Heat Pipe Heat Exchangers for Industrial and Renewable Energy Applications

By

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OVERVIEW

- The Heat Pipe and Thermal management Research group
- Heat Pipes, Introduction
- Heat Pipe Based Market-Ready Products
  - Waste Heat Recovery
  - Renewable Energy Harvesting
- Research and Development work
The Group Capabilities:

- Specialised laboratories fully equipped for experimental and analytical work
- Comprehensive data acquisition, analysis and management.
- Active International collaborations with 37 institutions worldwide
- Research work is supported by the industry, UKRI & EU grants (totaling £13.2M total funding income - £8.4M Since 2014).
- 17 patents filed/granted to date.
- Strong support from UK & International industries
“Heat Pipes”
What are they?
Multiple Redundancy
Each pipe operates independently so unit is not vulnerable to a single pipe failure
• This prevents cross contamination each heat pipe acts as an additional buffer between the two fluids

Better fouling management
Use of smooth pipes allows exchangers to be used in high particulate or oily applications

Ease of Cleaning & Maintenance
Can be maintained in situ (no uninstall)
Manual/automated cleaning systems

Isothermal Operation – no hot or cold spots
Eliminates cold corners and condensation
Allows greater energy recovery
Better longevity for thermal oil

Robust Materials and Long Life
Design allows pipes to freely expand and contract, thus no thermal stress on structure
Thick pipe walls resist erosion/corrosion

Intermediate Pipe Working
Temperature
Allows higher exhaust temperature
Limits on some applications

Highly Scalable, Customisable & Configurable
Modular design allows on site assembly
Can be designed for future expansion, to meet specific application or operational needs

Reactivity
Fast reaction time, offers different control options and suitable for sensitive apparatus: does not require preheating

Passive devices
No need for pumping energy to drive the heat transfer process through the heat pipe
Challenging waste heat recovery scenarios

Many industrial processes generate highly difficult exhaust conditions that can be characterised as follows:
1. High temperatures / mass flows
2. High particulate content that is abrasive and / or can cause fouling
3. Highly corrosive, acidic content SO2, SO3, NO2, etc.

Why Does The HP Solution Work Where Conventional Units Don’t?
1. HP metal temperature can be kept above the acid dew point.
2. Eliminates any localised acid condensation (cold spots).
3. Easy to clean.
4. The risk profile on pipe failure is minimised due to the multiple redundancy.

Systems delivered to date have delivered sub 24 month payback
Implementation of heat pipe technologies in industrial processes
Typical geometries of heat pipe based waste heat recovery systems

A schematic of a typical heat pipe unit
Heat Pipe Based Market-Ready Products
Waste Heat Recovery Systems

Gas to Air HPHE

Heat pipe heat exchanger
Hot exhaust
Preheated combustion air
Cold combustion air
Cooled exhaust to new stack

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Steam Generator, China National Offshore Oil Corp, China Sea, April 2016

- GA 6400 smooth pipe 2 stage steam generator
- On-site assembly
- High reliability required for offshore location
- Low footprint required by space limitations
- Instant start up from gas turbine

Exhaust to Coke Gas Unit, Steel mill Blast Furnace, Czech Republic 2011

- Heat pipe GPH
- 12.6 MW duty
- Each unit consists of 1575 X 7.6 Mtr helically finned, distilled water stainless steel heat pipes
- Unit performance increased significantly after upgrade
- Repeat order secured Sep 2013 delivery
- Full turnkey replacement delivered through Czech local distributor
**G2W, Shale Gas Well Head Fracking, Thermal Oxidiser, Canada 2012**

- GW 2000 hybrid pipe heat exchanger
- 2.2MW fracking water heater: highly robust mobile unit for travelling around Canada
- High particulate matter exhaust from furnace; removable panels incorporated for cleaning
- Low fouling, easy cleaning and maintenance, high reliability

