

Mobile Air-conditioning Actions for Global Warming Reduction

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DENSO CORPORATION

-
- 1. Mobile Air Conditioning and Global Warming**
 - 2. Refrigerant Emission Reduction**
 - 3. Energy Efficiency Improvement**

Mobile Air-conditioning and Global Warming

MAC's Refrigeration Cycle

Compressor



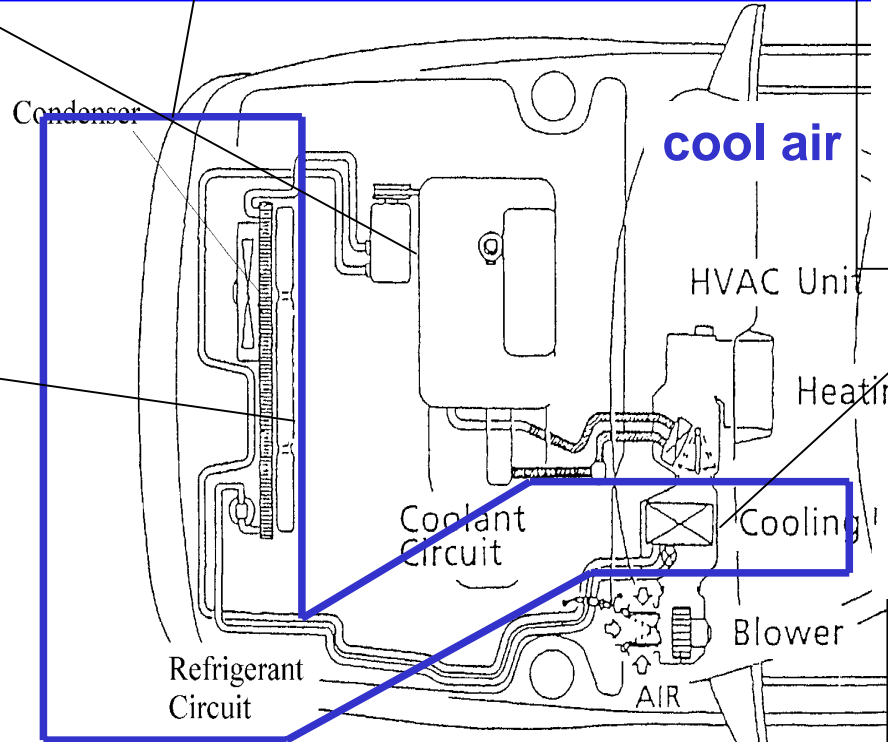
High press.
& high temp. gas



Condenser



Refrigeration Cycle



Evaporator

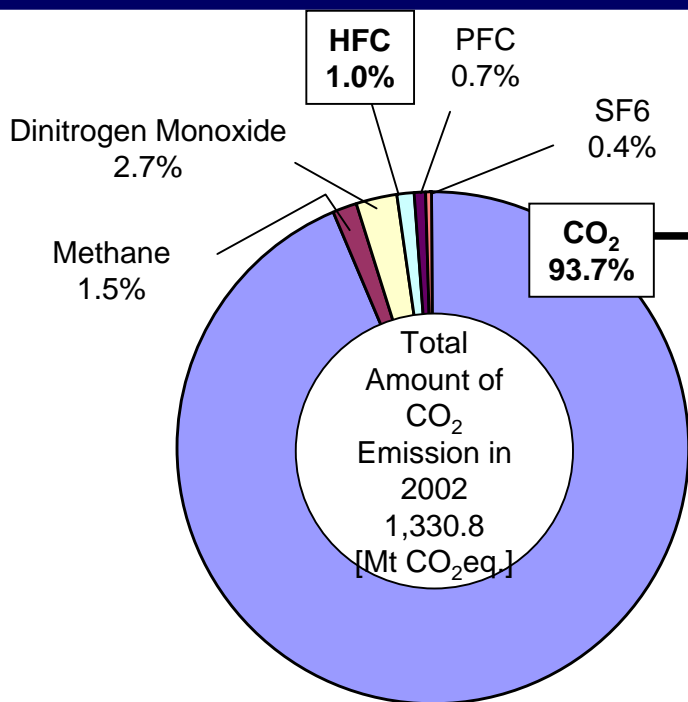


Low press.
& low temp. gas

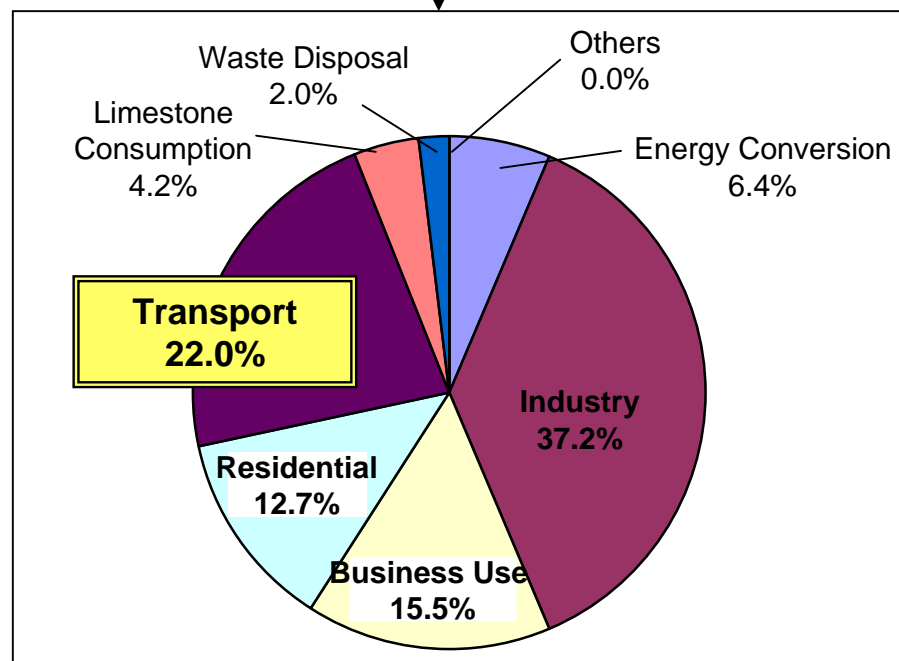
Expansion Valve



GHG Effects on Global Warming (Japan)

