Refrigerants for HAT

Refrigerants in high ambient temperature countries

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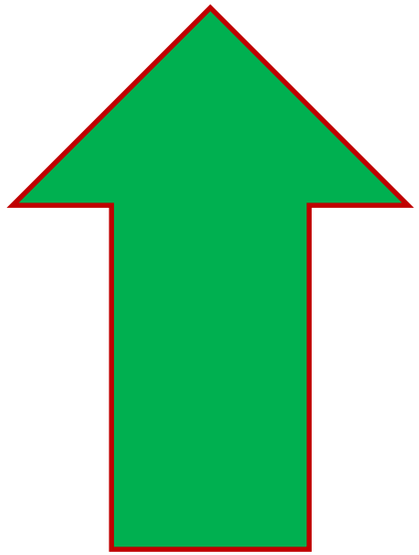
High Ambient Temperature (HAT) Countries

- Equatorial regions, the Middle East, northern Africa and parts of some other/regions/countries across the globe witness temperature around 50 degree C for long period in the year;
- Parties to the Montreal Protocol recognized since 2009 about the non-availability of refrigerant options for stationary AC for HAT;
- R-410A, the commonly used alternative to HCFC-22 was not found adequate in HAT due to its sharp degradation in the performance with the increased condensing temperature;
- Several Studies have been carried out by TEAP since 2009 on the request of Parties to the Montreal Protocol on this subject;
- Search for lower GWP alternatives has further added the uncertainties.

Choice of Refrigerants

Lower Emissions
(Lower-GWP)



Energy Efficient

Focusing on Emissions of Refrigerants &
Energy Efficiency is essential to do what's right

ASHRAE 34: Safety Classification of Refrigerants

	Lower (Chronic) Toxicity	Higher (chronic) Toxicity
Non-flammable	HCFC-22 R-744 HFC-134a R-410A, R-407C,R-404A	HFC-123
Mildly Flammable	HFC-1234ze HFC-1234yf HFC-32	
Flammable	HFC-152a	R-717
Higher Flammability	HC-290 HC-600a	

Increasing safety requirement

Increasing safety requirement

Lower- GWP Options- Single Component Refrigerants

Natural Refrigerants

HCs: R-600a, R-290, Ammonia and CO2

Fluorocarbon Lower GWP Refrigerants

High Pressure:

HCFC-22 Replacements - HFC-32

Medium Pressure:

HFC-134a Replacements- HFO-1234yf, HFO-1234ze (E), HFC-152a

Low Pressure: HCFC-123 Replacements- HFO-1233zd (E), HFO-1336mzz

Lower- GWP OPTIONS – Blends of Refrigerants

- Several Blends of HFO/ HFCs have been tested (list of potential blends not limited to)

Blend	Composition	Temperature Glide 0C	Safety Class	GWP (100Year)	Equivalent to
R-444B	HFC32/1234ze/152a	~10	A2L	290	HCFC-22
R-446A	HFC-32/1234ze/ 600	~5.4	A2L	460	R-410A
R-452B	HFC-32/1234yf/125	0.9	A2L	680	R-410A
R-448A	HFC 32/ 125 1234yf/ 134a /1234ze	5.7	A1	1300	R-404A
R-450A	HFO-1234ze/R-134a	0.6	A1	550	R-134a
R-513A	HFO-1234yf/134a	0.0	A1	570	R-134a
R-514A	HFO-1336mzz(Z) / dichloromethane	0.0	A1	<2	HCFC-123

