SAE Phoenix Alternate Refrigerant Symposium Summary July 18, 2004

June 28 –July 1, 2004 Ward Atkinson

The 6th 2004 SAE Alternate Refrigerant Systems Symposium June 28 –July 1, 2004 in Scottsdale Arizona hosted 221 world industry representatives. The attendees came from 12 countries, 98 companies, 3 universities including a representative from the European Commission and five U.S. governmental agencies. Included were representatives from 14-passenger car, truck and off road vehicle manufactures, 12 air-conditioning system manufacturers, 47 component and 4 material suppliers. In addition 12 chemical companies, several service industry organizations, 2 standard organizations and 2 testing and engineering companies were in attendance.

This overview covers the week's activities, vehicle comfort evaluations and areas of discussion during the symposium.

Symposium Activities

Workshops

Alternate Refrigerant Systems:

- The 2003 Brussels MAC Summit provided some mobile A/C system cost estimates for new alternate refrigerant systems. Using a production HFC-134a system for baseline the estimated added cost for new system technology ranged from \$20.00 (Euros) for an enhanced HFC-134a system to \$40.00 to \$180.00 (Euros) for a carbon dioxide system. [Table 1]
- To better define system description a new system class chart was sent to SAE ICCC working groups in March 2004. The chart identified two levels of refrigerant system classification covering components, controls and compressor types for HFC-134a, HFC-152a, secondary loop R290 and carbon dioxide systems. [Appendix A]
- On June 28, 2004 The U. S. EPA released Analysis of Cost to Abate International Ozone-Depleting Substance Substitute Emissions. In the report chart ES-4 identified mobile A/C issues covering the potential lifetime cost for emission reduction. The chart for HFC-134a indicates a range of US dollar cost saving of \$275.47 to an additional cost of \$7.02. The cost range for HFC-152a ranged from a cost saving of \$73.65 to an increase cost of \$30.81. Carbon dioxide systems were ranged from a cost saving of \$23.44 to an additional cost of \$180.72. Reference CD file: [Workshop Emissions]
- It was generally concluded that it is difficult to identify anticipated system costs due to the fact that there are no fully developed systems at this time and there is concern for sharing of competitive cost information.

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MAC Summit Preview



(Future costs uncertain, not including servicing and retooling) Not including added/reduced cost for training, recycling/recovery, refrigerant charge, refrig. tax, inspections, integrated heating functions

AC System	Reduced	Reduced	Added
Choice	Direct	Indirect	Cost
	Emissions	Emissions	(Euros)
HFC-134a	Baseline	Baseline	Baseline
Enhanced 134a	50%	25%	20
HFC-152a	95%	0-10%	15
Future 152a	95+%	30+%	40
CO ₂	100%	<20%	40-180?
Future CO ₂	100%	30+%	?

Table 1 2003 MAC Summit Alternative Refrigerant Cost Analysis

R134a Refrigerant Emissions

An SAE working group has developed an Assumption for R134a Leakage Chart spreadsheet based upon the current refrigerant system sealing technology. [Appendix *B Mobile A/C System Emissions*] Ref. CD File Workshop Emissions

The proposed procedure allows a classification rating of a production R134a system for the type of refrigerant connections and hose material. It does not define system refrigerant emission rate.

Future proposed system emission test procedures would establish a total refrigerant system mini-shed and vehicle shed test procedures.

It was acknowledged that ACEA is in the process of developing a procedure to determine refrigerant system emissions. JAMA has also been involved with this activity.

It was decided that any future SAE emission procedure activity would begin with the ACEA proposal which should become public by the last quarter of 2004

2004 Washington Mobile A/C Summit

During the 2004 Mobile A/C Summit there were many questions regarding mobile A/C activity. These questions on "You heard what?" were reviewed and the workshop provided some answers that are identified in red. The questions and workshop reply are found in CD File Wash 04.

- Discussion included a proposal for establishing internal core valve design standards for the R744 service ports. It was generally agreed that until more information and samples of the proposed design were available the internal design information would not be included in the J639 R744 service port requirements.
- The latest comments J639 from VDA were discussed. The proposed J639 document will be sent for first ballot.

R744 Service Equipment

The service equipment working group reviewed the propose equipment documents for R744. These proposed standards will be sent for ballot.

New SAE Cooperative Research Program

The establishment of the new SAE IRCRP [Improved R134a CRP] activity will address HFC-134a system design for:

- Reduced direct refrigerant emissions
- Reduced energy requirements

The working group activity included the establishment of member teams and identifying project goals. [*Appendix C SAE IRCRP*]

2005 Meeting Schedule [Appendix D]

The chart identifies some of the planned 2005 meetings.

