Selecting and Best Service Practices for Air-Conditioning and Refrigeration Equipment Using Next-Generation Refrigerants for Energy Efficiency and Climate Protection

Technical Challenges with Alternative Refrigerants for Automotive Air Conditioning Applications

Mr. Selvaraji Muthu, DGM-NTD
Mr. Aseem Kumar Jaiswal, VP-R&D
Under the Guidance of
Mr. Yuji Yamamoto, SVP-R&D
Subros Ltd

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Alternative Refrigerant for MAC Applications

Brief-Summary :

The Automotive Air conditioning system is presently employed with HFC based R134a refrigerant and as per the Europe and US norms and Global efforts to reduce the GHGs emission to the atmosphere by change over of HFC based refrigerants (R134a) in to HFOs (R1234yf / R1234ze) and Natural refrigerants (CO2, NH3).

Both the HFOs and CO2 have there own merits and demerits. The impact in terms of thermodynamic system level performance, the system integration and the proposed solution to be presented for the discussion.

Present technology vs need of new technology also to be discussed in terms of additional Internal heat Exchanger for R1234yf and 2 stage compression for CO2 refrigerants.

Alternative Refrigerant for Automotive Air Conditioning Applications

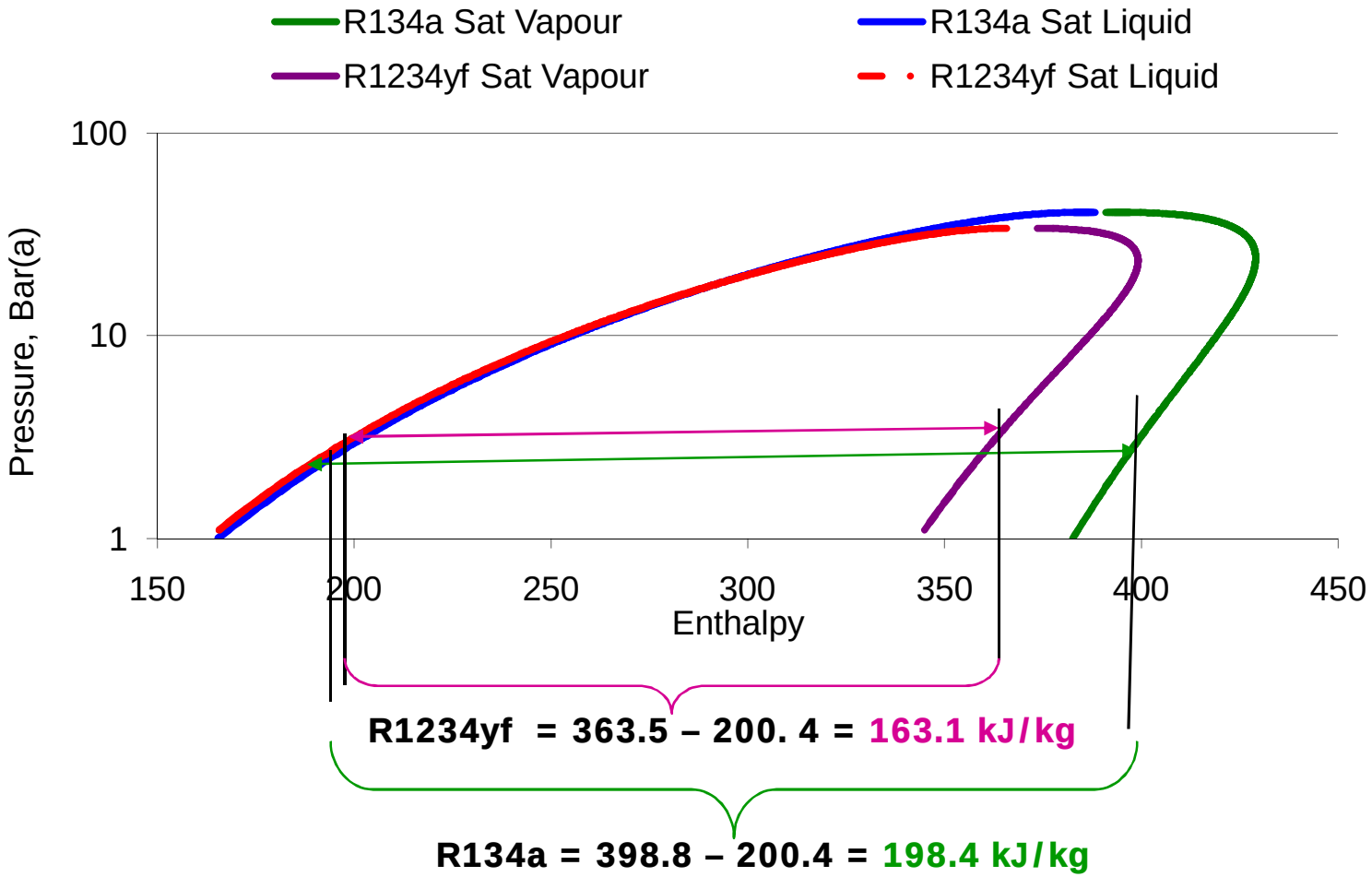
Benefits of R1234yf:

1. GWP=4.0 (& ODP=0.0)
2. Very low atmospheric life
3. Low TEWI
4. Complying to European Norms
5. Complying to US Norms

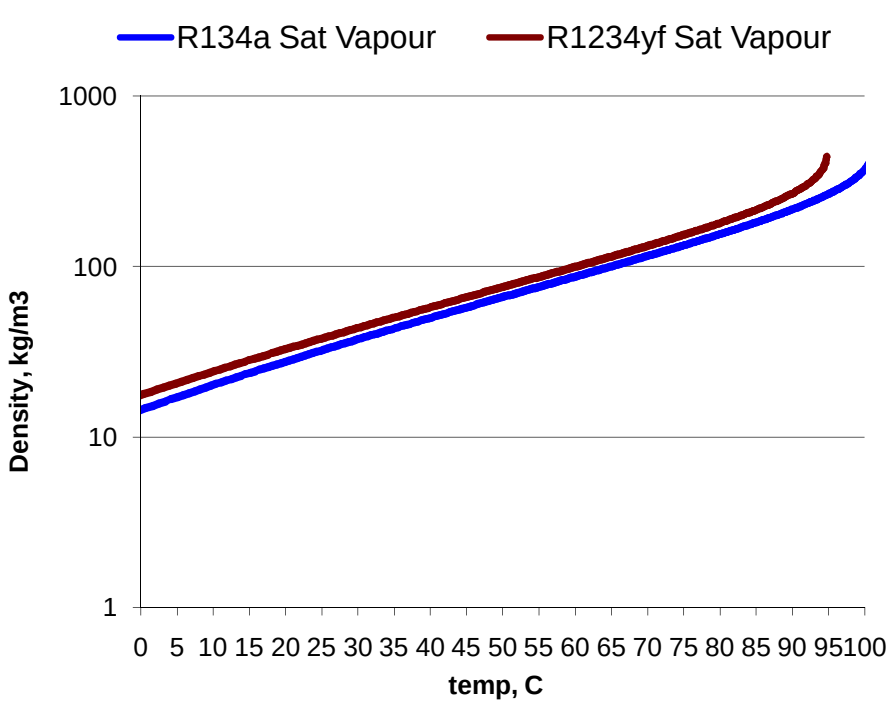
R1234yf Implementation issues:

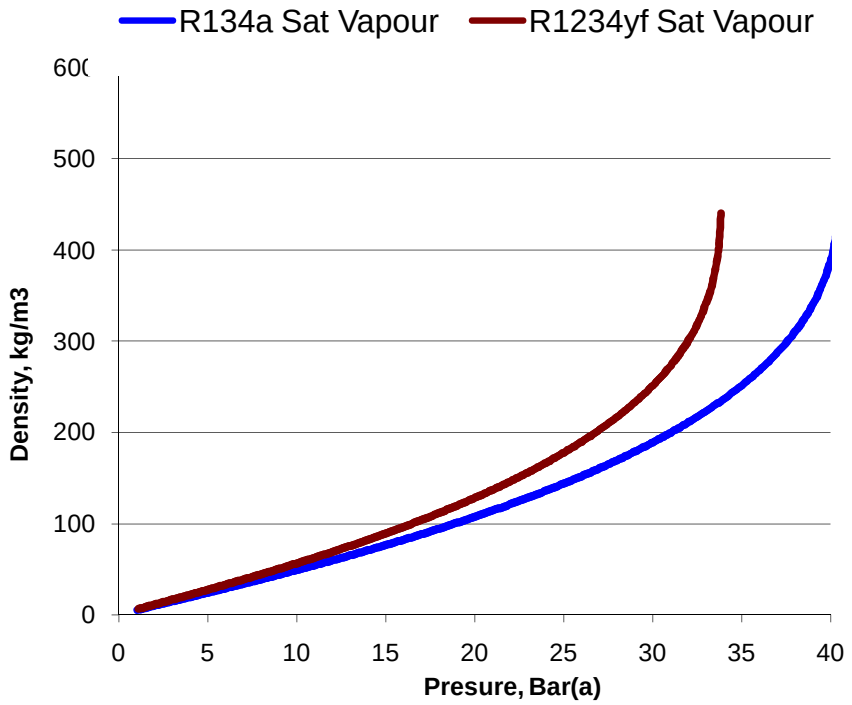
1) Performance impact
2) Additional part (IHX) to match the performance
3) Availability
4) Cost impact
5) Retro fitment issues (New oil type, New ports)
6) Mild Flammability

