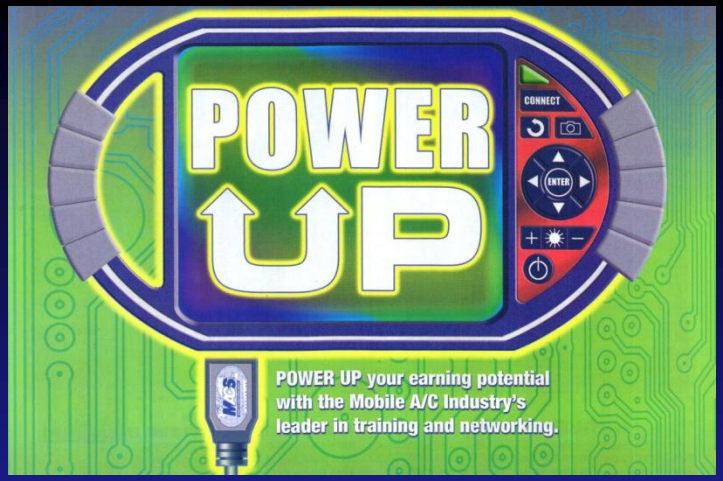


State of the Industry

New Orleans, LA
January 17, 2014
Ward Atkinson

2013 Field Service Vehicle Data

2013 MACS Field Survey

- VEHICLE INFORMATION
- VEHICLE SERVICE HISTORY
- PRIMARY REASON FOR SERVICE

2013 MACS Field Survey

Survey Information

- The survey was provided by 17 service facilities located in 12 states and New Zealand
- The service facilities have provide service profiles on 629 vehicles
- This is a preliminary report on only 507 service reports
  - The additional service information will be included in the final report at a later time

2013 MACS Field Survey

Survey consists of two groups (507 vehicles)

- **85 Vehicles 16.8% Produced 1994 MY and Earlier**
  - **Vehicles include Operational:**
    - **R-12 systems**
    - **Retrofitted R-12 to R-134a Systems**

      Early R-134a Systems
- **422 Vehicles 83.2% Produced After 1995 MY**
  - **MAC Systems Are R-134a Refrigerant**

2013 MACS Field Survey

- **17 Facilities 507 Service Reports**

Arizona	Nebraska
Arkansas	N. Carolina
California (3)	Ohio
Florida (2)	Pennsylvania
Georgia	Tennessee
Kentucky	Wisconsin

New Zealand

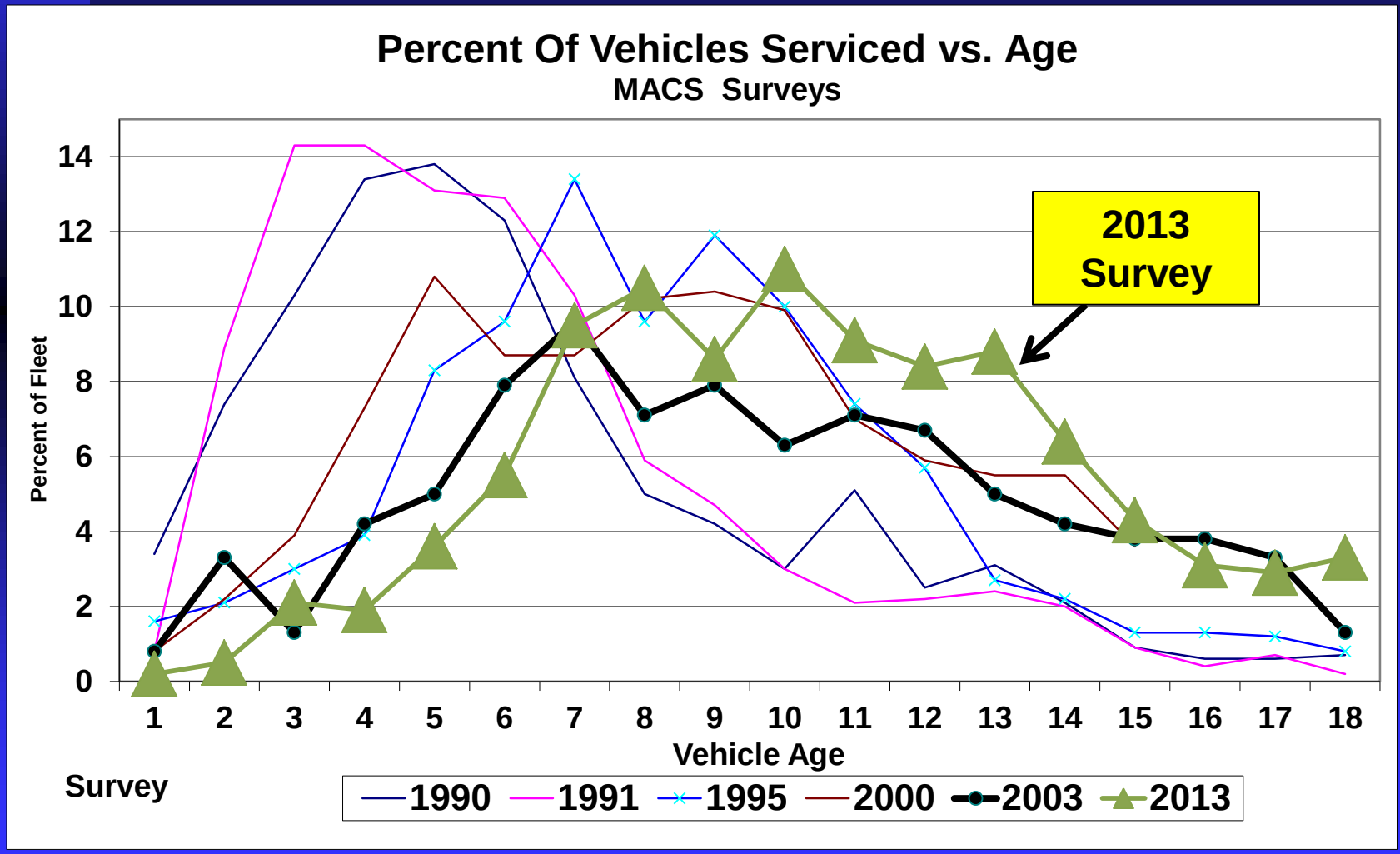
2013 MACS Field Survey

- Vehicles manufactured from 1994 MY and prior
  - 38.9% (33) were still operating with R-12 Refrigerant
  - 60.2% (50) were operating with R-134a including those retrofitted from R-12
- Vehicles manufactured in 1995 MY and later (424) are R-134a systems
  - 2.6% (11) of the fleet were Hybrid vehicles (Most had leaking condenser)

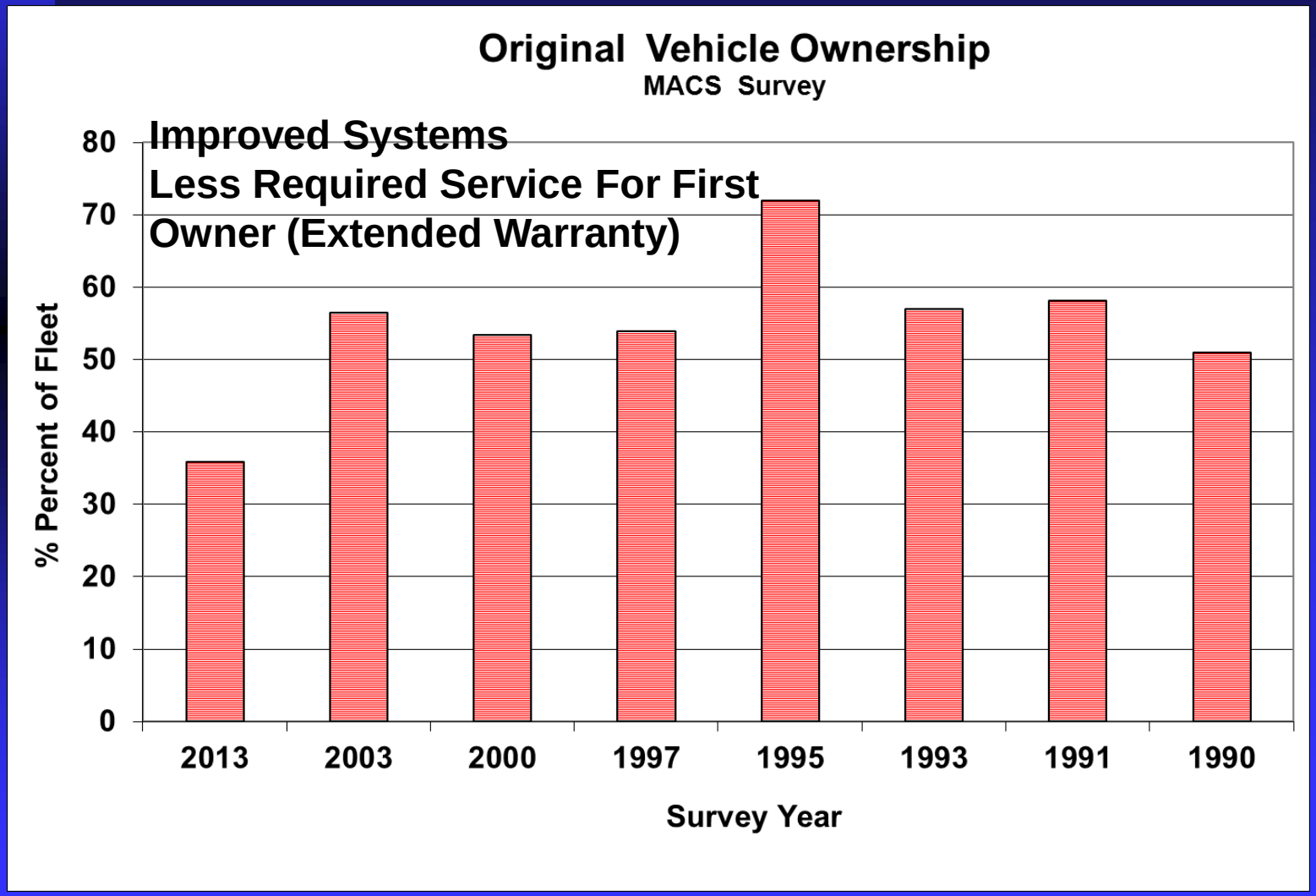
2013 MACS Field Survey

- 39.4% Had been serviced by the facility before
  - Those identified prior service period had been 1.1 years
- 69% of the fleet had refrigerant circuit service
  - 87.4% of the leaks were found
- 23.1% of the fleet had control service
- 8.1% of the fleet had a compressor clutch failure (Failures were indicated as electrical)

