...offering total cooling solutions
J & E Hall Ammonia Heat Pumps

DAIKIN

Daikin Applied UK
Applied AC

J & E Hall Ltd
Refrigeration

AAF UK Ltd
Air Filtration

Applied Service

Coulstock & Place

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- First manufactured cold air machines, 1875
- Two stage carbon dioxide compressor designed, 1889
- First "high speed" ammonia compressor manufactured, 1921
- "Veebloc" compressor launched, 1950
- Monobloc range launched, 1940
- Launched the single screw compressor, the HallScrew, 1978
- Ammonia air cooled chiller launched, 2003
- 7 new open type HallScrew compressors launched, 2017

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“Phase-Down” of the CO2-equivalents*

*CO$_2$-equivalent = Quantity x GWP of the gas

<table>
<thead>
<tr>
<th>Year</th>
<th>GWP Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>New</td>
<td>2500</td>
</tr>
<tr>
<td>Service</td>
<td>&gt; 10 kg R-404A</td>
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Sustainability of F Gases in EU

2015*

-500 0 500 1000 1500 2000 2500 3000 3500 4000 4500
GWP (AR4)

R404A/ 507
R134a
R410A
R407C
R2600
B1950
B1400
B600
Regeneration
HFO
Naturals

2030*

-10 0 10 20 30 40 50 60 70
GWP (AR4)

R407C
R134a
B1950
B1400
R32
HFO
B600
B250
B500
Andere
Regeneration
Naturals

* SKM Enviros & DuPont unter der Annahme gleichbleibender Kältemittelmengen
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- “Lower” GWP HFCs
- Aim of F-Gas Regulations is to drive down the use of these refrigerants
- HFC Quota System will limit supply and increase price
- No plans for future F Gas Regulations ... but who knows

- HFO blends
  - GWPs low enough to be maintained under the cap
  - A range of products for different applications
  - Availability and cost have been issues
  - “A2L”
Ammonia

- Widely used as industrial refrigeration for many years
- 87 years use in J & E Hall Ltd
- Cost – cheapest industrial refrigerant available
- Efficiency – superior thermal characteristics
- Disadvantages – The fear factor (Toxicity & Flammability)

Hydrocarbon refrigerants

- Suitable for wide range of temperatures
- More restrictions than ammonia

Carbon Dioxide

- High pressure design required / limited components
- Provides high water outlet temperature
- Non-toxic and non flammable
Why Use A Heat Pump

- Chillers and Process Cooling are a significant contributor to energy consumption.
- As part of the Cooling Process a Chiller will generate heat that must be rejected somewhere.
- Historically this heat has been rejected to the environment and lost.
- With today's focus on Energy Efficiency and Lowering Green House Gas emissions we can no longer afford to waste this energy.
- Most conventional chillers can only provide "low grade" heat (water temperatures at around 50°C and low kW outputs).
- With correct design modern heat pumps can deliver significant quantities of "high grade" heat (water temperatures of up to 80°C).
- By collecting this "waste heat" we can reduce energy bills used for heating hot water for other applications.
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HEAT REJECTED TO ATMOSPHERE

TRADITIONAL CHILLER

CONDENSER

COMPRESSOR

EVAPORATOR

EXPANSION VALVE

HEAT SOURCE TO BE COOLED

WASTE HEAT

COOLING CAPACITY

MOTOR POWER

WASTE HEAT = COOLING CAPACITY + MOTOR POWER

Pressur Enthalpy

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WASTE HEAT RECOVERED AND USED

WATER @ 75°C

HEAT PUMP

CONDENSER

EVAPORATOR

COMPRESSOR

EXPANSION VALVE

HEAT SOURCE TO BE COOLED

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WASTE HEAT = COOLING CAPACITY + MOTOR POWER
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- Process Cooling
- Power Generation
- River Water
- Air Conditioning
- Ground Water
- Air Source

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**Heat Pump Efficiencies**

\[ \text{COP}_{\text{Combined}} = \frac{\text{Cooling duty} + \text{heating duty}}{\text{Energy used for cooling} + \text{energy used for heating}} \]

**Example 1:**  
\[ \text{COP}_{\text{Combined, chiller+gasboiler}} = \frac{800 \text{ kW} + 1000 \text{ kW}}{200 \text{ kW} + 1250 \text{ kW}} = 1.25 \]

**Example 2:**  
\[ \text{COP}_{\text{Combined, chiller+heatpump}} = \frac{800 \text{ kW} + 1000 \text{ kW}}{300 \text{ kW}} = 6.00 \]

**Source**  
12th IER Heat Pump Conference, High efficient, high temperature industrial ammonia heat pump installed in central London, Kenneth Hoffmann
Case Study 1

- Client in Switzerland has combined Power Generation and District Heating operating since the 1980’s, comprising power generation equipment, reciprocating Compressor Heat Pump and oil-powered boilers to provide the hot water to the District Heating circuit at peak loads,

- Planned upgrade to install a new Water Source Heat Pump to supplement the existing heat pump and replace the oil-powered boilers with a new wood chip firing system for operation in the winter months (October to April),

- The district heating system will supply around 1,200 apartments adjacent to the power plant with heating and hot water.
Case Study 1

- Project Aims
  - The new woodchip burner will operate exclusively with chopped forest wood and is supplied with an environmentally friendly an exhaust gas condensation system to provide additional waste heat recovery
  - Minimise the use of the four oil-powered peak load centres,
  - The share of renewable energy is to be increased from 50 percent to over 70 percent.

