

Overview of Alternate Refrigerants

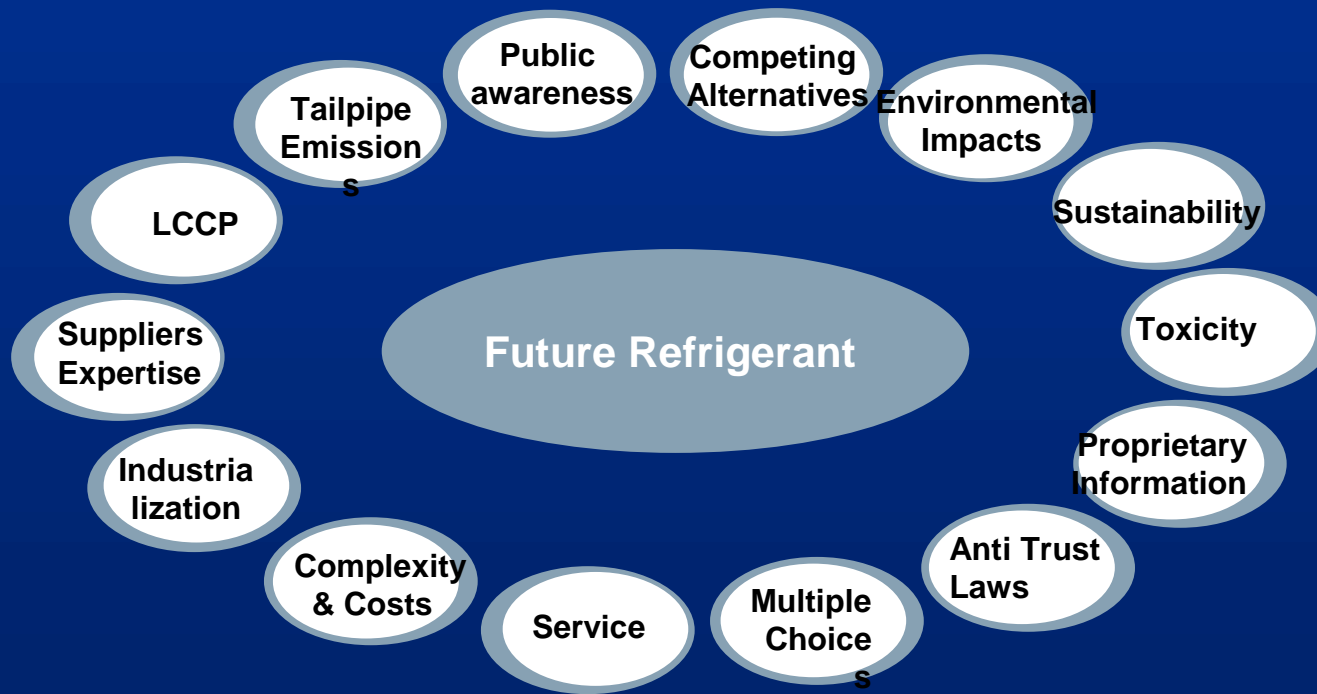
Presentation on the Alternate Refrigerant Systems Symposium
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Agenda

1. Challenge of the Automotive Industry
2. Refrigerant options
3. R744 Status of Technical Evaluation
4. GAR Status of Technical Evaluation
5. Conclusion
6. Outlook

1. Challenge for the Automotive Industry



The automotive industry has to decide the best substitute for R134a as future refrigerant for Mobile Air Conditioning

2. Refrigerant options

A replacement for R134a as working fluid in Mobile Air Conditioning for vehicle application shall provide sufficient cooling capacity combined with high efficiency. It shall be non toxic and non- flammable in its application. It shall fulfill the legal requirements and further match the automotive demands on vehicle operation, manufacturing, servicing and deposing. Further it is important in the concern of our customers that a viable overall vehicle concept is offered containing a sufficient balance between fuel consumption and customer benefit.

