Heatric

Printed Circuit Heat Exchangers for Supercritical CO_2 Cycles

MIT-Symposium on Supercritical CO2 cycle

6th March 2007

Stephen John Dewson

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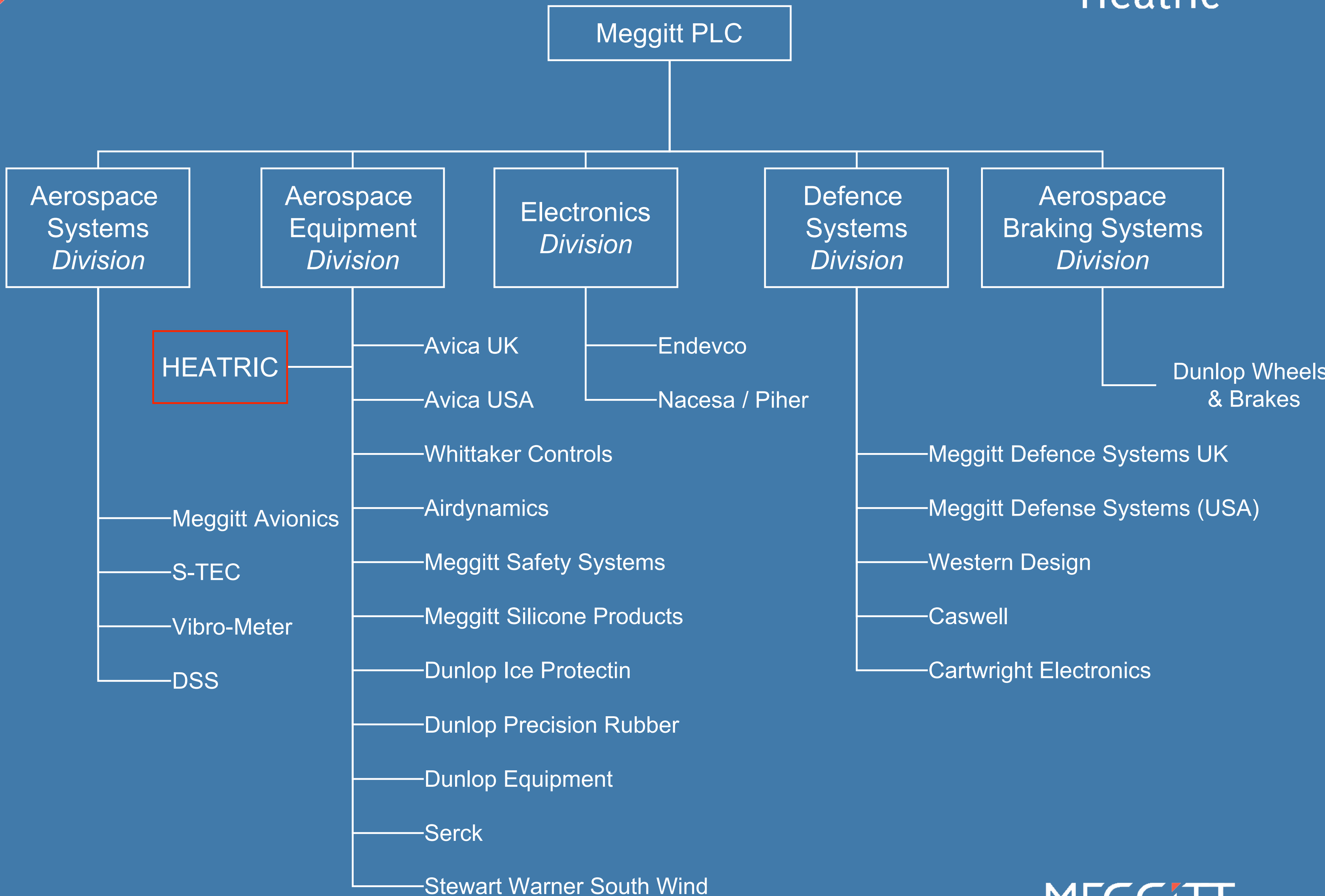

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Meggitt plc

- FTSE 250 company; market capitalisation (March 2006) ca. £1.5 billion ($2.9 billion)
- 5600 employees across 30 companies predominantly in USA, UK, Switzerland, China
- Focus on aerospace, defence systems and electronics sectors
- 2005 Results:
  - Turnover for 2005 up 30%, at £616 million ($1.29 billion)
  - Underlying profit before tax up 29%, at £116 million ($228 million)
- Product development spend during 2005 was £35 million ($69 million), 5% of turnover

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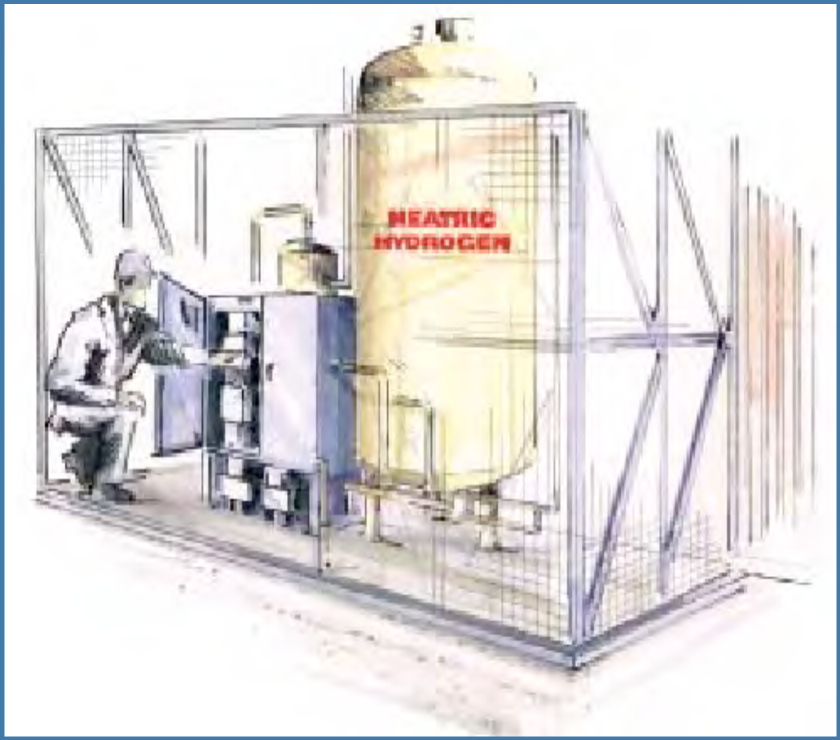
Printed Circuit Heat Exchangers
Printed Circuit Reactors



