

A simplified model to predict the MACS LFR as a function of temperature and MACS operation

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Outline



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Background



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⇒ Several European oems' MACS have been tested for the R-134a Leak Flow Rate



... both in the shed and in the real use



Background



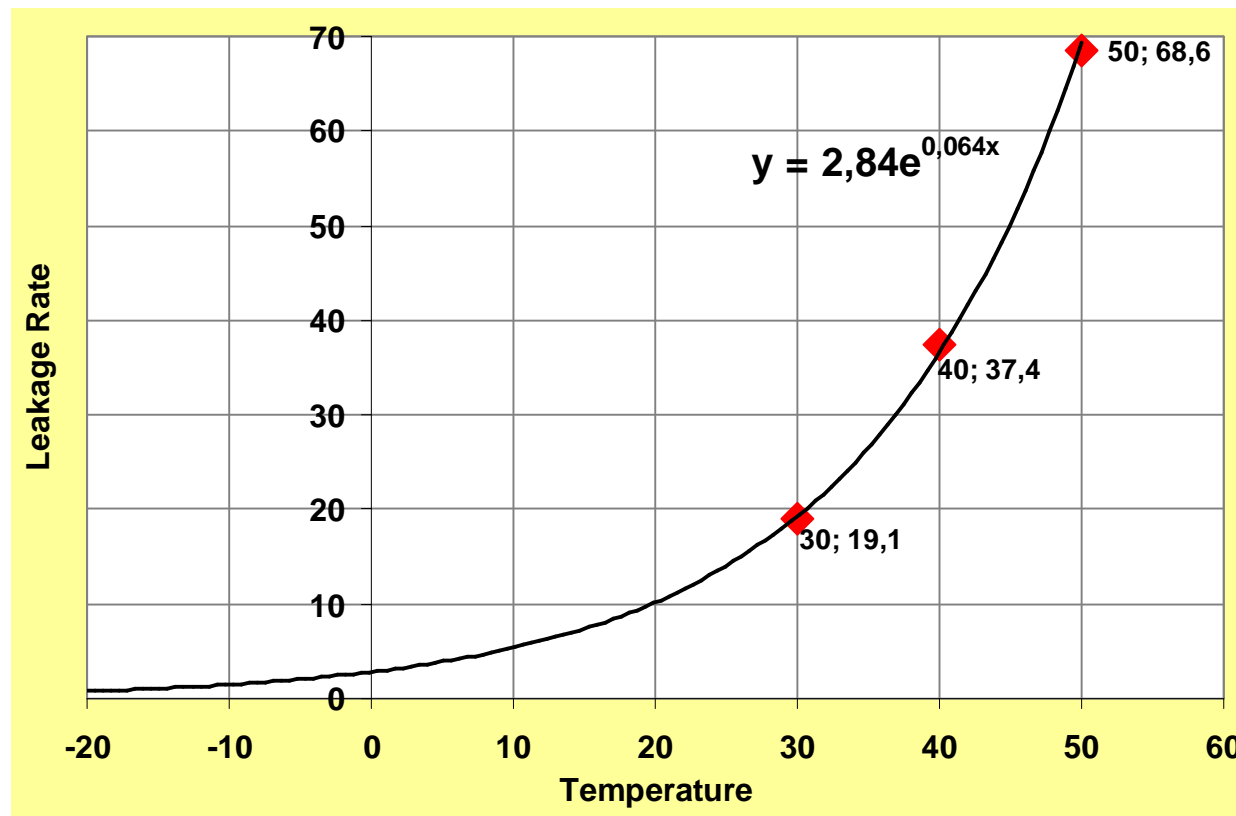
- ⇒ The Leak Flow Rate of the chosen MACS has been measured in the mini-SHED (photoacoustic detector) at temperatures of
 - 30 °C
 - 40 °C
 - 50 °C
- w/ non operated MACS and either with or without pre-conditioning
- ⇒ The LFR of the same MACS has also been measured on vehicle in the real use with via difference between accurate weighing of the charged refrigerant and the recovered one at the end of the vehicle mission

The advanced approach

The exponential fit



- ⇒ The Leak Flow Rate of an “avg EU technology” MACS can be predicted versus the ambient temperature
- ⇒ An exponential fit has been chosen