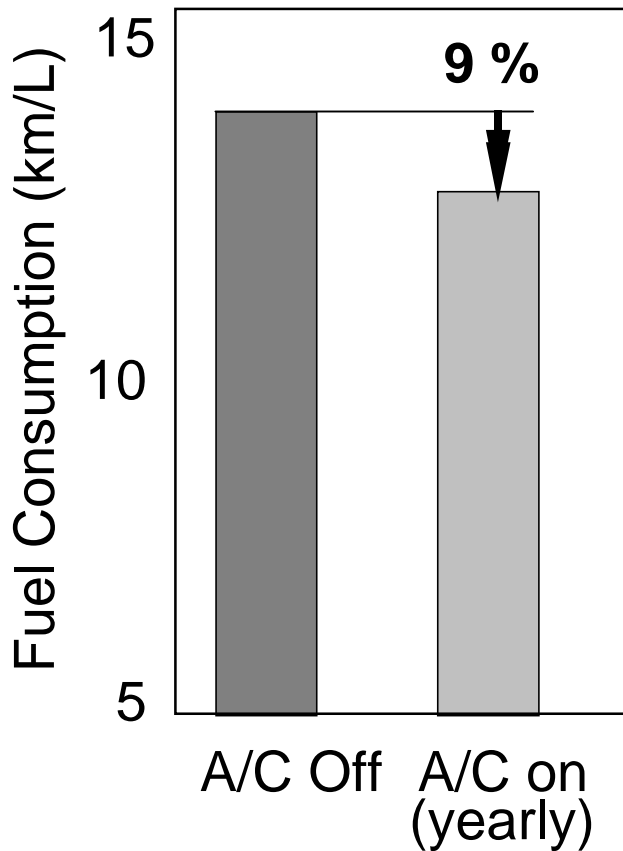


Breakdown of CO₂ Emission by Sectors



Influence of A/C on Fuel Consumption

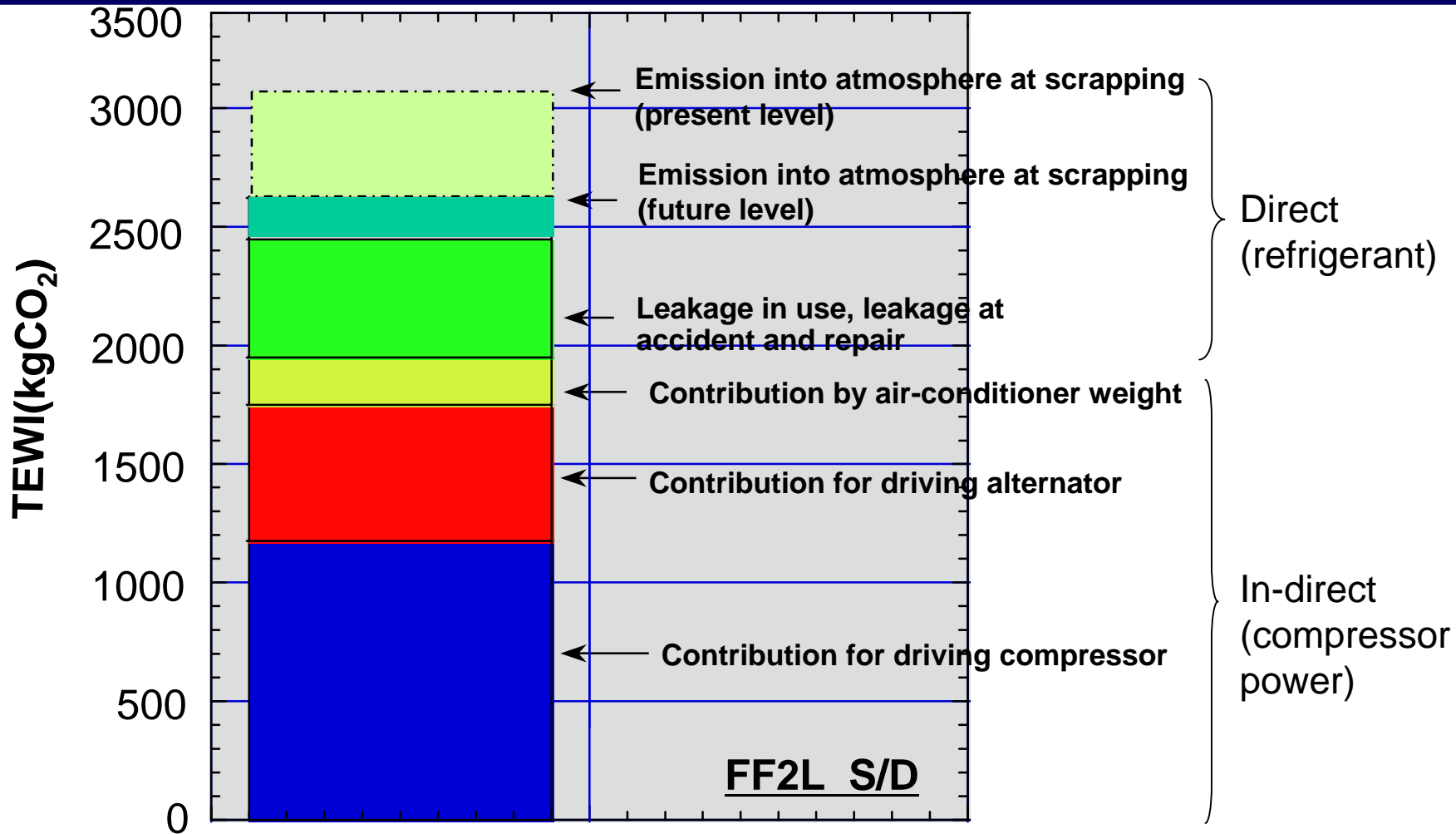
25 (50%RH), No Solar Radiation



Actual Running Mode:
Compact Car LA4: Stop Ratio 17%

	Yearly
Temperature (°C)	25
Humidity (%)	50
Sun Load (W/m ²)	0
Fresh / Recirculated Air	Fresh
Blower Speed	Low
Evaporator Outlet Air Temperature (°C)	10

Example of TEWI Calculation (JAMA)



Refrigerant Emission Reduction (JAMA's Action)

JAMA: Japan Automobile Manufacturers Association

JAMA's Action Plan

Reduction of refrigerant emission from HFC-134a A/C

1.Recommend to use small refrigerant charge components;

- Target is 20% reduction from 1995 to 2010.
- In 2004, the average of charge has been reached to 21% of 1995's charge (1995:700gram , 2004:553gram)

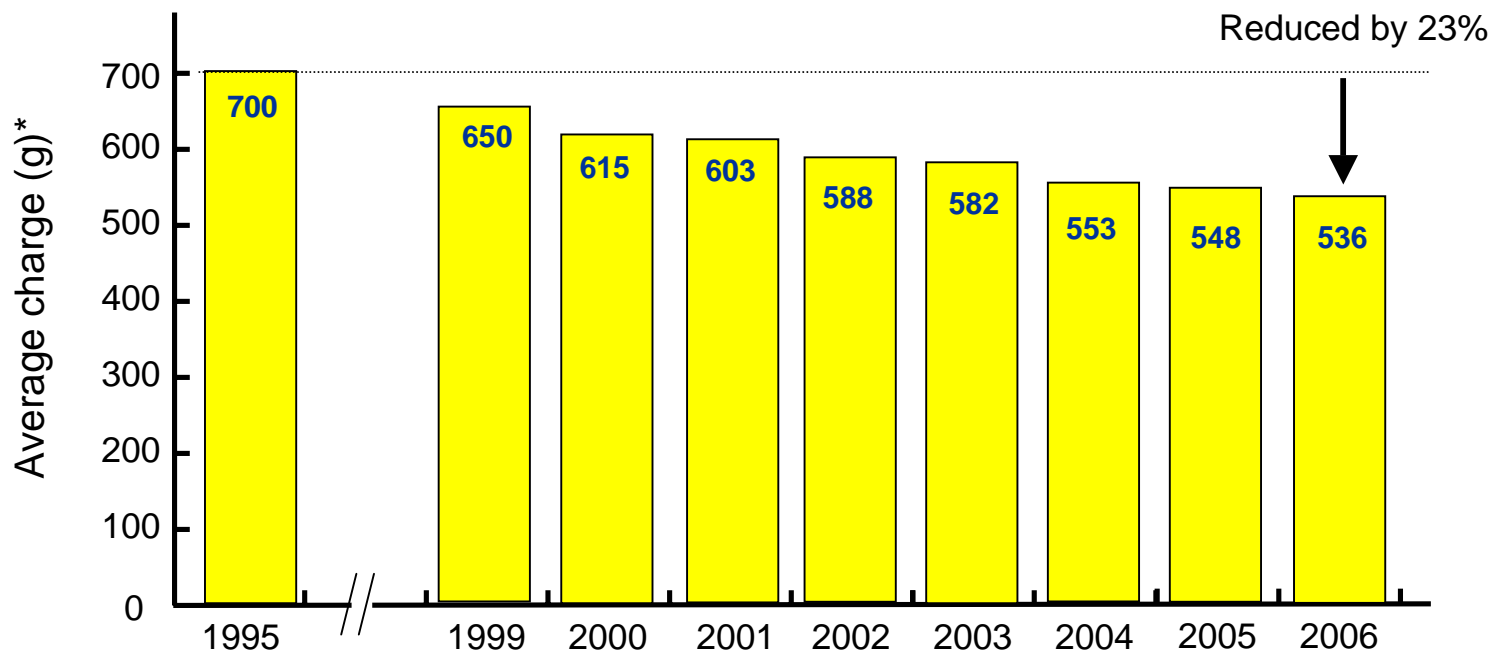
2.Recovery and destruction of Refrigerant:

- Fluorocarbons Recovery and Destruction Law enforced from October, 2002.
- Reported recovery rate of scrapped vehicles is approx. 40%.
- This law was incorporated into Automobile recycling law from January, 2005.

3.Recommend to use lower refrigerant leakage components;

- According to self-assessment of OEM, leakage in operation has been reduced from 15g/yr
- Field survey test was done from 2004 to 2005 to seek actual value.

Refrigerant Charge Reduction from 1995 to 2006

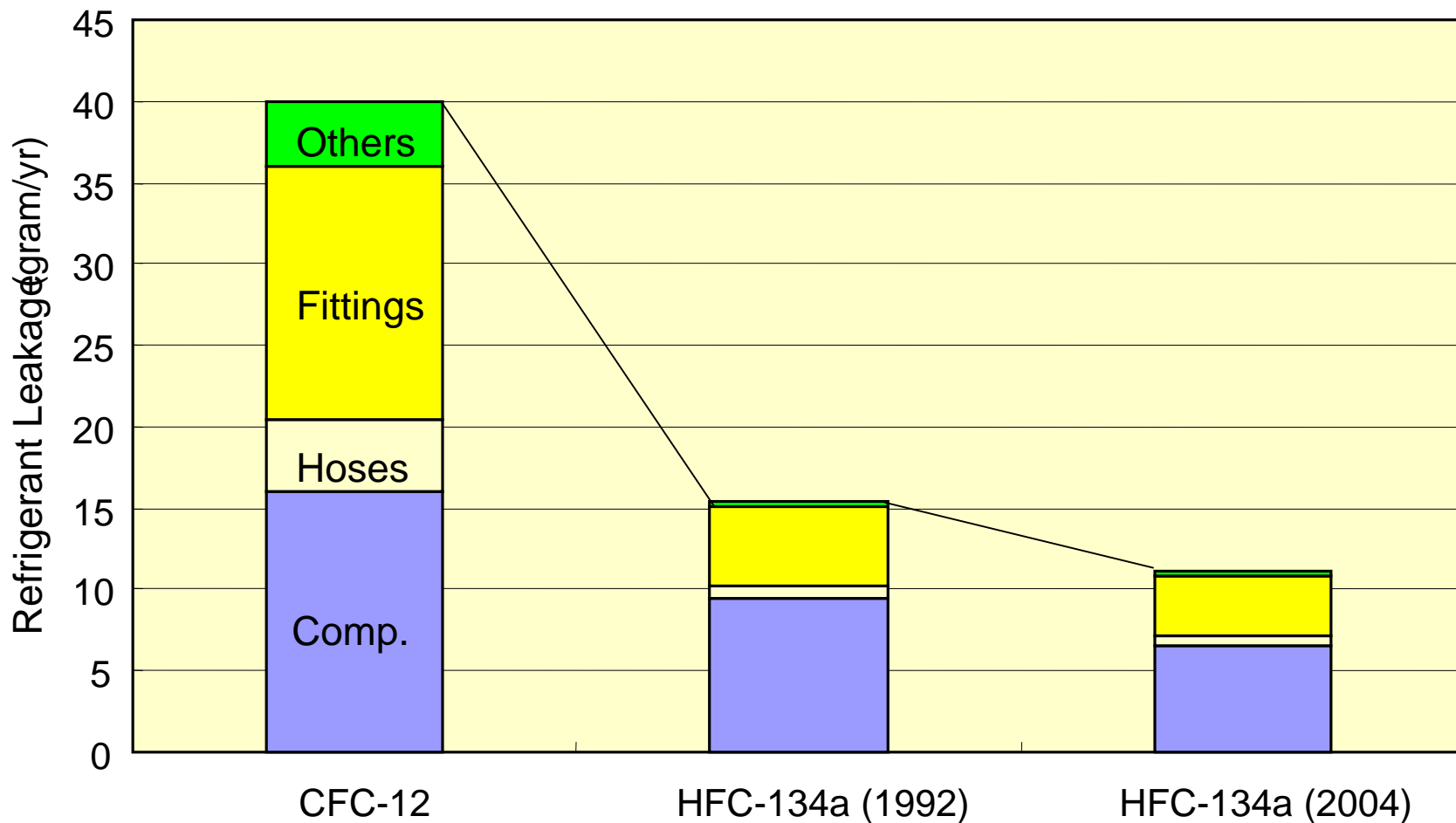


$$\text{*Average refrigerant charge} = \frac{\text{Total charging amount at vehicle production}}{\text{The number of produced vehicles}}$$

The Refrigerant Recovery Data when scrapping in Japan

	Refrigerant recovered vehicle numbers		Recovered amount (kg)	
	2005	2006	2005	2006
CFC-12	961,904	874,665	285,183	244,545
HFC-134a	1,083,231	1,500,828	372,089	496,971
Total	2,045,135	2,375,493 (+16.2%)	657,272	741,516 (+12.8%)

