Brunel University London

Heat Pipe and Thermal Management Research Group
College of Engineering, Design and Physical Sciences

Heat Pipe Heat Exchangers for Industrial and Renewable Energy Applications

By

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PhD, CEng, IntPE, FIMechE, FIEI, FCIBSE, MInstR, SFHEA

ASME
SETTING THE STANDARD

Online Seminar hosted by the ASME Fluids Engineering Division

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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

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Prof. Hussam JOUHARA
Founder & Head of the Group

The Heat Pipe & Thermal Management Research Group

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Senior Research Fellow

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PhD System modelling researcher

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PhD Research Assistant

Valentina Olabi
PhD Researcher

UK Atomic Energy Authority · Innovate UK · Newton Fund · InComEss · cultural E+ · HfT NETWORK+ · EPSRC · AIR PRODUCTS · iWATS · ETEKINA · PVcdapt · Smartcrop

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The Group Capabilities:

- Specialised laboratories fully equipped for experimental and analytical work
- Comprehensive data acquisition, analysis and management.
- Active International collaborations with **37 institutions** world-wide
- 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

SOLEX · spirax Sarco · SPC · AIR PRODUCTS · econotherm (An ISO9001 Organisation; WASTE HEAT RECYCLING TECHNOLOGY) · HERU · VP · JBMI · ALTEK · ventive · flint

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“Heat Pipes”
What are they?

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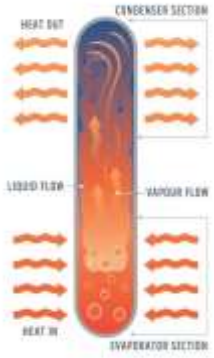

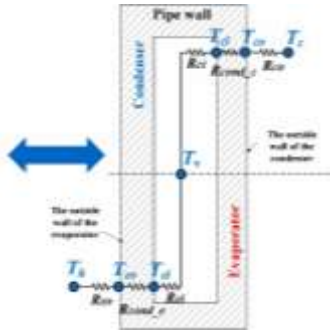

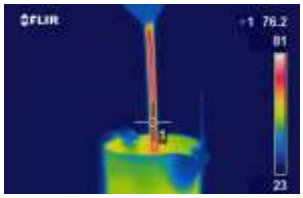

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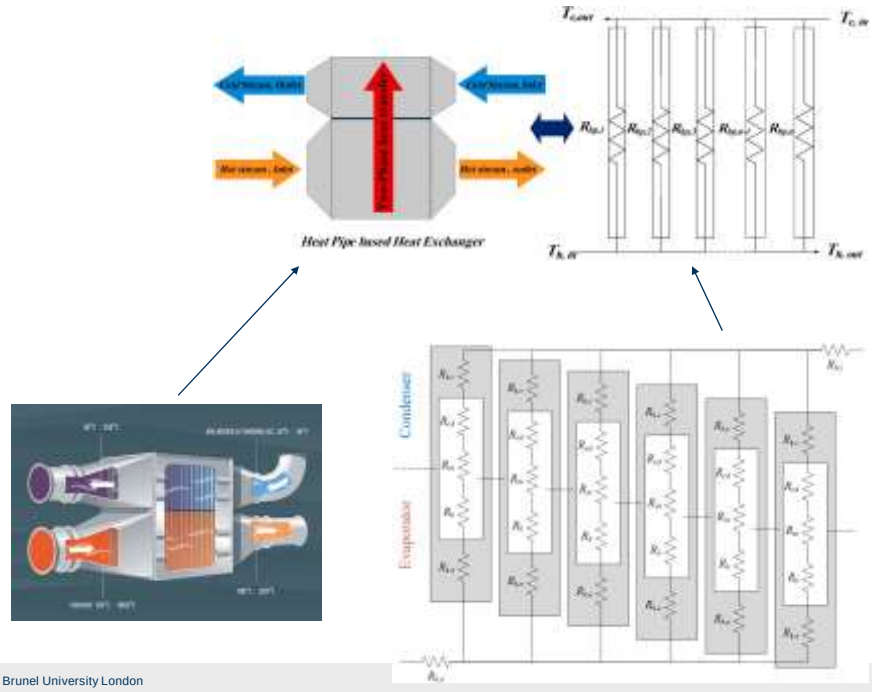

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Multiple Redundancy

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

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Challenging waste heat recovery scenarios

Many industrial processes generate highly difficult exhaust conditions that can be characterised as follows:

