

1999 Automotive Alternative Refrigerant Systems Forum

Title :

Experimental Evaluation of The Prototype CO₂ System and The HFC-134a System In Wind Tunnel

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Presented on June 30, 1999

Phoenix, June 28-July 1, 1999



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1. An Approach Towards Alternative Refrigerant for HFC134a Automotive A/C.

- (1) Industry concerns were raised, at the 1998 Kyoto Conference (COP3) which listed the HFC family as one of the six substances causing most damage to global warming. Worldwide consensus will play a significant role in the introduction and timing of CO₂ as the third refrigerant.
- (2) Active R&D efforts are underway to minimize leak amount (direct effect) and energy consumption (indirect effect) of compressors for the current HFC134a system.
- (3) Consistent with commitment to the environment, and potential future customer requirements, tests of the compressors for CO₂ transcritical cycle automotive A/C system is continuing.

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2. CO₂ A/C Systems Requirements

Under the condition determined for the specific range of geographical area or the seasonal climate change, compressor test specification must be drafted from the system operation data.

- (1) TEWI must be smaller than that of HFC-134a system.
- (2) Cooling performance and COP must be greater than that of HFC-134a system.
- (3) Total system weight must be less than that of HFC-134a. In order not to adversely impact the size and weight of the vehicle, the size of each component must be comparable or smaller than current system.
- (4) Reliability and durability must be equal or better than that of the current A/C system.
- (5) To assure and improve serviceability, global standards must be formulated and agreed upon.

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3. Direction Of System Engineers for CO₂ System Vehicle Applications

- (1) As a compressor manufacture, Sanden believe that Variable displacement compressors should be used for a better TEWI₍₁₎.
- (2) In order for the system engineers to improve economic viability, it is advantageous to maintain system configuration and components as simple as possible, thus making it possible to utilize the existing manufacturing facilities as much as possible.
- (3) System controls will be simplified as much as possible. For the system engineers, the possibility of utilizing conventional expansion device concept is worth further investigation.

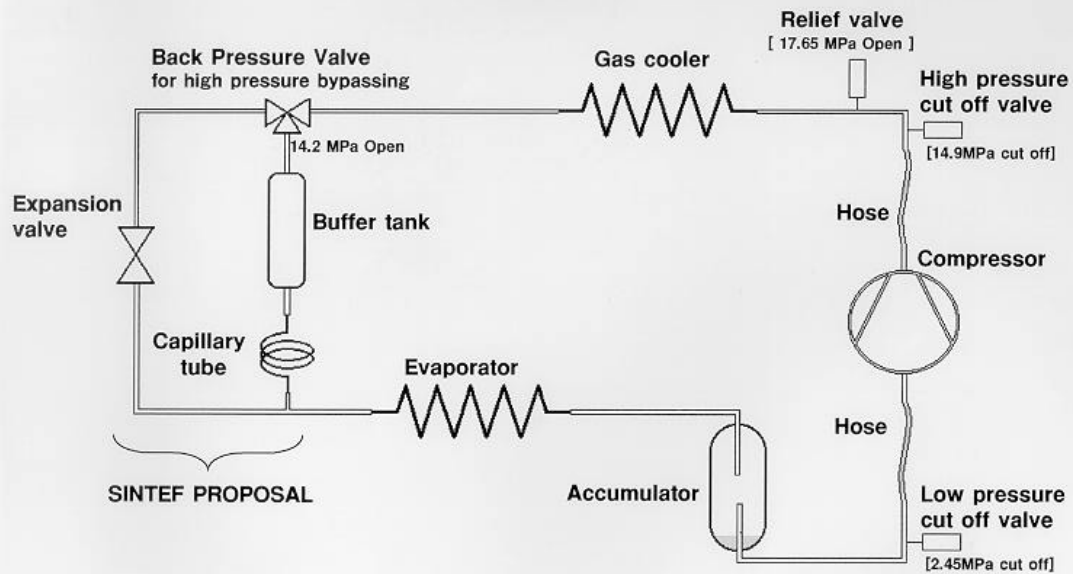
(1) Evaluation of Mobile A/C System for Environment Protection, SANDEN's presentation in the 98 Phoenix Project-Industry Forum on Mobile A/C Alternate Cooling, July 1998 SAE Interior Climate Control Committee

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4-1. Description Of Cycle Configuration



