Fuel-efficient, leak-tight HFC-134a systems through design and quality components

prepared & presented
by

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Content

- Efficiency of HFC-134a systems = fuel economy for use of mobile air conditioning
- Reduction of controlled losses / emissions of HFC-134a
- Reduction of uncontrolled losses / emissions
- Emissions in production / assembly plant
- Conclusion

Definitions

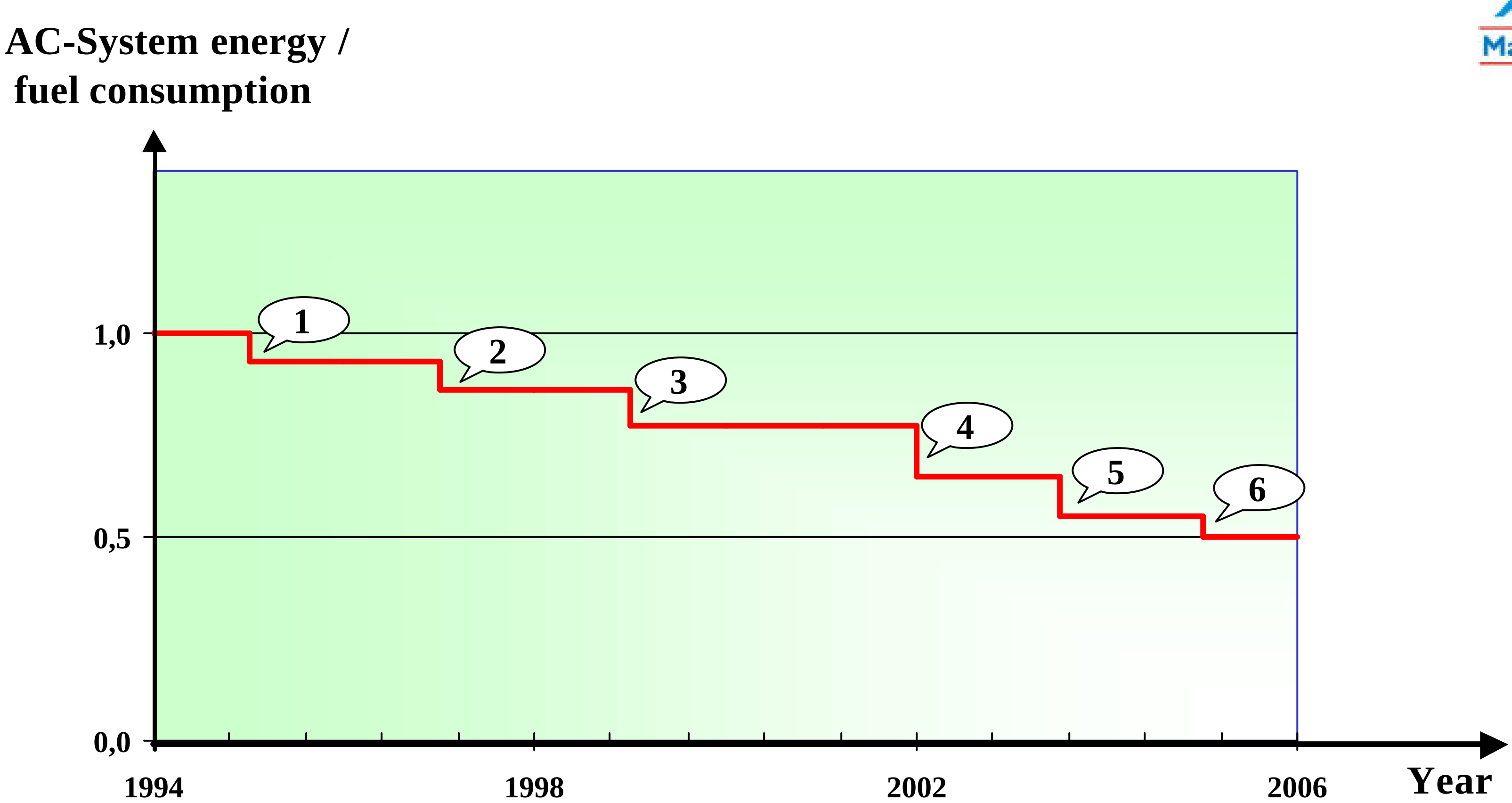
COP = **C**oefficient **O**f **P**erformance

$$COP = \frac{\text{System Cooling}}{\text{Power Input}} = \frac{\text{Evaporator Capacity}}{\text{Compressor Power}}$$

Higher COP → Lower fuel consumption

for the same cooling capacity (evaporator heat load)

HFC-134a = R 134a



1. New condenser, “sub cool” type

2. Externally controlled, variable displacement compressor

3. Adjustable set point -> prevent unnecessary “cool down & reheat”

4. New evaporator & next generation externally controlled, variable displacement compressor

5. Next generation (sub cool) condenser (11% system COP improvement)

6. Integrated and optimized climate - and engine control

SAE - ARCRP

SAE-ARCRP = **S**ociety of **A**utomotive **E**ngineers - **A**lternate **R**efrigerant **C**ooperative **R**esearch **P**roject

vs.

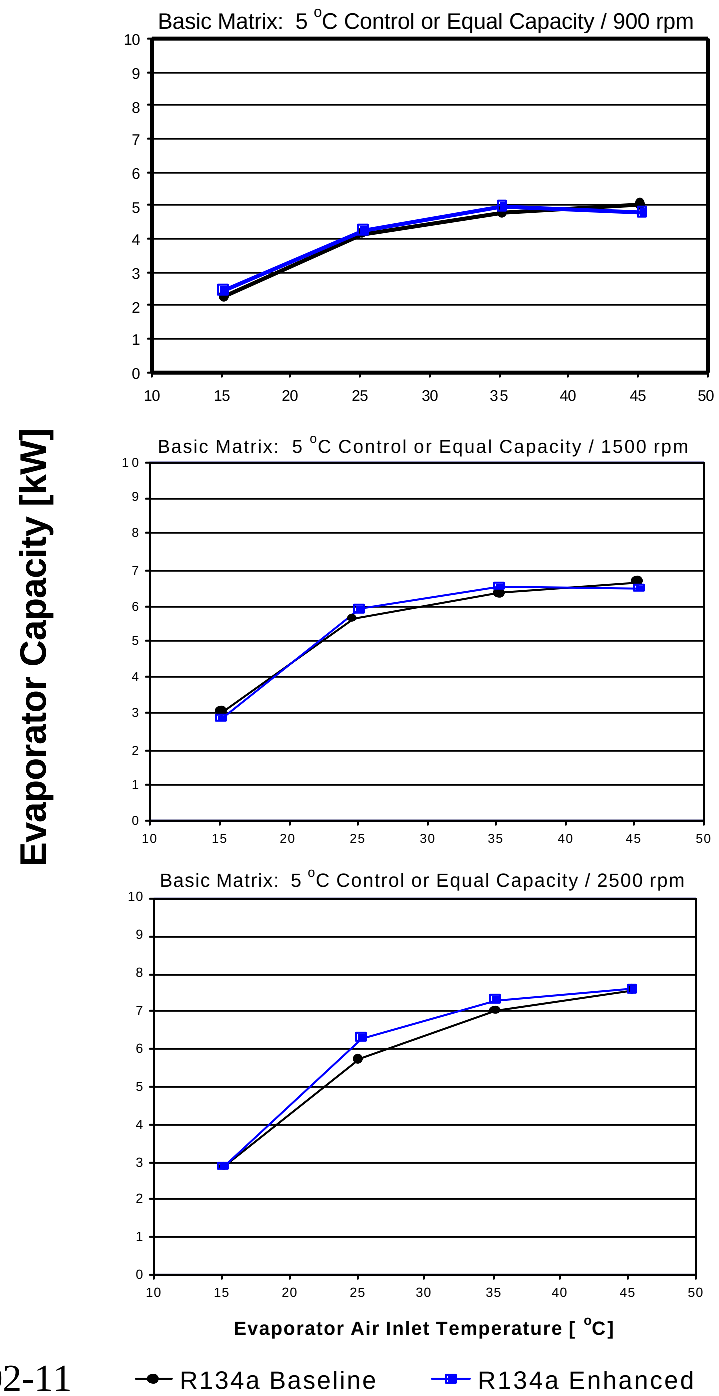
- Baseline R 134a
- Transcritical CO_2 (R 744)
- Enhanced R 134a
- Hydrocarbon (Propane R 290) secondary loop (indirect system)

