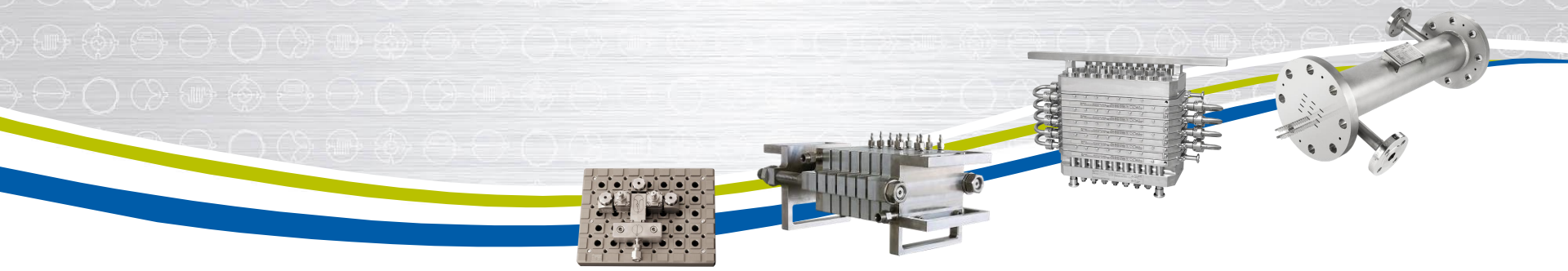
Continuous Flow Technology as an Attractive Approach to Move Towards the ‘Factory of Tomorrow’



Chemspec Europe, 01.-02.2016 Messe Basel
Anne Kaaden, Dr.-Ing. Joachim Heck, Dr. Frank Herbstritt,
Dr. Marc Piepenbrock

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→ A bit of theory: Characteristics

→ Application Examples

→ “Factory of Tomorrow”

→ Scale-up Strategy

→ Summary

Agenda

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A bit of theorie: Characteristics

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Characteristics

Micro- / Milli-structured channels

+

Continuous flow

- **Rapid mixing**
- **Rapid heat exchange (no “hot spots”)**
- **Well defined residence time**
- **Short response time**

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Who we are and where we go…

Metal equipment for laboratory syntheses (research level)

Metal equipment for process development (development level)

Consulting & Services related to R&D modules/ systems and production scale apparatusses

Metal equipment for large scale synthesis (pilot and production level*)

*** equipment flow rates up to 10.000 L/h (per reactor)**

Improve your technology position:

- Optimize your processes and products
- Master your scale-up
- Move forward with MicroReaction technology
- Realize the potential for cost savings

…with you.

Application Examples

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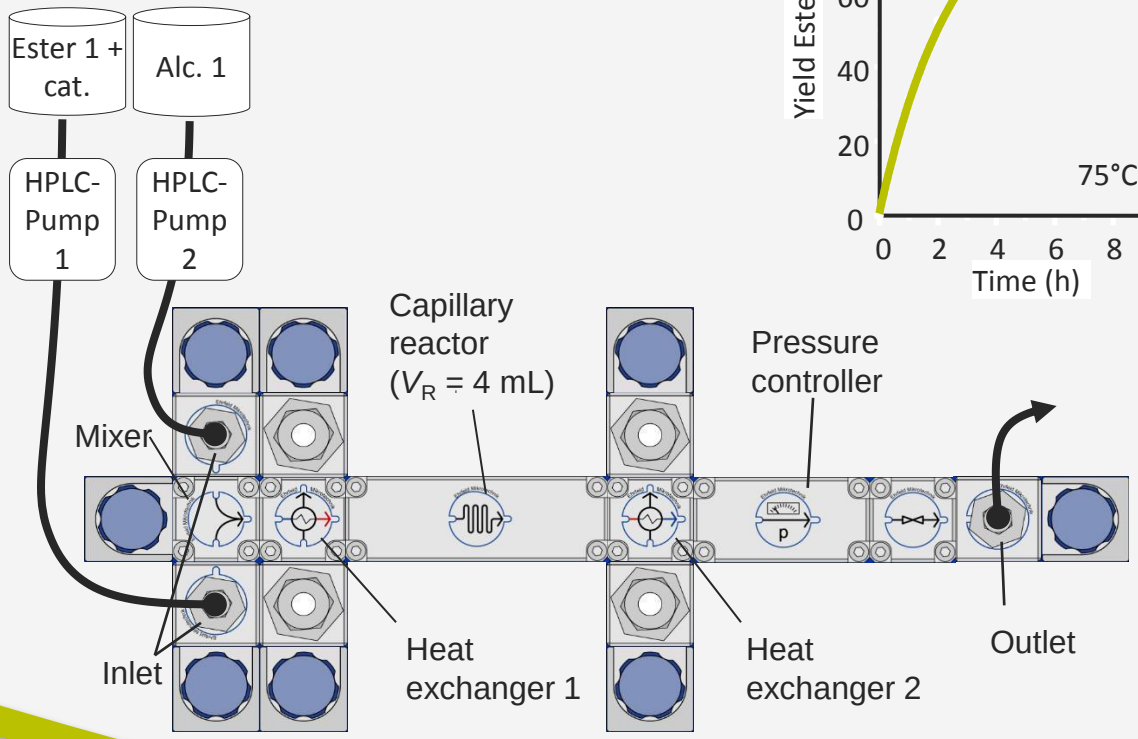
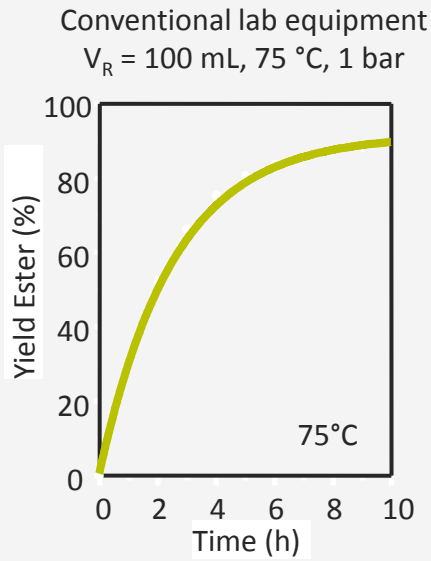
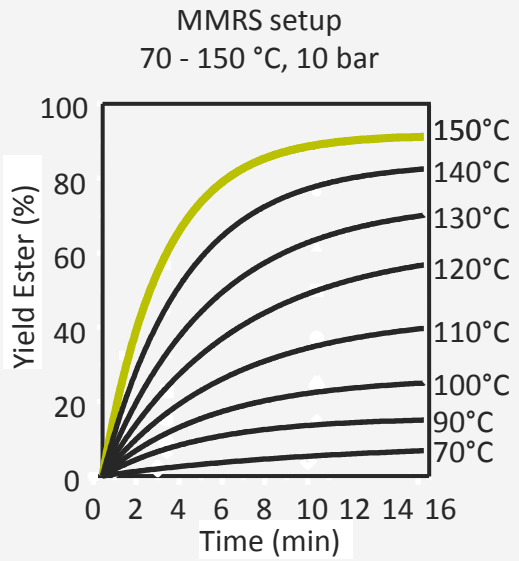
Application Examples

