Heatric

Exhaust Heat Exchangers and their maturity and related current offerings and success – Renaud Le Pierres

SAFETY FIRST

QUALITY
RIGHT FIRST TIME. EVERY TIME

MEGGITT smart engineering for extreme environments

Waste Heat Recovery

- Many different heat sources available:
  - Gas turbine exhaust – 450-600°C
    - Many turbines sizes to choose from (standardisation?)
  - Reciprocating engines – 250-450°C
    - Same challenge as for gas turbine
  - Industrial waste heat (Steel, cement, glass, biomass) with temperatures above 300°C
    - Many different size of plant (standardisation?)
    - Depending on exhaust composition may contain condensable / corrosive materials (life vs. more expensive higher grade alloy)

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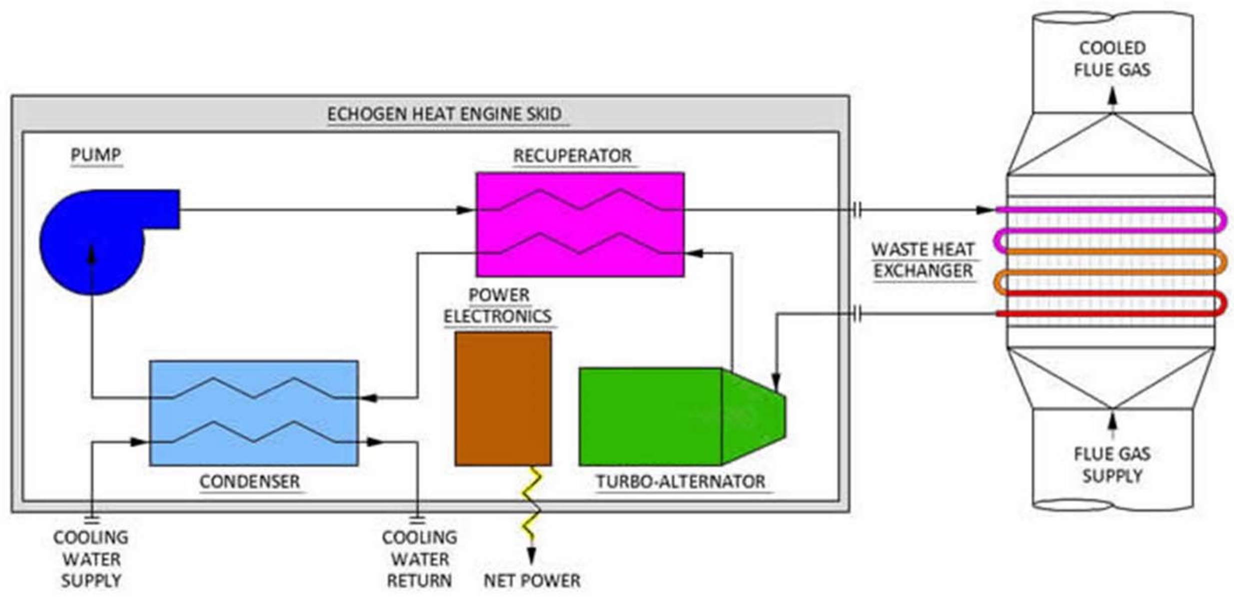
Echogen EPS 100



sCO2 WHRU Process conditions

- Exhaust gas with large volumetric flow rates (1s – 100s kg/s depending on exhaust source)
- Low pressure with very little allowable pressure drop on exhaust side (down to 1kPa)
- High pressure on the sCO2 side (20-30 MPa)
- Start-up / transient (Peak shaving requires very fast start-up)
- Potential corrosion due to impurities in flue gas (depending on heat source)
- Creep (depending on material vs. exhaust temperature)

sCO2 vs. Steam

- Steam waste heat recovery is established technology (>100 years)
- Existing supply chain for steam waste heat recovery components and HRSG (NEM, Nooter Ericksen, Citech)

- sCO2 is more compact and especially desirable for retrofit, offshore and remote locations installations
- sCO2 can be designed for direct in-stack, single phase (no pinch point limitation as for steam)
- sCO2 is more efficient and can use air cooling option (removing need for water)