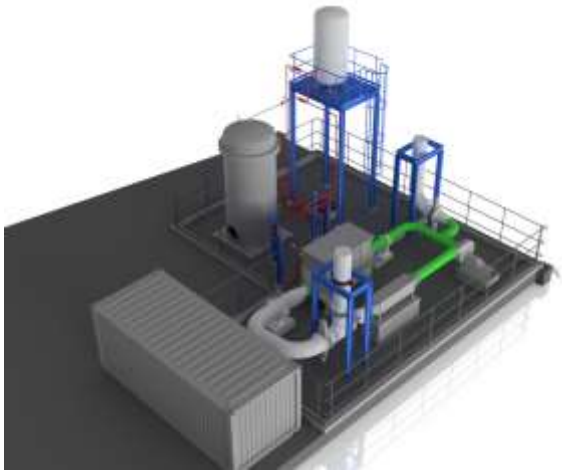
1. High temperatures / mass flows
2. High particulate content that is abrasive and / or can cause fouling
3. Highly corrosive, acidic content SO2, SO3, NO2, etc.

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



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Implementation of heat pipe technologies in industrial processes

Identification of potential heat recovery and process opportunities
- Evaluation of available waste heat
- Flue gas composition analysis
- Site survey for space and foot print available

Definition of technical specification for implementation
- Definition of plant requirement.
- Identification of Key Performance Indicators.
- Design code for pressure vessels identification.
- Identification of regulatory and safety aspect for implementations

Heat pipe theoretical and mechanical design
- Heat pipe theoretical design based on validated modelling tools
- Mechanical design according to technical specifications requirements
- General arrangement and detailed drawings issued

Piping and instrumentation diagram (P&ID) and BOM
- P&ID finalisation
- Identification of control strategies
- Bills of materials issued
- 3D plat design
- Prediction modelling tools for plant efficiency

Implementation and commissioning
- Experimental procedures issued
- Safety test
- User manual issued
- Commissioning approved by user

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Typical geometries of heat pipe based waste heat recovery systems

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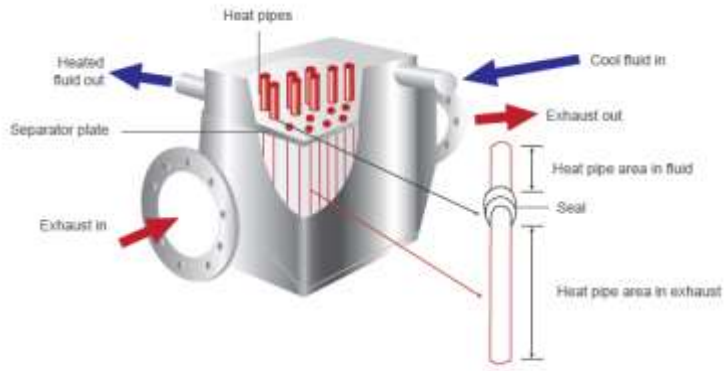
A schematic of a typical heat pipe unit



Heat pipe heat exchanger construction

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Heat Pipe Based Market-Ready Products
Waste Heat Recovery Systems

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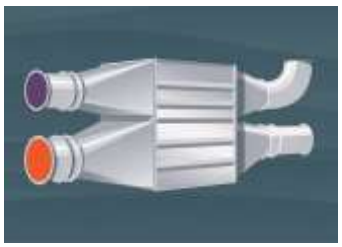
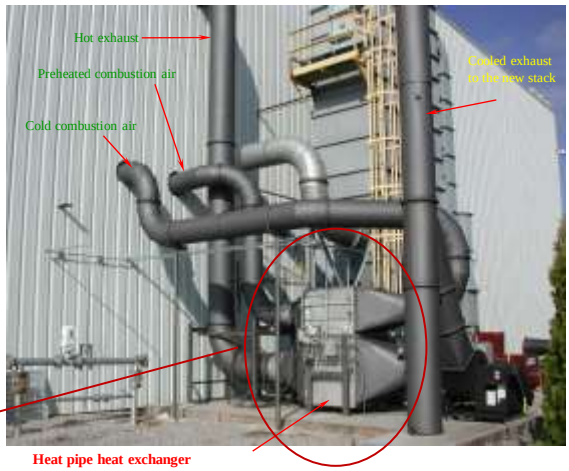
Gas to Air HPHE





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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

Gas to Steam

Exhaust Temp In/Out	400 C/250 C
Water/Steam Temp In/Out	50 C/180 C
Exhaust Flow/Steam Rate	130,000/ 8,000 Kg/h
Energy Recovered	6.4 MW
Recovered Energy	£2,100K p/a
Project Cost	£1,200K
Payback Period	7 Months
£/KW recovered	£328

