JAMA 社団法人 日本自動車工業会
Japan Automobile Manufacturers Association, Inc.

Views on Different Refrigerant Systems in Light of the European Regulation on MACs

Japan **A**utomotive **M**anufacturing **A**ssociation

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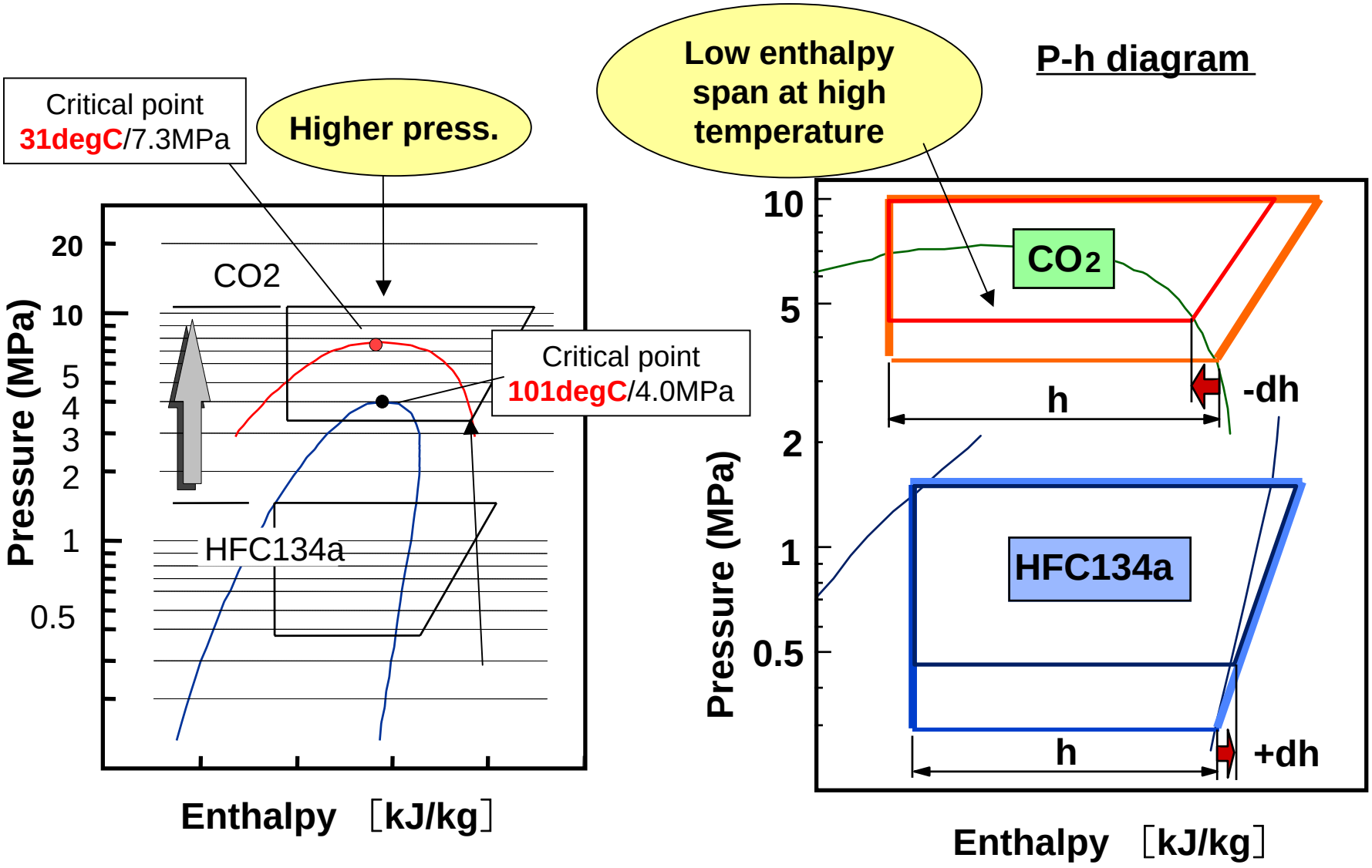
1. MAC system with CO_2 refrigerant
2. Impact on Environment
3. Impact on Refrigerant Polarization
4. Impact on Vehicle Performance
5. Summary
6. Requests

1.MAC System with CO_2 Refrigerant

1-a.Refrigerant property of CO_2 as compared to R134a



1.MAC System with CO_2 Refrigerant

1-a.Refrigerant property of CO_2 as compared to R134a

CO_2 refrigerant has :

advantages	disadvantages
• **Low Environmental Impact** → **ODP=0** → **GWP=1** • **High heat transportation**	• **High System Pressure** →6-7times R134a incompatibility with R134a system • **Low efficiency at high Temperature** →Compressor power increases

1.MAC System with CO_2 Refrigerant

1-b. Concerns on CO_2 MAC

- **Impact on Environment**

  Fuel consumption, TEWI

- **Impact on Refrigerant Polarization**

  Development, production, infrastructure of servicing

- **Impact on Vehicle Performance**

  Increase in compressor power and the number of components, more safety devices needed