Comparison of PH Dof R134a and R1234yf



1. R1234yf has comparatively low Latent heat than R134a
2. R1234yf has comparatively higher boiling at TXV than R134a
3. Hence, Cooling capacity is poorer, even though the density is higher for R1234yf





Refrigerant @ Evaporator saturation	Vapour Enthalpy, kJ/kg	Liquid Enthalpy, kJ/kg	Latent heat, kJ/kg	Vapour Density, kg/m3	Quantity of vapour, %	Quantity of Liquid, %	Liquid Mass flow, kg/h	Cooling Capacity, kW
R134a	398.78	200.4	198.38	14.58	37.70%	62.30%	98.0	5403.1
R1234yf	363.49	200.39	163.1	17.82	44.70%	55.30%	106.4	4819.3
diff.....			**-17.8%**	**22.2%**	**7.0%**	**-7.0%**	**8.5%**	**-10.8%**

Alternative Refrigerant for Automotive Air Conditioning Applications

S.No.	Refrigerant	Additional Sub-cool by IHX	Cooling Capacity, W	Power Consumption, W	COP	Quality of refrigerant at TXV outlet
1	R134a	0	5485.8	2185	2.511	0.377
2	R1234yf	0	5026.4	2136	2.353	0.447
			-8.4%	* -2.2%	-6.3%	7%
3	R1234yf	5	5210.6	2151	2.422	0.4
			-5.0%	-1.6%	-3.5%	2%
4	R1234yf	10	5382.9	2163	2.489	0.354
			-1.9%	-1.0%	-0.9%	-2%
5	R1234yf	15	5545	2173	2.552	0.309
			1.1%	-0.5%	1.6%	-7%
6	R1234yf	20	5698.6	2181	2.613	0.265
			3.9%	-0.2%	4.1%	-11%

Te=0.3 C

Tc=57.3 C

SH=10K

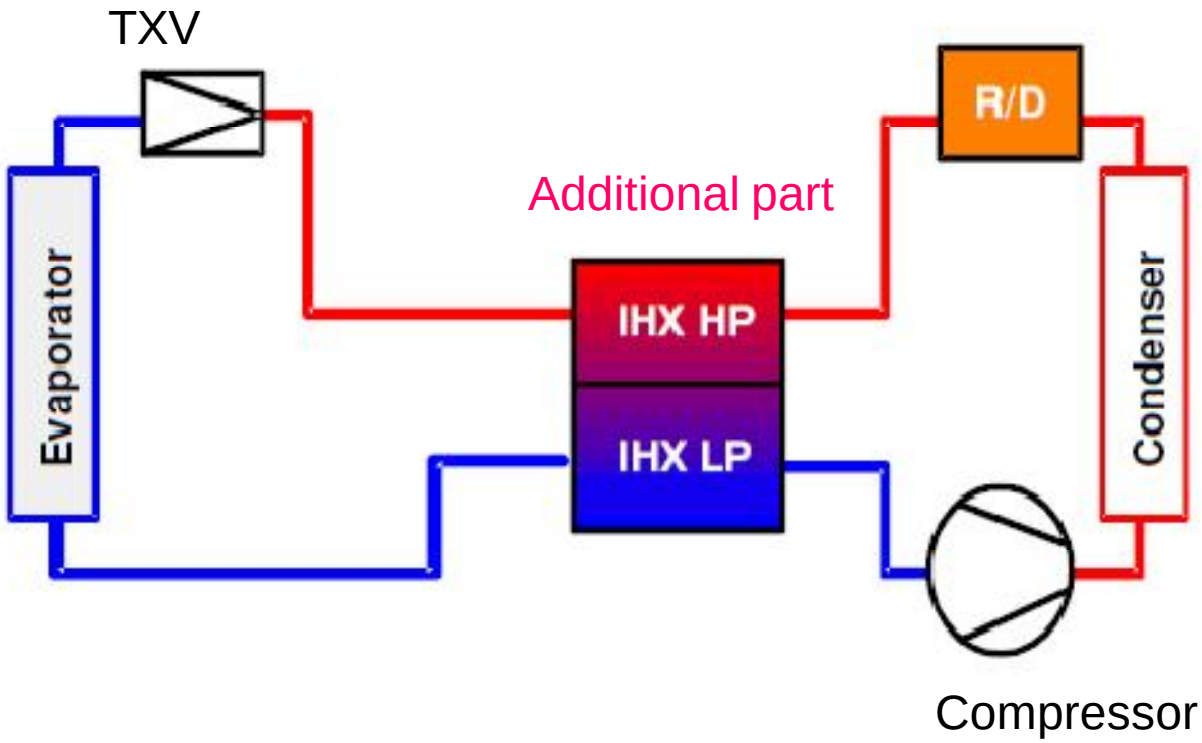
SC=5K

Displ = 0.004613 m^3/s

= 16.6 m^3/h

* In order to match the present cooling capacity, additional Internal heat Exchanger has to be used with additional cost implication and as well as there exists a technology gap for the same.

