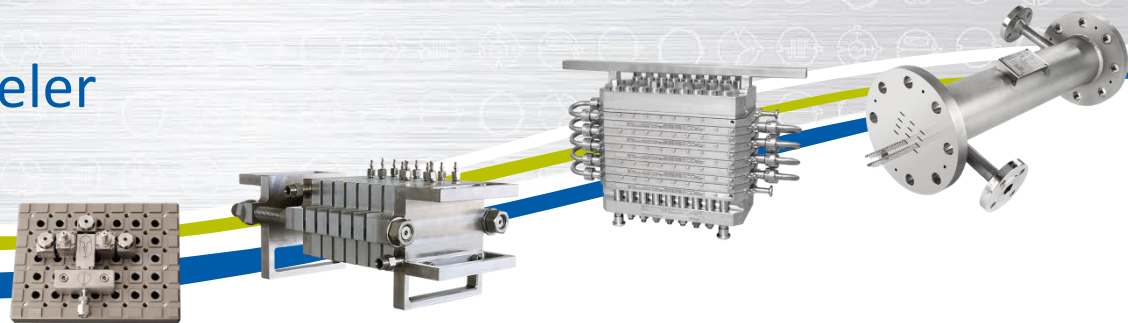


Growth from David to Goliath: Millireactor for Multi-Ton Production Application

Dr. Andrea Henseler

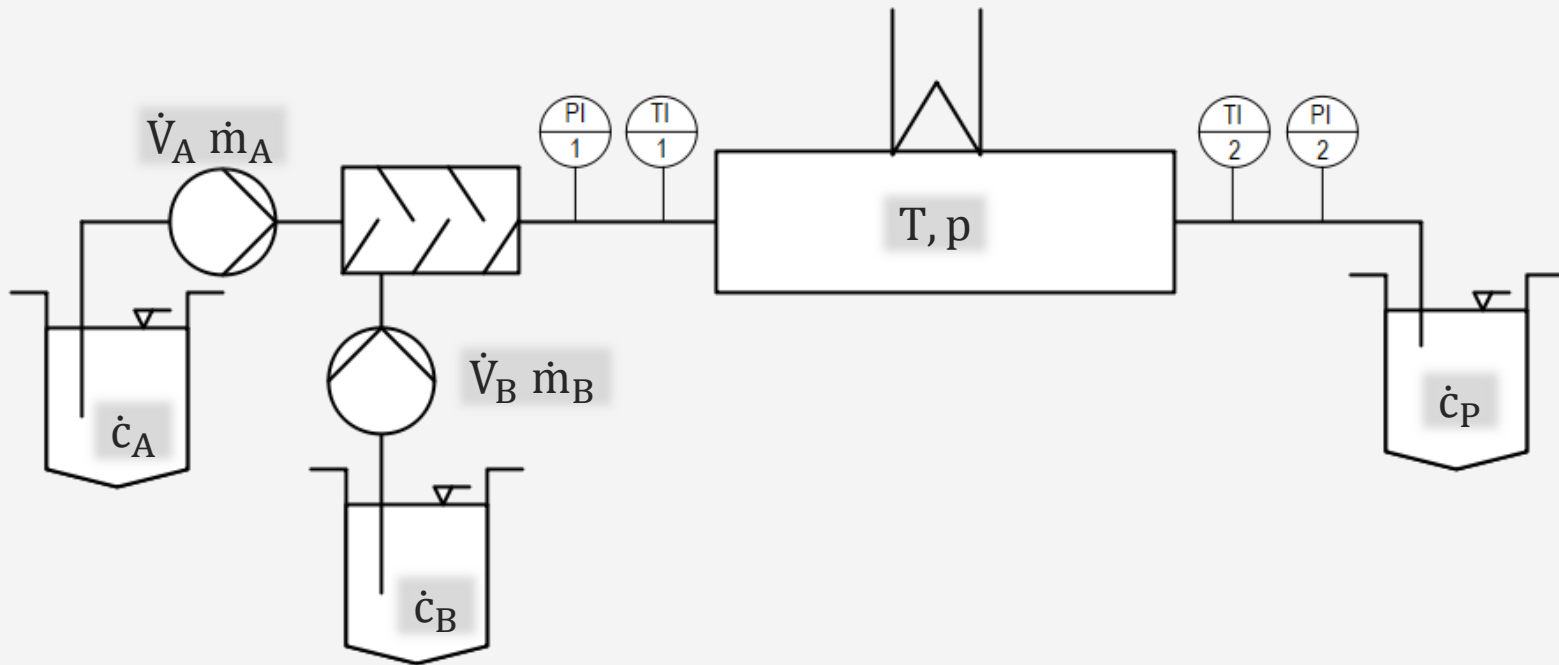


2017-06-01 Chemspec Europe

- Introduction Millireactors
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What We Do - Paradigm Change Batch to Conti



Operating conditions:

- Temperature up to 200 °C
- Pressure up to 100 bar
- Stainless steel or Hastelloy

Benefits

Continuous flow + Micro- / Milli-structured channels

Rapid mixing



Rapid heat exchange (no "hot spots")