Relative Performance of Refrigerants in HAT

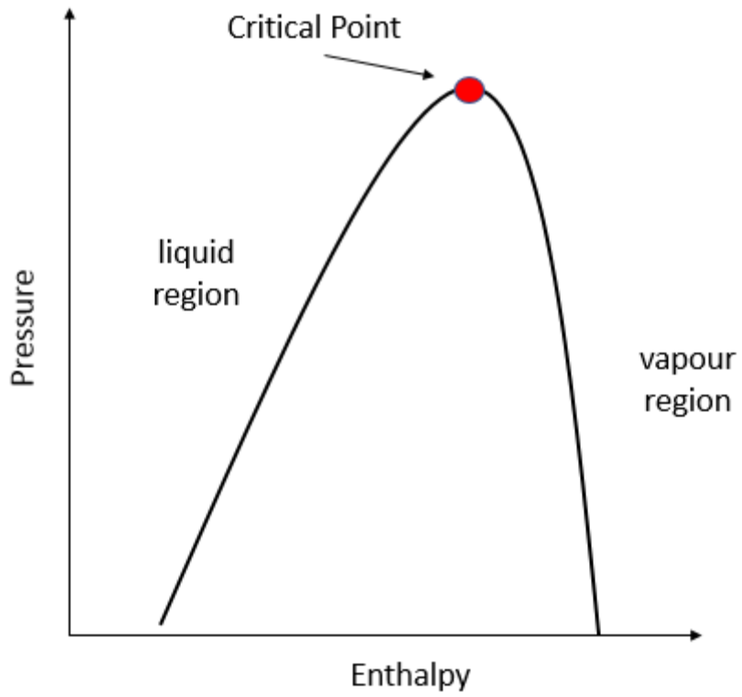
Refrigerant	Condensing Temperature (°C)			
	40	50	60	65
HCFC-22	100	100	100	100
HFC-32	100	100	99	98
HC-290	100	98	96	95
R-407C	100	97	94	92
R-410A	100	97	93	90

Units designed for equal capacity at 40 °C

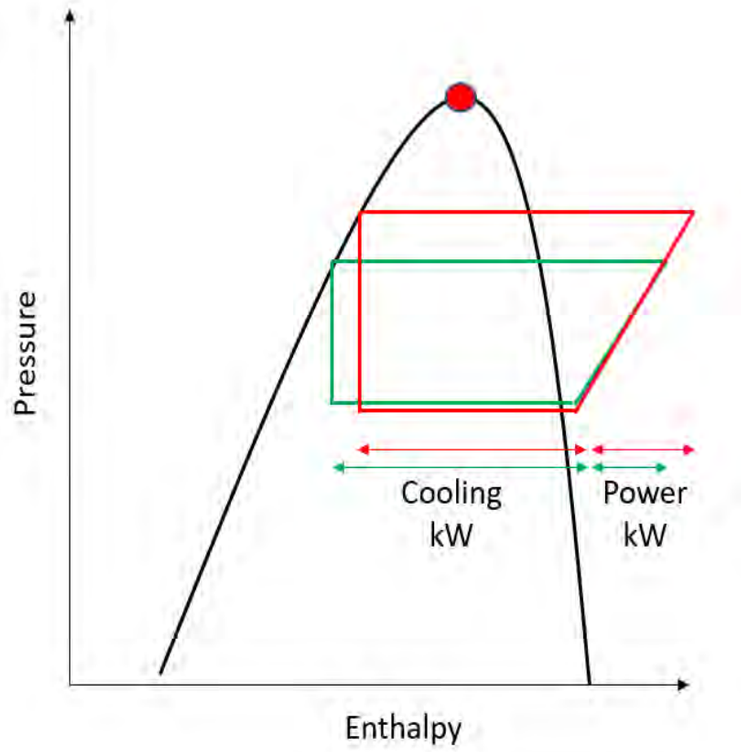
Lower cooling capacity and efficiency for all refrigerants as the heat-rejection (condensing temperature) temperature increases.

Source: RTOC 2010

Why decrease in performance in HAT?