Vehicle Ride Evaluations and Technical Presentations

The Tuesday through Thursday mornings included 24 technical presentations and the ride evaluations of 10 vehicles.

Weeks Agenda

Tuesday June 29, 2004

Opening/Greeting Ward Atkinson – CD Presentation File 1

European Commission Rule HFC-134a Phase-out *Rob Donkers, European Commission - CD Presentation File 2*

Emissions of HFC-134a in California

Richard Vincent, Alberto Ayala, Kevin Cleary, Richard Corey, CARB - CD Presentation File 3

Fuel Efficient Vehicles That Meet Consumer Expectations

Roland Gravel, DOE - CD Presentation File 4

Industry/Government Partnership For R134a Improved Technology Mobile A/C Systems Bill Hill, General Motors Corp. – CD Presentation File 5

Small Can Emission Reduction Partnership

Erin Birgfeld, Karen Thundiyil, U.S. EPA – CD Presentation File 6

Comparison of Two Mobile A/C LCCP Analyses

John Rugh, NREL – CD Presentation File 7

Comparing Road and Aero Tunnel Drag Effect of Vehicle Windows Open and Closed

Bill Hill General Motors – CD Presentation File 8

1:00 - 5:00 p.m. SAE Working Group

Wednesday June 30, 2004

A HMMWV's Air Conditioning System Using R744 (CO₂)

Sam Collier, Modine - CD Presentation File 9

JAMA's Voluntary Action Plan to reduce HFC-134a Emissions; Field Test and Leak Test Procedure

Koshi Kikuchi, Nissan Motor Co. Ltd. - CD Presentation File 10

Heavy Gas Transport: 152a and CO2 Dispersion in Cars *Neal Blackwell, U.S. Army - CD Presentation File11*

Potential Risk Assessments of R-152a and CO2 in Mobile A/C *Mark Zima, Delphi - CD Presentation File12*

Improvement of Power Saving in R134a AirConditioning System *Masahide Ishikawa, TOYOTA - CD Presentation File13*

Affects of Various Control Strategies on AC System Fuel Consumption Shunichi Furuya, Zexel File – CD Presentation File14

Effect of Flow Obstructions and Engine Compartment Recirculated Air on Heat Exchanger and System Performance as Simulated in the Test Bench Pega Hrnjak , Univ. of Illinois at Urbana-Champaign - CD Presentation File15

New Charge Valve Developments for CO2 Systems Peter Pfaffenwimmer, Ventrex Automotive GmbH – CD Presentation File16

1:00 - 5:00 p.m. SAE Working Group

Thursday July 1, 2004

A/C System New Function: Torque Heating and Cooling Refrigerant Systems *Paul Meurillon, Valeo Climatel – CD Presentation File 17*

Evaluation of Lubricants for a Carbon Dioxide and R152a Refrigeration System

Yasuhiro Kawaguchi, Idemitsu Kosan Co., Ltd. – CD Presentation File 18

Polyalkylene Glycols (PAG) for Alternative Refrigerant HFC152a for Automotive Air Conditioners

Myrna Serrano, Dow Automotive Fluids – CD Presentation File 19

Comparison of Oil Retention in R134a and CO₂ Climate Control Systems

Reinhard Radermacher, Univ. of Maryland – CD Presentation File 20

Assessment of Refrigerant Loss Rates from hoses and Components *Charles Thrift, TI Automotive – CD Presentation File 21*

Enhanced HFC-134a Systems with Refrigerant Permeation Rates Less than 20 Grams per Year

Eugene Dianetti, Parker Hannifin Corp. – CD Presentation File 22SAE 2004 Phoenix Alternate Refrigerant Symposium28 June – July 1, 20045 of 23

Operational Life Testing of Flexible A/C Hoses for CO₂-Systems

Carlo Burkhardt, Witzenmann GmbH – CD Presentation File 23

Status of SAE Standards *Ward Atkinson – CD Presentation File 24*

1:00 - 5:00 p.m. Industry/Government Partnership For Improved Technology HFC-134a Mobile A/C Systems

Presentation not made during meeting.