Well defined residence time



Short response time



Analogy to Well Established Equipment

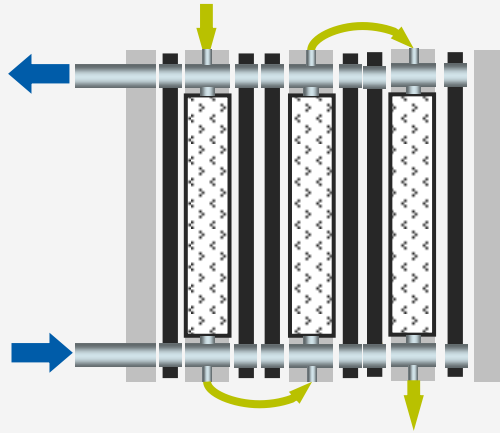
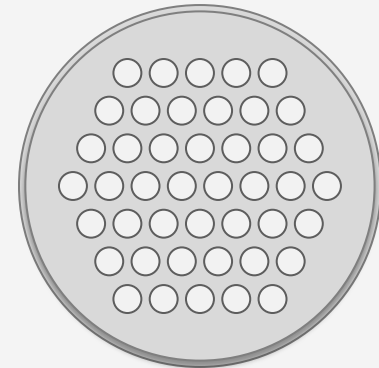
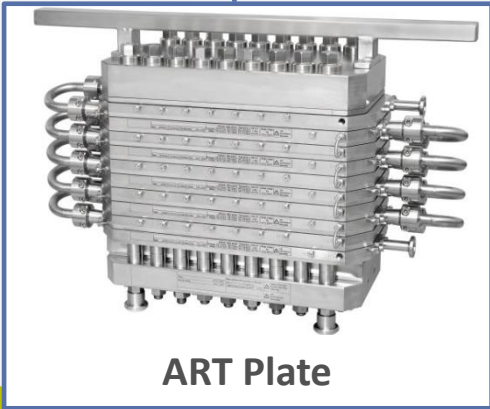


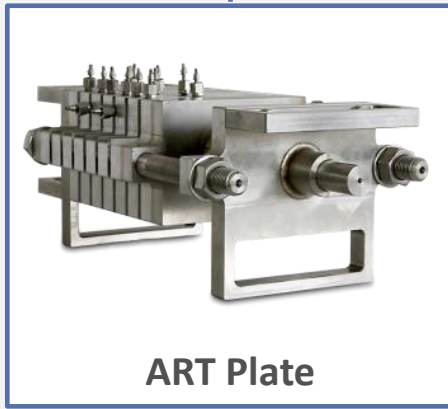
Plate Heat Exchanger



Tube Bundle Heat Exchanger



ART Plate

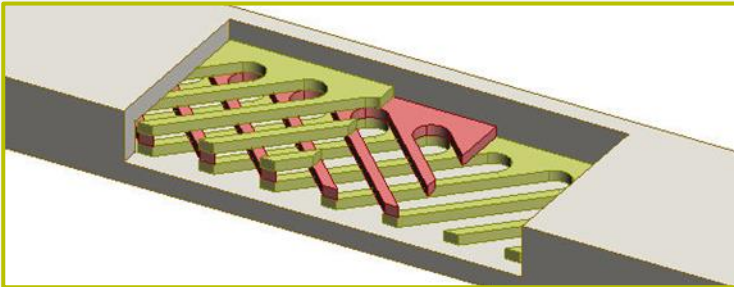
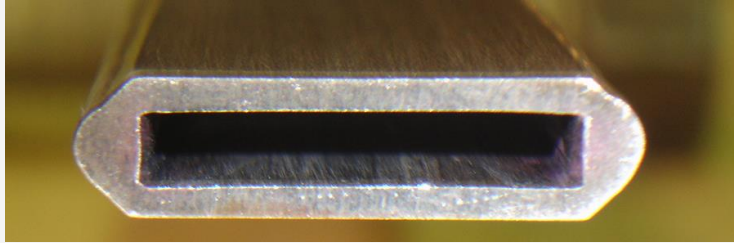