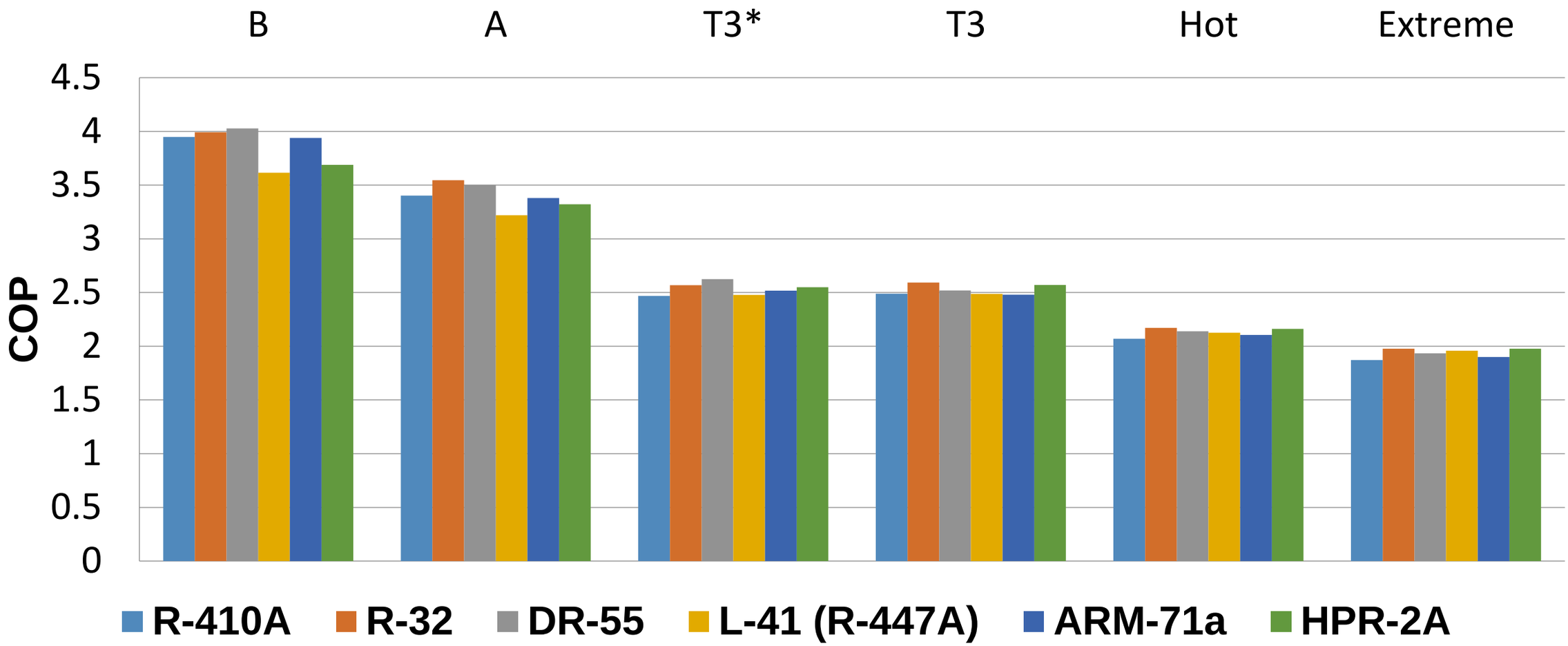
Refrigerant	T critical °C
HCFC-22	96.1
R-290	96.7
R-410A	71.4
HFC-32	78.1
R-452B	79.2
HFC-134a	110
HFO-1234yf	94.7
HFO-1z34ze	109.4
R-513A	97.7
HCFC-123	183.7
HFO-1233zdE	165.8
R-514A	197.4



Test Conditions Used For Evaluation of Alternative Refrigerants for High Ambient Countries

Test condition	Outdoor	Indoor		
	Dry-bulb temp.	Dry-bulb temp.	Wet-bulb temp.	Relative humidity
	°C (°F)	°C (°F)	°C (°F)	%
AHRI B	27.8 (82.0)	26.7 (80.0)	19.4 (67.0)	50.9
AHRI A	35.0 (95.0)	26.7 (80.0)	19.4 (67.0)	50.9
T3*	46 (114.8)	26.7 (80.0)	19 (66.2)	50.9
T3	46 (114.8)	29 (84.2)	19 (66.2)	39.0
Hot	52 (125.6)	29 (84.2)	19 (66.2)	39.0
Extreme	55 (131.0)	29 (84.2)	19 (66.2)	39.0