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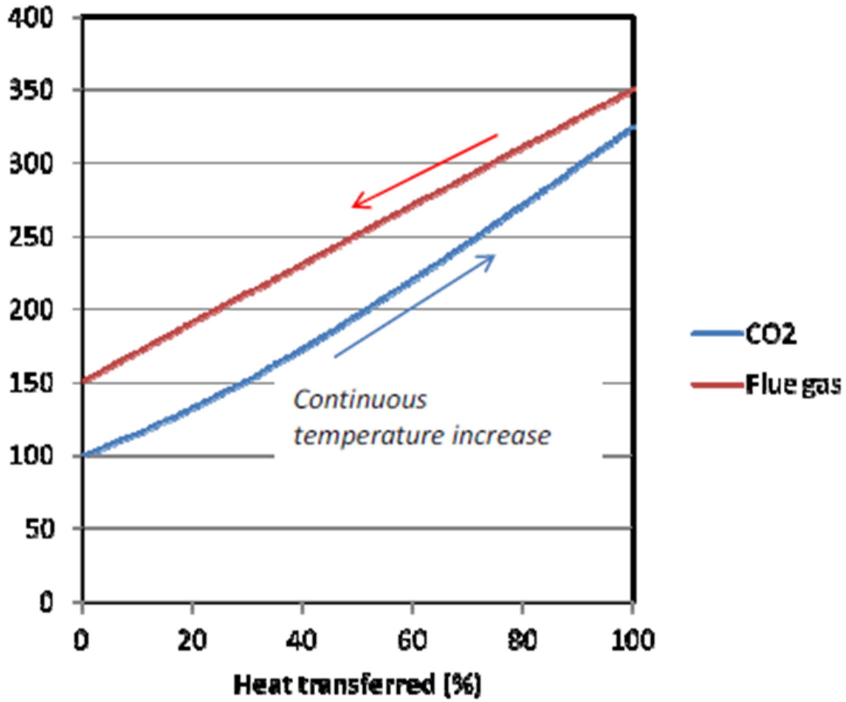
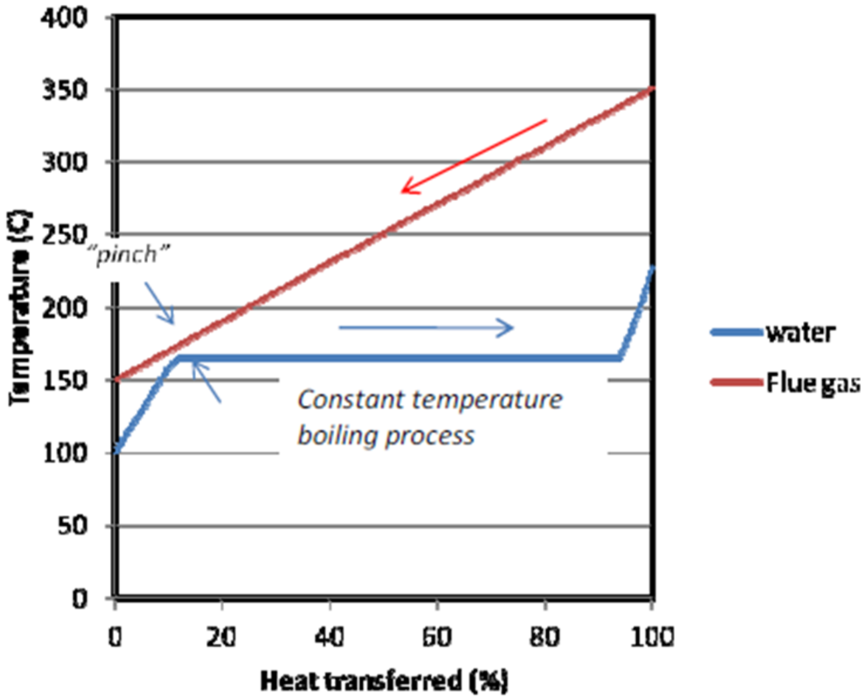




- Better heat recovery possible in SCO2 cycles with single phase exchangers
- Two phase boiling at constant temperature (steam cycles) limits close temperature approach (pinching)

