Refrigerants – Indian Perspective

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KYOTO PROTOCOL
World Top Ten GHGs Emitters (2010)

Country	CO_2 Emissions (million tons)	Share of World Total (percent)
China	8,415	25.4
United States	6,145	18.5
India	1,707	5.1
Russia	1,700	5.1
Japan	1,308	3.9
Germany	828	2.5
South Korea	716	2.2
Canada	605	1.8
Saudi Arabia	562	1.7
Iran	557	1.7
Total: Top 10	**22,545**	**68**
Total: World	**33,158**	**100**

Source: BP, Statistical Review of World Energy (London: June 2011)

RAC Sectors

Domestic Refrigeration – Refrigerators, watercoolers, deepfreezers, etc.

Commercial Refrigeration - Cold storage

Industrial Refrigeration – Chemical and Petrochemical

Central Air conditioning

Packaged Air conditioning- VRV, VRF

Unitary systems – WAC, SAC

Transport refrigeration – Bus , Car, Rail, etc.

Refrigerants and domestic refrigeration

- Refrigerants: 14 new ones commercialised since 2010.
- Focus is on non halogenated and unsaturated HFC candidates, with emphasis on low or very low GWP ones.
- More attention paid to (mildly) flammable refrigerants, one of them being HFC-32.
- Domestic refrigeration: HC-600a and HFC-134a continue to be preferred refrigerants; transition from HFC-134a to HC-600a is slow; some efforts to study HFC-1234yf are underway.
- New product development focuses on improved energy efficiency with e.g. variable speed compressors.

Commercial refrigeration

- **Commercial refrigeration:** Refrigerants as diverse as hydrocarbons (HC-600a and HC-290), carbon dioxide (R-744), intermediate blends (for drop-in or nearly drop-in replacements for HCFC-22), HFC-134a and R-404A, HFC-1234yf and its blends are in competition.
- Strengthened regulations such as in the EU will end the use of high GWP refrigerants, such as R-404A).
- Except for HC-290 (limited use in large systems due to safety concerns) there is a lack of low GWP refrigerants with large enough refrigeration capacity to replace R-404A or HCFC-22.
- Where regulations prohibit ammonia (R-717) or limit its charge, cascade R-744 systems or secondary fluids used.

Air conditioners

- **Air conditioners** using R-410A (with R-407C decreasing) are widely available in non-Article 5 Parties. Equipment using R-410A is also manufactured in some Article 5 Parties.
- Number of (lower GWP) HFC blends currently evaluated.
- HCs are being used in smaller equipment; voluntary and mandatory standards limit the quantity of the charge.
- HFC-32 considered for various types of AC units.
- Use of mixtures of three and four refrigerants with GWPs in the range 150-1000 are being investigated; technical data are not in the public domain, and development may take another 2-3 years.

Montreal Protocol OEWG-33 meeting

Heat pumps and chillers

- **Heat pumps:** HFCs, R-744 and HC-290 are currently used for new water and space heating heat pumps, new refrigerant options include low GWP HFCs and their blends.
- **Chillers:** Continuing trend in chiller development is to improve full load and seasonal energy efficiency to address global warming impact, building energy regulations etc.
- Chillers that employ R-717, water (R-718), R-744 and HCs continue to be available in certain capacities; absorption can be a good alternative in case of availability of waste heat or cogeneration.
- Testing for low GWP HFCs, HFC-32 and their blends (sometimes with HFC-134a) is underway (e.g., via AHRI in the USA).

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Large size, transport refrigeration and MAC

- **Large size systems:** R-717 is getting more widely accepted, cascade systems with R-744 and secondary loops are options.
- **Transport refrigeration:** Field testing by global manufacturers of R-744 in marine, rail and highway units continues.
- Development of low GWP HFC equipment (e.g., HFC-1234yf) could be a solution; requires further redesign of R-404A units.
- **MACs:** in 2012, HFC-1234yf was the universally preferred refrigerant to replace HFC-134a. Daimler carried out in-house tests and claimed that HFC-1234yf is too flammable when leaking in engine compartments; the significance of test results is disputed within industry and other organisations involved.
- Four German car manufacturers have pledged to use CO2