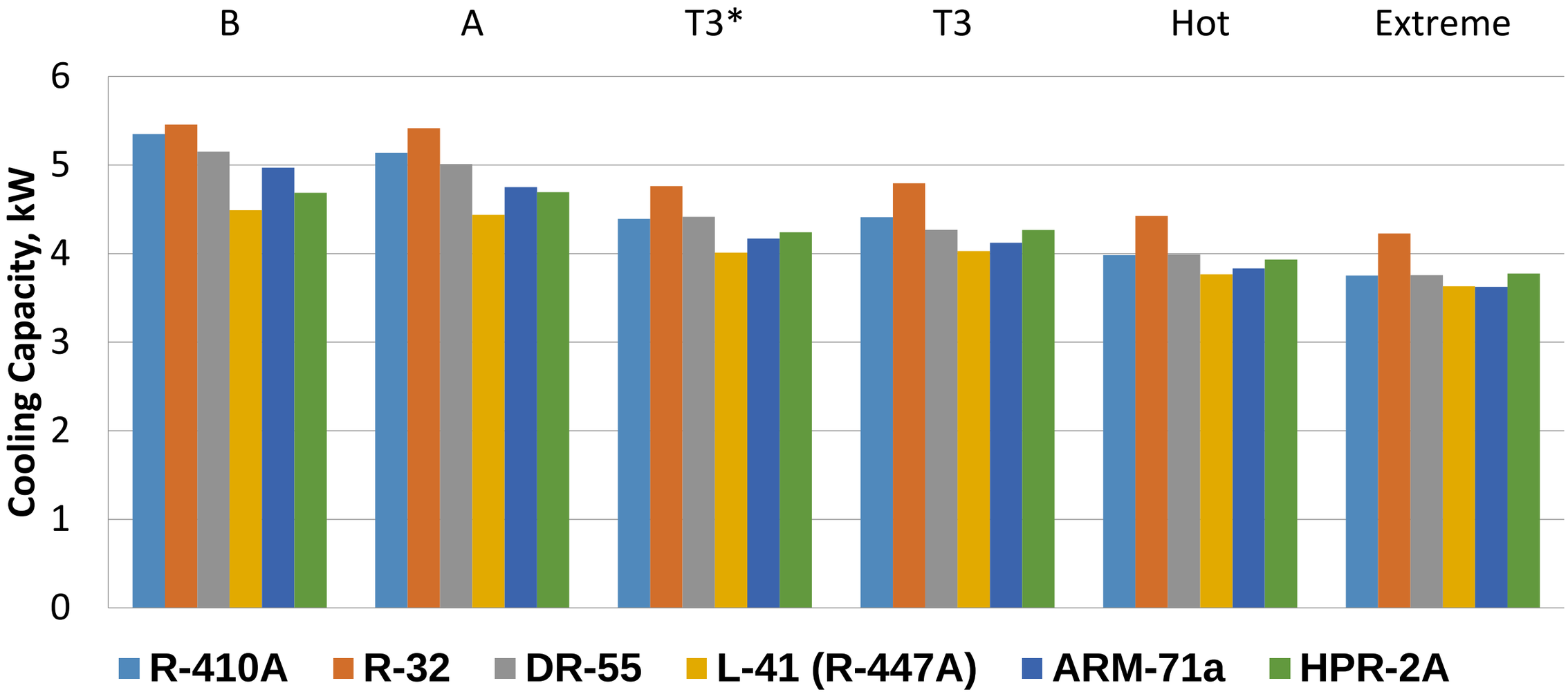
Impact of Ambient Temperature on COP R- 410A Options