Internal heat Exchanger (IHX)



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Alternative Refrigerant for Automotive Air Conditioning Applications

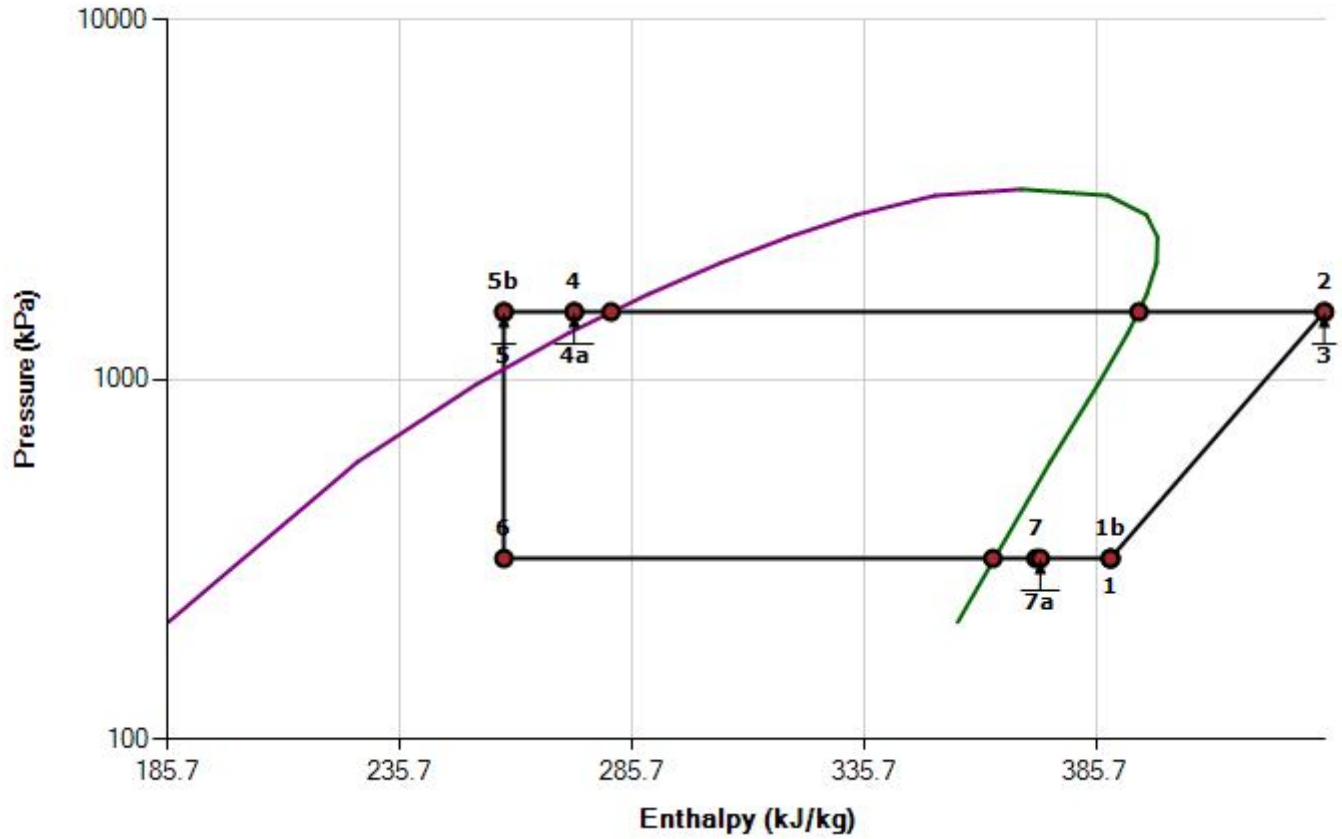
Performance Parameters

Refrigerant	R1234YF		**EER**	Btu/W.h	8.491
GWP	4		**Heating COP**	-	3.509
Mass Flow	kg/s	0.04694	**Subcooling Exp. Dev. In**	°C	15
Cooling Capacity	W	5382.88	**Superheat Evap. Out**	°C	10
Heating Capacity	W	7589.8	**Condensation Temp.**	°C	57.3
Power	kW	2.163	**Evaporation Temp.**	°C	0.3
Cooling COP	-	2.488			

