



Development of a new multi purpose continuous reactor system

15th PIN meeting

Cranfield University

21st November 2007

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Agenda

- Concept
- Design specification
- Reactors
 - Variable Channel Reactor (VCR)
 - Agitated Cell Reactor (ACR)



Concept

A flexible reactor system suitable for reactions of less 1 second to more than 100 hours:

1. Minimum number of components
2. Simple to configure



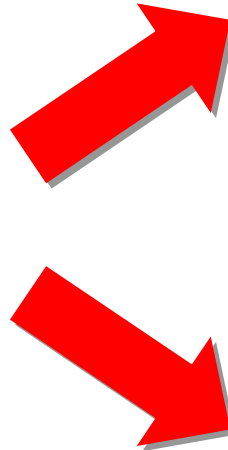
Design: Operating specification

- Good scale up characteristics
- Throughput 100 gram to >100 kg (per hour)
- Materials of construction (PTFE, Hastelloy, glass, stainless steel, etc)
- High or low operating pressure but low pressure drop
- Efficient mixing with the minimum of back mixing irrespective of reaction speed
- The reactor must be less than 5 m long
- Process surfaces accessible for inspection and cleaning



Design: Key driver – reaction time

**Reaction time is a
key consideration**



0 – 100 seconds

(Variable Channel Reactor)

100 – 100,000 seconds

(Agitated Cell Reactor)



1. Reactions <100 seconds

Reactions 0 – 100 seconds



1. Reactions <100 seconds

Fast reactions

- Short reaction time
- High heat output

Small flow channels



A reactor design based on a simple channel works well

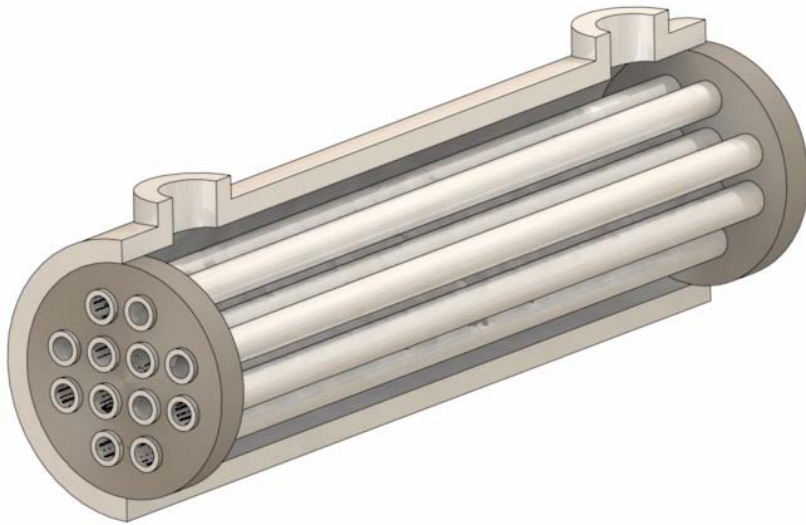
Benefits

- Good plug flow
- Good mixing
- Reduced tendency to foul
- Good heat transfer capacity



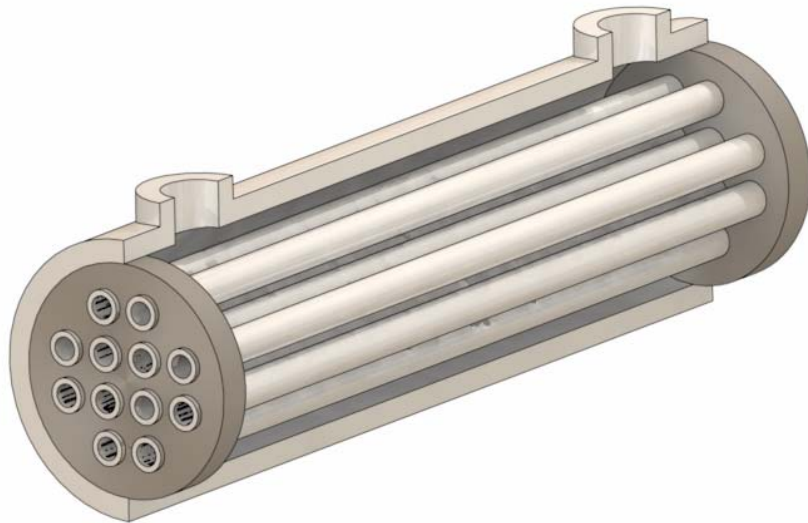
1. Reactions <100 seconds

Conventional design approach is to use heat exchangers with high surface to volume ratios





1. Reactions <100 seconds



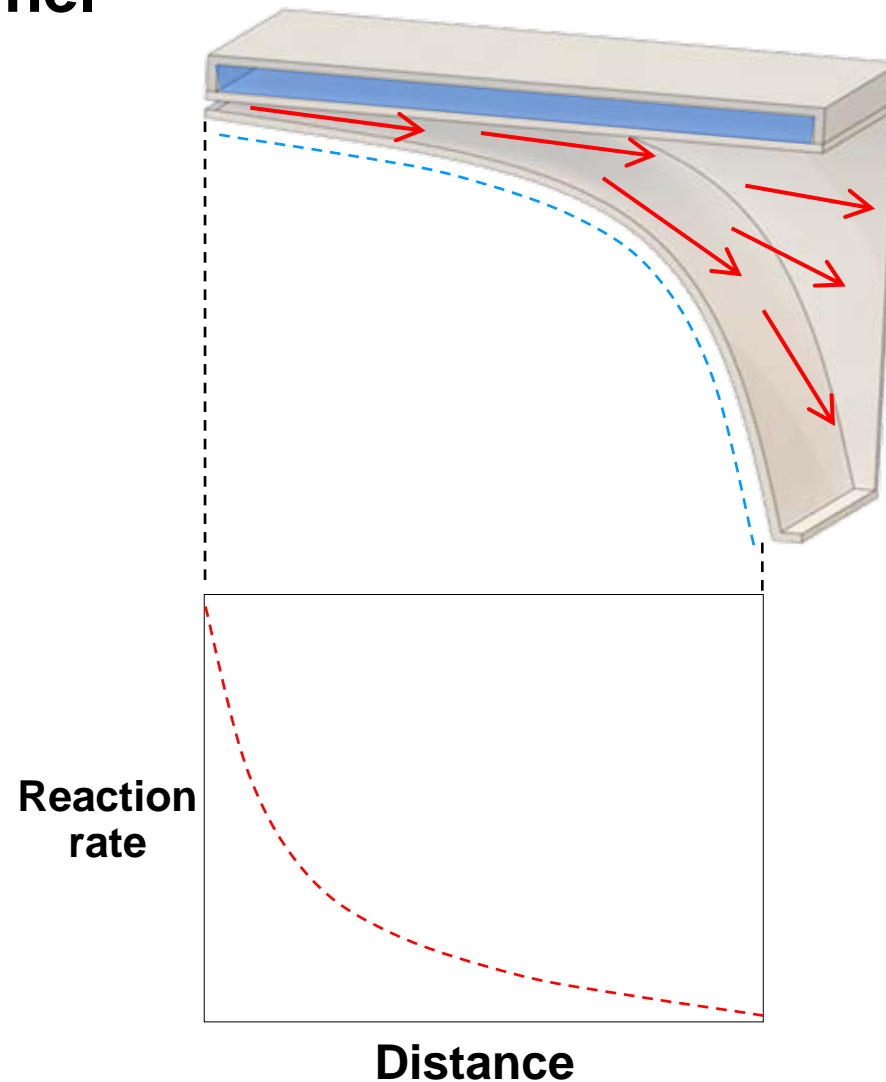
Disadvantages

- High pressure drop
- Blockage problems
- Process surfaces generally not accessible for cleaning



Variable channel reactor (VCR)

