

Development and Handling of Hydrocarbon Air-conditioners - The Godrej Experience



Introduction

- Who we are...
 - Godrej & Boyce Mfg. Co. Ltd - The Flagship Company of the Godrej Group
 - Into Business since 1897
 - One of the largest privately held Industrial Corporations
 - Annual Turnover of Rs. 62 Billion (approx.) for FY 2012-13
 - All India presence with 20 Branches & 51 Showrooms
 - Family of 11000 + employees

Introduction

- The Appliance Division...
 - The largest business unit of Godrej & Boyce Mfg. Co. Ltd
 - Established in 1958
 - Annual Turnover Rs. 17 Billion (approx) for FY 2012-13
 - Products
 - Refrigerators
 - Washing Machines
 - Air-conditioners
 - Chotukool (Thermo-electric refrigerator)
 - Introduced 100% CFC free refrigerators in 2000, using hydrocarbon technology – **the first and only Indian company to do so**

Commitment to the Environment



Land area in Vikhroli - 3200 acres of which 1750 acres is reserved for conservation of Mangrove Forests – the “lungs” of Mumbai

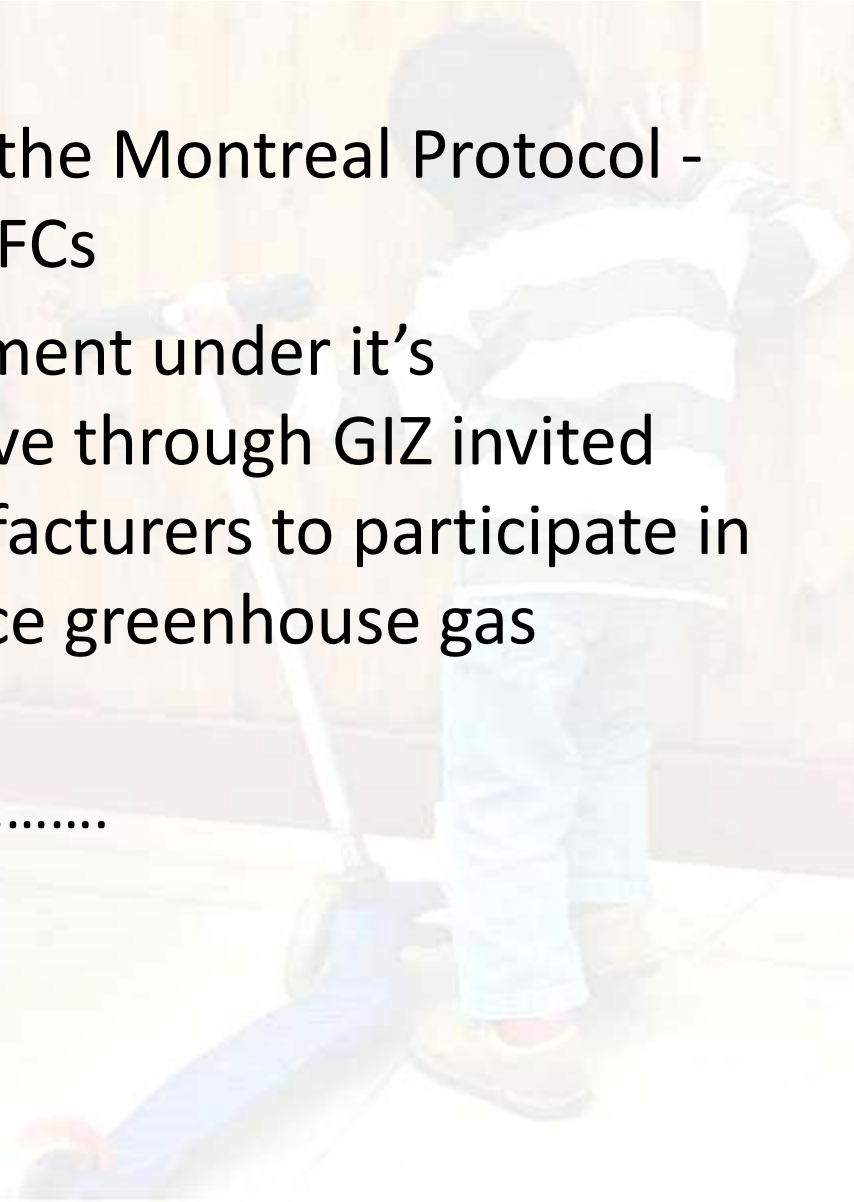
Agenda

- Background
- Product Development
- Manufacturing Set-up
- Service Training & Network
- Further Research



Background – The trigger

- Decision of the 19th MOP to the Montreal Protocol - Accelerated phase out of HCFCs
- German Ministry of Environment under it's International Climate Initiative through GIZ invited Indian air-conditioner manufacturers to participate in a project on HC-290 to reduce greenhouse gas emissions
 - Godrej responded to the call.....



Product Development



Lab Modifications

- Lab modifications to suit testing of HC-290
 - Safety Protection
 - Multi-point sensing gas detectors to cover all parts of test chamber
 - Low (1%), mid (1.5%) and high (2%) alarm levels with appropriate actions initiated at each level
 - Auto Exhaust System
 - Ventilation dimensioned to bring gas concentration below low alarm level within 10 min
 - Ventilation and exhaust air system at bottom (Propane heavier than air)
 - Electrical Equipment
 - Ex-proof lighting and blowers
 - All buttons and switches with ex. Protection

Lab Modifications

- Static Electricity Prevention
 - Proper earthing for equipment
 - Doors to have rubber seals
 - Test stands with anti-static epoxy paint
- Fire Emergency Devices
 - Auto water spray (mist head device)
 - CO2 fire extinguishers
- Security Identification
 - Warning markings
 - Safety procedures on lab doors



- Test methodology
 - Published data on performance of HC-290 vis-à-vis HCFC-22
 - Drop-in performance*
 - 3~15% drop in cooling capacity
 - 2~8% improvement in COP
 - Charge quantity 45~50% by weight
 - The strategy
 - Drop-in testing
 - Use standard HCFC-22 compressor with 5~10% higher rated capacity
 - Depending on results, work on other elements of refrigeration system

* Devotta S, Padalkar AS, Sane NK. 2005, Performance assessment of HC-290 as a drop-in substitute to HCFC-22 in a window air conditioner, *Int. J. of Refrig.* 28: 594-604.