<table>
<thead>
<tr>
<th><strong>Gas to Water</strong></th>
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<tbody>
<tr>
<td>Exhaust Temp In/Out</td>
<td>816°C/150°C</td>
</tr>
<tr>
<td>Water Temp In/Out</td>
<td>5°C/16°C</td>
</tr>
<tr>
<td>Exhaust/Water Mass Flow</td>
<td>11,016/180,000 Kg/h</td>
</tr>
<tr>
<td>Weight of unit</td>
<td>3,600 Kg</td>
</tr>
<tr>
<td>Exhaust pressure drop</td>
<td>800 Pa</td>
</tr>
<tr>
<td>Energy Recovered</td>
<td>2,260 KW</td>
</tr>
<tr>
<td>Recovered Energy Value</td>
<td>£360K p/a</td>
</tr>
<tr>
<td>Heat Exchanger Cost</td>
<td>£65K</td>
</tr>
<tr>
<td>Payback Period</td>
<td>&lt;3 Months</td>
</tr>
<tr>
<td>Price per KW recovered</td>
<td>£27</td>
</tr>
</tbody>
</table>

**Steam Condenser, Food, Dirty Steam, Ireland, 2010**

- SC model 400 smooth/finned hybrid pipe ‘through-flow’ heat exchanger
- 440 kW process water heater
- Contaminated steam; regulatory requirement to condense, fuel savings, stainless steel
- Eliminated existing air-cooled equipment

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<th><strong>Steam Condenser / Hot Water</strong></th>
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<tbody>
<tr>
<td>Steam Temp In/Out</td>
<td>105°C/90°C</td>
</tr>
<tr>
<td>Water Temp In/Out</td>
<td>10°C/85°C</td>
</tr>
<tr>
<td>Exhaust/Water Mass Flow</td>
<td>544/8,000 Kg/h</td>
</tr>
<tr>
<td>Weight of unit</td>
<td>300 Kg</td>
</tr>
<tr>
<td>Exhaust pressure drop</td>
<td>N/A</td>
</tr>
<tr>
<td>Energy Recovered</td>
<td>446 KW</td>
</tr>
<tr>
<td>Recovered Energy Value</td>
<td>2 x £20K p/a</td>
</tr>
<tr>
<td>Heat Exchanger Cost</td>
<td>2 x £10K</td>
</tr>
<tr>
<td>Payback Period</td>
<td>6 Months</td>
</tr>
<tr>
<td>Price per KW recovered</td>
<td>£22</td>
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</table>
• GW throughflow heat exchanger
• 2.1MW waste water treatment plant biomass incinerator plant: highly robust low fouling unit
• High organic particulate matter in exhaust; removable panels incorporated for cleaning
• Low fouling, easy cleaning and maintenance, high reliability

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<td>Payback Period</td>
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<tr>
<td>Price per KW recovered</td>
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3 Kiln Heat Recovery, RAK Ceramics, UAE, April 2016

• GA 970 smooth pipe heat exchanger
• 970 KW drier air pre-heater sourcing exhaust from 3 tunnel kilns
• Pre-heated air delivered to multiple usage points
• High particulate matter exhaust from kilns
• Integrated moving plate cleaning system

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<tbody>
<tr>
<td>Exhaust Temp In/Out</td>
</tr>
<tr>
<td>Air Temp In/Out</td>
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<tr>
<td>Exhaust/Air Mass Flow</td>
</tr>
<tr>
<td>Energy Recovered</td>
</tr>
<tr>
<td>Recovered Energy</td>
</tr>
<tr>
<td>Project Cost</td>
</tr>
<tr>
<td>Payback Period</td>
</tr>
<tr>
<td>£/KW recovered</td>
</tr>
</tbody>
</table>
Waste Heat Recovery Units – Steam Generators

Counter Flow 2 stage 520 kW HRSG 12 Bar steam with water pre-heater for Anaerobic Digester

Counter Flow 2 stage 1,200 kW HRSG 11 Bar steam with water pre-heater on Hydrogen plant