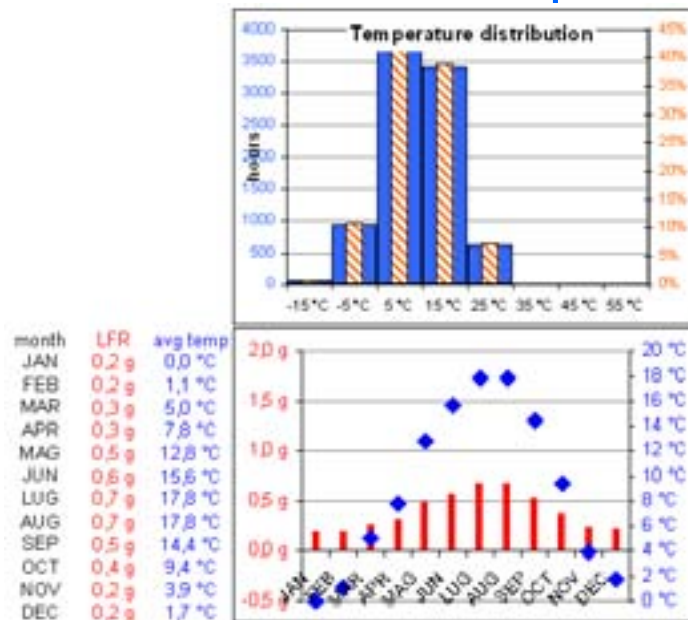
The advanced approach

The temperature distribution effect

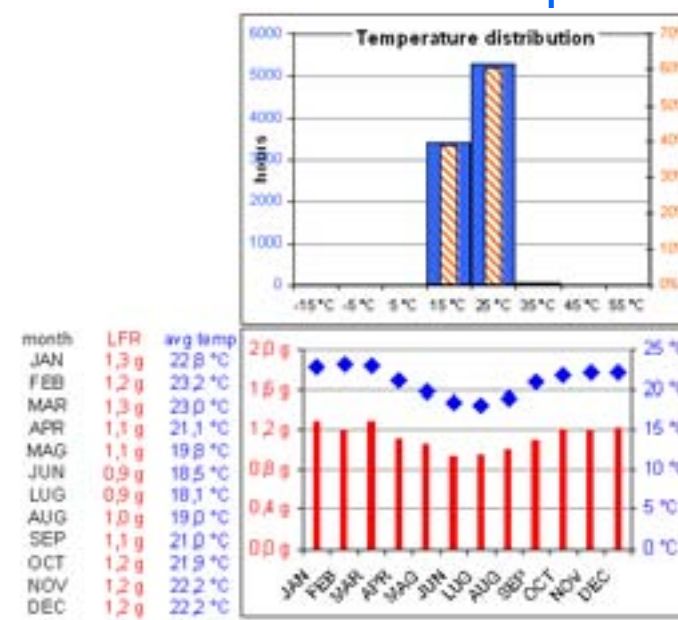


- ⇒ The temperature distribution along the year affects the LFR of the MACS
- ⇒ Both the temperature distribution along the year (8 clusters) and the LFR dependence on months show typical paths for the chosen latitudes

North hemisphere



South hemisphere



The advanced approach

The temperature distribution effect

The LFR figures related to the clusters adoption corresponding to different latitudes are:



LFR (g/y)	f(avg temp)	f(temp clusters)
Stuttgart	5,0	5,8
Turin	6,2	7,2
Shanghai	7,8	9,5
Athens	8,8	9,9
Belo Horizonte	10,8	11,5
Phoenix	12,1	14,8
New Delhi	14,2	16,3

The advanced approach

State of the MACS effect



- ⇒ When the MACS is operated the resulting LFR is higher
- ⇒ The following assumptions have been made:
 - avg EU yearly mileage (~14000 km/y)
 - vehicle driven only at 8 a.m. and 6 p.m.
 - MAC operated if air enthalpy > 25 kJ/kg

Note: the temperature and r.H. distribution along the year hour by hour are necessary as input for this approach