ART Plate



Miprowa

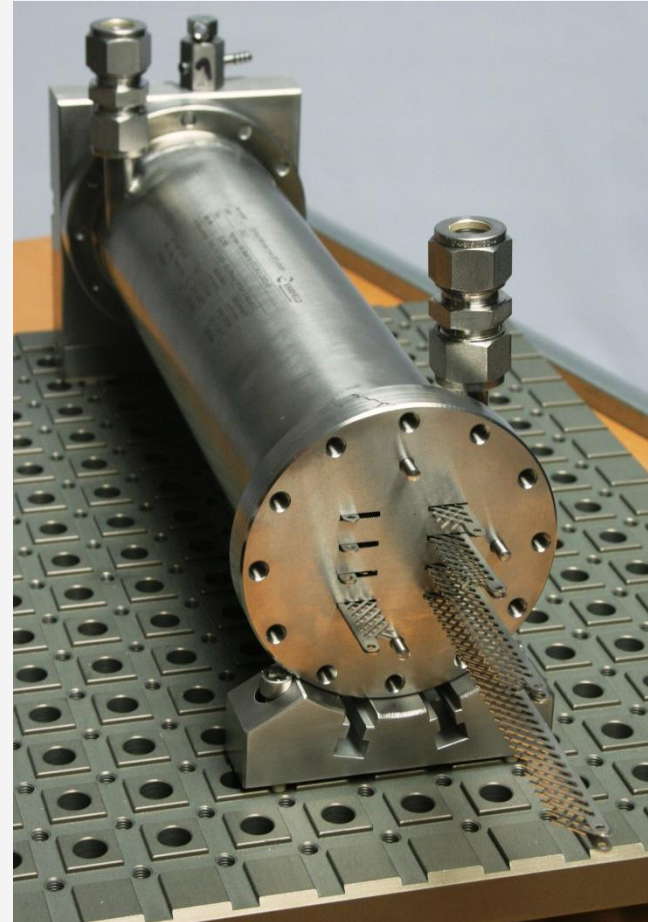
Rectangular Does the Trick



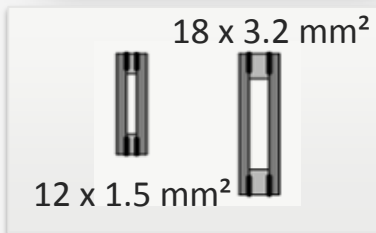
Rectangular channels + mixing inserts:

- ✓ Higher surface to volume ratio
- ✓ Excellent heat transfer
- ✓ Narrow residence time distribution

→ Higher yield and selectivity!



Scale-up Strategy: Lab to Production



Optimization

- Optimal configuration
- Control strategies
- Conversion, yield and selectivity (product quality)
- Process window

Validation

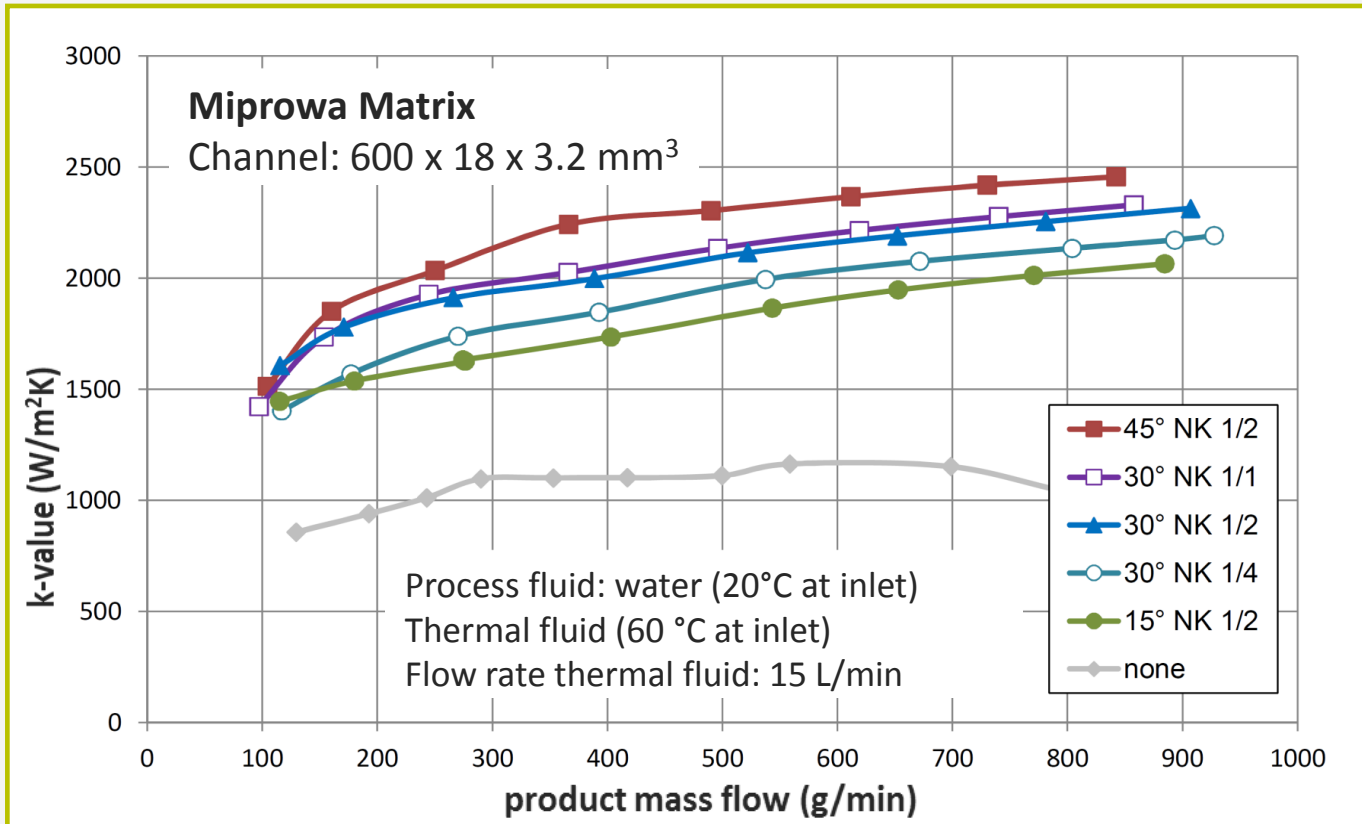
- Pilot scale = Production scale 1 or 3 channel reactor
- Using technical raw materials
- Monitoring of fouling and clogging
- Testing of Start-Stop strategies