An ISO9001 Organisation

econotherm
WASTE HEAT RECYCLING TECHNOLOGY

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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

Gas to Air

Exhaust Temp In/Out	286 C/156 C
Coke Gas Temp In/Out	62.2 C/197 C
Exhaust/Air Mass Flow	97,551/97,551 Kg/h
Energy Recovered	12,626 KW
Recovered Energy	£800K p/a
Project Cost	£400,000 *
Payback Period	Circa 6 Months *
£/KW recovered	£31.67 *
* Estimated figures based on extrapolated installed costs	

An ISO9001 Organisation

econotherm
WASTE HEAT RECYCLING TECHNOLOGY

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G2W, Shale Gas Well Head Fracking, Thermal Oxidiser, Canada 2012

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

- 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

An ISO9001 Organisation econotherm WASTE HEAT RECYCLING TECHNOLOGY

Steam Condenser, Food, Dirty Steam, Ireland, 2010

Steam Condenser / Hot Water	
Steam Temp In/Out	105 C/ 95 C
Water Temp In/Out	10 C/ 88 C
Exhaust/Water Mass Flow	844 / 8,000 Kg/h
Weight of unit	300 Kg
Exhaust pressure drop	N/A
Energy Recovered	446 KW
Recovered Energy Value	2 x £20K p/a
Heat Exchanger Cost	2 x £10K
Payback Period	6 Months
Price per KW recovered	£22

- 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

An ISO9001 Organisation econotherm WASTE HEAT RECYCLING TECHNOLOGY

G2W, In Line Through-Flow Recuperator, Biomass Incinerator, Bologna, Italy

Gas to Water

Exhaust Temp In/Out	610 C / 150 C
Water Temp In/Out	73 C / 90C
Exhaust/Water Mass Flow	17,500 Kg/h
Weight of unit	5,000 Kg
Exhaust pressure drop	400 Pa
Energy Recovered	2,100 KW
Recovered Energy Value	€315K p/a
Heat Exchanger Cost	€172,500
Payback Period	<18 Months
Price pe r KW recovered	€140/kW

- 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

An ISO9001 Organisation econotherm WASTE HEAT RECYCLING TECHNOLOGY

3 Kiln Heat Recovery, RAK Ceramics, UAE, April 2016

Gas to Air

Exhaust Temp In/Out	235 C/162 C
Air Temp In/Out	34 C/160 C
Exhaust/Air Mass Flow	41,771/ 27,400 Kg/h
Energy Recovered	970 KW
Recovered Energy	£209K p/a
Project Cost	£190K
Payback Period	11 Months
£/KW recovered	£195

- 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

An ISO9001 Organisation econotherm WASTE HEAT RECYCLING TECHNOLOGY

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

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Waste Heat Recovery Units - Oil & Gas, USA 2020

Gas to Air00

Exhaust Temp In / Out	431C / 156C
Air Temp In / Out	16C / 339C
Exhaust / Air Mass Flow	83,901kg/h / 78,608kg/h
Energy Recovered	7.1MW

ExxonMobil

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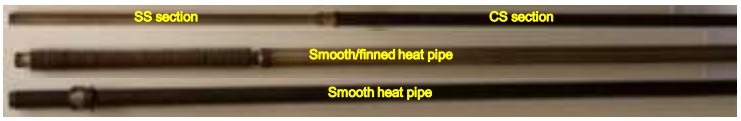
8m long


3m long


SS section
CS section
Smooth/finned heat pipe
Smooth heat pipe

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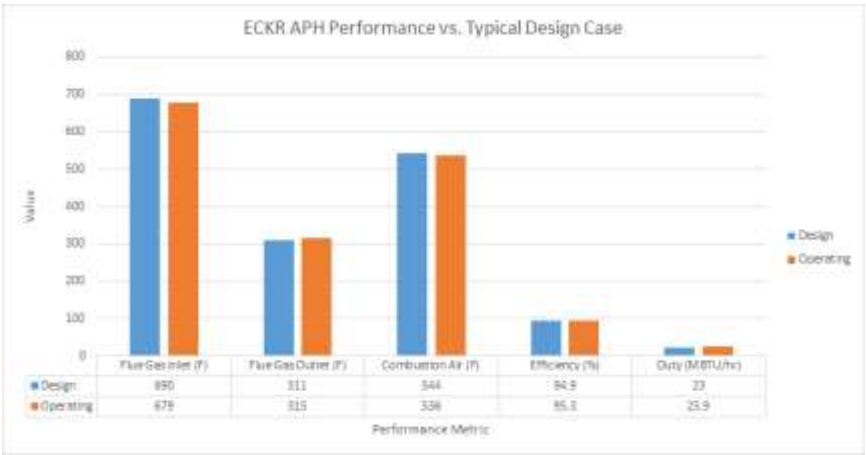
ECKR APH Performance vs. Typical Design Case
800
700
600
500
400
300
200
100
0
Value
Design
Operating
Flue Gas Inlet (F)
Flue Gas Outlet (F)
Combustion Air (F)
Efficiency (%)
Duty (MBTU/hr)
Design
890
311
544
84.9
23
Operating
679
315
336
85.1
25.9
Performance Metric

