SAE Improved Mobile Air Conditioning Cooperative Research Program

VDA Winter Meeting
15FEB2006

Improved MAC [IMAC] Program Objectives

- **Reduce direct and indirect HFC-134a refrigerant emissions from mobile A/C systems**
- **Provide a directly comparative engineering evaluation**
  - **Component Technologies under development**
  - **Vehicle and system control strategies**
  - **Design of service equipment, fittings, and methods**

I-MAC Overview

- First Invitation to join CRP 22APR04
- Four Teams formed in Fall 2004
- Financed by $3 million in Industry and Government funds
- Matching In-kind contributions by Industry
- Two year program
- Demonstration at Phoenix Forum 2006
- First Interim report published in Dec., 2005

Improved R134a Project Teams

	Team1	Team2	Team3	Team4
Team Name:	Refrigerant Leakage Reduction	AC System Efficiency Improvement	Vehicle Load Reduction	Service refrigerant loss Reduction
Number of Team Members:	23	19	6	25
OEM's:	4	5	2	5
Tier1's:	13	10	1	9
Others:	6	4	3	11
Goals:	50% Reduction in leakage	30% Increase in COP	30% Load Reduction	50% Reduction in refrigerant losses

IMAC Sponsors [28]

- Arkema Inc.
- Audi
- Behr
- BMW
- DCX
- Delphi
- Denso
- DuPont
- Ford
- Fujikoki
- General Motors
- Goodyear
- Honeywell
- Ineos Fluor
- Japan Fluor Mfg Assoc
- Modine
- Manuli
- Nissan
- Parker Hannifin
- Sanden
- Schrader-Bridgeport
- Solvay
- TI Automotive
- Toyota
- Trelleborg
- Viking Plastics
- Visteon
- Volkswagen

Team 1 - Refrigerant Leakage Reduction

- **Scope:**
  - **Identify Technologies To Reduce Mobile A/C System HFC-134a Refrigerant leakage by 50%**