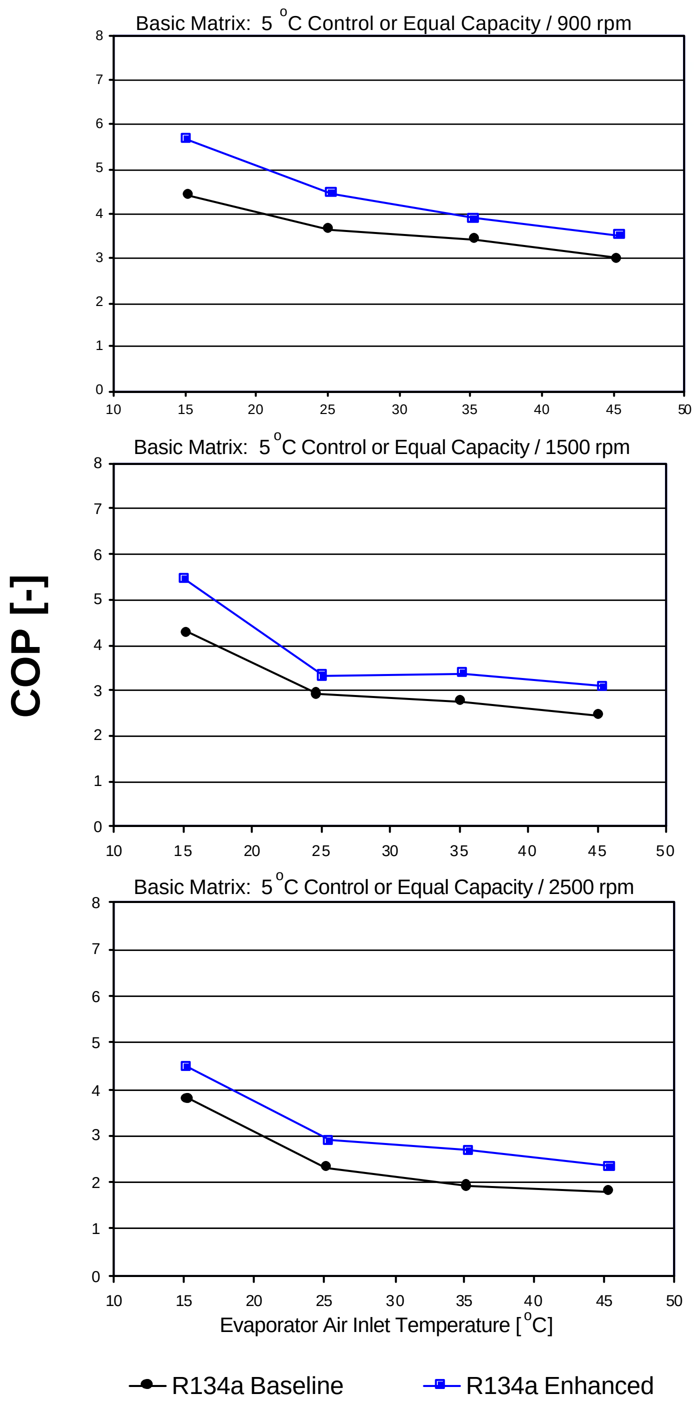
COP and cooling performance

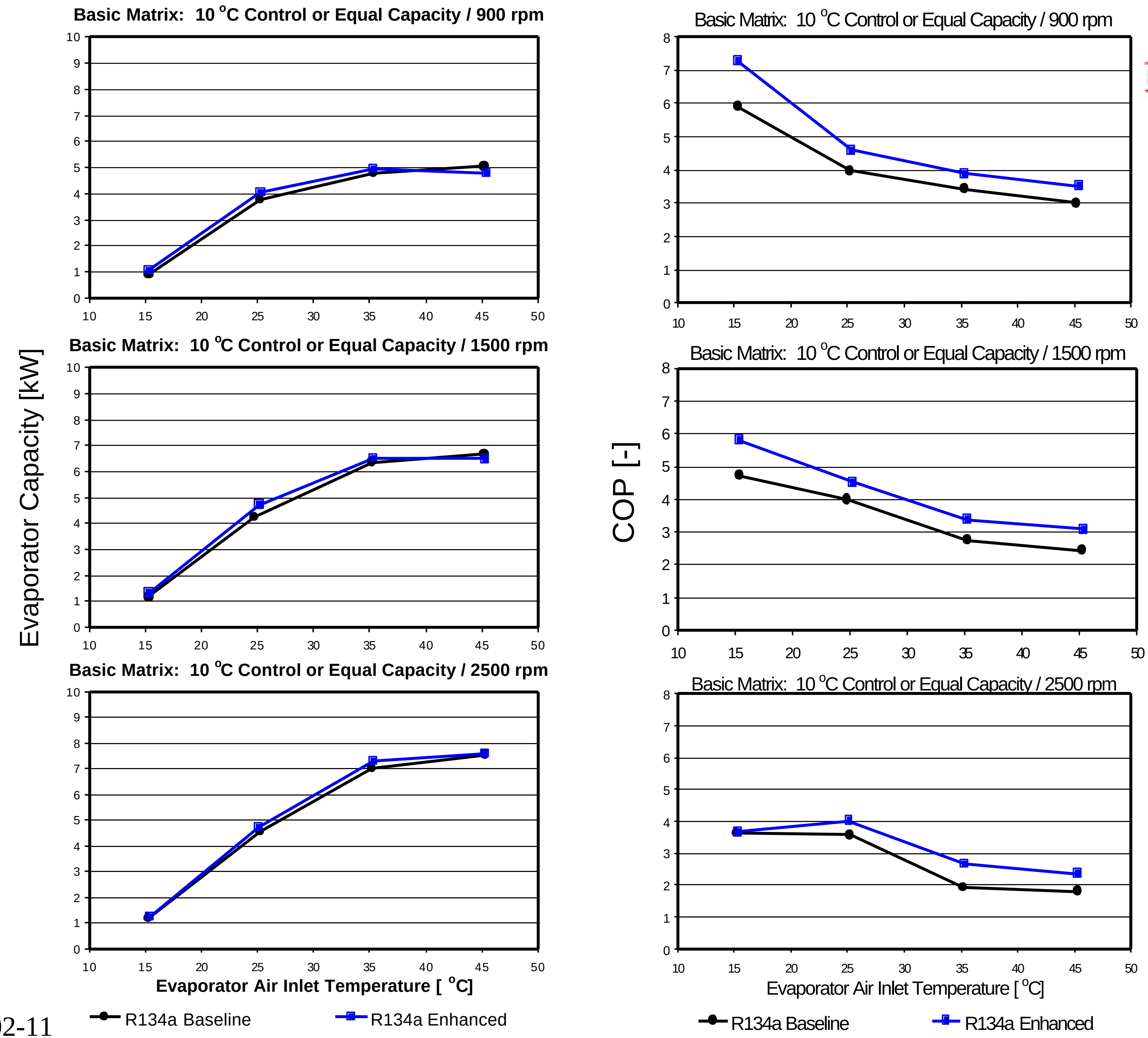
- steady state, +15 - +45 °C
- soak and cool-down
- dynamic behaviour
- effect of disturbed condenser/gas cooler air-flow

Graphs on the next two slides, showing evaporator capacity at 15, 25, 35 and 45°C for 900, 1500 and 2500 (compressor) rpm are with evaporator airflow = 109-130 l/s = max blower. This is NOT typical cooling load/ capacity at normal use (steady state) but more what appears first minutes of a cool-down sequence.

Typical cooling load levels for normal use are shown on the two slides for “Low evaporator airflow”.