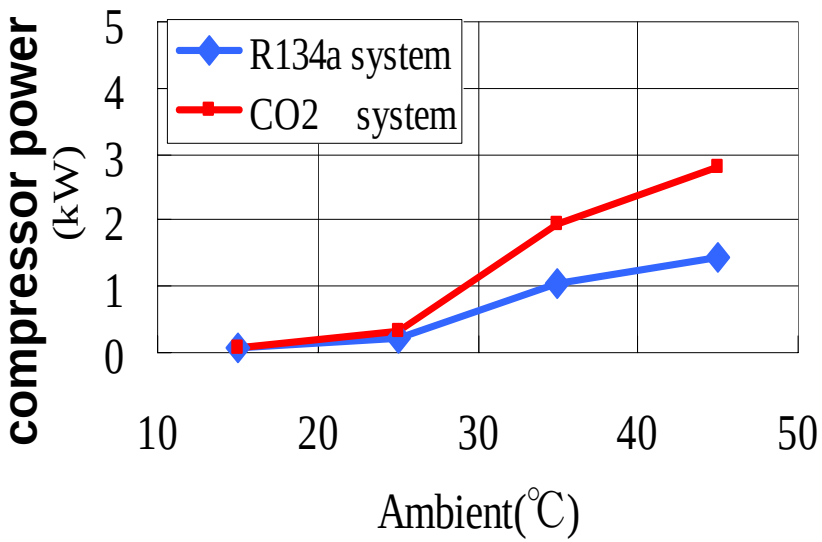
2.Impact on Environment

2-a.Comparison of compressor power between R134a and CO_2

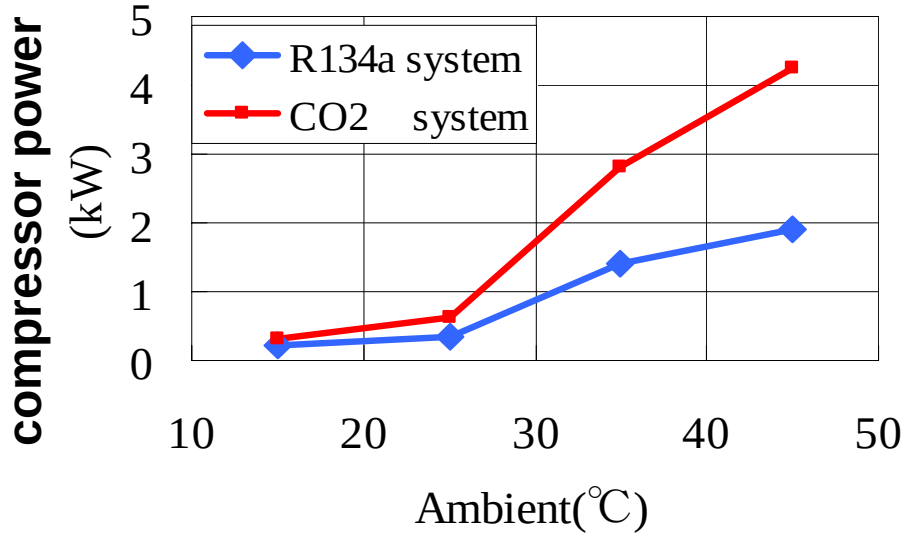
= Theoretical Study =

Under the same cooling performance

Running Vehicle Speed 40km/h



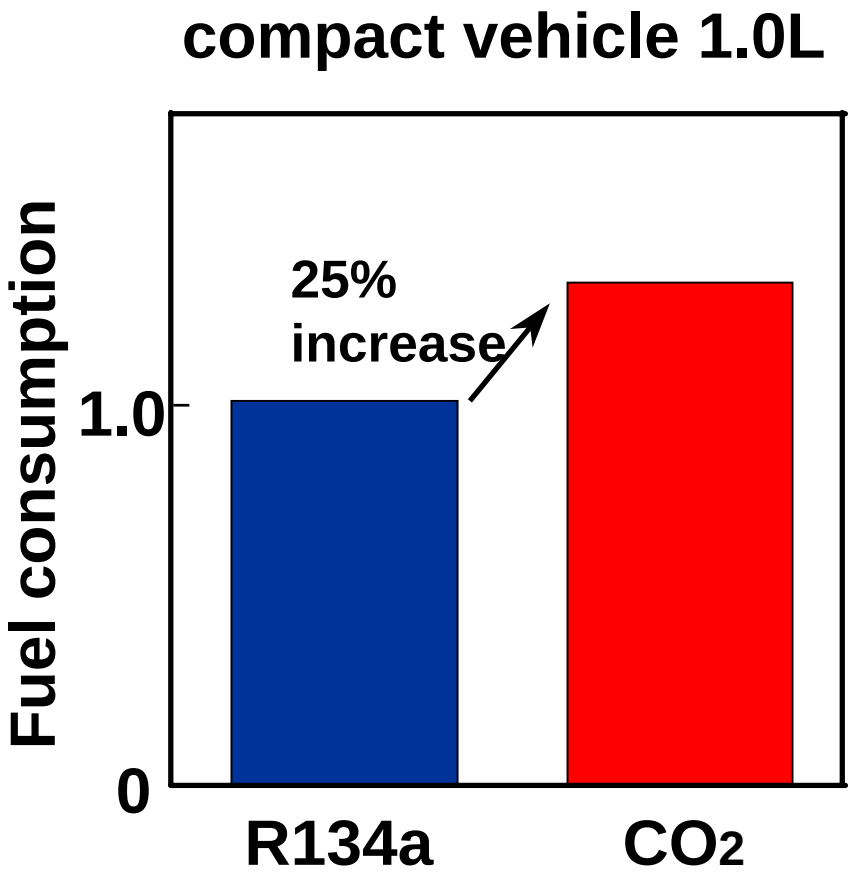
Idling



Theoretically, Compressor power of CO_2 MAC is higher than R134a

2.Impact on Environment

2-b.Impact of MAC Power on Vehicle Fuel Efficiency



Urban mode
30 degC w/solar radiation
Fresh air, Max Cool

In CO_2 MAC system, increase in the compressor power consumption affects fuel consumption

2.Impact on Environment

2-c. Comparison using TEWI

TEWI Calculation

TEWI （Total Equivalent Warming Impact）:
Equivalent CO_2 gas emission in vehicle life time

TEWI = Total Leakage x GWP + A x (1/B) x SUM(comp. power / C)

→ direct emission

- ✓Leakage at factory charging
- ✓Annual leakage
- ✓Annual irregular leakage
- ✓EOL emission

→ indirect emission

- ✓occurrence of temperature frequency
- ✓occurrence of each vehicle speed
- ✓outlet air temperature to be fixed one
- ✓Determine each compressor displacement (so that the pull down cooling performance become the same for R134a and CO_2)

A : amount of CO2 for Fuel of 1kg
B : energy for Fuel of 1kg
C : engine efficiency

TEWI calculation contents should be transparent

TEWI Calculation

Direct Effect

Refrigerant leakage calculation
- ✓Leakage at factory charging
- ✓**Annual leakage**
- ✓Annual irregular leakage
- ✓**EOL emission**