The Novacab System, a New Integrated Approach for Heat and Cooling Refrigerant System

Stéphane Bilodeau, P.Eng., Ph.D. Groupe Enerstat Inc. –CD Presentation File 25

Ride Results:

Weather Conditions

The weather conditions resulted in clear sky and low humidity during the test periods. Ambient temperatures ranged between 99 - 102°F (37-39°C) during the 3-day test period. [Table 2 and 3]

				10					
Day	Amb.	Amb.	W.B °F	%	Enthalpy	Enthalpy	Langley	Buth/ft	W/M ²
	°F	С°		Humidity	Btu/lb	J/kg		-sq.	
Tue. 6-	102	38.9	68.9	25.1	36.7	66	63.3	251.5	791.3
29-04									
Wed. 6-	99.4	37.6	63.8	12.0	29.4	49.7	65.3	247.8	780.7
30-04									
Thur. 7-	99.7	37.5	62.7	10.0	28.6	47.5	64.1	245.4	773.1
01-04									

Weather Data: Test Site Daily Average

Ride Data Reference

The meeting data CD has the following "Vehicle Ride Data" file ride.

All files include the original data, and a comfort, temperature graph for each vehicle. The average system results are found on graphs 1 and 2. Vehicle ride schedule is found on table 4.

Systems Evaluated

There were 10 vehicles evaluated during the symposium including 4 demonstration vehicles having R744 (CO_2) refrigerant systems. Three vehicles were production hybrid R134a systems and two vehicles were production HFC-134a systems. The vehicle specifications can be found in table 5.

System Performance

In general most demonstration vehicles provided a comparable level of comfort to production HFC-134a vehicles. Again, as in prior years, the system occupant comfort varied due to system airflow and panel outlet air temperature.

Because of the need to avoid evaporator temperatures that may cause ice accumulation on the evaporator core fin surface resulting in loss of airflow, typically panel outlet temperatures of production vehicles are limited to a minimum of 40 degrees F (4.4C). The vehicle panel temperatures recorded during the rides were in the ranges of 36 to 41 degrees F. (2.2 to 5.0C) at road speeds. This indicates the potential for possible evaporator ice formation, and the control settings have not been adequately developed for an acceptable for production system. As noted in prior years one R744 demonstration system was operating without adequate evaporator freeze protection resulting in potential core icing conditions. Panel outlet temperatures of the other R744 systems ranged from 43.7 to 46.3 degrees F (6.4 to 7.8C) as compared to 39 degrees F (3.8C) for the one vehicle noted above. This was evident when the vehicle was operated at road speed.



Graph 1



Graph 2

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2003 Weather Data [Recorded at test site]

Table 3

Weather Data

						Moisture Ratio	Enthalpy	Solar	
Tue. 7-15-03	Ambient F.	Ambient C.	W.B.F	W.B.C	% Humidity	g/kg	J/kg	Langley	Buth/ft- sq
11:30 a.m.	105	41	76	24	23	11.4	69.4	56	220
12:00 p.m.	110	43	77	25	22	12.1	73.3	51	200
12:30 p.m.	110	44	76	24	18	10.2	69.6	60	250
1:00 p.m.	110	44	77	25	20	11.7	73.4	40	160
1:30 p.m.	111	45	76	24	16	9.8	69.6	55	220
2:00 p.m.	112	45	76	24	16	9.8	69.6	25	80
2:30 p.m.	114	46	76	24	15	9.4	69.7	50	200
3:00 p.m.	115	47	75	24	13	9	69.7	49	190
3:30 p.m.	115	47	76	24	13	9	69.7	45	150
4:00 p.m.	112	45	75	24	16	9.8	69.6	5	32
4:30 p.m.	110	44	74	23	15	8.7	65.9	5	28
Average	111.3	44.6	75.8	24.1	17.0	10.1	70.0	40.1	157.3
						Moisture	Enthalpy	Solar	
Wod 7-16-03	Ambiont	Ambiont		WBC	0/		l/ka		Buth/ft_
weu. /-10-03	F	C	VV.D.I	W.D.C	70 Humidity	y/ky	J/Kg	Langley	Butil/It-
11·30 a m	107	42	76	24	21	11	69 5	85	300
12:00 p.m	109	43	76	24	19	10.6	69.5	75	295
12:30 p.m.	111	45	75	24	16	9.8	69.6	70	270
1:00 p.m.	112	45	77	25	19	11.3	73.4	69	261
1:30 p.m.	114	46	76	24	15	9.4	69.7	65	245
2:00 p.m.	114	46	73	23	13	7.9	66	50	200
2:30 p.m.	113	45	73	23	14	8.3	66	45	185
3:00 p.m.	114	46	74	23	13	7.9	66	40	160
3:30 p.m.	115	47	73	23	11	7.5	66	45	140
4:00 p.m.	115	47	73	23	11	7.5	66	45	150
4:30 p.m.	113	46	72	22	13	6.5	62.5	32	130
Average	112.5	45.3	74.4	23.5	15.0	8.9	67.7	56.5	212.4
						Moisture Ratio	Enthalpy	Solar	
Thur. 7-17-03	Ambient	Ambient	W.B.F	W.B.C	% Humidity	g/kg	J/kg	Langley	Buth/ft-
11:30 a m	100	38	72	22	23	97	62.2	20	80 80
12:00 n m	100	38	72	22	23	9.7	62.2	26	82
12:30 p.m.	100	38	74	23	20	11 1	65.7	10	50
1:00 p.m.	100	38	73	23	27	11.1	65.7	20	60
1:30 p m	100	38	73	23	27	11 1	65.7	20	60
2:00 p.m.	100	38	72	22	24	9.7	62.2	17	58
2:30 p.m.	100	38	74	23	27	11.1	65.7	12	55
3:00 p.m.	99	37	75	24	33	13	69.2	10	50
3:30 p.m.	98	37	72	22	26	10.1	62.1	10	45
4:00 p.m.	00				-			-	-
	99	38	73	23	27	11.1	65.7	10	45
4:30 p.m.	99 100	38 38	73 73	23 23	27 27	11.1 11.1	65.7 65.7	10 12	45 40