→ Transesterification







Benefits:

- Pressure stability of MMRS ena-bles process to be conducted at elevated temperature and therefore significantly increased reaction rate
- ⇒ fast screening of reaction conditions

Application Examples

→ API Production Process

→ Goal:

- Production of an aldehdye from a solid ester

→ Approach:

- Forming a pumpable slurry of the aldehyde
- Development of the production process using particle-robust components of the Modular Microreaction System

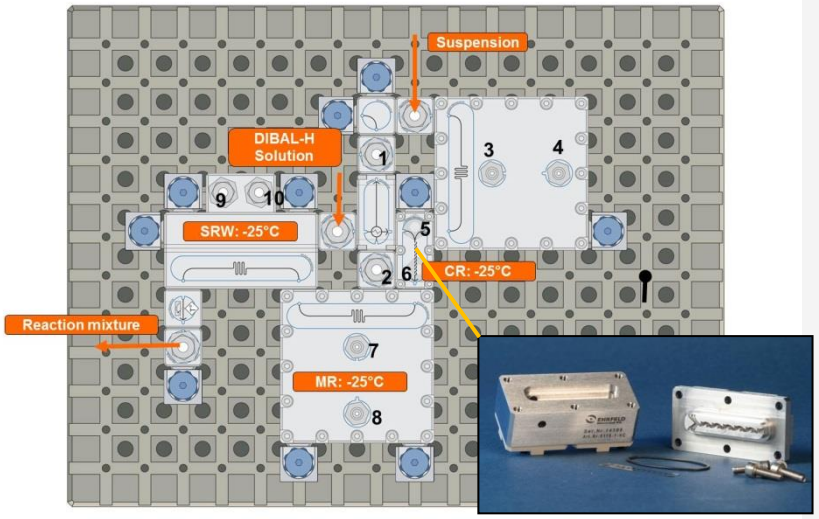
→ Results:

- Reliable continuous process on lab scale

+++ Mixing of slurries

Ester (slurry) → DIBAL-H, -25°C → Aldehyde (solution)