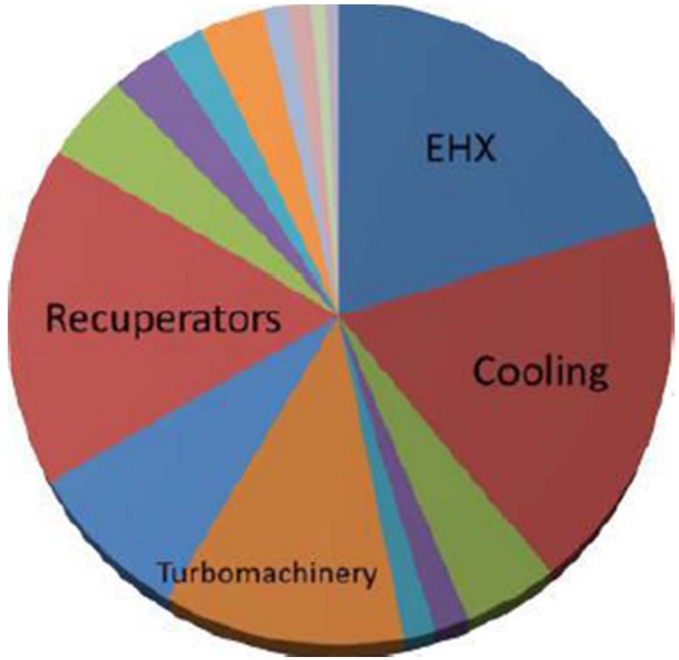
Current technology

Current WHRU

- Advantages:
  - Currently available as heat recovery steam generator
  - Proven to work in many applications including CCGT
  - Already used with some systems (EPS-100)
- Disadvantages:
  - Very large units making it a challenge where size is of the essence
  - Relative large thermal mass and associated inertia depending on flue gas
  - Large to very large internal fluid inventory

Current WHRU

- Disadvantages:
  - Price? RoI cannot be longer than 5 years (system cost)



Tim Held
Echogen

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New technologies – Compact?

6.5m (H) x 4.4m (W) x 6.3m (L)
40 tonnes each section. 2 sections.

5m (H) x 2.5m (W) x 4.3m (L)
23 tonnes

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On-going developments examples

- Thar Energy Sunshot programme (SWRI, GE, Thar Energy)
  - Tubular air to CO2
- Sandia National Laboratories
  - Diffusion bonded Hybrid construction
- Brayton Energy
  - Ingersoll rand based edge welded units