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Ride Comments

The breath level soak temperature ranged from 126 to 146°F (52-63°C) for the test periods. [Graph 3]

Occupant comfort is achieved by a combination of the panel outlet air temperature, total system airflow and the ability to direct the panel outlets toward the occupants. Reduced rear seat passengers comfort comments were greatest on systems that did not provide adequate rear seat airflow or additional rear seat outlets. [Graphs 4-5] As usual vehicles having leather seating surfaces were rated as being uncomfortable compared to fabric seats and occupants subjected to direct sun load complained.

Due to vehicle or system problems not all vehicles completed the 6 scheduled formal ride evaluations or extended idle tests.

The formal ride data for each vehicle is provided in Excel format. The individual vehicle data file has a spreadsheet containing the recorded data, a graph for comfort ratings, and a graph for breath and panel outlet air temperatures. Some vehicles had the same driver for all evaluations so their ratings are not included in the "all occupant" comfort. [CD File Ride]



Graph 3



Graph 4



Ride Summary

The following summary indicates the number of formal rides that were conducted and comments from the evaluators.

1. Vehicle A DOE Honda Civic Hybrid R134a

6 Rides

Compressor shuts off during acceleration Objectionable warm outlet air temperature Re-evaporation odor noted City traffic panel outlet temperature warm

2. Vehicle B Cadillac CTS R134a

6 rides

Reduced blower voltage change noticeable at idle Blower is noisy Insufficient airflow for rear seat passengers Ride team 1 many have been in outside air for a portion of ride

3. Vehicle C Cadillac CTS CO₂

6 rides

Evaporator odor Team 5 was on OSA for first city traffic idle Blower speed much lower during idle Right front could not adjust panel outlet airflow off body –results in discomfort Comment rear seat airflow higher than R134a vehicle

4. Vehicle D DOE Honda Insite Hybrid R134a

No rides

5. Vehicle E Chevrolet 2500HD Crew Cab CO₂

6 rides

Right front – lacked cooling to feet area Head support blocked airflow to RR Good airflow LR rear seat

6. Vehicle F Audi A4 CO₂

6 rides

Ride Team 4 reduced blower speed during ride

7. Vehicle G Volvo S40 R134a

6 rides

City traffic slow cooldown Comment on leather seat material Rear seat comfort lower area warm

8. Vehicle H DOE Prius (Gen I) Hybrid R134a

2 rides

9. Vehicle I Toyota Prius Hybrid R134a [Gen II]

6 rides

System has musty order Front seat high sun load in lap area Rear passengers wanted more airflow System cycling in P/I mode [no identification of P/I mode]

10. Vehicle J VW Touran CO₂

6 rides

Good cooldown

Rear seat outboard area hot due to sun load and air only available from rear center console outlet

Outlet air noise slightly high

Extended Idle

An addition test was included after the formal ride comparing panel outlet air and breath level temperatures during an extended idle period. The vehicles were idled for 15 minutes on outside air and recirculated air. To eliminate the effect of solar load the tests were run in a covered area. The panel outlet air and breath temperatures were recorded every 3 minutes. The data can be found in table 3.