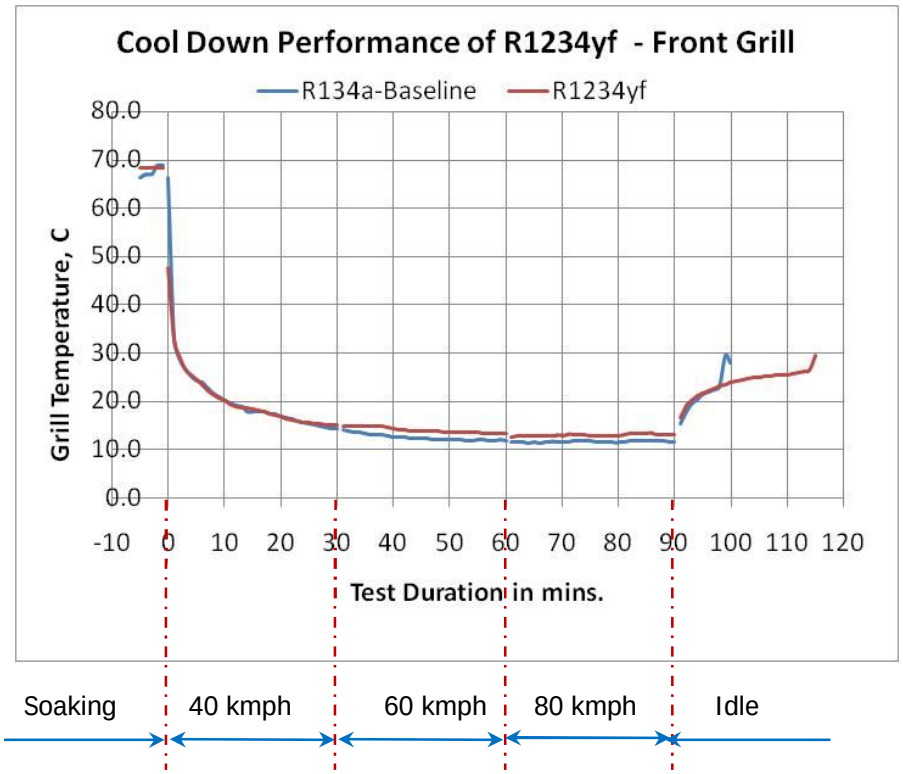
IHX = 10 C additional sub-cool

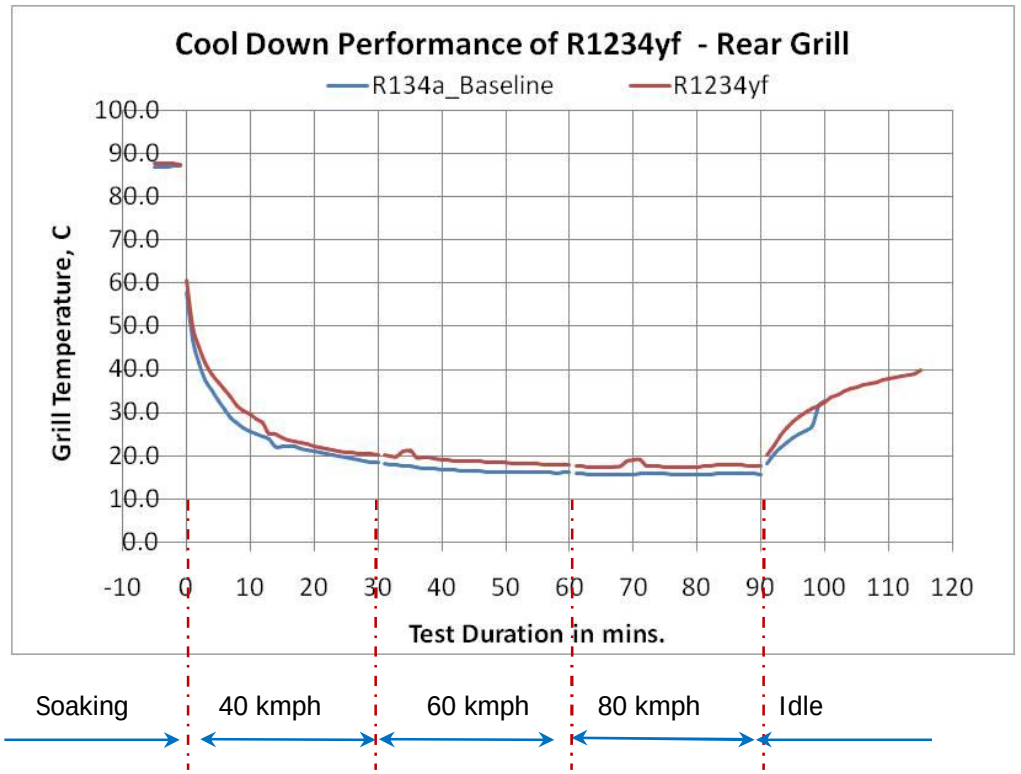
X=0.354

P-h Chart



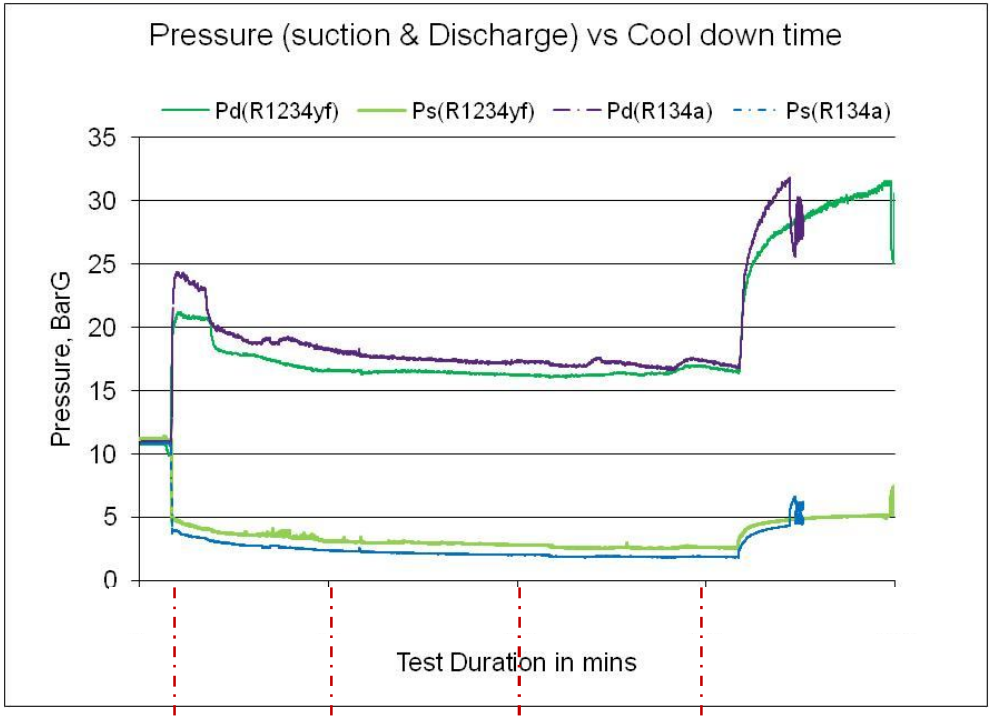
Vehicle Cool Down Test

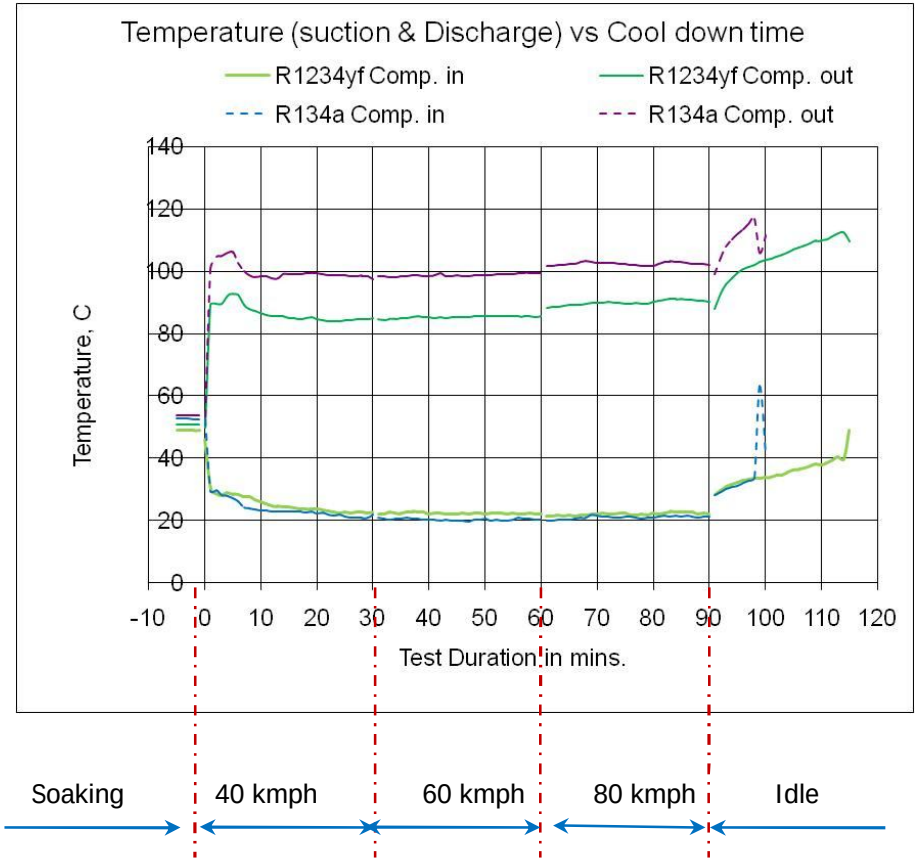




Temperature:	45 ° C
RH	40%
Solar load	1000 W/m2