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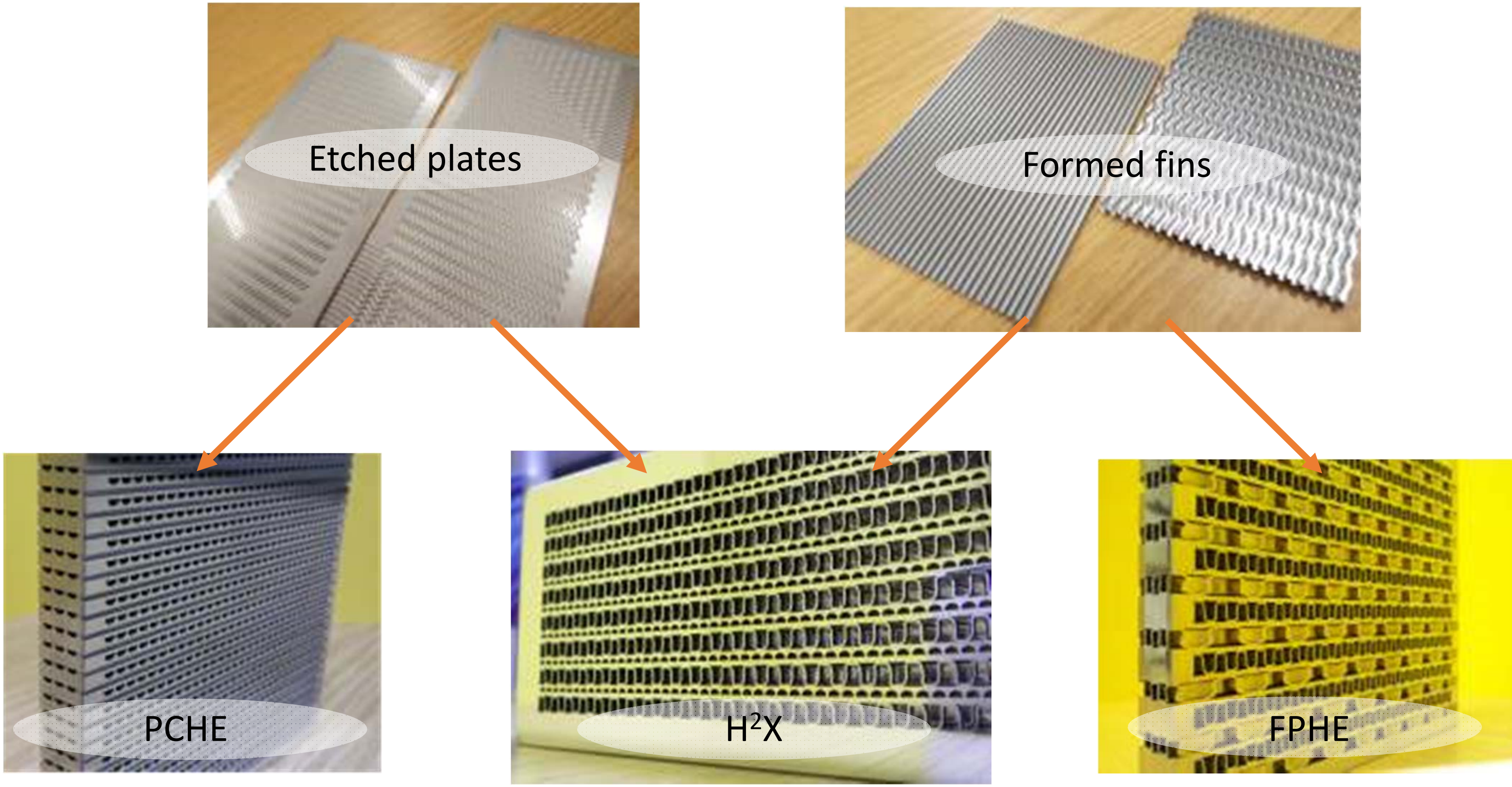