Source: OAK RIDGE National Laboratory Study

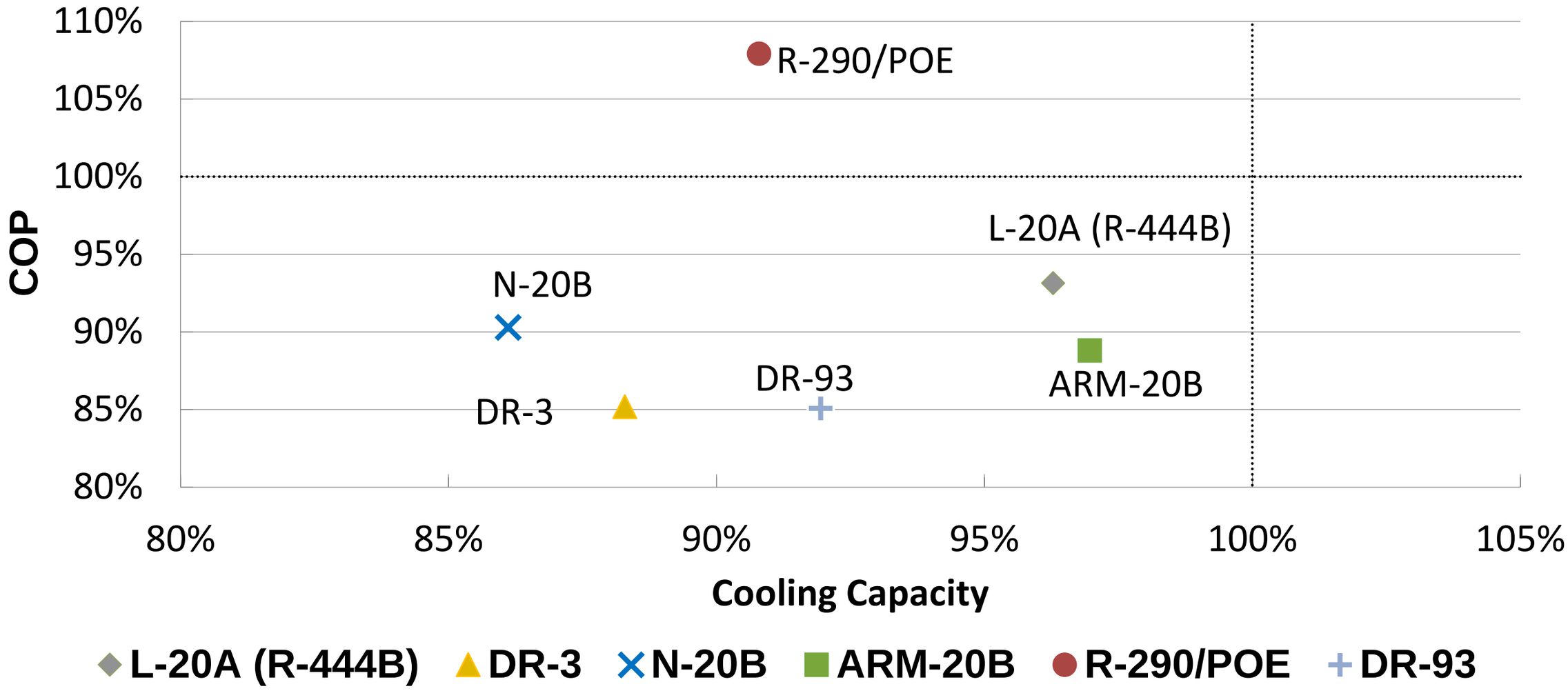
Impact of Ambient Temperature on Capacity - 410A