Profiled reactor channel

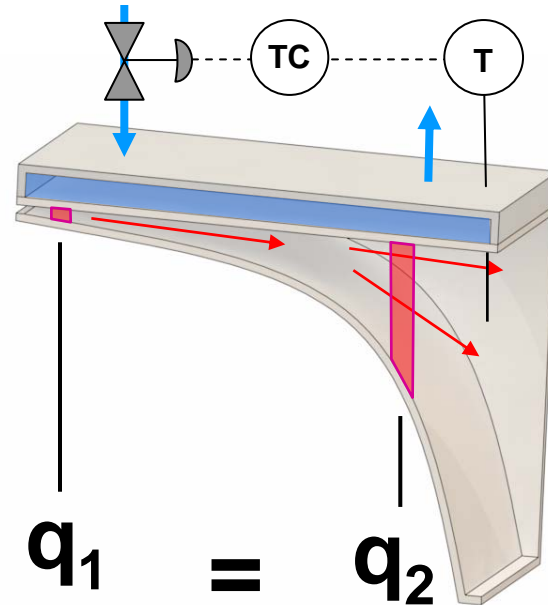
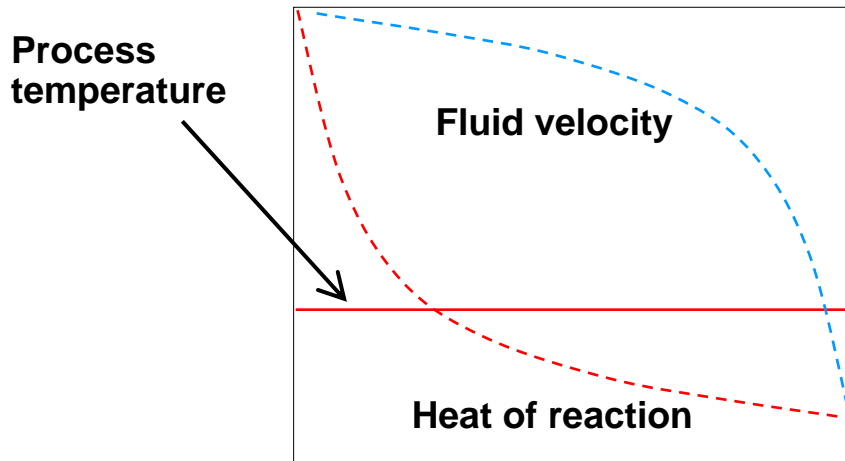




Variable channel reactor (VCR)

Process heat load (per unit length of jacket) remains constant throughout the reactor.

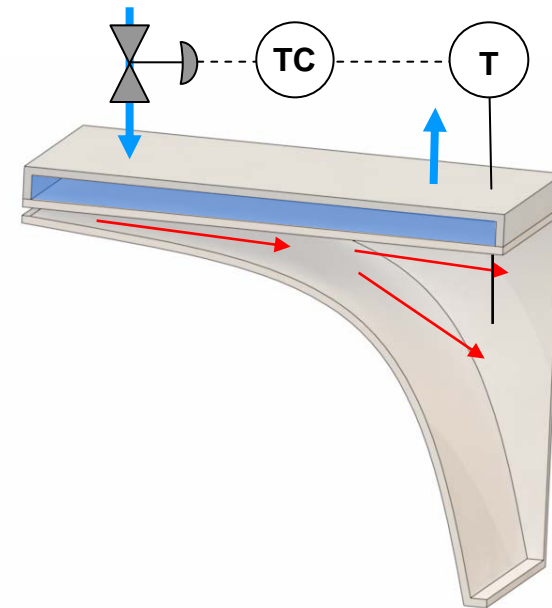
This allows the temperature of the whole reactor to be controlled rather than one point.





Variable channel reactor (VCR)

- Uniform temperature allows high LMTDs to be used without creating cold zones.
- Larger flow paths giving lower pressure drop and reduced tendency to block





Variable channel reactor (VCR)

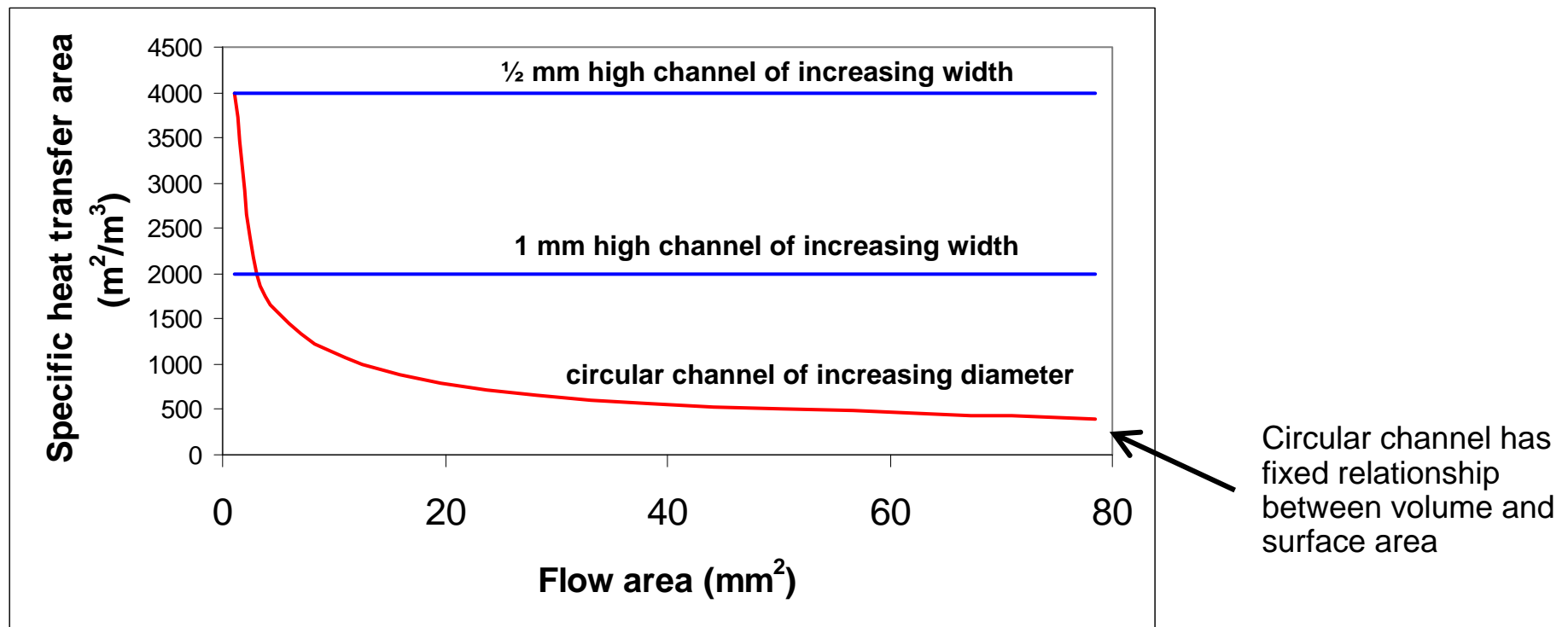
Design



Variable channel reactor (VCR)

Channel shape cross section: Circular vs Rectangular

Rectangular channels have better scale up characteristics than round pipes





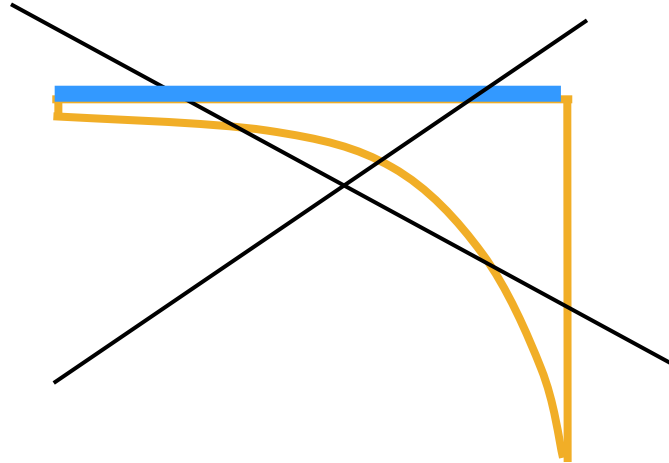
Variable channel reactor (VCR)