14 mg/mL solid content

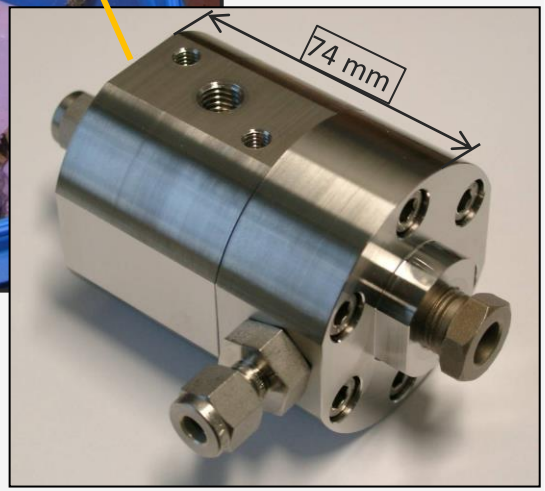


$\dot{V}_{tot}$ = 12 ml/min, Productivity 55 g/h

Application Examples

→ Precipitation of catalyst precursor: Process optimization and scale-up

Valve-assisted mixer (lab): 30 L/h



Valve-assisted mixer (pilot): 300 L/h

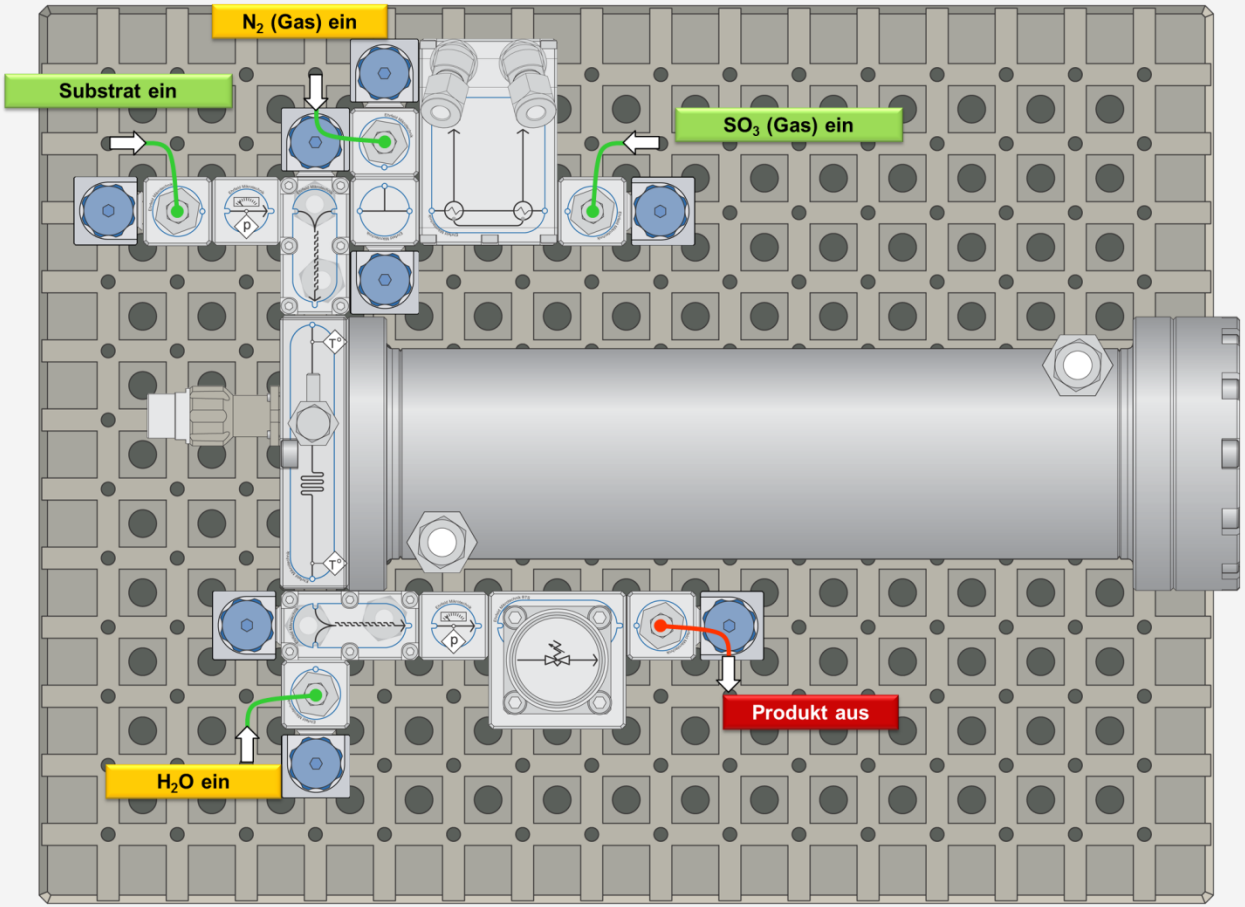
Application Examples

→ Oxidation of a melt

Temperature: 140 to 150 °C
Pressure: 7 bar
Flow rate of melt: 12 g/min
Source of oxygen: pressurised air

