Thermal Comfort Management and MAC Fuel Consumption on Alfa Romeo Giulietta and Jeep Liberty

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Pete Mueller (Chrysler)
Agenda

Introduction

Regulatory framework

Alfa Romeo Giulietta 1.4
  - MAC system and control
  - MAC fuel consumption testing
  - LCCP approach calculation: production vs modified

Jeep Liberty
  - MAC system
  - MAC fuel consumption testing
  - LCCP approach calculation: production vs modified

Conclusions
Introduction

Attention paid to the human impact on the global environment has increased in recent years as a consequence of entering the time of the Kyoto Protocol GHG emissions reduction targets.

The FGA and Chrysler teams have focused on system/component design and control strategies to maintain today’s level of thermal comfort while meeting the regulatory requirements to be established.
Regulatory framework
The EC legal acts

EUROPEAN COMMISSION

Brussels, 28.4.2010
COM(2010)186 final

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL AND THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE

A European strategy on clean and energy efficient vehicles

The Commission will:
• present a proposal by 2011 to reduce fuel consumption impacts of mobile air conditioning systems;
CO2 emissions credits granted to vehicles beginning in 2012 for MACs system efficiency improvements.

<table>
<thead>
<tr>
<th>Technology Description</th>
<th>Estimated Reduction in A/C CO₂ Emissions</th>
<th>A/C Efficiency Credit (g/mi CO₂)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced reheat, with externally-controlled, variable-displacement compressor</td>
<td>30%</td>
<td>1.7</td>
</tr>
<tr>
<td>Reduced reheat, with externally-controlled, fixed-displacement or pneumatic variable-displacement compressor</td>
<td>20%</td>
<td>1.1</td>
</tr>
<tr>
<td>Default to recirculated air with closed-loop control of the air supply (sensor feedback to control interior air quality) whenever the ambient temperature is 75 °F or higher (although deviations from this temperature are allowed if accompanied by an engineering analysis)</td>
<td>30%</td>
<td>1.7</td>
</tr>
<tr>
<td>Default to recirculated air with open-loop control air supply (no sensor feedback) whenever the ambient temperature 75 °F or higher (lower temperatures are allowed)</td>
<td>20%</td>
<td>1.1</td>
</tr>
<tr>
<td>Blower motor controls which limit wasted electrical energy (e.g., pulse width modulated power controller)</td>
<td>15%</td>
<td>0.9</td>
</tr>
<tr>
<td>Internal heat exchanger</td>
<td>20%</td>
<td>1.1</td>
</tr>
<tr>
<td>Improved condensers and/or evaporators (with system analysis on the component(s) indicating a COP improvement greater than 10%, when compared to previous industry standard designs)</td>
<td>20%</td>
<td>1.1</td>
</tr>
<tr>
<td>Oil Separator (with engineering analysis demonstrating effectiveness relative to the baseline design)</td>
<td>10%</td>
<td>0.6</td>
</tr>
</tbody>
</table>
Alfa Romeo Giulietta
Alfa Romeo Giulietta start-stop

Pedals & Gear Lever

Battery sensor

HMI Input Actuators

Battery status

Electrical Load Demands

HVAC

ICE Cooling

Brake System

Vehicle Stop

ICE Status

Voltage Stabilizer

Heavy Duty Battery

Start / Stop Coordinator

HMI Control

Starter Control

Transmission Control

ICE Control

Engine Control Module

Neutral sensor

Advanced RPM sensor

Instrument Panel

Reinforced Starter

Battery sensor

Pedals & Gear Lever
Intelligent management of the variable displacement externally controlled compressor with smart recirculation ctrl

Specific control parameters identification based on thermal manikins

Comfort feedback with Mean Radiant Temperature sensor
MACs emissions reduction assessment

MAC fuel consumption measurement based on air enthalpy

MAC use estimation based on enthalphy correlation

Overall CO2 emissions reduction calculation with FGA LCCP approach
AR Giulietta fuel consumption test results

- NEDC CYCLE (4 ECE + 1 EUDC)
- MACS CTRL UNIT SET-UP: 22°C, FULL AUTO, SINGLE ZONE

**Modified AR Giulietta int ctrl**

**Production AR Giulietta ext ctrl**

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Modified</th>
<th>Production</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>15°C &amp; 70%</td>
<td>-0.24 (-28%)</td>
<td>-0.24 (-28%)</td>
<td></td>
</tr>
<tr>
<td>28°C &amp; 50%</td>
<td>-0.28 (-22%)</td>
<td>-0.28 (-22%)</td>
<td></td>
</tr>
<tr>
<td>35°C &amp; 60%</td>
<td>-0.11 (-6%)</td>
<td>-0.11 (-6%)</td>
<td></td>
</tr>
</tbody>
</table>
AR Giulietta fuel consumption vs enthalpy

![Graph showing fuel consumption vs enthalpy for different temperatures and conditions.](image-url)
LCCP definition

Refrigerant Production

Direct Effect
Atmospheric degradation products
TFA, HCOF, COF₂, COFCI

Indirect Effect - Component Production

End-use of chemicals
Recycling
Breakdown

 Mine
Transportation
Direct (refrigerant gas) and Indirect Emissions (CO2 due to fuel consumption)
## AR Giulietta MACs LCCP assessment