Evaporator Capacity [kW]
Basic Matrix: 5 °C Control or Equal Capacity / 900 rpm
Basic Matrix: 5 °C Control or Equal Capacity / 1500 rpm
Basic Matrix: 5 °C Control or Equal Capacity / 2500 rpm
Evaporator Air Inlet Temperature [°C]
R134a Baseline
R134a Enhanced

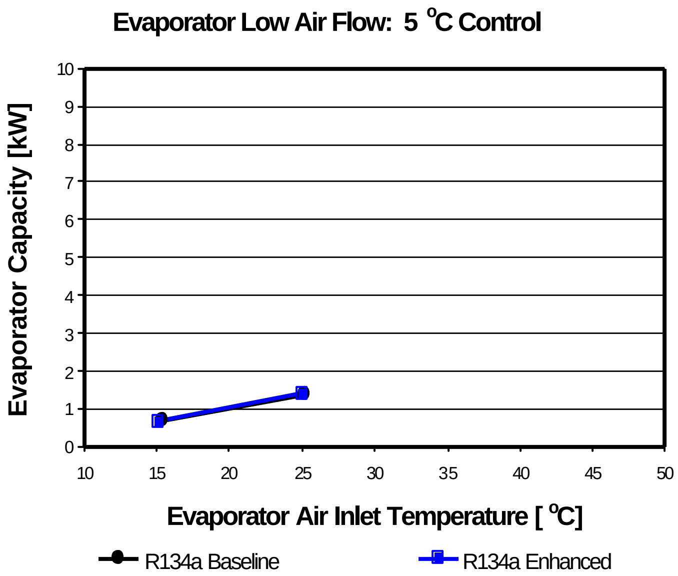

COP [-]
Basic Matrix: 5 °C Control or Equal Capacity / 900 rpm
Basic Matrix: 5 °C Control or Equal Capacity / 1500 rpm
Basic Matrix: 5 °C Control or Equal Capacity / 2500 rpm
Evaporator Air Inlet Temperature [°C]
R134a Baseline
R134a Enhanced