Application Examples

→ Sulfonation



Temperature: < 20°C
Flow rate: < 10 mL/min
Pressure: > 7 bar

Application Example – Modular MicroReaction System

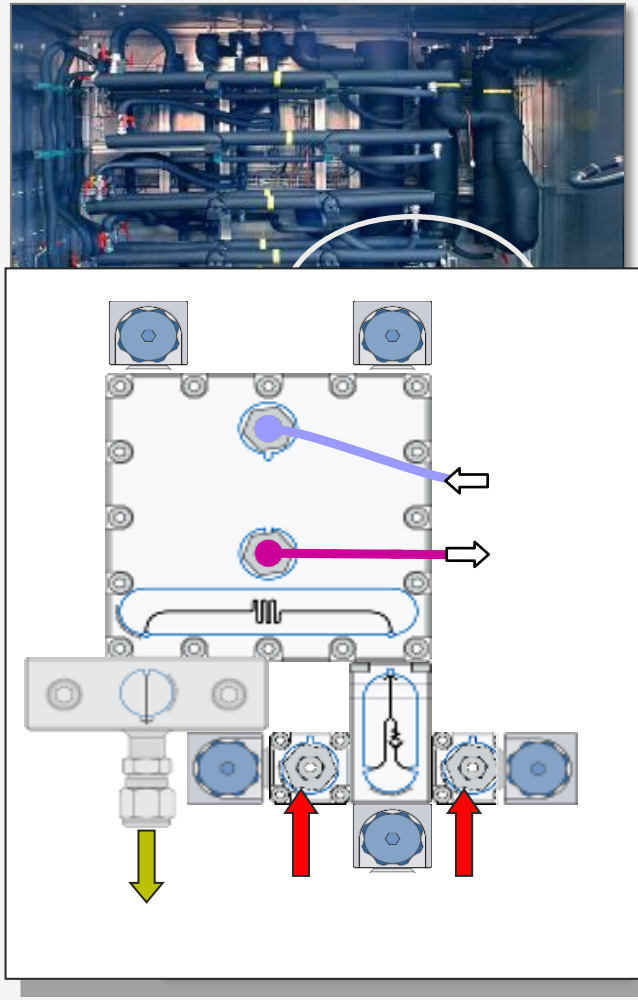
Low-Temperature Organometallic Chemistry

Reactand → (1. Lithiation; 2. Electrophile) → Product

- Throughput: 20 kg/h
- Continuous production of 100 kg isolated product

Benefits:

- Increased selectivity from 86 % to 94 %
- Fastened reaction rate by temperature increase: -70 °C to -40 °C
- Increased safety: hold-up reduced from 400 L to 2 L
- Set-up costs: ~ 30 k€



„Factory of Tomorrow“

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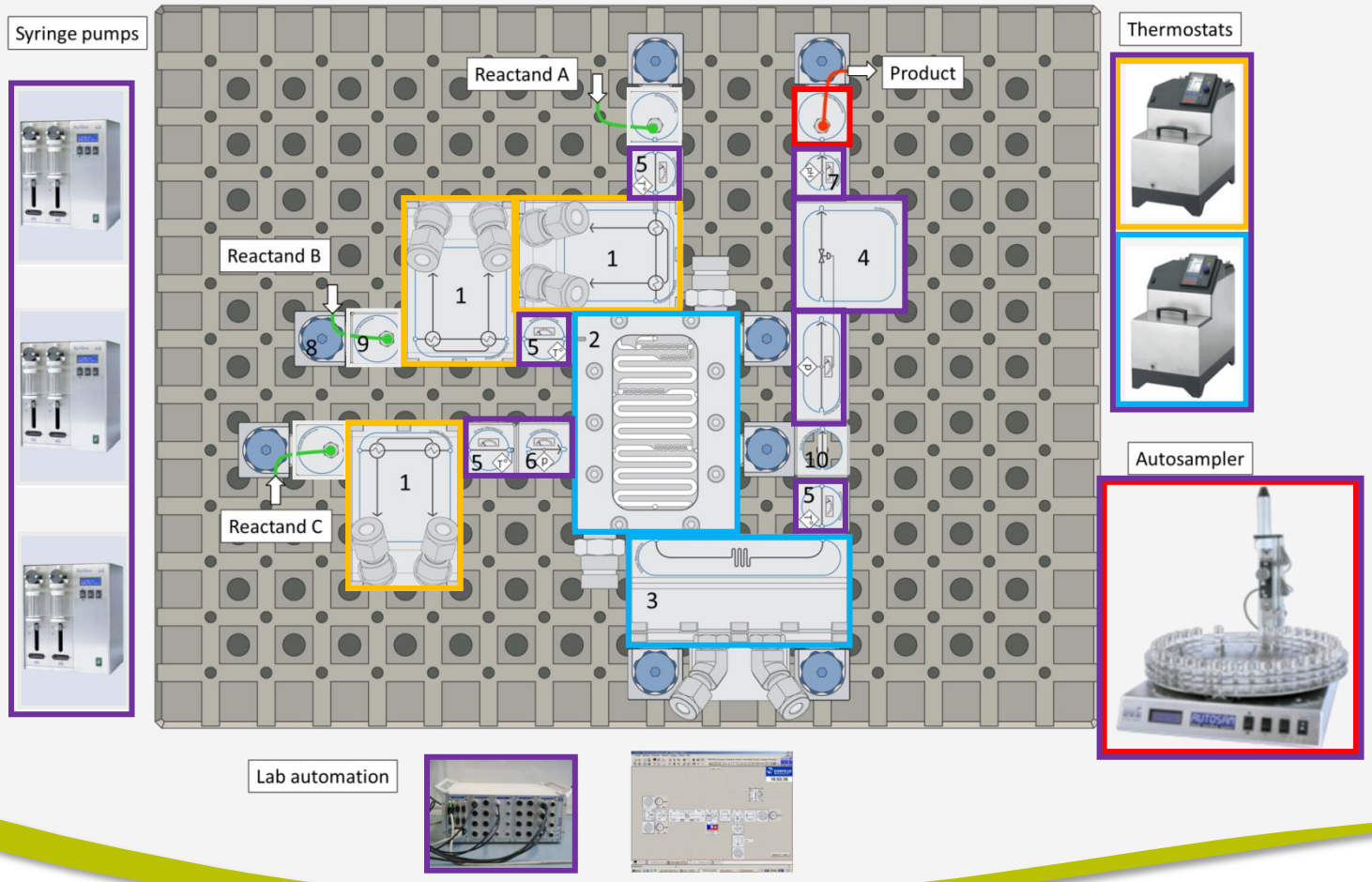
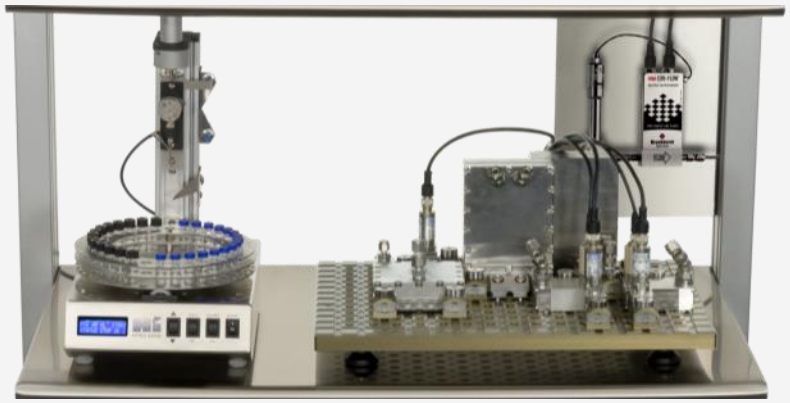