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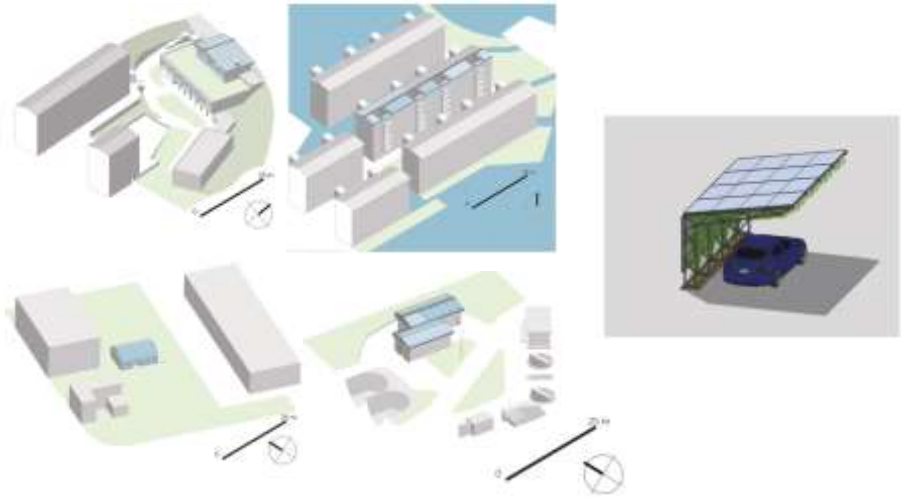
Renewable Energy Harvesting

FHP applications: The Photovoltaic Roof

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

03 April 2024



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

03 April 2024

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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

Innovate UK
Newton Fund
Brunel University London
São Mateus
SENAI
acaratherm

03 April 2024

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.

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Mate plantation

03 April 2024

shredding

Aging

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The Old Production Line

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03 April 2024

Conventional Drying

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The new Heat Pipe Production Line

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The Heat Pipe Based Drying System

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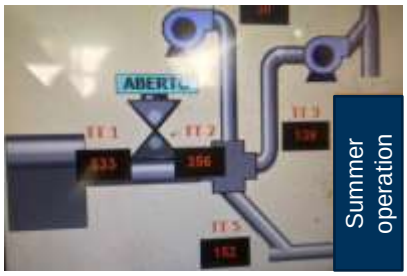
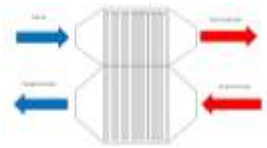
Field Results

03 April 2024





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IMPACT

- 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

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IMPACT

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

DREAM

https://www.spire2030.eu/dream

H2020 funding €5.1M
Brunel's income: €490k

DREAM: Design for Resource and Efficiency in cerAMic kilns

atlas concorde

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

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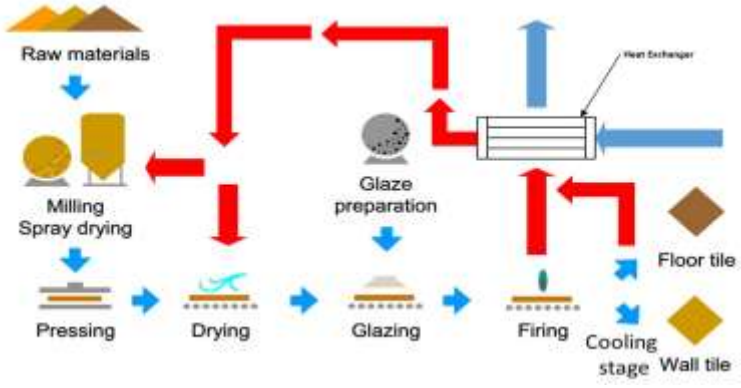
DREAM: Design for Resource and Efficiency in cerAMic kilns