Production

- Numbering up of channels

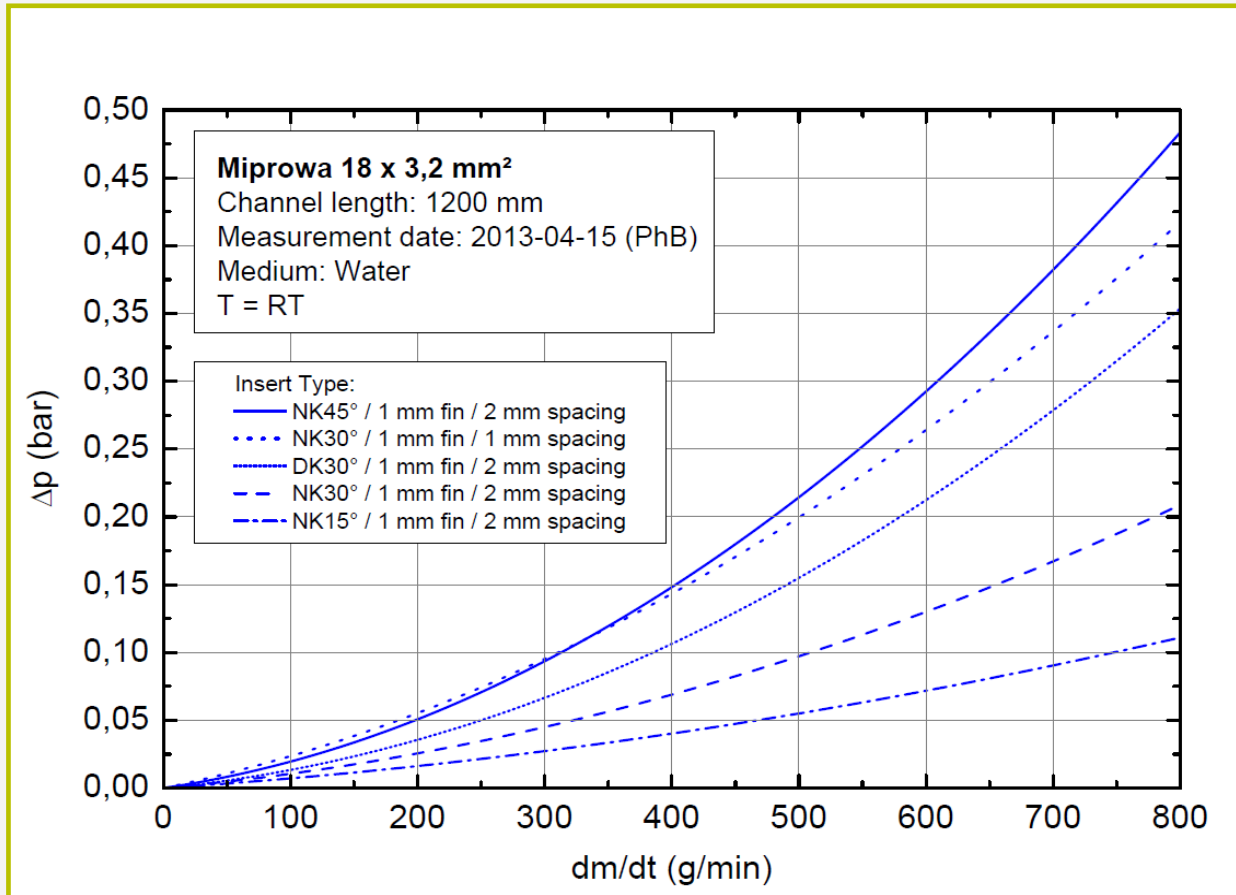
➤ Design of Reactor

Heat Transfer vs. Mixing Inserts



Higher heat transfer capacities, enhanced by mixing inserts

Pressure Drop Characteristics

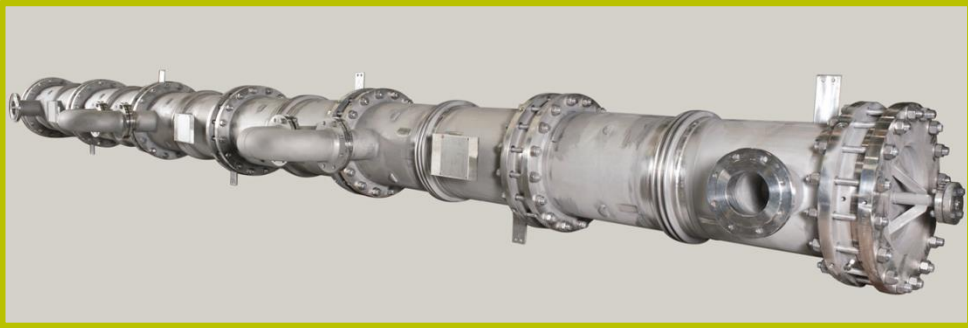
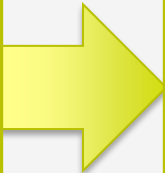