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R22 Alternatives

			Refrigerant physical properties							
			Cond. Press. MPa	Capacity R22 ratio	COP R22 ratio	ODP	GWP (IPCC4)	Life Year	Flamm-ability	Toxicity
HCFC22		Single	1.73	100	100	0.05	1810	11.9	No	Low
HFC	HFC407C	Zoetrope	1.86	102	99	0	1770	-	No	Low
HFC	HFC410A	Azeotorope	2.72	141	92	0	2090	-	No	Low
HFC	R32	Single	2.80	160	97	0	675	5	Low	Low
HFC	HFO1234yf	Single	1.16	57	90	0	4	7day	Low	?
HFC	HFO mixture	?	Under investigation					?	?	Low
Natural	Propane (R290)	Single	1.53	83	98	0	3	-		Low
Natural	CO2(R744)	Single	10.00	243	41	0	1	120	No	Low
Natural	Ammonia (R717)	Single	1.78	116	106	0	0	0	Low	High

Candidates for preventing global warming

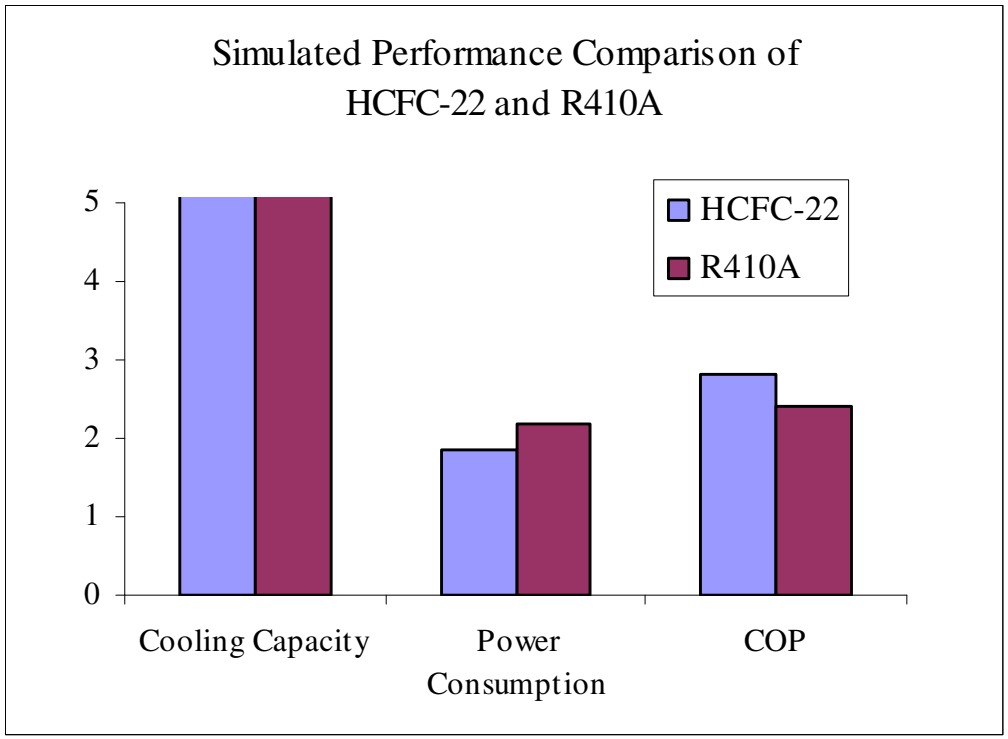
In case of Residential A/C Commercial A/C

Note: Ammonia is not considered as a candidate refrigerant for small air-conditioners due to its high toxicity