Idle Tests

Table 3

Extended Idle Study June 2004

		Date		Start	Ambie	nt	3 min.	6 min.	9 min.	12 min.	15 min.
Vehic	le										
А	DOE Honda Civic	6-30	Rec		101	Panel Temp.	52	52	53	51	51
						Breath Temp.	68	68	67	66	66
А	DOE Honda Civic	6-29	OSA	2:45	104	Panel Temp.	55	59	63	64	64
						Breath Temp.	74	74	74	75	74
В	Cadillac R134a	6-30	Rec	1:45	101	Panel Temp.	52.7	53.8	54.7	54.5	55.4
						Breath Temp.	70	70	70	70	70
В	Cadillac R134a	6.29	OSA	3:52	104	Panel Temp.	52	54	56	57	57
		<u>Run i</u>	n Rec?	????		Breath Temp.	72	71	71	72	72
С	Cadillac CO ₂	6-30	Rec	3:45	104	Panel Temp.	48.2	48.2	46.7	45.9	45.9
						Breath Temp.	65	67	64	63	62
С	Cadillac CO ₂	6.29	OSA	3:50	100	Panel Temp.	53.6	55.2	56.7	58.8	60.1
		Run i	n rec			Breath Temp.	71	73	72	73	74
D	DOE Honda Insight	Not R	un			Panel Temp.					
						Breath Temp.					
Е	Chev. Truck CO ₂	6-29	Rec	3:44	101	Panel Temp.	46.2	45.7	44.7	45.7	45.9
						Breath Temp.	64	63	64	63	62
Е	Chev. Truck CO ₂		OSA			Panel Temp.	54	56.1	57.8	58.5	59.7
						Breath Temp.	70	72	73	74	74
F	Audi CO ₂	6-30	Rec	3:40	101	Panel Temp.	48.4	48	47.7	47.7	47.7
						Breath Temp.	67	67	67	67	66
F	Audi CO ₂		OSA			Panel Temp.	50	51	52	53.8	52
						Breath Temp.	70	70	70	70	70
G	Volvo HFC134a	6-30	Rec	3:45	101	Panel Temp.	54	55	56	56	55
						Breath Temp.	73	73	73	73	72
G	Volvo HFC134a	6-29	OSA	3:50	104	Panel Temp.	56	56	56	56	57
		Run i	n Rec?	????		Breath Temp.	78	79	79	78	76
Н	DOE Prius		Rec			Panel Temp.					
						Breath Temp.					
Н	DOE Prius	6-29	OSA	1:50	104	Panel Temp.	53.8	58.7	58.3	59.2	61.4
						Breath Temp.	72	74	75	73	73
J	VW CO ₂	6-29	Rec	1:50	102	Panel Temp.	51	47.7	47	47.7	46.8
						Breath Temp.	72	67	64	64	63
J	VW CO ₂	6-30	OSA	2:36	101	Panel Temp.	50.7	50.9	50.7	50.4	50.6
						Breath Temp.	67	66	67	66	66
I	Toyota Prius	6-30	Rec	2:45	101	Panel Temp.	49.3	49.3	48.6	47.9	47.9
						Breath Temp.	70	68	68	66	66
I	Toyota Prius	6-29	OSA	3:52	100	Panel Temp.	50.2	50.9	51.3	51.8	52
						Breath Temp.	70	70	70	70	70

"C" Cadillac CO₂ OSA point run in Rec

"C" Cadillac CO2 OSA point run in Rec

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2004 Formal Ride Schedule Table 4

Vehicle Soak and Ride

Times

Vehicle		Tuesday	y June 2	9, 2004	Team		Wednes 2004	sday Jun	e 30,	Team		Thursda	ay July 1	, 2004	Team	
	Vehicle	10:45	11:45	12:45	1:45	2:45	10:45	11:45	12:45	1:45	2:45	10:45	11:45	12:45	1:45	2:45
Group 1																
DOE Cvic 134a	Α		S	2	S	1	S	3	S	4		S	6	S	5	
Cadillac 134a	В		S	4	S	3	S	2	S	1		S	5	S	6	
Cadillac CO2	С	S	2		S	6		S	5	S	4	S	1	S	3	
Visteon CO2	F	S	4	S	1			S	6	S	3		S	2	S	5
Toyota Prius 134a	I		S	6	S	5		S	2	S	1		S	3	S	4
		10:50	11:50	12:50	1:50	2:50	10:50	11:50	12:50	1:50	2:50	10:50	11:50	12:50	1:50	2:50
Group 2																
DOE Insite Chev Truck CO2	D E	S	s 10	8 S	s 7	12		s S	11 12	s S	10 9	S	7 S	s 8	9 S	11
Volvo	G		S	11	S	10		S	8	S	7	S	12		S	9
DOE Prius 134a	Н	S	11	S	9		S	12	S	8			S	10	S	7
Valeo VW CO2	J	S	12	S	8		S	11	S	9		S	10	S	7	
12 ride teams																
s= 1 hr. soak		S														