Soaking Time:2:00hr + 30mint. Open door soaking without solar load @45 ° C	

Vehicle Cool Down Test





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Changeover from R134a to R1234yf

1) R1234yf may require about a 5% increase in refrigerant vs. R134A

2) The current R134A PAG oil will not work with R1234yf, new type of oil is required.

3) R1234yf can be recycled in the same way that R134A has been in the past, but the service equipment needs to be manufactured to a different standard

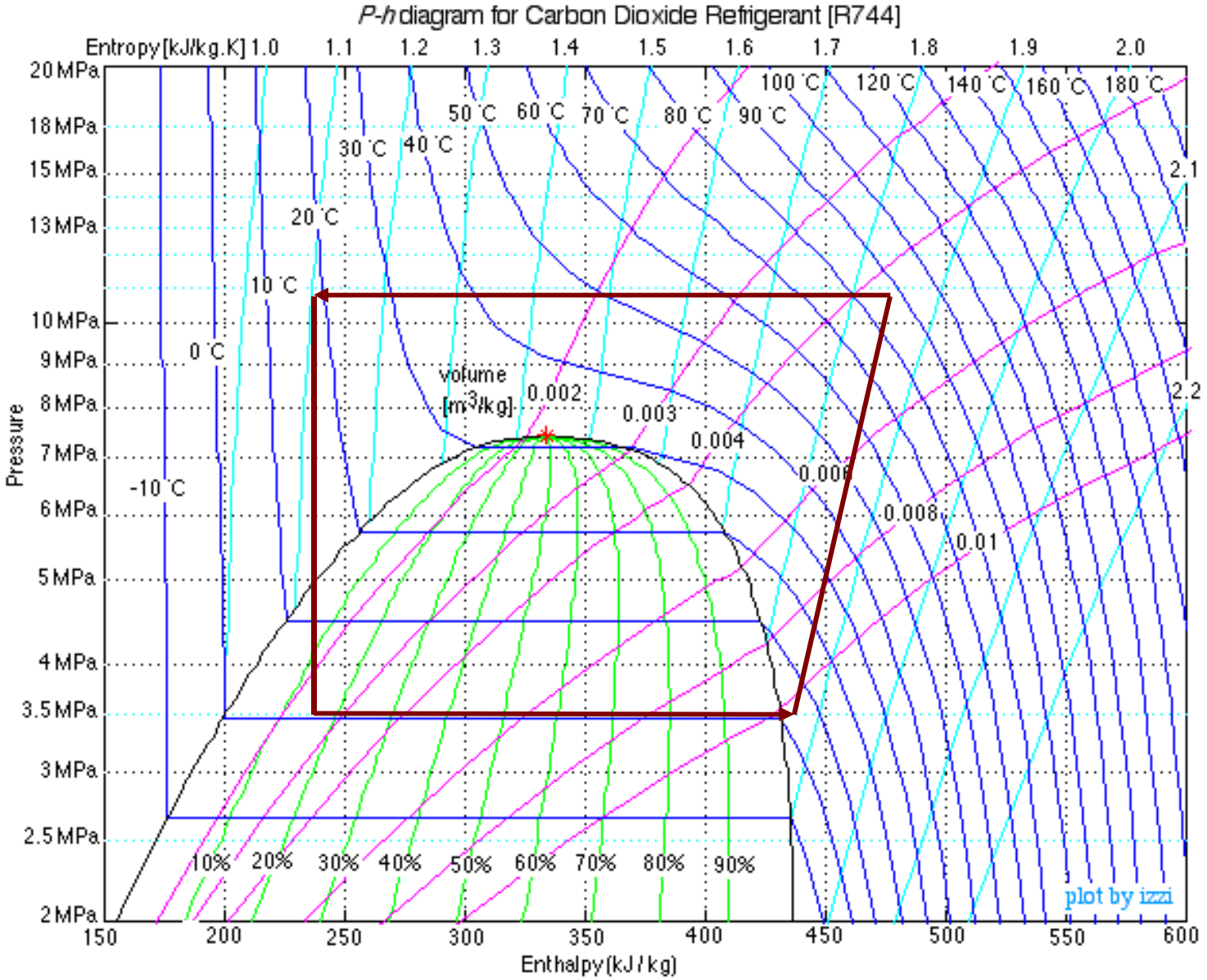
4) Garages will require new RRR service equipment and will need to use it alongside their R134a equipment.