What is a sustainable footprint for the industry?

- The goal is to make chemical production faster, more sustainable and more resource-efficient. This is a key requirement to stay competitive in the globalized world.
- The industry has indentified the driver for getting more sustainability and speed.
- The research and development level is partly equipped with flow equipment to support the next stage: pilot, technical and production scale.
- What are the next steps to be taken to succeed?



Requirements for container-sized plants

→ **Compact design**

→ **+ high specific performance**

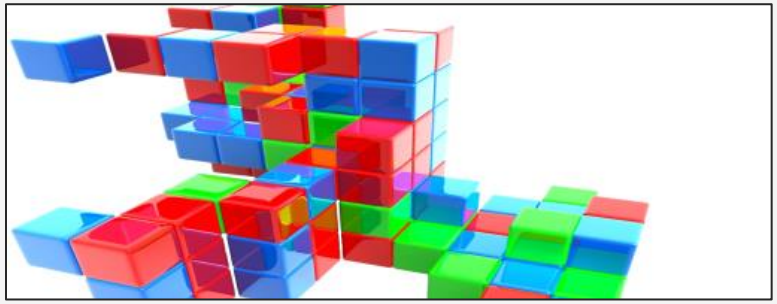
- Process intensification by use of relatively high surface-to-volume ratios (wall effects), e.g. mixing, dispersion and heat transfer capacity

→ **Time-efficient scalability**

- Toolbox for scale-up → modular, flexible equipment with excellent scale-up factor
- Extensions with standard modules (PAT, down-/upstream equipment, …)

Robustness

- Impurities
- Product quality
- Fluctuations of the operating point
- Mechanical stress
- Susceptibility to damage / failure of components, ease of maintenance
- Safety



One key point for future production concepts

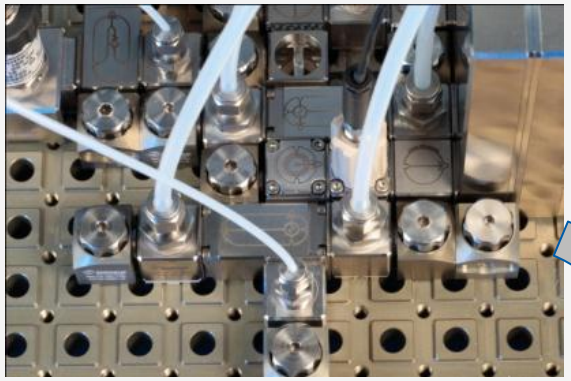
The idea

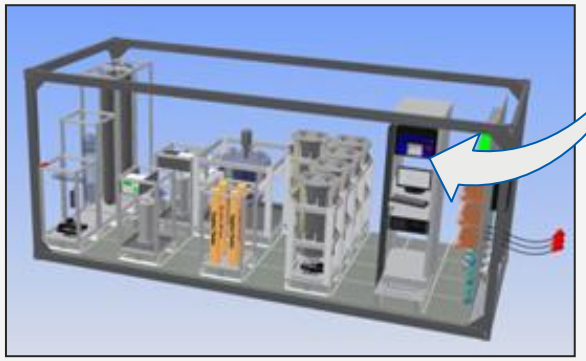
– be <u>modular</u> from the beginning!