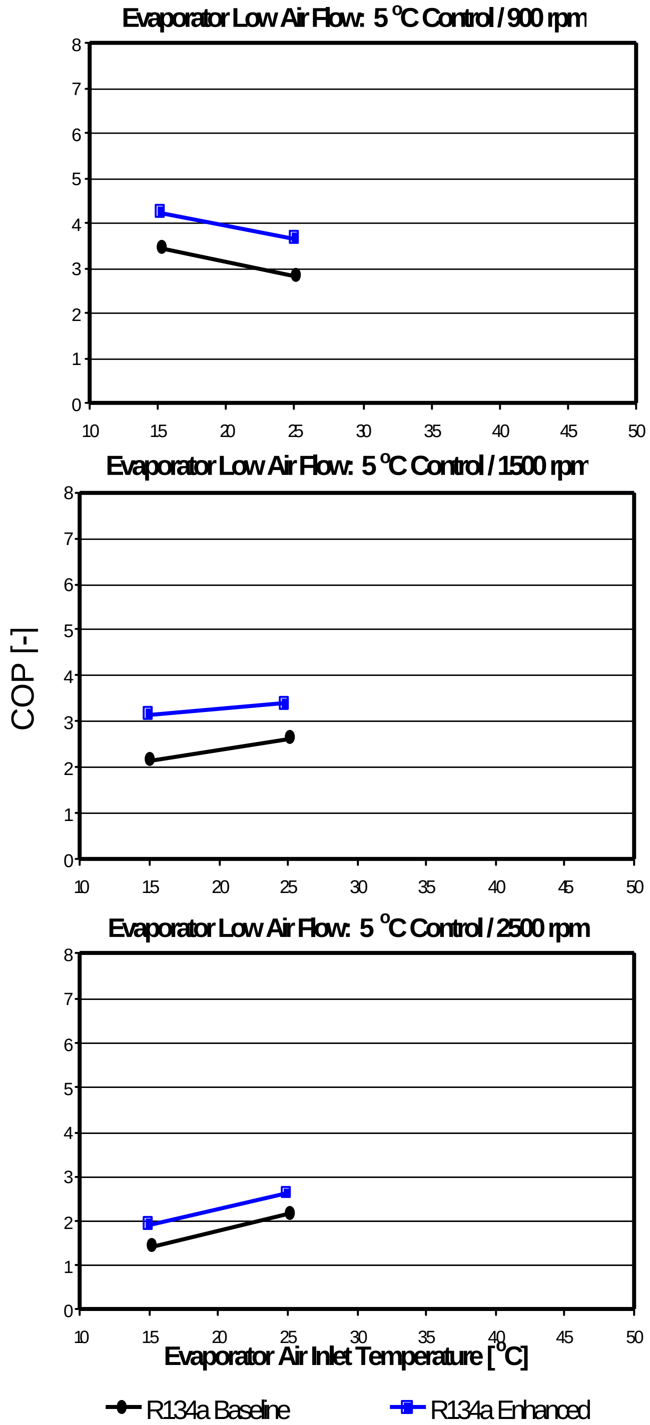


Basic Matrix: 10 °C Control or Equal Capacity / 900 rpm
Basic Matrix: 10 °C Control or Equal Capacity / 1500 rpm
Basic Matrix: 10 °C Control or Equal Capacity / 2500 rpm
Evaporator Capacity [kW]
COP [-]
Evaporator Air Inlet Temperature [°C]
R134a Baseline
R134a Enhanced

Low evaporator airflow = 28 lit/s

Set-point = 5°C

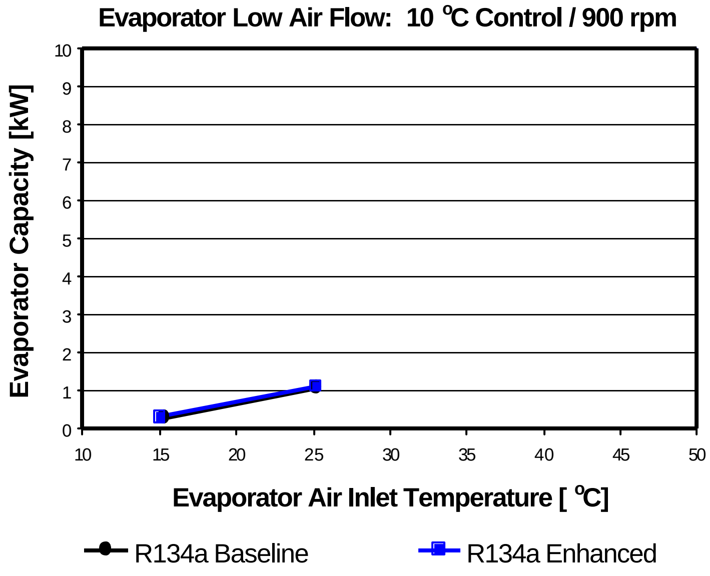




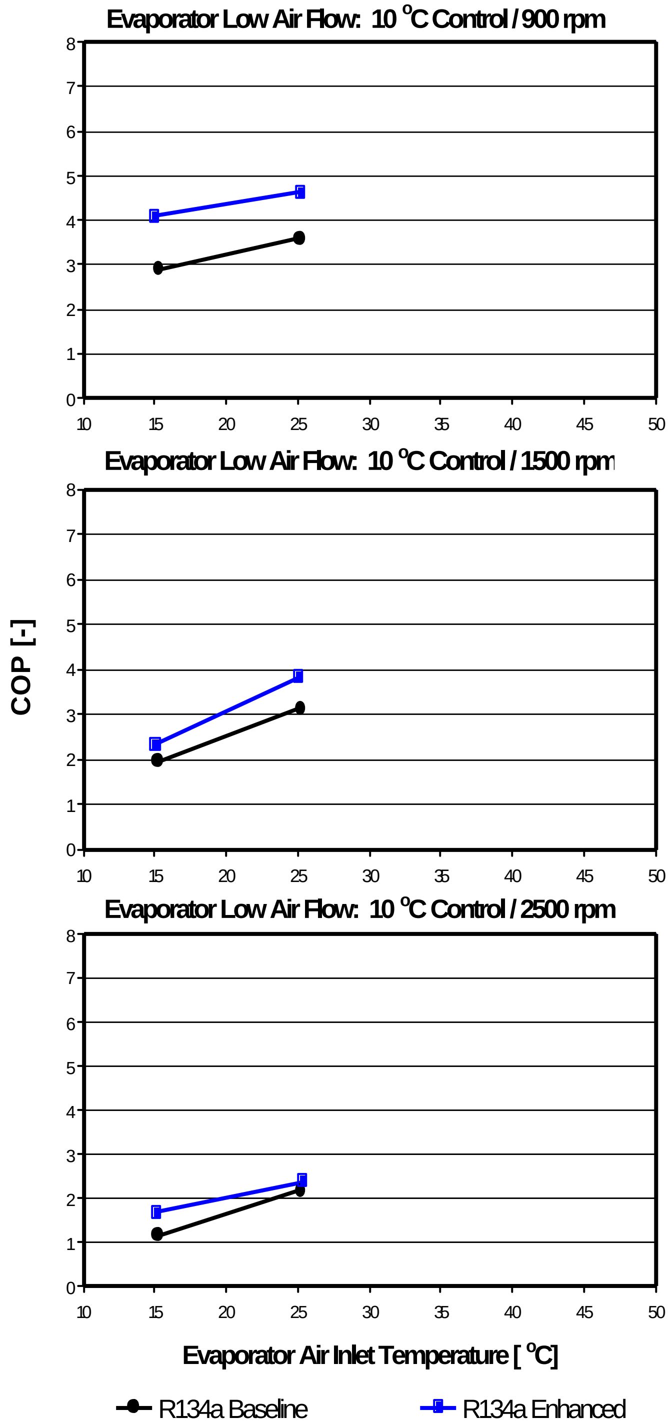
Same cooling capacity for 900/ 1500/ 2500 rpm