- Drop-in Test Results (vis-à-vis HCFC-22)
 - Cooling capacity lower by 6%
 - COP higher by 14%
 - Power consumption lower by 17.8%
 - Charge quantity 50% (by weight) – average **575 g.**
- Compressor of 10% higher capacity
 - Cooling capacity higher by 4.3%
 - COP higher by 7%
 - Power consumption lower by 3.5%
 - Charge quantity 51% (by weight) – average **585 g.**

Charge quantity - a matter of concern

- Charge limit as per EN 378

$$m_{\max} = 2.5 \times \text{LFL}^{5/4} \times h_0 \times A^{1/2},$$

where

m_{\max} is the allowable maximum charge in a room in kg;

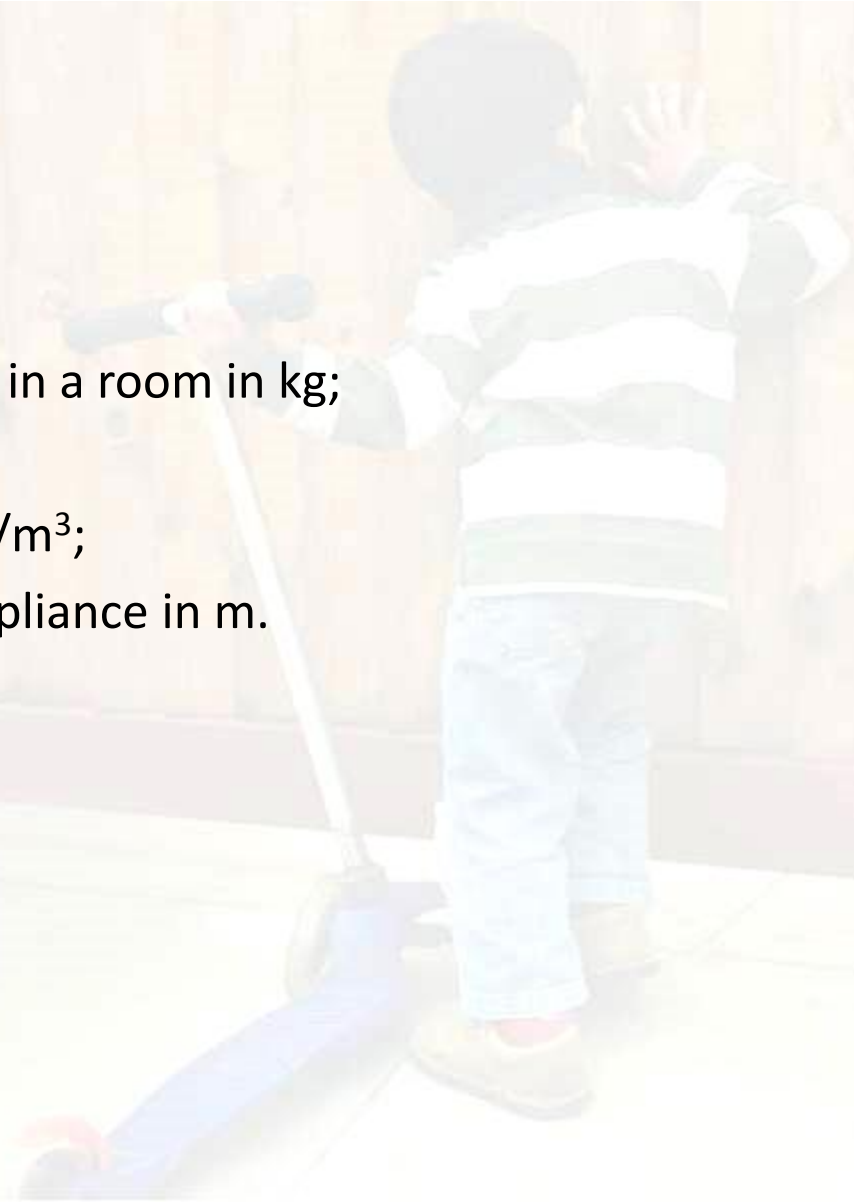
A is the room area in m^2 ;

LFL is the lower flammable limit in kg/m^3 ;

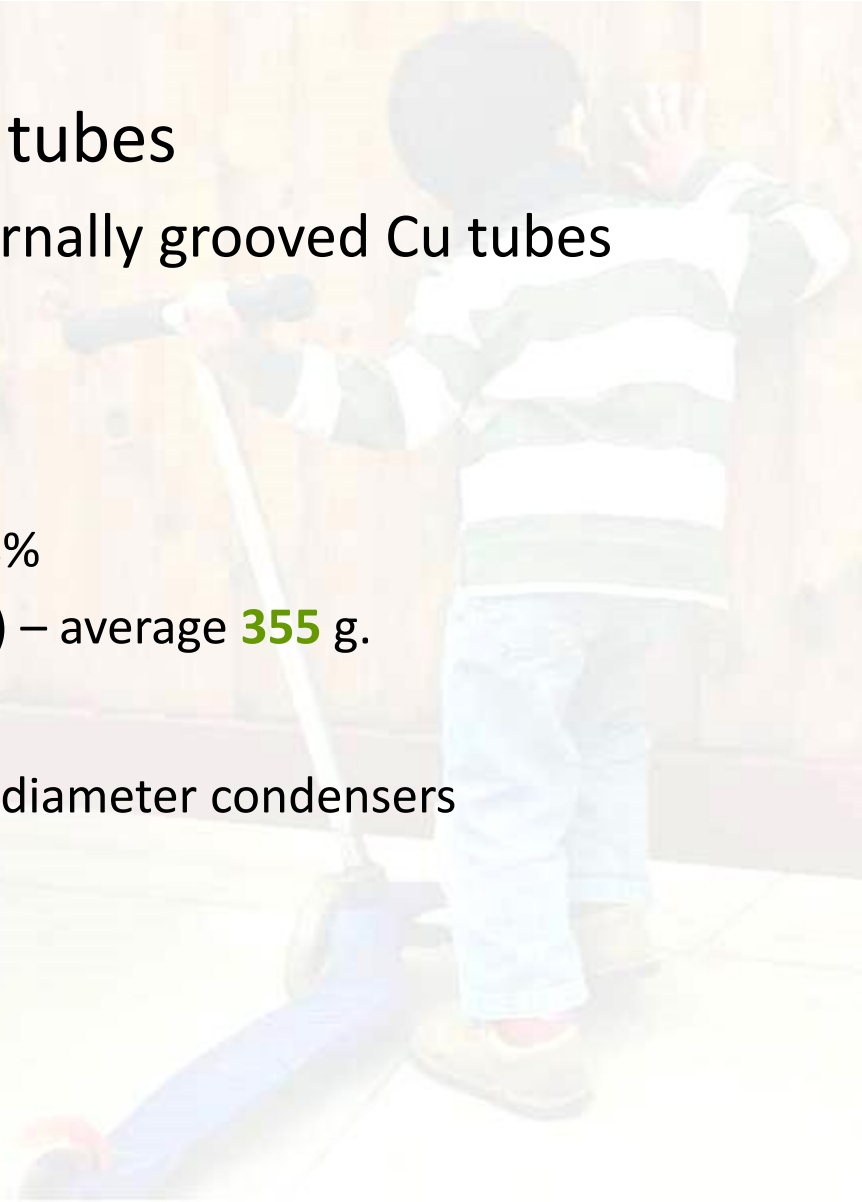
h_0 is the installation height of the appliance in m.