DREAM



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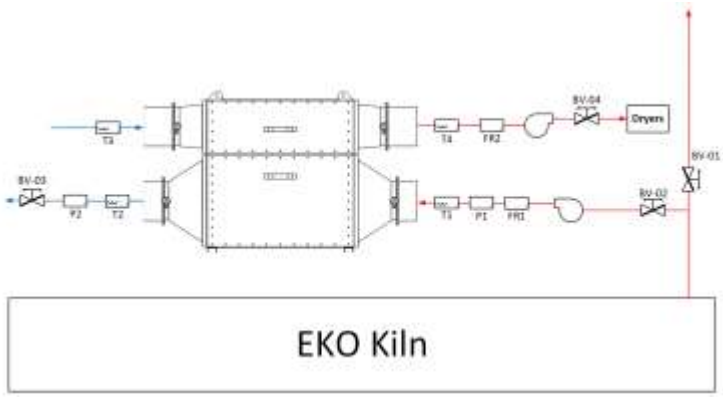
DREAM: Design for Resource and Efficiency in cerAMic kilns



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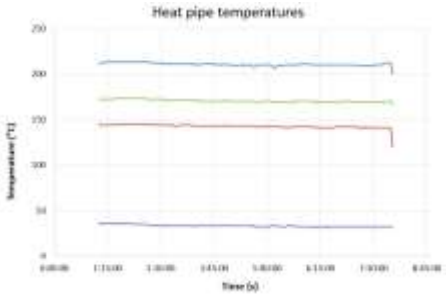
DREAM: Heat Pipe Heat Exchanger installation



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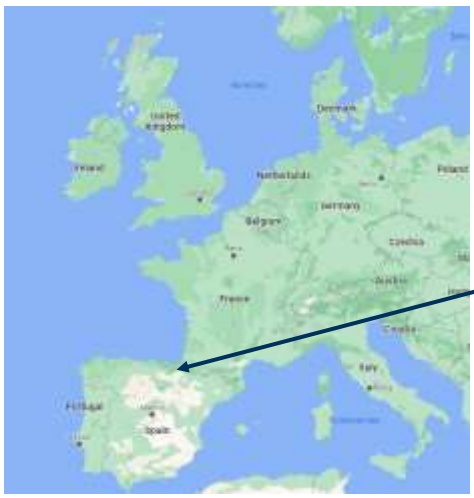
ETEKINA
Thermal energy recovery

https://www.etekina.eu/

H2020 funding €4.6M
Brunel's income: €700k

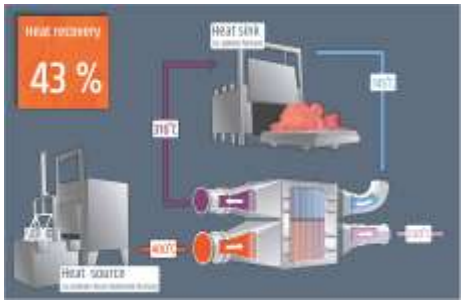
ETEKINA

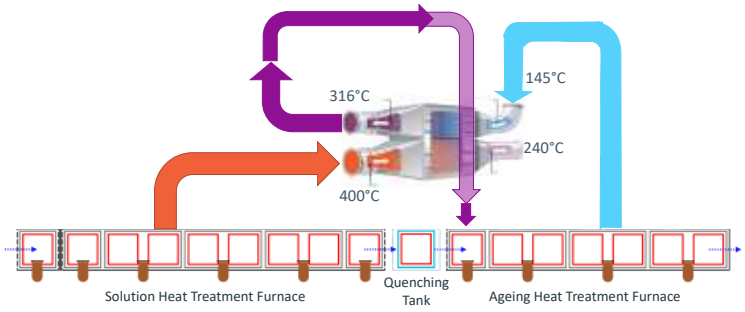
Aluminium industrial installation



fagorederlangroup

Aluminium Industrial installation





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Aluminium Industry, Commissioning