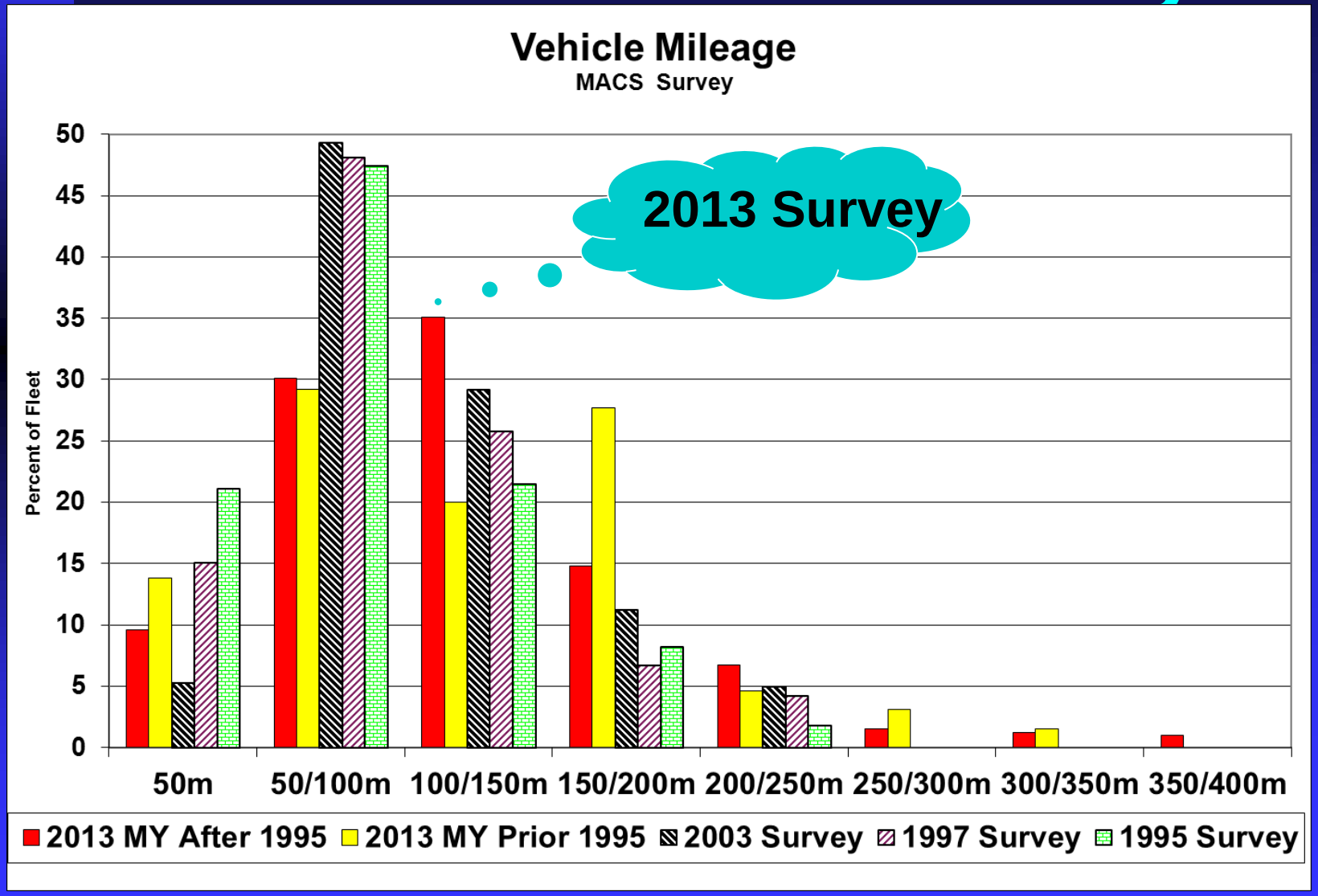
2013 MACS Field Survey



2013 MACS Field Survey



2013 MACS Field Survey



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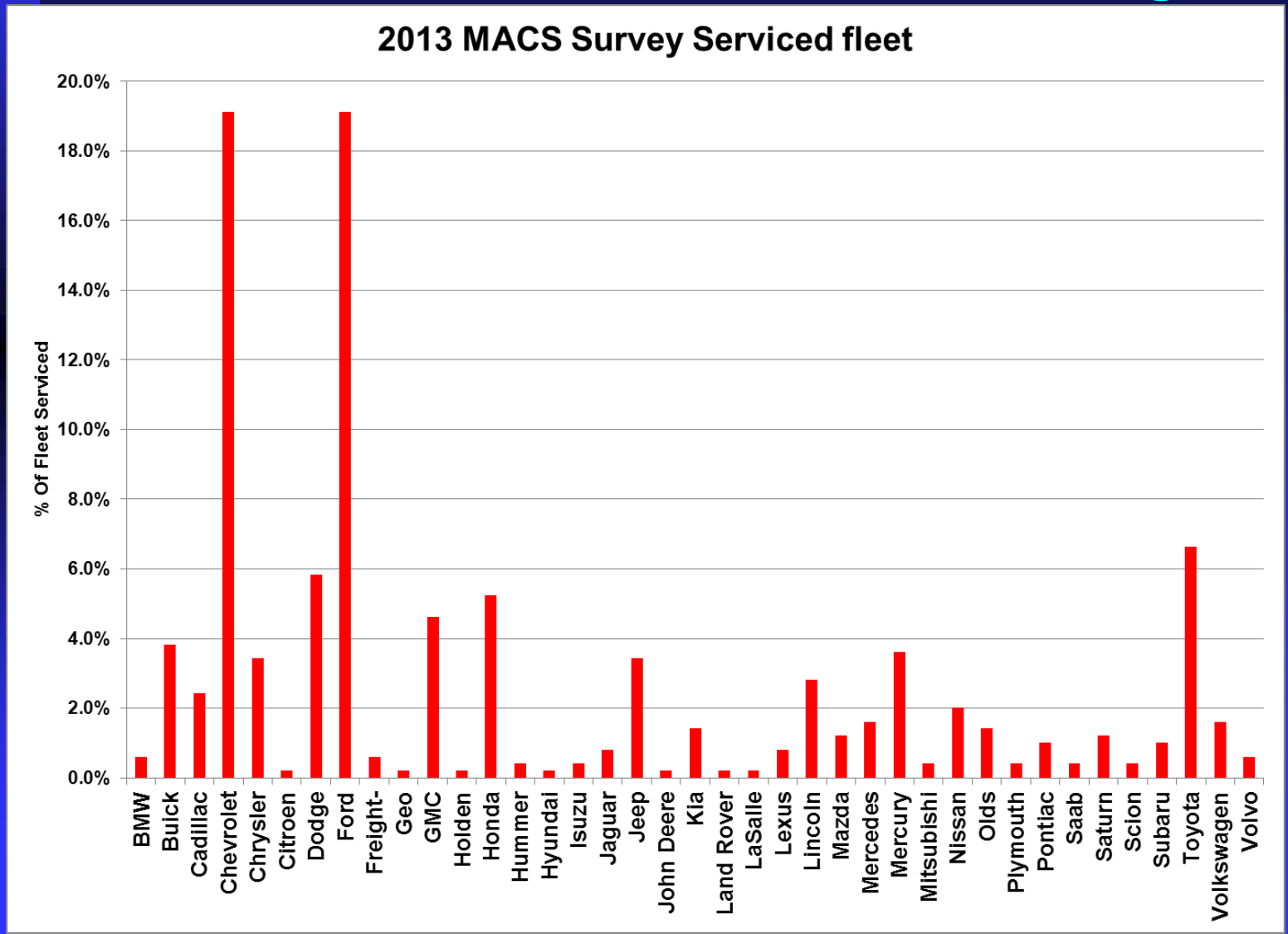

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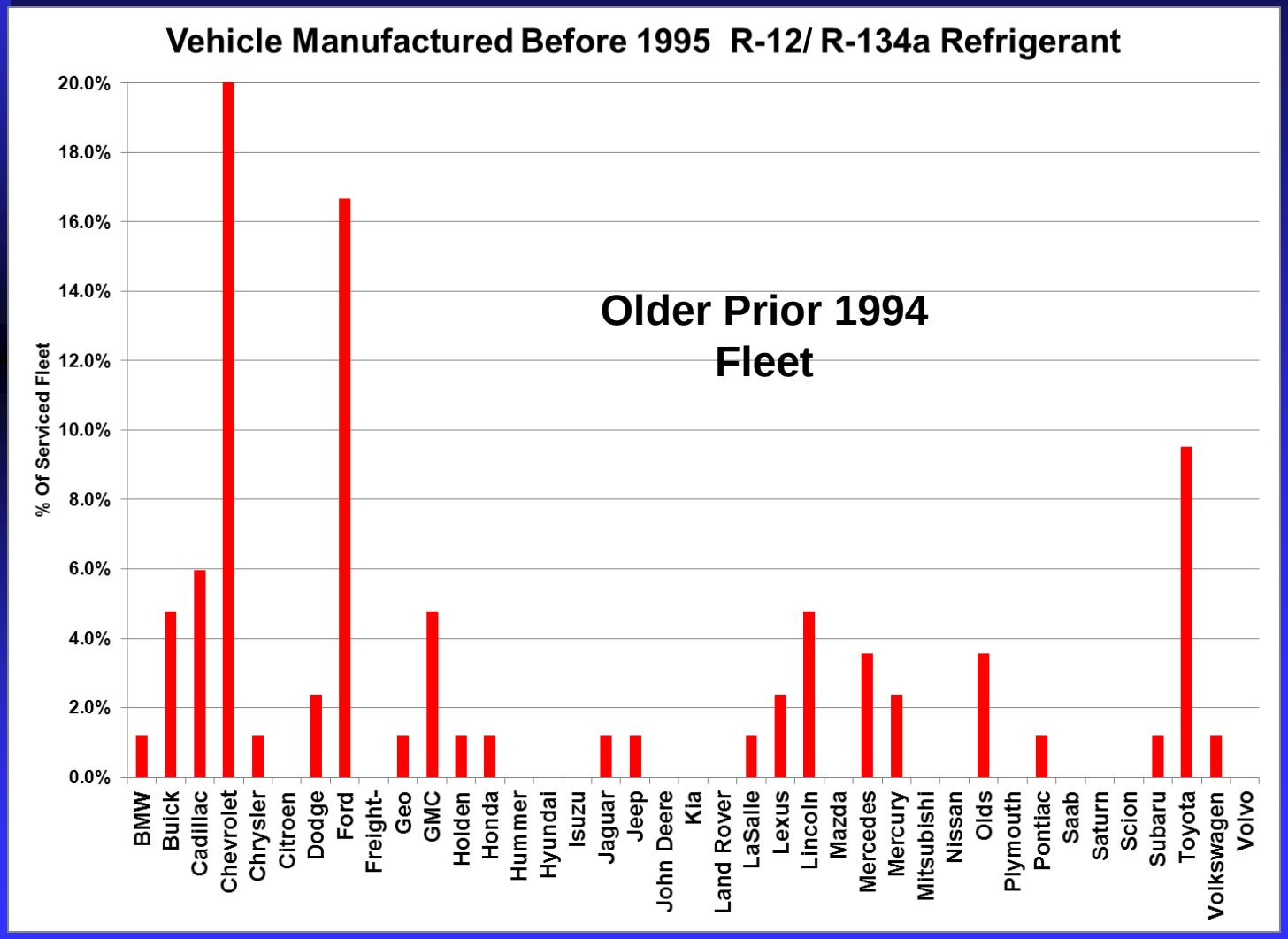
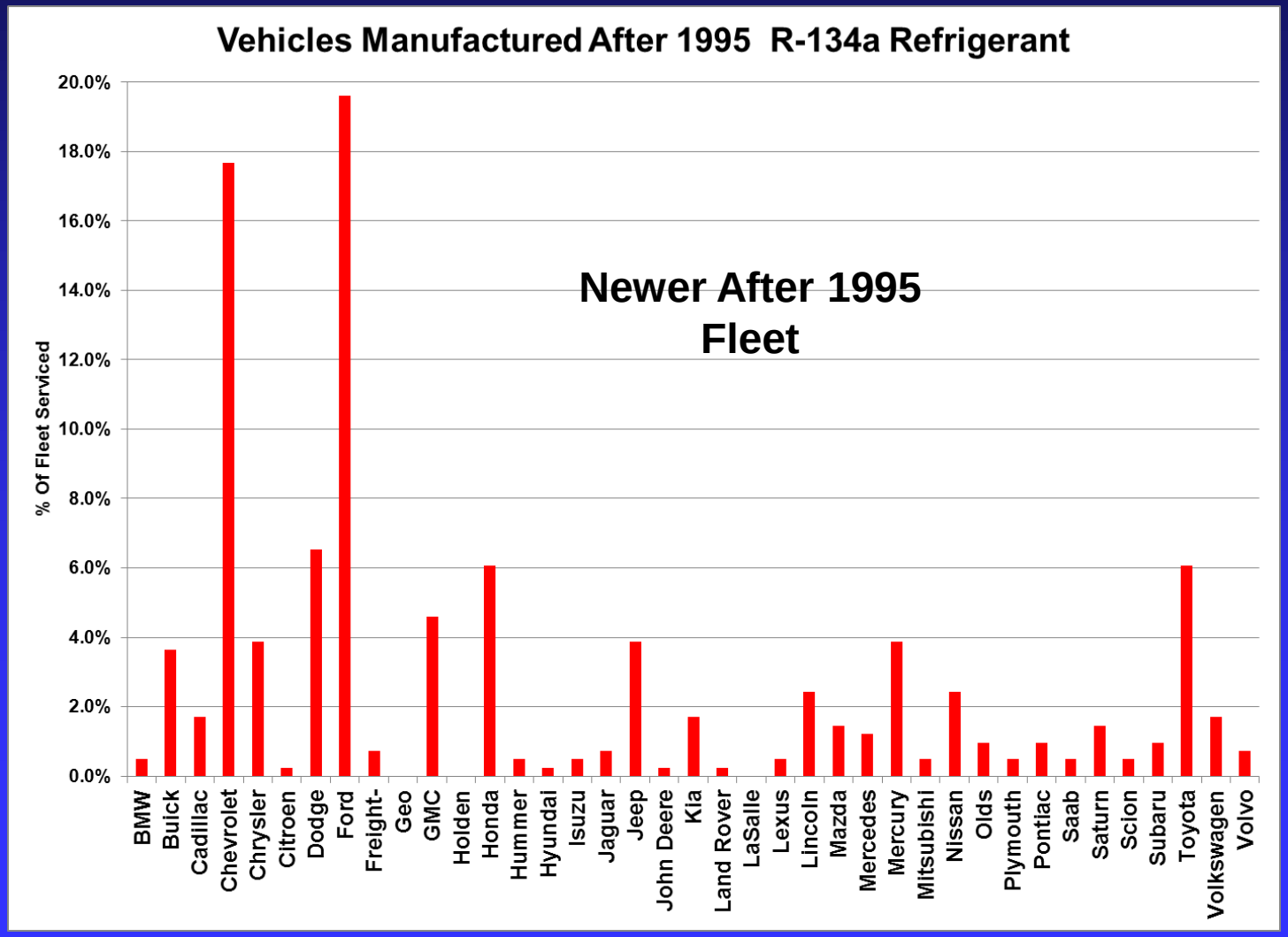