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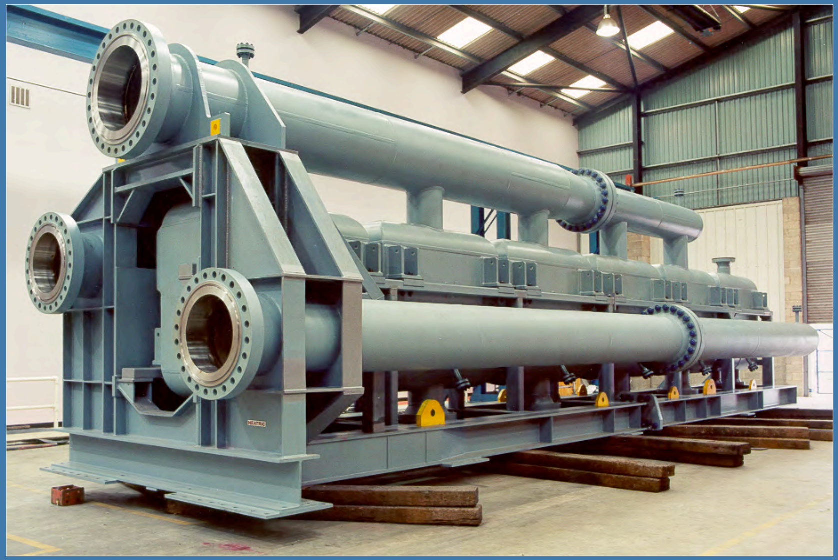
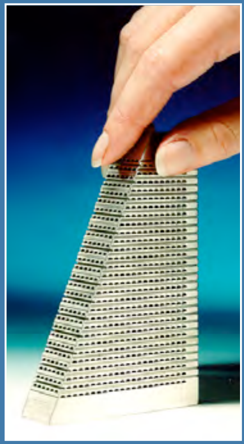
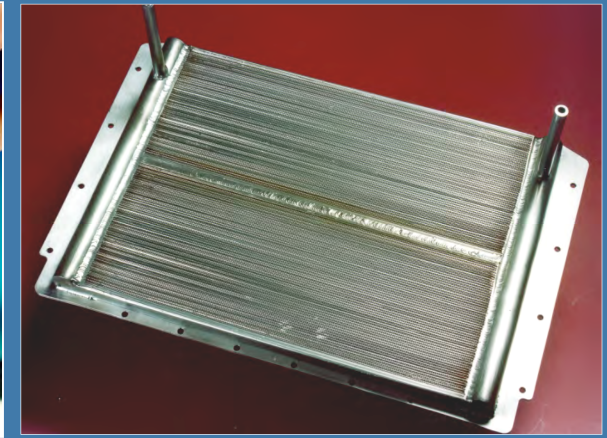
Heatric

- 1980 PCHEs developed at Sydney University
- 1985 Heatric founded in Australia
- 1990 Relocated to UK - joined Meggitt group
- 2006 70 staff, $35 million annual sales.
- 2007 Factory Extension







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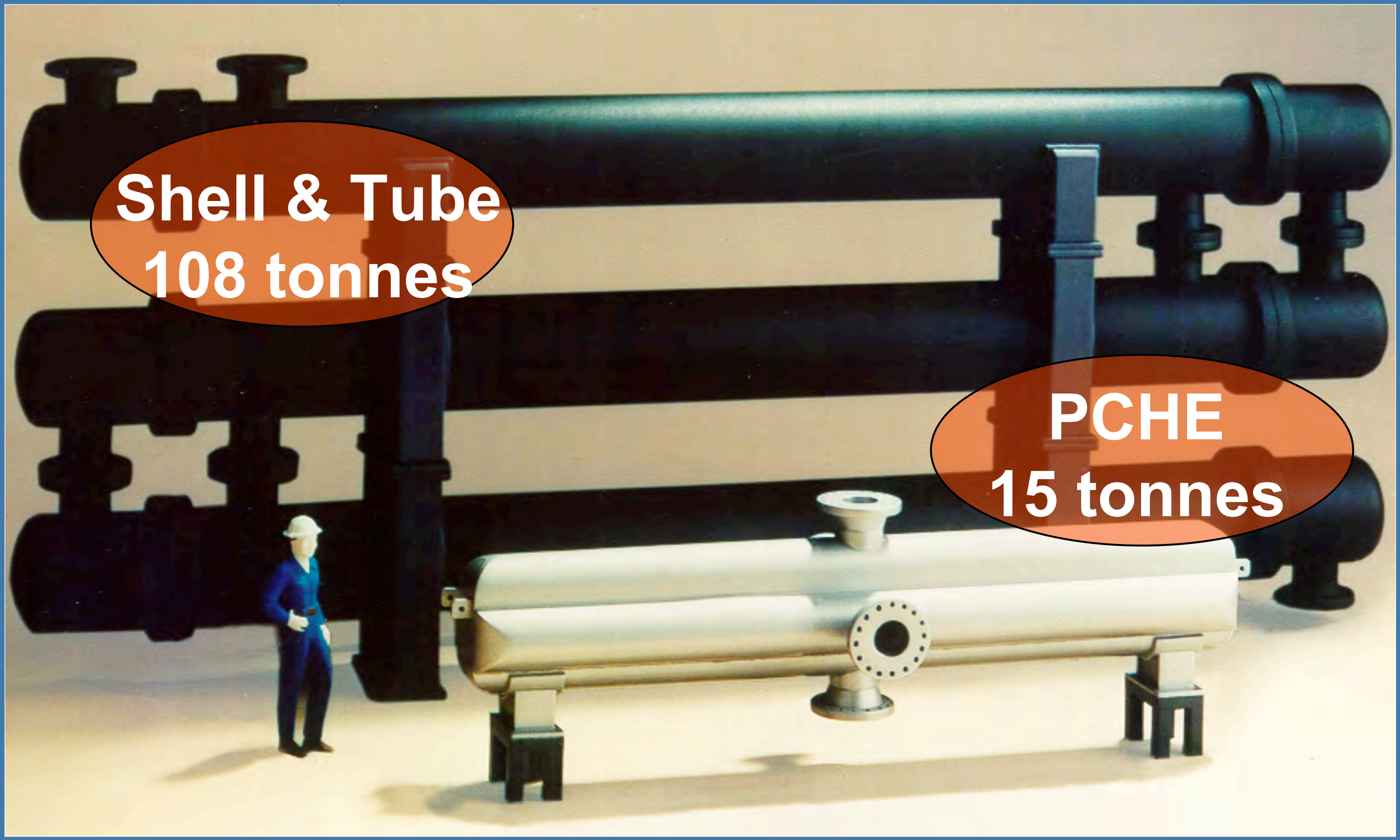
PCHE Characteristics – space and weight savings