In-direct Effect

Make table of AC running time

Determine thermal load condition
- ✓Select region
- ✓**Calculate occurrence of temperature frequency**

Determine driving condition
- ✓Select driving mode
- ✓**Calculate occurrence of each vehicle speed**
- ✓Calculate driving time of each vehicle speed

Determine AC the profile (AC ON vs ambient)

AC running time

Tamb.	Idling	40 kmh	100 kmh
35	3.9	3.8	3.8
30	13.6	13.3	1.9
25	34.9	34.3	4.9
20	38.8	38.1	5.4
15	14.8	14.6	2.1
10	0	0	0
5	0	0	0
0	0	0	0
-5	0	0	0

Make table of compressor power

Determine AC system
- ✓Select the best components for R134a and CO2
- ✓**Determine each compressor displacement so that the pull down cooling performance become the same for R134a and CO_2**
- ✓Fix the cycle control method
  - ✓Control expansion valve optimally
  - ✓**Control outlet air temperature to be fixed one**
- ✓Consider cond. Air temp. rise due to hot air recirculation

R134a compressor power

CO_2 compressor power

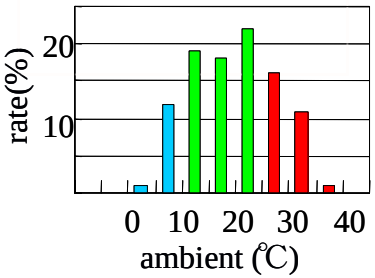
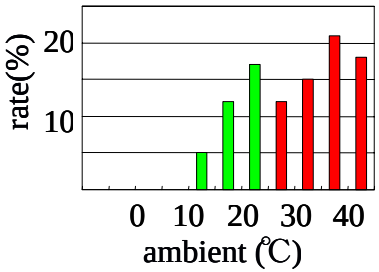
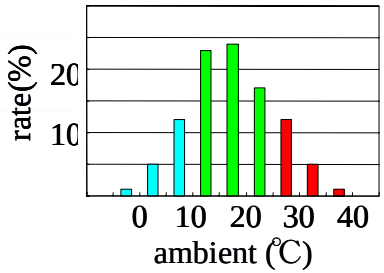
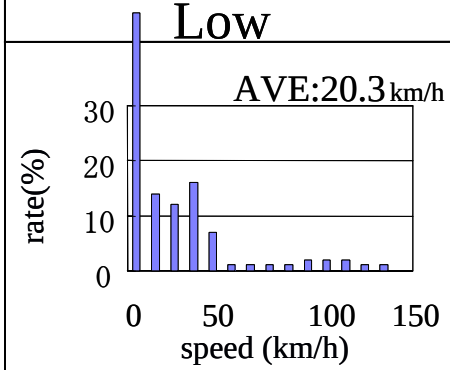
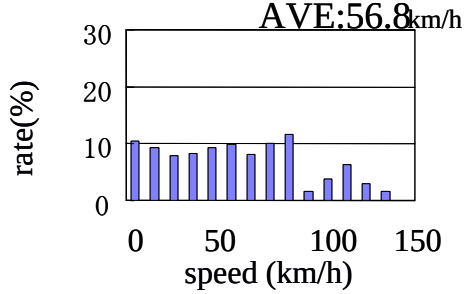
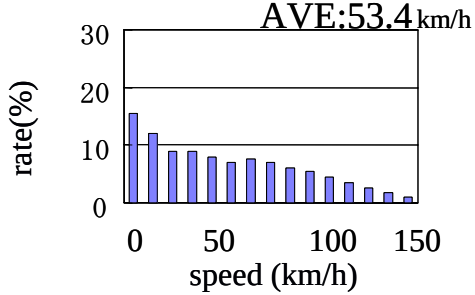
Tamb.	Idling	40 kmh	100 kmh	g	40 kmh	100 kmh
35	1.80	2.28	3.44	67	*	*
30	1.65	1.57	2.01		*	*
25	1.02	0.93	1.21		*	*
20	0.56	0.59	0.77		*	*
15	0.46	0.52	0.67		*	*
10	0	0	0		*	*
5	0	0	0		*	*
0	0	0	0		*	*
-5	0	0	0		*	*

Calculation of Annual total compressor power, then annual total engine power by engine efficiency

TEWI = Calculate direct emission (Total leakage * GWP) + Calculate indirect emission

2.Impact on Environment

2-c. Comparison using TEWI

	JPN (Tokyo)	USA (Phoenix)	EUR (Frankfurt)
Climate	Mid	High	Mid
			
Vehicle Speed	Low	High	High
			
Mileage (km/year)	approx.10000	approx.17000	approx.14000

2.Impact on Environment

2-c. Comparison using TEWI

Specifications of MAC components for TEWI

compact vehicles 1.5L

	CO_2	HFC-134a
Compressor	Variable	Fixed
Gas cooler /Condenser	W615 xH343xD16	←
Evaporator	W199 xH231xD38	←
Internal Heat Exchanger	W45 xH230xD13	—

Compressor power consumption is obtained by actual test result using above components.

