Understanding the Process
Intensification Opportunity

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Agenda

- Background
- Heatric’s PCHE Experience
- PI Technologies – The Underlying Principles
- Examples
- Barriers to Adoption
- The Way Forward
Background
“Process Intensification”

- PI concept for capital cost saving
- Intensified unit operations e.g. HiGee
- Early PCHE applications
Heatric’s PCHE Experience
Heatric’s PCHE Experience

1980  PCHEs developed at Sydney University

1985  Heatric founded in Australia

1990  Relocated to UK - joined Meggitt group

2003  >60 staff, $22 million annual sales
Heatric’s PCHE Experience

A Typical Offshore North Sea Project

- BG Armada
BG Armada

Feasibility Study: PCHEs potential savings of up to $20 million for typical 10,000 tonne topsides (1991 basis)

Conceptual Design: Conservatism and insufficient detail result in failure to establish convincing PCHE savings - Still the lowest cost, but simplicity of direct system preferred

Detailed Design: Changes in Gas Sales Agreements meant project cost had to be reduced
PCHEs contributed:

- 3m of deck length saving, on all levels
- 30 tonnes equipment weight reduction
- Single module lift

**Saved ~ $30 million**

(British Gas estimate)
PCHEs were the Project Enabling Technology
Heatric’s PCHE Experience

Since 1990 Heatric has manufactured many microchannel devices:

- More than 700 custom-designed heat exchangers
- 3000 tonnes of microchannel components
- Microchannel devices worth > $180 million
PI Technologies
–
The Underlying Principles
Underlying Principles – the Established Approach

Intensify a phenomenon: e.g.
- Mass transfer
- Heat transfer
- Rate of reaction

And/or

Perform multiple functions simultaneously: e.g.
- Mixing and reaction
- Reaction and heat transfer
- Heat transfer and separation

A Unit Operations approach
Underlying Principles

An Alternative Approach:

- Frame the problem – a conflict that needs to be resolved
- Identify potential solutions – at a fundamental level
Underlying Principles

Fundamental solutions could involve:

- Segmentation (e.g. multiple, smaller steps)
- More reactive species (e.g. O₂ vs. air, increased concentration)
- Higher activity catalyst
- Changed reaction conditions (pressure, temperature)
- Supercritical conditions
- Non-uniform, locally tailored conditions
Underlying Principles

An Alternative Approach:

• Frame the problem – a conflict that needs to be resolved

• Identify potential solutions – at a fundamental level

• Pursue a practical embodiment of the preferred solution
Examples
Batch vs. Continuous (microreactor)

Product quality:
- Average particle size
- Particle size distribution

Parameters:
- Residence time
- Mixing
- Temperature

Courtesy of Clariant GmbH
Batch vs. Continuous (microreactor)

Impact on:

- Mean particle diameter
- Particle size distribution (log scale)

(1): Pigment out of microreactor, D$_{50}$ = 90 nm
(2): Batch pigment, D$_{50}$ = 598 nm

Courtesy of Clariant GmbH
Compact Reforming

Emerging Syngas Users:
- Monetization of stranded gas (GTL)
- Distributed hydrogen
- Fuel cell systems

Challenges:
- Size
- Complexity
- Safety
- Emissions
Compact Reforming

The **HEATRIC** solution:

- Catalytic combustion
- Staged fuel addition
- Heat transfer to process between combustion stages
- Combustion within pressure-containing system
HEATRIC process (prototype):

- 9 x catalytic combustion stages
- 9 x reforming stages
- Conventional particulate catalyst (reduced size)
Barriers to Adoption
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- Lack of user understanding
Lack of User Understanding

Understand the NEEDS:

- Laboratory program
- Problem definition
Barriers to Adoption

- Lack of user understanding
- Perceived need for design tools
Perceived Need for Design Tools

- Tools generally exist
- Proprietary know-how
- Work with competent suppliers
Barriers to Adoption

- Lack of user understanding
- Perceived need for design tools
- Impact on plant reliability, flexibility
Plant Reliability and Flexibility

- Comprehensive pilot trials
- Process understanding
- Prudent equipment design
- Appropriate sparing policy
Barriers to Adoption

- Lack of user understanding
- Perceived need for design tools
- Impact on plant reliability, flexibility
- Scale-up
## Scale-up

<table>
<thead>
<tr>
<th>Application property A [dH]</th>
<th>Application property B [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Classic scale-up phenomenon</strong></td>
<td><strong>1:1 reproducibility</strong></td>
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</tbody>
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### Diagram

![Diagram showing scale-up phenomenon](image)

- **Lab (Batch, 1l)**
- **Pilot plant (Batch, 1 m³)**
- **Production plant (Batch, 40 m³)**
- **MRT-Lab**
- **MRT-Pilot plant**

**Key**
- Blue: Application property A [dH]
- Red: Application property B [%]

**Values**
- Lab (Batch, 1l): Application property A = 6.0, Application property B = 150
- Pilot plant (Batch, 1 m³): Application property A = 5.5, Application property B = 135
- Production plant (Batch, 40 m³): Application property A = 4.6, Application property B = 135
- MRT-Lab: Application property A = 5.5, Application property B = 140
- MRT-Pilot plant: Application property A = 5.8, Application property B = 145

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**Courtesy of Clariant GmbH**
Barriers to Adoption

- Lack of user understanding
- Perceived need for design tools
- Impact on plant reliability, flexibility
- Scale-up
- Cost, payback time
Cost, Payback Time

- Equipment costs ~20% of total plant cost
- Engineering may outweigh hardware costs

But

- Beware cost justification for new technology
The Way Forward
The Way Forward

- Educate, Educate, Educate!
- Focus on Chemistry Needs; seek bespoke solutions, not Unit Operations
- Forget marginal justification, focus on Project-Enabling opportunities
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