Reduction in Refrigerant Leakage in Operation



Refrigerant Leakage Field Test

(From April, 2004 to December, 2005)

✓Location

Tokyo, Nagoya (average temperature 16C)

✓Number of test vehicles

78 vehicles (seven auto makers)

✓A/C system

Single AC (16 type vehicles)

Dual AC (6 type vehicles)

✓Charge amount

Single:	Average: 516gram	Max: 760gram	Min:409gram
Dual:	Average: 804gram	Max: 1141gram	Min:663gram

✓Driving distance

Single:	Average: 17,402km	Max: 38,381km	Min:1,952km
Dual:	Average: 20,590km	Max: 40,983km	Min:4,803km

✓Compressor running time

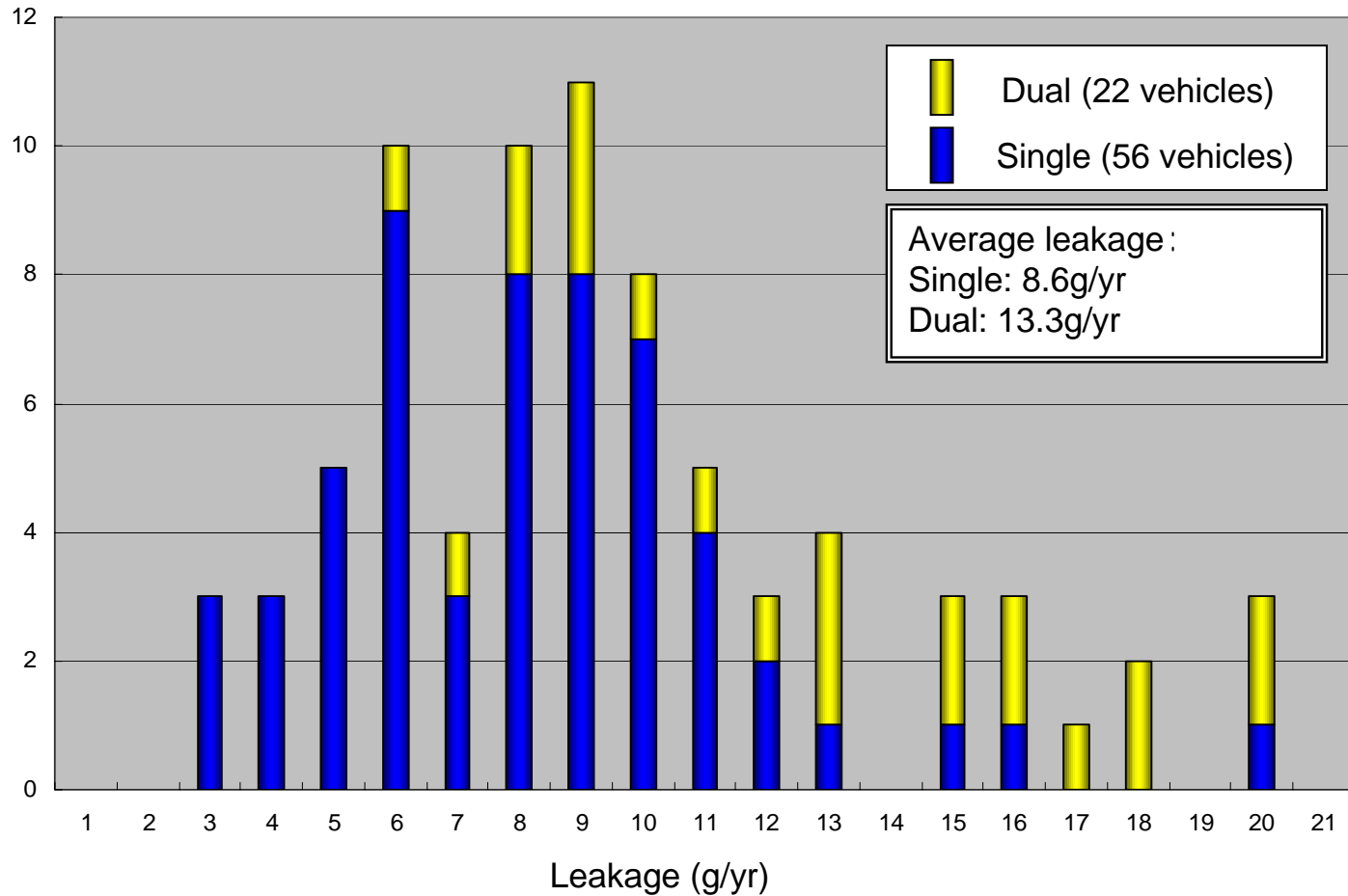
Single:	Average: 211.3hrs	Max: 938.0hrs	Min:24.4hrs
Dual:	Average: 248.9hrs	Max: 758.9hrs	Min:51.5hrs

✓Compressor cycling number

Single	Average: 32,544	Max: 97,627	Min:253
Dual	Average: 36,302	Max: 98,777	Min:2178

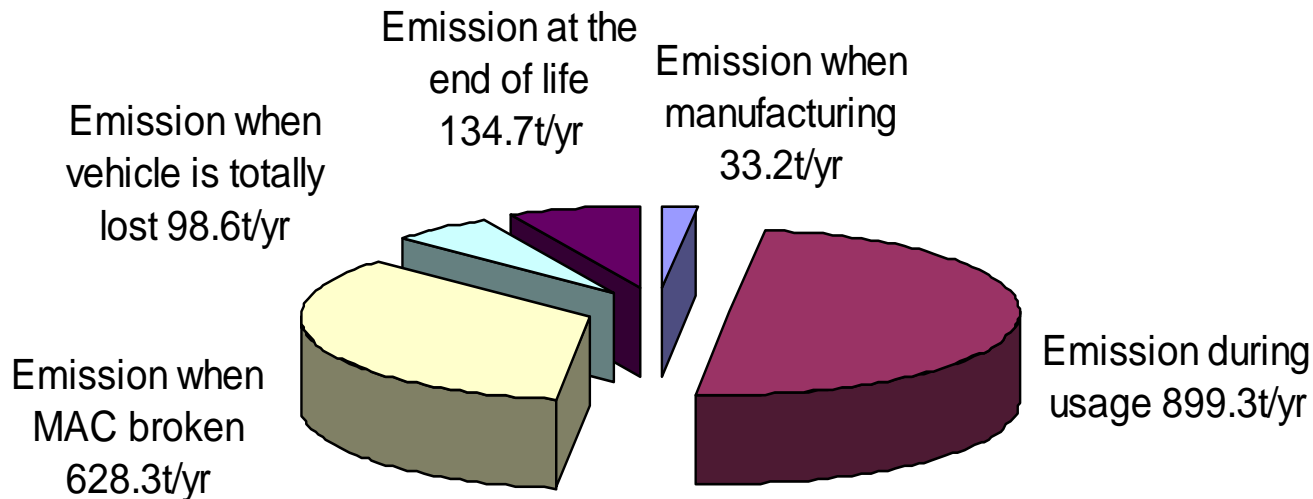
Annual Refrigerant Leakage

Region: Tokyo & Nagoya (Normal load), average temp.: 16C



Estimated Breakdown of Refrigerant Leakage from MAC in Japan

Reported to METI (Ministry of Economy, Trade and Industry)