2.Impact on Environment

2-c. Comparison using TEWI

Results of JAMA's field survey on refrigerant leak and the Recycling law

Initial charge amount : 500g

Leakage at factory charging : 3.5g

Annual leakage : 9.5g/year

Annual irregular leakage : 12g/year

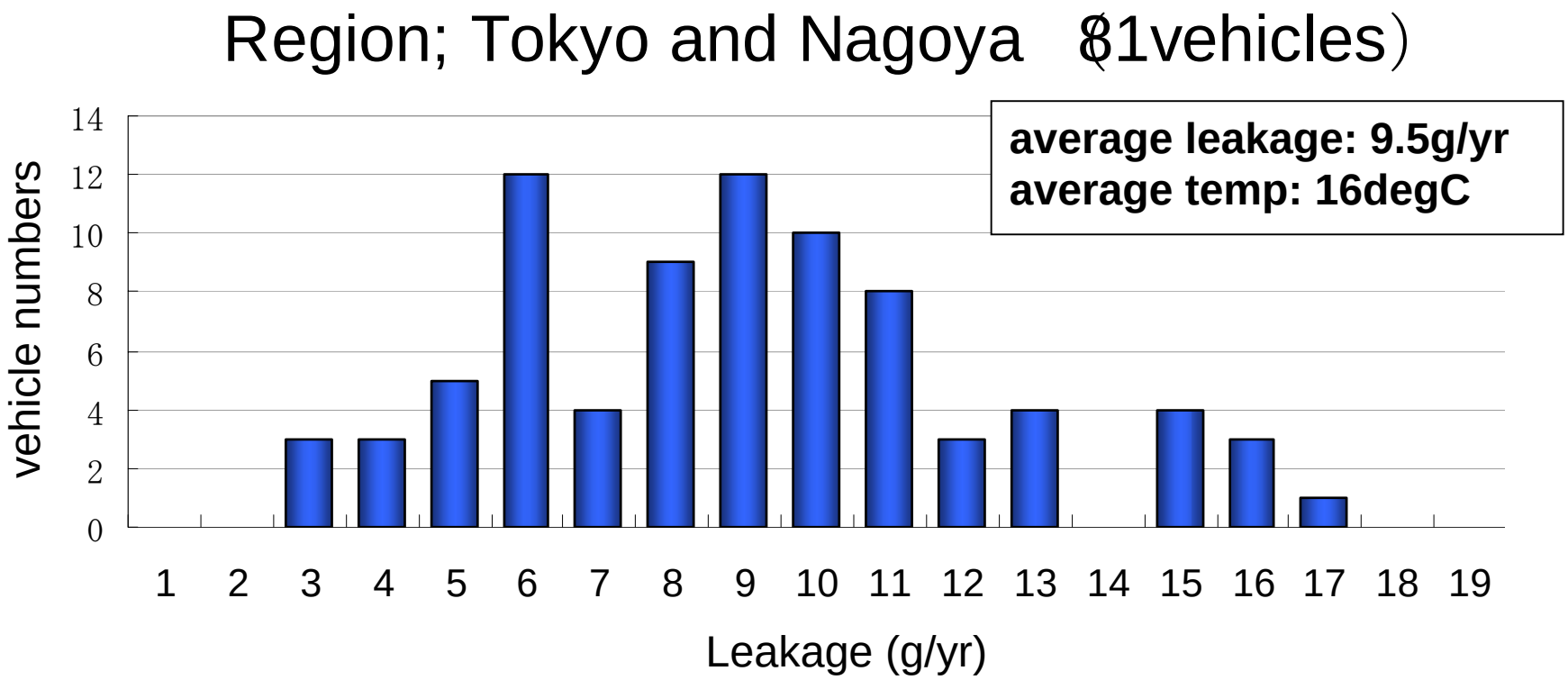
EOL emission : recovery rate 0% (worst case)