CO₂ is one of the first refrigerants of mankind in the 19th century. Automotive Systems with R744 have been researched since at least 12 years and were considered as new MAC systems since 1999. The natural refrigerant R744 has the lowest possible Global Warming Potential of 1 and is currently used in industry, mainly in supermarket and heat pump applications. Due to the thermodynamic and thermo-physical properties of R744 completely new refrigerant circuit components are under development.

The so called Low GWP refrigerants were proposed by the chemical industry in early 2006. These new chemicals have an expected low Global Warming Potential between 4 and 127. Since the refrigerant properties of the new working fluids are close to the R134a, widely the proven technologies for automotive systems are expected to be used. 4

3. R744 Status of Technical Evaluation

Systems

Single and Dual Evaporator systems successfully assessed

Capacity

System performance in Cool down and Idle equal or better than today's serial systems

Efficiency

Slight advantages under European Climate Conditions

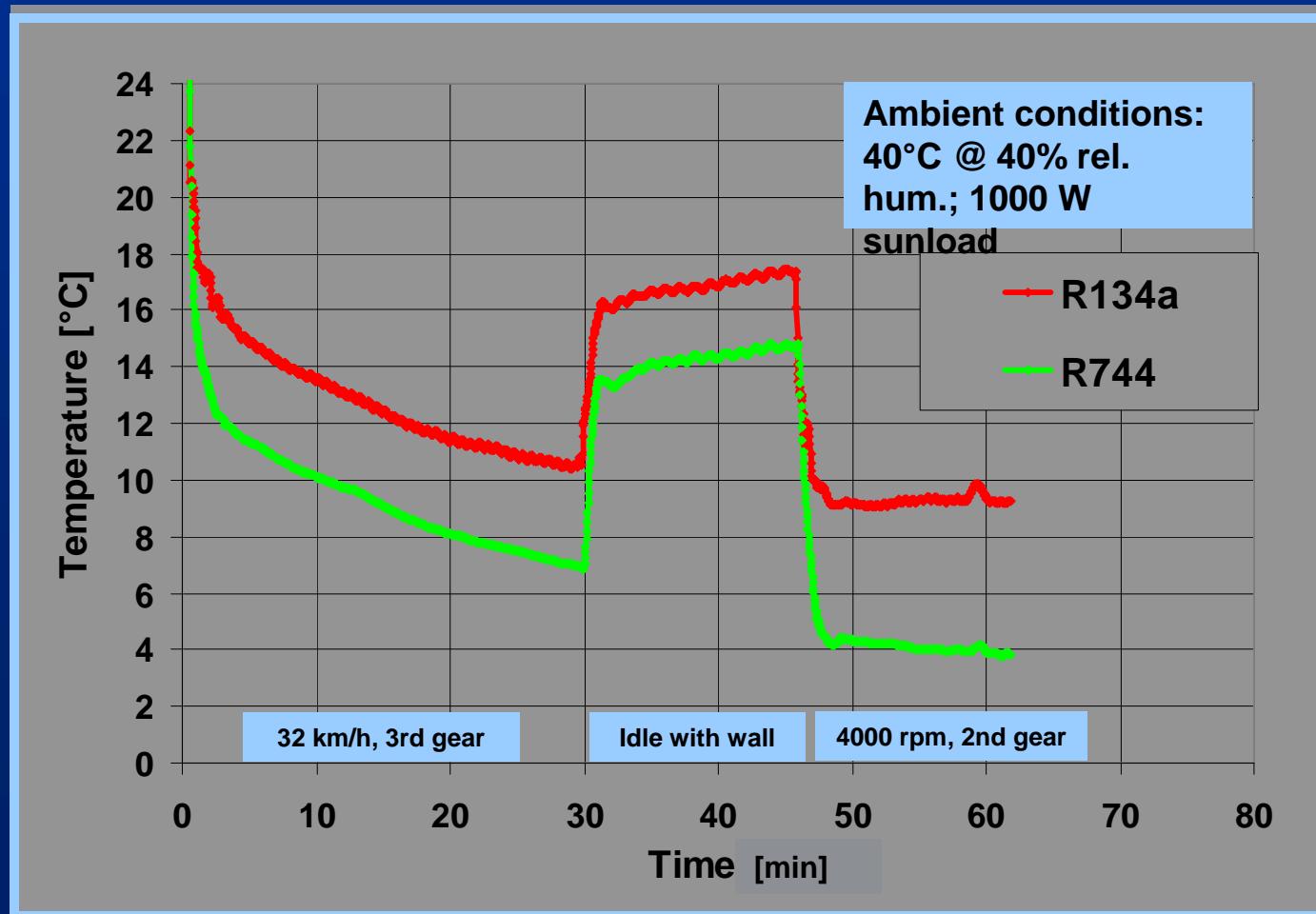
Drivability

Achievable for the variety of vehicles

NVH

Higher noise levels require higher effort to compensate

Pull Down Common Spec Book: Evaporator Air Temperatures



Sedan with Dual Evaporator System

VDA standard pull down in Climatic Wind tunnel

R134a
Production system

R744
Vehicle assembled in production test

Mean Air Outlet Temperatures
Front- Evaporator

3. R744 Status of Technical Evaluation

Durability

Long term durability not yet achieved , remaining issues e.g. on compressors , pipes and hoses

Supplier capability

Few suppliers have reached the competence on R744 technology

Global acceptance

R744 is still banned by some US state laws , barrier removal program by EPA is underway
Appropriate SAE J Standards are established.

Serviceability

For R744 service procedures and equipment are defined

Economy

Cost assessments are underway; further cost optimization seems necessary

4. GAR Status of Technical Evaluation

System

Single and dual evaporator systems have been investigated.

Cooling capacity

Appropriate cooling capacity can be reached with adapted and additional components.
Differences between the fluids