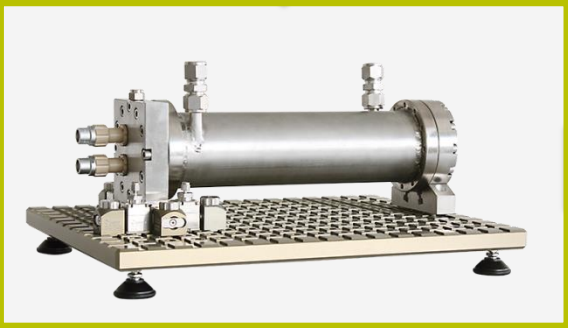
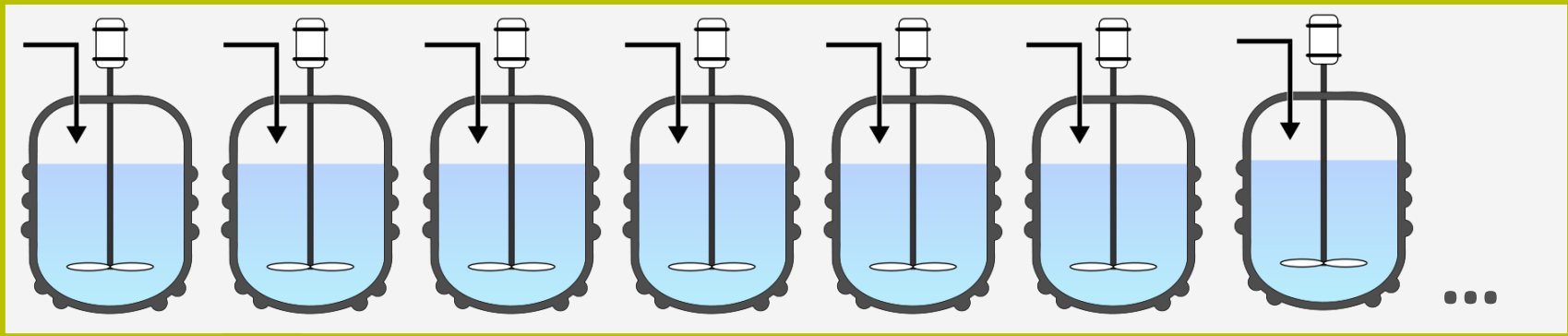


Pressure drop variation by using different mixing inserts

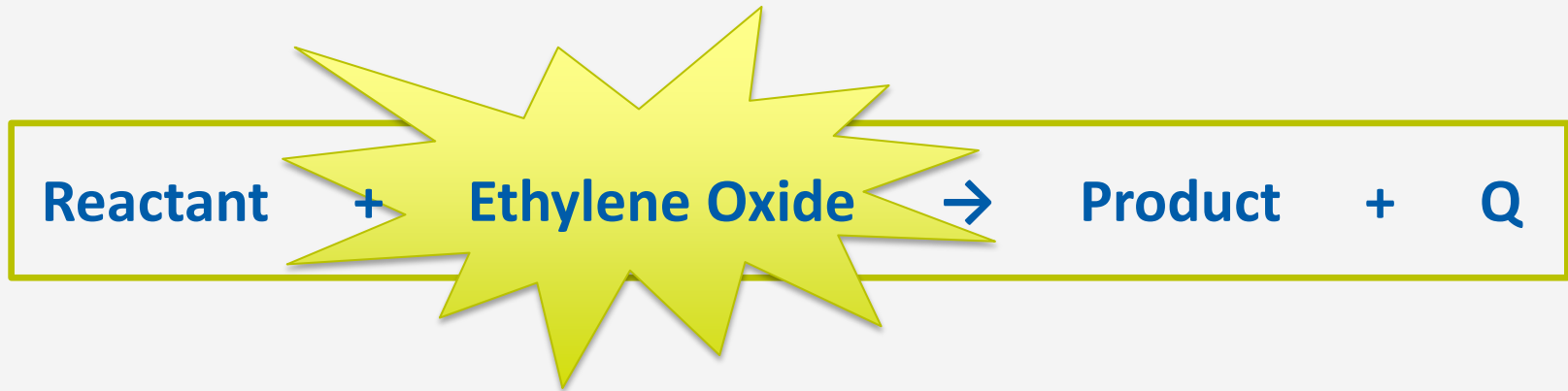
- Introduction Millireactors
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From Batch to Continuous Production