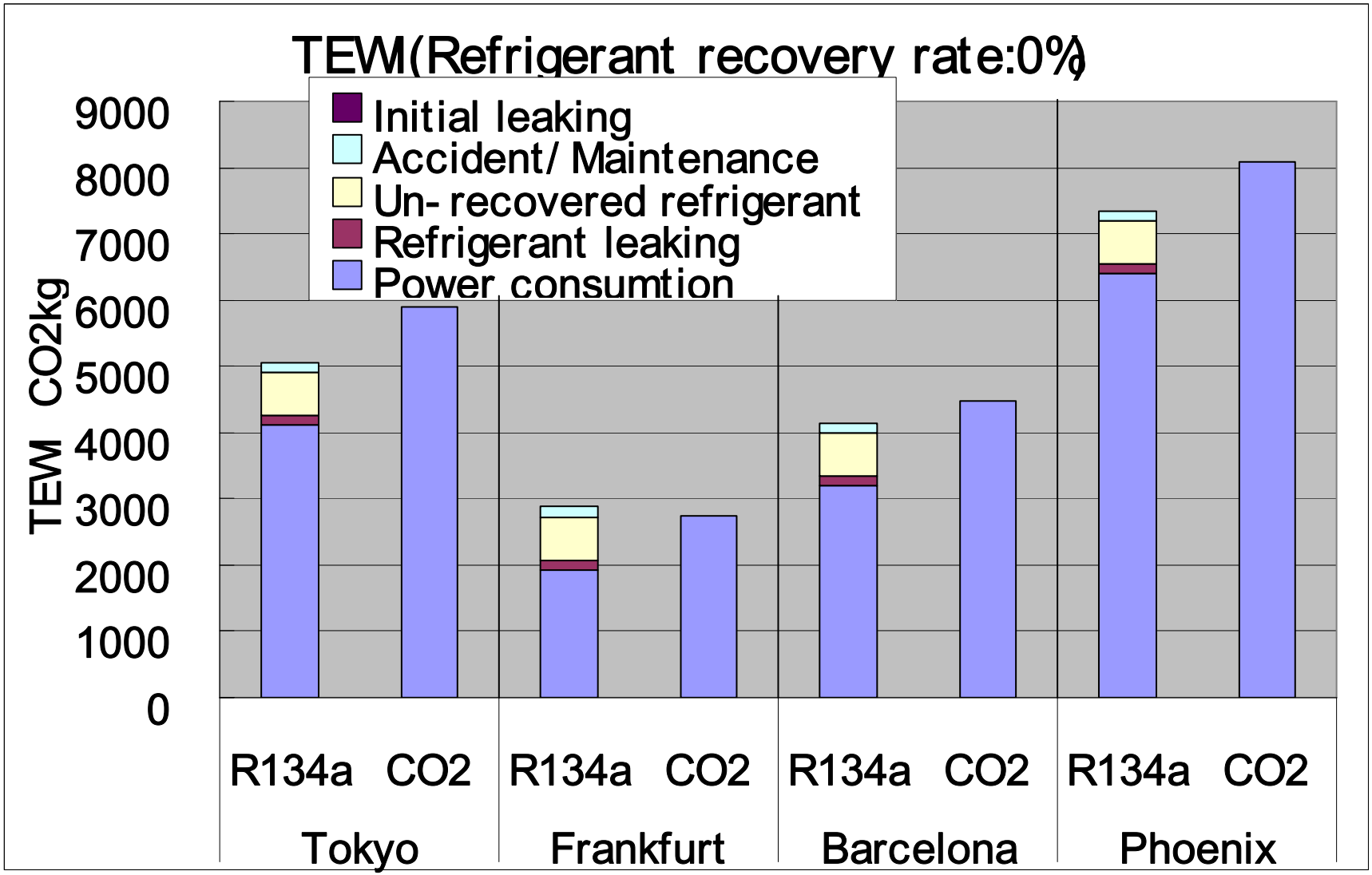
2.Impact on Environment

2-c. Comparison using TEWI

Results of JAMA's field survey on refrigerant leak and the Recycling law

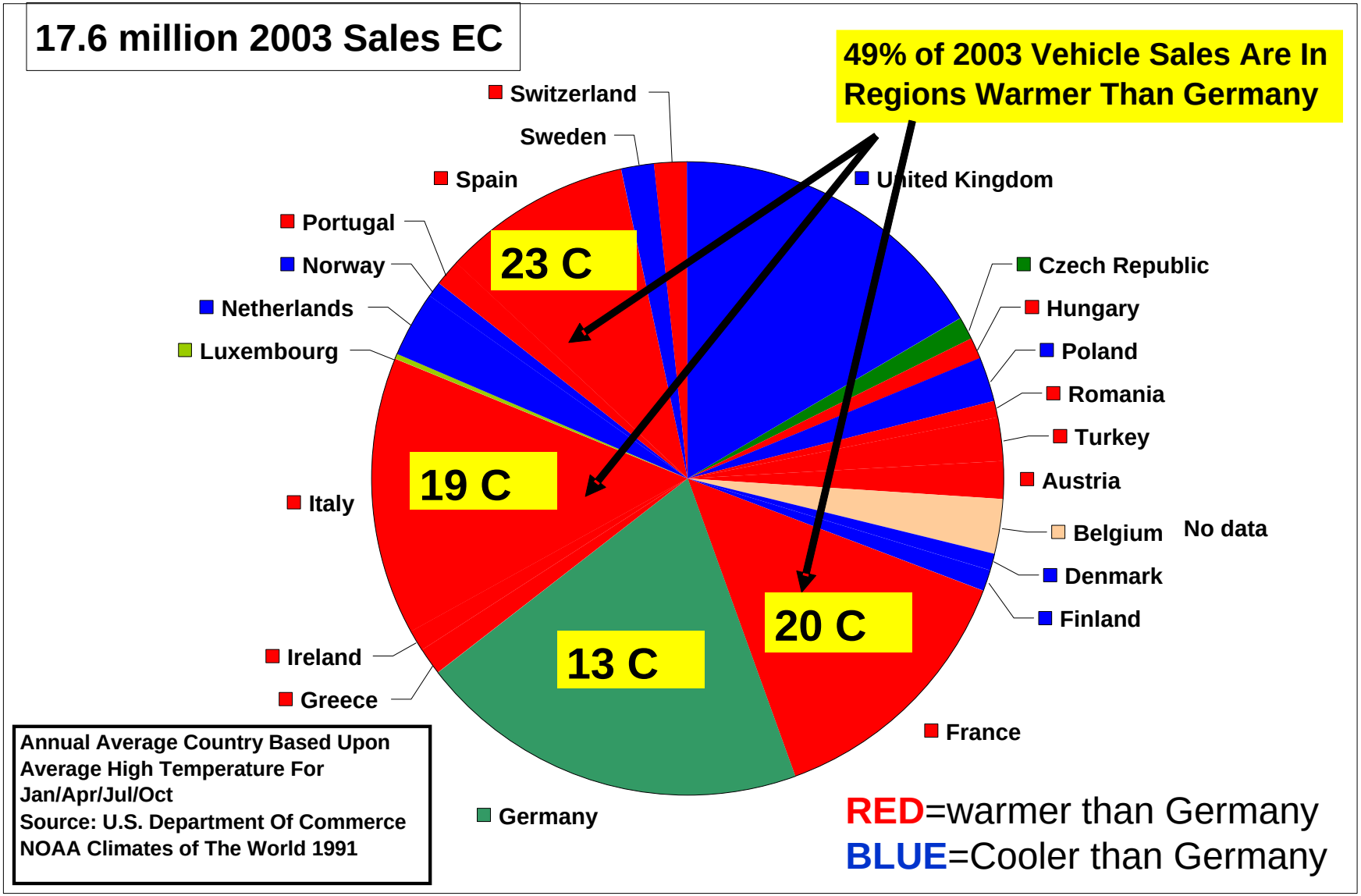
JAMA field survey results




TEW(Refrigerant recovery rate:0%)
Initial leaking
Accident/ Maintenance
Un- recovered refrigerant
Refrigerant leaking
Power consumtion
TEW CO2kg
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
R134a CO2
Tokyo
R134a CO2
Frankfurt
R134a CO2
Barcelona
R134a CO2
Phoenix

2.Impact on Environment

2-d.Sales volume and Temperature in Europe



2.Impact on Environment

2-e. Conclusion for impact to the environment

- Calculation procedure and the conditions (e.g.: temperature, speed, baseline, refrigerant leakage etc) of TEWI evaluations should be transparent.

- For many regions, CO_2 is not the most appropriate refrigerant.

- Even in Europe, CO_2 refrigerant can deteriorate TEWI in the region at the high temperature.

3. Impact of Refrigerant Polarization

3-a. Impact on Development and Production

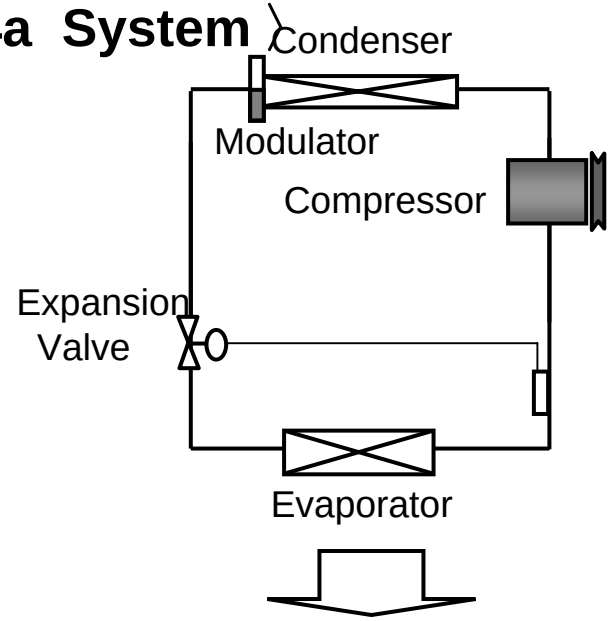
- All countries except Europe will continuously use R134a. This means MAC industry have to use two refrigerants.
- Incompatibility of components for R134a and CO_2 causes all components' change and additional components.
- Refrigerant Polarization requires two different production lines for all components. Development and manufacturing facilities will double.