Channel profile

Poor mixing

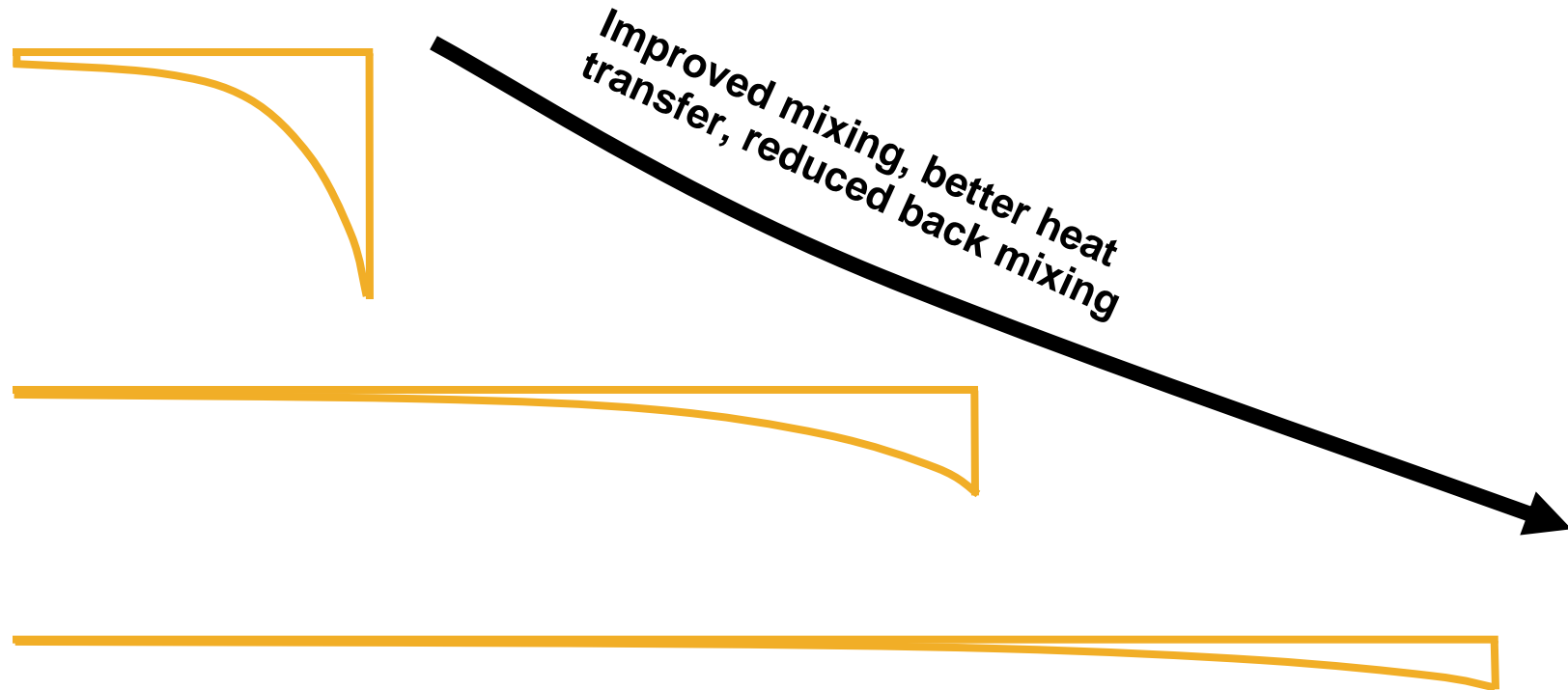
Back mixing

Ineffective cooling



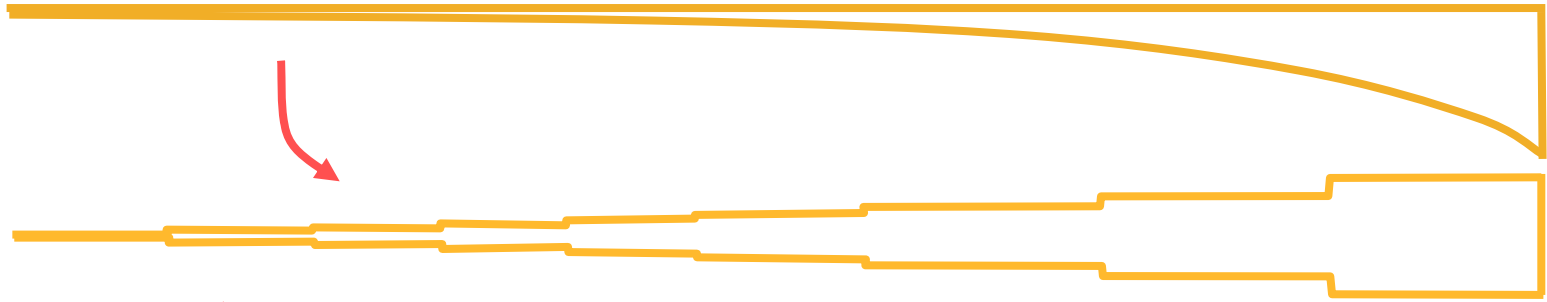
A Variable channel reactor (VCR)

Channel profile

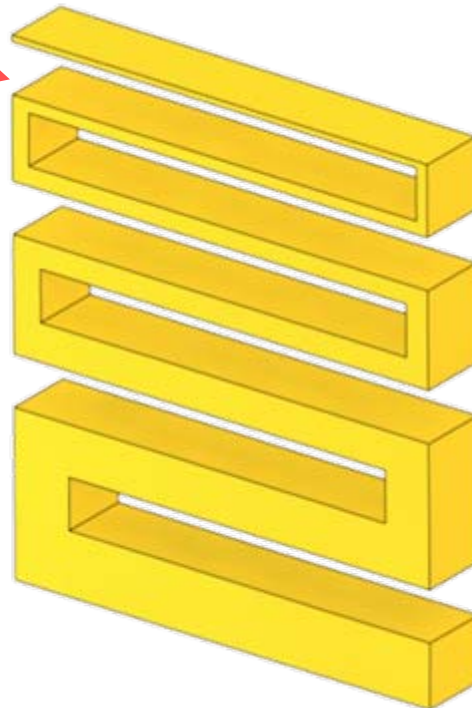




Variable channel reactor (VCR)



**Compact design is achieved
by folding the flow path**



Process flow profile

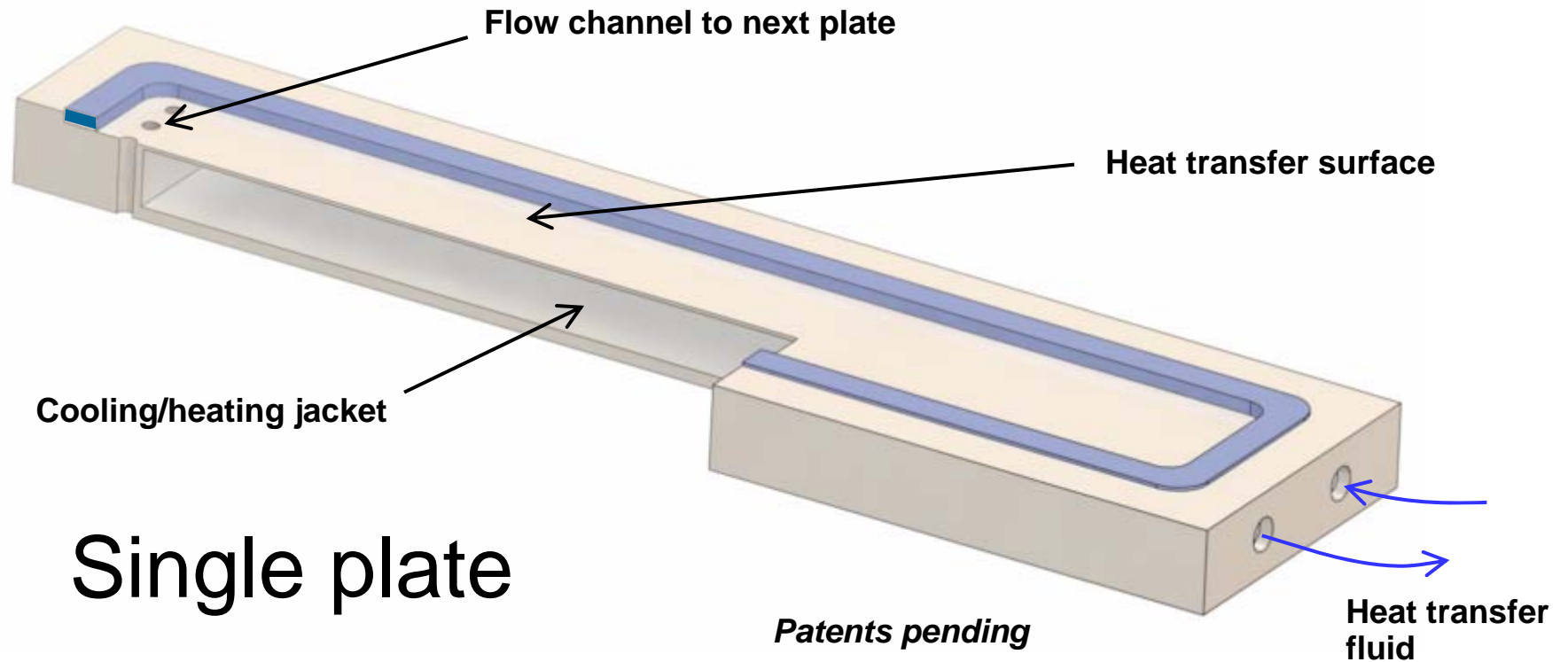


Variable channel reactor (VCR)

