Waste Heat and Water Recovery from Industrial Flue Gases

By

Professor Hussam Jouhara
PhD, CEng, IntPE, FIMechE, FIEI, FCIBSE, MInstR, SFHEA
OVERVIEW

- Heat pipes – What are they
- Waste heat recovery systems
- Waste heat and water recovery systems
“Heat Pipes”

What are they?
Low temperature heat pipe

High temperature heat pipe
The heat pipe based system consists of $n^*$ heat exchangers connected in parallel, from thermal point of view.

*$n$: the number of heat pipes in the system

A schematic of a typical heat pipe unit
Innovative Waste Heat Recovery Systems
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.
http://smartrec.eu/

H2020 funding €4.6M
(Brunel’s income: €700k
SMARTREC Waste heat recovery solution
Ceramic Industry: Manufacture and Installation

Developing a standard modularised solution for flexible and adaptive integration of heat recovery and thermal storage capable of recovery and management of waste heat.
Ceramic Industry: Commissioning and Testing

Ceramic Industry: Testing

SMARTREC Waste heat recovery solution

Aluminium Recycling Industry

Developing a standard modularised solution for flexible and adaptive integration of heat recovery and thermal storage capable of recovery and management of waste heat
Developing a standard modularised solution for flexible and adaptive integration of heat recovery and thermal storage capable of recovery and management of waste heat.
https://www.spire2030.eu/dream

H2020 funding €5.1M
Brunel’s income: €490k
DREAM: Design for Resource and Efficiency in cerAMic kilns
DREAM: Design for Resource and Efficiency in cerAMic kilns
DREAM: Design for Resource and Efficiency in ceramic kilns

EKO Kiln
DREAM: Heat Pipe Heat Exchanger installation

Heat pipe temperatures

Heat Recovery (KW)
https://www.etekina.eu/

H2020 funding €4.6M
Brunel’s income: €700k
Aluminium industrial installation
Aluminium Industrial installation

Heat recovery
43%

Heat source
i.e. solution heat treatment furnace

Heat sink
i.e. ageing furnace

316°C
145°C

400°C
240°C
Aluminium Industry Thermal and Mechanical Design
Aluminium Industry Piping and Instrumentation Diagram
Aluminium Industry 3D Representation
Aluminium Industry, Commissioning
Aluminium Industry Results

Return On Investment of less than 24 months, 88 kW

100 kW heat recovery
Steel industrial installation, Slovenia
Steel Industrial installation, Concept
Steel Industry Thermal and Mechanical Design
Steel Industry Piping and Instrumentation Diagram

New chimney

Heating system

Existing chimney

V=20000m³/h
Hₚₖ=65000Pa@20°C
Tₘₚ=350°C

TM: Temperature measurement
PM: Pressure measurement
HM: Heat meter
M: Motor

Recuperator
Steel Industry, Commissioning
Steel Industry Results

Return On Investment of less than 9 months, 350 kW
Ceramic Industrial installation, Concept
Ceramic Industrial installation, Concept
Ceramic Industry Thermal and Mechanical Design

Design Parameters:
1. Exhaust Mass Flow Rate = 26,000 Kg/h.
2. Water Mass Flow Rate = 11,280 Kg/h.
3. Exhaust Average Specific Heat Capacity = 0.257 Kcal/Kg°C
4. Water Average Specific Heat Capacity = 1.000 Kcal/Kg°C
5. Exhaust Inlet Temperature = 245 °C
6. Exhaust Outlet Temperature = 155 °C
7. Water Inlet Temperature = 115 °C
8. Water Outlet Temperature = 167 °C
9. Recovered Heat = 699,279kW
11. Design Pressure Steam Side 16 Bar(G).
12. Corrosion Allowance on Steam Side = 1mm.
13. Impact Testing Exempt As Per UG20(7).
14. No Radiography Required (Joint Efficiency Factor 0.7 Used).
15. Water Chamber to be Hydrotested at 23Bar (1.43 Times Operating).
16. Graphoil Gasket Used, m = 2, Y = 10MPa

Notes:
1. Expansion Joints Must be Used to Allow for Thermal Expansion.
2. Unit to Operate in Vertical Orientation as Shown.
3. Dry Assembly Weight 12,050kg.
4. Material of Construction:
   - Exhaust Side - Stainless Steel
   - Waterside - Carbon Steel
   - Heat Pipes - Carbon Steel

263-01-Assembly Bill of Materials

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DRAWING NUMBER</th>
<th>DESCRIPTION</th>
<th>QTY</th>
<th>REVISION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>263-01-1000</td>
<td>Heat Pipe Assembly</td>
<td>896</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>263-01-2000</td>
<td>Steam Side Assembly</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>263-01-3000</td>
<td>Separation Plate</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>263-01-4000</td>
<td>Exhaust Assembly</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>263-01-5000</td>
<td>Name Plate</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
Ceramic Industry Thermal and Mechanical Design

Inspection Services Design Appraisal Document

Client: Econotherm (UK) Limited
Manufacturer: Econotherm (UK) Limited
Subject: Gas to Water Economiser
Design Pressure: 16.0 barg
Volume: 1373 litres
PED Category: IV
Module: G

Data
11 March 2020

PRU1100254977 O-36808/PS

The documents listed below have been examined to comply with the design requirements of ASME VIII Division 1:2017, in support of the Essential Safety Requirements of the Pressure Equipment Directive (2014/68/EU) for the design conditions stated on the documents and are assigned an appraisal status as indicated:

1. The following points are advised for information:
2.1. It is concluded that code stamping is neither intended nor applied.
2.2. It is noted that non-ASME listed materials are proposed and the requirements of UG-10 apply.

Name: P Swanton
Office Details: Sheffield
Phone: +44 (0) 114 2468137
Email: paul.swanton@lr.org

Status Key
A: Examined
SI: Retained as supporting documentation for information only

Distribution
Lloyd’s Register Inspection Services (Birmingham): 1 Set
Lloyd’s Register Inspection Services (Sheffield): 1 Set
Econotherm (UK) Limited: 1 Set
Ceramic Industry Piping and Instrumentation Diagram
Ceramic Industry, Commissioning
Ceramic Industry Results

Return On Investment of less than 24 months, 700 kW
Innovative WAter recoverY Solutions through recycling of heat, materials and water across multiple sectors

https://www.iways.eu/

H2020 funding €10.5M
Brunel’s income: €817k
The consortium
Innovative WAter recovery Solutions through recycling of heat, materials and water across multiple sectors
Innovative WAter recoverY Solutions through recycling of heat, materials and water across multiple sectors

- Condensation occurs when the heat pipe surface temperature $T_e$ is lower than the dew point of the composition $T_{dew}$: $T_e < T_{dew}$

Condensate

Hot Flue gas

Heat sink fluid

Sensible heat

$T_e > T_{dew,SO_3}$

$T_e < T_{dew,SO_3}$

Condensate

$T_e < T_{dew,NO_3}$
Innovative WAter recoverY Solutions through recycling of heat, materials and water across multiple sectors
Innovative WAter recoverY Solutions through recycling of heat, materials and water across multiple sectors

Funded by European Union’s Horizon 2020 research grant agreement no. 818342
Innovative WAter recoverY Solutions through recycling of heat, materials and water across multiple sectors

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