3. Impact of Refrigerant Polarization

3-a. Impact on Development and Production

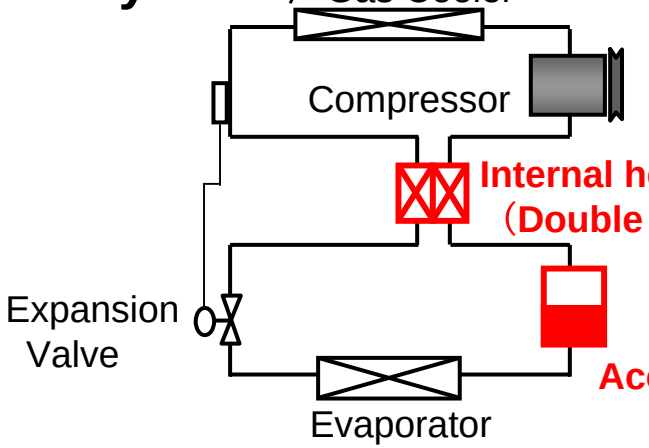
System Comparison:R134a vs CO_2

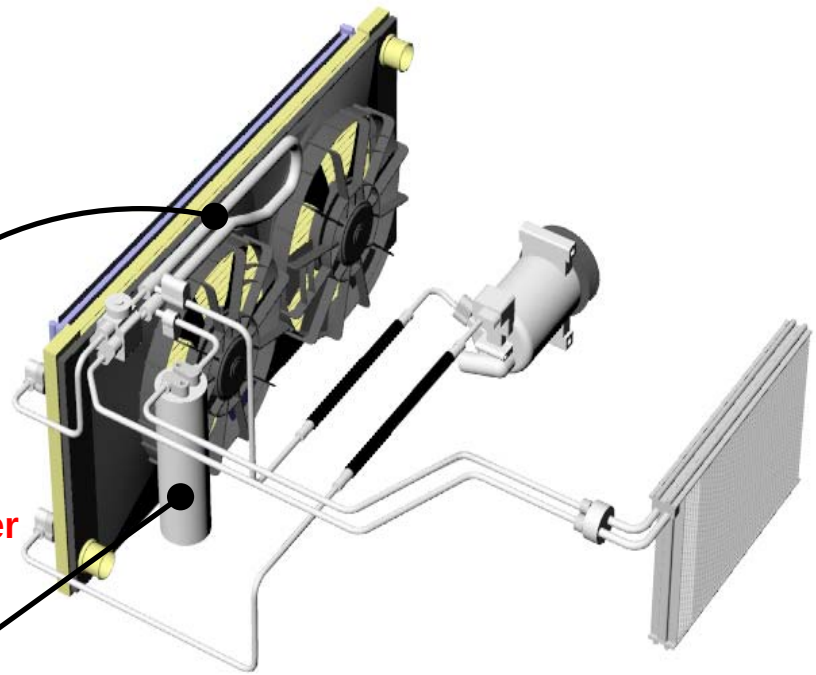
〈 R134a System 〉



All components must be redesigned and new additional parts, such as accumulator and internal heat exchanger, are necessary in CO2 MAC system.

〈 CO2 System 〉





3. Impact of Refrigerant Polarization

3-b. Concerns for Infrastructure of Servicing

- Each country's regulation in terms of CO_2 gas

  US: DOT, EPA
  Japan: METI
  Other countries: under investigation

- The number of servicing tools will double

- Technicians should be trained (especially in respect of the high pressure).

3. Impact of Refrigerant Polarization

3-c.Regulations in the US and Japan

Market: US Regulation

- DOT (NHTSA)
  - will insist CO_2 refrigerant system technology should be safe.
- EPA
  - CAA Sec609： Facilities and service technician should be certified by organization such as MACS
  - CAA Sec612: Plans to make rules for CO_2 MAC systems under SNAP program to prevent dangerous exposure to occupants
  - depends on industry standards like SAE for safe design

3. Impact of Refrigerant Polarization

3-c.Regulations in the US and Japan

Japan Regulation

High pressure gas control law:

- CO_2 refrigerant charging comes under “second classification of gas manufacturing” .
- Notification to the Japanese local government is required for the actions such as refrigerant charging, sales and storage.

Some obligations such as certification of servicing tools to satisfy safety standards, organization of servicing technician and maintenance personnel etc. have to be taken for each servicing facility.

