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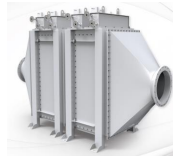
HEAT PIPE HEAT EXCHANGERS FOR INDUSTRIAL HEAT RECOVERY

By

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spirox sarco apnootherm

Challenging Waste heat recovery scenarios

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OVERVIEW

- The potential of the heat pipe technology in challenging waste heat recovery applications
- Heat pipes, an overview
- Typical configurations of heat pipe units for waste heat recovery applications
- Case studies

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.

Heat pipes can manage these difficult conditions!



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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

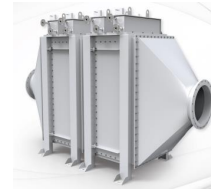
Reactivity

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

Typical geometries of heat pipe based waste heat recovery systems



Heat pipe units: typical configurations

Standard cross flow HP heat exchangers

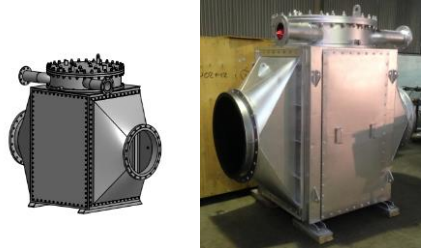
- Air preheaters
- Gas to water
- Gas to thermal oil
- Steam generators

Modular cross flow HP heat exchangers

- Gas to water
- Gas to thermal oil

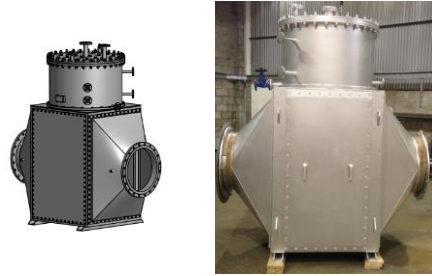
Throughflow HP heat exchangers

Cross flow HP units: Gas to water



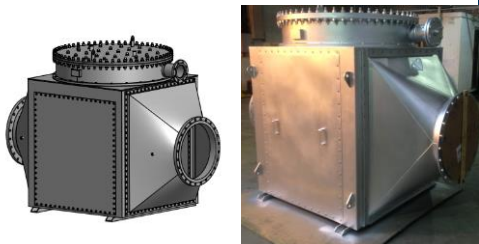
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Cross flow HP units: Steam generator



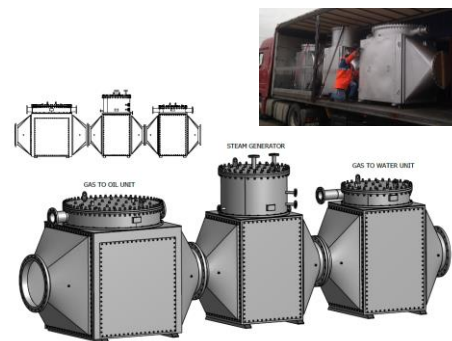
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Cross flow HP units: Gas to thermal oil



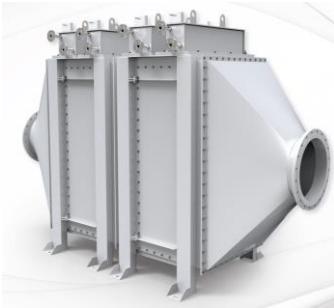
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Cross flow HP units: A combination of various units



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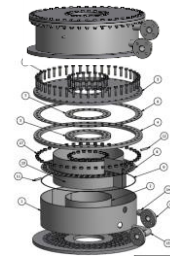
Modular cross flow HP units



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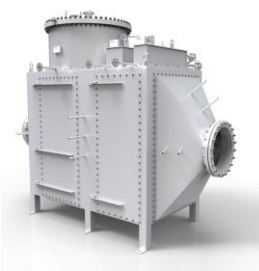
Throughflow HP units

Through-Flow = for exhaust temperatures above 500C



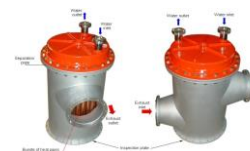
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Modular cross flow HP units



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Other HP units' configurations



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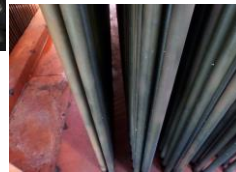


Steam Condenser, Food, Dirty Steam, Ireland

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STEAM GENERATION FROM WASTE HEAT



Duty: Circa 6MW
Steam generation rate: 8t/h

ROI: <2 years

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SAMPLES OF RECENT PROJECTS



G2W, Shale Gas Well Head Fracking, Thermal Oxidiser, Canada 2013

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Spirax Sarco Thermal Storage And Heat Recovery System From Process Waste STEAM