Construction

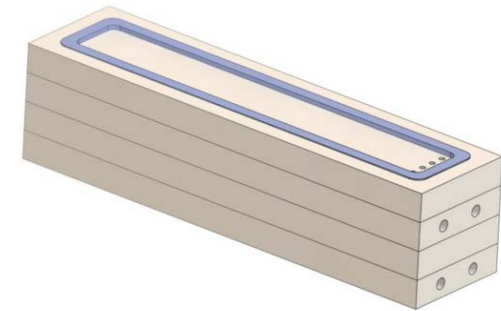
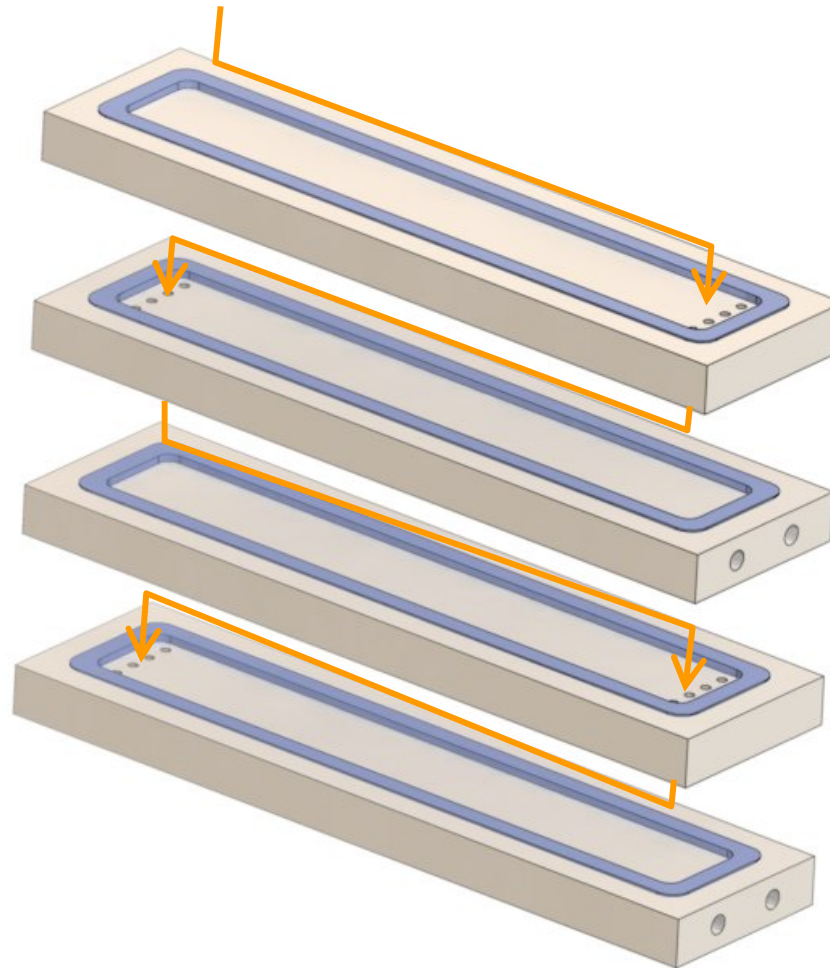


Variable channel reactor (VCR)

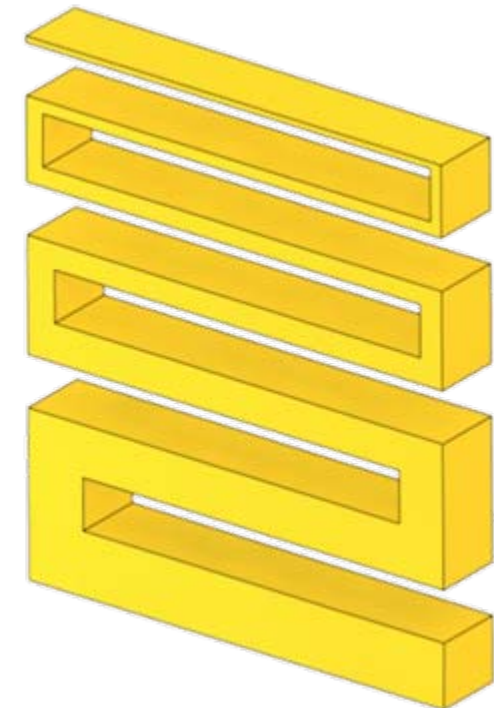




Variable channel reactor (VCR)

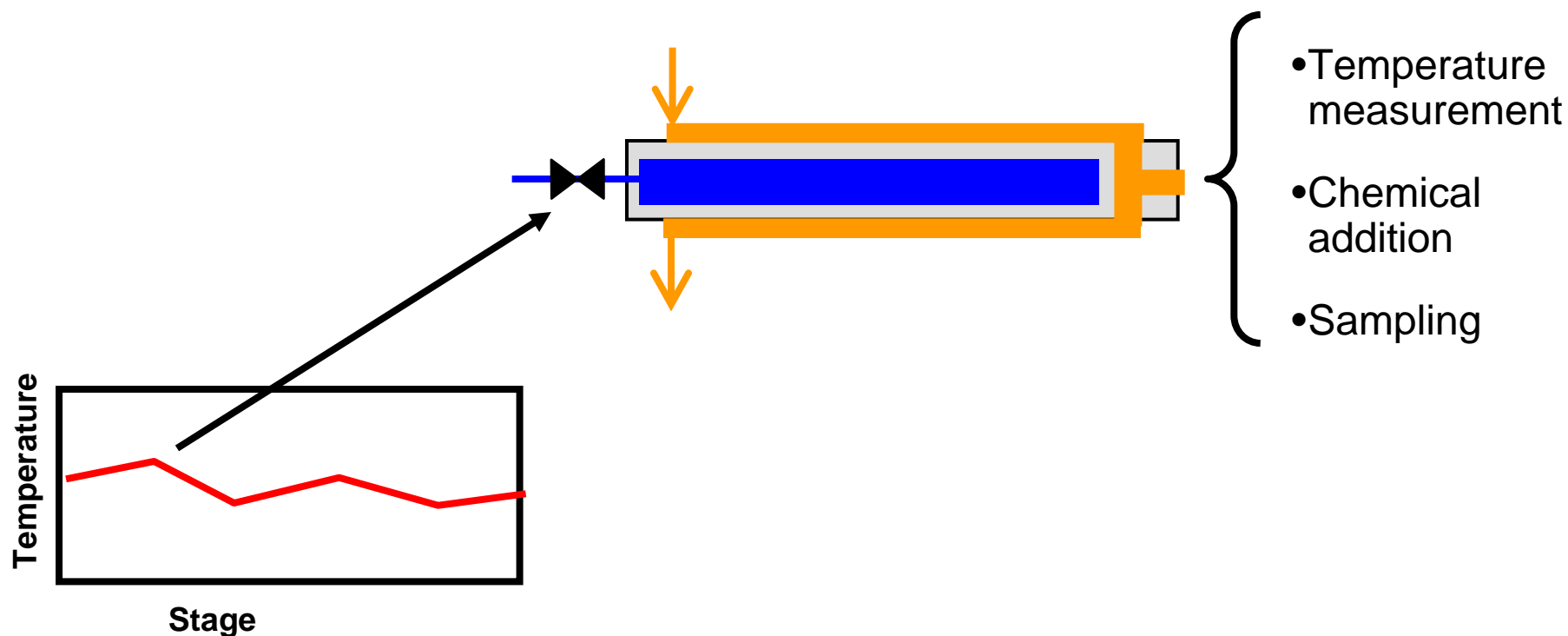


Patents pending



Variable channel reactor (VCR)

Each plate has independent temperature control, temperature measurement plus sampling/chemical addition.