For a typical 5kW split AC unit,

$$\begin{aligned} m_{\max} &= 2.5 \times 0.038^{5/4} \times 2.3 \times 14^{1/2} \\ &= 361 \text{ g.} \end{aligned}$$



- Smaller diameter condenser tubes
 - Trials with 5mm diameter internally grooved Cu tubes (instead of 7mm)
 - Cooling capacity lower by 0.5%
 - COP higher by 21%
 - Power consumption lower by 18%
 - Charge quantity 50% (by weight) – average **355 g**.
 - Availability, an issue
 - Only one manufacturer of 5mm diameter condensers
 - Development shelved



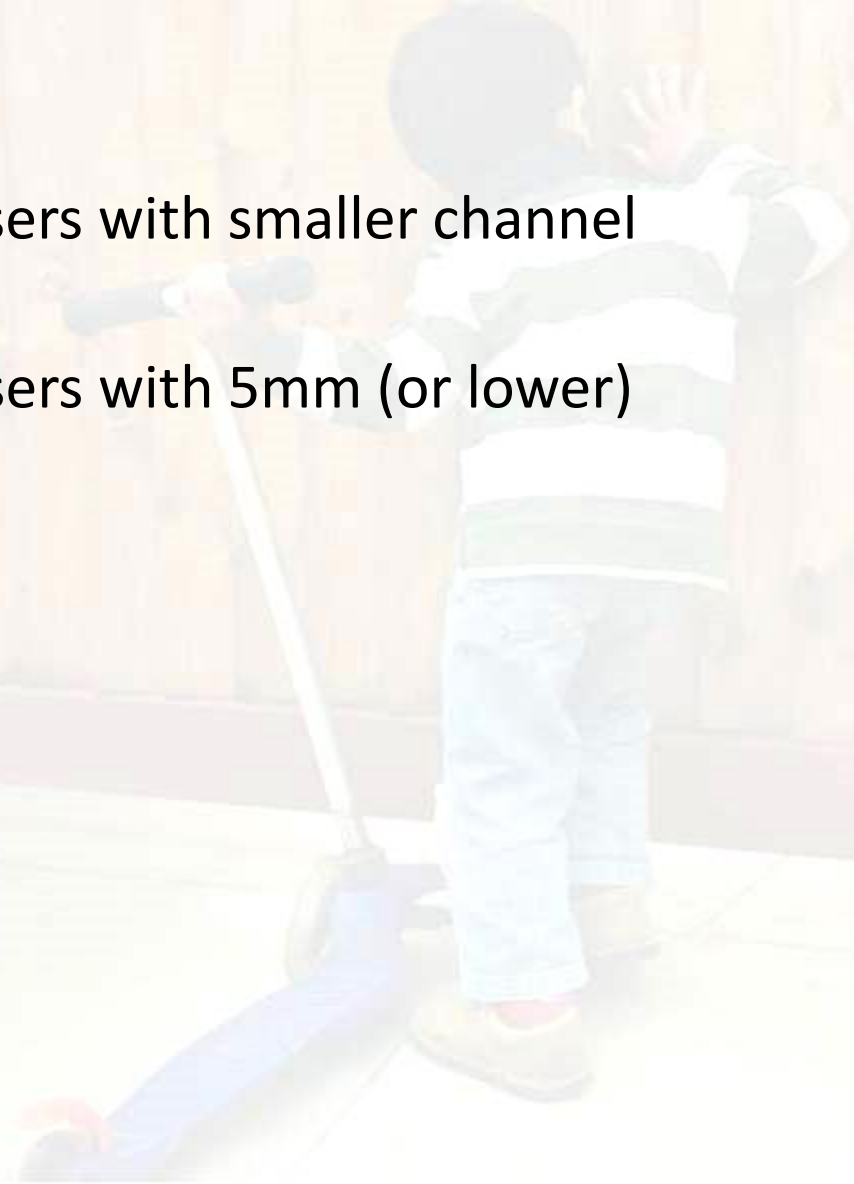
R&D Methodology

- Micro-channel heat exchangers (brazed aluminium) – the game changer
 - Use of 50 channel condensers in conjunction with higher efficiency compressors
 - Cooling capacity lower by 3%
 - COP higher by 16.5%
 - Power consumption lower by 20%
 - Charge quantity 46% (by weight) – average **360 g**.

Charge quantity on the threshold of EN 378 requirements

R&D Methodology

- The way forward
 - Use of micro-channel condensers with smaller channel sizes
 - Explore availability of condensers with 5mm (or lower) diameter Cu tubes