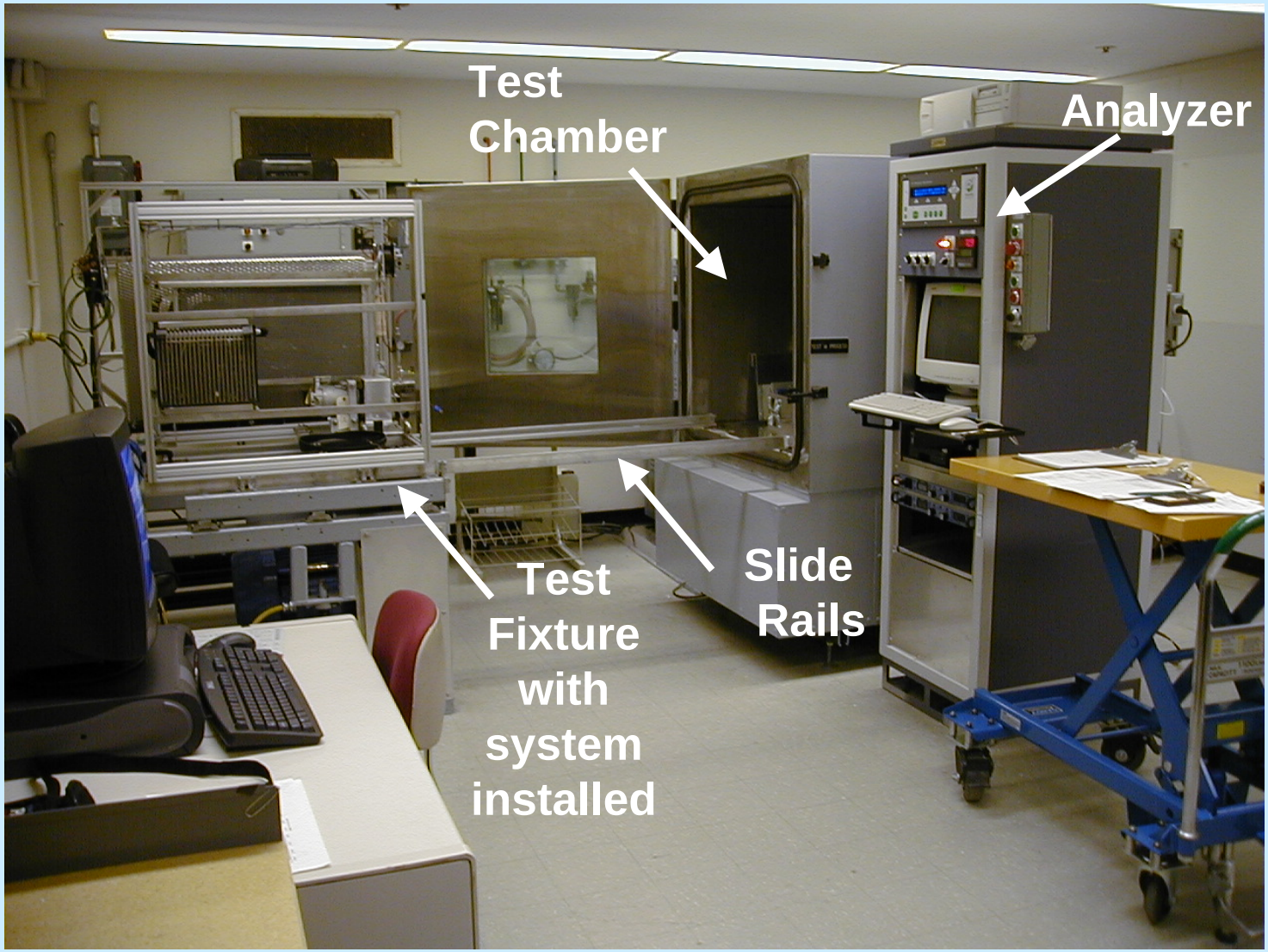
Team 1 Technologies

- Compressor:
  - Reduce (eliminate) / less body seals
  - Lip Seal
    - Improved (different design)
    - Tighter tolerance
    - Improved concentricity (better balance for reduced vibration)
- Hose:
  - Near "zero" permeation
- Seals:
  - Dual seals
  - Seal washers
  - Metal seals

Team 1 - Status

- **Repeatable test method and test cycle has been developed for system level mini-shed testing**
- **Initial baseline testing has shown system leakage rates of 5-8 g/y depending upon the climate**
- **Initial standard for leakage test developed**