Efficiency

Mostly lower efficiency at high loads, one refrigerant with minor disadvantage

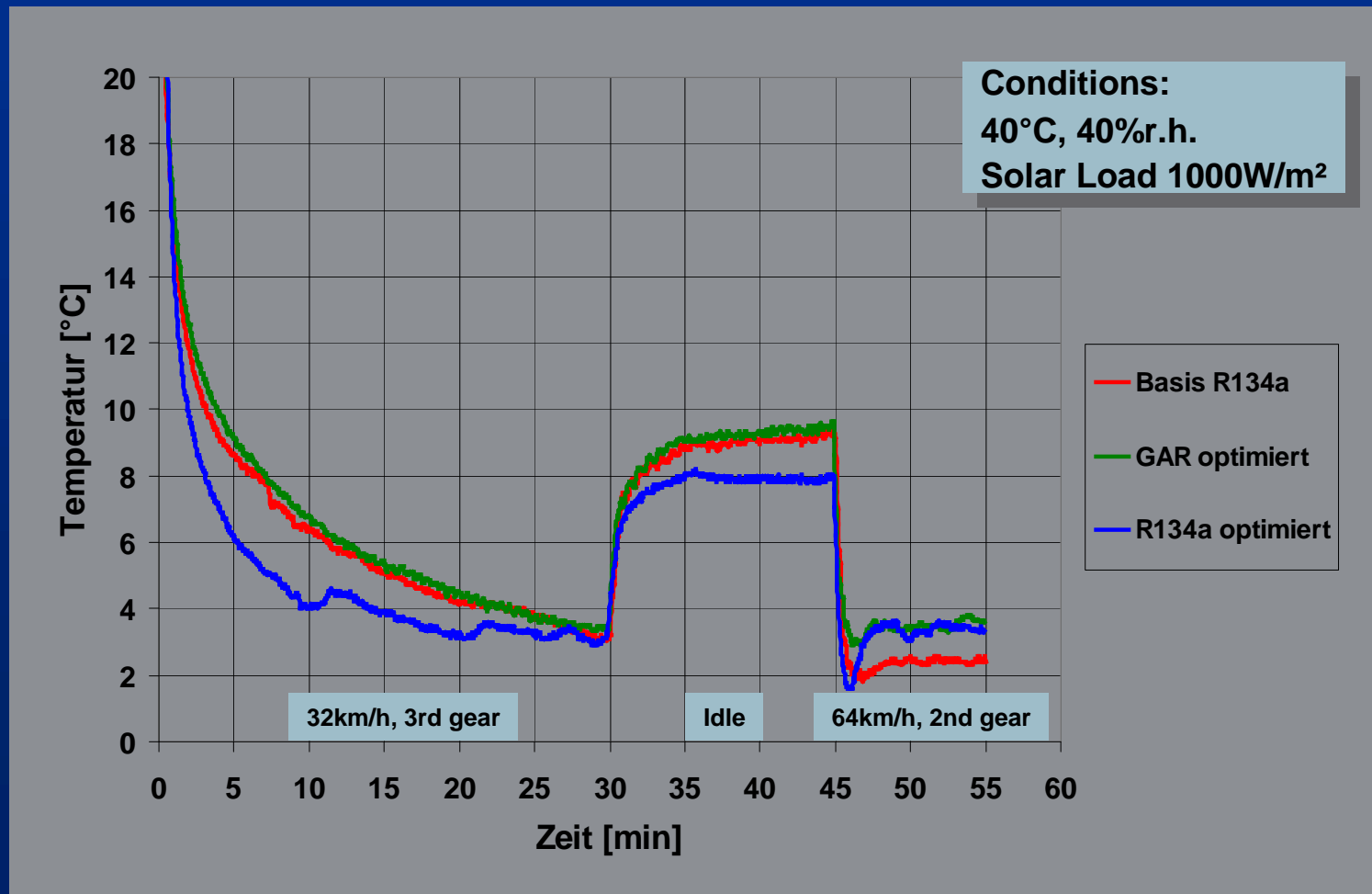
Toxicity and Risks

Risk assessments combine cabin concentration and toxicity information

Material compatibility and thermal stability

Peculiarities on some working substances have been observed

Pull Down Common Spec Book: Evaporator Air Temperatures



4. GAR Status of Technical Evaluation

Drivability and Durability

Durability tests have started on component base and in vehicles

Supplier capability

Components favorable in capacity and efficiency for both GAR and R134a are needed

Serviceability

Concept, Equipment, Supply and Distribution Net are challenging
Warranty costs for OEM and service costs for customer are expected to increase

Global Acceptance and Industry Standards

The acceptance of at least one Alternate Refrigerants by car industry seems possible,
Standards are needed .

Economy

Major burden is related to the substance, system enhancements and aftermarket issues

6. Conclusion

Benefits

Lowest GWP
No recycling and Recovery
Heat Pump optional

R744

No large technology change
Global approach might be possible

GAR

Open Issues

SNAP Approval / Remaining legal barriers
Noise level due to pulsation of compression
Slight increase of fuel consumption at specific conditions
Large development, component and investment costs
Efficiency advantages only with further technology enhancements
Large scale production and servicing of a new technology

SNAP Approval / Toxicity issues
Service / Handling of a refrigerant blend
Slight increase of fuel consumption