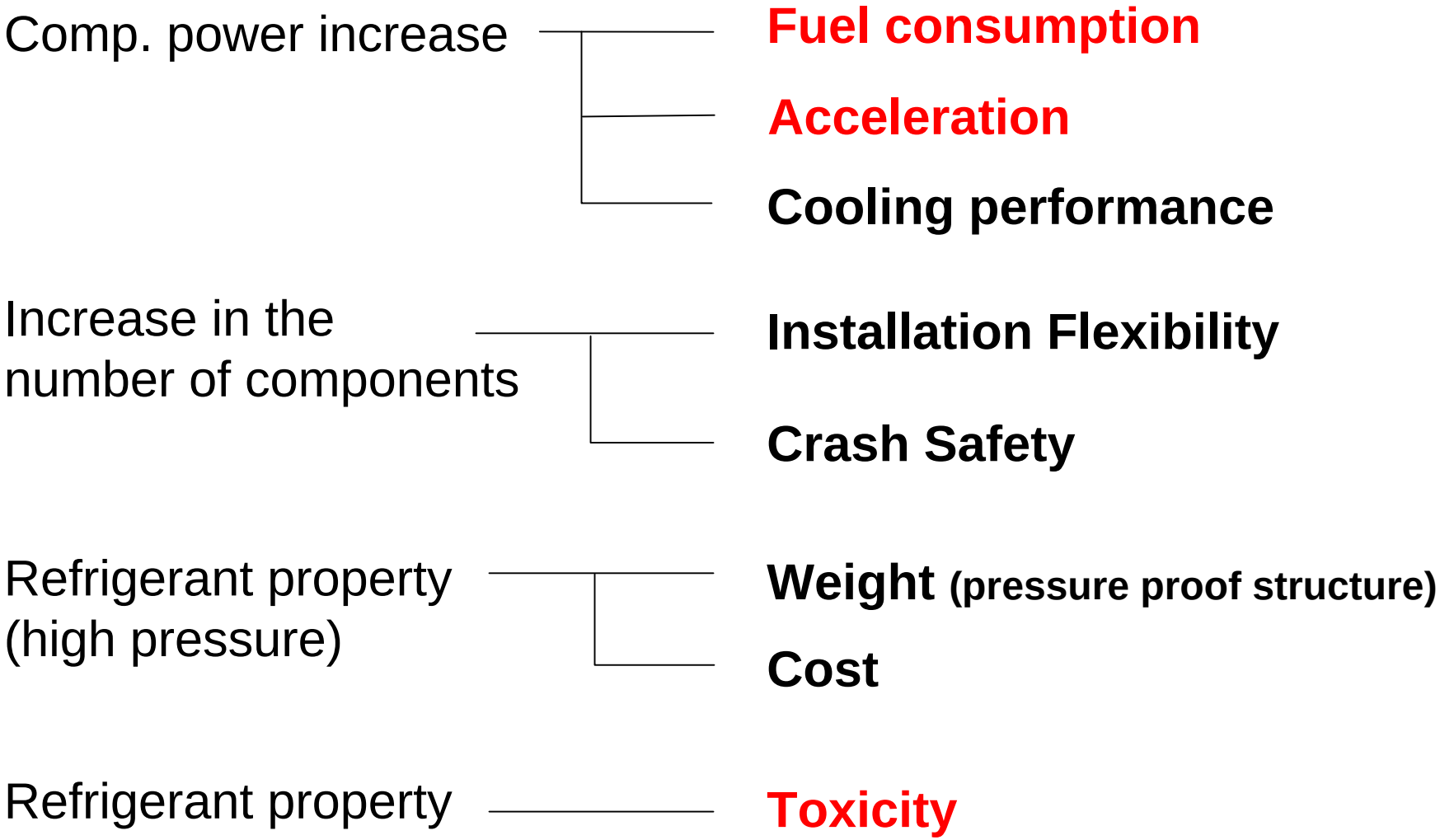
3. Impact of Refrigerant Polarization

3-d. Conclusion for impact of refrigerant polarization

- **CO_2 MAC is not a global solution.**
- **Refrigerant Polarization will double the development and production of the vehicle and MAC system, and also causes complicated infrastructure of servicing in the aftermarket.**

4. Impact on Vehicle Performance

4-a.Impact to Vehicles



4. Impact on Vehicle Performance

4-b.Impact on fuel consumption

- **Comparison of fuel consumption by actual road test**

Engine 1.5L petrol / Transmission AT
Mileage：140km (Highway, Hill climb, Urban)
MAC setting: Fresh air, Fan:2nd, Face mode

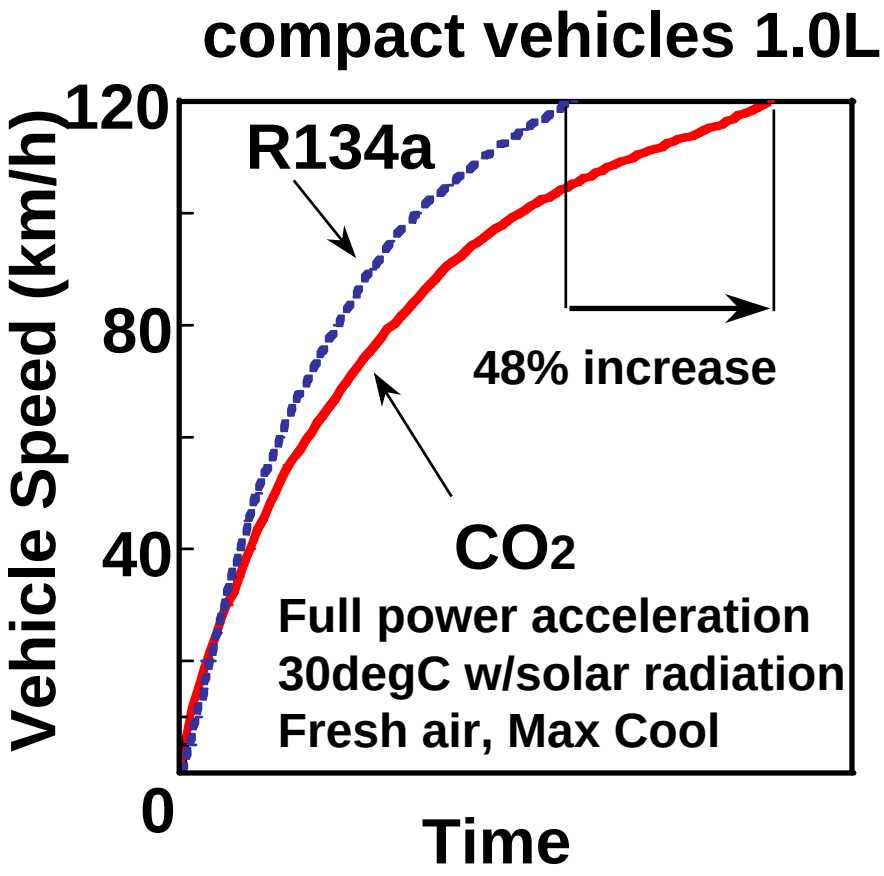
September 12th.(AMB：25 degC.cloudy)
original (R134a) : 7.04 L/100km (14.2km/L)
CO_2 : 7.69 L/100km (13.0km/L)→**9%down**

September 20th (AMB：20 degC.rainy)
original (R134a) : 7.35 L/100km (13.6km/L)
CO_2 : 8.33 L/100km (12.0km/L)→**12%down**

In CO_2 MAC system, the increase in compressor power consumption deteriorates fuel consumption.