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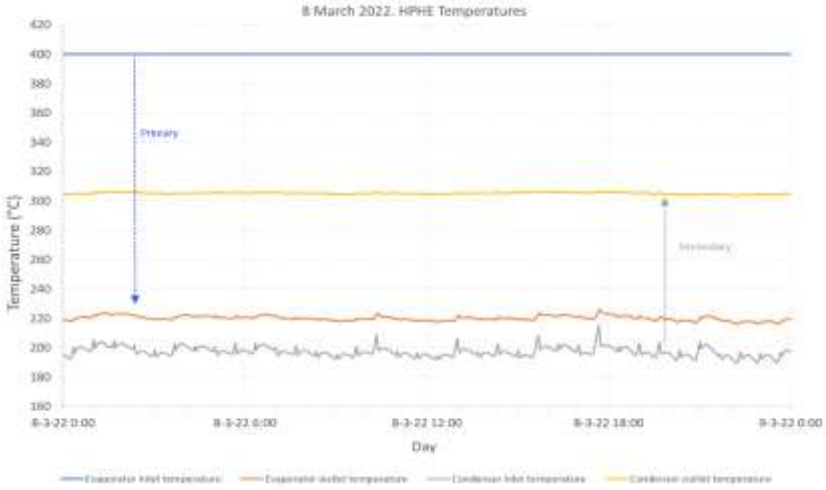
DC1: Results Reference Day



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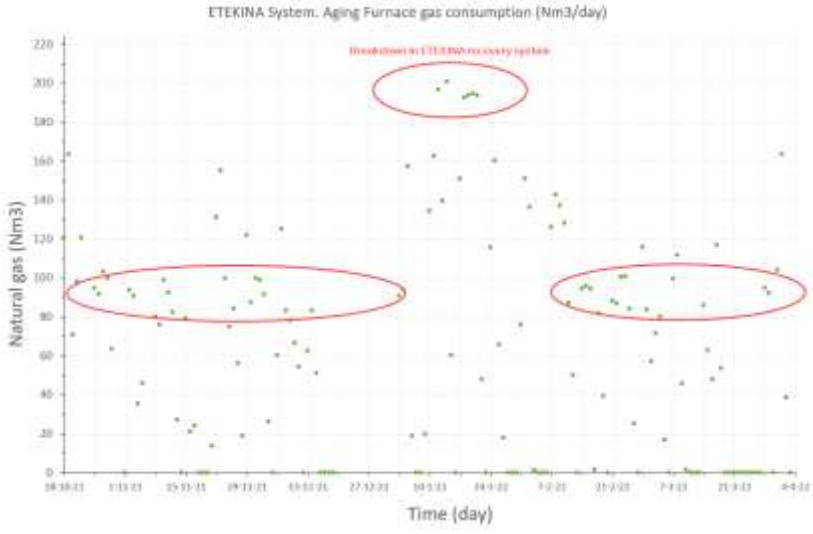
Ageing Furnace NG consumption



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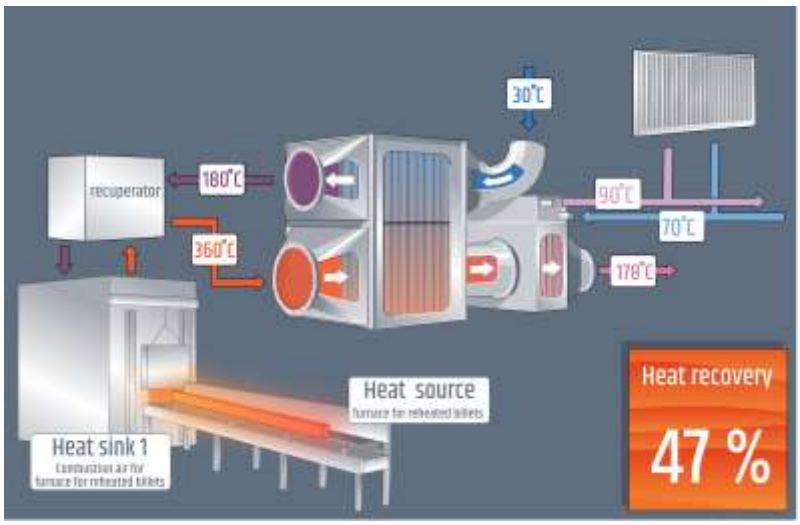
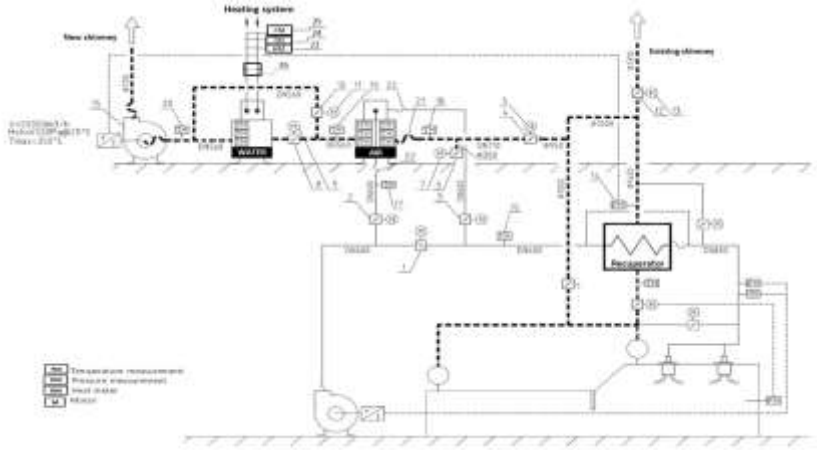
Steel industrial installation, Slovenia

sij | ravne systems

Steel Industrial installation, Concept



Steel Industry Piping and Instrumentation Diagram



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Steel Industry, Commissioning