Options



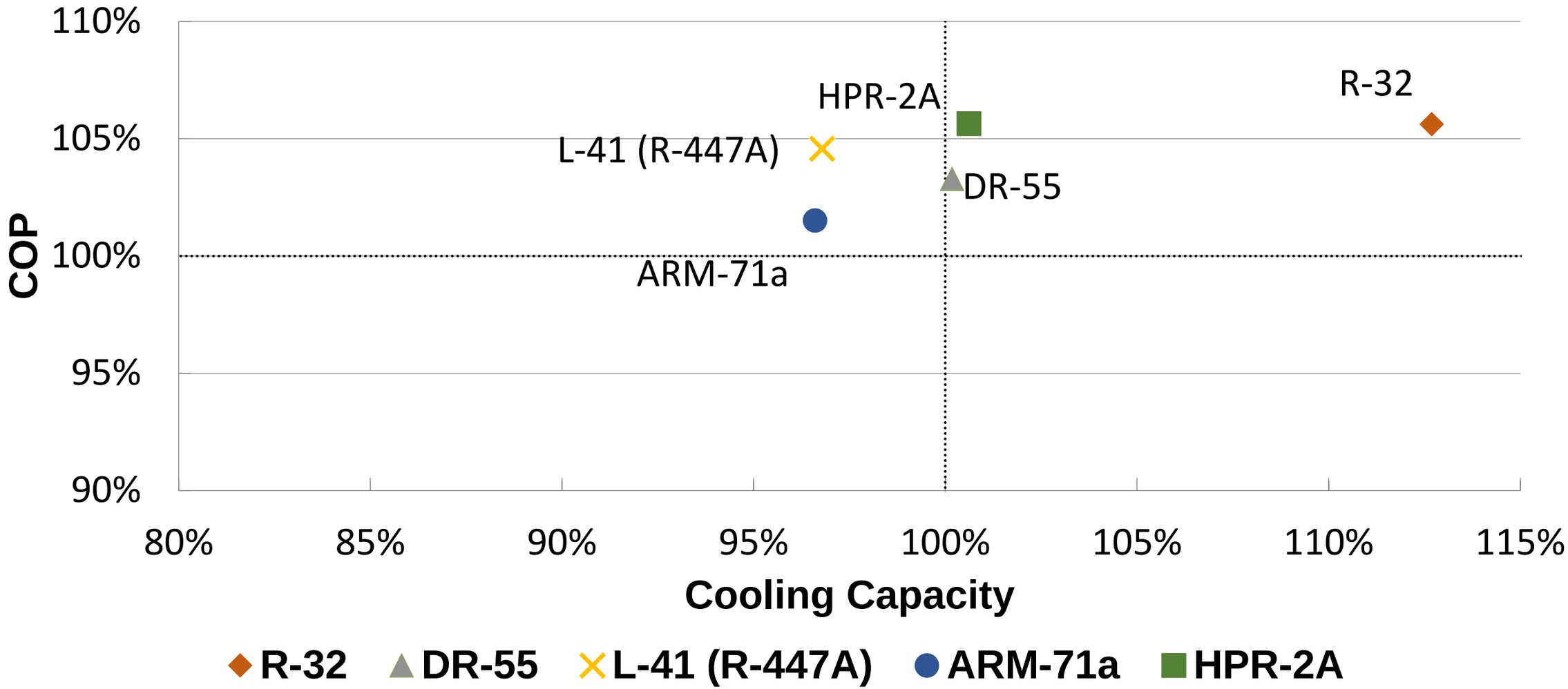
Source: OAK RIDGE National LaboratoryStudy

Performance Relative to HCFC-22 at Extreme Conditions 55°C (131.0°F Outdoor, 29°C (84.2°F) Indoor



Source: OAK RIDGE National Laboratory Study

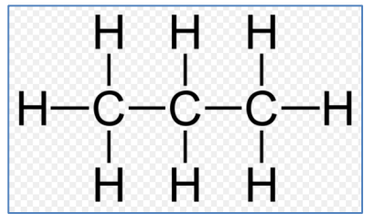
Performance Relative to R-410A at Extreme Conditions – 55°C (131.0°F Outdoor, 29°C (84.2°F) Indoor