Prototype

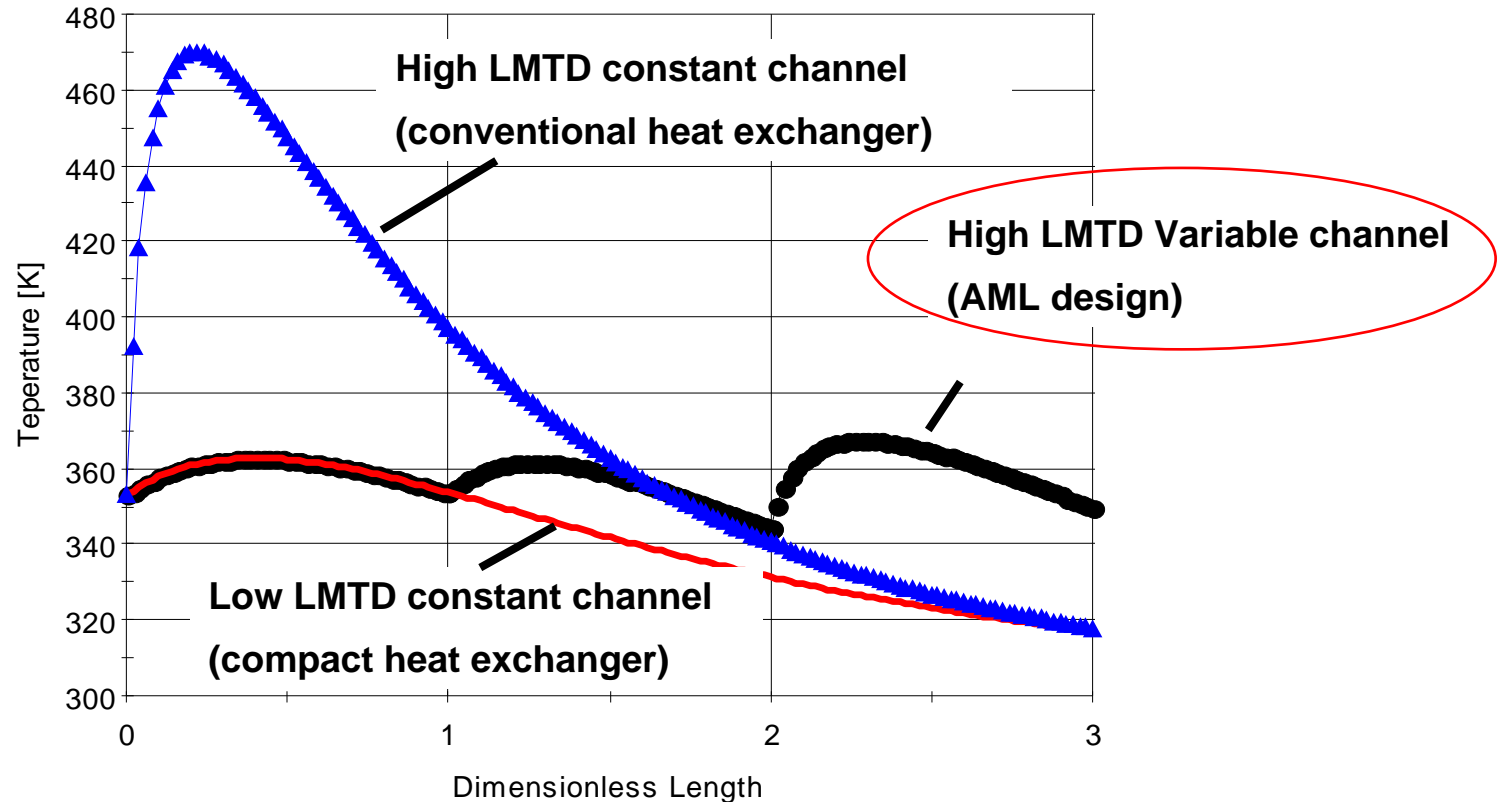
- 10 stages
- Channels from 0.2 to 2 mm
- Hastelloy C with PTFE seals
- 10 bar rated
- 100 Watts



Patents pending



Variable channel reactor (VCR)



By permission of Imperial College

A Variable channel reactor (VCR)



- High cooling capacity ($> 1,000,000$ Watts/litre)
- Large flow channels (low pressure drop + reduced tendency to block.)
- Modular design
- Simple to configure
- Simple to dismantle and clean

Patents pending

2. Reactions >100 seconds

Reactions 100 – 100,000 seconds



2. Reactions >100 seconds

Slow reactions

- Long residence time
- With low heat output

Large flow channels



A reactor design based on a simple pipe only works with a long pipe.

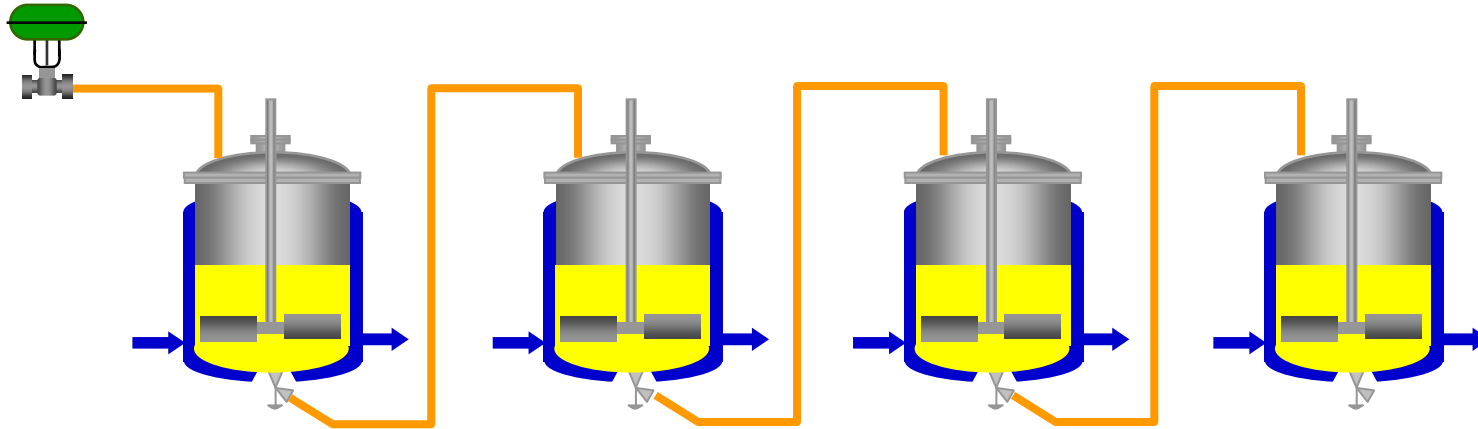
Disadvantages

- Back mixing problems
- Poor mixing
- Increased tendency to foul
- Poor heat transfer capacity



2. Reactions >100 seconds

The CFSTR concept offers the best compromise between good agitation and good separation between products and reactants