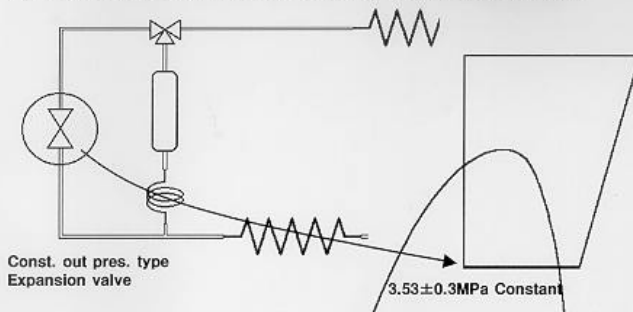
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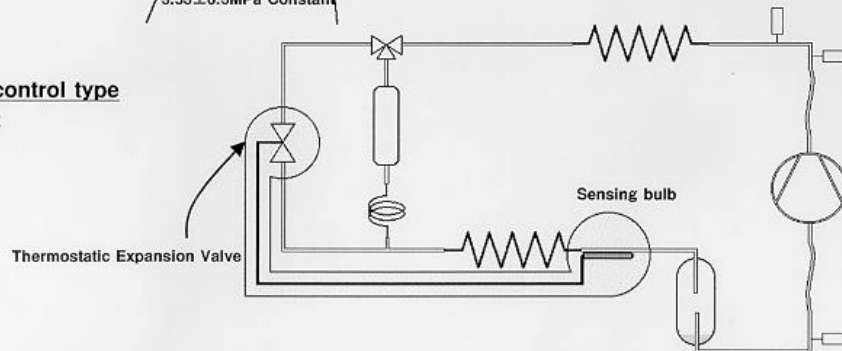
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4-2. Description Of Cycle Configuration

① with constant outlet pressure type expansion valve



② with superheat control type expansion valve



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4-3. Components Of Reference HFC-134a System And Prototype CO₂ System

	HFC - 134a system	Prototype CO ₂ system
Compressor	Displacement Max :161cc/rev Variable Comp. Drive ratio:1.08	Displacement 29.8cc/rev Fixed displacement Drive ratio:1.08
Evaporator	Fin and Tube W 261×H 228×L 80	Serpentine type W 259×H 226×L 80
Condenser/ Gas cooler	Multi-flow type W 600×H 341×L 20	Const. V. Proto.#1 Serpentine type w609×H341×L32
		T.X.V Proto.#2 Multi-flow type w606×H342×L16
Control	Thermostatic Expansion valve	Proto.#1 Constant out pres. type Proto.#2 Thermostatic expansion valve Back pressure valve
Protective Device	High pres. cut off switch 3.14MPa off Low pres. cut off switch 1.57MPa off Relief valve 3.9MPa off	High pres. cut off switch 14.9MPa off Low pres. cut off switch 2.45MPa off Relief valve 17.65MPa off
Receiver/ Accumulator	Receiver ϕ 75 mm × 168 mm	Accumulator ϕ 51 mm × 200 mm



4-4. Wind Tunnel Test Conditions (after RACE)

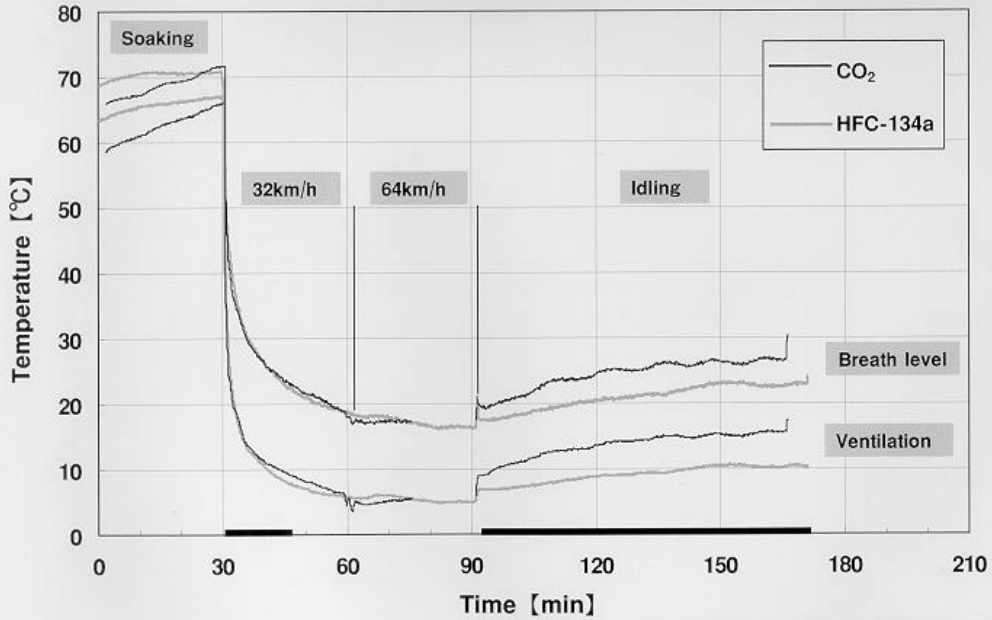
Phase	Soaking		Test		
	Preconditioning	Passive Heating	32km/h	64km/h	Idle
Time [min]	480	90	30*	30	80
Temperature [°C]	40	40	40	40	40
Rel. Humidity [%]	25	25	25	25	25
Sol. Radiation [w/m ²]	0	950	950	950	950
Engine Speed [rpm]	0	0	1600	1860	865
Velocity of Wind [km/h]	12	0	32	64	7
Inside Moistening [g/h]	0	0	0	0	0
A/C Setting			Fan : Max. Temperature Setting : Min. Air Recirculation : 100%		