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2004 Vehicle Specifications Table 5

Vehicle			Туре	Model	Body Style	Engine	Trans	Axle Ratio	Color Ext.	Color Int.	Windows	Seat Surface	Comp. Ratio
Group 1													
DOE	Α	1	134a	Honda Civic		hybrid							
GM	В	2	134a	Cadillac CTS	Sedan	3.6IHFV 6	5 spd auto	3.42	Gray			leather	1.36
GM	С	3	CO2	Cadillac CTS	Sedan	3.6I HFV6	5 spd auto	3.42	White Diamond	Tan	70% Trans. Min.	leather	1.36
Visteon	F	6	CO2	Audi A4	Sedan	1.91 diesel	Manual 5 spd	fwd	Dark blue	black	tinted		1.4
Toyota	I	9	134a	Toyota Prius	Sedan	hybrid	CVT auto				Solar glass		
Group 2													
DOE 2 Seat Veh.	D	4	134a	Honda Insight		hybrid							
GM	E	5	CO2	Chevrolet Silverado 2500 HD	Crew cab Pick up	6.61 turbo diesel V8	Allison 5 spd auto	3.73	Black	Dark Charcoal		Custom cloth	1.7
Volvo	G	7	134a	Volvo S40	Sedan	2.4I turbo	5spd auto		Grey metallic	Grey		leather	1:1.26
DOE	Η	8	134a	Toyota Prius (Gen I)		hybrid							
Valeo	J	10	CO2	VW Touran	MPV	1.61	manual		silver				

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Appendix A Mobile A/C System Classification

Component	Base R134a	Level I Enh R134a	Level II Enh R134a	Level I R152a	Level II R152a	Level I Second Loop R152a	Level II Second Loop R152a	Level I Second Loop R290	Level II Second Loop R290	Level I R744	Level II R744
Compressor Displacement	Variable	Variable	Variable	Variable	Variable	Variable	Variable	Variable	Variable	Fixed	Variable
Compressor Control	Internal	Internal	External	Internal	External	Internal	External	Internal	External	N/A	External
Compressor Integral Oil Separator	N/A	N/A	X	N/A	Х	N/A	Х	N/A	X	N/A	X
Condenser/Gas Cooler	Base	Enh	Enh	Enh	Enh	Enh	Enh	Enh	Enh	Enh	Enh
Integral Condenser/RD	N/A	X	X	X	х	X	X	X	x	N/A	N/A
Intercooler	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Х	x	X	Х
Refrigerant Flow Control	TVX	TXV	Elect.	TXV	Elect.	TXV	OT	TXV/OT - Acc'l	Elect.	Mech.	Elect.
Evaporator	Base	Enh	Enh	Enh	Enh	N/A	N/A	N/A	N/A	Enh	Enh
RD/Acc'l	Base	N/A	N/A	N/A	N/A	N/A	N/A	х	X	X	Х
Refrigerant lines	Base	Enh	Enh	Base	Enh	Base	Enh	Base	Enh	Base	Enh
Cost	BASE										
HVACLeak	N/A	N/A	N/A	x	x	N/A	N/A	Ν/Δ	N/A	x	x
Sensor	N// C		1 W/ X	×	×		N// C	N// (N// C	×	×
Dump Device	N/A	N/A	N/A	Χ	×	N/A	N/A	N/A	N/A	~	×
Cost	BASE	0	0			0	0	0	0		
HVAC Cooler	N/A	N/A	N/A	Ν/Δ	N/A	Base	Enh	Base	Enh	N/A	NI/A
Chiller	N/A	N/A	N/A	N/A	N/A	Base	Enh	Base	Enh	N/A	N/A
Coolant Pump	N/A	N/A	N/A	N/A	N/A	Base	Enh	Base	Enh	N/A	N/A
plumbing <u>Cost</u>	BASE	0	0	0	0					0	0
HVAC Controls	Manual	Manual	Auto	Manual	Auto	Manual	Auto	Manual	Auto	Manual	Auto
<u>Cost</u>	BASE	0	0	0	0					0	0
Total Cost	BASE										
Cooling	BASE										
Performance	DAGE										
<u>System</u> <u>Refrigerant</u>											
Svstem Leakage	57	25/30	25/30	30/35	25/30	15/20	10/15	15/20	10/15		
Estimate G/vr Leakage *GWP	BASE										
GWP Rating Relative To	Base	1300	1300	78	78	78	78	9, [VOC]	9, [VOC]	1	1
Annualized	BASE										
<u>energy</u> System Mass	BASE										
Ka											

WA 2 March 2004

Appendix B Mobile A/C System Emissions

Proposed System "Leakage Chart"

April 4, 2004

Current industry standards do not exist for determining refrigerant emissions from mobile air conditioning systems. Test procedures are not common between production component suppliers in establishing leakage values.