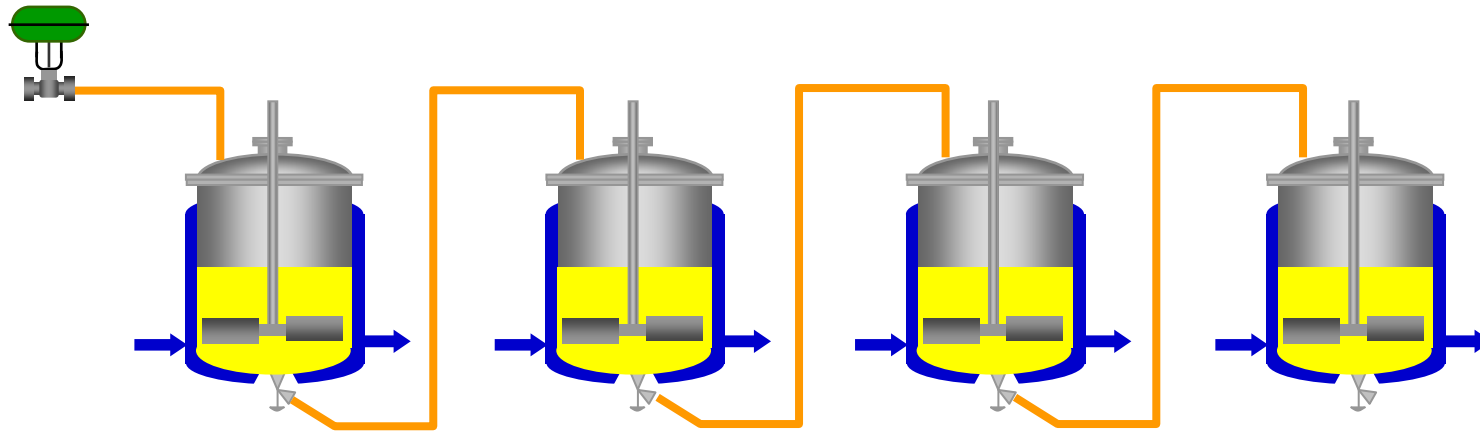


Cost and complexity



2. Reactions >100 seconds

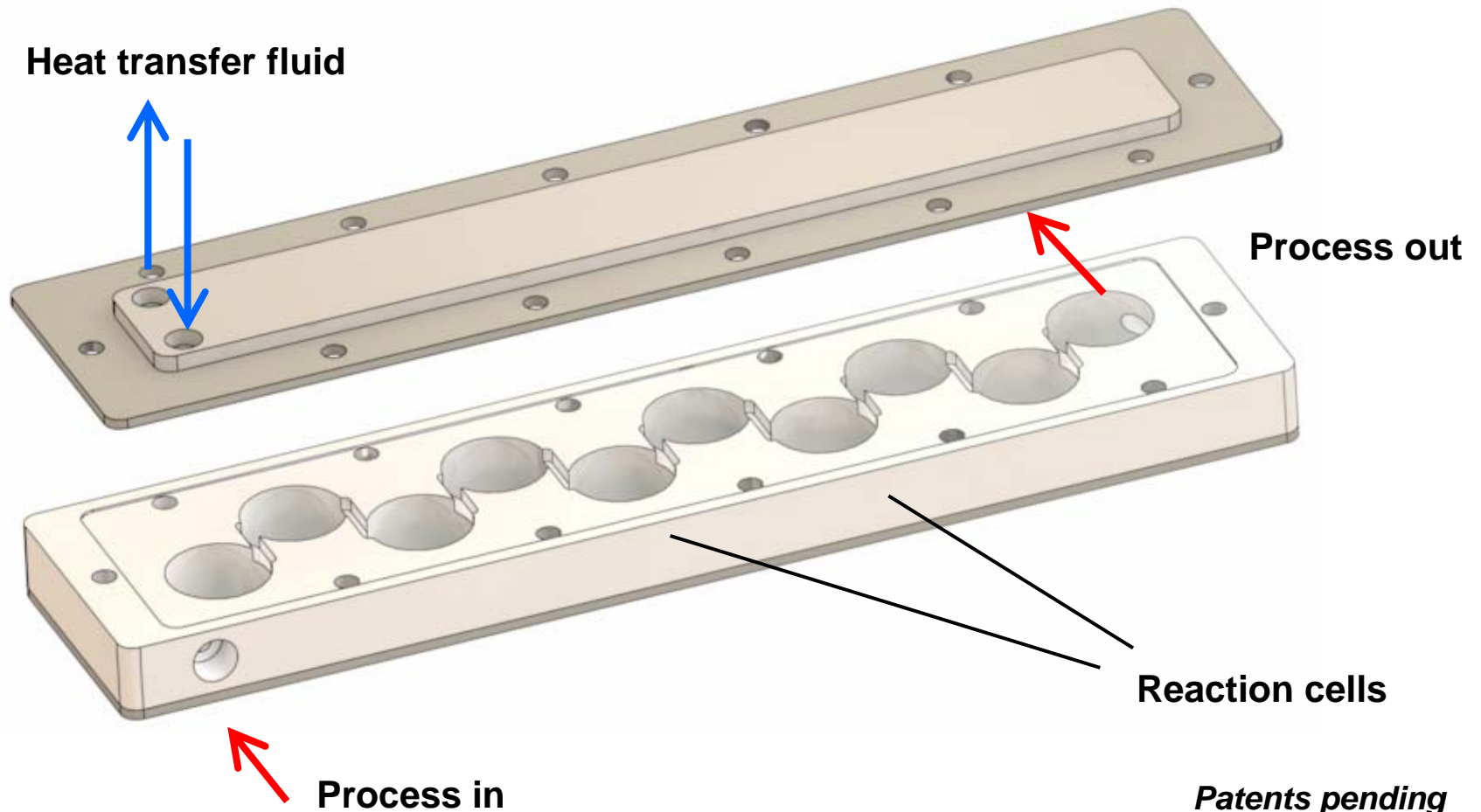
Cost and complexity





Agitated cell reactor (ACR)

Reactor assembly

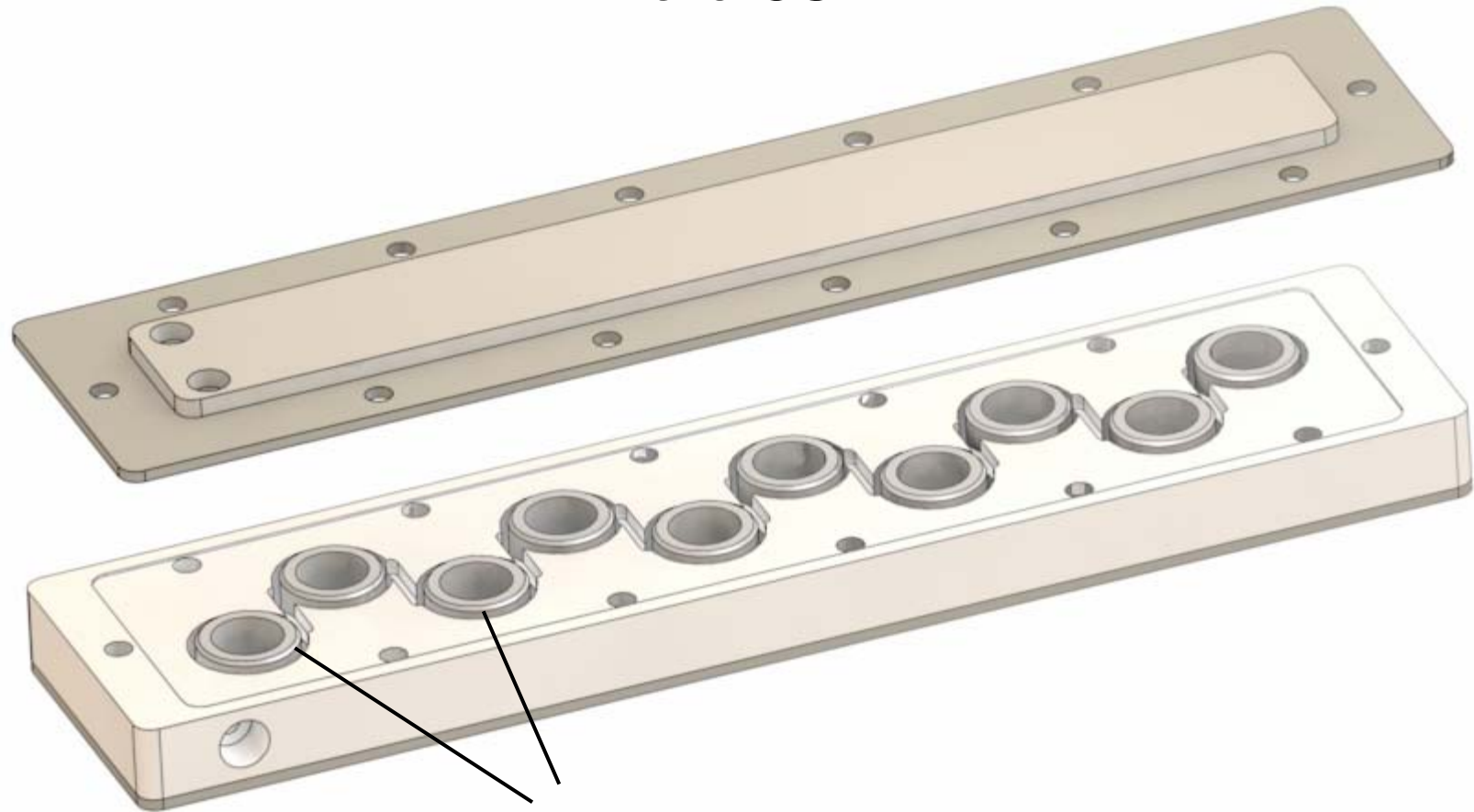


Patents pending



Agitated cell reactor (ACR)