5-1. Pull-Down Performance, CO₂ With Constant Outlet Pressure Type Expansion Valve

9

(Condition) Ambient temperature & humidity : 40°C, 25% Sol. Radiation : 950W/m²



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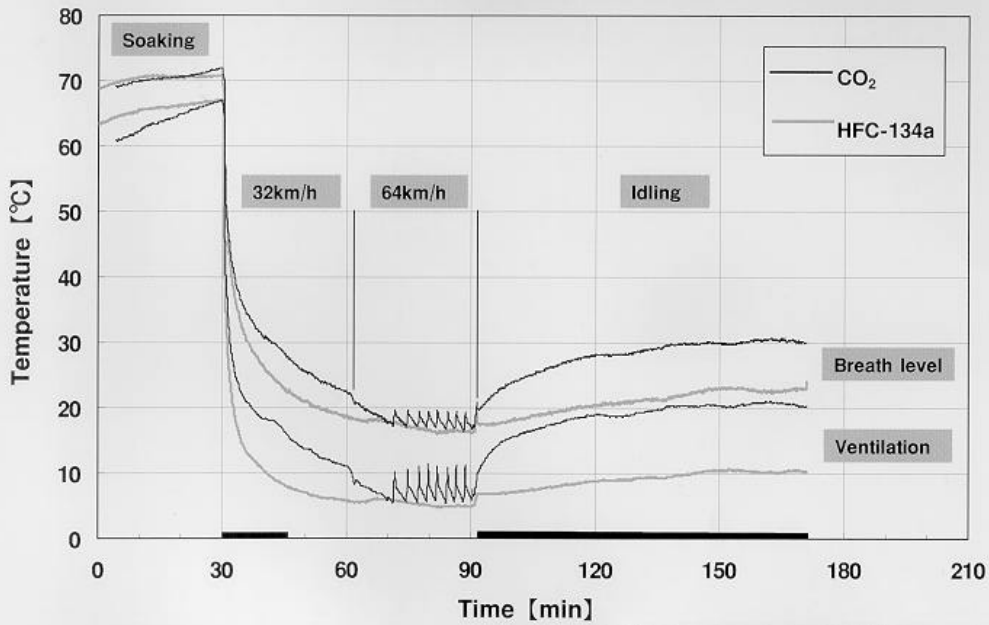
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5-2. Pull-Down Performance, CO₂ With Superheat Control Type Expansion Valve