2013 MACS Field Survey



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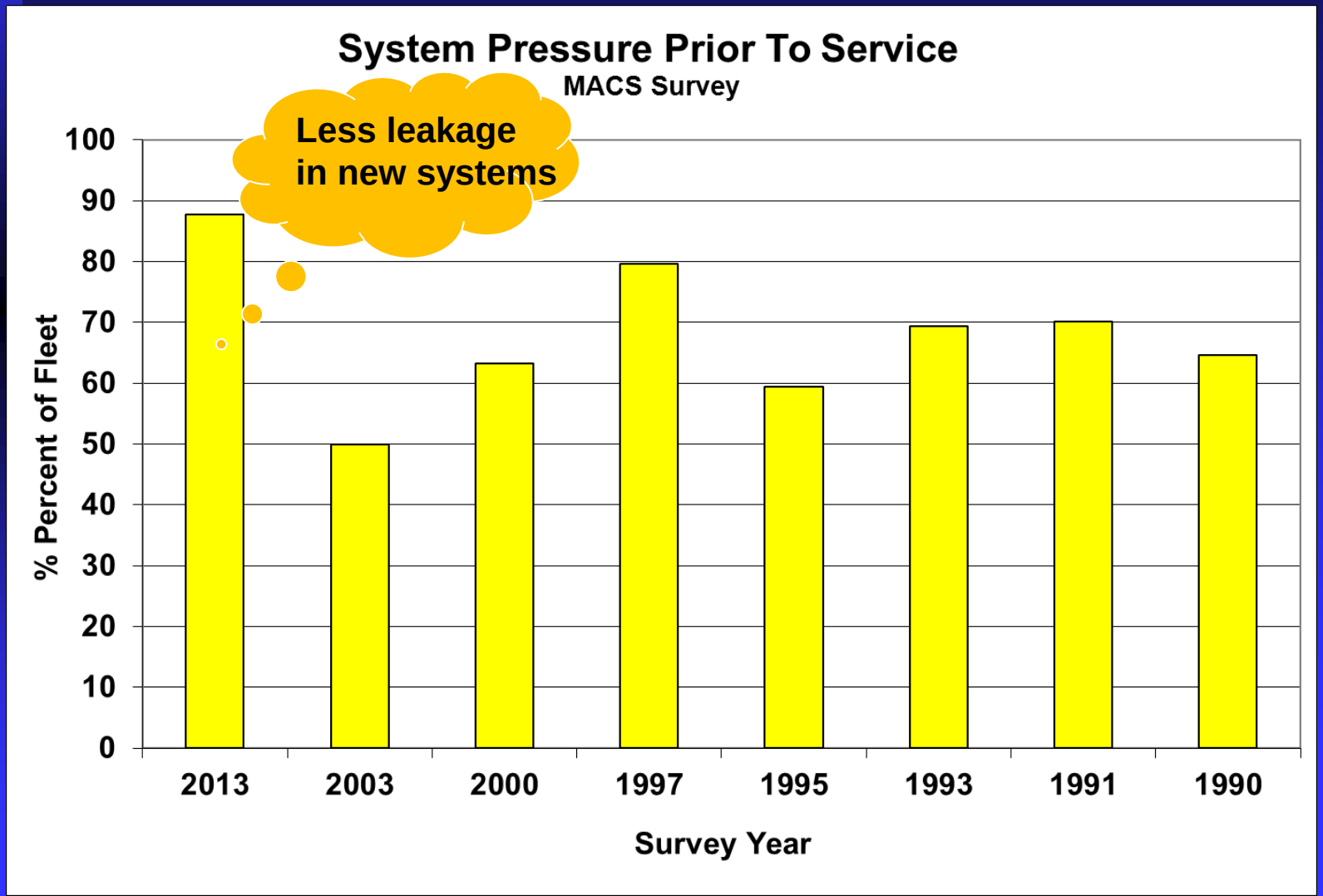

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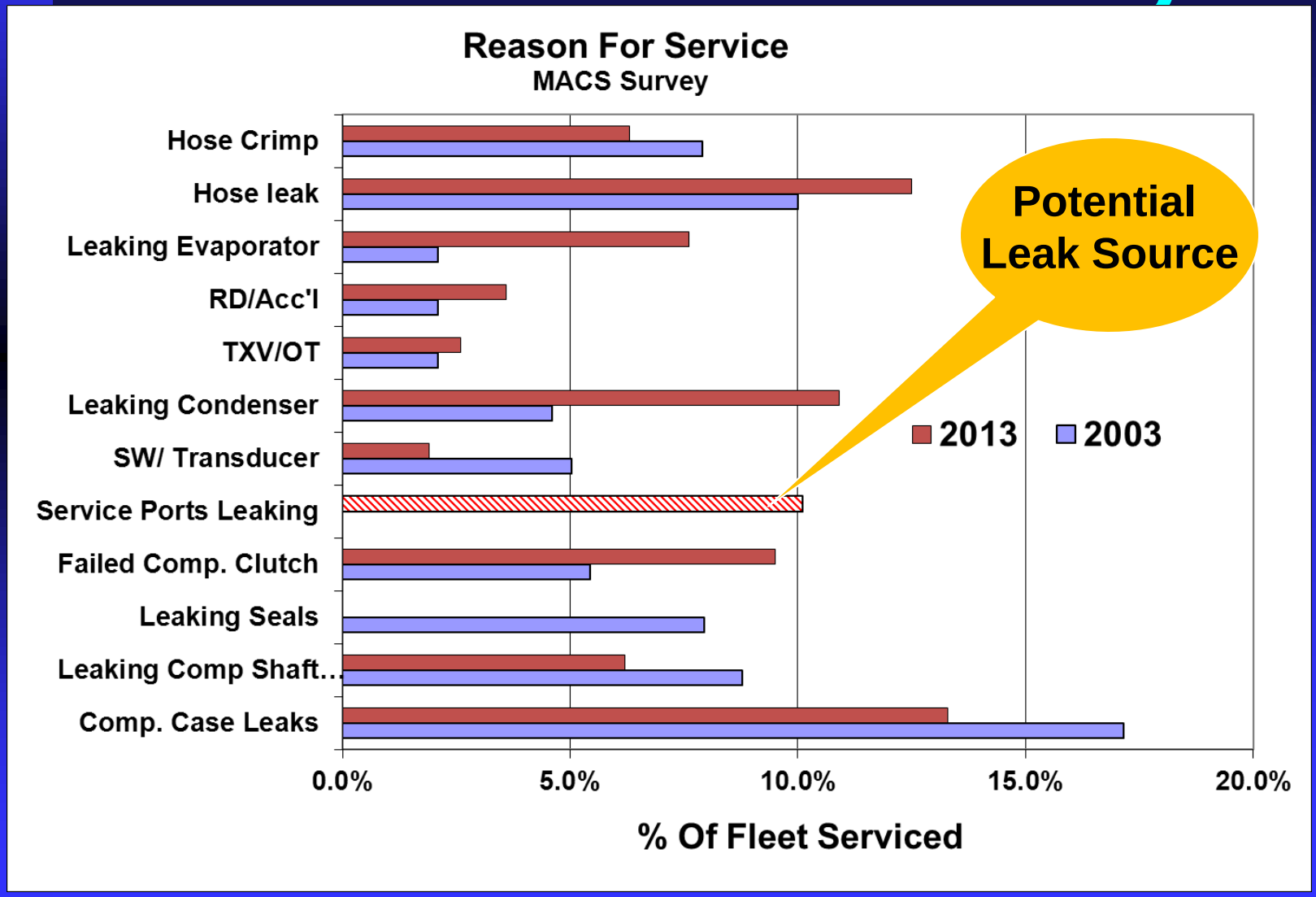

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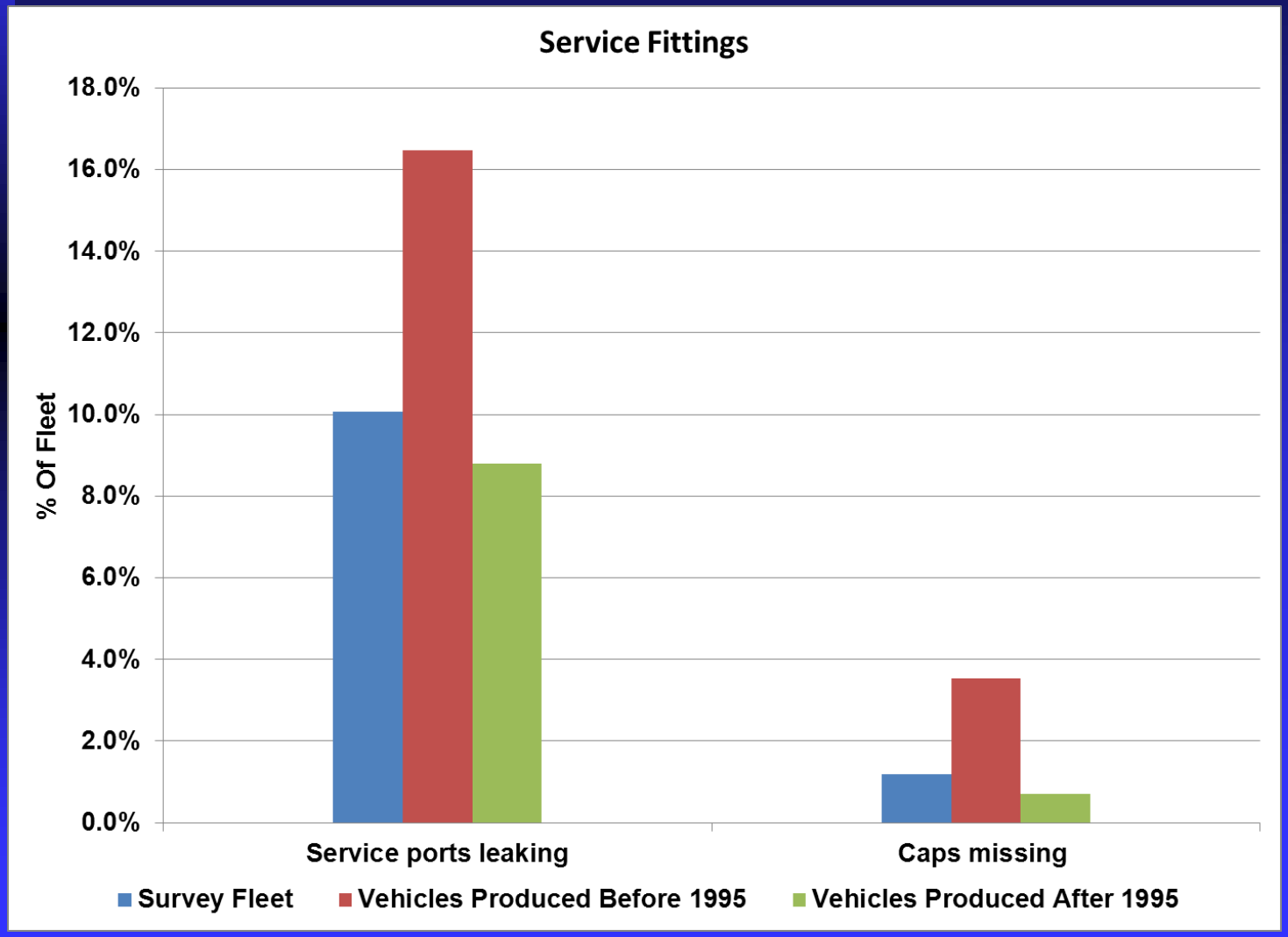