Low evaporator airflow = 28 l/s

Set-point =10°C



Same evaporator capacity for 900/ 1500/ 2500 rpm



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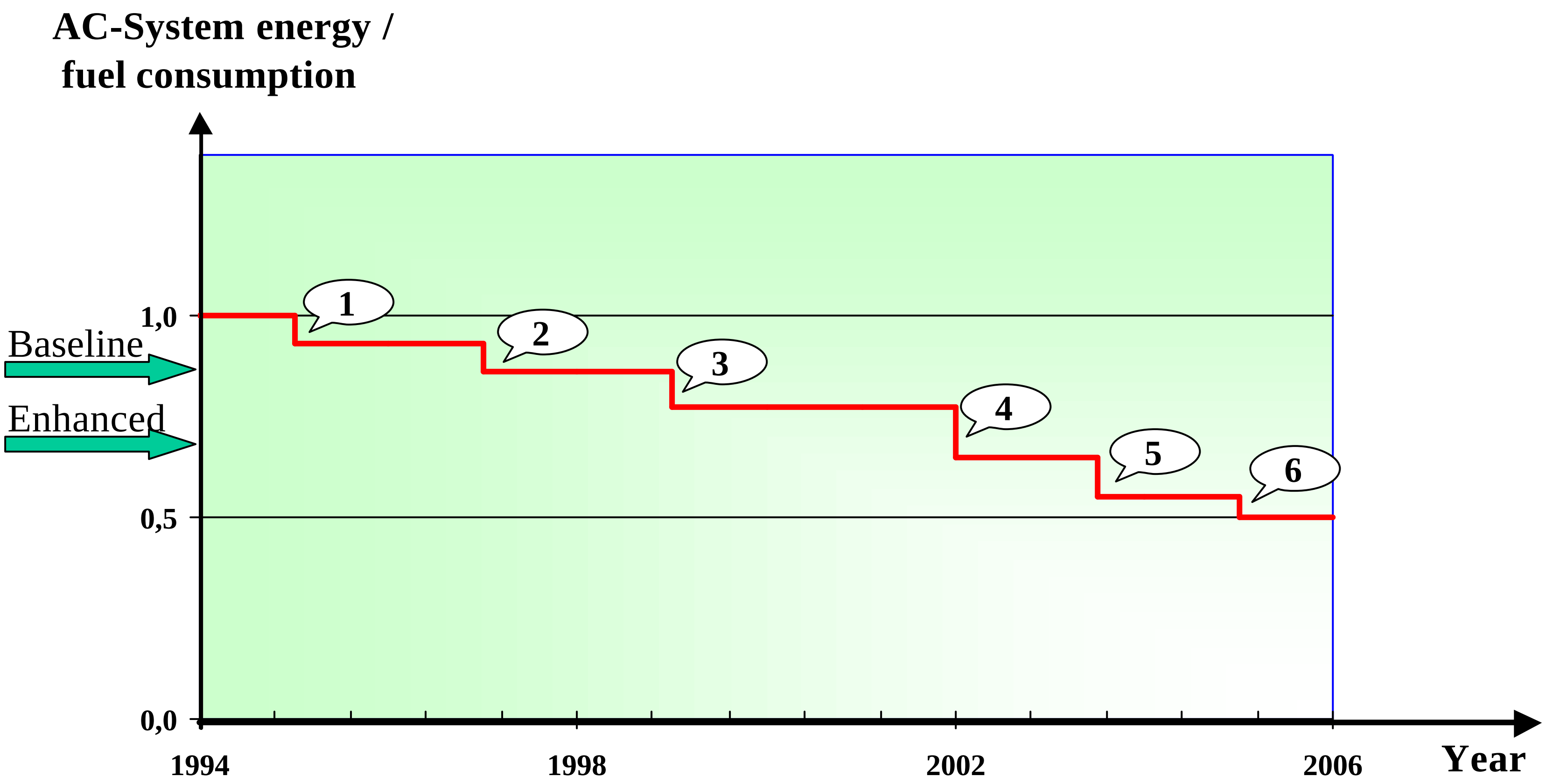
Summery of SAE-ARCRP results

Baseline R 134a	COP
5°C s.p.	1.8 - 4.4
10°C s.p.	1.8 - 5.9
Low evaporator airflow	1.2 - 3.6

Enhanced R 134a	COP
5°C s.p.	2.4 - 5.7 = 14-38% up
10°C s.p.	2.4 - 7.3 = 0.4-38% up
Low evaporator airflow	1.7 - 4.6 = 10-47% up

Average, over a total of 36 conditions, COP for Enhanced R 134a is up 24.7% compared to COP for Baseline R 134a.



AC-System energy /
fuel consumption
1,0
0,5
0,0
Baseline
Enhanced
1
2
3
4
5
6
1994
1998
2002
2006
Year

Conclusions & comments on COP

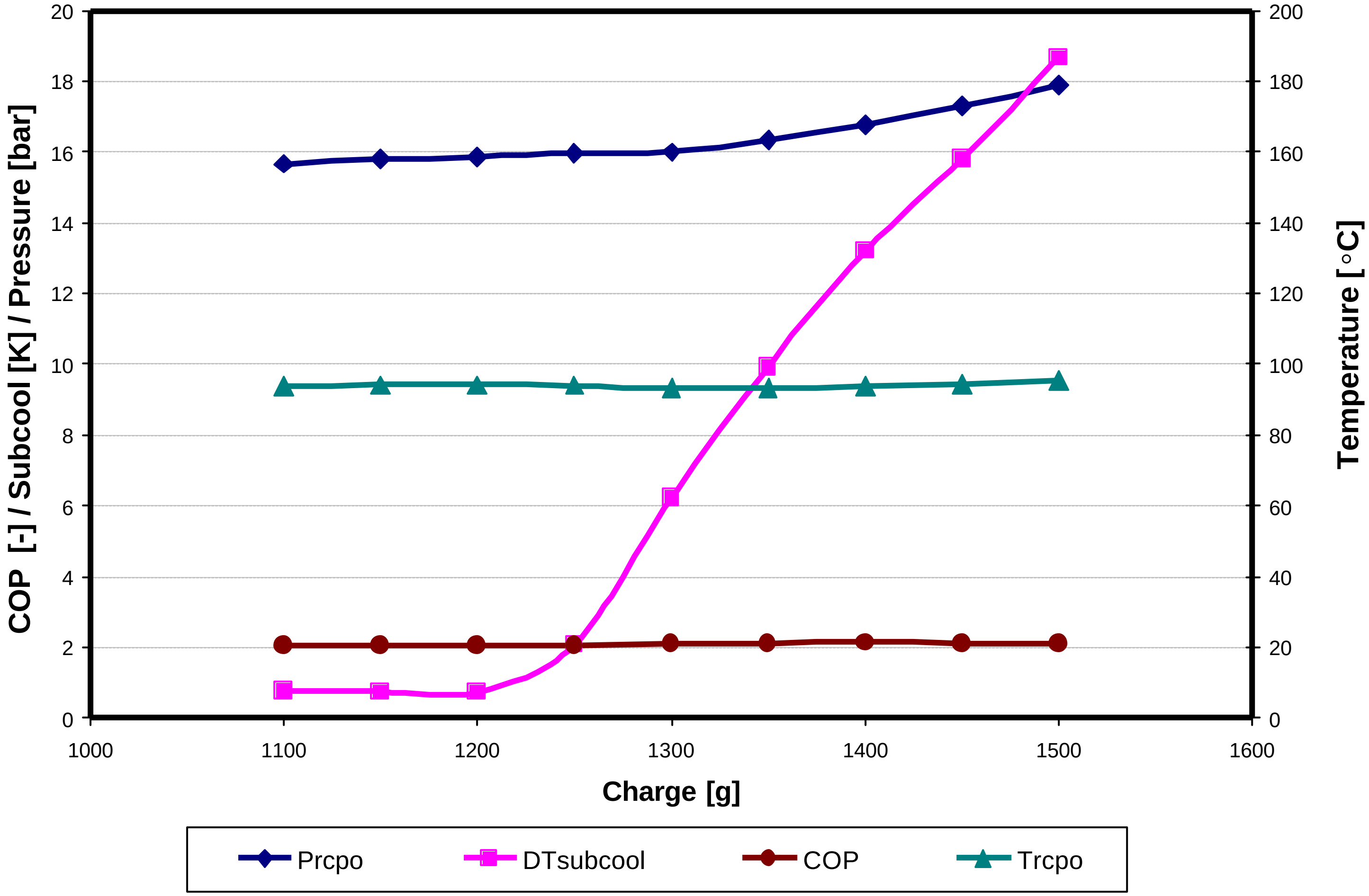
- wide span of COP depending on operating conditions
- no significant influence on COP due to loss of refrigerant (see next slide)
- no direct connection between size of charge (g R 134a) and COP