Source: http://jexp.de/blog/2008/08/on-lego-powered-time-tracking-my-daily-column/

Source: http://assessment-tools.wikispaces.com/

- **Implementation of production modules**
- **On-demand production**
- **Flexible, mobile and distributed production concepts**



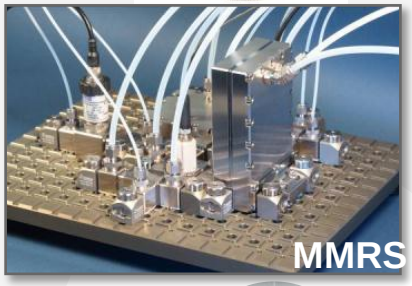


Reactor concepts

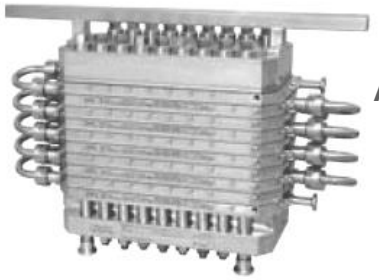
Interface module
Lonza FlowPlate® Lab

Lonza
FlowPlate®
Reactors

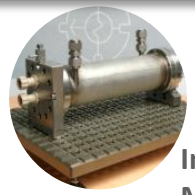
Origin:
Tube
Bundle
HEx



Interface module
ART® LabPlate™



Alfa Laval
ART® Plate
Reactors



Interface module
Miprowa® Lab

Miprowa®
High performance reactors

Origin:
Plate HEx

R&D and Kilo Lab
0.05 – 10 L/h

Pilot Scale
10 L/h – 100 L/h

Production Scale
40 L/h – 10,000 L/h

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Scale-up Strategy

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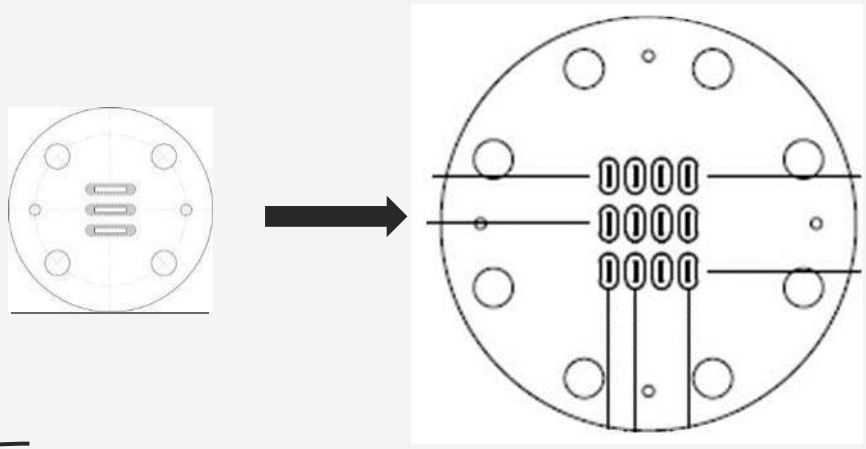
Scale-up concepts

Multi channel design (Miprowa®)

→ channel equaling up:

- Increase of channel number
- Use of corresponding channel geometry by consideration of characteristic parameters (k*A/V, mixing time, shear rates, …) @ the same residence time

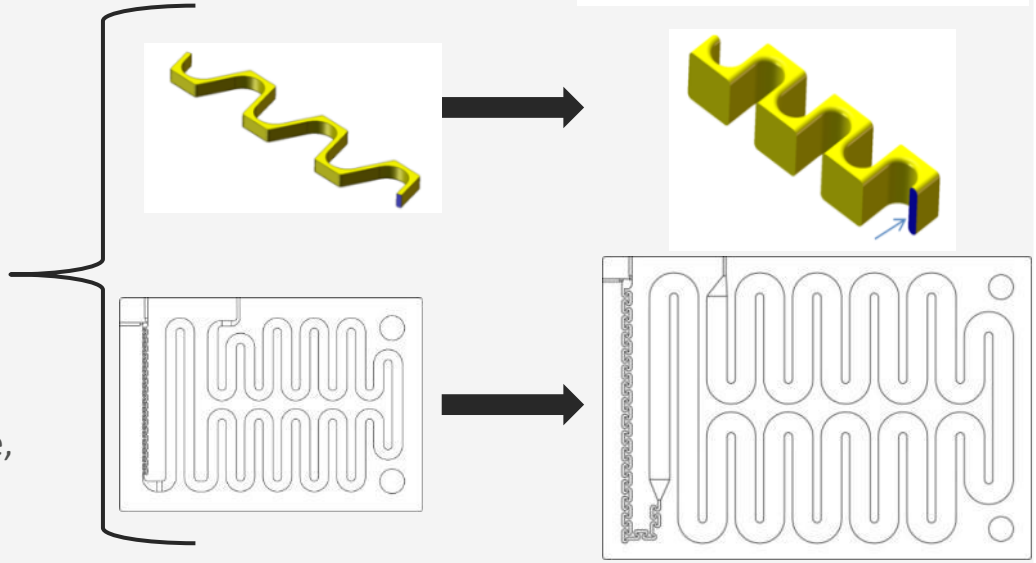


One channel design

(Lonza FlowPlate®/ART® PR)

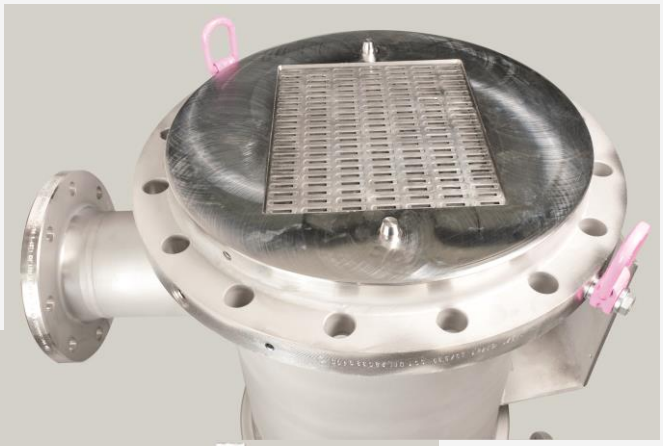
→ channel sizing up:

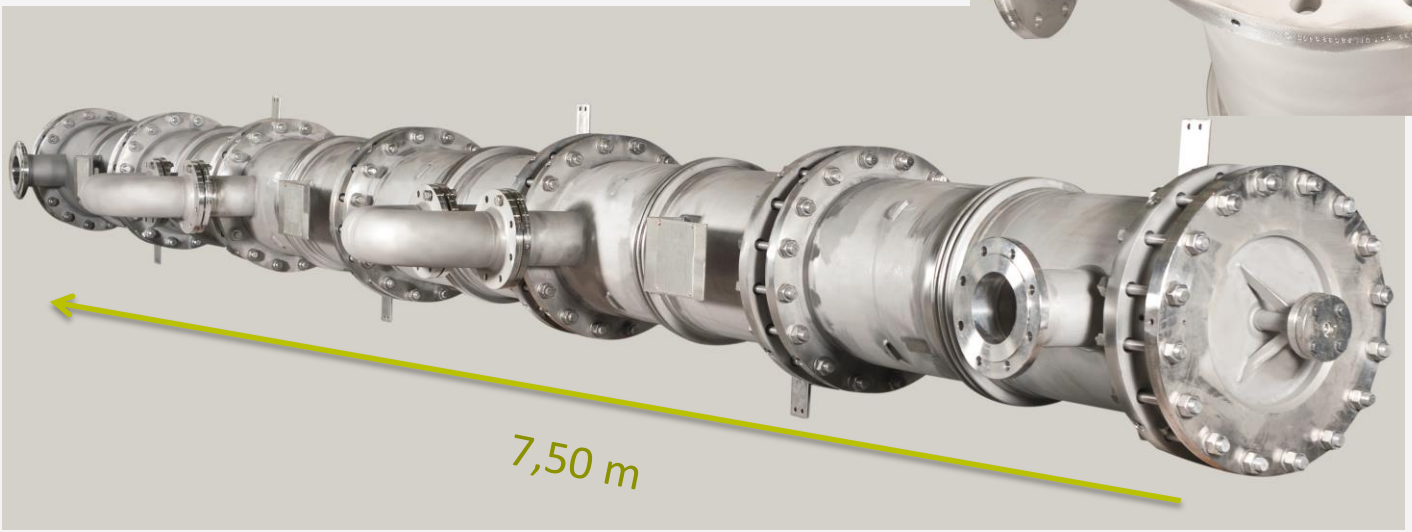
- Increase of channel size and length
- Use of corresponding channel geometries by consideration of characteristic parameters (k*A/V, mixing time, shear rates, …) @ the same residence time