This System Assumption "Leakage Chart" has been developed from industry experience of expected refrigerant leakage gains from system design changes.

It allows a comparison and rating value of various technologies that are currently available.

The "Leakage Chart" should be expanded as new technologies are offered and/or developed.

Examples of a system are found in the "Sample" Excel file.

The Excel file "Template" is a blank "Leakage Chart" for making system analysis.

Assumptions for R134a Leakage Chart spreadsheet

1. Not all leak paths can be determined with a high level of accuracy for real world conditions due to

Assembly Variation Wear & Degradation Affects of vibration and localized temperatures

- 2. The values in this spreadsheet apply to systems as delivered to the customer.
- 3. Due to lack of standard tests, reference values used here are agreed upon placeholders until tests are defined and evaluations completed.
- 4. Fitting reference values are a function of leakage and "assembly robustness".
- 5. Rigid pipe connections are those tube and pipe assemblies with no hose joints. Leakage occurs only at the two fitting connections at either end.
- 6. Flexible hose assemblies include tube, hose and crimping. Leakage occurs through the hose and at the crimps. The leakage at the tube fitting connections at either end is included in the "System Component Connection" category.
- 7. Hose permeation rate is a function of location, material, and inner area. An Industry standard does not exist for "ultra-low" permeation hoses It is assumed veneer hoses use an adhesive or O-rings for crimps It is assumed that high-pressure hoses permeate at twice the rate of low-pressure hoses due to higher temperatures and pressures when in operation, but leakage is the same when the vehicle is static. Hose permeation rates include leakage from the tube/hose crimps
- 8. Compressor major permeation paths are shaft seal and housing seals. It is assumed that multiple lip shaft seal better than single lip seals

Dust seals shall not count as secondary refrigerant seals unless shown to reduce leakage levels.

It is assumed that gasket housing seals are better than O-rings

- 9. Assumes that caps with integrated seals are installed on all refrigerant system service fittings.
- 10. Heat exchangers are considered as robust and the Leakage Chart assigns a value of .001 for their emissions.
- 11. The rating Values are:
 - < 5 (greater than) Standard Leakage
 - 4 Leakage Enhancement Level I
 - 3 Leakage Enhancement Level II
 - 2 Leakage Enhancement Level III
 - 1 (less than) Leakage Enhancement Level IV

Sample							
	Lea	kage Chart					
System Component Connection		ž					Calculated
Fittings							Value
Rigid Pipe Connections and Flexiable	Single O-ring	Single Captured	Multiple O-ring	Seal Washer	Seal Washer	Metal Gasket	Do Not Enter
Hose Connections	о о	O-ring			with O-ring		Data
Total Emissions	125	75	50	10	5	1	
Number of fittings:	9	1		2			1.220
High Side service port							
Total Emissions	60	60	40	10	5	1	
Number of fittings:	1						0.060
Low-Side service port							
Total Emissions	40	40	25	10	10	1	0.040
Number of fittings:	1						0.040
PRV, Switches, Transducers	10	10	05	10	40		
I otal Emissions	40	40	25	10	10	1	0.400
Number of fittings:	2	1				F 101 F 11	0.120
			Ontendente d			Fittings Lota	1.440
			Calculated	Turner	411		-
Flexible Hose Includes Hose and Hose Counting	Longth	Diameter	Surface Area	All Dubbor Hose	Of Hose Standard Parrier	Liltro Jow Dorm	Do Not Entor
Crimps [End Connections included in	Imml	Imml	Do Not Entor	All Rubbel Hose	or Vopoor Hoso	Barriar or Vancor	Do Not Enter
Component Connection	[iiiii]	[rinii]	Data		or veneer riose	Hose	Data
			Dulu			TIOSC	
High processes line 1	650	10	20420		1		0.021
High pressure line 2	650	10	20420				0.231
High pressure line 3			0				0.000
High pressure line 4			0				0.000
Low pressure line 1	650	16	32673	1			1.470
Low pressure line 2			0				0.000
Low pressure line 3			0				0.000
Low pressure line 4			0				0.000
TOTAL	[place hose size i	n appropriate cell]		[place a "1" in the	appropriate cell]	Hose Tota	1.701
Heat Exchangers							
A							0.004
Assumption = 0.001	the extension of the second				H	eat Exchange Total	0.001
	Ineat exchanger				Ineat exchanger		
	value pre-set				value pre-set		
	Value 1				Value II		
Comprossor							
Compressor		Type of seal					
	Single Lin+ Body	Single Lin+Body	Multiple Lip and	Multiple Lip +			Do Not Enter
	O-rings	Gaskets	Body O-rings	Gaskets			Data
Total Emissions	2500	2000	1200	700			
Compressor	1					Compressor Total	2.500
		[place a	"1" in the approp	riate cell]			
Summary	% Contribution						
Fittings	25.5%	1	9	6 System Compone	ent Contribution		