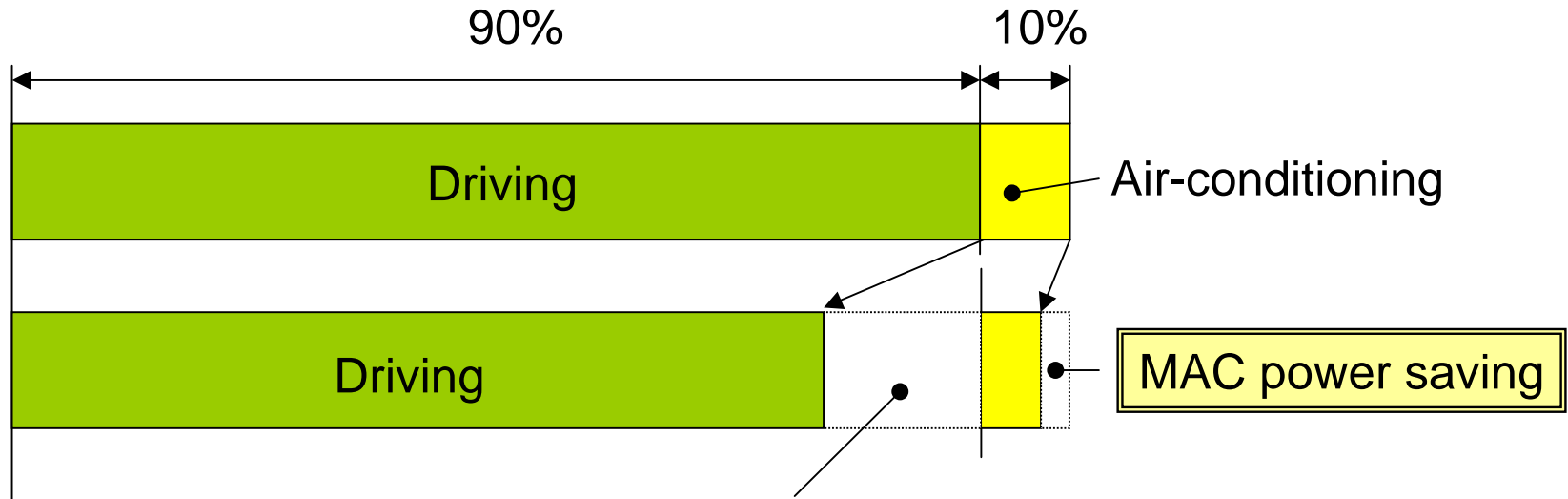
Total emission: 1794.1 ton/year



- **2.33 M CO₂-ton/yr**
- **0.2% of baseline (1237 M CO₂-ton/Yr)**

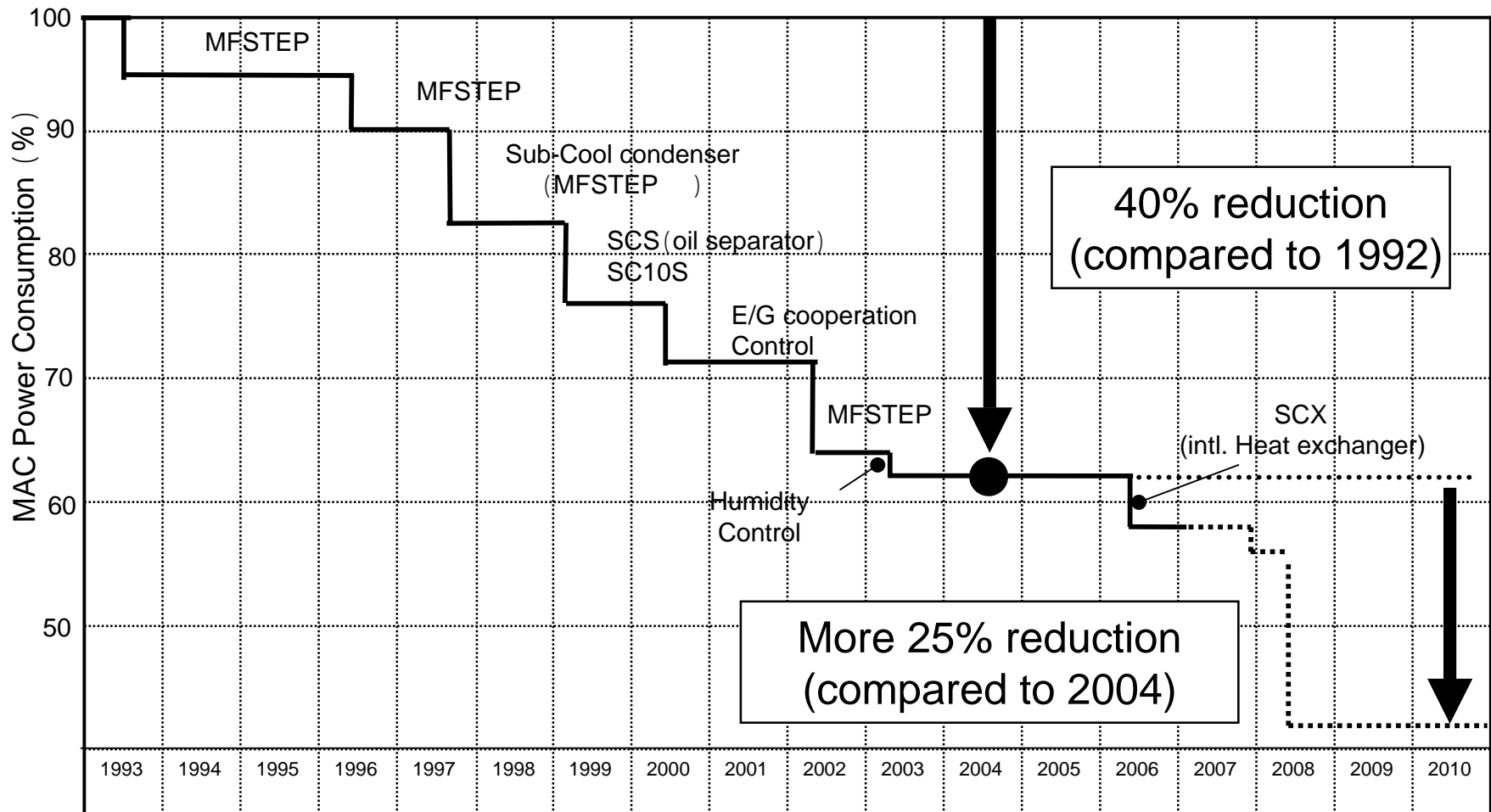
Energy Efficiency Improvement

Fuel Consumption

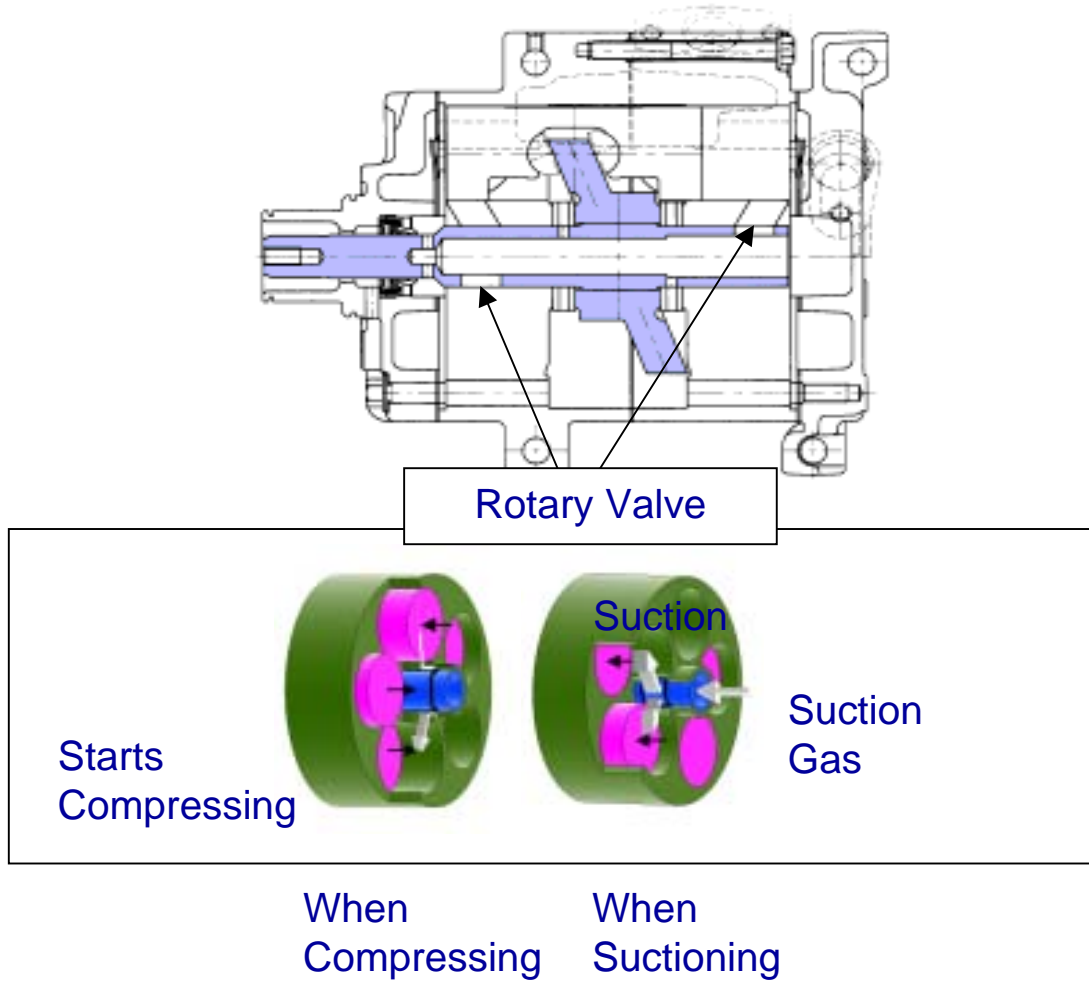


- Engine efficiency improvement
- Light weight of vehicle
- Thermal management

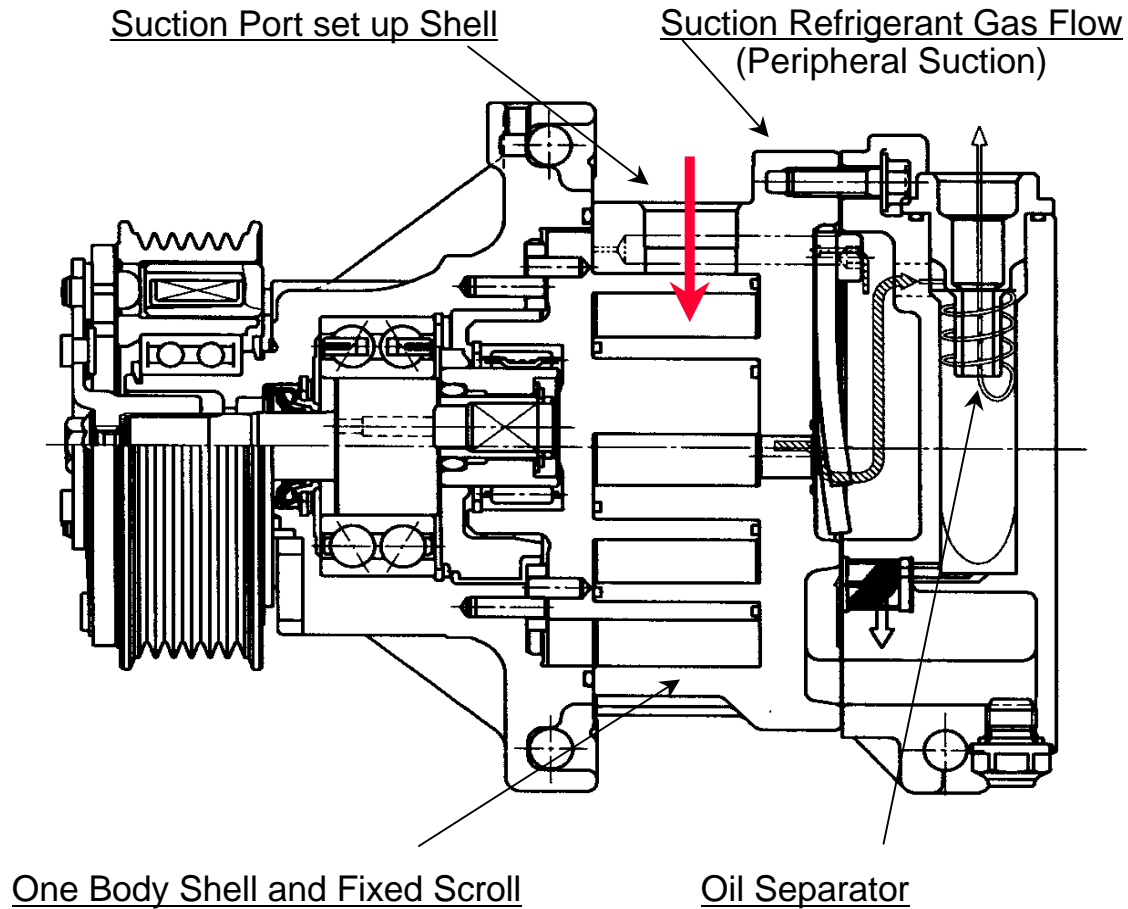
Trend of MAC Power Saving



Example of Energy Efficiency Improvement: Compressor

