Development of high temperature Heat Pumps using a low GWP refrigerant

2018.2.13
Hideki Fuchikami
• Company profile
  ✓ MAYEKAWA’s Proposal with “Natural Five”
  ✓ Products from -271 °C to + 180°C
  ✓ Cooling System with NH₃/CO₂

• Heat Pump system with CO₂

• Mayekawa’s challenges in Heat Pump field with low GWP refrigerant
  ✓ Circulation heating Heat Pump
  ✓ 150°C generation Heat Pump
  ✓ 200°C generation Heat Pump
[Natural Five] are natural refrigerants utilized for refrigerators & Heat Pumps to achieve both [Energy Saving] and [No Use of Fluorocarbons]. Mayekawa has developed wide range of application with [Natural Five].

Air Cycle refrigerator “PascalAir”

NH$_3$/CO$_2$ Indirect Cooling System “NewTon”

CO$_2$ Heat pump “unimo”

Adsorption Refrigerator “AdRef-Noa”

Air-conditioning/Water-supply Heat Pump
**MAYEKAWA’s Proposal with [Natural Five]**

[Natural Five] are natural refrigerants utilized for refrigerators & Heat Pumps to achieve both [Energy Saving] and [No Use of Fluorocarbons]. Mayekawa has developed wide range of application with [Natural Five].
MAYEKAWA’s Refrigerators and Heat Pumps using Natural Refrigerants

Steam Expander

HC

+180°C

Air +120°C

Water +90°C

CO₂ Heat Pump “unimo”

NH₃ Heat pump

HC Heat Pump

+150°C

+50°C

CO₂ Heat Pump Desiccant Dehumidifier

NH₃ Heat pump

NH₃/CO₂ “NewTon”

+5°C

Adsorption Chillers

NH₃•CO₂ Cascade

NH₃ – Ethane Cascade Refrigerator

Turbo Comp.&Exp.

He Compressors

-50°C

-95°C

Air Cycle “Pascal Air”

Brayton refrigerator

-120°C

Air

-180°C

-208°C

-269°C

Helium Refrigerator, Helium Compressor

Ne
NH₃/CO₂ Indirect Cooling System “NewTon”

**Energy Saving**
- IPM Motor-driven Semi-Hermetic Screw Compressor
- Matrix Converter for IPM Motor
- New Screw Profile for NH₃
- Shell & Plate Heat Exchanger

**Safety**
- “Indirect Cooling” method minimizing NH₃ circulation area
- Minimum NH₃ Charge: 21kg (R-3000)
- Bellows valves

**Compact**
- Downsizing: 24% less in weight
- Packaging for shorter installation

**Support**
- Remote Monitoring for Predictive Maintenance
- Maintenance Support 24hr/365day

**Compound Screw Compressor for NewTon-R,F**

**Single-stage Screw Compressor for NewTon-C**
<table>
<thead>
<tr>
<th>Application</th>
<th>Type (Capacity)</th>
<th>Liquid CO₂ supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frozen Cold</td>
<td>Reabel R-3000</td>
<td>CO₂ supply: -32°C (in-house temp. : -25°C)</td>
</tr>
<tr>
<td>Warehouse</td>
<td>R-6000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>R-8000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(37.6kW)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(94.7kW)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(189.4kW)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(270.0kW)</td>
<td></td>
</tr>
<tr>
<td>Chilled</td>
<td>Sierra C</td>
<td>CO₂ supply: -5°C (in-house temp. : -2°C)</td>
</tr>
<tr>
<td></td>
<td>(24.1kW)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(237.0kW)</td>
<td></td>
</tr>
<tr>
<td>Freezer</td>
<td>F-300</td>
<td>CO₂ supply: -42°C (inside freezer : -35°C)</td>
</tr>
<tr>
<td></td>
<td>F-600</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F-800</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(70.0kW)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(140.0kW)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(170.0kW)</td>
<td></td>
</tr>
<tr>
<td>Ice Rink</td>
<td>S</td>
<td>CO₂ supply: -11°C</td>
</tr>
<tr>
<td></td>
<td>(185.0kW)</td>
<td></td>
</tr>
</tbody>
</table>