The Manufacturing Project

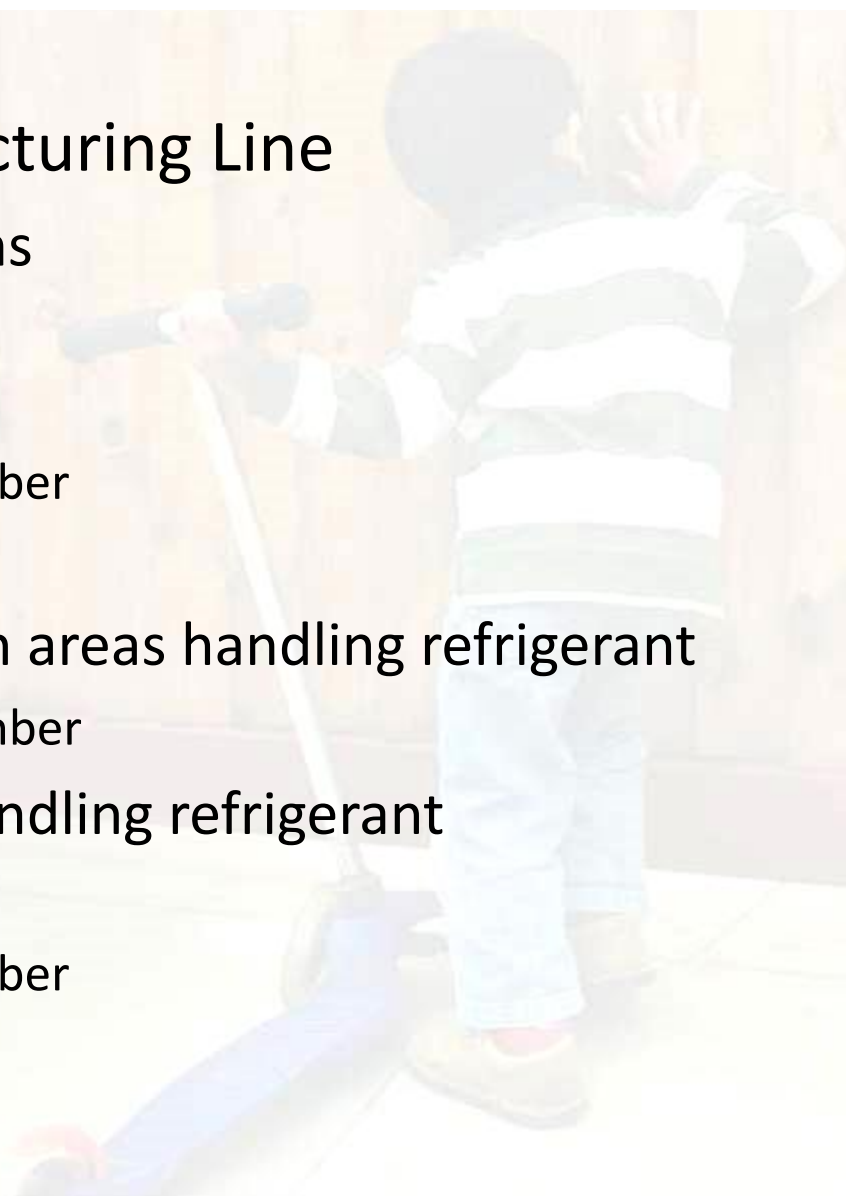


The Manufacturing Project

- Tripartite agreement, Ozone Cell/GIZ/Godrej – Dec 2010 – to set up manufacturing facility for annual output of 180,000 Split and Window type Air-conditioners
 - Equipment Specifications, Tendering – June 2011
 - Equipment Delivery – Dec 2011
 - Installation & Commissioning – Jan ~ March 2012
 - TuV Audit of Manufacturing Line – March 2012
 - BEE Certification – March 2012
 - Pilot Production - April 2012

The Manufacturing Project

- Safety Measures on Manufacturing Line
 - Gas Sensors and Alarm Systems
 - Refrigerant Storage Area
 - Refrigerant Charging system
 - Product Performance Test Chamber
 - Product Repair Area
 - Ex-proof electrical hardware in areas handling refrigerant
 - Product Performance Test Chamber
 - Ventilation System in areas handling refrigerant
 - Refrigerant Charging system
 - Product Performance Test Chamber
 - Product Repair Area



The Manufacturing Project

Gas charging station with ventilation ducting & gas alarms



The Manufacturing Project

Repair area gas recovery system with ducting & gas alarm interlock



Fire proof junction boxes in Refrigerant charging areas



The Manufacturing Project

Ventilation system in HC 290 gas charging station and performance test chamber – with two speed option & gas alarm mechanism and complete power cutoff interlock



The Manufacturing Project

- The Product...



AC Cooling Capacity : 3375W
Compressor details : Rotary
Power Supply : 230/1/50 (V/Phase/Hz)
Power Input : 912W
EER : 3.7
Star Rating : 5 Star



AC Cooling Capacity : 5000W
Compressor details : Rotary
Power Supply : 230/1/50 (V/Phase/Hz)
Power Input : 1325W
EER : 3.7
Star Rating : 5 Star

The Manufacturing Project

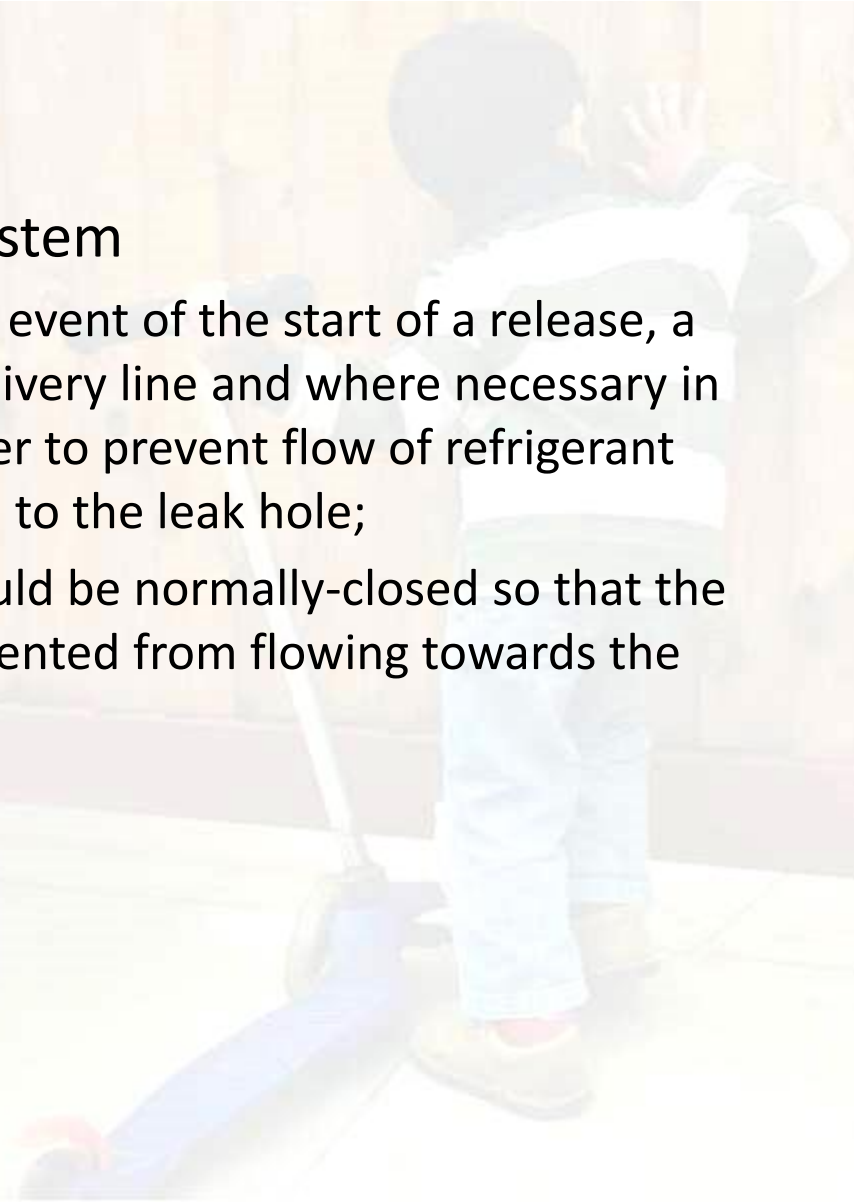
- Risk Analysis & Mitigation
 - Leak simulation testing*
 - Under a catastrophic, instantaneous leak situation, between 65% - 75% of the refrigerant exits the system
 - In off-mode, when using a gas detector inside the IDU (set at 20% of LFL) to indicate a leak and initiate IDU airflow, the floor concentration did not exceed 70% of LFL (charge equivalent to 40% of LFL; 450 g in a 30 m³ room)
 - Use of solenoid shut-off valves in the liquid line (and where necessary, in the suction line) can further reduce the leakage to around 20% of the charge quantity

The Manufacturing Project

- Leak Detection & Mitigation
 - Refrigerant Leak Detection System
 - Issues a visible and audible alarm under the simultaneous existence of the following condition:
 - Machine current and sensed temperature are less than a determined value.
 - The device must remain active after the initial activation till the device is reset.
 - Upon issuing an alarm, the device must:
 - Override the signal from the machine controller and switch OFF the compressor and
 - Override the signal from the machine controller and operate the blower on the IDU and fan on the ODU at maximum speed.