Waste Heat Recovery Units - Oil & Gas, USA 2020

Gas to Air00

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exhaust Temp In / Out</td>
<td>431C / 156C</td>
</tr>
<tr>
<td>Air Temp In / Out</td>
<td>16C / 339C</td>
</tr>
<tr>
<td>Exhaust / Air Mass Flow</td>
<td>83,901 kg/h / 78,608 kg/h</td>
</tr>
<tr>
<td>Energy Recovered</td>
<td>7.1 MW</td>
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ExxonMobil
Brunel University London

ECKR APH Performance vs. Typical Design Case:

- Design
- Operating

<table>
<thead>
<tr>
<th>Value</th>
<th>Flue Gas Inlet (F)</th>
<th>Flue Gas Outlet (F)</th>
<th>Combustion Air (F)</th>
<th>Efficiency (%)</th>
<th>Duty (MBTU/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design</td>
<td>695</td>
<td>311</td>
<td>544</td>
<td>94.9</td>
<td>23</td>
</tr>
<tr>
<td>Operating</td>
<td>679</td>
<td>013</td>
<td>538</td>
<td>85.3</td>
<td>25.9</td>
</tr>
</tbody>
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Performance Metric:
Renewable Energy Harvesting

FHP applications: The Photovoltaic Roof

Cardiff

London
Prefabrication, Recyclability and Modularity for cost reductions in Smart BIPV systems

03/04/2024
R&D in Heat Pipe Research

Collaborative Research with the Industry in Brunel
Samples of International Collaborative Projects

Heat Pipe Based Drying Solution

IUK Project #: 102716
**Mate (Yerba)**

Mate is a herbal beverage rich in caffeine, traditionally consumed in central and southern regions of South America, especially in Brazil and Argentina.

**Mate plantation**

- Shredding
- Aging
The Old Production Line

Conventional Drying
The new Heat Pipe Production Line
The Heat Pipe Based Drying System
Field Results

- Safer drying process due to separating the exhaust from the drying fluid
- Any bio-mass fuel can be used – more sustainable biomass can be utilised
- Tremendous reduction in by-product waste – used as biomass
IMPACT

1. Healthy Drink
2. New Business for the Companies in Brazil & the UK
3. New Knowledge

https://www.spire2030.eu/dream
H2020 funding €5.1M
Brunel's income: €490k
DREAM: Design for Resource and Efficiency in cerAMic kilns

Brunel University London
Funded by European Union's Horizon 2020 research grant agreement no. 818342

DREAM: Design for Resource and Efficiency in cerAMic kilns

Brunel University London
DREAM: Design for Resource and Efficiency in ceramic kilns

DREAM: Heat Pipe Heat Exchanger installation
https://www.etekina.eu/
H2020 funding €4.6M
Brunel’s income: €700k

Aluminium industrial installation
Aluminium Industrial installation

Solution Heat Treatment Furnace
Quenching Tank
Aging Heat Treatment Furnace

316°C
400°C
145°C
240°C

Aluminium Industry, Commissioning
DC1: Results Reference Day

Ageing Furnace NG consumption
Steel industrial installation, Slovenia

Steel Industrial installation, Concept
Steel Industry Piping and Instrumentation Diagram

Steel Industry, Commissioning
Steel Industry Results

Return On Investment of less than 9 months, 350 kW

Monitoring Results – Recovery Efficiency

Heat recovery 47 %
Ceramic Industry Thermal and Mechanical Design

Ceramic Industry, Commissioning
Ceramic Industry Results

Return On Investment of less than 24 months, 700 kW

Flat Heat Pipe based heat exchanger for waste heat recovery in the steel industry

Heat Energy Recovered

Experimental Theoretical
Between 1 and 2 kW/m² heat recovery were achieved in JBMI.

15 to 17 kW/m² heat recovery were achieved in ArcelorMittal.
Thank you