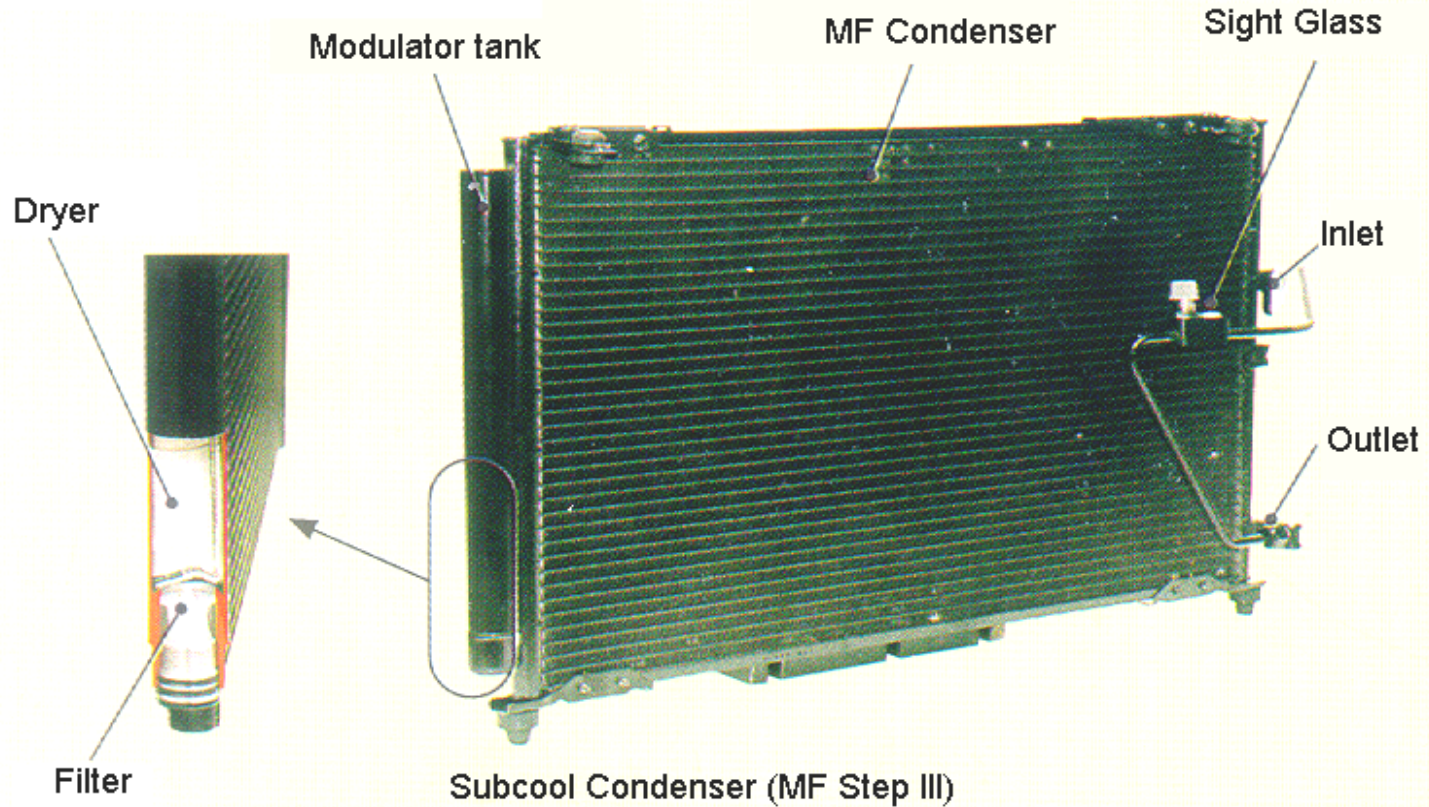


Example of Energy Efficiency Improvement: Compressor

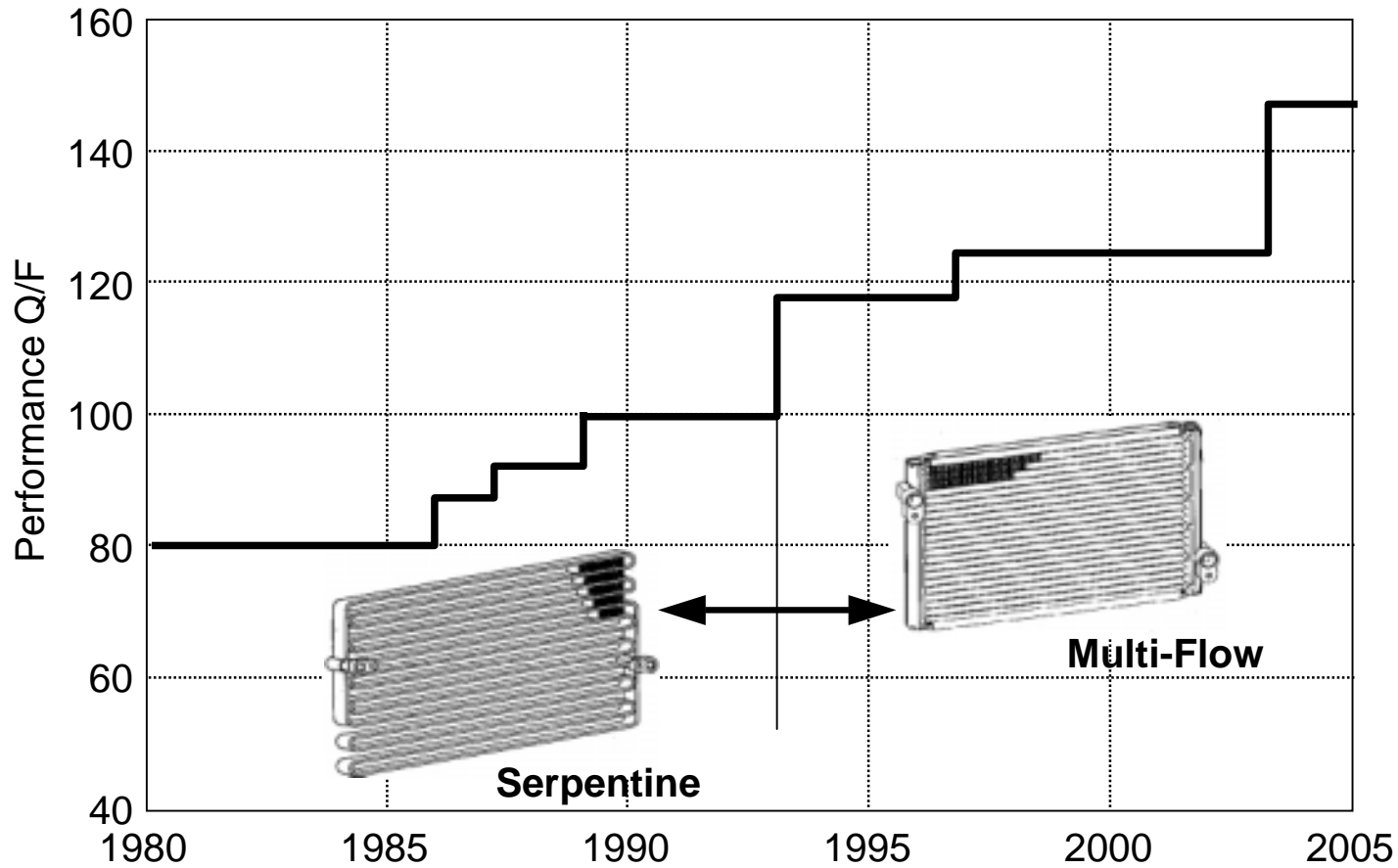


Example of Energy Efficiency Improvement: Sub-Condenser

Efficiency: 10%
Improved/QTY of Refrigerant: 100g
Reduced/Weight Reduction: 350g

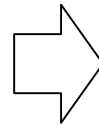


Example of Energy Efficiency Improvement: Condenser



Example of Energy Efficiency Improvement: Compact Evaporator