The Manufacturing Project

- Leak Detection & Mitigation
 - Refrigerant Leak Mitigation System
 - Solenoid shut-off valves – in the event of the start of a release, a shut off valve in the liquid or delivery line and where necessary in the suction line can close in order to prevent flow of refrigerant from the high side of the system to the leak hole;
 - During off-mode the valve(s) could be normally-closed so that the refrigerant is automatically prevented from flowing towards the leak.



Service Training & Network

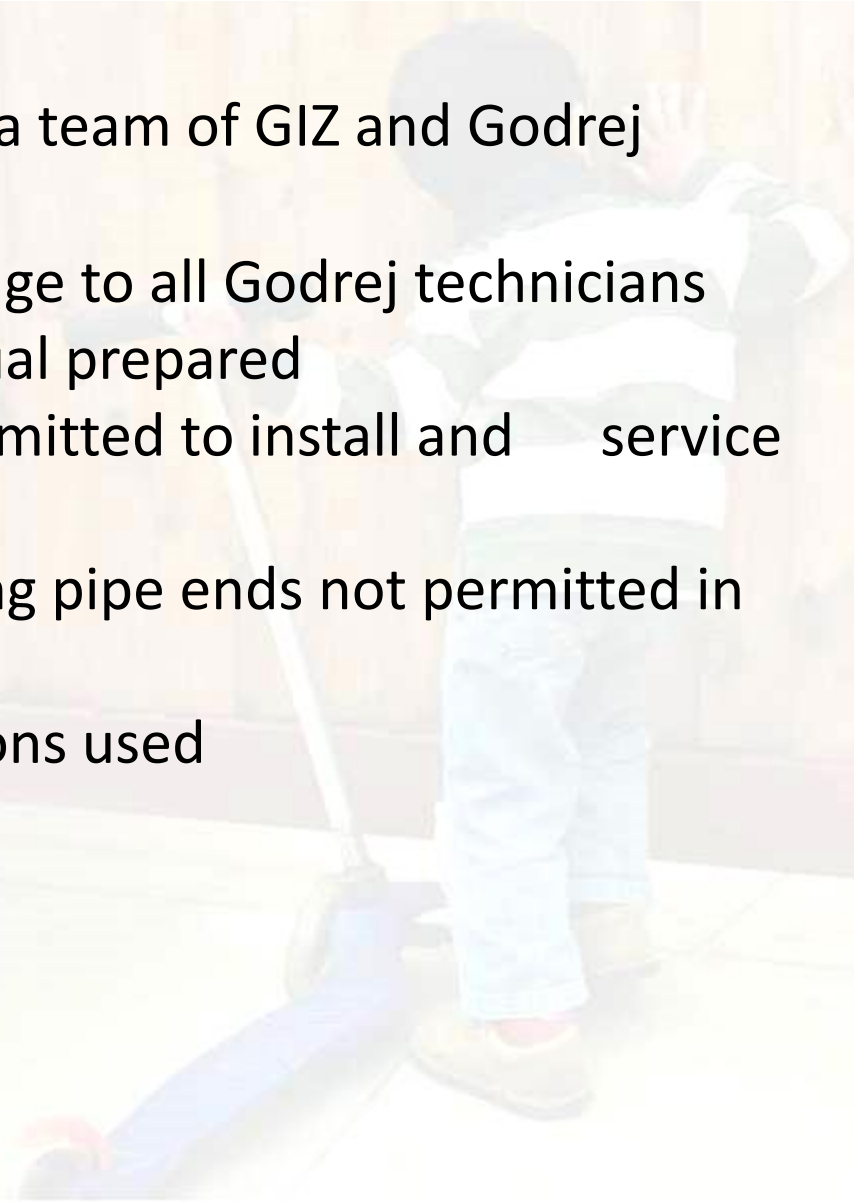


Service Training

- Godrej - the only Appliance company in the industry appointed by the Government of India to carry out Training for their projects like NCCOPP, HIDECOR.
- Godrej Vocational Training School imparts training in training institutes (ITI's)
- Godrej Refrigerators with HC refrigerants are produced since 2001 , 13 years of manufacturing. More than 10 million units installed and serviced by Godrej trained field engineers successfully.
- Godrej Appliance Service has also trained field staff in Bangladesh.

Service Training

- All master technicians trained by a team of GIZ and Godrej experts
 - Dissemination of this knowledge to all Godrej technicians
 - Comprehensive training manual prepared
- Only certified technicians are permitted to install and service the HC 290 AC
- For Split ACs, flaring of connecting pipe ends not permitted in the field
 - Only Factory flared connections used



Tested R22 and R290 split ACs

Characteristic	HCFC-22 air conditioner	HC-290 air conditioner
Nominal capacity	5.19 kW	4.83 kW
Nominal COP (cooling)	3.08	3.60
Evaporator type	Finned tube	Finned tube
Evaporator block volume	5.45 litres	5.45 litres
Evap no. tubes, circuits	32, 3	32, 3
Evaporator airflow rate	850 m ³ /h	850 m ³ /h
Condenser type	PFC	PFC
Condenser block volume	6.06 litres	6.03 litres
Condenser no. tubes	52	52
Compr swept volume	5.27 m ³ /h	5.39 m ³ /h
Compressor rated COP	3.10	3.38
Cap tube length, OD	0.8 m, 3.0 mm	0.65 m, 3.2 mm
Refrigerant charge	0.75 kg	0.36 kg