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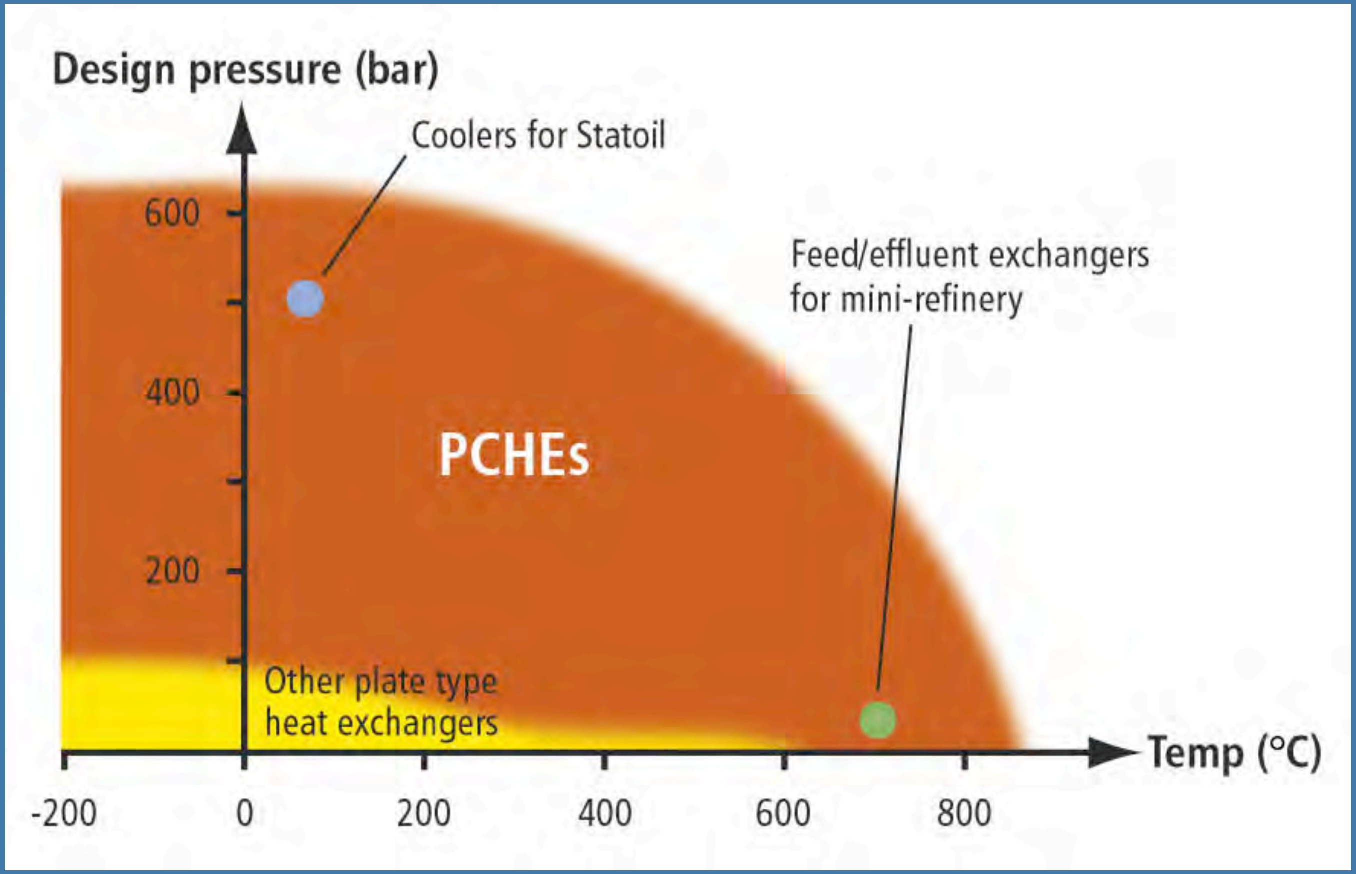
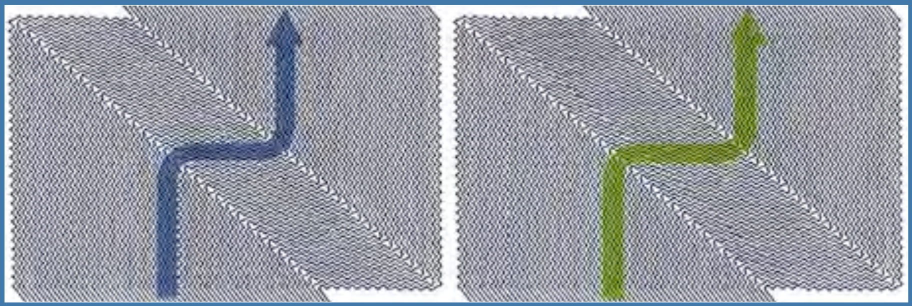
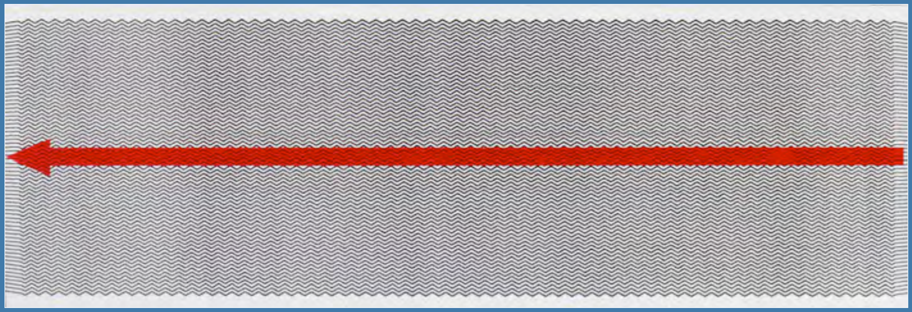
PCHE Characteristics – temperature and pressure



PCHE Characteristics – versatile design

Size and cost reduction by multistream heat transfer





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PCHE Characteristics – construction

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PCHE Construction

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Heatric Development Strategy

