Performance Comparison of R32, R410A and R290 Refrigerant in Inverter Heat pumps application

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Agenda

• Introduction
  • System configuration
  • Experimental and testing condition
  • Testing results
  • Conclusion
Next refrigerant? 

- Climate change
- Protection of the ozone layer
- Energy resource
- Maximum unit efficiency
- Efficient use of resources
- Safety
- Ease of conversion

- Low-GWP
- CFC reduction
- Charge reduction
- Emission reduction
- HCFC reduction
- High efficiency
- High COP
- Compact, lightweight
- Low toxicity
- Non-combustible, low flammability
- Economy
- Reliability
- Construction, maintenance

Next generation refrigerant
Candidate refrigerant in heat pumps application
Introduction

Refrigerant properties

<table>
<thead>
<tr>
<th>Item</th>
<th>Type</th>
<th>Condensing pressure (Mpa)</th>
<th>Capacity (R410) ratio</th>
<th>COP (R410) ratio</th>
<th>ODP</th>
<th>GWP (IPCC4)</th>
<th>Flammability</th>
<th>Toxicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>R410A</td>
<td>HFC</td>
<td>2.72</td>
<td>100</td>
<td>100</td>
<td>0</td>
<td>2090</td>
<td>No</td>
<td>Low</td>
</tr>
<tr>
<td>R290</td>
<td>Natural</td>
<td>1.53</td>
<td>59</td>
<td>107</td>
<td>0</td>
<td>&lt;3</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>R32</td>
<td>HFC</td>
<td>2.8</td>
<td>113</td>
<td>105</td>
<td>0</td>
<td>675</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

Discharge temperature

*Best efficiency at B0W55*
**Introduction**

Expand control point

**DSH** : Refrigerant flow control via EEV directly by CT and Td
: Can avoid unstable control when SSH = 0 K

\[ SSH = Ts - Tsat \text{ (at } Ps) \]

\[ DSH = Td - Tsat \text{ (at } Pd) \]
Agenda

- Introduction

**System configuration**

- Experimental and testing condition
- Testing results
- Conclusion
Discharge superheat control concept

**SSH control**
- Ts, Ps for superheat controlling
- SSH = Ts – Tsat (at Ps)
- Control TXV via suction side

**DSH control**
- Td, Pd for superheat controlling
- DSH = Td-Tsat (at Pd)
- Control EEV via discharge side

**High pressure shell type**
- Able to compress some liquid portion.
- SSH = 0 K.
- DSH = 10 K.
Agenda

- Introduction
- System configuration

**Experimental and testing condition**

- Testing results
- Conclusion
Experimental and testing condition

EN14825 SCOP

Brine to Water Heat pump

<table>
<thead>
<tr>
<th>Point</th>
<th>Brine temp °C</th>
<th>Water in °C</th>
<th>Water out °C</th>
<th>Load %</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
<td>29</td>
<td>34</td>
<td>88</td>
</tr>
<tr>
<td>B</td>
<td>0</td>
<td>25</td>
<td>30</td>
<td>54</td>
</tr>
<tr>
<td>C</td>
<td>0</td>
<td>22</td>
<td>27</td>
<td>35</td>
</tr>
<tr>
<td>D</td>
<td>0</td>
<td>19</td>
<td>24</td>
<td>15</td>
</tr>
<tr>
<td>Tdesign</td>
<td>0</td>
<td>30</td>
<td>35</td>
<td>100</td>
</tr>
</tbody>
</table>

Under floor heating average zone

Air to Water Heat pump

<table>
<thead>
<tr>
<th>Point</th>
<th>Air temp °C</th>
<th>Water in °C</th>
<th>Water out °C</th>
<th>Load %</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-7</td>
<td>29</td>
<td>34</td>
<td>88</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>25</td>
<td>30</td>
<td>54</td>
</tr>
<tr>
<td>C</td>
<td>7</td>
<td>22</td>
<td>27</td>
<td>35</td>
</tr>
<tr>
<td>D</td>
<td>12</td>
<td>19</td>
<td>24</td>
<td>15</td>
</tr>
<tr>
<td>Tdesign</td>
<td>-10</td>
<td>30</td>
<td>35</td>
<td>100</td>
</tr>
</tbody>
</table>

Under floor heating average zone
Inverter driven compressor was fixed with this experiment.

**Limitation of Superheat**: $\text{SSH} \geq 0 \text{ K} \ , \ \text{DSH} \geq 10 \text{ K}$
Experimental and testing condition

Heat pump unit

Air to water

Brine to water

Size 10 kw

Size 14 kw
Agenda

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Testing results

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Testing results

Refrigerant charge amount

Brine to water

Compressor for R290

Compressor for R32

Compressor for R410A

Suitable refrigerant quantities at design condition (Tdesign) for BTW

<table>
<thead>
<tr>
<th>Refrigerant</th>
<th>Quantity (g)</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>R32</td>
<td>630</td>
<td>-38%</td>
</tr>
<tr>
<td>R290</td>
<td>370</td>
<td>-64%</td>
</tr>
<tr>
<td>R410A</td>
<td>1020</td>
<td>-38%</td>
</tr>
<tr>
<td>R32</td>
<td>670</td>
<td>-38%</td>
</tr>
<tr>
<td>R290</td>
<td>420</td>
<td>-61%</td>
</tr>
<tr>
<td>R410A</td>
<td>1080</td>
<td></td>
</tr>
</tbody>
</table>
Testing results

Refrigerant charge amount

Air to water
Testing results

Discharge temperature with **SSH** control

High discharge temperature

**Problem**: Td cannot control under limit when using *suction superheat control* especially for high compression zone.
Testing results

Discharge temperature of **R32** with SSH control

**ET = -15°C, CT = 60°C (ATW)****

**Problem**: Low Td = Low SSH → Liquid back, Difficult to control SSH nearly 0 K
Testing results

Discharge temperature with DSH control

**DSH ≥ 10 K

**DSH control**: Td can be controlled under limit at 120°C by refrigerant flow adjustment
Testing results

Discharge superheat set point

Brine to water

Air to water
Testing results

Unit performance

**R32**: Shows better performance for all load demand which effect directly to the compressor speed and heating capacity.
From the testing results, R32 could improve 6% of SCOP when compared with R410A in Brine to water system, and 12% improvement in Air to water system. Meanwhile, R290 cannot improve SCOP level when compare with R410A.
Testing results

Compressor impact

CT = 50°C, ET = -5°C

When we are comparing with R410A
- R290 must increase stroke volume of compressor 50%
- R32 can be reduce around 10%
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**Conclusion**
Conclusion

1. For Brine to water system, the SCOP improvement of R32 when compared with R410A is 6% and 12% for Air to water system.

2. SCOP of R290 is same level as R410A in Brine to water system and 6% of SCOP lower than R410A in Air to water system.

3. The stroke volume of compressor, which was using R32 could be reduced when compared with the same capacity level of compressor which using R410A.

4. R32 can be applied in heat pump application with high pressure shell type compressor when discharge superheat control has been implemented.