R744 MAC Status and System Standardisation

Stefan Morgenstern
VDA-Wintermeeting, Saalfelden (A), 13.02.2008
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VDA Statement on Alternative Refrigerants

VDA press release, 06-09-2007

… Following investigation of numerous alternatives to the refrigerant currently being used, vehicle manufacturers in the German Association of the Automotive Industry (VDA) have now agreed to use the especially environmentally-friendly natural refrigerant R744 (carbon dioxide) in vehicle air-conditioning systems in future – and they will be the first world-wide automotive companies to do so. …
Why R744?

compared to R134a systems R744 MAC ...

✓ reduce direct greenhouse effect by a factor of more than 1000
✓ offer improved AC Performance at equal package space
✓ show higher over all efficiency
✓ heat pump function as future option

furthermore ...

✓ human’s exposure to R744 is scientifically well researched
✓ R744 is non flammable
✓ R744 follows all present and future legal demands

_F-Gas-Directive:_

“With effect from 1 January 2011 Member States shall no longer grant EC type-approval or national type-approval for a type of vehicle fitted with an air conditioning system designed to contain fluorinated greenhouse gases with a global warming potential higher than 150.”
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"Plug and play" Cool Down Performance
at series conditions w/o optimising measures

BMW Group
Standard Cool Down
@ 40°C / 30%r.F. / 1000 W/m² solar load, 90 min soak

Head
Vents
Temperature distribution consideration for fuel consumption estimation

intersection at ca. 35°C

frequency of vehicle use vs. ambient temperature

Data from National Climatic Data Center
U.S. Department of Commerce; www.ncdc.noaa.gov
8000 weather stations worldwide
Data considered from the years 2000 to 2006
relative comparison of A/C caused fuel consumption

vehicle A

vehicle B

vehicle C

vehicle D

*Improved System with integrated IHX
Vehicle Integration

with R744 MAC …

✓ no secondary loop is necessary, direct evaporating system
✓ no fire mitigation system needed
✓ fits to R134a vehicle architecture
✓ fits to R134a vehicle package
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AK dt. OEM 2.4.2a
R744 MAC Status and System Standardisation

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Risks

Costs:

✓ high pressure levels, permeation demands
✓ additional parts, more complex parts
✓ additional refrigerant type (quantity split, parallel handling, parallel engineering)

Maturity and Quality:

Development:
✓ no long term experience, no wide base experience

Production:
✓ no mass production experience
Solving Cost and Quality Issues by

✓ System Standardisation

✓ Component Standardisation
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Working Pressure and Temperature Limits

- Max. release pressure 17 MPa accord. SAE J639
- Maximal burst pressure
- Mean Burst Pressure 16 MPa
- Maximal burst pressure
- Mean Burst Pressure 16 MPa
- Max. allowable pressure 16 MPa
- Max operating pressure 14 MPa
- Max. working pressure 13.3 MPa
- Min operating pressure 2.5 MPa
- Max operating temperature 165°C short time 180°C less 5'
- Max operating temperature 165°C short time 180°C less 5'
Standstill System Pressure Limits

Max release pressure 13 MPa acc.to SAE J 639
Max burst/relief pressure +1 MPa
Min burst/relief pressure -1 MPa
Mean Burst Pressure 12 MPa

Tolerance

Max allowable pressure 12 MPa
System charged with s/c: 260 g/l

J 639 Soak-Temperature
400 gr/l
350 gr/l
300 gr/l
250 gr/l
200 gr/l

Max release pressure 13 MPa acc.to SAE J 639

20° C
54° C
40° C
80° C
60° C
160° C
120° C
100° C

50 150 250 350 450 550
spec. Enthalpie h [kJ/kg]
# Component Standardisation

<table>
<thead>
<tr>
<th>Component</th>
<th>Description / characteristic</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressor</td>
<td>Externally controlled s/m/l stroke Volume, proportional control valve</td>
<td>Mass flow as f(control current), 400 Hz PWM variable</td>
</tr>
<tr>
<td>Gas cooler</td>
<td>PF or CF- Design Depth ≤ 16mm</td>
<td>P/T Sensor and HP Service under investigation</td>
</tr>
<tr>
<td>Accu/IHX-Unit</td>
<td>Ø = 75 mm h = 380 mm, Ø = 85 mm h = 170 mm</td>
<td>No heat transfer from IHX in liquid refrigerant, Vapor quality (X) indep. from refrig. flow, drying agent</td>
</tr>
<tr>
<td>Accumulator and Internal Heat exchanger</td>
<td>Ø = 50 mm h = 380 mm, Ø = 75 mm h = 170 mm, coaxial pipe, dia = 16 mm</td>
<td>drying agent</td>
</tr>
<tr>
<td>Evaporator</td>
<td>Safe Evaporator; Depth ≤ 40mm</td>
<td>Needs to fit into R134a evaporator package</td>
</tr>
<tr>
<td>Piping</td>
<td>Aluminium tube with inner Ø 9/6/4 mm SS Tubes at flexible hoses Mat.1.4541</td>
<td>ID Tube from stainless Steel are under discussion (6 mm)</td>
</tr>
<tr>
<td>Flexible piping</td>
<td>LP elastomer hose</td>
<td>HP LT elastomer hose under qualification</td>
</tr>
<tr>
<td></td>
<td>HP HT corrugated tubes</td>
<td></td>
</tr>
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<tr>
<td>Joints</td>
<td>Block Joint technology</td>
<td>Evaluation in Prod. &amp; Service</td>
</tr>
<tr>
<td>Charge &amp; Service Port</td>
<td>'Push Pin' Principle</td>
<td></td>
</tr>
<tr>
<td>P/T Sensor</td>
<td>Integrated Unit: Thermocouple at top, both LIN Bus Communication and analogue communication</td>
<td>-Sealing principle in revision, LIN connection in discussion,</td>
</tr>
<tr>
<td>High pressure relieve devices</td>
<td>HP and LP</td>
<td></td>
</tr>
<tr>
<td>Expansion Device</td>
<td>TXV OTB</td>
<td></td>
</tr>
<tr>
<td>Refrigerant</td>
<td>CO2 with odorant</td>
<td></td>
</tr>
<tr>
<td>Service equipment</td>
<td>For workshop use</td>
<td></td>
</tr>
<tr>
<td>Production and plant service units</td>
<td>For plant use and rework incl. leak detection support</td>
<td></td>
</tr>
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Present and ongoing OEM activities

**Engineering:**
- ✔ developing and defining target R744 system
- ✔ optimising cost, acoustics, weight, variants, …

**Production:**
- ✔ investigation about influence on production site and processes
- ✔ variant handling, leak testing and charging within the existing plant and production, assembly, …

**Service:**
- ✔ service equipment and process, unmounting/mounting
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Conclusion

*major steps*

- concept confirmation
- precise detailing and confirmation of target vehicle demands (project)
- development for series quality, process confirmation
- SOP
Conclusion

✓ R744 MAC is the right decision and the only known alternative refrigerant to meet 2011 SOP
✓ we made a good approach to assess alternatives
✓ the refrigerant type should not be a selling proposition
✓ everyone’s invited to cooperate