Development of multi-function CO2 Heat Pump Water Heater
Background of multi-function water heater

Market trend of gas combustion multi-function water heater

Energy consumption at residence

- Annual report of residential energy statistics (1999)
- Proceed energy saving based on “Top Runner Approach” standards of energy efficiency

Market of multi-function hot water heater is glowing

Need to develop high efficiency system
Main task of multi-function heat pump water heater

Characteristics of multi-function system

- Use hot water in the storage tank directly for hot tap water
- Use hot water in the storage tank indirectly for heat source of space heating

Main problem
Return water from primary heating circuit is mixed into cold feed-water

Heat pump COP becomes down with higher inlet water temp.
Countermeasures of task

Characteristics of CO₂ heat pump

- Decline of heating capacity and COP under high inlet water temp. cond.

Isotherm.

- To use return water for tap water (medium temp. water)

Countermeasures for decline of COP

- To improve heat pump COP at higher inlet water temp. condition

Development of Cascade heat process system

Development of ejector cycle for heat pump water heater
**Outline of cascade heat process system**

**Conventional storage tank**
- Medium temp. water can not use
- Heat pump COP becomes down

**Cascade heat process system**
- 2 additional water return ports for primary heating circuit to prevent to mix water
- 2 additional outlet ports to use medium temp. water for hot tap water

**Characteristics**
- Too low temp. for hot tap water
- Cause inlet water temp. for heat pump rising and COP becomes down

- Heat pump COP becomes down

Medium temp. water and cold feed-water flow into tank by turns.
- Too low temp. for hot tap water
- Cause inlet water temp. for heat pump rising and COP becomes down

3 different temp. water in the 3 portions of the storage tank
Optimization of port position for cascade heat process system

Basic idea:
Fit for general working pattern

- Tank volume 460L
- Space heater
- Return port
- Feed-water
- Outlet port
- Hot tap water

**<Optimization of upper additional outlet port>**

- Potential amount of hot tap water
- Outlet port position

**<Characteristic of boundary layer between hot and cold water>**

- Tank volume 460L
- Space heater
- Return port
- Feed-water
- Outlet port
- Hot tap water

**Basic Idea:**
Fit for general working pattern

- Tank volume 460L
- Space heater
- Return port
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**<Optimization of upper additional outlet port>**

- Potential amount of hot tap water
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**<Characteristic of boundary layer between hot and cold water>**

- Test result
- Simulation analysis
Evaluation result of cascade heat process system

operation pattern of tap water, floor heating, bathroom heating

- Tap water: IBEC L mode
- Floor heating: area 13.2m², 8hr
- Bathroom heating: heating capacity 2kW, 20min
- Ambient temp.: 7°C
- Feed-water temp.: 9°C

Position of storage tank

Conventional tank system

- Above 70°C
- 70°C - 35°C
- 35°C - 20°C
- 20°C - 0°C

Cascade heat process system

- Above 70°C
- 70°C - 35°C
- 35°C - 20°C
- 20°C - 0°C
Outline of ejector cycle

Ejector cycle for CO2 heat pump

- Kinetic energy loss of CO2 is 3 times higher than HFCs

Benefit of ejector cycle

<table>
<thead>
<tr>
<th>Condition</th>
<th>Ambient temp.(°C)</th>
<th>feed-water temp.(°C)</th>
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</thead>
<tbody>
<tr>
<td>Winter</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Intermediate</td>
<td>16</td>
<td>17</td>
</tr>
<tr>
<td>Summer</td>
<td>25</td>
<td>24</td>
</tr>
</tbody>
</table>

JRA4050 standard

Ejector with variable nozzle

CO2

HFCs

enthalpy

Ejector cycle

Driving flow

Suction flow

Pressure rise

Higher inlet water temp.

Kinetic energy loss

CO2 kinetic energy loss is 3 times higher than HFCs

Winter Intermediate Summer

feed-water temp.

Winter

Intermediate

Summer

JRA4050 standard

COP

10% UP

6.0 kW ejector

6.0 kW conventional

DENSO
1. We have developed cascade heat process system, and have evaluated this performance at field test.

2. We have started to product multi-function CO2 heat pump water heater using variable nozzle ejector cycle at July 2003.