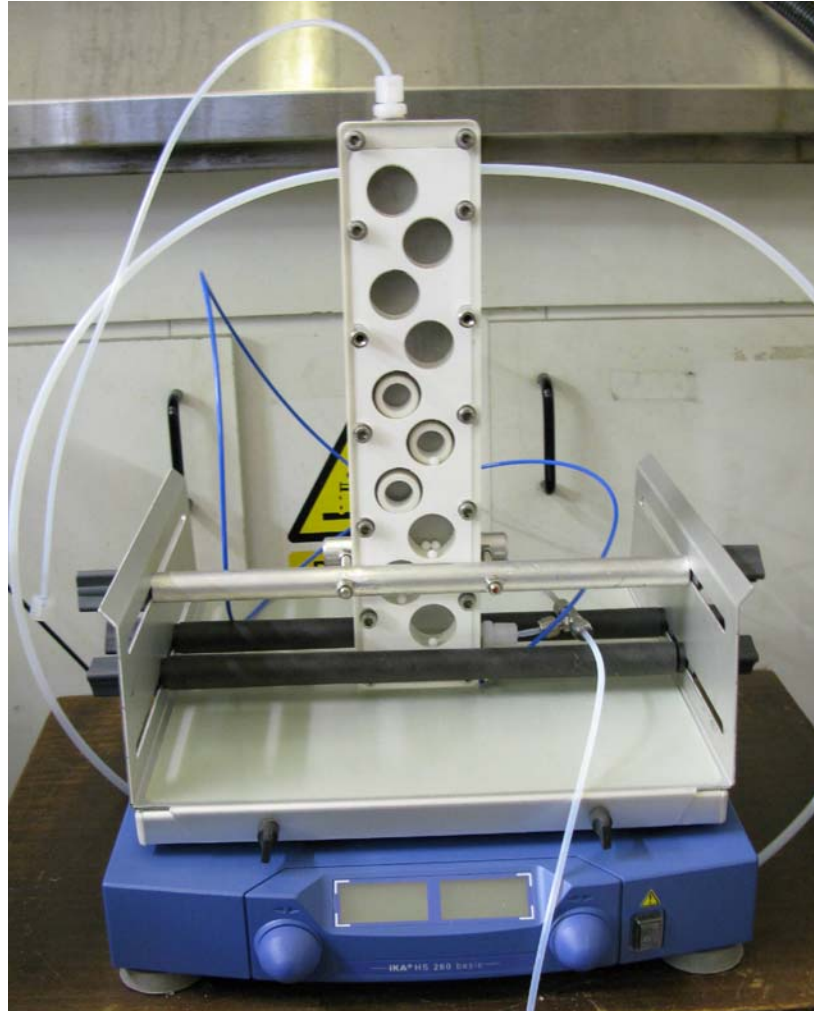
Micro CSTR



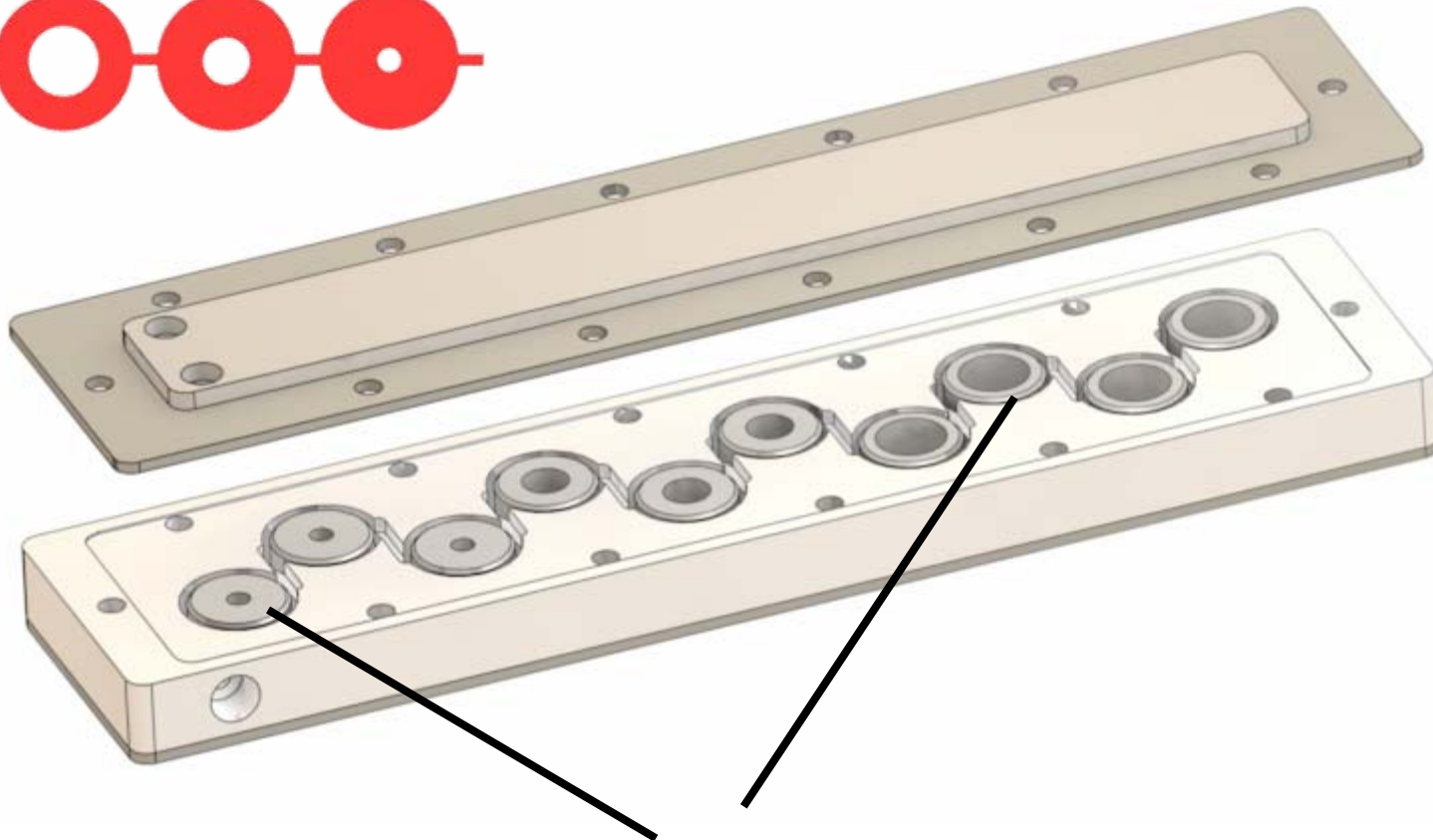
Agitating element

AM Agitated cell reactor (ACR)

Reaction cells are mounted on a vibrating platform



A Agitated cell reactor (ACR)

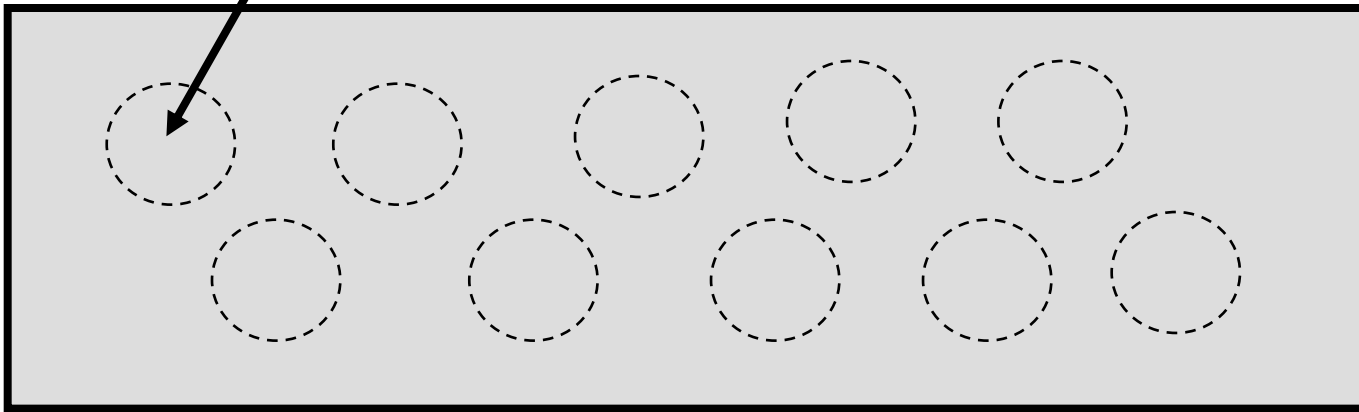


Different sized agitator elements permit surface/volume ratio and residence time to be adjusted in different cells.

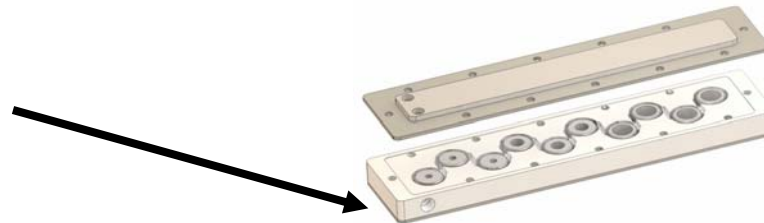


Agitated cell reactor (ACR)