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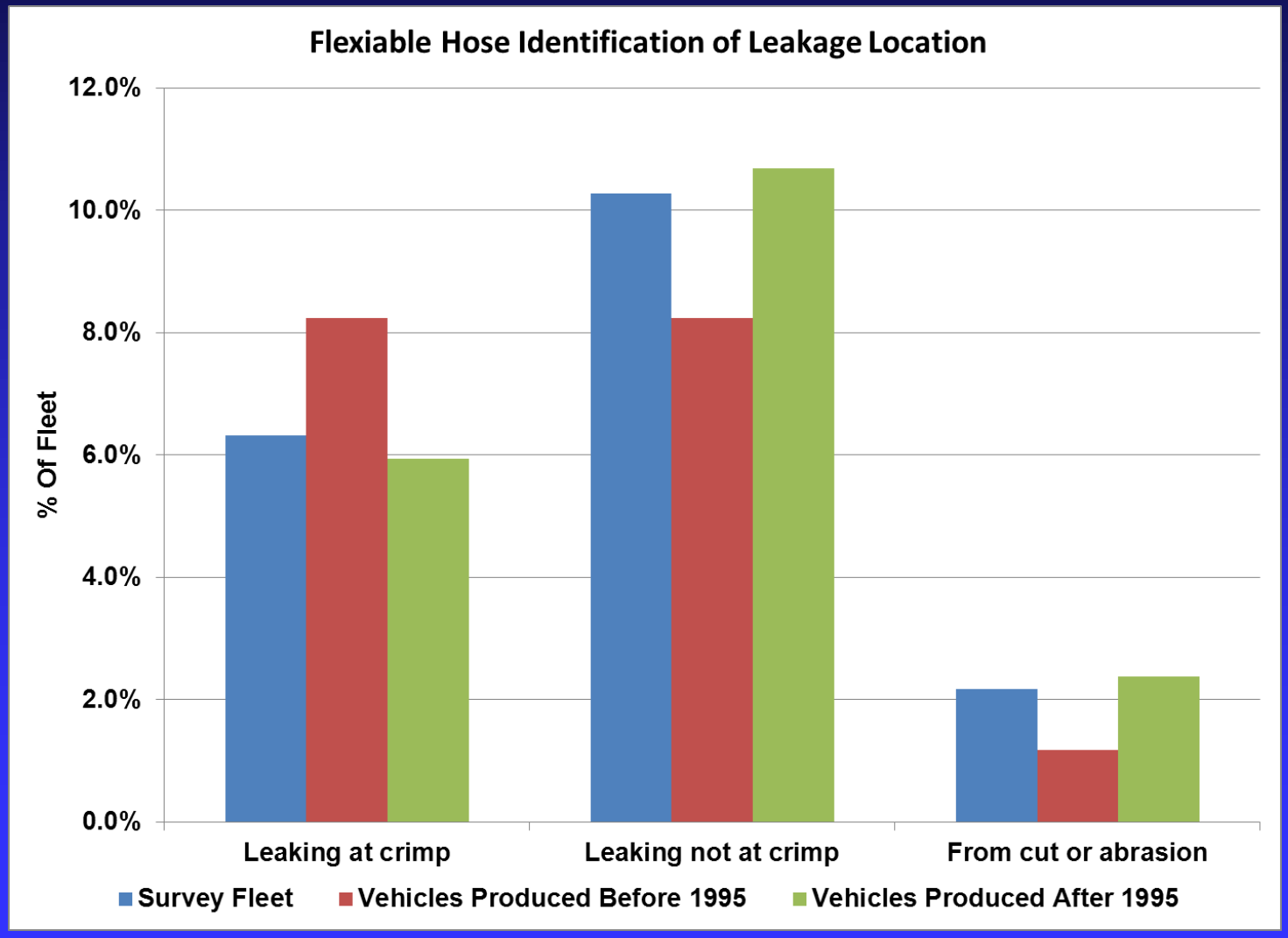

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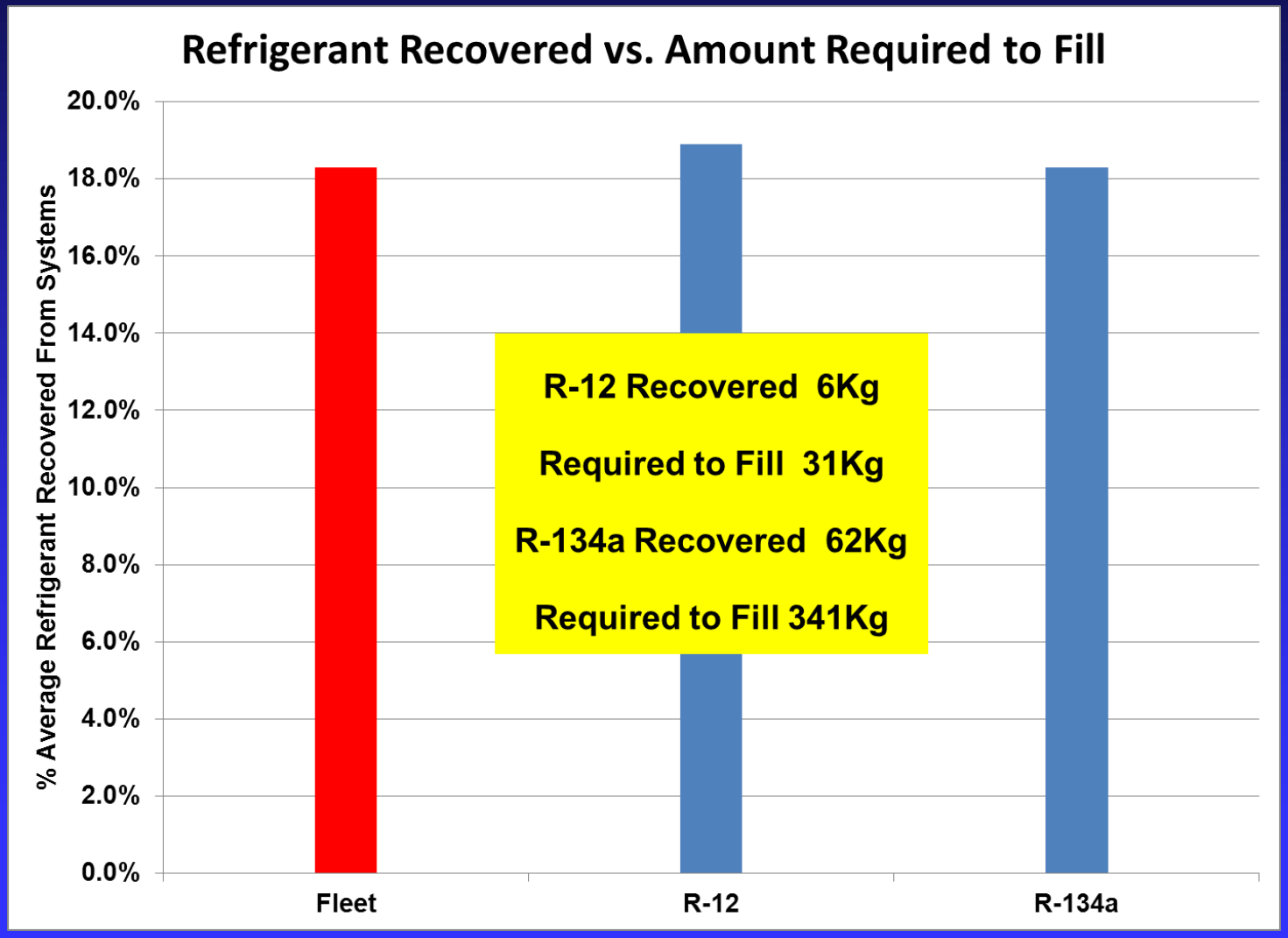

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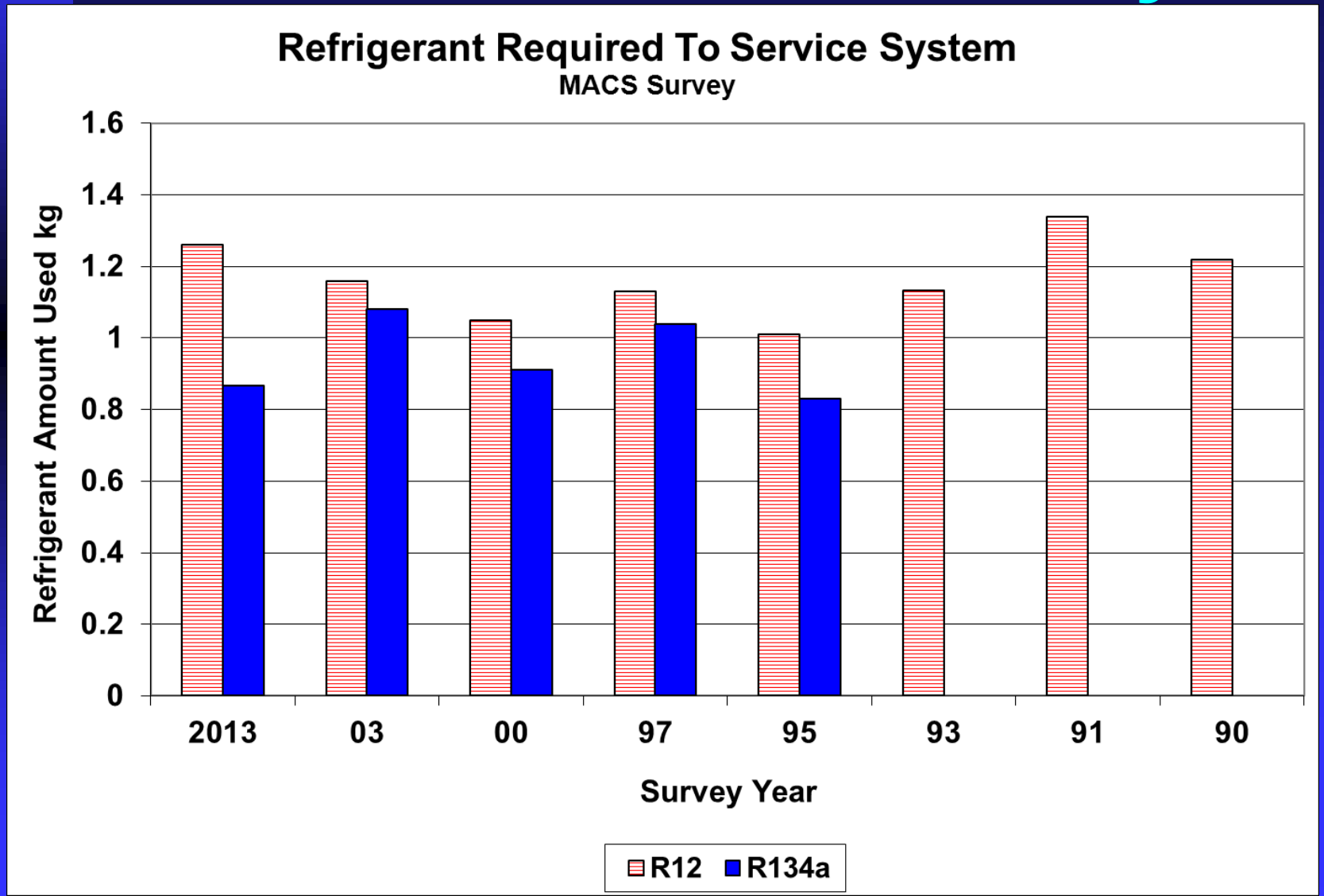