<table>
<thead>
<tr>
<th>town</th>
<th>enthalpy (kJ/kg)</th>
<th>MAC ON</th>
<th>fuel overcons</th>
<th>indirect CO₂</th>
<th>indirect impact</th>
<th>LCCP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>min</td>
<td>avg</td>
<td>max</td>
<td>(h/y)</td>
<td>%</td>
<td>l/y</td>
</tr>
<tr>
<td>Oslo</td>
<td>-17</td>
<td>18</td>
<td>54</td>
<td>142</td>
<td>35%</td>
<td>15</td>
</tr>
<tr>
<td>Turin</td>
<td>-9</td>
<td>31</td>
<td>78</td>
<td>260</td>
<td>59%</td>
<td>52</td>
</tr>
<tr>
<td>Detroit</td>
<td>-21</td>
<td>25</td>
<td>71</td>
<td>289</td>
<td>50%</td>
<td>58</td>
</tr>
<tr>
<td>Phoenix</td>
<td>-1</td>
<td>40</td>
<td>80</td>
<td>474</td>
<td>81%</td>
<td>98</td>
</tr>
<tr>
<td>Mumbay</td>
<td>31</td>
<td>70</td>
<td>104</td>
<td>435</td>
<td>100%</td>
<td>190</td>
</tr>
</tbody>
</table>
AR Giulietta MACs LCCP assessment

- **Europe**: -1.0 MTCO2 (-38%)
- **USA**: -1.2 MTCO2 (-30%)
- **Asia**: -1.0 MTCO2 (-24%)
Jeep Liberty Sport Utility Vehicle
Intelligent management of the fixed displacement compressor with smart recirculation control

Specific control parameters calibrated in climate chamber

SAE International™
Jeep Liberty HVAC System Testing

- Tested fuel economy benefit of raising evaporator outlet air temperatures in two ways:
  - Production system with MEOT algorithms
  - Production system substituting humidity sensor and feedback control algorithms
- Compared the results over several ambient conditions/relative humidities/solar loads
## Jeep Liberty MACs LCCP assessment

<table>
<thead>
<tr>
<th>Town</th>
<th>Enthalpy (kJ/kg)</th>
<th>MAC ON</th>
<th>Fuel overcons</th>
<th>Indirect CO₂</th>
<th>Indirect impact</th>
<th>LCCP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>min</td>
<td>avg</td>
<td>max</td>
<td>(h/y)</td>
<td>%</td>
<td>l/y</td>
</tr>
<tr>
<td>Oslo</td>
<td>-17</td>
<td>18</td>
<td>54</td>
<td>142</td>
<td>35%</td>
<td>17</td>
</tr>
<tr>
<td>Frankfurt</td>
<td>-11</td>
<td>27</td>
<td>65</td>
<td>232</td>
<td>53%</td>
<td>39</td>
</tr>
<tr>
<td>Turin</td>
<td>-9</td>
<td>31</td>
<td>78</td>
<td>260</td>
<td>59%</td>
<td>55</td>
</tr>
<tr>
<td>Rome</td>
<td>-9</td>
<td>31</td>
<td>78</td>
<td>296</td>
<td>74%</td>
<td>63</td>
</tr>
<tr>
<td>Athens</td>
<td>9</td>
<td>38</td>
<td>73</td>
<td>384</td>
<td>88%</td>
<td>72</td>
</tr>
<tr>
<td>Boston</td>
<td>-18</td>
<td>27</td>
<td>76</td>
<td>291</td>
<td>50%</td>
<td>64</td>
</tr>
<tr>
<td>Detroit</td>
<td>-21</td>
<td>25</td>
<td>71</td>
<td>289</td>
<td>50%</td>
<td>62</td>
</tr>
<tr>
<td>Sacramento</td>
<td>6</td>
<td>37</td>
<td>76</td>
<td>443</td>
<td>76%</td>
<td>95</td>
</tr>
<tr>
<td>Phoenix</td>
<td>-1</td>
<td>40</td>
<td>80</td>
<td>474</td>
<td>81%</td>
<td>105</td>
</tr>
<tr>
<td>Miami</td>
<td>30</td>
<td>61</td>
<td>96</td>
<td>584</td>
<td>100%</td>
<td>220</td>
</tr>
<tr>
<td>Sapporo</td>
<td>-13</td>
<td>23</td>
<td>78</td>
<td>145</td>
<td>44%</td>
<td>30</td>
</tr>
<tr>
<td>Beijing</td>
<td>-14</td>
<td>29</td>
<td>95</td>
<td>223</td>
<td>51%</td>
<td>63</td>
</tr>
<tr>
<td>Tokyo</td>
<td>0</td>
<td>37</td>
<td>92</td>
<td>202</td>
<td>62%</td>
<td>56</td>
</tr>
<tr>
<td>Shanghai</td>
<td>-2</td>
<td>42</td>
<td>109</td>
<td>296</td>
<td>68%</td>
<td>93</td>
</tr>
<tr>
<td>Mumbay</td>
<td>31</td>
<td>70</td>
<td>104</td>
<td>435</td>
<td>100%</td>
<td>197</td>
</tr>
</tbody>
</table>
Jeep Liberty MACs LCCP assessment

Europe
-1.3 MTCO2
(-42%)

USA
-1.5 MTCO2
(-33%)

Asia
-1.3 MTCO2
(-27%)

LCCP (MTCO2/veh Life)

Oslo, Frankfurt, Turin, Rome, Athens, Boston, Detroit, Sacramento, Phoenix, Miami, Sapporo, Beijing, Tokyo, Shanghai, Mumbai

production Jeep Liberty MEOT
modified Jeep Liberty HS
Conclusions

✓ AR Giulietta and Jeep Liberty MAC systems have been presented and their environmental impact assessed by fuel consumption tests and by the means of the FGA LCCP model

✓ Results on AR Giulietta and Jeep Liberty show that the adoption of an external control compressor with an appropriate control strategy, achieve a sensible level of MAC fuel consumption reduction, while maintaining both an adequate level of comfort and the required visibility in critical fogging situations

✓ The reduction in overall CO2 emissions predicted by the FGA LCCP assessment are consistent between the Alfa Romeo Giulietta and the Jeep Liberty for the systems tested.
THANK YOU!

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