Addition, sampling and temperature measurement is possible on each plate

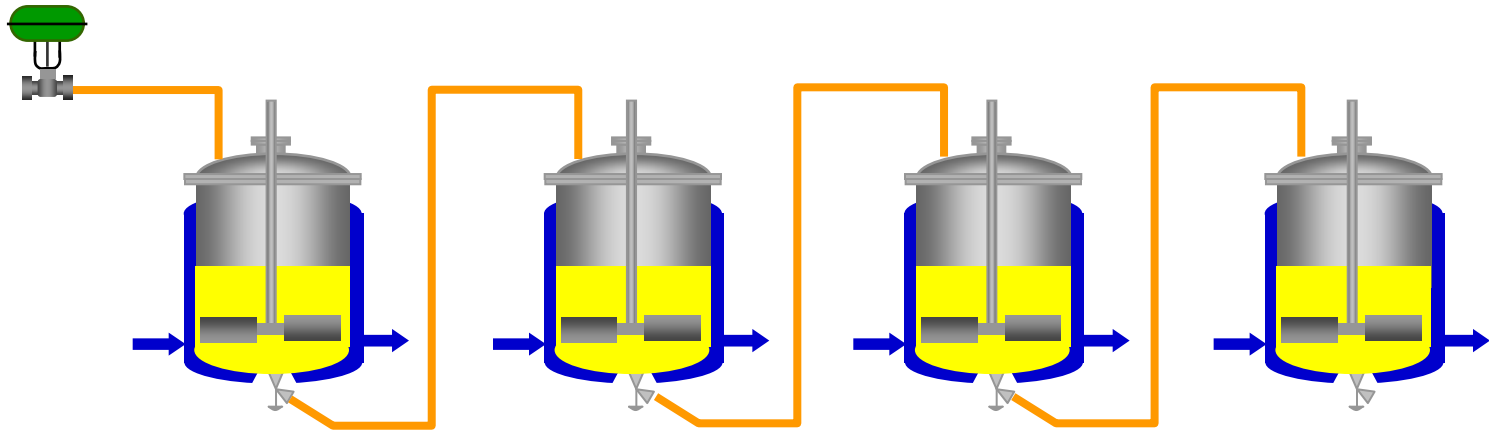


2nd plate



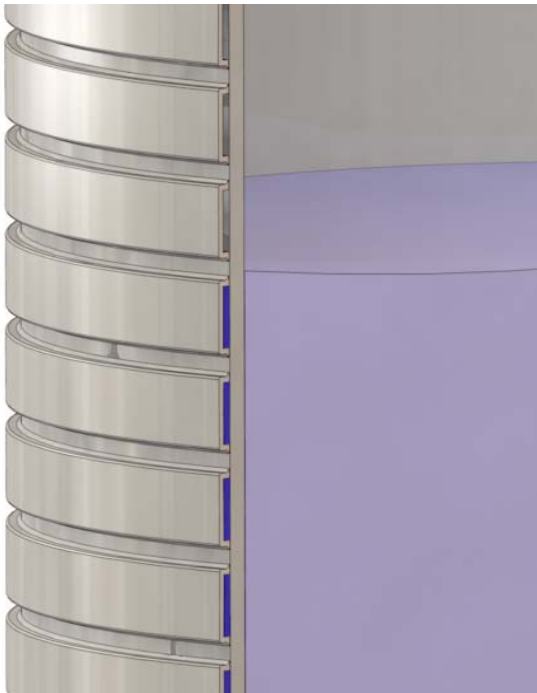
Large CSTRs and loop reactors

? Controlling flow during start up and normal operation

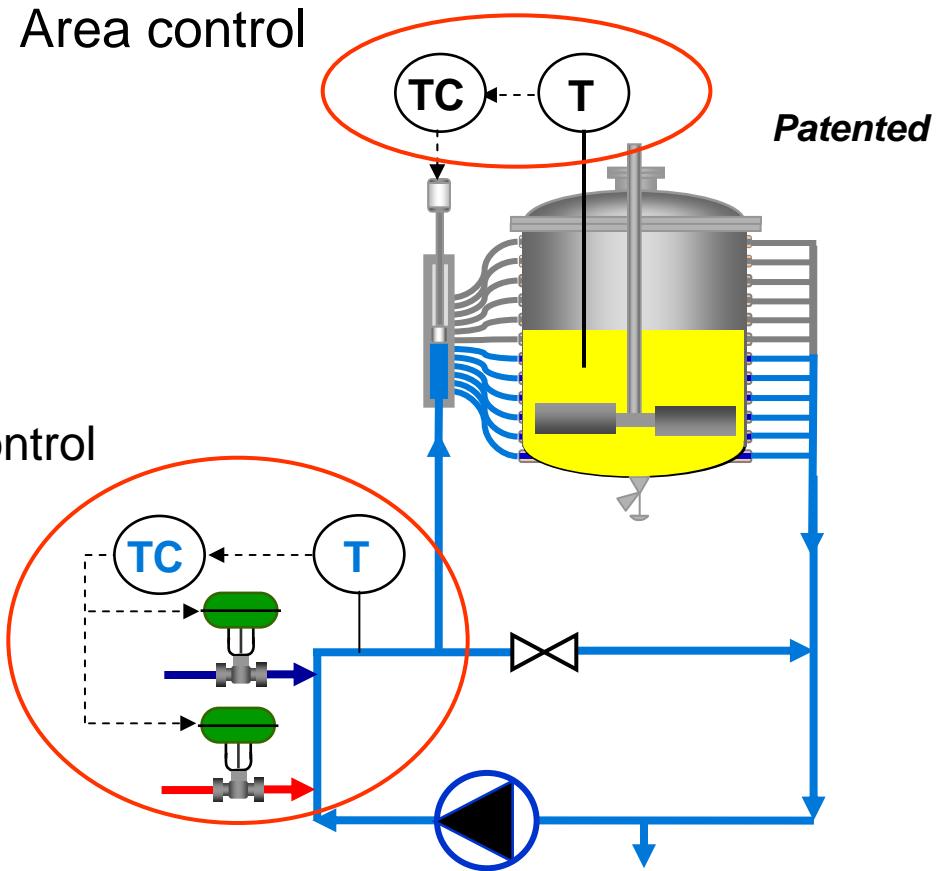


AM Large CSTRs

Coflux uses both area and temperature control

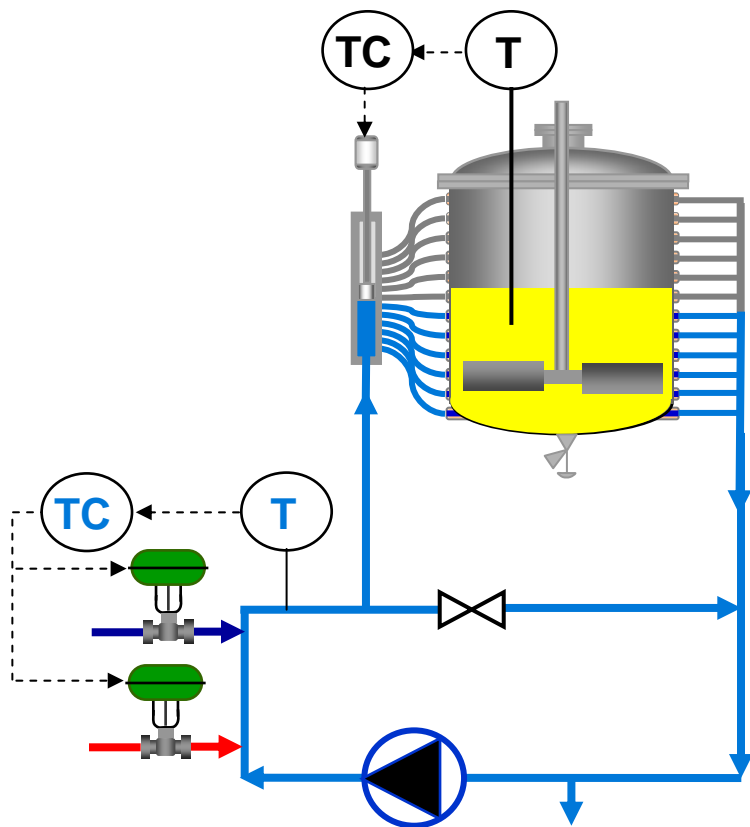


Temperature control



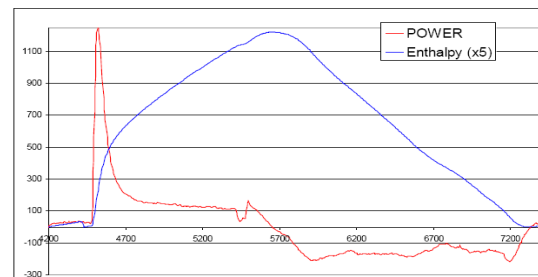
M Large CSTRs

Monitoring and controlling large CSTRs and recycle reactors



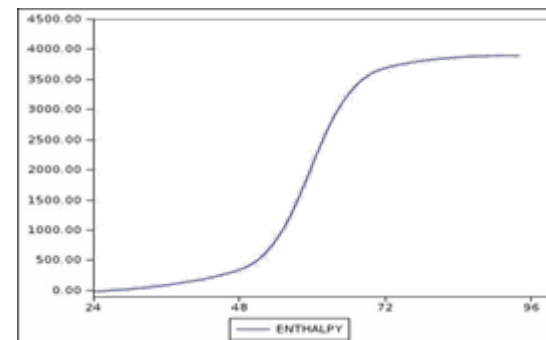
Patented

$$q = m \cdot c_p (t_{in} - t_{out})$$

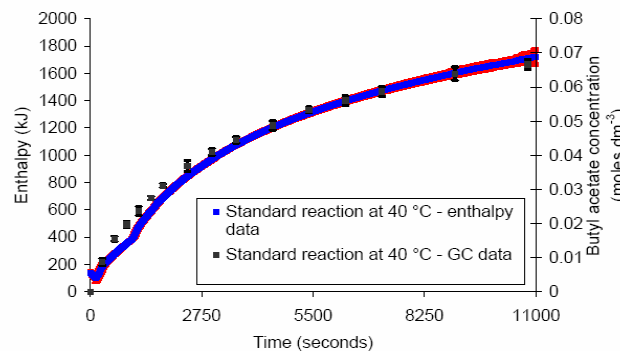


Crystallisation

Melting



Bio reaction



Chemical reactions