⇨ a 600 g system can have same, lower or higher COP compared to a 1000 g system

COP is determined by:

- technology used for components (evaporator, condenser, compressor,...)
- design of tubes and hoses (pressure drop)
- operating conditions (P_D level = condenser cooling,...)
- ...

SAE R134a Baseline System Charge Determination (1300g was selected)



Prcpo = pressure compressor out DTsubcool = subcool condenser out Trcpo = temperature compressor out

Fuel consumption

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Preliminary calculations based on results from SAE-ARCRP for the "**Baseline R 134a**" system, using Euro combined drive cycle and US climatic profile

⇨ average, annual (compressor) power = **1.16 kW**

For the above conditions, the estimated additional fuel (gasoline) consumption is approx. **0.055 lit./ kW / 10 km**.

With an annual, average mileage of **15 000 km**, this gives an annual fuel use for use of the AC-system

1.16 × 0.055 × 15 000/10 = **96 lit. / year**
(add 6.5 % to annual fuel consumption)

Note: European climatic profile is cooler / lower than US
→ annual, average fuel consumption for Europe < 96 lit./y.
Similar calculations remains to be done for Enhanced R 134a and the other two systems in SAE-ARCRP.

Controlled losses (emissions)

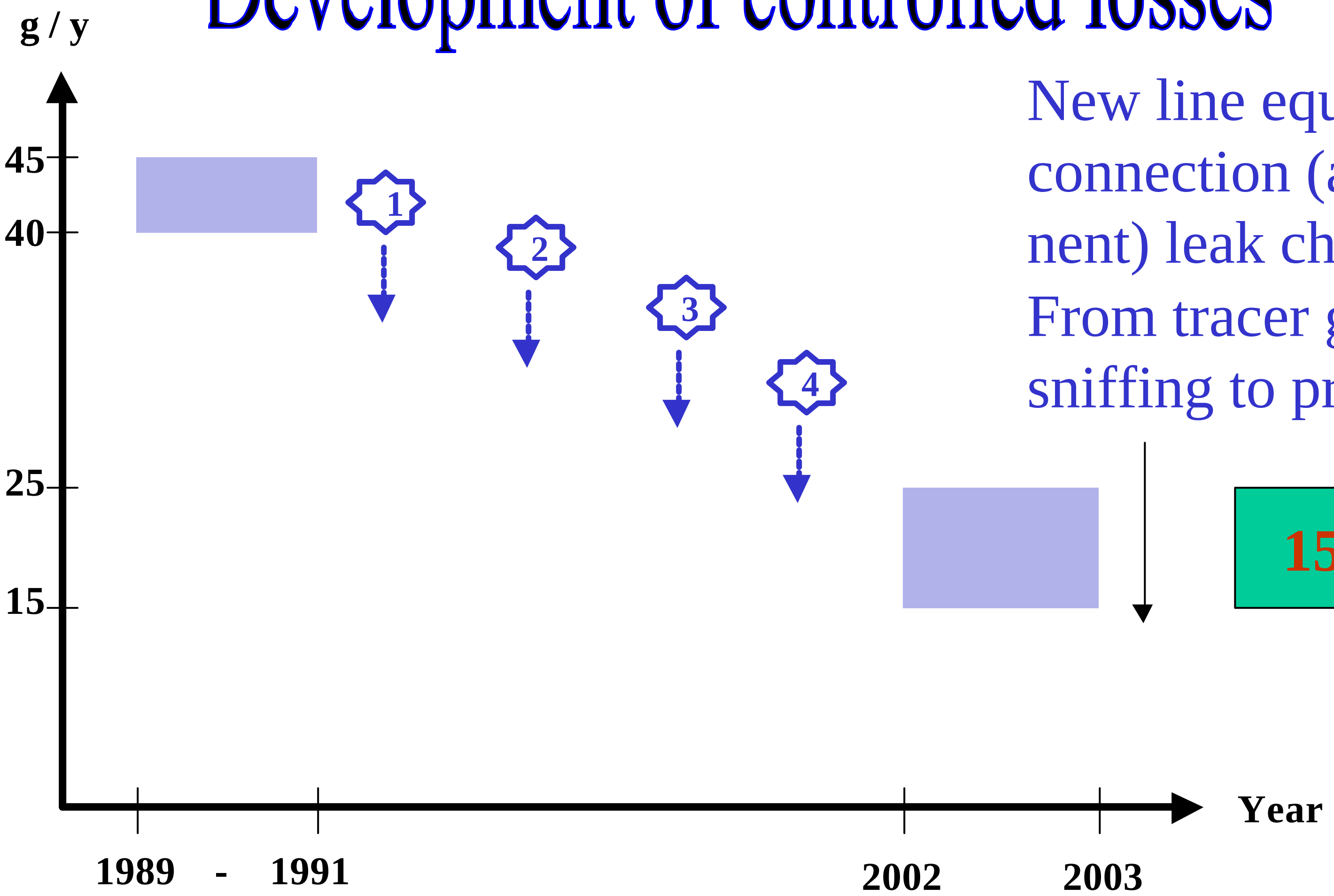
Material, design and specification related

- hose permeation
- seal/o-ring permeation
  - connections
  - components (compressor body, R/D, etc.)
- compressor shaft-seal (normal) leak flow

Process method and equipment related

- component leaks (braze/weld porosities etc. / component supplier leak check)
- connection leaks / assembly line leak check