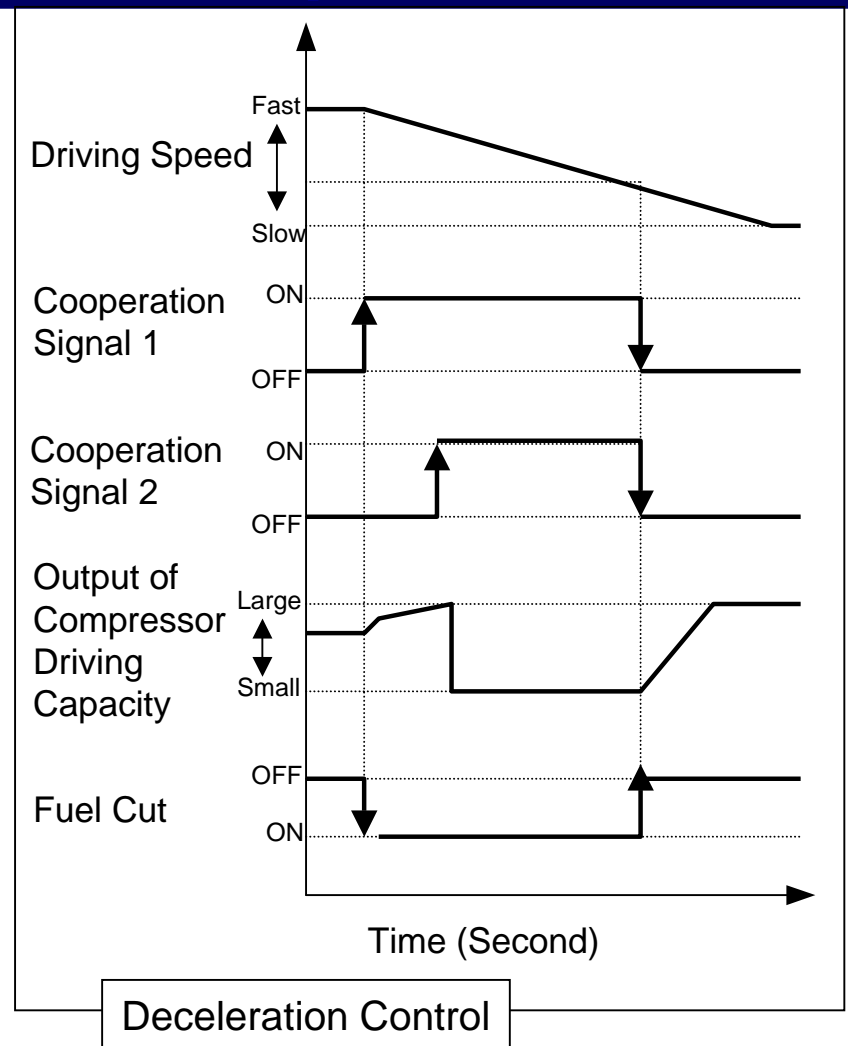
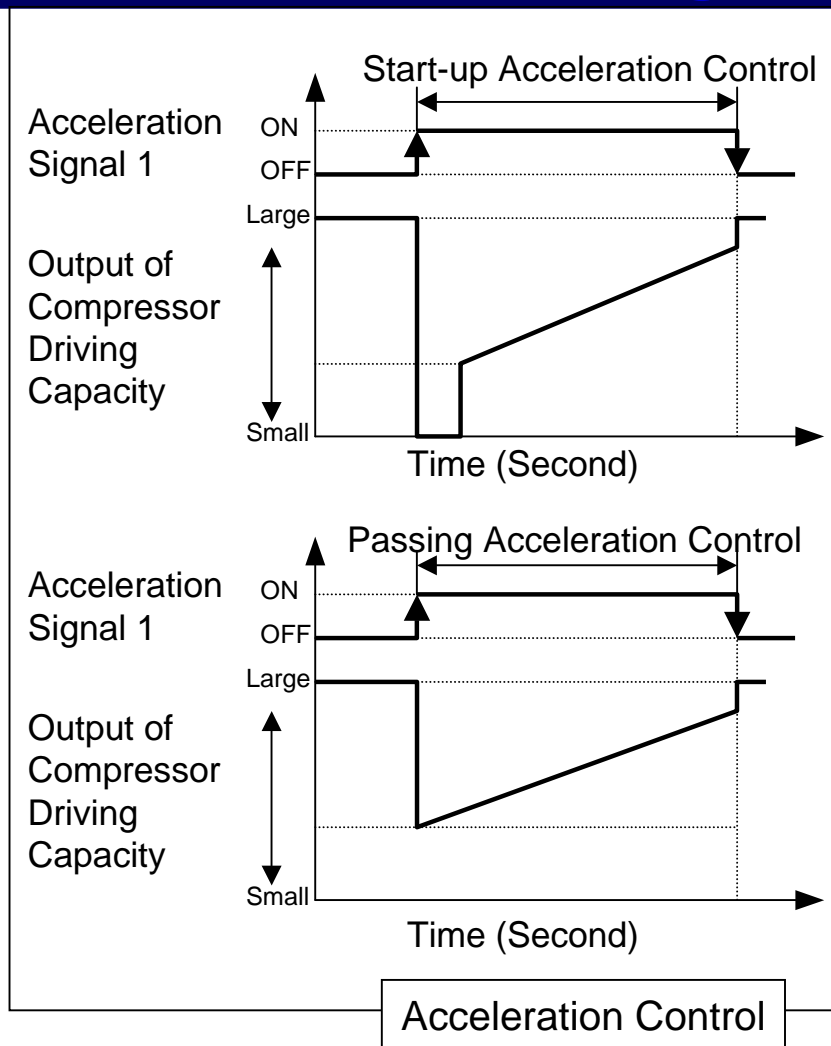
Conventional Type



Enhanced type



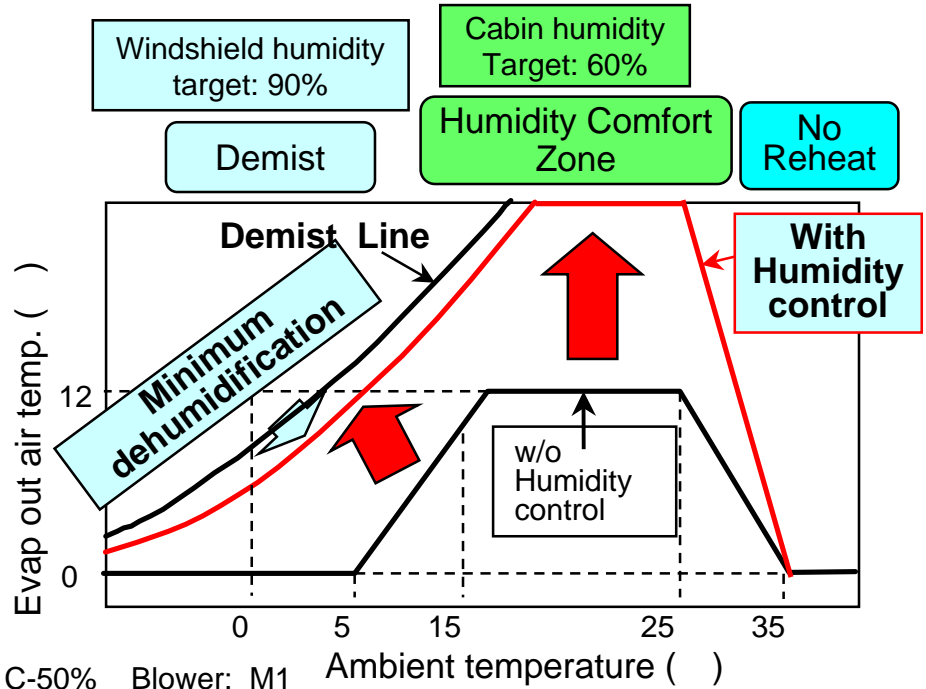
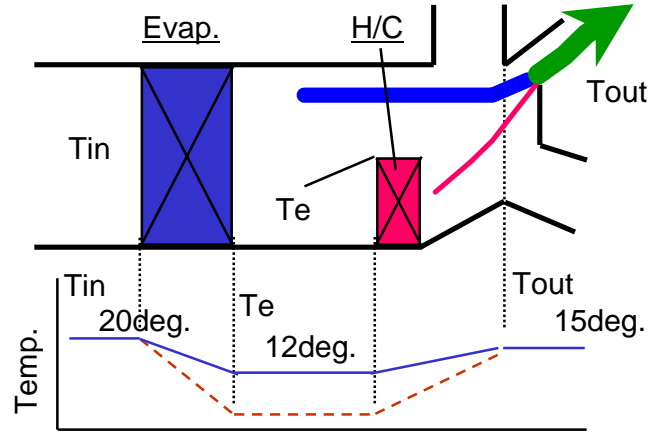
Example of Energy Efficiency Improvement: Engine-A/C Cooperation Control



Example of Energy Efficiency Improvement: System with Humidity Sensor

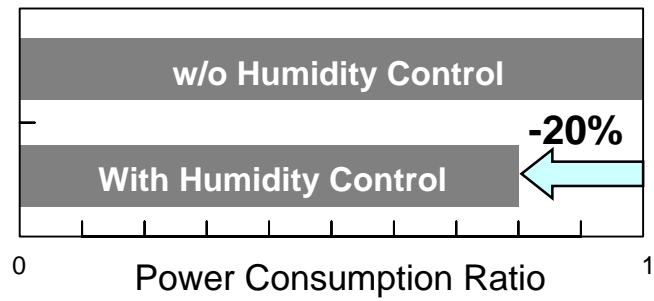
Power saving Control

(External Variable Compressor)