Unitary Air conditioning

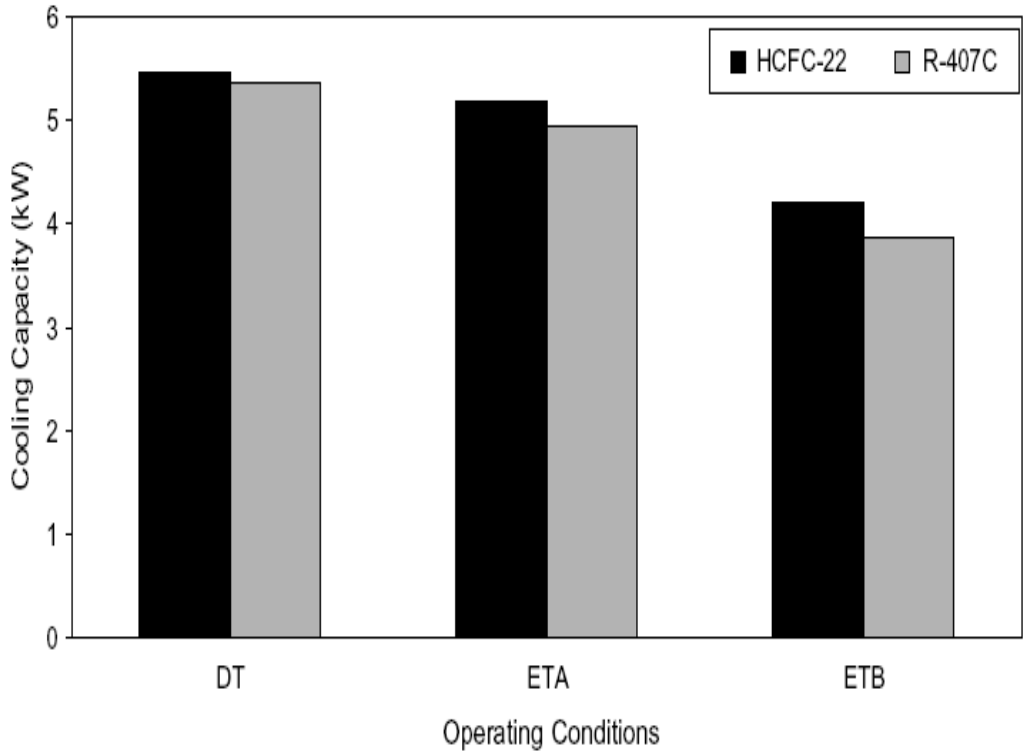
Alternatives	Environmental	Performance-cooling capacity (% of HCFC-22)	Performance – COP (% of HCFC-22)	Suitability/Design Changes in RAC
R-410A	ODP=0; GWP= 1725	>100	98-102%	50% higher operating pressure;new design; small compressor displacement
R-407C	ODP=0; GWP=1600	98%	93-97%	Minimum changes in system
HC-290	ODP=0; GWP ~3	94% under drop-in; 101% new design	114% under drop-in; 136% new design	Higher Flammability; Charge size reduction; High EER compressor; Larger dia capillary
HFC-32	ODP=0; GWP= 675	>100	~100	Small compressor displacement;
HFC-161	ODP=0; GWP= 12	~100	>100	Higher Flammability; Charge size reduction; Under evaluation
CO2	ODP=0; GWP=1	>100	<100	High Pressure