- Benefits
  - Reduced energy consumption from fossil fuels
  - Reduced CO2 emissions.
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Case Study 1

- Heat Pump Requirements
  - Heating Capacity: 675 kW to 2,450 kW
  - Cooling Water Temperatures: 20°C to 26°C
  - Cooling Water Flow Rate: 80 m³/hr to 274 m³/hr
  - Hot Water Temperatures: 40°C to 70°C
  - Hot Water Flow Rate: 40 m³/hr to 141 m³/hr

- Challenges
  - Cooling Water Inlet Temperatures and Flow Rates can vary suddenly
  - Hot Water Return Temperatures and Flow Rates can vary suddenly
  - Maximum width (to suit plant room layout): 1,800 mm
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The J & E Hall Solution

Separator Vessel

Flooded Shell & Plate Evaporator

Shell & Plate Lube Oil Cooler

Control / Starter Panel

HalScrew Compressor

Vertical Oil Separator

PHE Condenser

PHE de-superheater

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Heating Capacity: 2,456 kW
Water Inlet @ 55°C (normal)
Water Outlet @ 70°C

Compressor Absorbed Power
556 kW

Cooling Load: 1,900 kW
Water Inlet @ 26°C
Water Outlet @ 20°C

COPh: 4.42
(4.20 inc. motor/VSD losses)
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Design Features

- New HallScrew HSO 5200 Series Compressor with 40 barg design pressure
- Flooded Shell & Plate Evaporator with close approach temperatures to maximise efficiency
- Condenser, De-superheater and Oil Cooler arranged in series to maximise outlet temperature
- Vertical Oil Separators to minimise the installation foot print
- Delivered to site with on skid starter / control panel pre-wired to minimise site installation time
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Customer Feedback

- Heat Pump is much more stable than their existing heat pumps

- Able to cope with rapidly changing operating conditions

- Measured COP is above the quoted COP

- At same operating conditions COP is around 5.0 (12% to 15% improvement on COP)
Case Study 2

- The Company maintains and operates a district heating net in the Basel, Switzerland.
- Currently the majority of the energy is created by oil- and gas boilers (1 each), supported by a heat pump.
- The Company wished to increase the amount of renewable energy used for the district heating so installed a larger heat pump and new woodchip burners.
- Heat source for the pump is cleaned water from a wastewater treatment plant.
- The Heat Pump supplies the base load of the district heating and is the sole heat generator active over the summer.
Case Study 2

- Heat Pump Requirements
  - Heating Capacity: 835 kW to 1,600 kW
  - Cooling Water Temperatures: 2°C to 19°C depending on time of year
  - Cooling Water Flow Rate: 126 m³/hr
  - Hot Water Temperatures: 40°C to 75°C
  - Cooling Water Flow Rate: 48 m³/hr to 138 m³/hr

- Challenges
  - Cooling Water Inlet Temperatures and Flow Rates can vary suddenly
  - Hot Water Return Temperatures and Flow Rates can vary suddenly
  - Maximum installation width (to suit plant room layout): 1,800 mm
J & E Hall Ammonia Heat Pumps

- Shell & Plate De-superheater
- Shell & Plate Condenser
- "Combined" Shell & Plate Evaporator
- Vertical Intercooler
- Shell & Plate Lube Oil Cooler
- Low Stage Compressor
- High Stage Compressor
- Horizontal Oil Separator
- Skid Split For Shipping

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The J & E Hall Solution
J & E Hall Ammonia Heat Pumps
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Heating Capacity: 1,600 kW
Water Inlet @ 60°C (normal)
Water Outlet @ 75°C

Cooling Load: 1,172 kW
Water Inlet @ 15°C
Water Outlet @ 7°C

COP: 3.55
(3.36 inc. motor/VSD losses)

High Stage Compressor
Absorbed Power: 256 kW

Low Stage Compressor
Absorbed Power: 203 kW

3°C
75°C
37.1 bara
13.9 bara
4.8 bara
Conclusions

- Throwing away “waste” heat is no longer acceptable
- As responsible engineers we should be looking to utilise heat pump technology wherever possible
- Always look to match heating and cooling loads
- Long term sustainability of HFC refrigerants is in doubt
- Natural refrigerants have a long history ... and a long future
- Don’t be scared of Natural Refrigerants ... we can manage the “risks”
...thank-you

www.jehall.com