5) Leak detection equipment that meets the current standard will work with R1234yf.

6) Service ports are similar to R134A, however they are smaller in size to prevent misuse.

7) Testing to date has found that the same desiccant type and quantity works with R134A and R1234yf

CO_2 Natural Refrigerants



1. Very high Suction and Discharge pressure
2. Issue of Co2 leakage and higher concentration
3. Choice of secondary loop
4. Complex and expensive system

Ref: NIST Chemistry WebBook

Impact Comparison for next generation Refrigerants

Mobile Air-Conditioning

Component which increases cost

	HFO1234yf	CO2(R744)
Refrigerant price	**Expensive**	**Cheap**
Cost for performance		
Compressor,	**Larger comp.**	**Two-stage comp.**
EX, etc.	**Larger pipe etc.**	**High-pressure etc.**
Cost for safety		
Charge reduction	**Necessary**	**Necessary**
Joint	**Special joint**	**-**
Electronic parts	**-**	**-**
Leak detector	**-**	**-**
Ventilation	**-**	**-**
Cost for handling		
Manufacture	**Modified facility**	**Modified facility**
Supply chain	**Modification**	**Qualification**
Installation	**Modification**	**Qualified person**
Service	**Modification**	**Qualified person**
Disposal	**Modification**	

Challenges to Market Entry and Potential Solutions

Challenges to Market Entry of R1234yf	**Potential Solutions**
Slight Flammability Risks	Safety System Installation & Engineering Design
Limited Production Capacity	Increase Production Capacity
Regulatory Approval	Currently Under EPA's Significant New Alternatives Policy (SNAP) Program Review
Limited Availability May Prevent Full Market Penetration in the Near-Term	Currently Under EU Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH) Review for High Volume Applications
Additional Internal Heat Exchanger (IHX) to match the present performance	Cost and Technology Impact to be resolved
Cost of Refrigerant	Currently higher than R134a

End

References

1) *ttp://ec.europa.eu/enterprise/sectors/automotive/environment/macs/index_en.htm*

2) *http://www.epa.gov/ozone/snap/refrigerants/lists/mvacs.html#1234yf*

3) *http://conf.montreal-protocol.org/meeting/mop/mop-24/ngo-publications/NGO%20Publications/NRDC-IGSD-Cooling%20India%20With%20Less%20Warming.pdf*

4) *http://www.honeywell-refrigerants.com/india/applications/automobile-ac/*

5) *http://www.sae.org/mags/aei/11870/*

6) *http://www.motor.com/article.asp?article_ID=2039*

7) *R1234yf.fld* - NIST, www.boulder.nist.gov/div838/theory/refprop/R1234YF.FLD

8) *R1234ze.fld* - NIST , www.boulder.nist.gov/div838/theory/refprop/R1234ZE.FLD

9) http://www.sae.org/mags/aei/8702

10) http://www.sae.org/mags/AEI/8074

11) http://www.sae.org/standardsdev/tsb/cooperative/altrefrig.htm

References

12) Calm JM, The next generation of refrigerants - Historical review, considerations, and outlook, Int. J. Refrig. 31 (7), 1123-1133 (2008). http://dx.doi.org/10.1016/j.ijrefrig.2008.01.013

13) Calm JM, Refrigerant Transitions ... Again. ASHRAE-NIST Refrigerants Conference 2012

14) Handbook for the Montreal Protocol on Substances that Deplete the Ozone Layer, Ninth edition (2012), United Nations Environment Programme.

15) The Montreal Protocol and the Green Economy, 2012, UNEP.

16) KYOTO PROTOCOL TO THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE, 1998, UN.

17) Selvaraji Muthu and Aseem Kumar Jaiswal , Refrigerant types, issues, trends and future options, ACRECONFINDIA International Conference , New Delhi, India, 8 – 9th Feb'2013

18) Selvaraji Muthu and Aseem Kumar Jaiswal , "Emerging refrigerant and retrofit options" at 'ACR TrendZ-2013 Conference', the 9th edition, on 18th & 19th October 2013 at Le Meridian, Pune, organized by ISHRAE Pune chapter

19) Subros Report on Alternate Refrigerant R1234yf to Ministry OF India , 14th Jun 2013

20) Subros Report on Alternate Refrigerant R1234yf for MAC for Ministry Environments and Forests of India , 6th Aug 2013

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Thanks for the Opportunity and your Attention

Let us Discuss for mutual understanding and clarification on the subject