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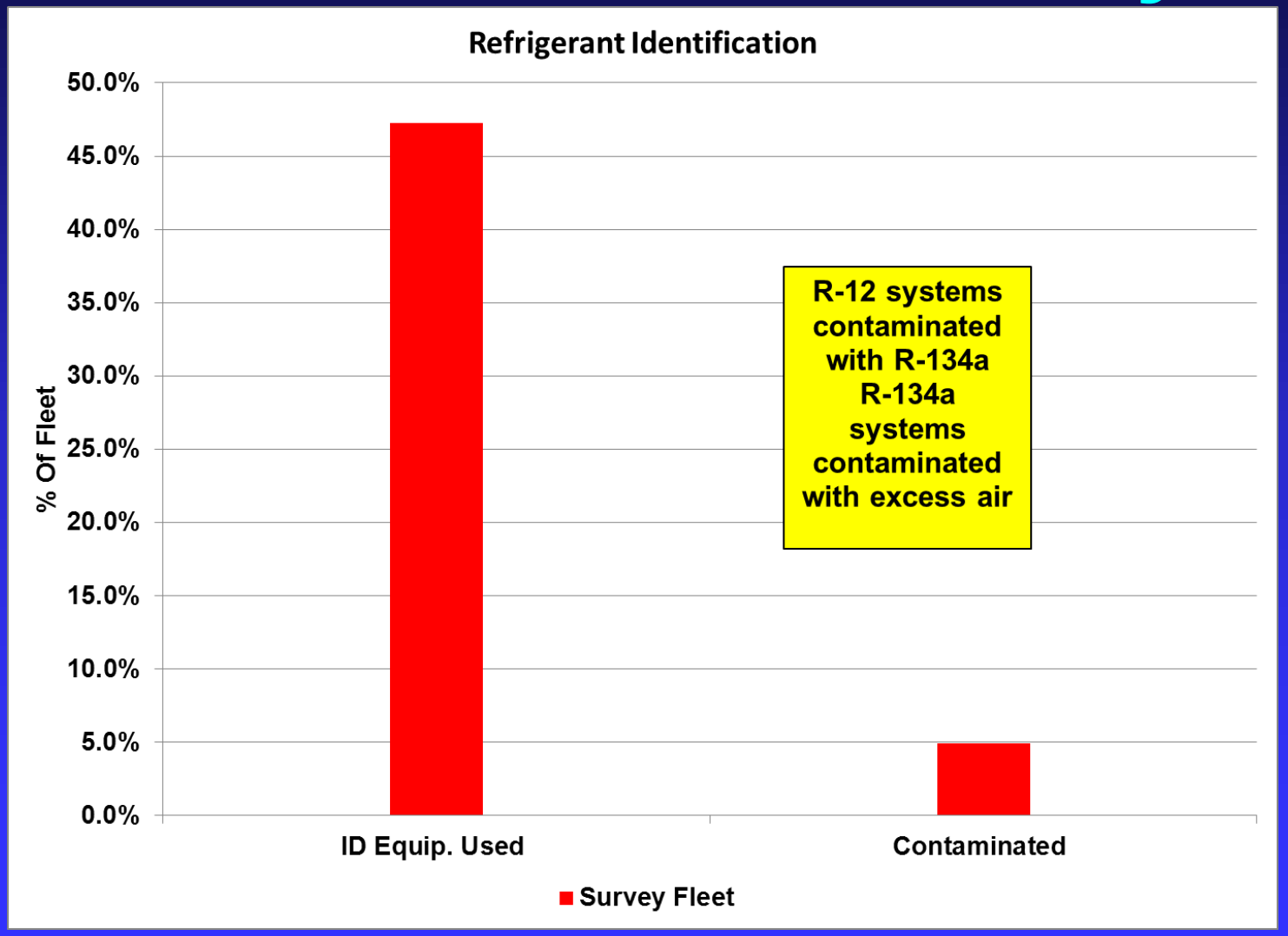

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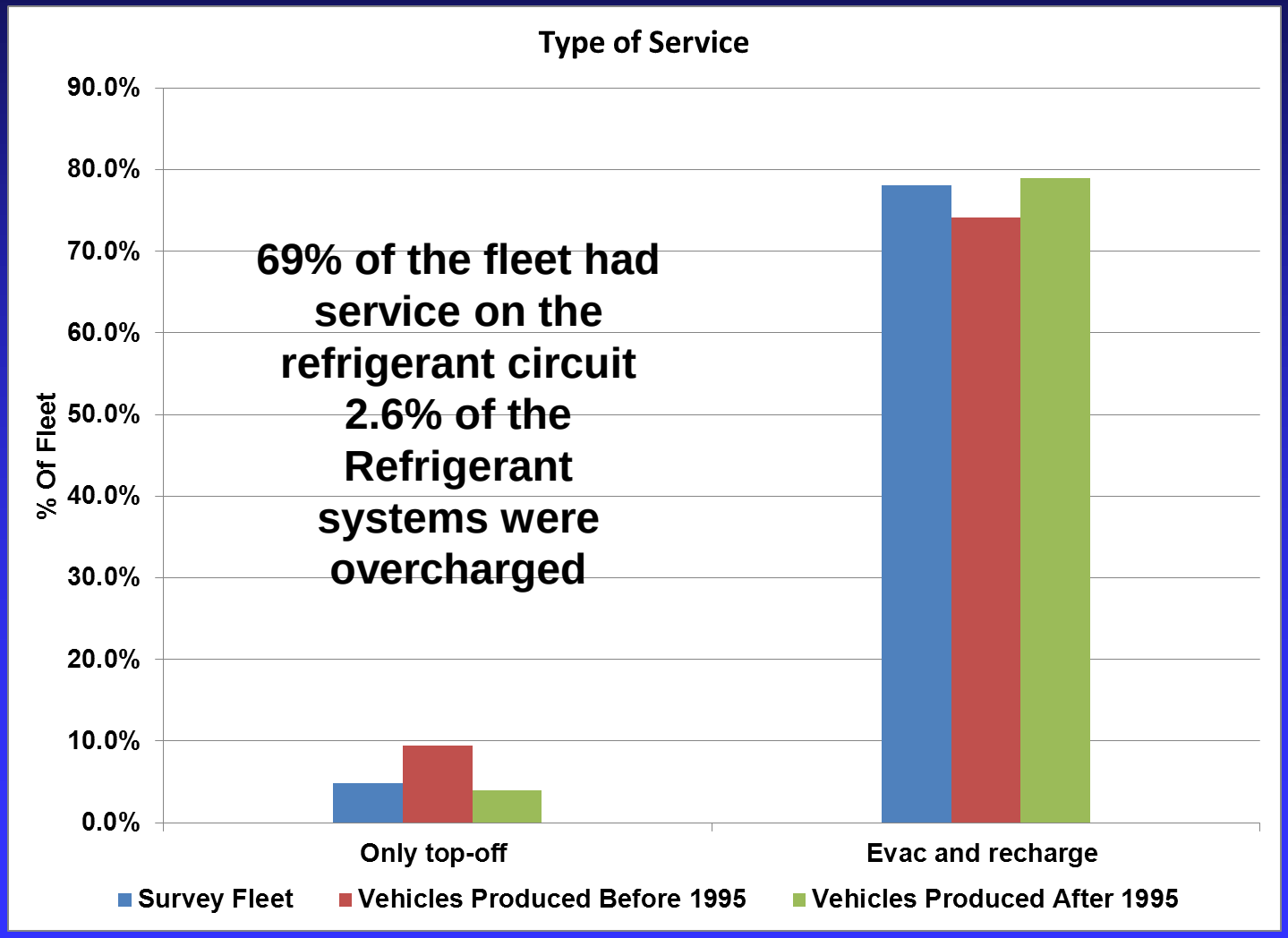

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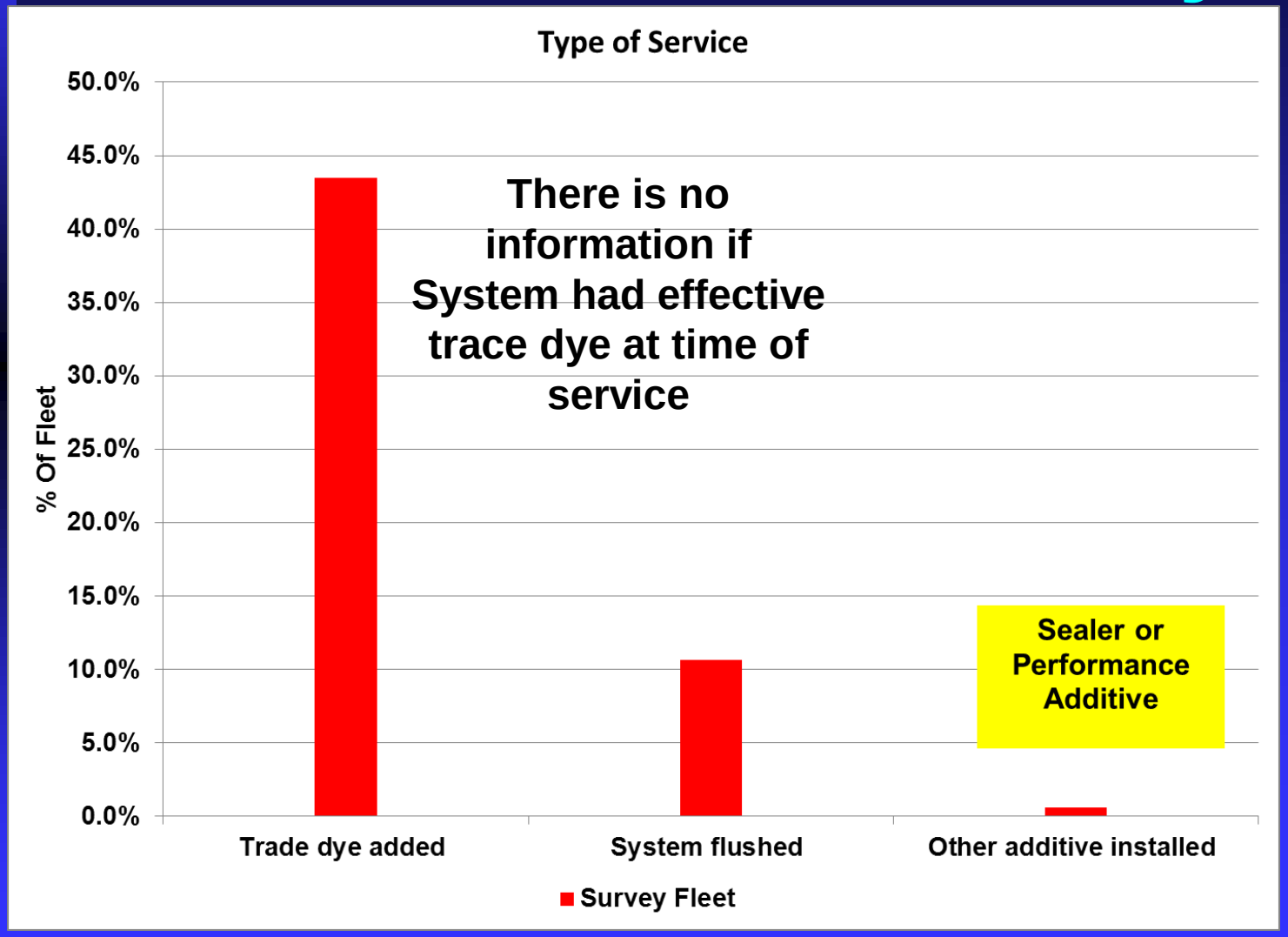