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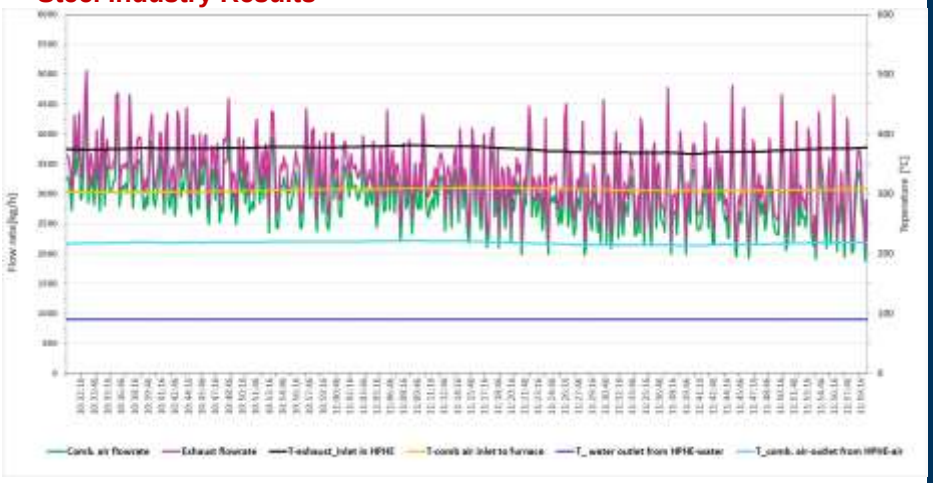
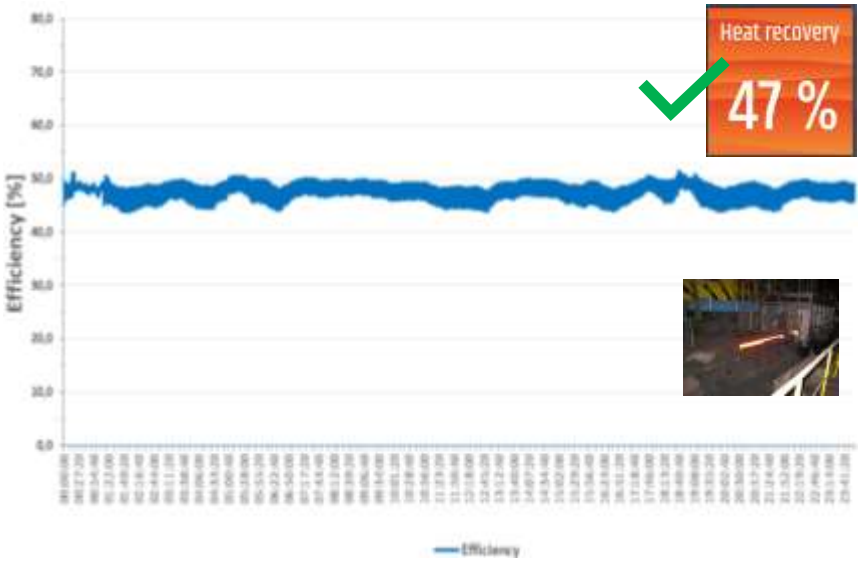
Steel Industry Results