The Chemistry Behind



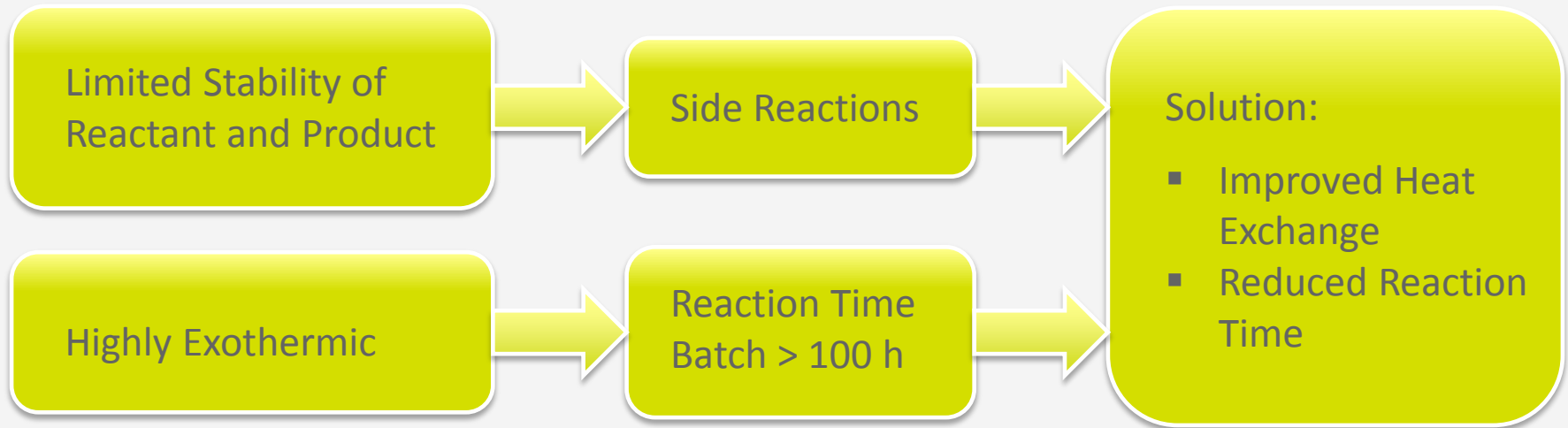
- Explosive
- Extremely Flammable
- Toxic