- Maximise:
  - Value
  - Growth
- Balance:
  - Technology Strengths
    - Materials
    - Engineering design
    - Manufacturing
  - Commercial Opportunity
    - Oil and Gas
    - Chemical processing
    - Non fossil fuels
  - Market Understanding
    - Energy

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PCHE Materials – diffusion bonding

- Stainless steels 300 series
- Duplex UNS S31803
- Titanium grade 1, 2 & 3
- Nickel 200 & 201
- Copper

pre-2004

- Alloy 800H

2004

- 253MA
- Alloy HX
- Alloy 617
- Alloy 230

development

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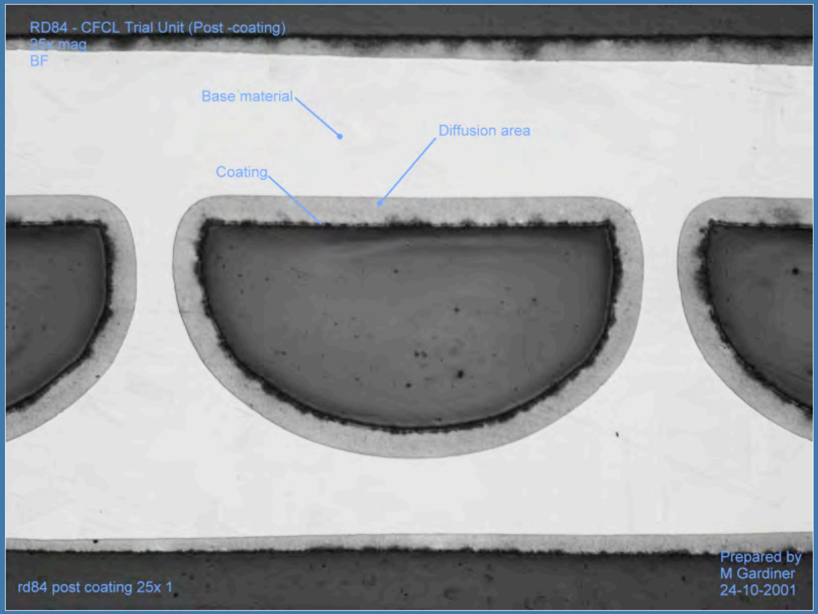
Materials - development

Diffusion Bonded Alloy 617

Aluminium Coated PCHE Passages



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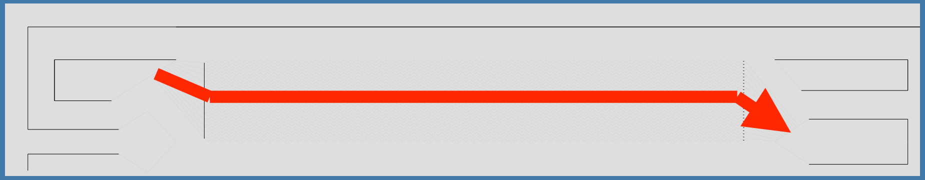
Heat Exchanger Developments – Platelet Design



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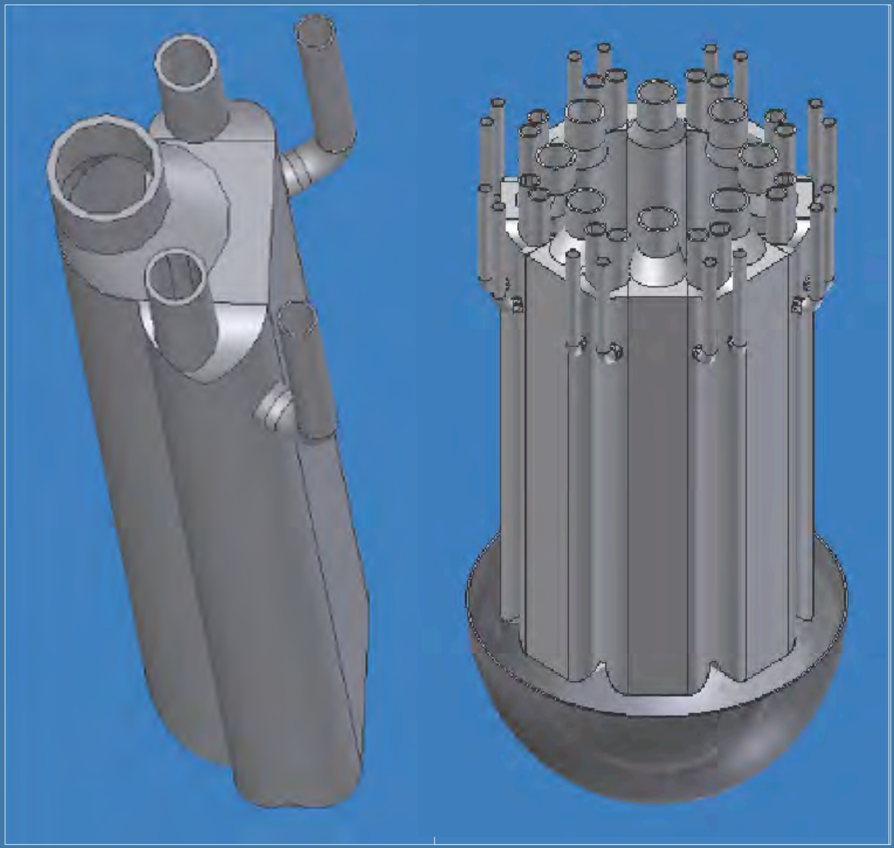
Heat Exchanger Developments – IHX Concept

- He vs. He or N_2 IHX
- 600MW
- Design Temp 950ºC
- Alloy HX, 617 or 230
- Weight < 100 tonnes