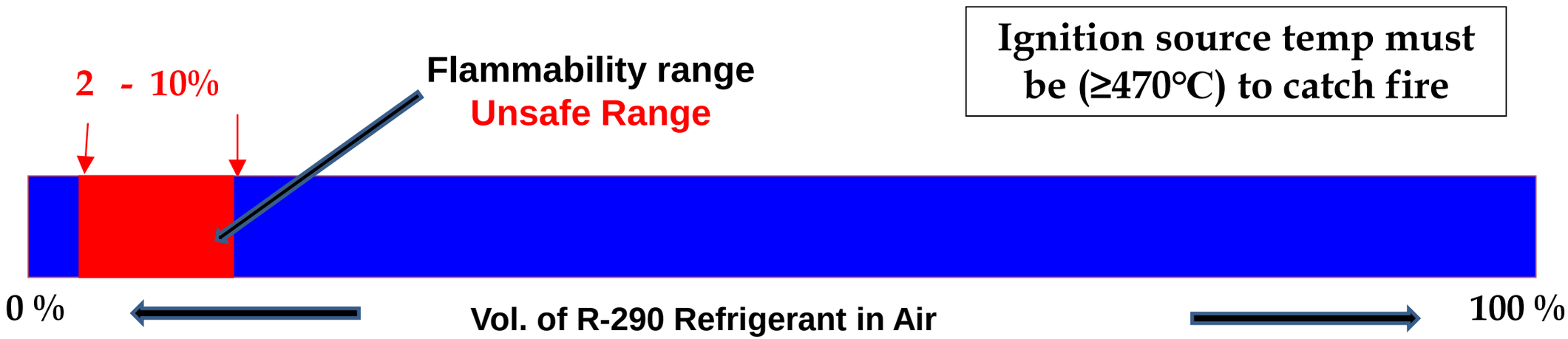


Source: OAK RIDGE National Laboratory Study

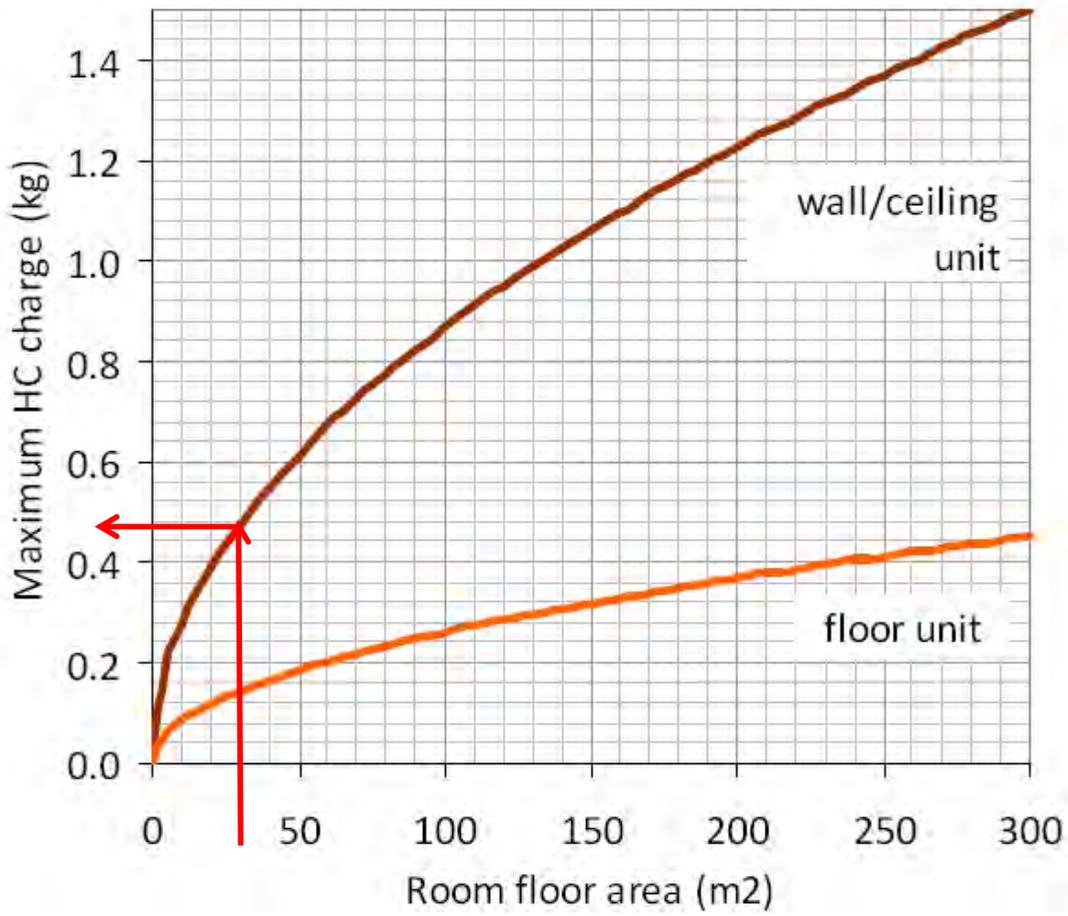
Characteristics of R-290 & Its Limitation