Mini-Shed Testing



Mini-Shed Emission Test Sequence

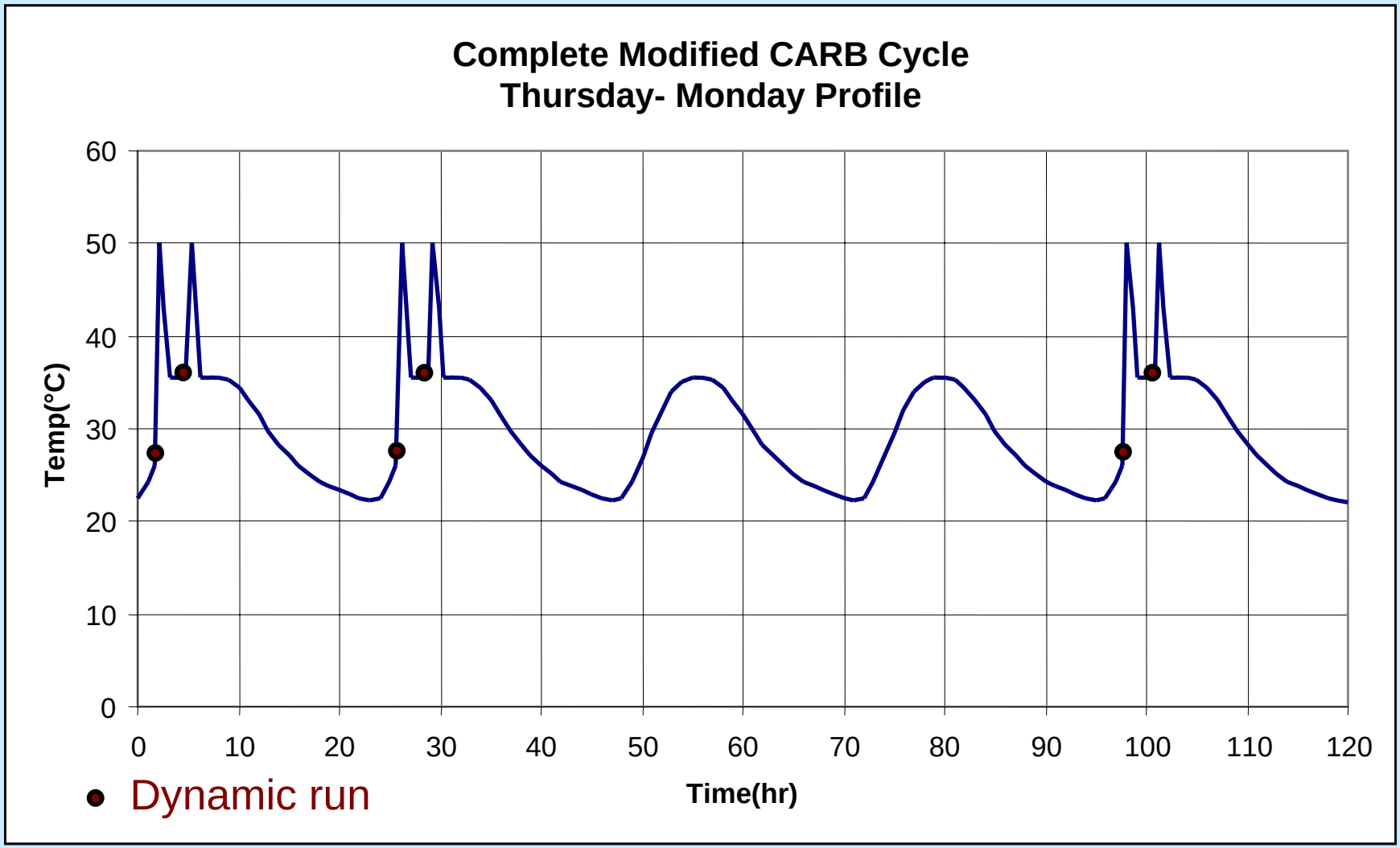
IMAC

1. System Pre-Conditioning for 10 days @ 35ºC
2. Operate compressor for 30 minutes @ 2000 RPM to distribute refrigerant and lubricant to seals
3. Emission Test temperature cycle includes two dynamic operations per day to simulate morning and afternoon drives plus weekend non-use [120 h]
4. Emission Rate calculated Emissions = 4*(Average emissions of first two day cycles) + emissions from 48 hour static + emissions from 24 hour cycle after static
5. No Correlation to fleet test

ACEA Proposed

1. System Pre-Conditioning for 20 days @ 40ºC [varies for individual parts]
2. Operate compressor for 1 minute at 250 RPM [optional]
3. Emission Test temperature static at 40ºC for 24-96 hours [until stable]
4. Emission Rate calculated Emissions = $C*[P_{inside}^2 - P_{outside}^2]/\mu$
5. Correlation to vehicle fleet test [multiply lab result at 40ºC by 0.280]

Proposed Test Cycle



Dynamic runs are synchronized with test chamber ambient temperature profile
[Second profile run with ambient range of 13-23ºC]

Team 2-System Efficiency

- **Scope:**
  - **Improve HFC-134a Mobile Air Conditioning Systems COP (Efficiency) by 30% Over Enhanced R134a system of the ARCRP**

Team 2 Technologies

- Compressor:
  - Improved piston compressors
  - Alternative technologies
- Heat Exchangers:
  - Improved Effectiveness evaporators and condensers
  - Internal heat exchangers
- Controls:
  - Optimized superheat controls
  - Optimized Sub-cooling controls
  - Optimized compressor controls
  - Flash gas removal
- Other items:
  - Optimized plumbing
  - Control of re-circulation

Status – Team 2

- Improved compressors have yielded ~15% improved COP
- Improved Controls have yielded ~25% improved COP
  - Together these two changes have yielded 32% improved COP
- Addition of IHX improves COP 6-26% [most beneficial at 15°C]
- Additional technologies will be evaluated before Summer of 2006
- Demonstration vehicle being prepared for Phoenix in June
- Initial draft of standard on measuring energy consumption has been drafted

Efficiency Test Standard Proposals

IMAC

1. Steady State Test Bench data
2. Annualize based on Visteon weather data analysis and NEDC drive schedule speeds
3. Not life cycle based
4. Direct emissions handled by Team 1 & 4
5. Cooling demand based on mid-sized vehicle