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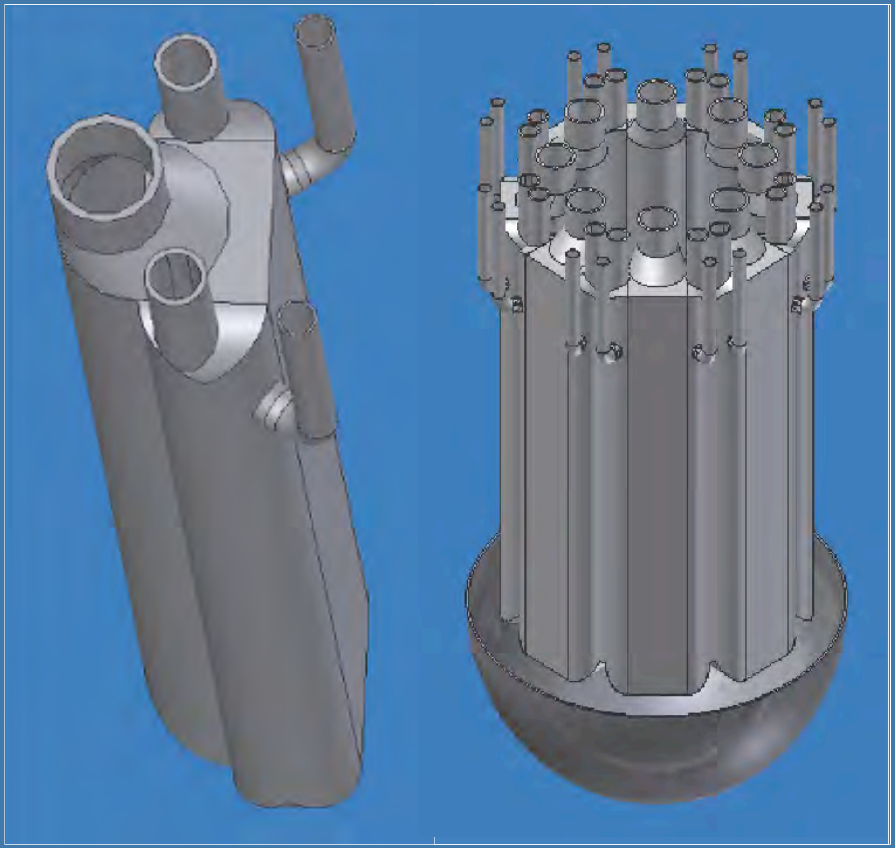
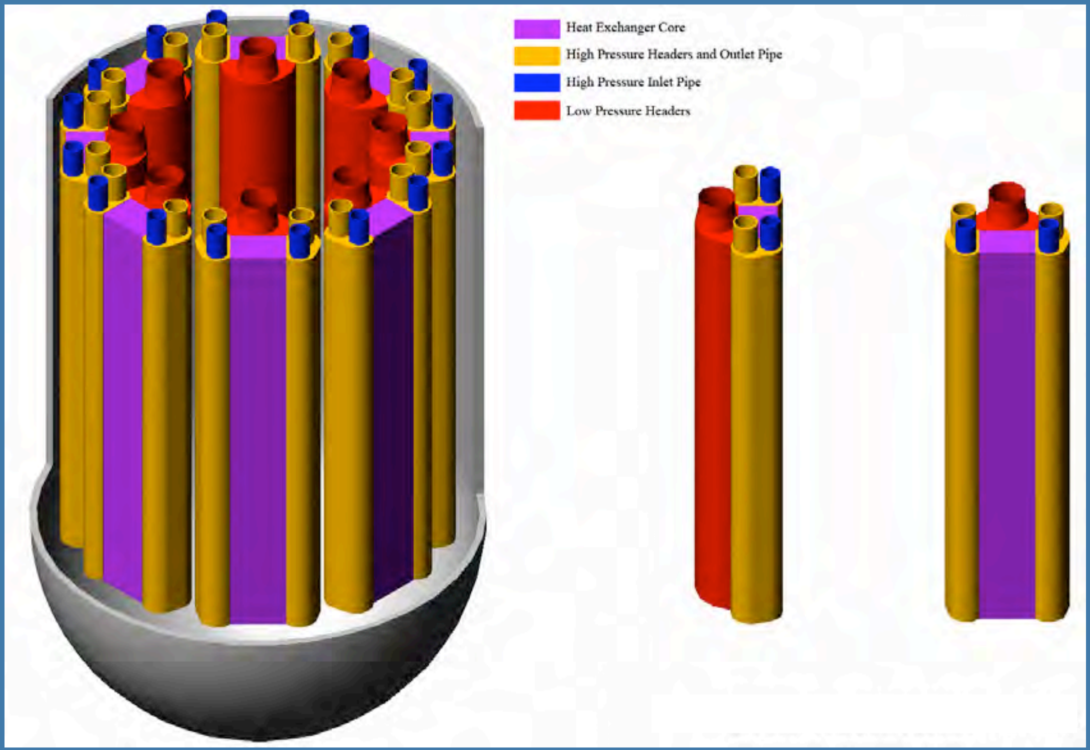
Heat Exchanger Developments – s-CO_2 Concept

- s-CO_2 vs. s-CO_2 or water
- 170MW
- 98% Effectiveness
- Design pressure 200 bar
- Weight < 75 tonnes



Heat Exchanger Developments – Helium IHX Concept

- Helium vs. Helium
- 170MW
- 98% Effectiveness
- Design pressure 80 bar
- Weight < 75 tonnes