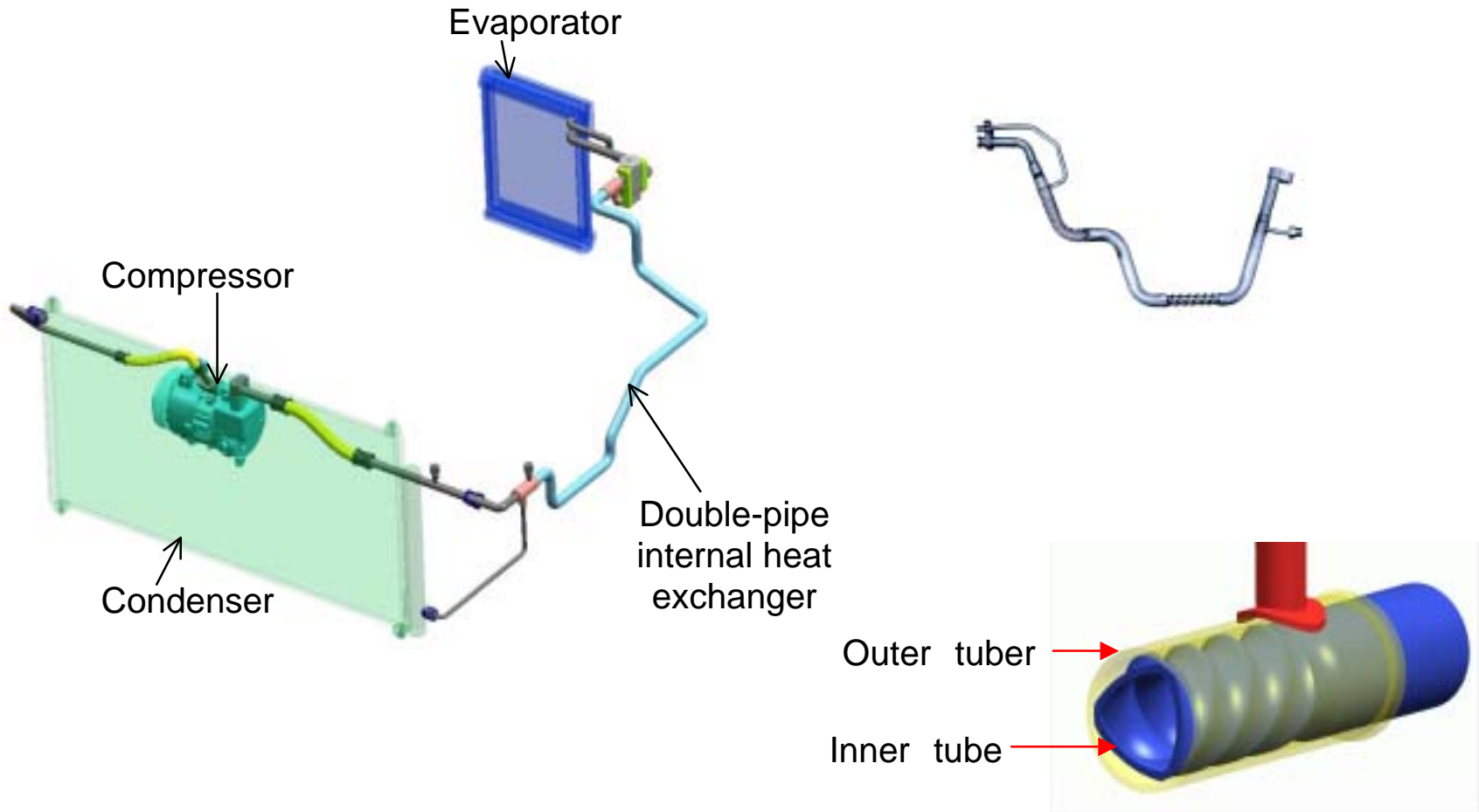


Effect

Conditions: 25 ° C-50% Blower: M1



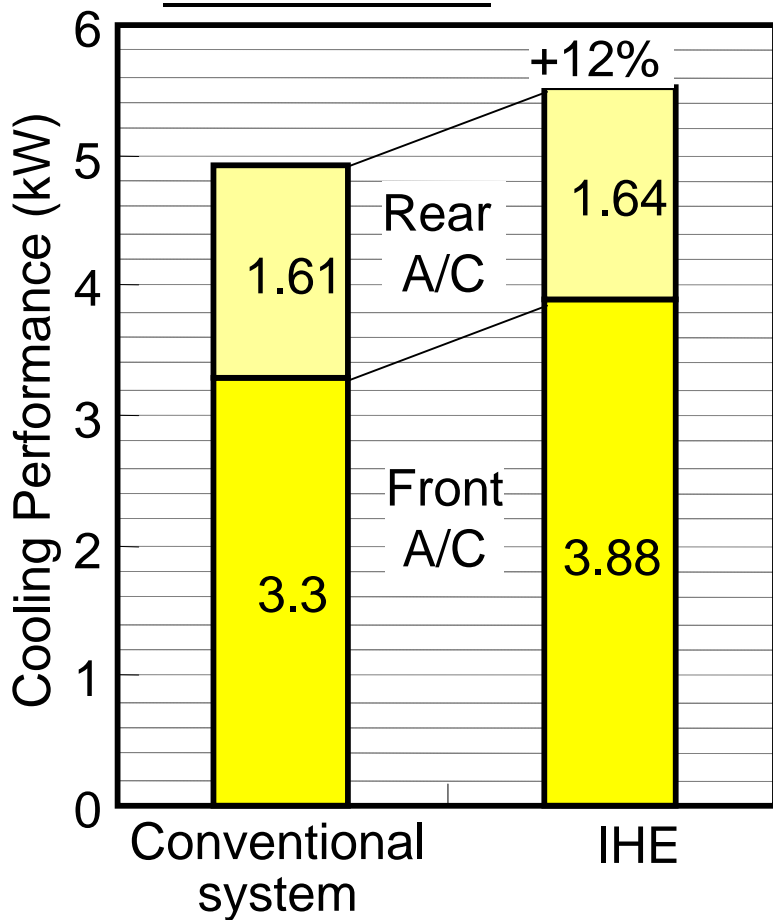
Example of Energy Efficiency Improvement: Internal Heat Exchanger



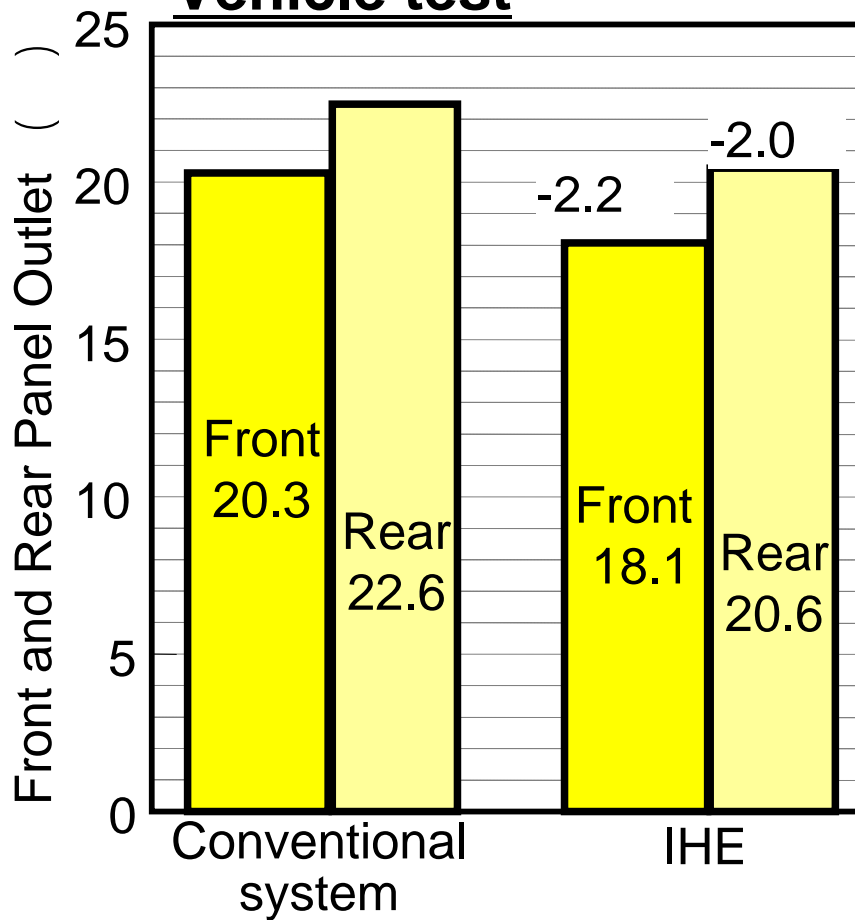
Cooling Performance Improvements

Conditions: Large car, idling, ambient temperature 45° C

Bench Test



Vehicle test



Fuel Consumption Improvement

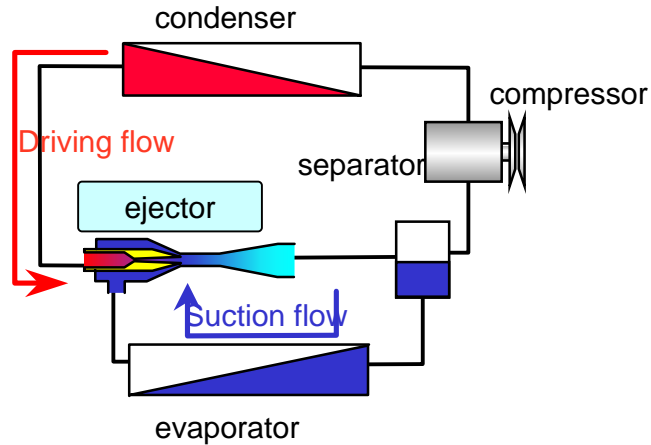
Conditions: Compact car, TEWI * evaluation in Tokyo, Japan

	Vehicle Speed	A/C	Ambient Temperature & Fuel consumption (liter)					Total Annual Fuel Consumption
			35° C	30° C	25° C	20° C	15° C	
Conventional system	0 km/h	OFF	1.4	4.7	10.2	7.6	3.3	400 L (224.78 L with A/C ON)
		ON	3.2	10.0	23.3	14.5	5.5	
	40 km/h	OFF	3.8	13.7	33.3	25.0	11.3	
		ON	5.5	17.4	40.2	28.9	12.7	
	100 km/h	OFF	2.6	9.9	23.2	17.6	7.6	
		ON	3.0	10.7	25.3	18.6	8.0	
IHE	0 km/h	OFF	Same as conventional system					395 L (-5liter or -1.3%) (219.76 L with A/C ON)
		ON	2.8	8.9	18.7	13.9	5.6	
	40 km/h	OFF	Same as conventional system					
		ON	5.4	17.1	40.1	29.1	12.9	
	100 km/h	OFF	Same as conventional system					
		ON	2.9	10.7	25.0	18.7	8.1	

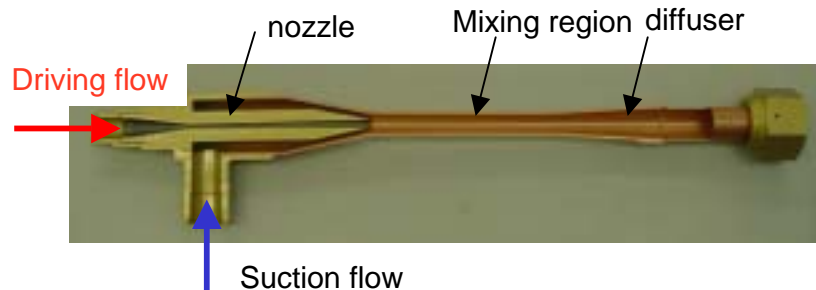
* TEWI: Total Equivalent Warming Impact

Example of Energy Efficiency Improvement: Recovery of Expansion Energy

Ejector cycle



Ejector



Development of World First Ejector Cycle Refrigerator : EJECS

50% of Energy Efficiency Improvement!!