Quotation and Quantities/ Supply schedule / Market situation
Lubricant/ Stability

The current status from our point of views, chemistry, toxicity, technology and expected usage during vehicle life time shows a remaining need to continue with R744 as long as the complete suitability of at least one Alternate Refrigerant is evident

7. Outlook

- In Europe only the use of refrigerant with low GWP < 150 substance in vehicle Air Conditioning is enforced by law. In other markets the new substances in AC systems needs to accomplish due competitiveness.
- The German Auto Industry is seriously challenging the feasibility of the new alternative refrigerants . These substances has been considered as potential candidates to fulfill the EU-Regulation as well as the demands of the automotive industry.
- The evaluation of the current level of R744 technology is continuing, unless the major doubts of the alternate refrigerants have disappeared. As long as the evaluation is ongoing, R744 is kept and developed as fallback option in vehicle projects. In case that the R744 shall be used as future refrigerant the timeline is expected to be very critical, in regard that the whole industry has to ramp up that new technology.
- The German Auto companies will make decisions about the future refrigerant independently. This will be attended by the ongoing exchange of views with our globally acting competitors in working groups as ACEA, SAE, JAMA, etc..
- The timeline for a decision inside the companies is strongly influenced by the individual constraints, such as model launches in the year 2011 and is expected in the second half of 2007.

Thank you !