Unitary Air conditioning



Cooling capacity of HCFC-22 and R410A

Unitary Air conditioning



Cooling capacity of HCFC-22 and R407C

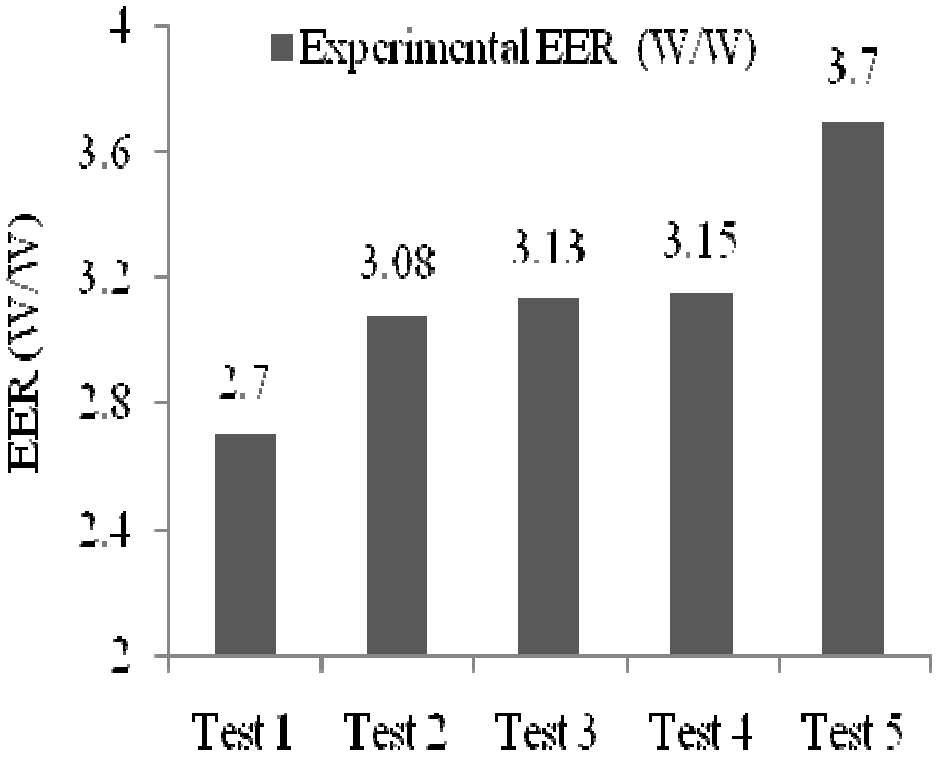
Unitary Air conditioning

HC-290 - Godrej pilot project

- Test 1: HCFC-22
- Test 2 is the drop-in test with HC-290 with optimum charge
- Test 3 is HC-290 test with modified capillary length and 30% higher capacity condenser
- Test 4 is HC-290 test with 5 mm tube OD condenser
- Test 5 is HC-290 test with aluminum PFC and a compressor with EER of 3.20