Energy saving ▲16~41%
Installation as of 2017 1,495sets
“NewTon” Installation

NewTon to the World

Nashville(USA) to North and Central America (Since 2015)
- Canada: 4sets
- USA: 2sets
- Mexico: 1set

Aruja(Brazil) to South America (Near future)

Moriya(JP) to Asia
- Korea: 1 set
- China: 2 sets
- Taiwan: 32 sets
- Vietnam: 4 sets
- Thailand: 11 sets
- Indonesia: 16 sets
- Australia: 4 sets
- Philippines: 1 set
- Myanmar: 4 sets

Japan
- 1,413sets
## CO₂ Heat Pump “unimo”

### Products Line-up

<table>
<thead>
<tr>
<th>unimo_AW</th>
<th>unimo_WW</th>
<th>unimo_AWW</th>
<th>“Eco Sirocco”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air-source “Eco Cute”</td>
<td>Water-source “Eco Cute”</td>
<td>Air-source/Water-source “Eco Cute”</td>
<td>Water-source CO₂ Heat Pump supplying Hot Air</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Supply of Hot water 65℃~90℃</th>
<th>Supply of Hot water 65℃~90℃ or Supply of Hot water 65℃~90℃</th>
<th>Supply of Hot water 65℃~90℃ or Supply of Hot water 65℃~90℃</th>
<th>Supply of Hot air 80℃~120℃ and Cold water -9℃~35℃</th>
</tr>
</thead>
<tbody>
<tr>
<td>And Cold water -9℃~35℃</td>
<td>And Cold water -9℃~35℃</td>
<td>And Cold water -9℃~35℃</td>
<td>And Cold water -9℃~35℃</td>
</tr>
</tbody>
</table>

Food Plant, Manufacturing Plant Hotel, Hospital, Spa, etc.

[Images of product models]
Heat Pump (HP) ••• developing

Supply Temperature & Heat Capacity

Supply Temperature [℃]

Supply of Hot water:
- Heating medium: 65°C ~ 90°C
- Heat capacity: 35kW
- Compressor: Scroll
- Circulation heating

Supply of Hot oil:
- Heating medium: 120°C ~ 150°C
- Heat capacity: 260kW
- Compressor: Screw
- Circulation heating

Supply of Hot oil:
- Heating medium: 160°C ~ 200°C
- Heat capacity: 500kW
- Compressor: Turbo
- One-way heating

Heat Pump (HP) ••• developing

Heat Capacity [kW]

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Circulation Heat Pump

Picture of test facility

Food Plant, Manufacturing Plant, Hospital etc.

Feature
- Low GWP refrigerants (GWP: 1~4)
- Circulation heating (ΔT = 5~10℃)

Specifications (Design)

<table>
<thead>
<tr>
<th>Item</th>
<th>Design value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refrigerant</td>
<td>HFO-1234ze(E) or HC-based</td>
</tr>
<tr>
<td>Compressor</td>
<td>Scroll</td>
</tr>
<tr>
<td>Lubricating oil</td>
<td>PAG or PAO</td>
</tr>
<tr>
<td>Design pressure</td>
<td>3.5 MPaG</td>
</tr>
<tr>
<td>Heat capacity 90℃</td>
<td>35.0 kW ※1</td>
</tr>
<tr>
<td>Heat capacity 65℃</td>
<td>29.5 kW ※2</td>
</tr>
<tr>
<td>COP&lt;sub&gt;h&lt;/sub&gt;</td>
<td>3.0 ※1</td>
</tr>
<tr>
<td>Heat source temp.</td>
<td>40℃</td>
</tr>
<tr>
<td>Hot water temp.</td>
<td>85℃ ⇒ 90℃</td>
</tr>
</tbody>
</table>

※1 Heat source inlet temp. 40℃, Hot water inlet temp. 85℃
※2 Heat source inlet temp. 25℃, Hot water inlet temp. 60℃
150°C generation Heat Pump

Research project sponsored by NEDO.