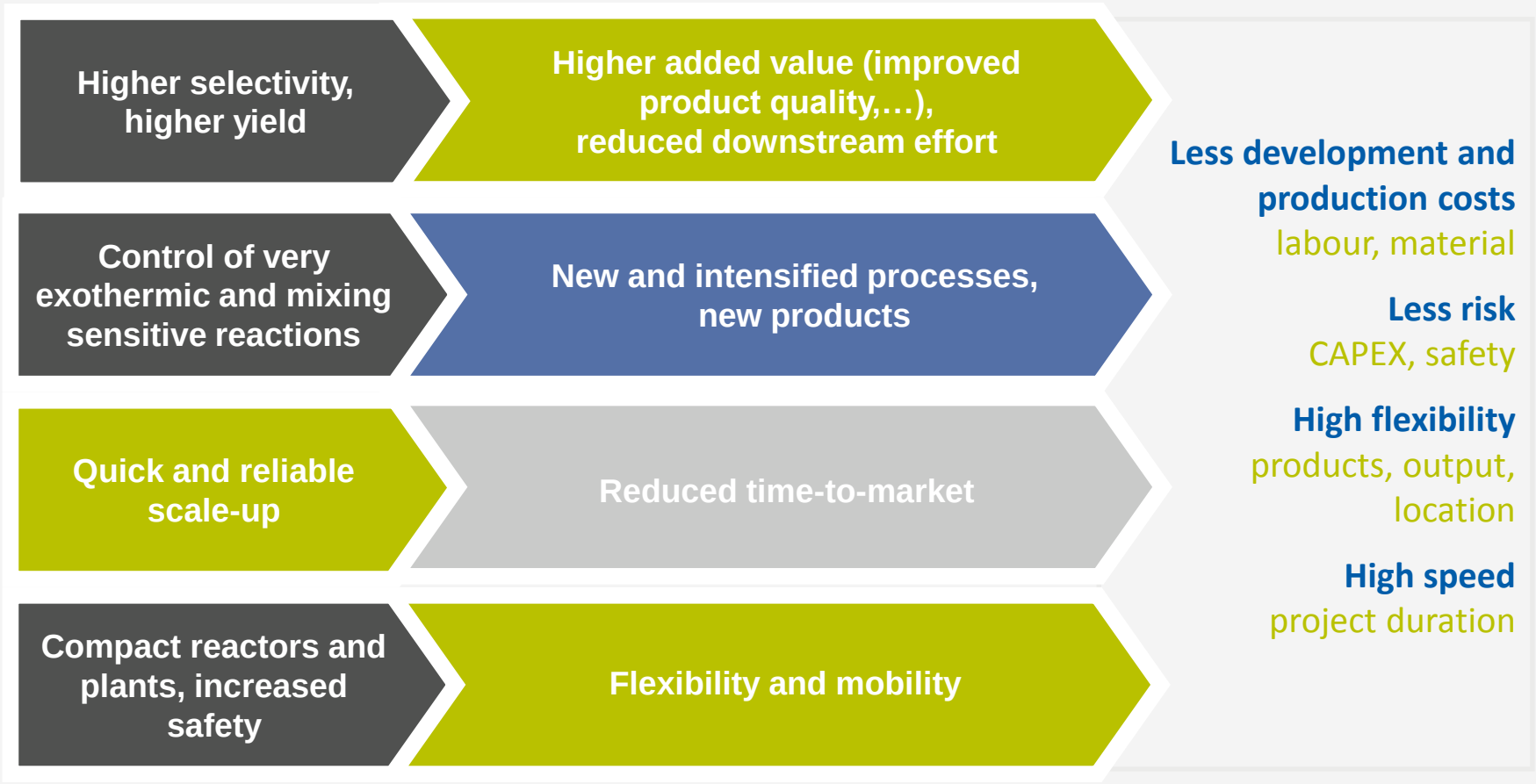
Lighthouse Reference Project

- → 6 modular MIPROWA elements with ~ 150 channels each
- → 18mm x 3,2 mm x 1200mm
- → ~5.000 t/a
- → Al





Benefits


Higher selectivity, higher yield
Higher added value (improved product quality,…), reduced downstream effort
Control of very exothermic and mixing sensitive reactions
New and intensified processes, new products
Quick and reliable scale-up
Reduced time-to-market
Compact reactors and plants, increased safety
Flexibility and mobility
Less development and production costs
labour, material
Less risk
CAPEX, safety
High flexibility
products, output, location
High speed
project duration

Guidance

- Proof-of-principle studies…

  → …help you to select the right equipment.

- Training and Education…

  → …help you to start quickly with high performance flow devices.

- Effective after-sales-support…

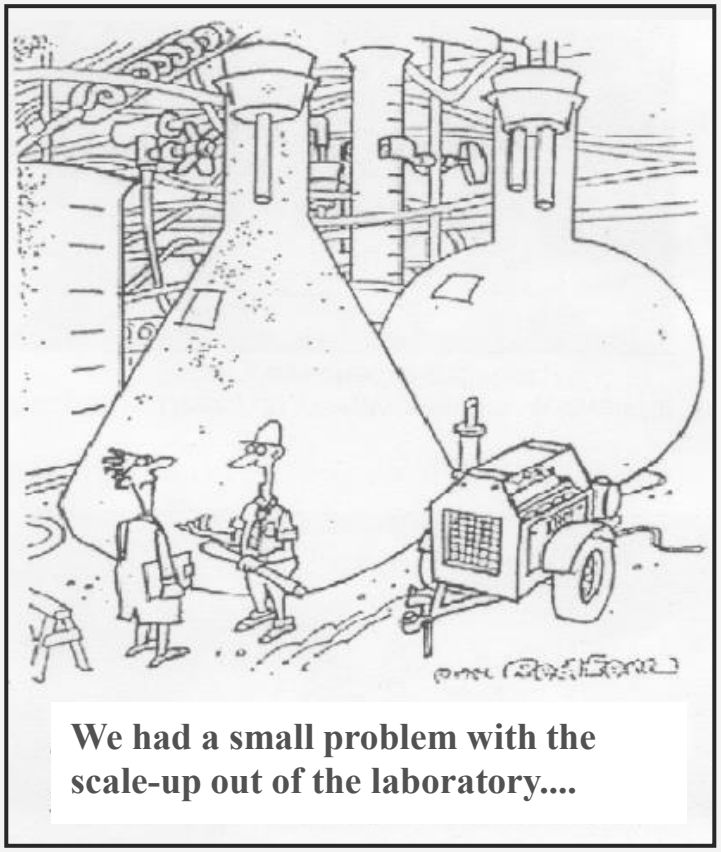
  → …helps you to conduct a smooth project performance without delays.

- Equipment related consulting – strategic partnership…

  → …helps you in the fastest way to improve your know-how and to slope the learning curve by adapting flow technologies in your company.

Summary

- → Proof-of-Principle Studies and Consulting… Confirm Suitability
- → Time saving on laboratory scale, quick & reliable scale-up
- → Simplified process intensification and cost reduction on production scale
  - › New synthesis routes
  - › Lower energy demand
  - › Lower raw material usage
- → Safety – reduction of hazard potential
- → Flexibility & mobility, easy product switches



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Thank you for your attention!

Now it´s your turn to change…

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→ We will be happy to support you.