B-Cool Proposal

1. Dynamic drive on NEDC cycle-vehicle test or bench test simulation
2. Annualize based on average European climate data-drive time in day time only
3. Includes life cycle analysis
4. Includes direct emissions effects
5. Cooling demand based on B-size vehicle

Team 3-Vehicle Load Reduction

- **Scope:**
  - **Reduce vehicle soak and driving heat loads by 30% over current production vehicles to reduce A/C system cooling requirements**

Status – Team 3

- **The following have been demonstrated:**
  - **Ventilated vehicle**
  - **Reflective paint**
  - **Reflective glass**
  - **Improved Insulation**
- With solar fan and reflective films on windows & roof the following reductions in temperatures have been achieved:
  - Dashboard: 14C cooler
  - Breath level air: 10C cooler
  - Front seat surface: 7C cooler
  - ~20-25% load reduction estimated
- **Model is being developed to show impact on vehicle load**

Team 4 –Reduction in Refrigerant Loss During Servicing

- **Scope:**
  - **Reduction of Refrigerant Loss During Service and at end of life by 50 %**

Team 4 - Status

- **Standards**
  - **I-MAC Recovery and Charging**
    - **Will drive improvement in equipment**
  - **Leak Detection Standard**
    - **Sweep test past a 4 gr/yr calibrated leak, probe moving at a rate of 3 in/second.**
    - **Clear in a contaminated atmosphere test (500 ppm) within two seconds**
    - **Test for leak detection against a 14 g/yr calibrated leak on a mid-position of the detector**
- **Communication**
  - **Automotive Recyclers Association meeting**
  - **Website Link**

Reclaim Standards

Large potential impact on emissions...

Average System Charge	795 grams		With 20 million recoveries/y	With 25 million recoveries/y
	% Not Recovered	Grams	Annual Emissions [kg.]	Annual Emissions [kg.]
Refrigerant Not Recovered	30%	239	4,770,000	5,962,500
	25%	199	3,975,000	4,968,750
	20%	159	3,180,000	3,975,000
	15%	119	2,385,000	2,981,250
	10%	80	1,590,000	1,987,500
	5%	40	795,000	993,750

"…an estimated 20 to 25 million automotive A/C systems are serviced annually…"
Increasing Summer Profits with A/C Work, Larry Carley, Brake & Front End, 3/2005

Reducing refrigerant left in system at recovery could reduce emissions by millions of pounds at service annually.

5 to 27 g/y Improvement

Vehicle Salvage

1.6 to 2.2 Million+ kg. at stake...

Average Remaining Charge:450 grams	
Vehicles Scrapped Annually in USA: 12 million	
Emissions if 30% have retained charge	Emissions if 40% have retained charge
1,634,400	2,179,200

Studies done in New Jersey and California suggest that 30% to 40% of vehicles arriving at end of life have an average refrigerant charge of one pound in system.

Better compliance and improved recovery techniques needed to reduce emissions.

7 to 10 g/y Improvement

Container Heels

3 Million pounds at stake...

Average Can Charge: 340 grams Cans sold annually in USA: 35 million	
Heel %	Emissions/y [kg]
1.3%	154,928
1.8%	214,515
1.9%	226,433
7.5%	893,813
10.0%	1,191,750

1 to 5 g/y Improvement

Less than 1 g/y Improvement

Average Cylinder Charge: 13.6 kg Cans sold annually in USA: 1.1 million	
Heel %	Emissions/y [kg]
4.3%	644,226
12.0%	1,797,840
26.0%	3,895,320

If heel is reclaimed, these losses can be eliminated!