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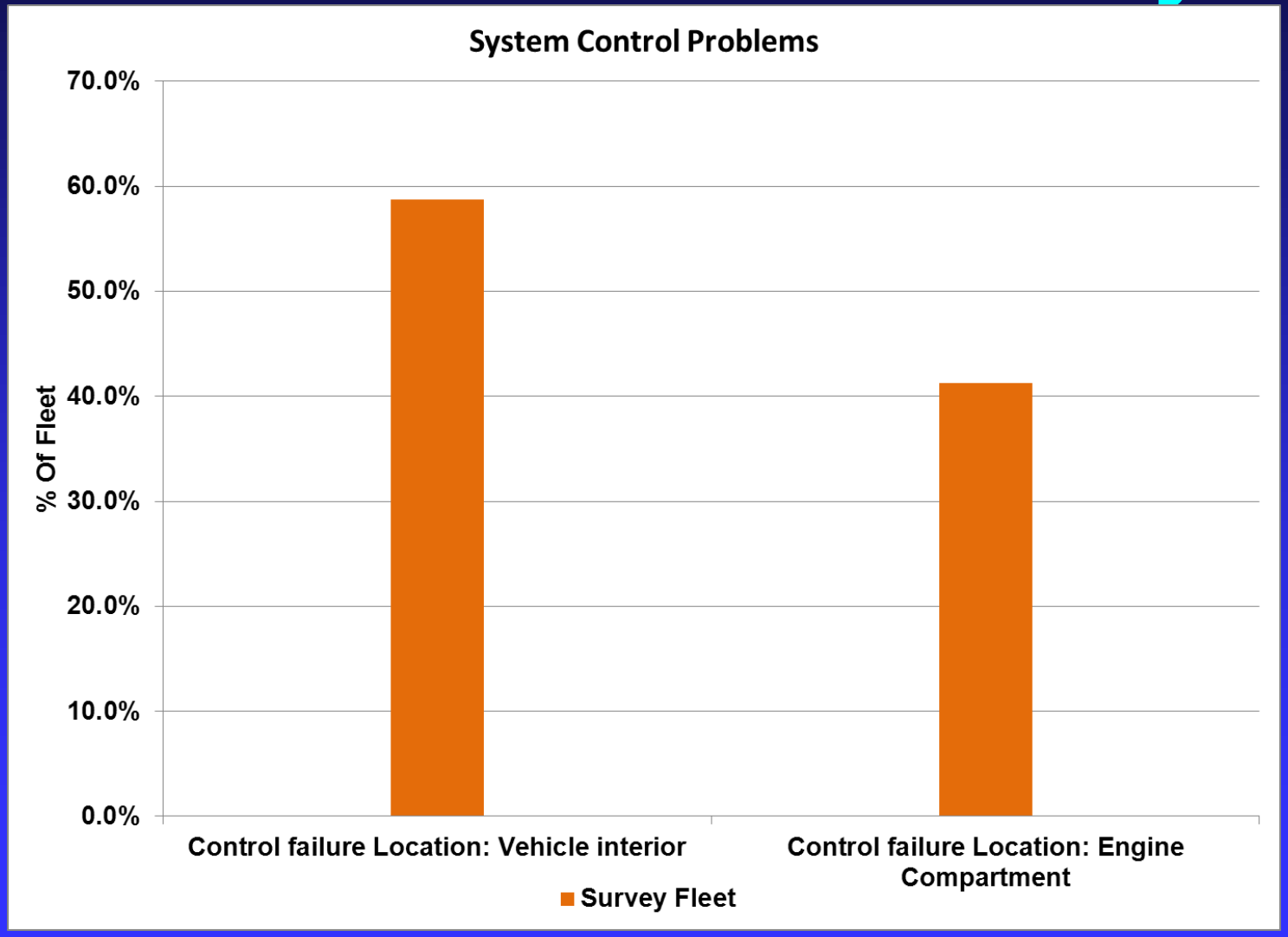

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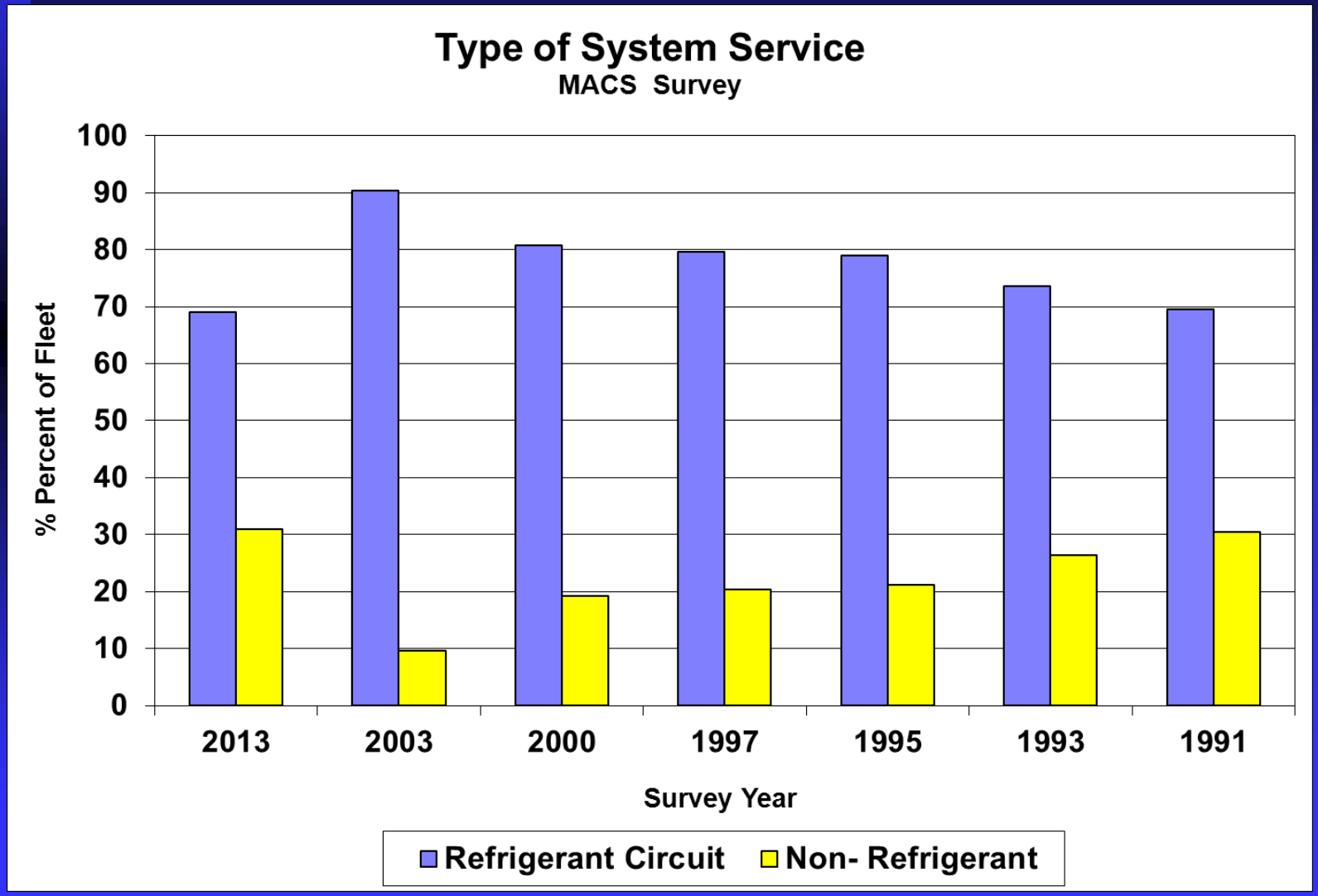
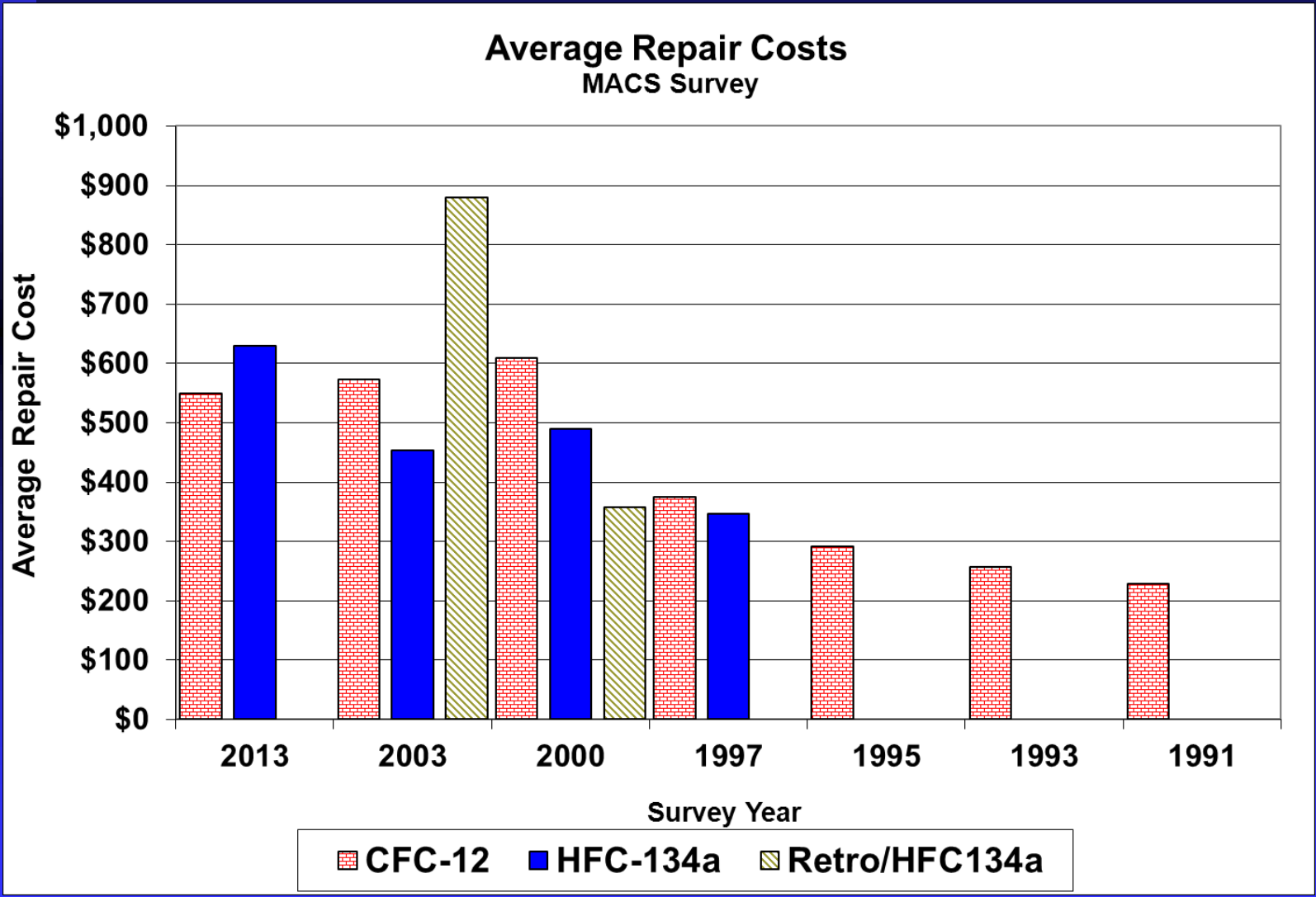


2013 MACS Field Survey

- **The fleet Repair Cost**

Group	R-12 Avg.	R-134a Avg.	Number of R-12 Over $1,000	Highest R-12 cost	Number of R-134a Over $1,000	Highest R-134a cost
Prior1994 MY	$548	$481	3	$3,162 Show car	7	$1.558
1995 MY and later	-	$649	-	-	83	$2,295