¹²⁻Apr-04

See CD File: Workshop Ref. Emissions for additional information

Hoses 30%

Appendix C SAE IRCRP

Project Teams

Refrigerant Leakage

Description of	Lead Investigator
<u>Technology</u>	
Improved Crimps	Gene Dianetti/Chhotu N. Patel
Improved fittings	Gene Dianetti/Chhotu N. Patel
Compressor shaft seal	Jacob Bayyouk /Ned Wolfe
Hose Permeation	Brad Haines
Service valves/caps	Fred Schroeder/S Major
Evaporator	Markus Wawzyniak/Ned Wolfe
Condenser	Markus Wawzyniak/Ned Wolfe
Receiver/Accumulator	
Material integrity-tubing	Hans Ferqvist
Reduced number of joints	G. Dianetti/C. Patel/C. Thrift
TXV	Dennis Littwin
Transducer/switches	Texas Instruments
Manufacturing specifications	Joe Rahaim
Leakage Test Procedure	
End of life leakage	
Robust Manufacturing	Joe Rahaim

System Efficiency <u>Compány</u> anden

Name	Company
Jacob Bayyouk	Sanden
John Burrow	ITW
David Barwin	Nissan
Mahmoud Ghodbane	Delphi
John Busch	Hyundai
Alan Cohen	UOP
John Meyer	Visteon
Erin Birgfeld	EPA
Mark Spatz	Honeywell
Steve Lepper	Ford
Gene Dianetti	Parker
Joe Rahaim	DCX
Markus Wawzyniak	Behr
Bill Hill	GM

System Efficiency

Description of	Lead Investigator
<u>Technology</u>	
Improved Heat Exchangers	M. Ghodbane/M.
	Wawzyniak
External Control	Bill Hill
Compressor	
Internal Heat Exchanger	Pega
Scroll Compressor	David Barwin
Fixed vs Variable	Steve Lepper
Compressor	
Oil Separator	Bill Hill
Ejector system	Bill Hill
Increased Condenser	Joe Rahaim
Airflow	
Increase use of RECIRC	Joe Rahaim
airflow	
Reduced Front End	Joe Rahaim
Recirculation	
Insulated suction line	Gene Dianetti
Optimized compressor	Bill Hill
efficiency	
Improved Control Algorithm	Bill Hill
Reduced low side pressure	Gene Dianetti
drop	
Flash gas removal	Pega
"Digital" Scroll	David Barwin
Improved distribution	David Barwin

Vehicle Integration Issues						
Name	<u>Company</u>					
John Busch	Hyundai					
John Rugh	NREL					
Greg Major	GM					
John Meyer	Visteon					
Roland Gravel	DOE					
Ser	vice					
Name	Company					
Elvis Hoffpauir	MACS					
Jim Baker	Delphi					
Paul Weissler						
Tom Potter	Denso					

CD FILES

- Report
- Attendees
- Presentations
- Ride Includes vehicle data Comfort and Temperature Graphs
 - o Idle
 - Weather
- Workshop
 - Refrigerant Emissions
 - Washington Summit
 - Workshop Doc.

Appendix D 2005 Meetings

Meetings 2005

- SAE J Refrigerant Meeting Japan Jan. 25-27 in Tokyo
 - MACS Convention Las Vegas February 1-3 2005
 - VDA Alterante Refrigerant Winter Meeting Saalfelden, Austria February 22-24, 2005
 - MAC 2005 Summit Proposed Mid Feb
 Hosted by California ARB
 - SAE Congress Detroit April 11-14, 2005
 - VTMS7 Toronto, Canada May 9-12, 2005