The advanced approach

State of the MACS effect



⇒ The MACS LFR can be modeled by considering the following 5 different possible conditions:

- MAC ON
- MAC "just OFF"
- MAC OFF w/ engine ON
- MAC OFF w/ engine "just OFF"
- MAC OFF w/ engine OFF

⇒ The MACS temperature is increased by a certain ΔT with respect to the ambient temperature which has been determined comparing bench and "on the road" LFR values

	15 K	5 K	35 K	25 K
engine ON		engine "just OFF"	MAC ON	MAC "just OFF"

The advanced approach

State of the MACS effect



The figures corresponding to this approach are:

LFR (g/y)	f(temp clusters)	f(MAC state)
Stuttgart	5,8	8,0
Turin	7,2	10,5
Shanghai	9,5	13,9
Athens	9,9	14,6
Belo Horizonte	11,5	17,2
Phoenix	14,8	22,2
New Delhi	16,3	25,2

The advanced approach



- ⇒ This approach has been validated by applying it to predict the LFR of the MACS which were tested in the EU activity
- ⇒ These MACS were operated in the real use in Dusseldorf, Frankfurt, Hannover, Paris, Stuttgart, Turin
- ⇒ The predicted LFR figures underestimate the real ones on average by 25%

The simple model



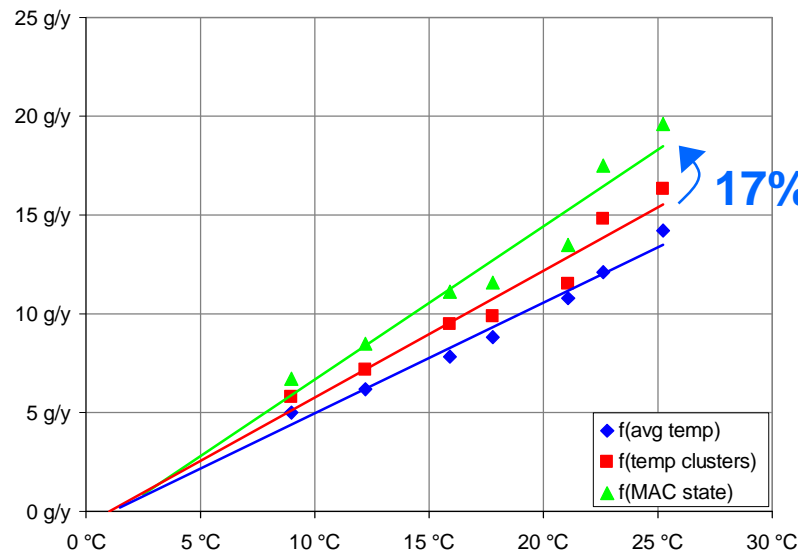
- ⇒ A simpler model has to be used if the hourly temperature distribution is not available
- ⇒ Let's consider the Leak Flow Rate average profile of the considered avg technology MACS
- ⇒ The figures corresponding to the average ambient temperature at different latitudes are:

	avg temp	LFR (g/y)
Stuttgart	9 °C	5,0
Turin	12 °C	6,2
Shanghai	16 °C	7,8
Athens	18 °C	8,8
Belo Horizonte	21 °C	10,8
Phoenix	23 °C	12,1
New Delhi	25 °C	14,2

A correlation between the models



In case the sole temperature cluster or the avg temperature were available, correlation coefficients are provided as well



34%

17%

Advanced model LFR =
= c × simple model LFR

“Advanced” LFR = 1,34 × “avg.temp” LFR

“Advanced” LFR = 1,17 × “temp. cluster” LFR

Conclusion and outlook



- 1) The proposed approach allows to predict the LFR of MACS using the different set of available data
- 2) By the other side, the method overestimates the LFR at hot climates because the real use does never put the MACS in operating in steady conditions
- 3) The presented model can be used in the framework of a LCCP assessment
- 4) The model could be improved by considering at some extent the influence of the r.H. on LFR (MACS state), as well
- 5) In order to validate the proposed approach, two additional test are recommended:
 - MACS test at the shed with temperatures 0-20 °C
 - MACS in real use test in extreme climates



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THANK YOU!
ANY QUESTIONS?