2013 MACS Field Survey



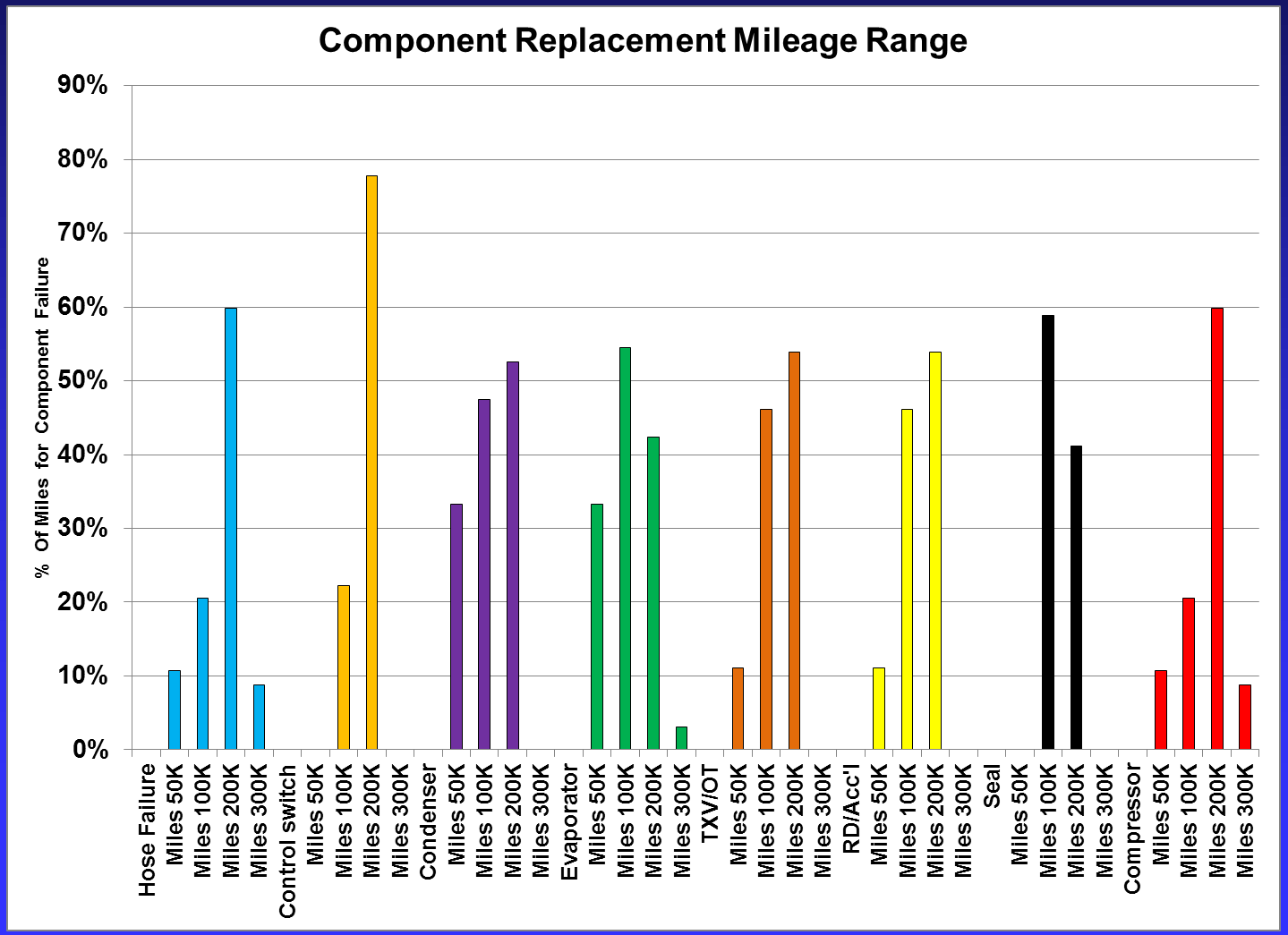
2013 MACS Field Survey

System Component failure

- **Mileage Range**
  - **0 to 49,999**
  - **50,000 to 99,999**
  - **100,000 to 199,999**
  - **200,000 to 299,999**
  - **300,000 and more**

Hose Failure
Control switch
Condenser
Evaporator
TXV/OT
RD/Acc'l
Seal
Compressor

2013 MACS Field Survey



2013 MACS Field Survey

Replaced Factory parts at service

Hose Assemblies

Prior 1995 MY	**4.7%**
1995 to current MY	**7.4%**
Fleet Average	**6.9%**

Compressor

Prior 1995 MY	**18.8%**
1995 to current MY	**5.5%**
Fleet Average	**7.7%**

Group Including
Control Switch
Condenser
Evaporator
RD/Accumulator
Seals
Txv/OT

Prior 1995 MY	**14.1%**
1995 to current MY	**15.2%**
Fleet Average	**15.0%**

2013 MACS Field Survey

Lubricant

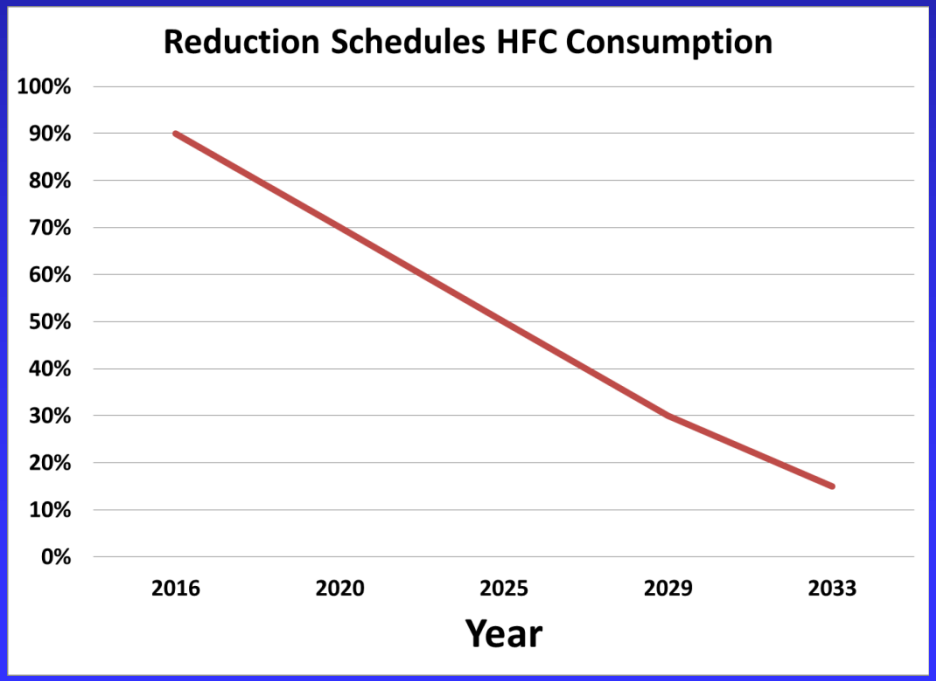
- Avg. Lubricant added 3.6 ounces
  - Highest amount added 11 ounces
- From the indication the correct lubricant was used for service each type of system

FUTURE OF MACS

MAC Refrigerant Usage

Future Direction R134a

- Proposed EPA HFC Production Phase Down
- Will future supplies of R-134a be adequate?



MAC Refrigerant Usage

- R-1234yf
  - Is rated as 2L mildly flammable
  - Cost very high compared to R-134a
  - Being supplied by Honeywell and DuPont
    - Honeywell announces new high volume plant
  - Arkema Building Plants in China and Europe
    - Operation 2017
- R744
  - Under development by German Auto Manufacturers
    - Non flammable
    - Safety system required
- R- 445A - New Blend low GWP refrigerant(AC6)
  - Being Developed by MEXICHEM
    - Is rated as 2L mildly flammable

EPA SNAP Approval

- SNAP has approved, subject to use conditions:
  - R-1234yf (Design study requirements)
  - R-744 (Limits cabin CO_2 concentrations and design study requirements)
- R-445A - Blend refrigerant has been submitted for SNAP approval and its approval is pending
- SAE Standards cover:
  - MAC system design
  - Service Equipment
  - Technician Training
- Standards are complete for R134a, R-1234yf and R-445A are under development and will have similar standard requirements

Refrigerant Cost (Phoenix Market)

- R-134a
- 30# cylinder (US)
  - $85.00 $2.83 pound
- 30# cylinder (China)
  - $55.00 $1.83 pound
- January US FTC Investigation on imported refrigerant

- R-1234yf (OEM vehicle dealer) 10# cylinder
  - $1,236.80
  - $123.68 pound
  - $7.73 ounce

MAC Systems Using R-1234yf

Cadillac XTS (2013, 2014)

Chevrolet Spark EV (2014)

Chrysler 300 (2014)

Dodge Challenger (2014)

Dodge Charger (2014)

Honda Fit EV (2013, 2014)

Jeep Cherokee (2014)

Range Rover (2014)

Range Rover Sport (2014)

European R-1234yf Issue

- German Ministry of Transports launched an enhanced analysis of the risks involved in the use of refrigerant R-1234yf in mobile air-conditioning systems.
  - Three technical meetings
    - 20 November (Brussels),
    - 11 December (Brussels)
    - 24 January 2014 (Brussels)
      - Awaiting results of January meeting
- SAE International, with participation from the Detroit 3 and several Asian automakers, CRP report concluded that R-1234yf is "safe and effective".
- A second analysis, released in August by the German environmental regulator KBA, concluded the new refrigerant is somewhat riskier than R134a, but not dangerous.

EPA R-744 SNAP Use Conditions

EPA Section 609 June 6, 2012

- This action removes CO_2 from the list of acceptable substitutes for MVAC systems and instead lists it as acceptable subject to the following use conditions:
  - Engineering strategies and/or mitigation devices shall be incorporated such that in the event of refrigerant leaks the resulting CO_2 concentrations do not exceed:
    - The short term exposure level (STEL) of 3% or 30,000 ppm averaged over 15 minutes in the passenger free space; and
    - The ceiling limit of 4% or 40,000 ppm in the passenger breathing zone

Current R744 Issues

- Higher operating pressures (5 to 10 times)
- Leakage
- Reduced high temperature performance
- Efficiency
- EPA use requirements covering exposure limits in passenger cabin

R-445A Blend Refrigerant

Summary of MRB CRP service fill

The specification and tolerances of the ternary blend R-445A composition is as follows;

- R-744 = 6% (± 1%) – service equipment will control to +1%, -0.5%
- R-134a = 9% (± 1%)
- R-1234ze = 85% (± 2%)

No special changes for the technician – automated process

- Service equipment will have an additional cylinder of R-744

New R-445A service fill equipment automated process to;

- Refrigerant Charge must be fully recovered from the MAC
- Checked and correct the R-744 blend composition by the recovery service fill equipment
- Recharge the vehicle

It is not recommended for DIYers to recharge with R-445A

- Proper service fill equipment is required

New R-445A SAE Service Standards

New Standards

- **The technician procedures for this new Blend Refrigerant will be basically similar to existing servicing procedures for MAC systems, however three new standards are being developed with SAE ICCSC**
  - **J3032 (based on J2912)**
    - **The use of a R-445A Refrigerant Diagnostics Identifier (RDI) will be mandatory and an integrated part of the service equipment**
  - **J3034 (based on J2912)**
    - **To cover the Recovery / Recycling / Re-composition / Recharging equipment for R-445A blend refrigerants.**
  - **J2845**
    - **Updated Service Technician training standard**

VEHICLE FIRES AND CABIN AIR QUALITY

Source: NFPA's "Automobile Fires in the U.S.: 2006-2010 Estimates" report by Marty Ahrens, September 2012.

Vehicles

- U.S. fire departments responded to an estimated average of 152,300 automobile fires per year in 2006-2010. These fires caused an average of 209 civilian deaths, 764 civilian injuries, and $536 million in direct property damage.
- Facts and Figures
- Automobile fires were involved in 10% of reported U.S. fires, 6% of U.S. fire deaths.
- On average, 17 automobile fires were reported per hour. These fires killed an average of four people every week.
- Mechanical or electrical failures or malfunctions were factors in roughly two-thirds of the automobile fires.
- Collisions and overturns were factors in only 4% of highway vehicle fires, but these incidents accounted for three of every five (60%) automobile fire deaths.
- Only 2% of automobile fires began in fuel tanks or fuel lines, but these incidents caused 15% of the automobile fire deaths

The National Institute of Standards and Technology (NIST) is an agency of the U.S. Department of Commerce.

- "The changing nature of motor vehicle fires is such that collisions are more impact-survivable than in the past, but collisions cause most of the fatal motor vehicle fires. Moreover, plastics have now surpassed gasoline as the main fire load"
- "Motor vehicles cause numbers of fire deaths comparable to those from mattresses or upholstered furniture"

The National Institute of Standards and Technology (NIST) is an agency of the U.S. Department of Commerce.