Return On Investment of less than 9 months, 350 kW

Monitoring Results – Recovery Efficiency

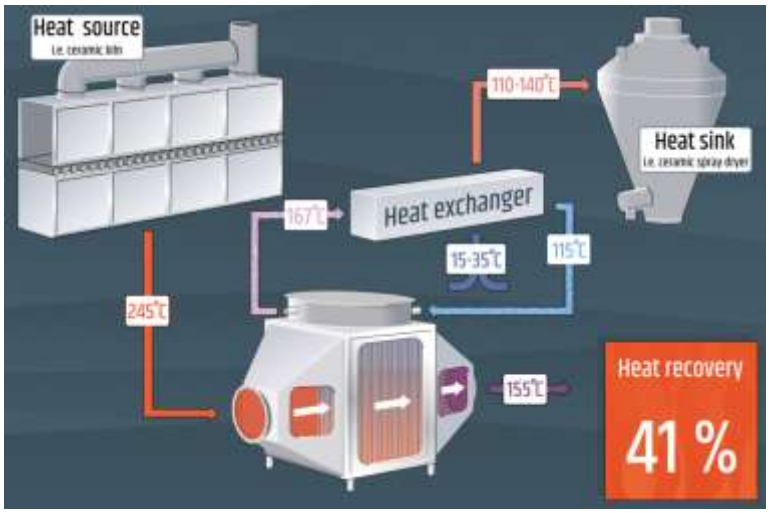


Ceramic Industrial installation, Concept

atlas concorde

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

Ceramic Industrial installation, Concept



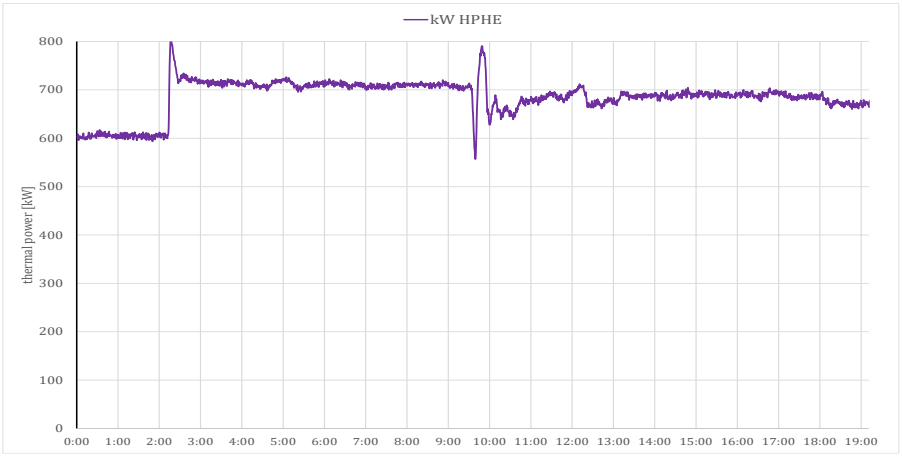
Ceramic Industry Thermal and Mechanical Design

Inspection Services
Design Appraisal Document

Inspection Services
Design Appraisal Document

Ceramic Industry, Commissioning

Ceramic Industry Results



Return On Investment of less than 24 months, 700 kW

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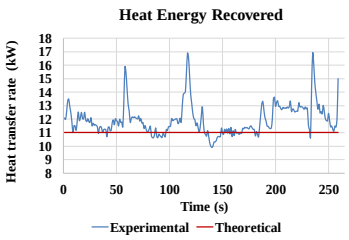
Flat Heat Pipe based heat exchanger for waste heat recovery in the steel industry



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Between **1 and 2 kW/m²** heat recovery were achieved in JBMI

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

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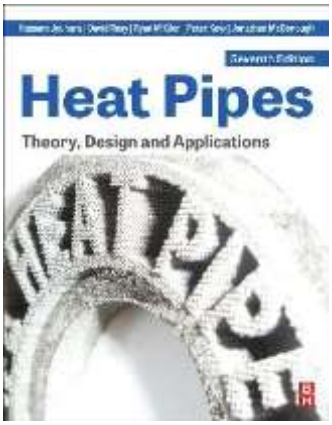
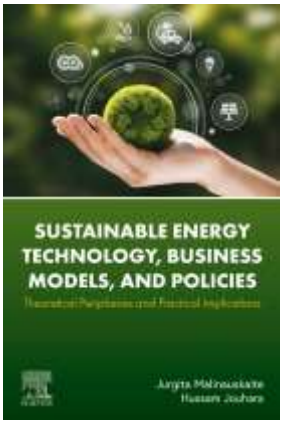
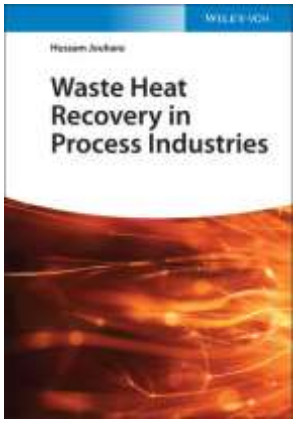


Heat Pipes - 7th Edition (elsevier.com)



Sustainable Energy Technology, Business Models, and Policies



Waste Heat Recovery in Process Industries | Wiley

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Thank you