Tested R22 and R290 split ACs



R22 model



R290 model

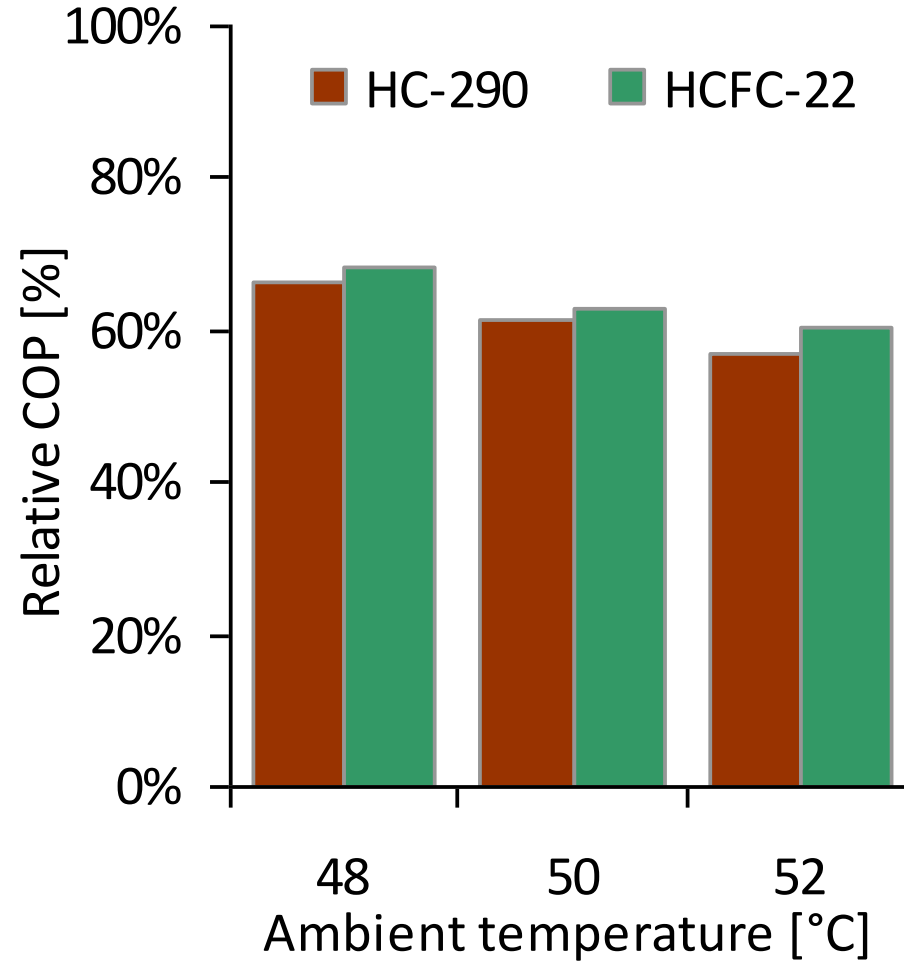
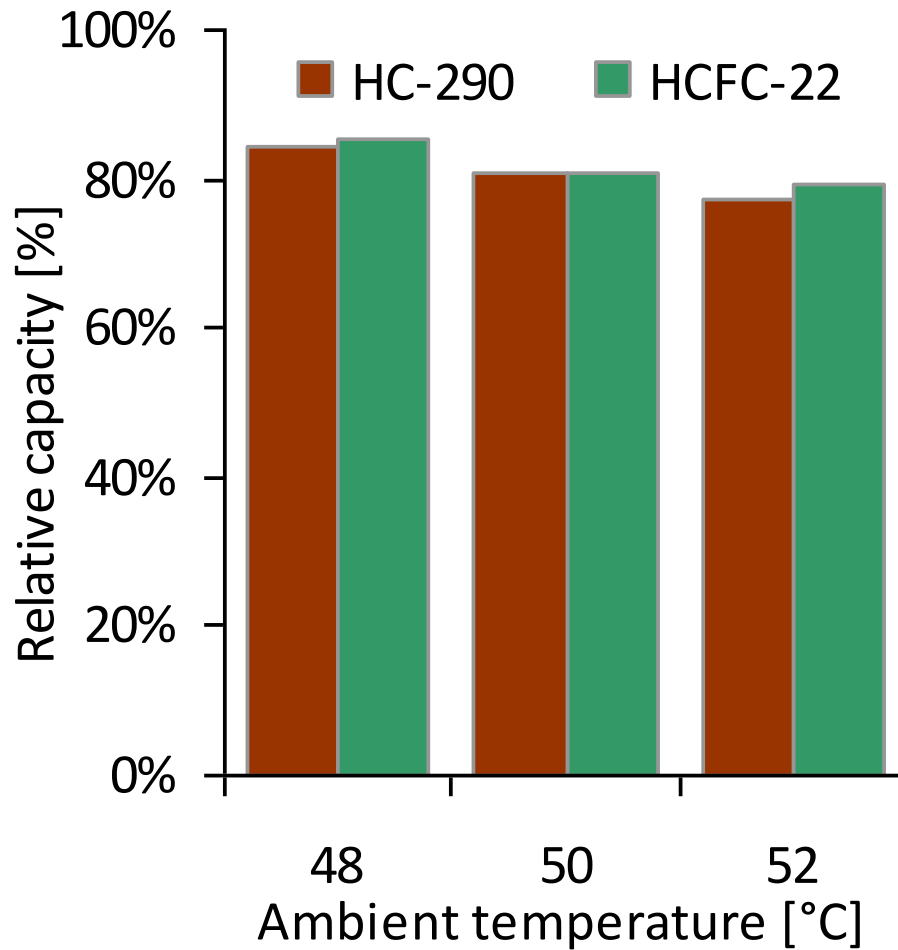