10

(Condition) Ambient temperature & humidity : 40°C, 25% Sol. Radiation : 950W/m²

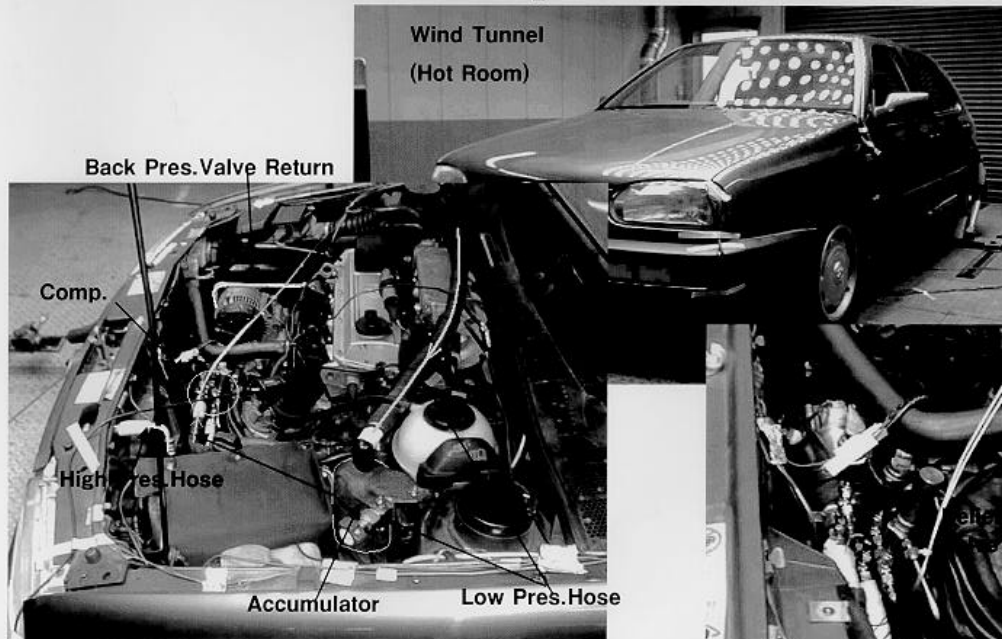


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One Of The Vehicles With CO₂ System Installed

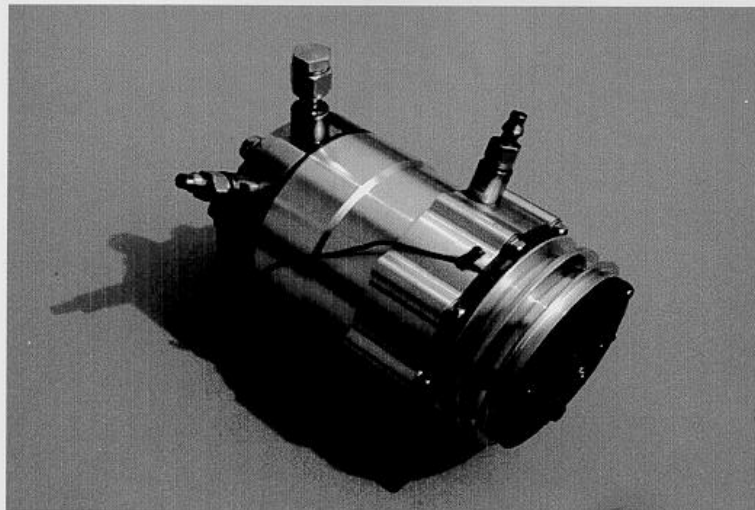


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Prototype Compressor



**Swash-Plate
Displacement : 29.8cc**

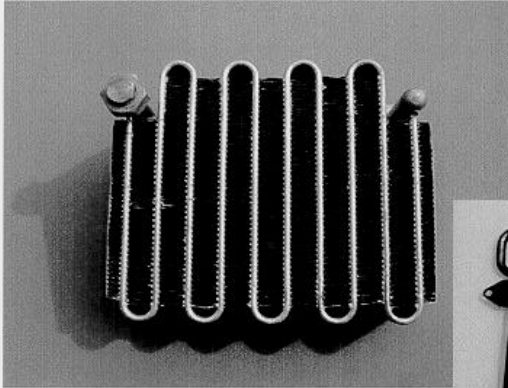
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Prototype Evaporator