- "Plastics that are exterior to the passenger cabin (i.e., in the engine compartment and body panels) represent a comparable fire load and fire hazard to the interior materials but are not required to pass any fire performance test. In fact, not even all passenger cabin materials are required to pass a fire test."
- "automotive plastics that pass FMVSS 302 offer little or no safety benefit to vehicle occupants in a post-crash fire compared to commodity plastics and they are much more flammable than aircraft cabin materials"

Vehicle Fires

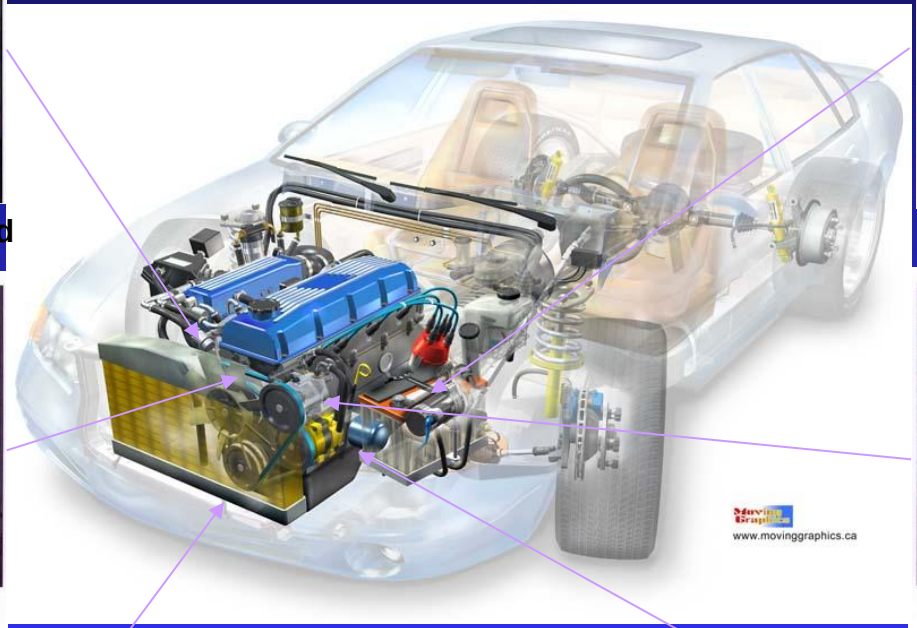
- When any HFC or HFO refrigerant is ignited by another fire source:
  - Similar levels of HF are produced from R134a and similar alternative refrigerants when vehicle fires occur
- Burning plastic vehicle parts also release many toxic fumes

Vehicle Fluids Flammability Tests

Diesel and Petrol burn; Engine Oil burns; Engine coolant burns; Brake fluid burns; Transmission Oil burns; Compressor Oil burns; Screen Washer fluid burns…

Automatic transmission fluid

Brake fluid

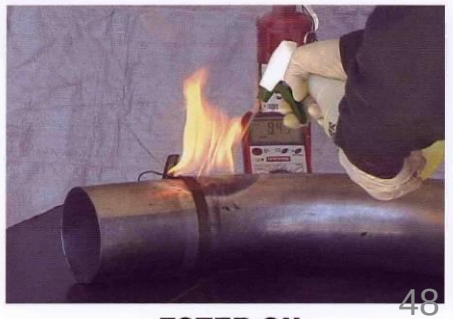


89 OCTANE GASOLINE

PAG 46

Ethylene glycol green 50/50

HFO-1234yf ignites at a temperature in excess of 750 C. It is by far one of the less flammable under hood Fluids.



ESTER OIL

1977 Chev. Gasoline Fire Carburetor After Fire Dept. Arrival (Aftermarket Air Cleaner)

Phoenix car fire Nov 16, 2012
A two vehicle crash on West bound I-10 near 48th street ended with an SUV in flames. No one was seriously hurt in the crash.
First responders had not arrived.

EPA AC17 test and requirements to meet 2017 - 2025 MAC CAFE

Indirect Credits	GHG Credit (g/mi CO_2)			CAFE Credit (gallon/mi)	
	2012-2016MY	2017-2025MY		2017-2025MY	
Technology Description	All	Car	Truck	Car	Truck
Reduced reheat with externally controlled variable displacement compressor	1.7	1.5	2.2	0.000169	0.000248
Reduced reheat with fixed displacement compressor or with internally controlled variable displacement compressor	1.1	1.0	1.4	0.000113	0.000158
Default to recirculated air above 75 deg. F ambient with a sensor	1.7	1.5	2.2	0.000169	0.000248
Default to recirculated air above 75 deg. F ambient without a sensor	1.1	1.0	1.4	0.000113	0.000158
Pulse Width Modulated (PWM) Blower Control	0.9	0.8	1.1	0.000090	0.000124
Internal Heat Exchanger (IHX)	1.1	1.0	1.4	0.000113	0.000158
Improved heat exchangers (with analysis and 10% COP improvement)	1.1	1.0	1.4	0.000113	0.000158
Compressors with built in Oil Separator	0.6	0.5	0.7	0.000056	0.000079
Maximum credits	*5.7*	*5.0*	*7.2*	*0.000563*	*0.000810*

Rec. Air Requirement

Use of 100% Recirculated Air

EPA Vehicle Emissions Credits Allows:

- **Default to recirculated air with closed- loop control of the air supply (sensor feedback to control interior air quality) whenever the outside ambient temperature is 75 °F or higher (although deviations from this temperature are allowed if accompanied by an engineering analysis) 30%**
- **Default to recirculated air with open-loop control of the air supply (no sensor feedback) whenever the outside ambient temperature is 75 °F or higher (although deviations from this temperature are allowed if accompanied by an engineering analysis) 20%**

Potential Concerns From 100% Rec Air Operation:

- **Odors from collection of foreign materials/moisture retention in evaporator housing**
- **High carbon dioxide concentration from occupants breathing**
  - **Are Requirements to control Cabin CO_2 Levels Needed?**
    - **Selective blending of outside air**

Industry Carbon Dioxide Exposure limits

Building CO_2 concentration

ASHRAE standard 62 (ASHRAE, 1999) specifies the safe levels of carbon dioxide in conditioned space for humans.

The CO_2 concentration limit per ASHRAE is 700 ppm (on a continuous basis) over the ambient conditions on a continuous basis. Typical ambient concentration level of CO_2 is approximately 392 ppm. Hence, if the CO_2 concentration exceeds approximately 900 ppm inside of a home or in a vehicle cabin, then we must introduce outside air into the home or vehicle cabin to reduce the CO_2 concentration.

If indoor carbon dioxide levels are more than 1,000 ppm, there is probably inadequate ventilation; and complaints such as headaches, fatigue, and eye and throat irritation may be prevalent.

- MAC in 100% Rec Mode Can Exceed This ppm Level

Industry Carbon Dioxide Exposure limits

SAE Technical Papers cover cabin CO_2 build up from occupant breathing when the system is operated on 100% recirculated air

To minimize CO_2 levels within the cabin the MAC system should provide the ability to control cabin CO_2 levels by adding outside air

SAE 2013-01-1494 Vehicle Cabin Air Quality with Fractional Air Recirculation Published 04/08/2013 Michael L. Grady and Heejung Jung Univ of California-Riverside Yong chul Kim, June Kyu Park and Bock Cheol Lee Hyundai Motor Company

SAE 2013-01-1497 Modeling CO2 Concentrations in Vehicle Cabin Published 04/08/2013

Heejung Jung Univ. of California-Riverside

SAE 2008-01-0829 Field Tests to Monitor Build-up of Carbon Dioxide in Vehicle Cabin with AC System Operating in Recirculation Mode for Improving Cabin IAQ and Safety Gursaran D. Mathur

CalsonicKansei North America **As stated in the report:**

"The vehicle's AC system should not be operated in recirculation mode for extended periods of time due to build up of CO_2 inside the vehicle cabin."

SAE 2013-01-1494 Vehicle Cabin Air Quality

Michael L. Grady and Heejung Jung Univ of California-Riverside

Yong chul Kim, June Kyu Park and Bock Cheol Lee Hyundai Motor Company

Time

Figure 2. Effect of full air recirculation on water vapor and CO_2 concentration in cabin with one passenger

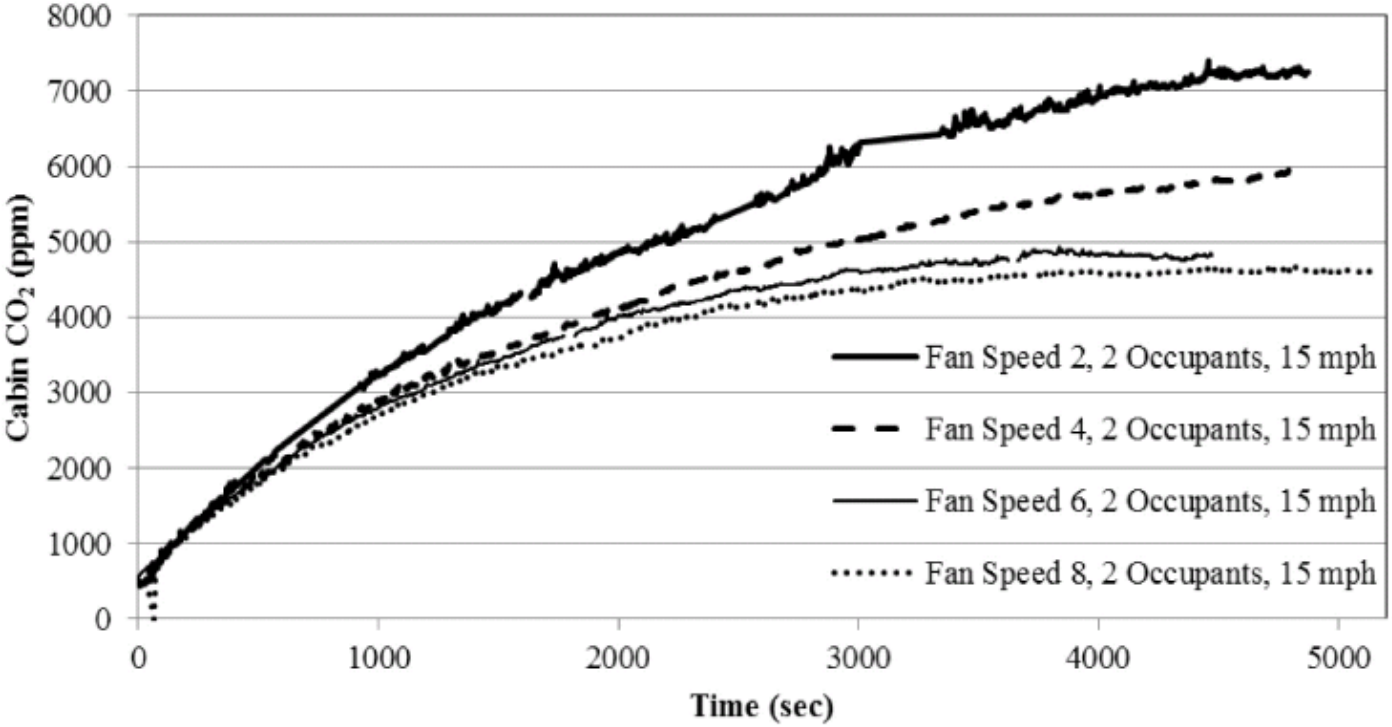


Figure 3. Evolution of cabin CO_2 concentration as a function of time and fan speed. Test conducted at full recirculation condition with two passengers

CO_2 Toxicity

Concentration	Effect
1%	Breathing rate increases slightly.
2%	Breathing rate increases to 50% above normal level. Prolonged exposure can cause headache, tiredness.
3%	Breathing increases to twice normal rate and becomes labored. Weak narcotic effect. Impaired hearing, headache, increased blood pressure and pulse rate.
4 - 5%	Breathing increases to approximately four times normal rate, symptoms of intoxication become evident, and slight choking may be felt.
5 - 10%	Characteristic sharp odor noticeable. Very labored breathing, headache, visual impairment, and ringing in the ears. Judgment may be impaired, followed within minutes by loss of consciousness.
50 - 100%	Unconsciousness occurs more rapidly above 10% level. Prolonged exposure to high concentrations may eventually result in death from asphyxiation

Extended use of recirculated air

- Recent reduced body leakage rates for quiet cabins will reduce outside air infiltration at road speeds
- Increased vehicle fuel mileage can extend longer trip and exposure times
- The use of 100% Rec air over 75 degrees needs a study of what cabin CO_2 concentration's should not be exceed
- Use of 100% rec air should require Modulation of the air door to allow some outside air for improved IAQ in the cabin
  - Both for Levels of odor & CO_2
  - Time or sensor for air quality control

State of the Industry

- Without question the service industry has changed and MAC Systems last longer & require less service
- Multiple Refrigerants will have to be dealt with in the future of the service industry
- EPA regulations should consider consumer usage for MAC system designs