Results; global performance

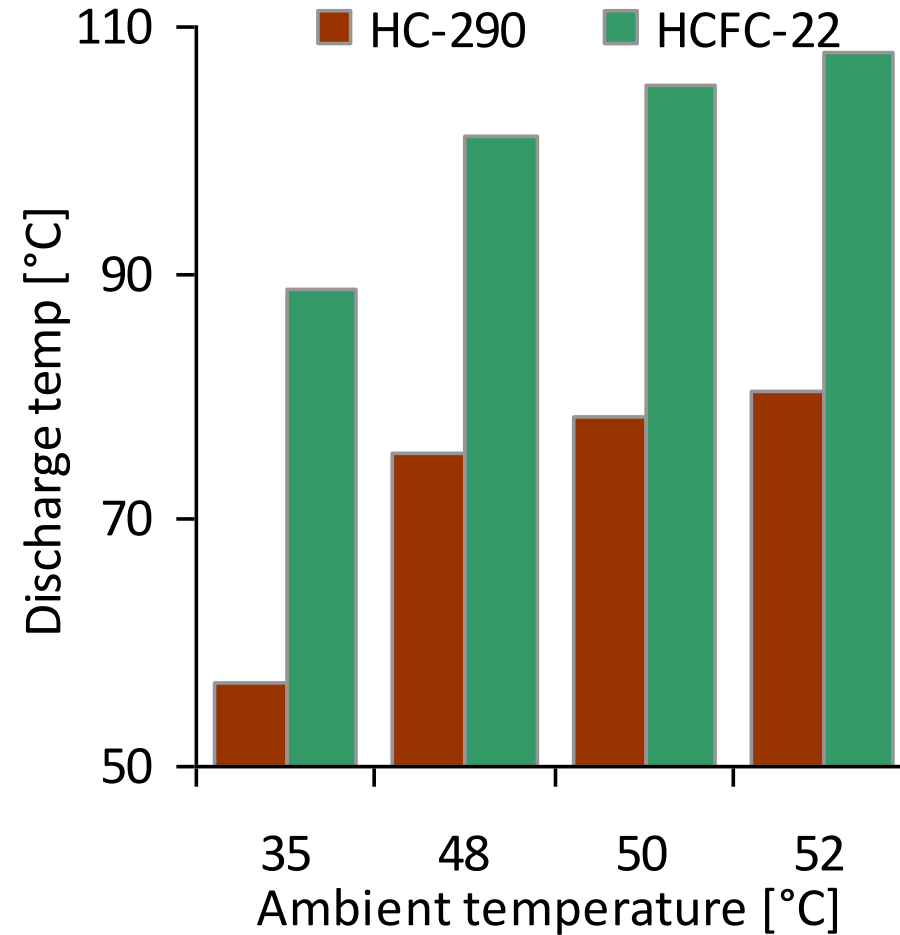
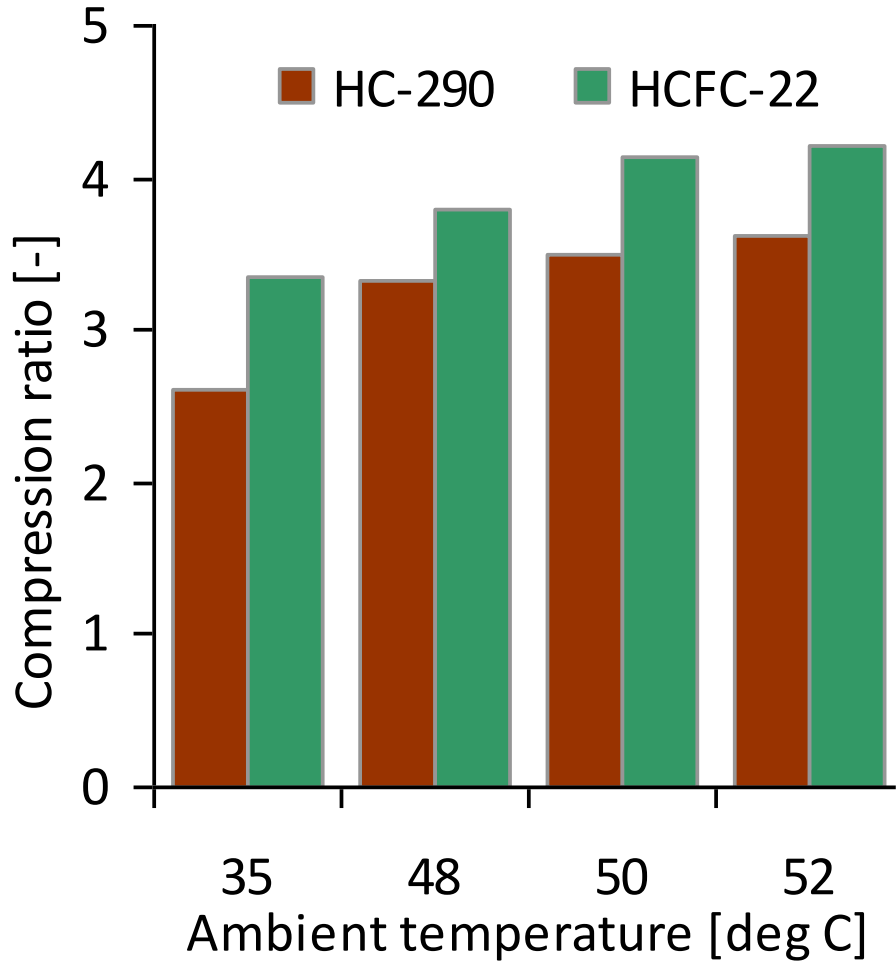
- Global results show
 - Cooling capacity of R-290 model is 7% lower at rating conditions; gets marginally greater at higher temp by 3%
 - Improvement in COP of R-290 over R-22 also declines

Parameter		Outdoor temperature				
		35°C	48°C	50°C	52°C	54°C
Cooling capacity (kW)	HC-290	4.84	4.08	3.90	3.74	3.64
	HCFC-22	5.19	4.43	4.20	4.12	—
	Difference	7%	8%	8%	10%	—
COP (kW/kW)	HC-290	3.60	2.38	2.21	2.04	1.91
	HCFC-22	3.08	2.11	1.93	1.86	—
	Difference	16%	12%	13%	10%	—

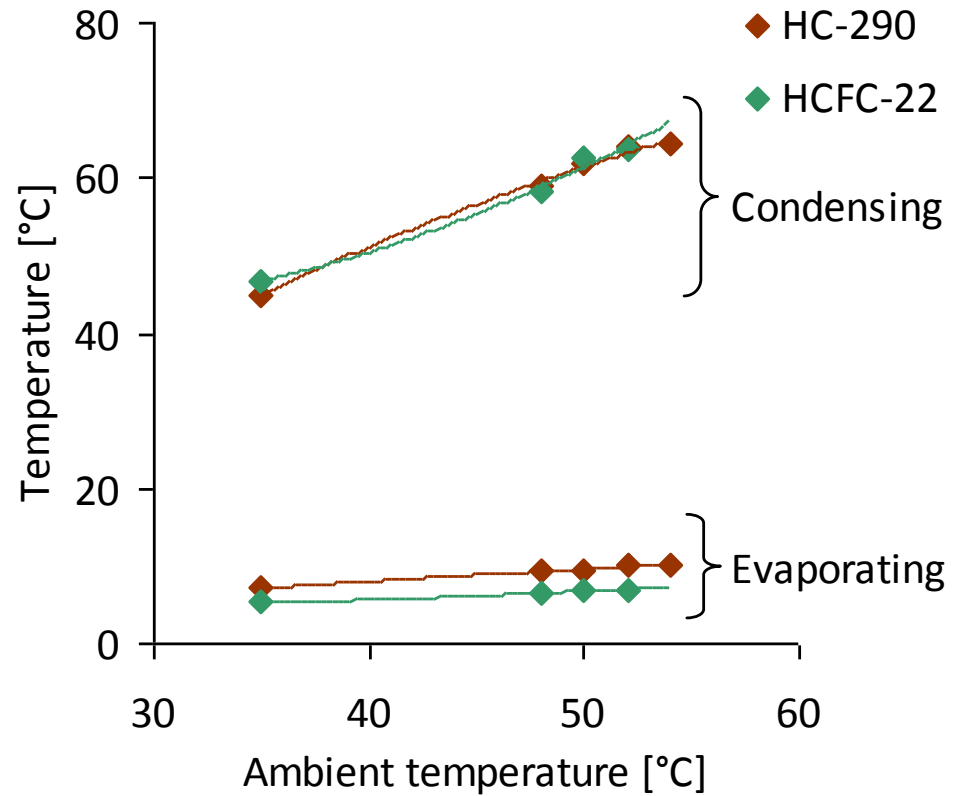
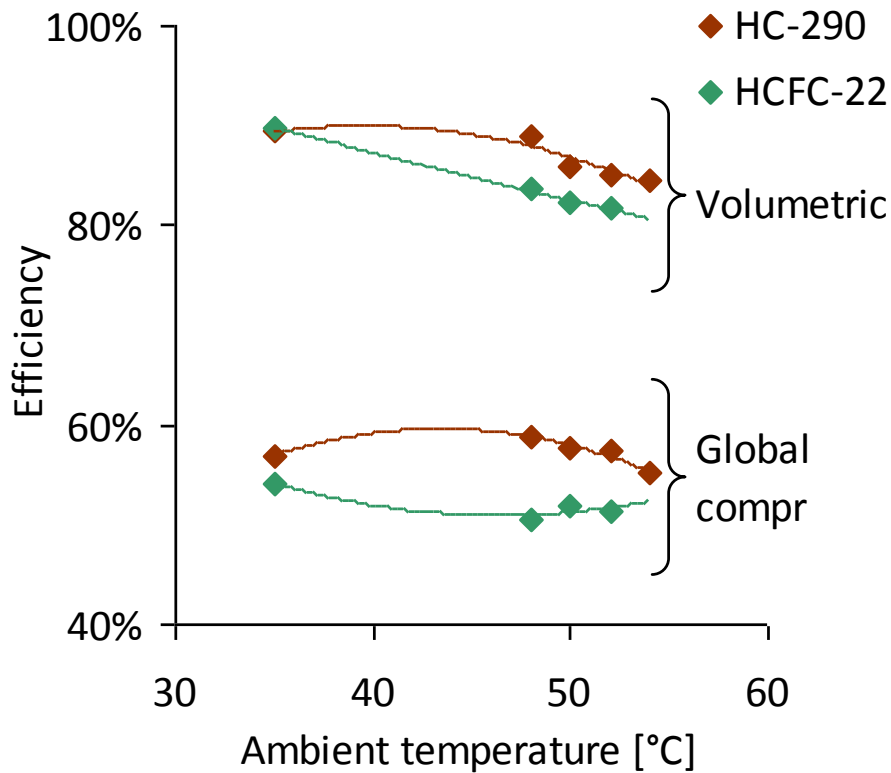
Results; relative capacity and COP