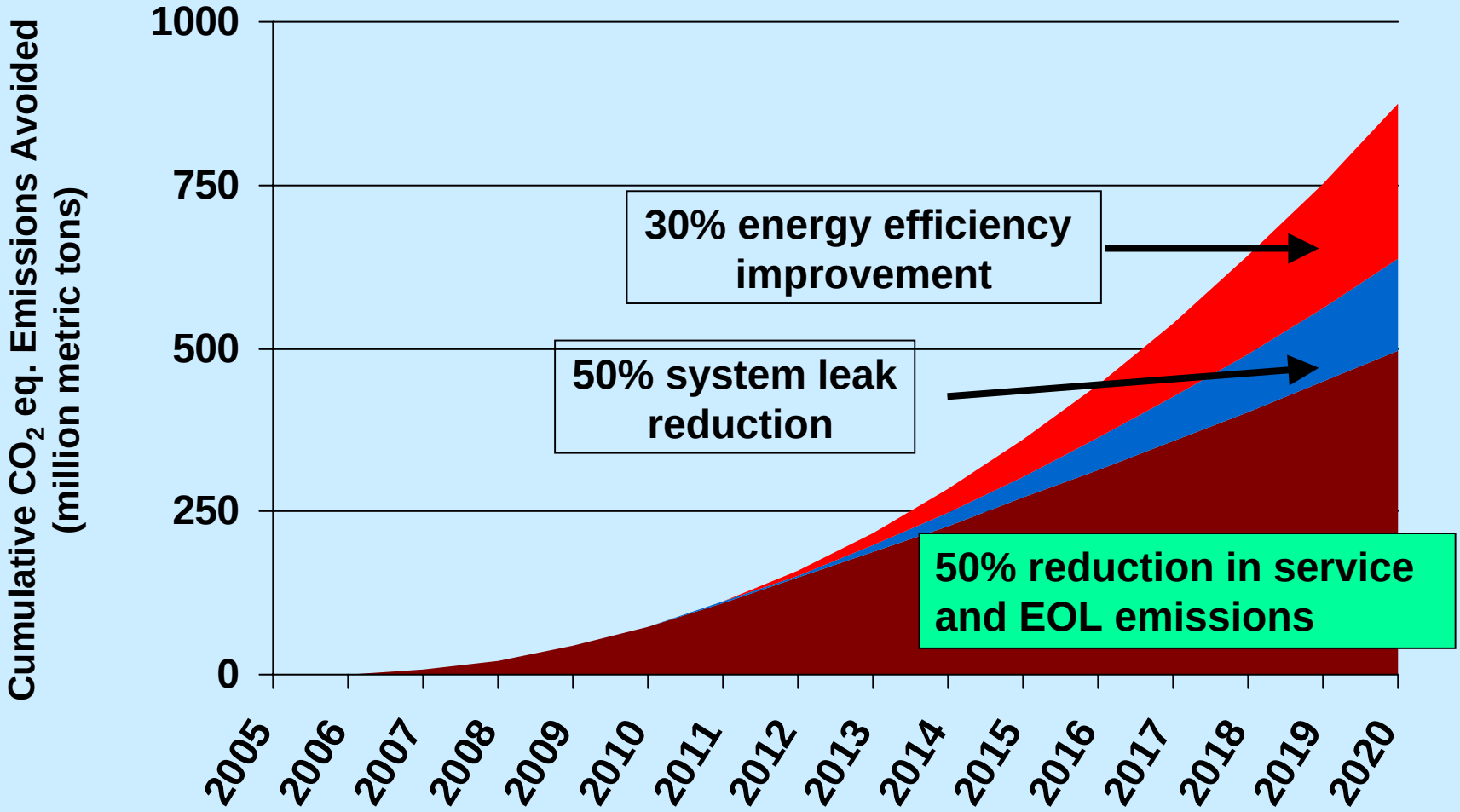
Summary of Service Impact

- **Summary of Fleet impact in grams/yr refrigerant release**

[A/C Vehicles US fleet (221,575,336)]

	High		Low	
Small can heel	**5.4**	**10%**	**1.1**	**2%**
– 35 Million cans				
13.6 kg. Container	**0.6**		**0.1**	
– 1.1 Million containers				
12 Million Salvage	**9.8**	**40%**	**7.4**	**30%**
– 1 pound recovery on 40 and 30% of salvage vehicles				
Service Recovery	**26.8**	**70%**	**4.5**	**95%**
– Refrigerant recovery at service efficiency 70 – 95% of charge removal				
Total Release gr/yr per operational A/C fleet				
	42.6		**13.1**	

CO_2 equivalent emissions avoided with HFC-134a I-MAC global implementation



I-MAC CRP Project

- **$3+ Million Project Budget**
  - **Two Year Project [2005 and 2006]**
  - **Funded By Industry and Government**
- **Key results to date**
  - **Dynamic leakage bench test developed**
  - **Efficiency improvements greater than 30% identified**
  - **Load reduction technologies greater than 20% identified**
  - **Service improvement opportunities identified**
    - **Standards for new procedures and equipment are developed**

Thank You