4. Impact on Vehicle Performance

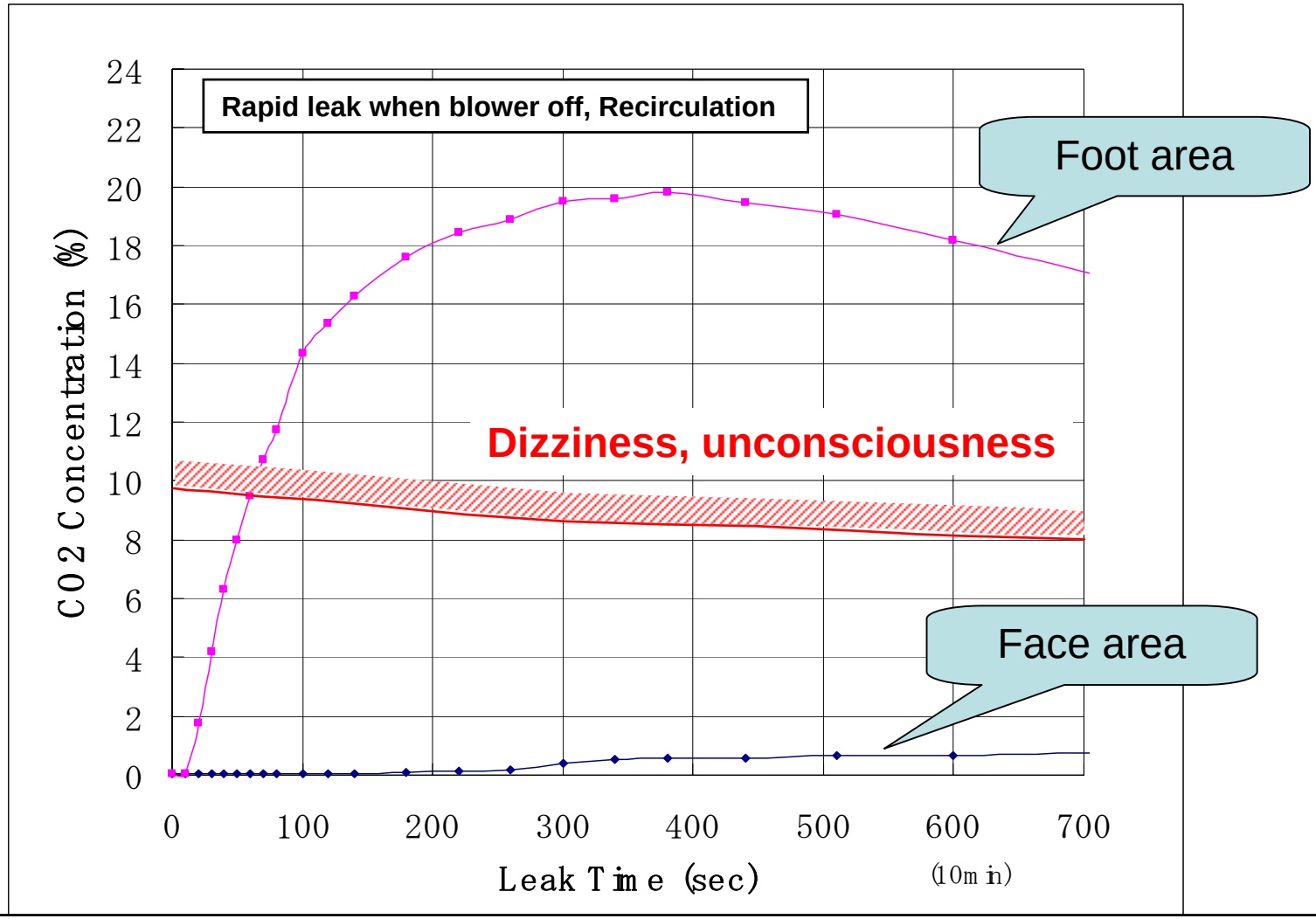
4-c.Impact to acceleration



In CO_2 MAC system, the increase in compressor power consumption deteriorates acceleration performance

4. Impact on Vehicle Performance

4-d.Toxicity



During FAN off, cabin room reaches a serious condition locally regardless of slow leak or rapid leak.

4. Impact on Vehicle Performance

4-d.Conclusion for impact on vehicle performance

MAC using CO_2 refrigerant impacts vehicle performance significantly from the perspective of:

- compressor power increasing
- increase of the number of components
- refrigerant property (high pressure, toxicity)

JAMA is really concerned that :
- the compact car will be avoided by consumers if CO2 MAC system consumes more energy
- the earth will be really harmed without energy efficient cars.

5.Summary

Problems of CO_2 MAC:

- **No clear evidence that the environmental impact of CO_2 MAC system is better than R134a MAC system.**
- **Disadvantage due to Refrigerant Polarization (development, production and servicing).**
- **A lot of unsolved issues that significantly impact on vehicle performance, especially on compact vehicle performance.**

Therefore, to achieve the global solution,

- **TEWI calculation contents should be transparent like climate and vehicle conditions, parts specification, etc., then it should be discussed continuously.**

6.Requests

JAMA proposes two requests ;

- To evaluate the environmental performance of CO2, R134a and other alternatives.

- To review the time of R134a ban based on the test results which will be available in 2007

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Japan Automobile Manufacturers Association, Inc.

Thank you for your attention !

From

Japan
Automotive
Manufacturing
Association

The energy consumption at Production of R134a

From mine to refrigeration:
a life cycle analysis of the production of HFC-134a, A.A. Lindley, 2003, International Journal of refrigeration

6.6kg-CO_2 /(1 kg of HFC-134a production)

→ **3.3kg-CO2 / one vehicle is added into TEWI**