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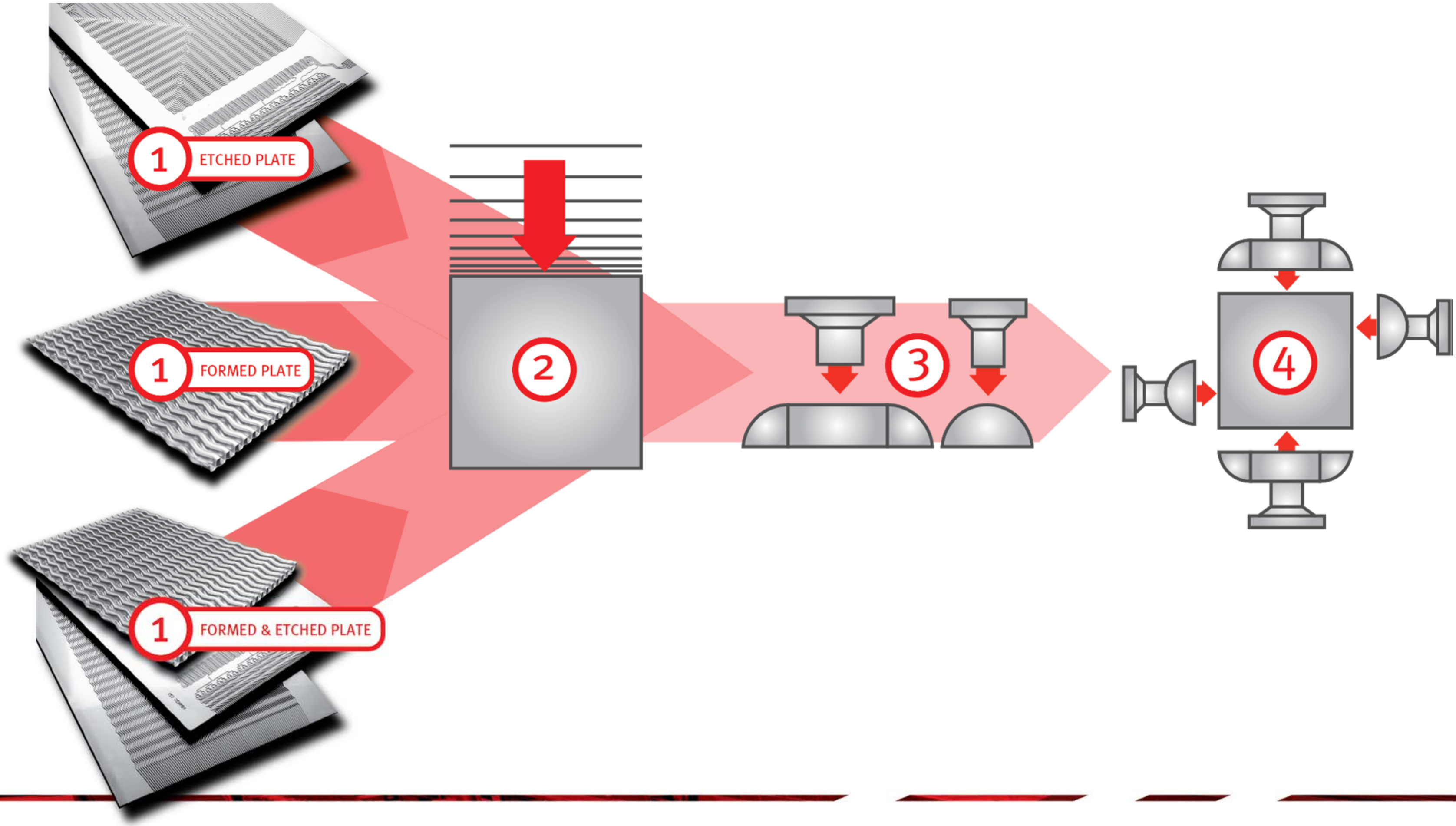
Heatric core product



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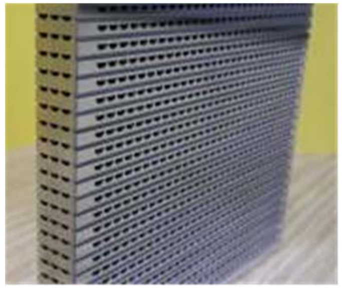
Heatric development



- PCHEs
  - PCHEs typical channels are 1 mm deep (2 mm semi circular)
  - They are well suited for sCO2 but not for exhaust side due to pressure drop constrains
  - PCHEs are already used as Recuperators in sCO2 systems
  - Heatric has developed deep etch technology currently able to achieve 2.5 mm deep channel (5 mm semi circular)
  - TRL 7-8 - may be suitable for small scale WHR units

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Heatric development

- FPHEs
  - FPHE fins can achieve taller profiles than PCHEs (4 mm high)
  - Fins are not as well suited for sCO2 as channels but may be more suitable for exhaust side
  - FPHE was designed for ~20 MPa so this product is not ready for most sCO2 pressures

Heatric development

- H^{2}Xs
  - H^{2}Xs aim to combine 2 or more different product forms in a single product
  - To date H2X has been considering combining Fins to PCHE channels
  - Work is in progress to validate H^{2}X as part of the Cranfield test loop
  - Further work is on-going to expand channel size on the exhaust side to dH > 5 mm
  - TRL 5

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Material of construction

- Material price changes drastically when considering higher operating conditions / corrosive environment (x10 / x20):
- Product form and supply chain must be investigated as some materials are limited in choice
- Above 550C Creep must be considered with Austenitic stainless steel (304, 316) which will reduce plant life
- Operation of WHRU is critical depending on application

Waste Heat Recovery Success?

- sCO_2 Bottoming cycle can be achieve with existing technologies
- EPS100 has already demonstrated system performance using ‘conventional’ WHRU
- WHRU units has to answer challenges of size reduction, response time for peak shaving and price
- Compact WHRU technologies for large size units are currently in development


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