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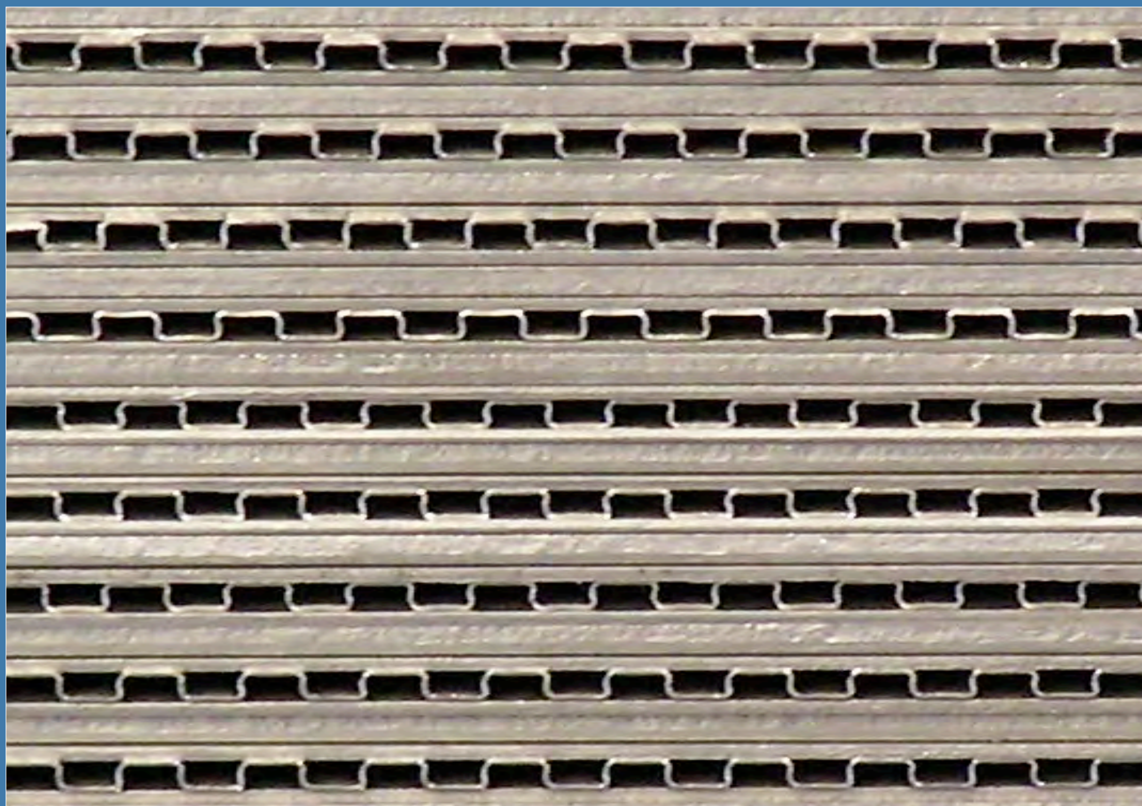
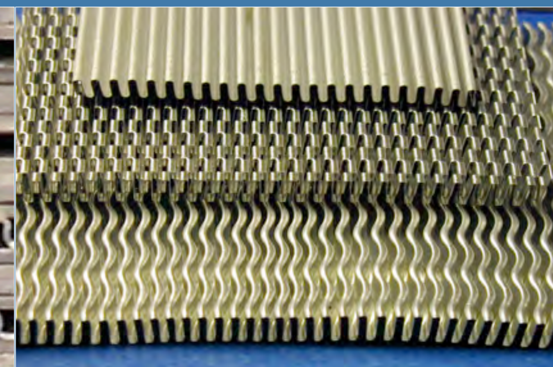
Heat Exchanger Developments – Diffusion Bonded

Formed Plate Heat Exchanger (FPHE)





Heat Exchanger Developments – Diffusion Bonded Formed Plate Heat Exchanger (FPHE)

- Manufacture in Corrosion Resistant Alloys
- Weight Reduction
- Size Reduction
- Cost Savings

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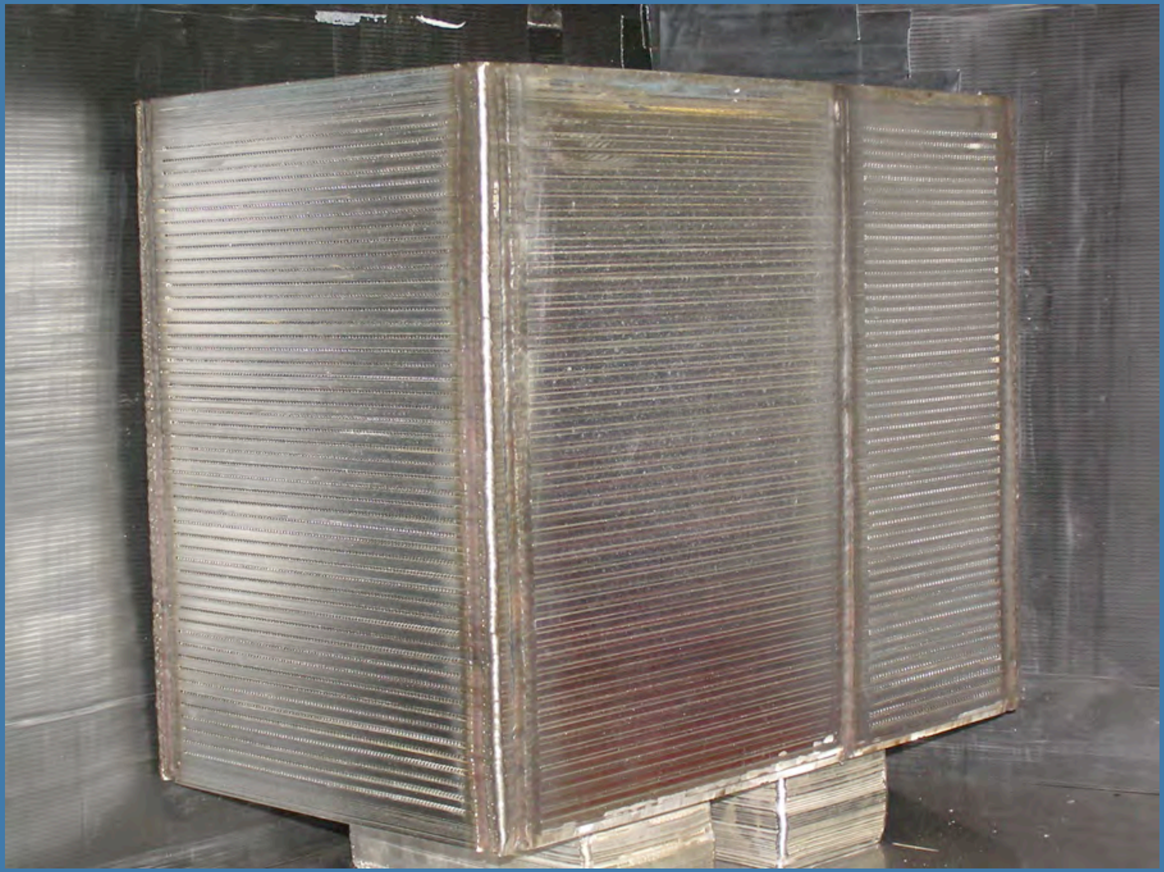
Bonded FPHE core



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Current PCHE and FPHE Heat Exchangers

Requirements	PCHE	FPHE
High Temperatures	800°C+ (limited by material)	800°C+ (limited by material)
High Pressures	500 Bar (Max Typical)	200 Bar (Max Typical)
High Effectiveness	98% +	98% +
Low Pressure Drop	Based on Design	Bigger channels
High Compactness	Highly Compact	
Erosion Resistance	Limited by material	
Corrosion Resistance	Limited by material	
Longer Life	Limited by material	

Over 700 PCHEs in operation worldwide

Over 20 tonnes of FPHEs sold since market launch in 2005

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Software and Modelling

- In-House Design Capabilities for:
  - Thermal Design
  - Hydraulic Design
  - Mechanical Design
- Steady state and Transient Analysis
- Design models proven with operational experience
- Supported by 15 years testing at Sydney University

