Scroll compressors for Low GWP Heat Pumps using R290 natural refrigerant

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Danfoss Commercial Compressors

- Leading compressor R&D and manufacturing for commercial air conditioning, heating and refrigeration applications since 1971
- Manufacturing in Europe, USA, China
- Leading the market in commercial inverter scrolls with prequalified drives
- Pioneers of Danfoss Turbocor Compressors with oil-free, magnetic bearing technology

- Reciprocating: 1.5 - 13 Hp
- Scroll: 3 - 10 Hp
- Scroll: 3 - 40 Hp
- Scroll: 9-40 Hp
- Turbocor: 60-200TR
HFC Applications in A/C & HP

R410A APPLICATION

Sat Suct Temp °C

Conditions for Seasonal Performances

97% of running time
NxtHPG Project baseline

**NxtHPG Project aims**

- Heat pumps reaching higher efficiency and lower carbon footprint than current state of the art HFCs/HFOs or Sorption heat pumps

- Include efficient capacity modulation and the highest capabilities for combination and integration with other renewable sources in the energy systems of Buildings and Industry

- Hydrocarbons (HCs): air or water to water heat pumps supplying hot water at (40-50ºC) for heating applications as well as to produce sanitary hot water at 60ºC
# NxtHPG Project baseline

## Heat pump application

<table>
<thead>
<tr>
<th>Case</th>
<th>Fluid</th>
<th>Source</th>
<th>T(°C)</th>
<th>Sink</th>
<th>T(°C)</th>
<th>Application</th>
<th>(kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HC (Propane)</td>
<td>Air</td>
<td>-10 to 10</td>
<td>Water</td>
<td>40 to 50</td>
<td>Heating water production</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60</td>
<td>Low demand of Sanitary hot water</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>HC (Propane)</td>
<td>Water (brine)</td>
<td>-5 to 15</td>
<td>Water</td>
<td>40 to 50</td>
<td>Heating water production</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60</td>
<td>Low demand of Sanitary hot water</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>HC (Butane)</td>
<td>Water</td>
<td>Neutral loop at 25</td>
<td>Water</td>
<td>60</td>
<td>Sanitary hot water production</td>
<td>50</td>
</tr>
</tbody>
</table>

**Case 1**  NxtHPG051 + Inverter  
**Case 2&3** NxtHPG038

**Note**

1. Case 1 & 2 should be suitable for reversible application.
2. Case 3 will use R290
R290 NxtHPG Applications Project

Sat Disch Temp °C

R290 APPLICATION

20 25 30 35 40 45 50 55 60 65 70

-30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30

Mild weather conditions A/C
(could be a large % of the yearly running time)

Case 1W
Case 1S
Case 2 W
Case 2 S
Case 3 W
Case 3 S

Winter Case 1&2
Summer Case 1

Scroll compressor for **R290 refrigerant** heat pump adaptation

- Compression process efficiency improvement
- Lubricants selection
- Compressor design
- Compressor reliability

- Case 1  NxtHPG051 + Inverter
- Case 2&3  NxtHPG038
Compression process efficiency improvement: Intermediate Discharge Valve

**Description:** Mechanical valve that adapts the motor effort to the pressure conditions in the system to improve part-load efficiency of air conditioning systems

**Main Benefits**
- Energy savings in part-load conditions
- Applied cost savings
- Lower starting load / stress on mechanical parts

**Diagram:**
- **High Pressure Ratio:** IDV closes
- **Low Pressure Ratio:** IDV opens

**Graph:**
- Efficiency (η) vs. Pressure ratio
- Data points for pressure ratios 1.3, 1.8, 2.3, 2.8, 3.3, 3.8, 4.3, 4.8
Compression process efficiency improvement: High Pressure Ratio Conditions

\[ P_{\text{cond}} > \text{BIPR} \times P_{\text{evap}} \]

**Real compression curve**

**Ideal compression curve**

**Backflow effect**: since the gas goes back into the last compression chamber, the gas mass to be compressed increases as well as the pressure. When \( P_{\text{compr}} \geq P_{\text{cond}} \), the gas is discharged.
Compression process efficiency improvement: **IDV Benefits**

\[ P_{\text{cond}} < BIPR \times P_{\text{evap}} \]
Compressor performance testing

Note Hardware:

- Use secondary fluid HC lab 30kW calorimeter and large single fluid calorimeter >100kW
- Adapted to HC lab safety requirement
Performance measurement:
NxtHPG051 + drive @ 50Hz

IDV performance improvement delta EER [W/W] and(delta [% ratio])
Compression process efficiency improvement: extra **IDV Benefits**

**Danfoss Intermediate Discharge Valves...**

- reduce the compression mechanism torque
- reduce line amps during starting transient period
- allow to start at higher Saturated Suction Temperature
Compressor lubricant selection

- R290 is very soluble in classic lubricants
- We investigated in the past:
  - MO
  - POE
  - AKB
  - Experience (rule of thumb) use two viscosity higher grades

- Based on Low HC soluble POE and PAG materials.

- Today we will focus on:
  - Compressor reliability
  - R290 solubility on oil compressor sump for reduced SH conditions
Compressors reliability testing

- Discharge check valve
- Fixed scroll
- Discharge port
- Oldham coupling
- Upper bearing & shaft
- Lower bearing and oil pump
- Orbiting scroll
- Orbiting scroll bearing and thrust bearing
- Electrical motor
Compressors reliability testing

- Setting the life test conditions
- Based on existing experience & knowledge
- We use 4 modes LFT for large scrolls

➤ Bearing improvement done for flooded conditions
Refrigerant Solubility % in Compressor Oil Sump: steady state comparison @ SST 10°C
R290 Dynamic Solubility tests done

**Principle:**
- Run the compressor in required conditions
  - Various suction gas super heat
  - One or two saturated condensing temperatures
- In steady state conditions, sampled lubricant from oil sump and measured the R290 % solubilized in lubricant oil sump
Refrigerant % in oil sump
Conclusions

- NxtHPG scrolls are based on **existing HFC** platform

**IDV integration on these R290 scrolls compressor brings:**
- Better performances at lower pressure ratio running conditions
- Same compressor can be used in a wider pressure ratio applications range
- Improved reliability by lower mechanical load during pull down and/or pull up situations
- Allows to enlarge application range in higher evaporating conditions

**Lubricants:**
- We have developed a new low soluble lubricant for Hydro Carbons operating in low SH conditions
- We are investigating the application of low miscibility lubricants

- Compressor design has been adjusted to keep the **high reliability level**
Thank you for your attention

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