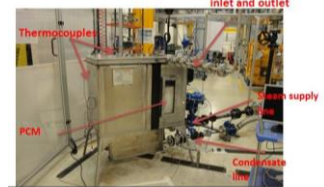
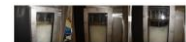


Fig 5. Thermal Energy Storage Heat Exchanger test rig



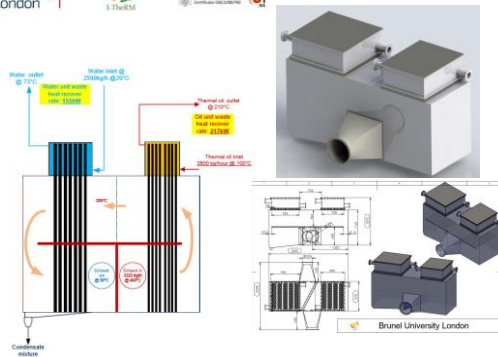
Charging



Discharging

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I-Therm Condensing Economiser



Gas to Air Unit, Automotive, Aluminium Furnace, USA 2008



| Gas to Air | |
|-----------------------|------------------|
| Exhaust Temp In/Out | 490 C/266 C |
| Air Temp In/Out | 30 C/293 C |
| Exhaust/Air Mass Flow | 12,000/6,374 Kgh |
| Energy Recovered | 528 KW |
| Recovered Energy | \$156K pia |
| Project Cost | \$160K |
| Payback Period | 16 Months |
| \$/KW recovered | \$123 (£76) |



- GA 360 smooth pipe heat exchanger
- 500 kW combustion air pre-heater
- High particulate matter exhaust from furnace
- Low fouling, easy cleaning and maintenance, high reliability
- Unit positioned outside main factory premises
- Customer advised it was not possible by consultants (acid etc)

Heat Pipe Based Waste Heat Recovery Systems: Case Studies

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



| Gas to Air | |
|-----------------------|-------------------|
| Exhaust Temp In/Out | 286 C/158 C |
| Coke Gas Temp In/Out | 62.2 C/197 C |
| Exhaust/Air Mass Flow | 97,551/97,551 Kgh |
| Energy Recovered | 12,628 Kwh |
| Recovered Energy | £400,000 pia |
| Project Cost | £400,000 * |
| Payback Period | Circa 6 Months * |
| \$/KW recovered | £31.67 * |



- 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


| Gas to Water | |
|-------------------------|--------------------|
| Exhaust Temp In/Out | 816 C / 150 C |
| Water Temp In/Out | 5 C / 16 C |
| Exhaust/Water Mass Flow | 11,816/180,000 Kgh |
| Weight of unit | 3,600 Kg |
| Exhaust pressure drop | 820 Pa |
| Energy Recovered | 2,250 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

Steam Condenser, Food, Dirty Steam, Ireland, 2010


| Steam Condenser / Hot Water | |
|-----------------------------|-----------------|
| Steam Temp In/Out | 105 C / 85 C |
| Water Temp In/Out | 10 C / 88 C |
| Exhaust/Water Mass Flow | 844 / 8,000 Kgh |
| 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

Multi-stage, in series, steam/water, natural gas, Spirax Sarco Italy 2012


| Multi-stage Steam Generator and Water Pre-Heater | |
|--|------------------------|
| Exhaust Temp In/Out | 420 C / 150 C |
| Water Temp In/Out | 150 C / 188 C (12 bar) |
| Exhaust/Water Mass Flow | 11,484/ 500 Kgh |
| Weight of unit | 1852 Kg |
| Exhaust pressure drop | 700 Pa |
| Energy Recovered | 820 KW |
| Recovered Energy Value | £19K p/a |
| Heat Exchanger Cost | £19K |
| Payback Period | 12 Months |
| Price per KW recovered | £21 |



- Anaerobic digester genset in food industry
- 1 stage of 198C/12 Bar steam generation, left hand side
- 2 stages of water heating delivered by 2 standard modules, visible on right of unit
- Pipes screwed in from underneath on standard modules; modules can be removed individually
- Hinged access doors for easy cleaning, sealing nuts will be replaced by latches on future units

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


| Gas to Water | |
|-------------------------|---------------|
| Exhaust Temp In/Out | 510 C / 150 C |
| Water Temp In/Out | 73 C / 80C |
| Exhaust/Water Mass Flow | 17,500 Kgh |
| Weight of unit | 6,000 Kg |
| Exhaust pressure drop | 400 Pa |
| Energy Recovered | 2,100 KW |
| Recovered Energy Value | £319K p/a |
| Heat Exchanger Cost | £172,500 |
| Payback Period | <18 Months |
| Price per KW recovered | £148/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



Thank you