Truck transport refrigeration unit using ejector

エジェクタサイクル, Ejector Cycle and EJECS are registered trademarks of DENSO corporation

Truck Transport Refrigeration Unit using Ejector Cycle (EJECS)

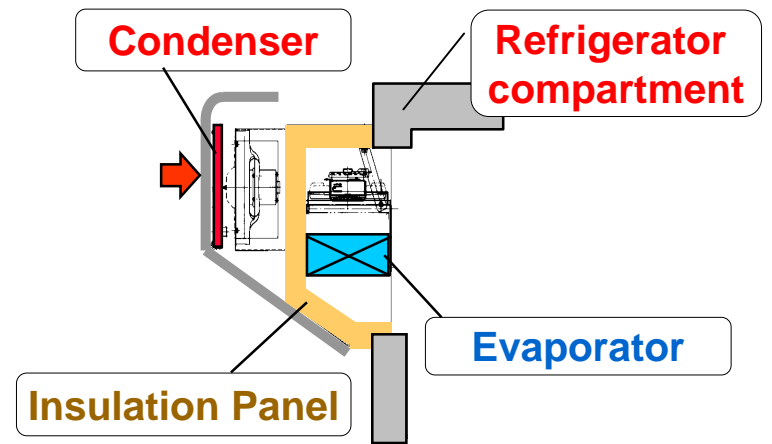
Purpose: Compressor power saving and Fuel economy improvement



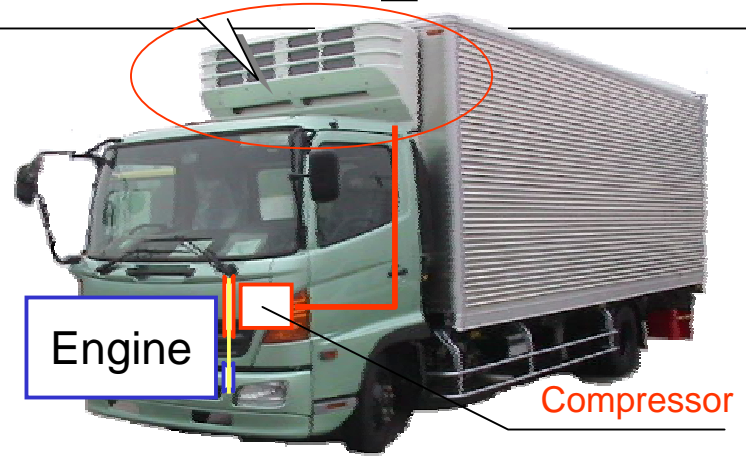
**COP (*1)
+50%**

**Weight
40%**

- Cross view of the structure -
Front ← → Back






Adopt World First Ejector Cycle



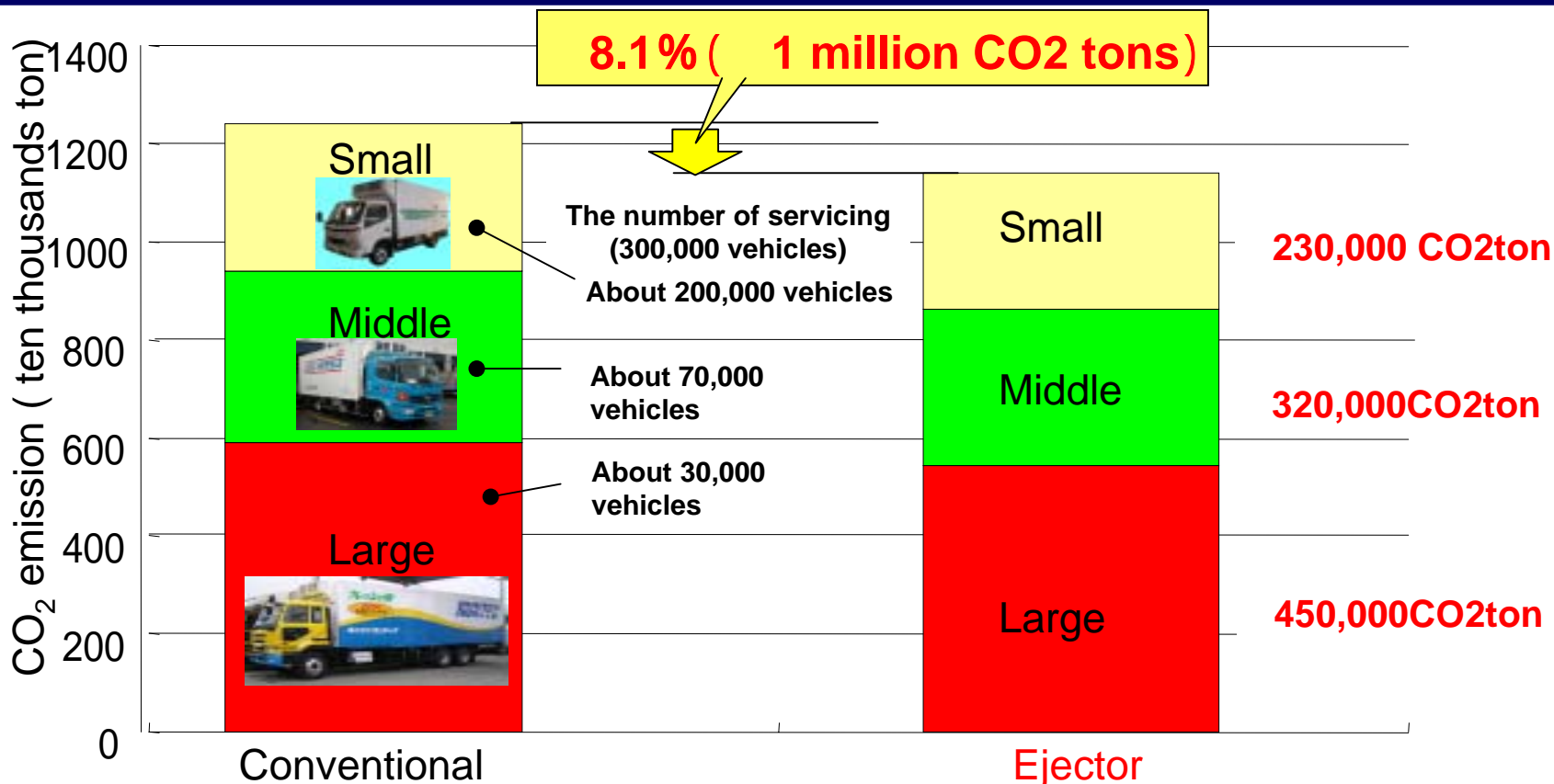
Result of Vehicle Monitor Test



Example: Large truck transportation refrigeration unit

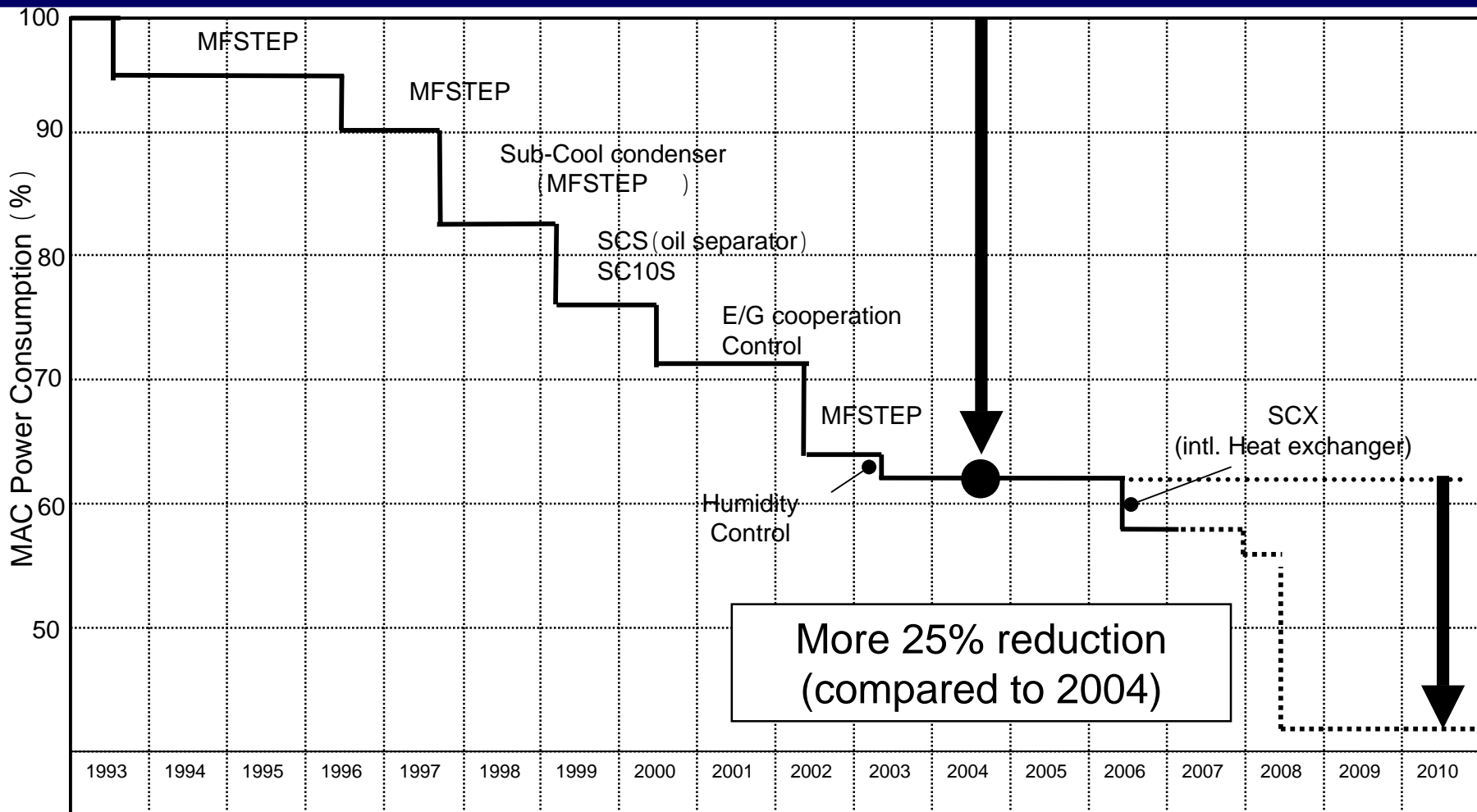
Classification	Load capacity: 10 ton		
Driving pattern	Kyusyu-Kansai (611 km) long-distance transporter for highway Load: frozen and refrigerated food		
Period & Method	From 2003 December to 2006 November Fuel consumption measurement: Fill up method		
Refrigeration unit	Company A Refrigerator (Sub engine system)	Company A Refrigerator (direct coupling)	Ejector Cycle Refrigerator (direct coupling)
	Weight 560kg	Weight 234 kg	Weight 186 kg
			
# of vehicles	7	10	6
Annual fuel consumption (liter)	Average 70750 (l)	Average 63875 (l)	Average 55845 (l)
<p style="text-align: center;"> 22% 12% </p>			
<p>Succeed to decrease fuel consumption by 12% to 22% compared to conventional refrigerators (sub-engine and direct coupling)</p>			

CO2 Emission Reduction Effects based on All Refrigerated Vehicle in Japan



Effects of CO2 emission reduction by 1 million CO2 tons thanks to the ejector refrigerator

Trend of MAC Power Saving



Current Situation for alternative refrigerant

MAC directive

- 2008 ~ Directive 2006/40/EC (Emission of R134a)
- 2011 ~ Banning the use of R134a for new type of vehicle
- 2017 ~ Banning the use of R134a for new vehicle

Europe

- VDA 2008/07 : decided to use CO2
- Other Not decided yet
(French, Italy, US, Japan)

Under evaluation of Low GWP refrigerant. We are discussing about not only direct effect but energy efficiency (fuel consumption) by refrigerant.
The point is LCCP estimate.