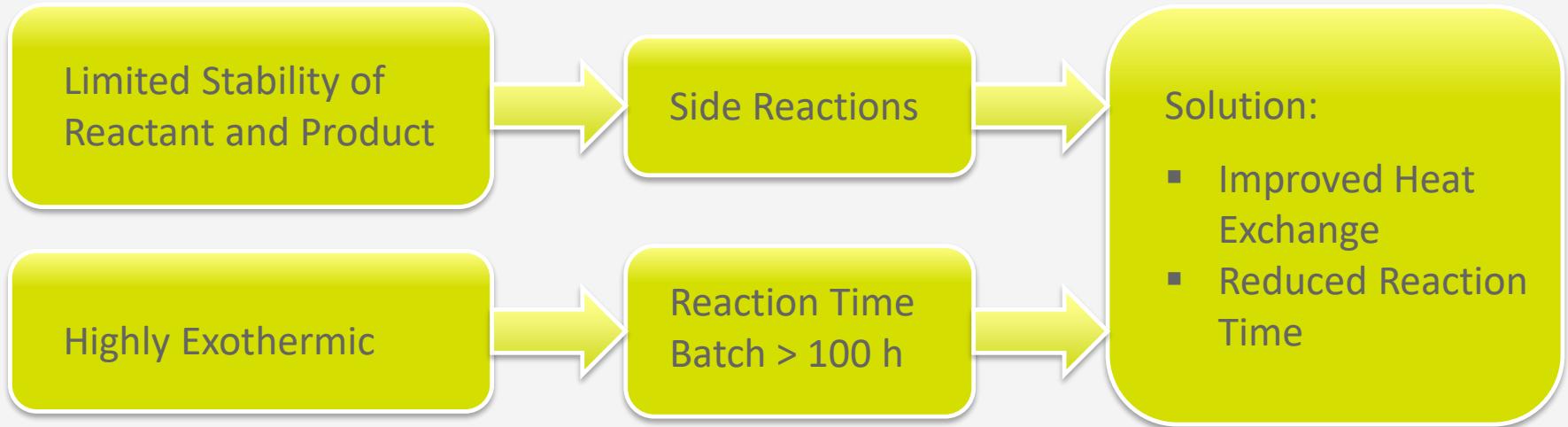
- Explosive
- Extremely Flammable
- Toxic