The University of Sydney
Australia

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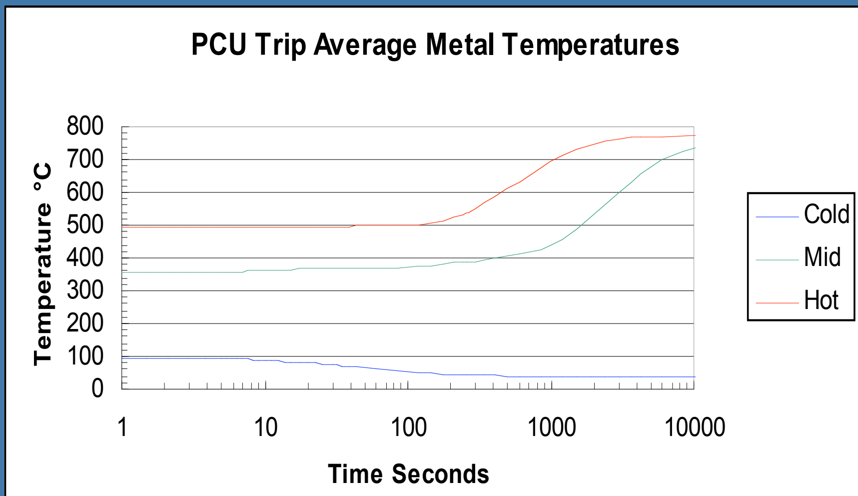
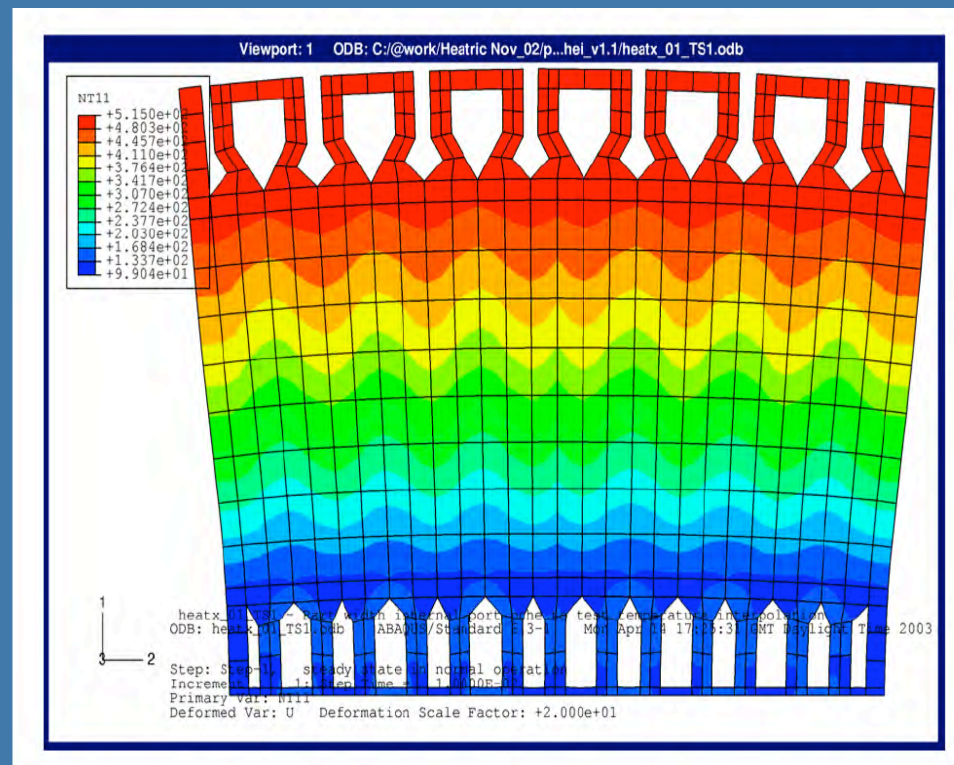
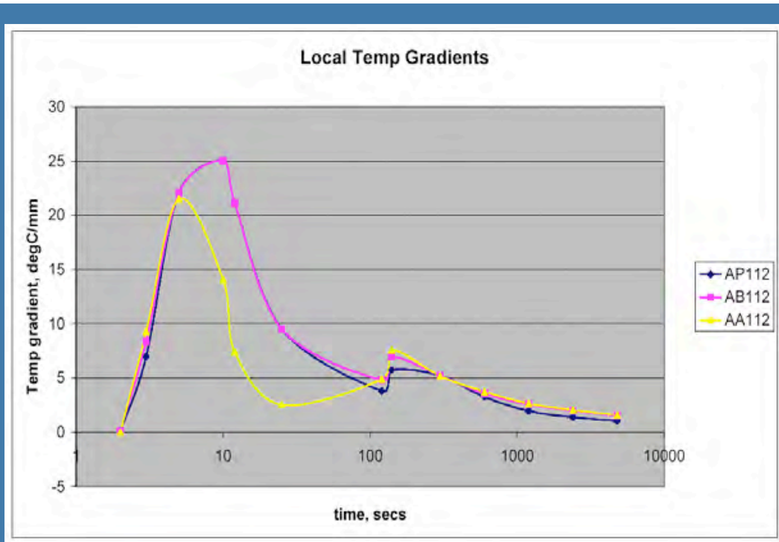
Software and Modelling – Transient Analysis







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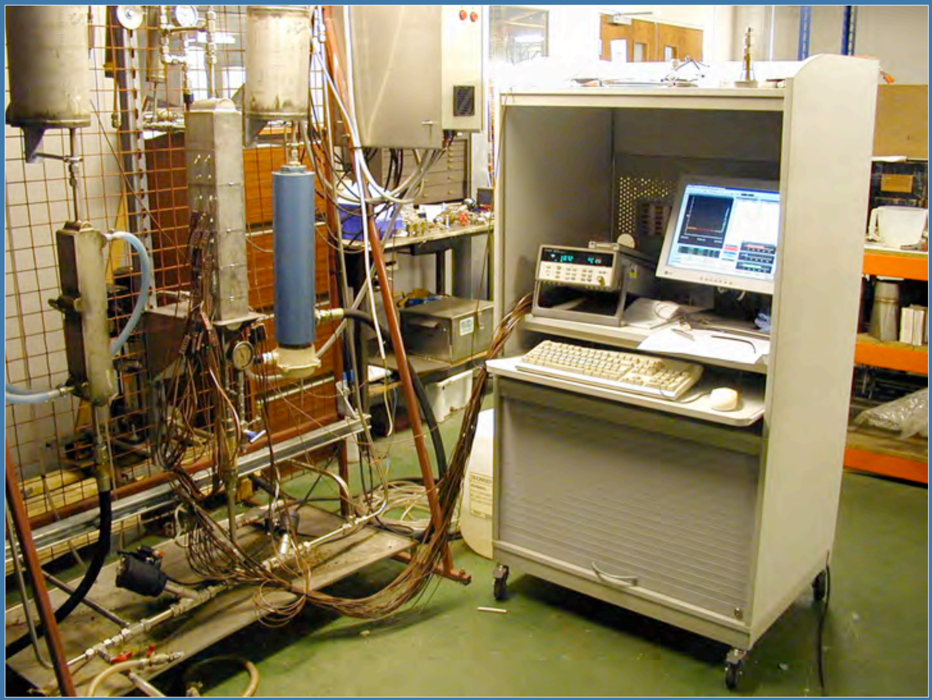
Software and Modelling – Validation