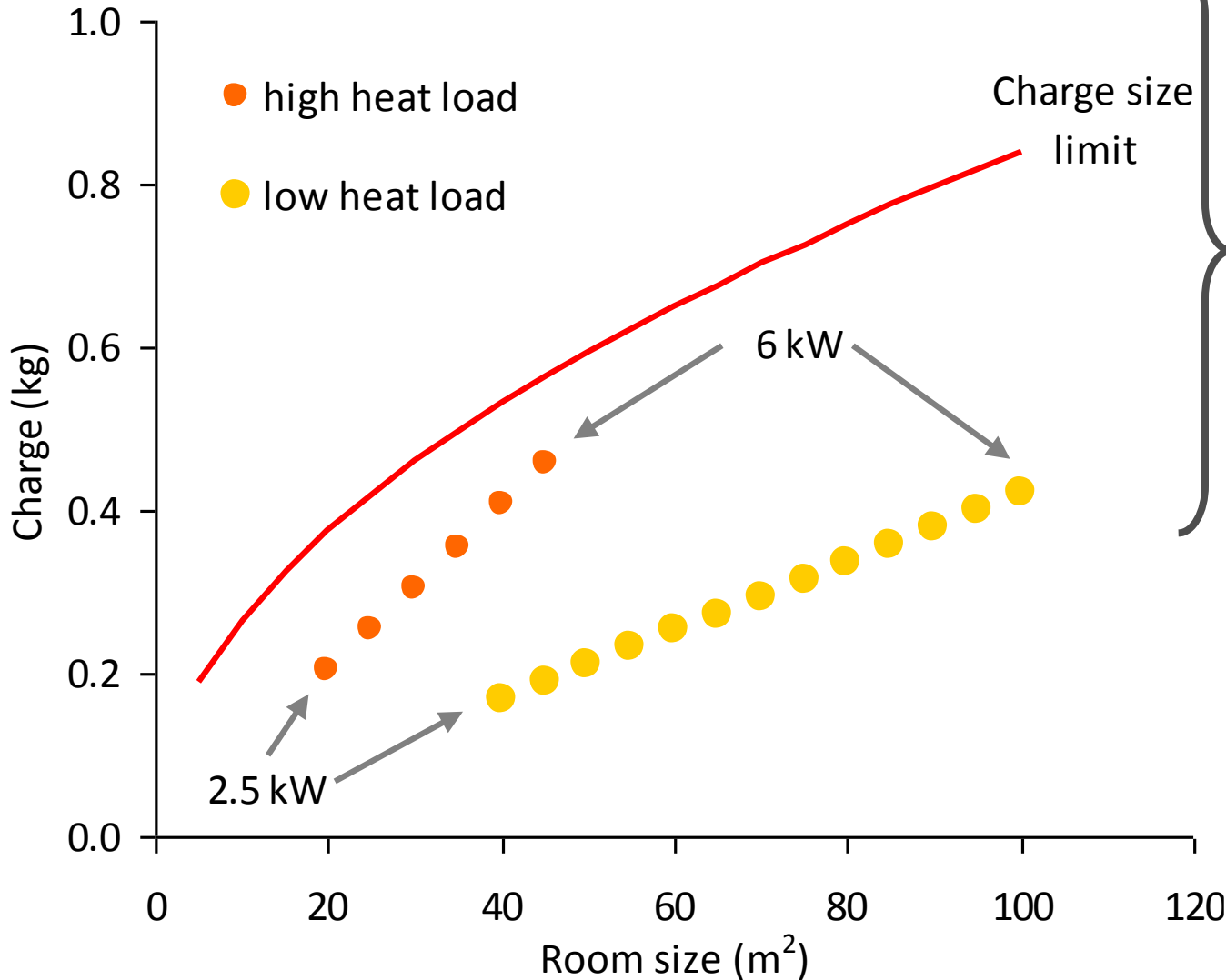
Results; pressure ratio and discharge temp



Results; compressor efficiency and dTs



Remarks on safety



Despite certain obstructive safety standards, HC ACs can still be within limits

[Based on Kuwait Code of Practice for design heat loads; air conditioner charge size as with the tested AC (75 g/kW) but in reality, only ¾ of charge leaks out!]

Final remarks

- Alternatives to HCFC-22 in ACs...
 - Concern over suitable options for high ambient regions
 - R-410A normally considered to be unsuitable
- Other alternatives include HC-290
 - Normally efficiency in ACs is particularly good and flammability risk is known to be negligible
 - Data on performance at high ambient is very sparse...
- Current work presents results of testing HC-290 and HCFC-22 split ACs at high ambient
 - Variation in COP at high temperature for HC-290 same as with HCFC-22
 - Variation in capacity of HC-290 same as with HCFC-22
 - Consistent with the theoretical calculations, but marginally better results observed
- Evident that HC-290 is well suited to high ambient regions

Thanks!