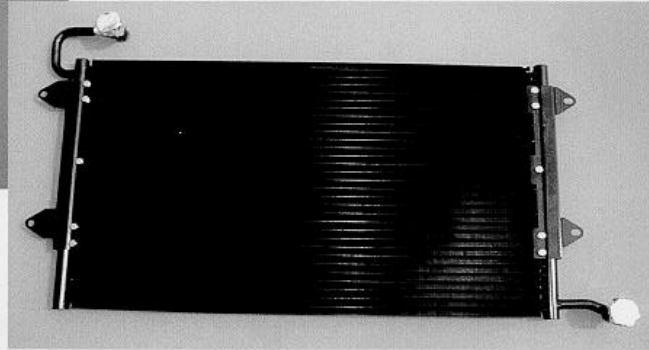
W 256mm × H 226mm × L 80mm



Serpentine type

Prototype Gas cooler

W 606mm × H 342mm × L 16mm



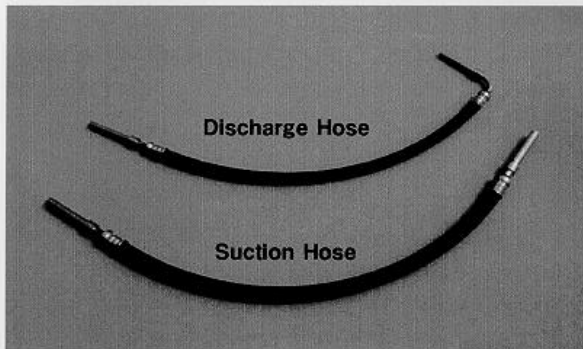
Multi-flow type, 5path

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Hose

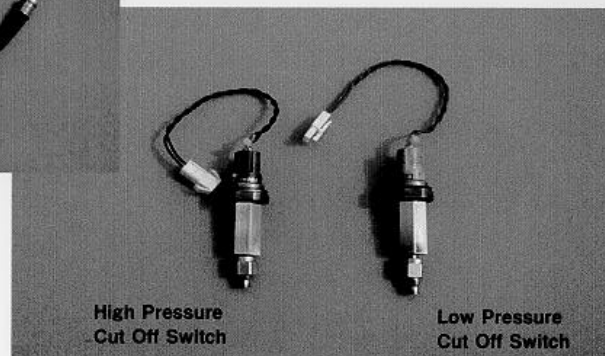


Discharge Hose

Suction Hose

1mm Nylon liner
Suction Hose I.D. ϕ 12.0mm
Discharge Hose I.D. ϕ 8.5mm

Clutch Cut Off Switch



High Pressure
Cut Off Switch

[14.9MPa cut off]

Low Pressure
Cut Off Switch

[2.45MPa cut off]

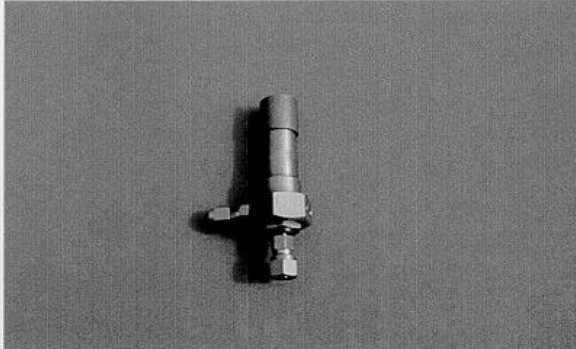
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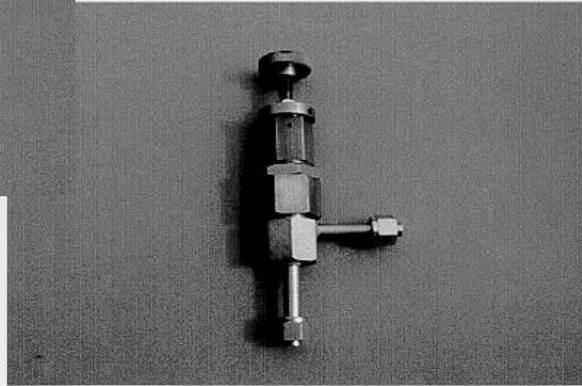
High Pressure Relief Valve

Relief Pres.: 17.65 MPa Open



Back Pressure Controller for high pressure bypassing

Bleed Pres.: 14.2 MPa Open



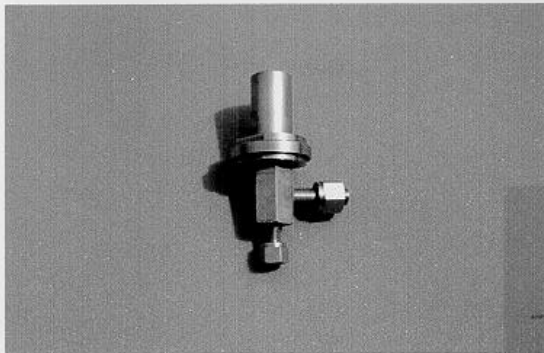
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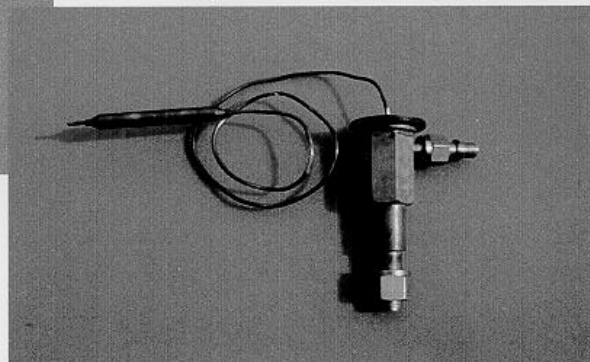
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Expansion Valve

(1) Constant Outlet Pressure Type



(2) Thermostatic Expansion Valve superheat control type



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6. Conclusions

- (1) A CO₂ system with constant outlet pressure type expansion valve showed excellent pull down during 32 km/h and 64 km/h modes. Performance at idle speed must be improved.
- (2) Data for a system with superheat control type expansion valve showed poor performance. The expansion valve does not seem to be functioning as expected.
- (3) A realistic approach to the CO₂ transcritical cycle mobile A/C by use of mechanical expansion control type expansion valves seems to be worth continuing.