- Transient Testing



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Nuclear Applications

- Helium Recuperators
  - operating temperatures 550°C
  - operating pressures 100 bar
- Carbon Dioxide Recuperators
  - operating temperatures 450°C
  - operating pressures 200 bar
- Intermediate Heat Exchangers
  - operating temperatures 1000°C
  - operating pressures 100 bar
  - He / He and He / N_2

Nuclear Applications - Supplied

- Helium Recuperators

KAIST

- –operating temperatures 800°C
- –operating pressures 30 bar

IST

- –operating temperatures 450°C
- –operating pressures 100 bar

PBMR (design contract)

- –operating temperatures 500°C
- –operating pressures 86 bar

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Nuclear Applications - Supplied

Carbon Dioxide Recuperators

- MIT
  - operating temperatures 650°C (design T 662°C)
  - operating pressures 200 bar (design P 210 bar)

- Argonne
  - operating temperatures 200°C
  - operating pressures 215 bar
- TIT
  - operating temperatures 300°C
  - operating pressures 130 bar

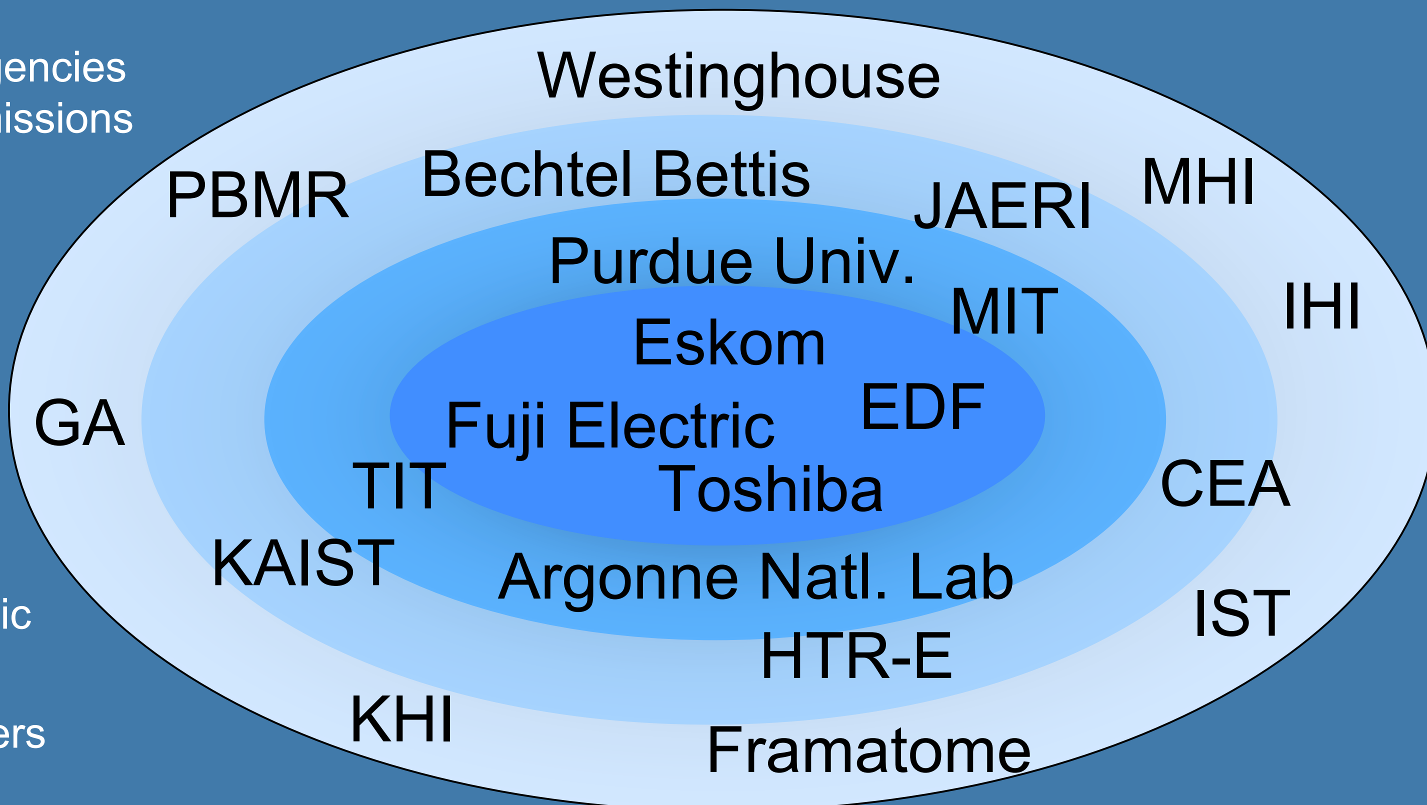
Nuclear Applications – Commercial Experience

Industry

Govt. Agencies & Commissions

Academic

End Users



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Conclusions

Heatric

- Heatric PCHE and FPHE Heat Exchangers are fully developed, commercially available, and capable of meeting the requirements of Generation IV.
- Heatric manufacture a wide range of PCHE, FPHE and PCR products.
- PCHE and FPHE have Thermal, hydraulic, mechanical and life characteristic fully developed.
- Continual leading edge product development.
- Have the engineering resource to undertake studies and development programmes.
- Actively involved in nuclear applications since 1999
- A leading position for the supply of recuperators
- The only currently available technology for the supply of high temperature IHX

- Heatric are ideally placed to support the US nuclear renaissance.

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www.heatric.com

Smart engineering for extreme environments

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