Increased
Safety Risk

Solution:
Reduced
Reactor Volume

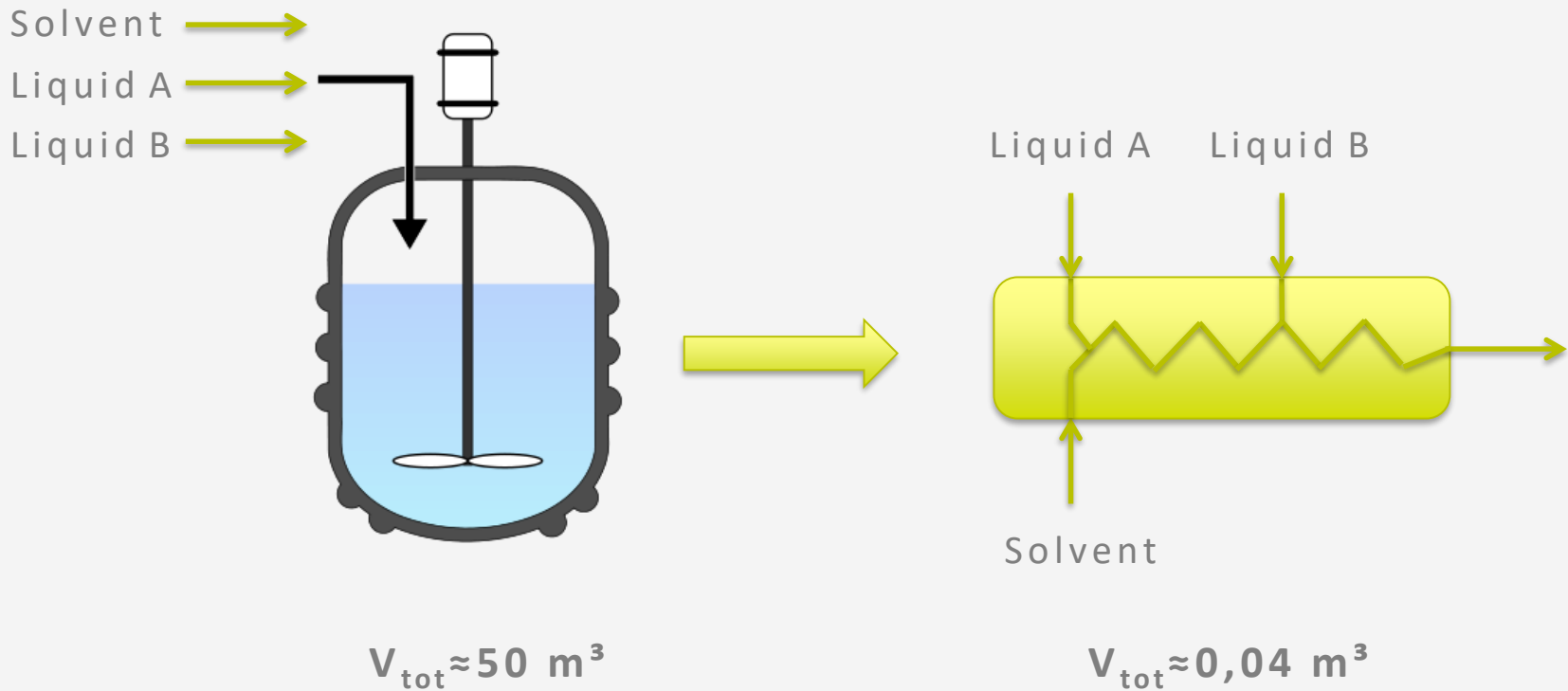
✓ Increase of Safety

The Chemistry Behind



✓ **Increased Production Efficiency**

From Batch to Conti in about 8 Months

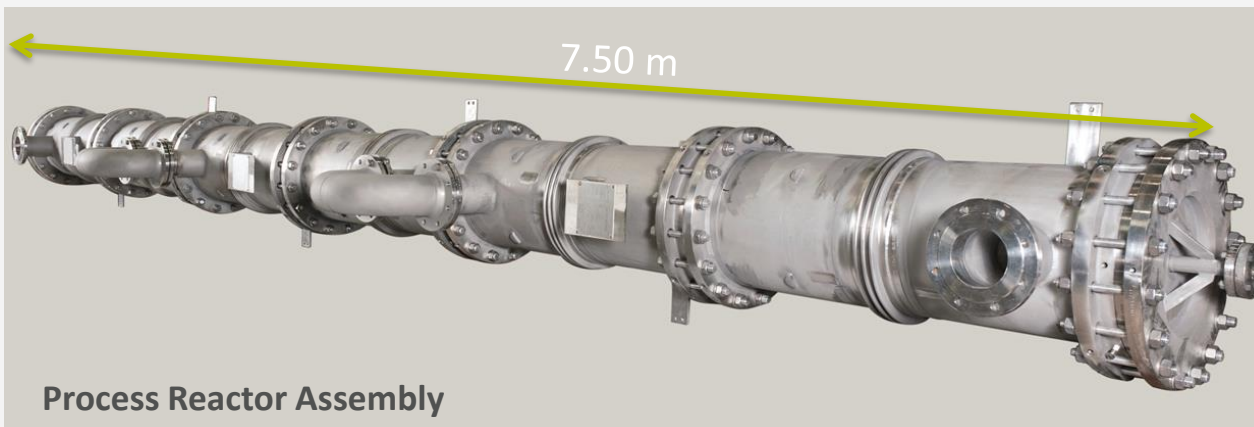


Millireactor in Production – Lighthouse Reference Project

- 6 Modular Miprowa reactor cores in serial
- 154 channels (18 x 3 x 1200 mm³), each core
- Dimensions: 7.50 m length, DN 400
- Total volume: ca. 40 L
- 5000 – 10.000 t/a throughput
- Commissioning Sept. 2016



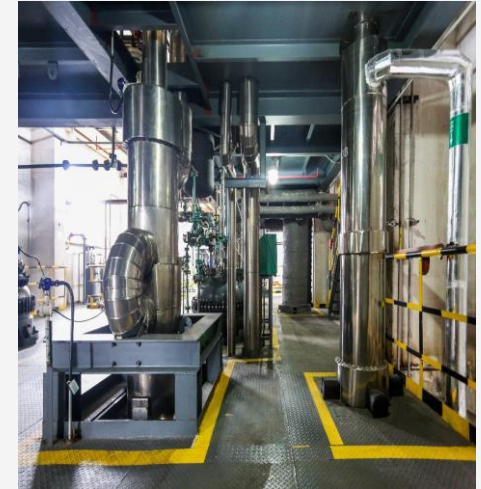
Single reactor core



Process Reactor Assembly

Millireactor in Production – Lighthouse Reference Project

- 6 Modular Miprowa reactor cores in serial
 - 154 channels (18 x 3 x 1200 mm³), each core
 - Dimensions: 7.50 m length, DN 400
 - Total volume: ca. 40 L
 - 5000 – 10.000 t/a throughput
 - Commissioning Sept. 2016
-
- **Former process in ca. 20 batch reactors (Volume ca. 50 m³)**
 - › 100% capacity increase
 - › Significant yield enhancement
 - › Higher product quality
 - › Upgrade of safety
 - › Reduction of energy consumption & space footprint



Production plant

Summary - Platform Micro-/Millireactors

- Establishing as process technology started and proceeds
- Lighthouse reference in production scale visible – production capacity 30.000 jato
- Attractive market segments/applications and design basics available
- Time efficient integrated scale-up based on established equipment concepts
- Chinese market goes ahead – European market follows





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