Increased
Safety Risk

Solution:
Reduced
Reactor Volume

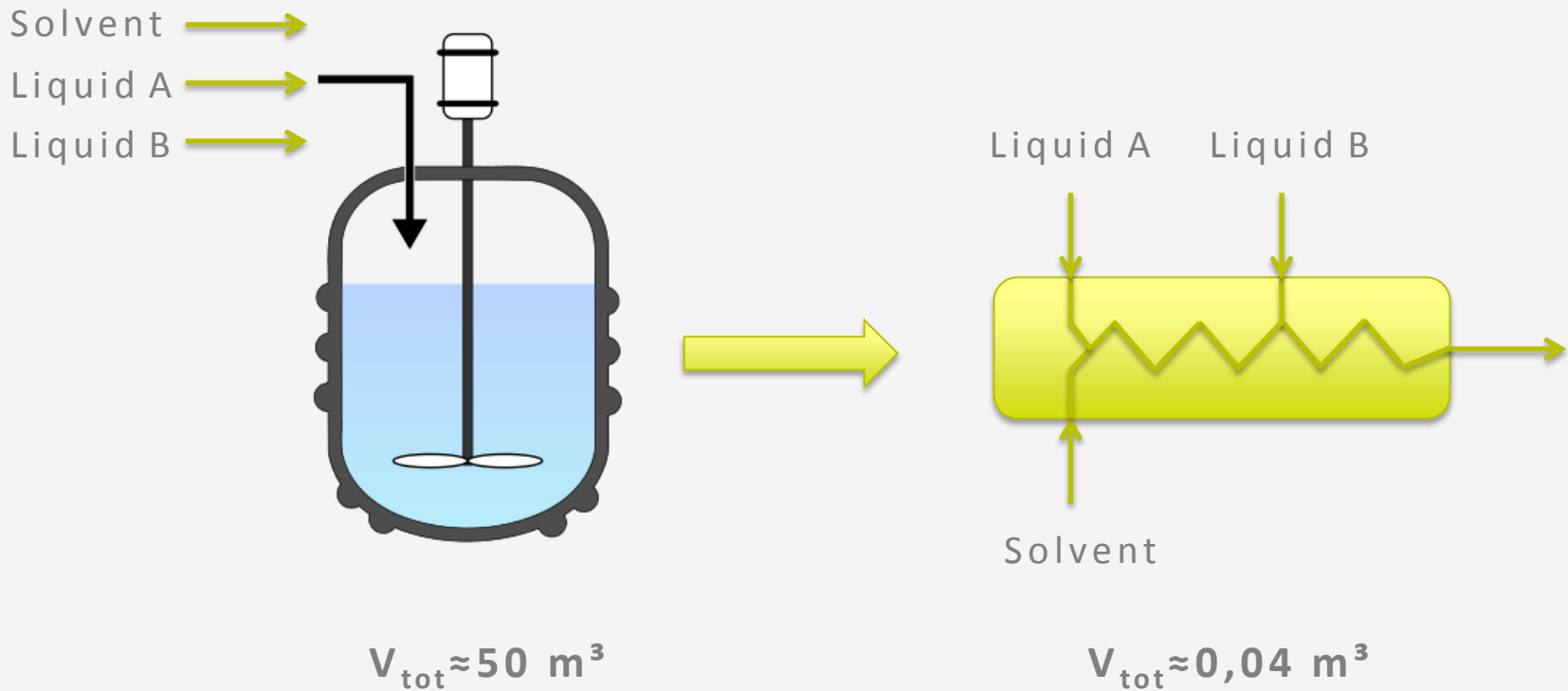
✓ Increase of Safety

The Chemistry Behind



✓ **Increased Production Efficiency**

From Batch to Conti in about 8 Months



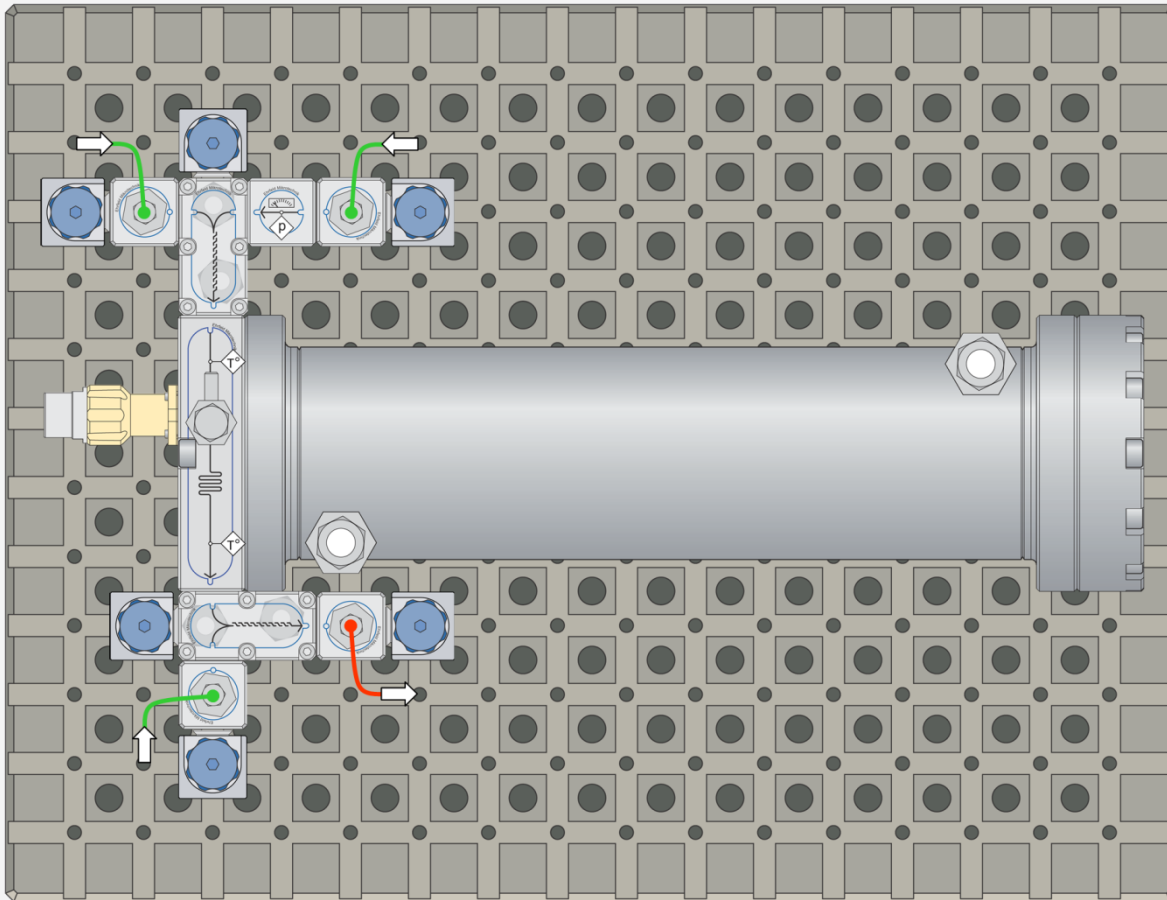
Step 1: Transformation into Scalable Technology

- A. Selection of **interface** technology MIPROWA®
- B. Optimization of reactor configuration
- C. Monitor product stability, conversion and selectivity by variation of process parameters
- D. Process optimization



MIPROWA® Lab interface

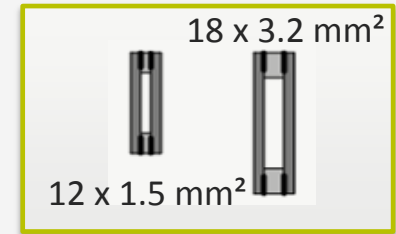
Step 1: Transformation into Scalable Technology



MIPROWA® Lab interface

Step 2: Transformation of Lab Procedure to Pilot Scale

- A. Transfer to pilot reactor (matrix)
- B. Verification and optimization of reactor configuration
- C. Long-term stability run
- D. Generation of process data for design of production reactor



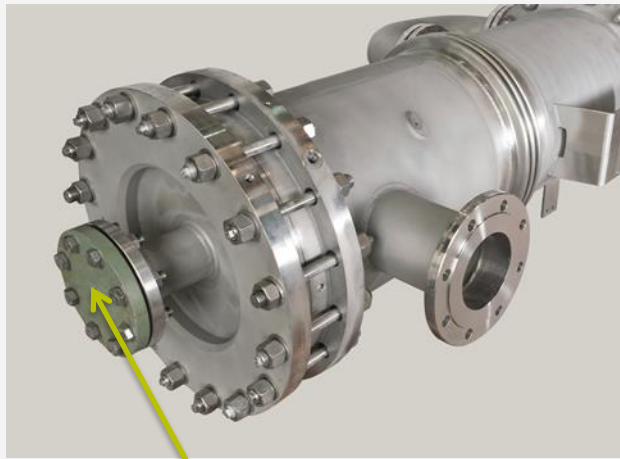
Miprowa[®] Lab



Miprowa[®] Matrix

Step 3: Engineering and Construction of Production Reactor

- A. Engineering & fabrication work
- B. Delivery and assembly support
- C. Installation support