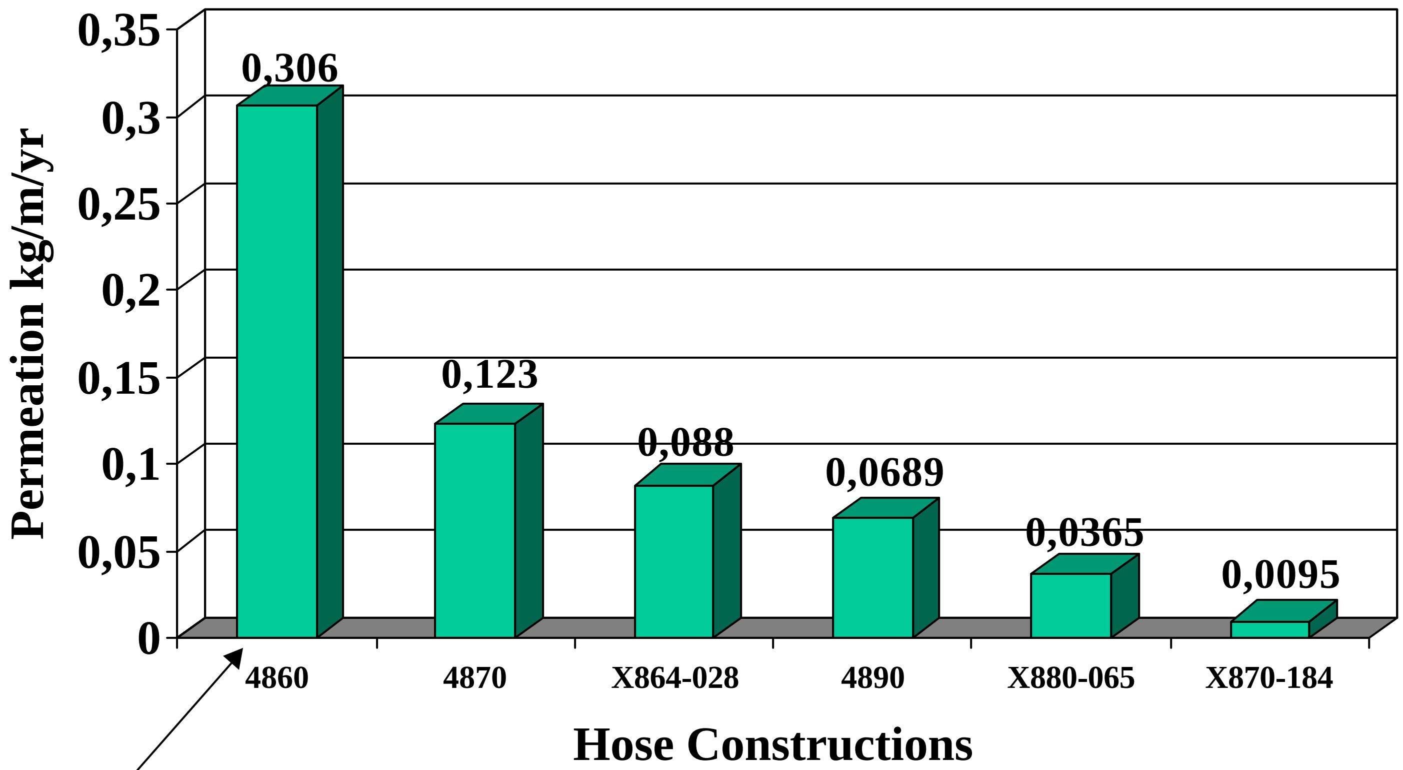
Development of controlled losses



New line equipment for connection (and component) leak check.
From tracer gas/ manual sniffing to pressure decay.

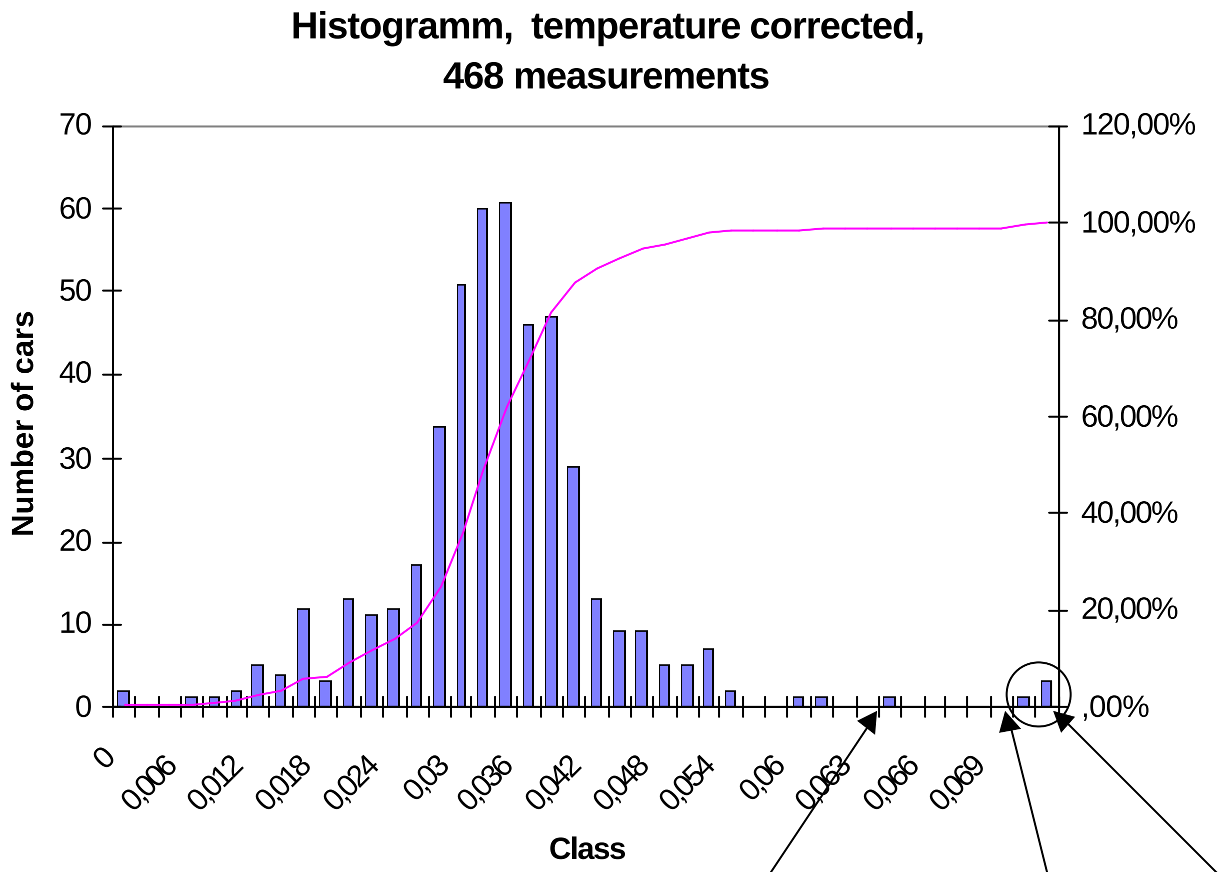
1. **Nylon lined hoses (lower permeation)**
2. **New compressor shaft-seal, mechanical ® lip type**
3. **Increased component requirements vs. suppliers**
4. **Shorter hoses, double o-ring crimp-fits and connections**

PERMEATION COMPARISON - 15 DAYS AT 90 °C



R-12 'rubber/rubber' hoses » 3 times higher

Courtesy of Good Year Automotive Hoses



Pressure decay test method, (dry) air 20 bar, 16 minutes.