**Feature**
- Low GWP refrigerants (GWP: 3)
- Circulation heating ($\Delta T = 5\sim20^\circ\text{C}$)

**Specifications (Design)**

<table>
<thead>
<tr>
<th>Item</th>
<th>Design value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refrigerant</td>
<td>n-Pentane</td>
</tr>
<tr>
<td>Compressor</td>
<td>Screw</td>
</tr>
<tr>
<td>Lubricating oil</td>
<td>PAG</td>
</tr>
<tr>
<td>Design pressure</td>
<td>2.0 MPaG</td>
</tr>
<tr>
<td>Heat capacity</td>
<td>260 kW</td>
</tr>
<tr>
<td>$\text{COP}_h$</td>
<td>3.0</td>
</tr>
<tr>
<td>($T_c=160^\circ\text{C}, T_e=80^\circ\text{C}$)</td>
<td></td>
</tr>
<tr>
<td>Heat source temp.</td>
<td>90°C</td>
</tr>
<tr>
<td><strong>Hot oil temp.</strong></td>
<td>130 $\Rightarrow$ 150°C</td>
</tr>
</tbody>
</table>
200°C generation Heat Pump

Feature

• Low GWP refrigerants (GWP: 15)
• Magnetic bearing (No lubricating oil)

Specifications (Design)

<table>
<thead>
<tr>
<th>Item</th>
<th>Design value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refrigerant</td>
<td>n-Butane</td>
</tr>
<tr>
<td>Compressor</td>
<td>Turbo</td>
</tr>
<tr>
<td>Lubricating oil</td>
<td>Not used</td>
</tr>
<tr>
<td>Design pressure</td>
<td>6.0 MPaG</td>
</tr>
<tr>
<td>Heat capacity</td>
<td>500 kW</td>
</tr>
<tr>
<td>COPₜₜ (hot oil 100°C/200°C)</td>
<td>3.5</td>
</tr>
<tr>
<td>Heat source temp.</td>
<td>80°C</td>
</tr>
<tr>
<td>Hot oil temp.</td>
<td>100°C ⇒ 200°C</td>
</tr>
</tbody>
</table>

Food, Beverage, Pharmaceutical, Chemical industries etc.

Picture of test facility
Research project sponsored by METI※ & NEDO. 10-year plan from 2013 to 2022.

※ METI: Ministry of Economy, Trade and Industry (Government of JAPAN)

- First 5 years: Hot oil temp. 80°C ⇒ 160°C
- Last 5 years: Hot oil temp. 100°C ⇒ 200°C

Developing heat pump to provide heat 160°C. (FY2017)
Mayekawa’s challenges

High temperature Heat Pumps using a low GWP refrigerant

Supply of Hot oil:
(heating medium)
160°C ~ 200°C
Heat capacity: 500kW
Compressor: Turbo
One-way heating

Supply of Hot oil:
(heating medium)
120°C ~ 150°C
Heat capacity: 260kW
Compressor: Screw
Circulation heating

Supply of Hot water:
65°C ~ 90°C
Heat capacity: 35kW
Compressor: Scroll
Circulation heating

150°C generation HP

HC-based: GWP=4
HFO-1234ze(E): GWP<1

200°C generation HP

Supply of Hot oil:
(heating medium)
160°C ~ 200°C
Heat capacity: 500kW
Compressor: Turbo
One-way heating

n-Butane
GWP=15

Sponsored by METI & NEDO

150°C generation HP

Supply of Hot oil:
(heating medium)
120°C ~ 150°C
Heat capacity: 260kW
Compressor: Screw
Circulation heating

n-Pentane
GWP=3

Sponsored by NEDO

Circulation HP

n-Pentane
GWP=3

※ GWP values based on the IPCC’s 5th report or Ministry of the Environment report.
Thank you for your attention

Web Site of MAYEKAWA
http://www.mayekawa.co.jp/
http://www.mayekawa.eu/