Process media feed

Cooling media feed



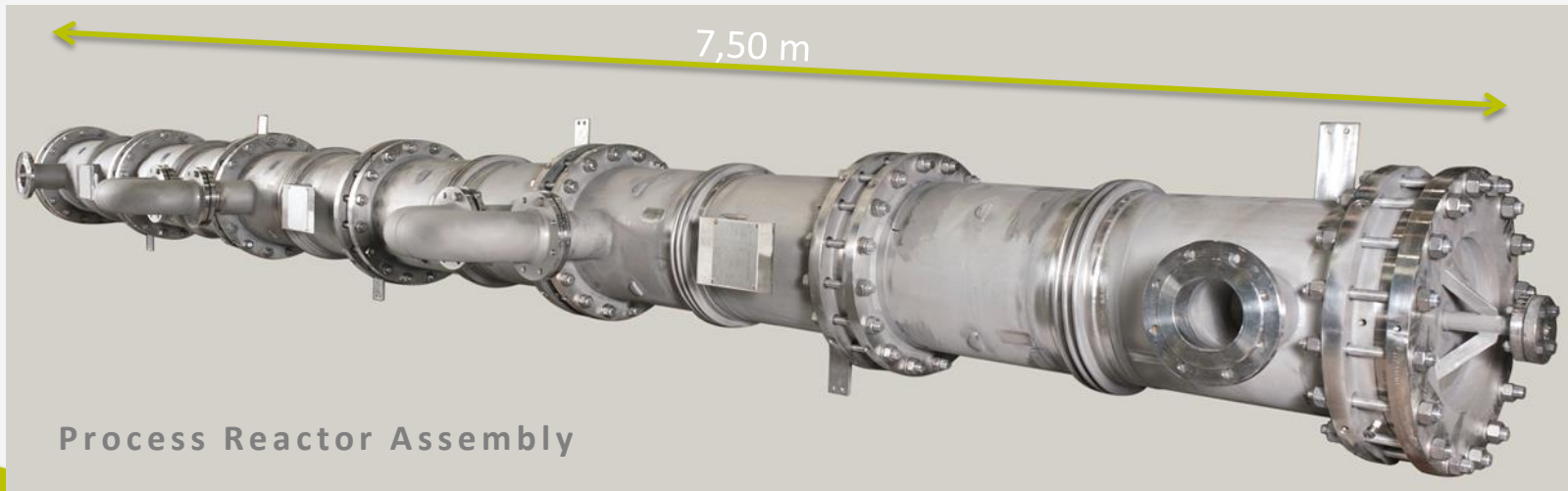
Single reactor core

Millireactor for Production Application

- 6 Miprowa reactor cores in serial
- 154 channels (18 x 3 x 1200 mm³)
- Dimensions: 7,50 m length, DN 400
- Total volume: 40 L
- 5.000...10.000 t/a throughput
- Commissioning September 2016

Inspection of reactor cores after 6 month of continuous run:

- no damage
- no corrosion
- no fouling





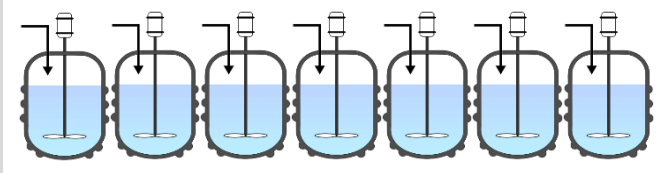
Potential for Cost Reduction by Batch to Conti

Product with 10000 t per year capacity and 8000 h per year operating hours.

	Batch	Conti
Reactor volume in m ³	110	0.190
Yield in %	80	95
Demand of raw material in t/t _{Product}	1.25	1.04
Raw material costs in 1000 €/t _{Product}	12.5 Mio €	10.4 Mio €
Cost savings per year		2.1 Mio €

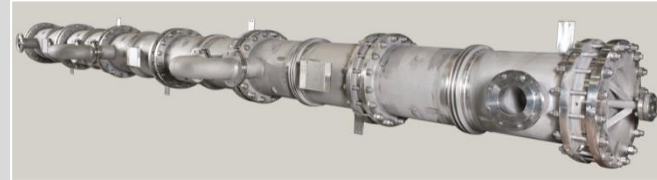
+ energy savings, lower downstream effort...

Current Batch Process with Multiple Reactors



- Large Volume
- > 20 Batch Reactors
- Long Reaction Time
- Formation of Side Products

New Process with Miprowa[®] Reactor



- Small Volume
- Short Residence Time
- Significantly Improved Yield and Product Quality
- Capacity: up to 10,000 tons/a
- Reduction of Carbon Footprint & Energy Consumption
- Safer Production Process



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