Result from line test October 2001.

All 468 cars were OK at the regular He-sniffing leak check.

30 g/y

40 g/y

Total of 4 cars > 40 g/y

Result above and method concept implies that average loss rate for OK systems after this test **£ 20 g/y**

Summery of controlled losses

- achievable total, controlled losses (permeation + component/ connection leaks) for European conditions £ 15 + 20 £ 35 g/y

- the (controlled) loss rate is totally independent of size of charge.
® a poorly designed and checked 600g system can have a loss rate of 70-100 g/y where a well designed ("state of the art") 1000g system can be well below 35 g/y.

- therefore, the unit for loss rate should be [g/y] and NOT [%].

- if % of nominal charge is being used for any volunteer agree-ment or regulation, regarding max allowable loss-/emission rate, this will stop, or even reverse, the general and ongoing trend to reduce system charges.

Uncontrolled losses (emissions)

= leaks that occur on the system during usage due to:

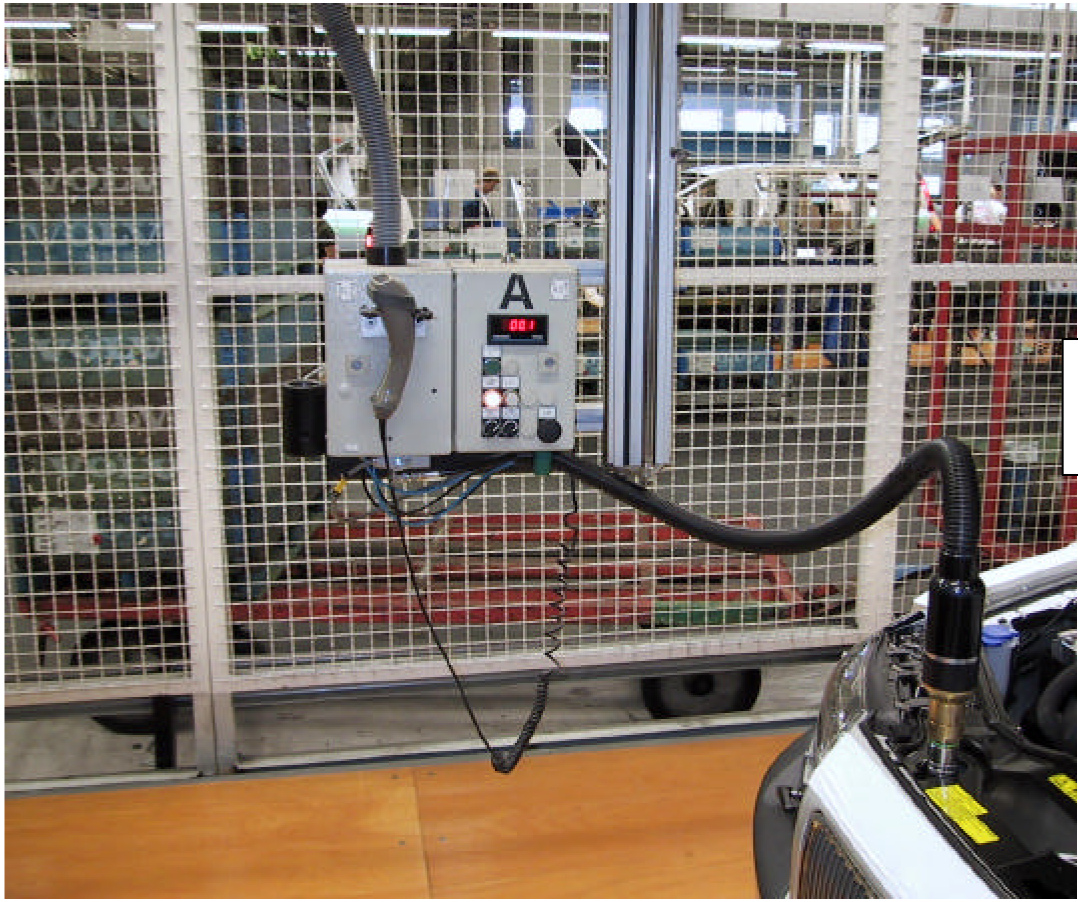
- corrosion (external)
- wear
- fatigue (cracks)
- mechanical damage (e.g. stone shot on condenser)

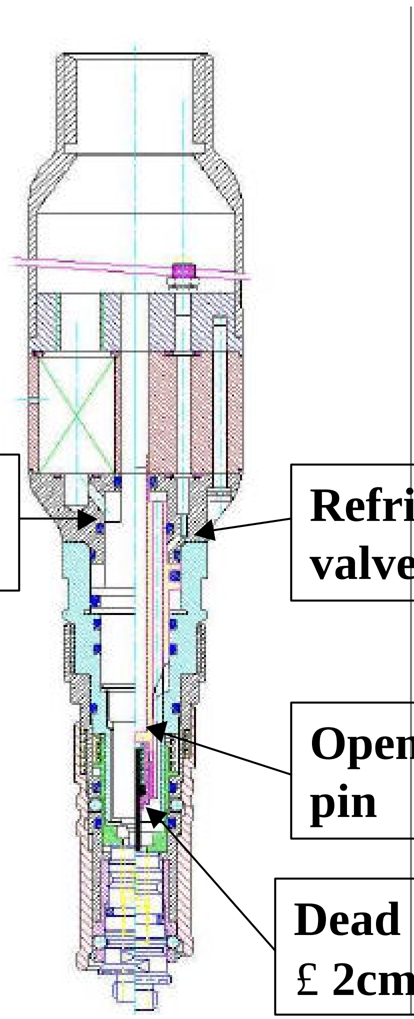
All of the above reasons for leaks can be avoided or minimised by proper choice of materials used in components, by proper designs and careful work regarding packaging and assembly line instructions and work.

That the above can be achieved, and to a very reasonable cost, have already been demonstrated.

Emissions in production / assembly plant

Production adapter / filling gun





Emissions / car £ 0.1 g HFC-134a

Final Summery

- Preliminary calculations on fuel consumption confirm previous estimations (ECCP) of + **5-6%**
- Substantial improvements already demonstrated with “Enhanced R 134a” system ⇨ **75-80 l/y**
- Further improvements of system efficiency / reduced fuel consumption are envisioned ⇨ **60 l/y**
- Technologies and designs for fully acceptable refrigerant containment are already available £ **35-40 g/y**
- Cost to implement fuel efficient, low emissive HFC-134a systems is moderate, or none, if done in a proper and wise way.

Conclusion

HFC-134a systems offers well proven, well functioning and safe mobile air conditioning

Next generation HFC-134a systems are highly viable environmental alternatives, both regar-ding direct as well as indirect emissions

Can be achieved with already available technologies to very competitive cost

Thank you for your attention