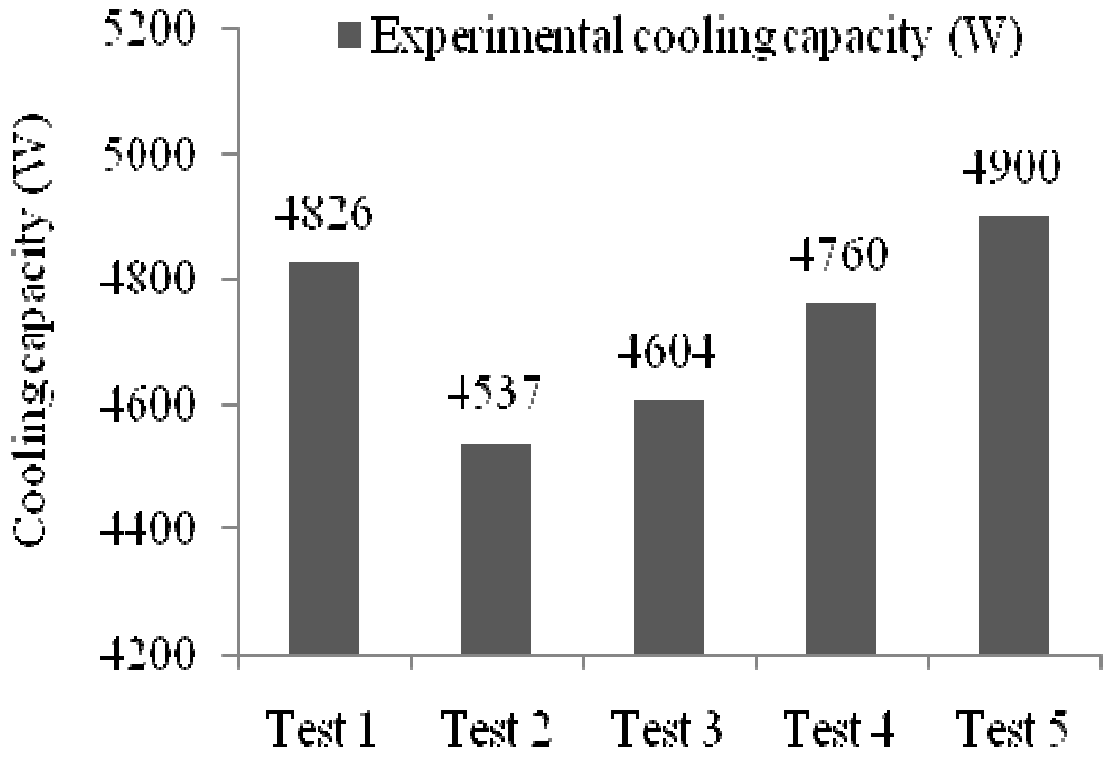
Unitary Air conditioning

HC-290 - Godrej pilot project



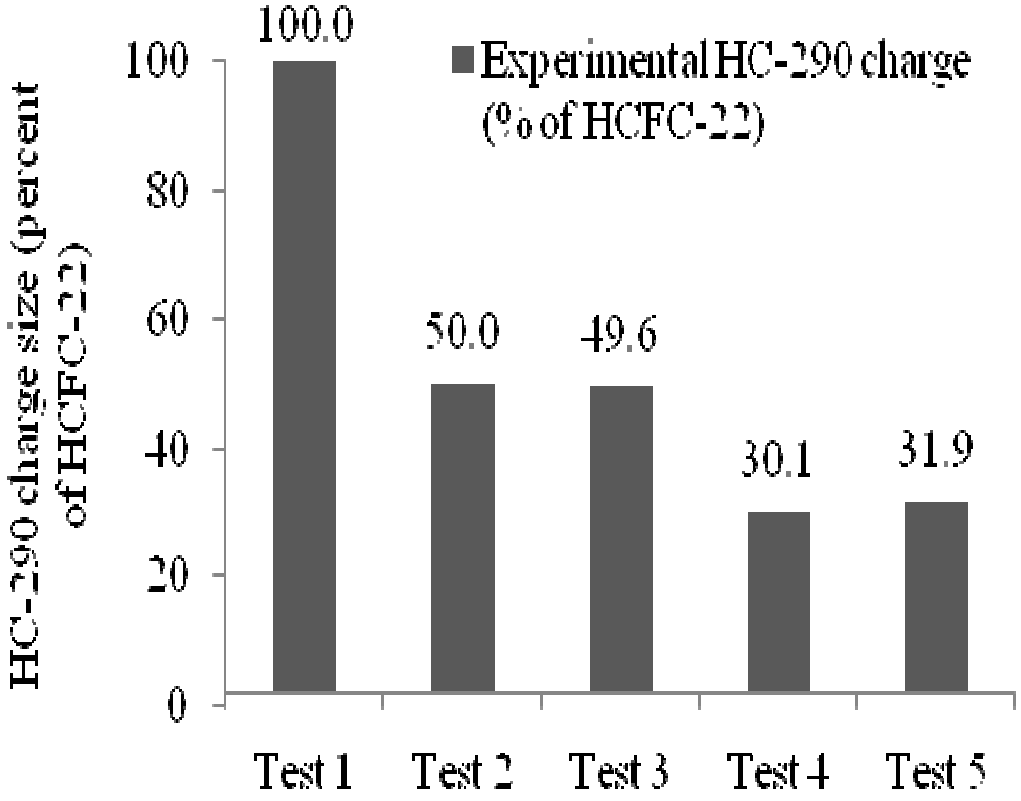
Unitary Air conditioning

HC-290 - Godrej pilot project



Unitary Air conditioning

HC-290 - Godrej pilot project



Mobile AC

- MAC market is expected > 5500k by 2015
- MAC → CFC-12 is replaced by HFC-134a (year 1990)
- HFC-134a is not controlled under Montreal Protocol
- GWP of HFC-134a is 1430
- In 1997 under Kyoto Protocol non-Article 5 countries agreed to reduce GHG emission
- EU Directives → refrigerant in MAC with GWP < 150
- Currently HFO-1234yf is being considered as replacement to HFC-134a
- CO2 may be another alternative

Mobile AC: Alternatives

- In India, currently no phase out plan for HFC-134a in MAC
- All MAC needs converted from HFC-134a to its alternatives by 2017 for export market

Alternatives	Environmental	Performance-cooling capacity (% of HFC-134a)	Performance – COP (% of HFC-134a)	Suitability/Design Changes in MAC
HFO-1234yf	ODP=0; GWP ~4	~100%	~100%	Mild flammable; Thermally stable
CO2	ODP=0; GWP=1	-	-	High Pressure; transcritical cycle; under development
HFC-152	ODP=0; GWP=120	~100%	~100%	Moderate Flammable; Similar components as R134a
Fluid H (Honeywell)*	ODP =0; GWP<150	91.7	94.7	Insufficient in thermal stability; Drop-in is difficult
DP-1 (Du pont)*	ODP =0; GWP<150	87.7	101.7	Under evaluation
AC-1 (INEOS Fluor)*	ODP =0; GWP<150	90.1	98.2	Very similar to HFC-134a, Under evaluation

* Undisclosed fluids

Mobile AC Alternative: R1234yf

Upper Flammability Limit, Vol. % in air (21°C, ASTM E681-01)	12.3
Lower Flammability Limit, Vol. % in air (21°C, ASTM E681-01)	6.5
Minimum Ignition Energy, mJ at 20C and 1 atm (DuPont in-house method. Tests conducted in 12 liter flask to minimize wall quenching effects)	5,000-10,000
Autoignition Temperature, °C (EC Physico/Chemical Test A15, Measured by Chilworth Technology, UK)	405
Heat of Combustion, MJ/kg per ASHRAE Standard 34 (Stoichiometric composition 7.73% in air)	11.8
Fundamental burning velocity, cm/s (per ISO 817, Measured by AIST, Japan)	1.5

* Undisclosed fluids

Thank You !