- Single Fluid
- Boiling point -42.1°C
- Compatible with mineral oil with viscosity correction
- Hydrocarbons purity class 99.5% as refrigerant
- No acid formation in combination with water
- **Highly Flammable (A3)**
- **Charge quantity is limited for a given space for safety considerations**





Charge Quantity Limits for R-290



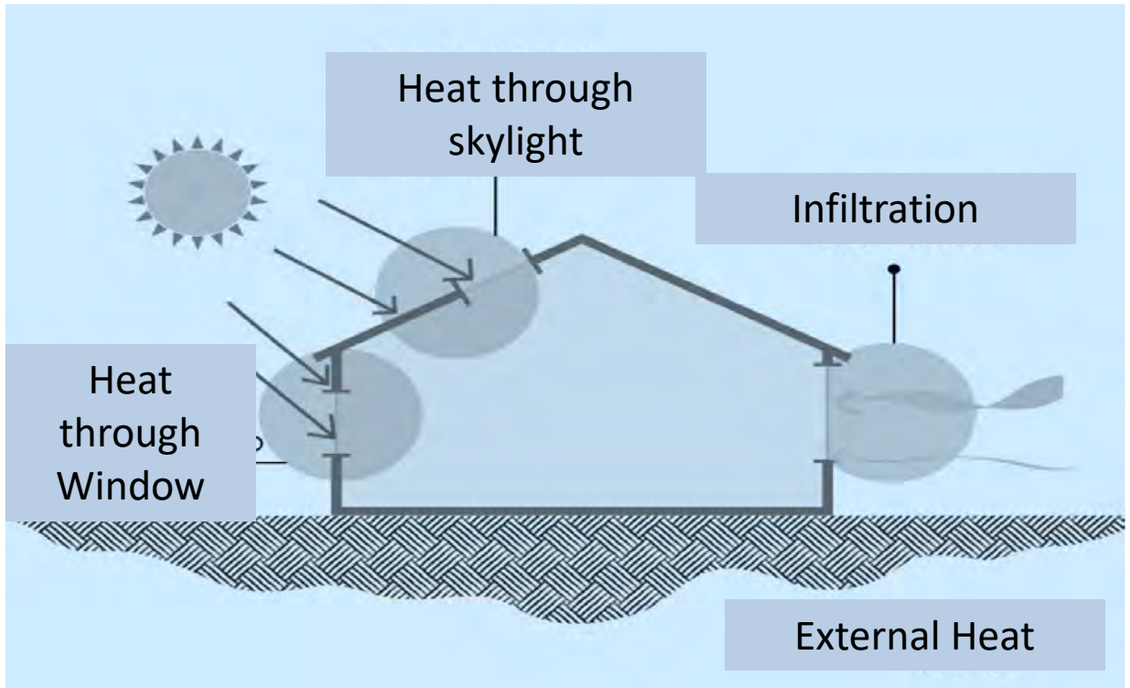
- **The Charge quantity should be based on as per the IEC 60335-2-40**

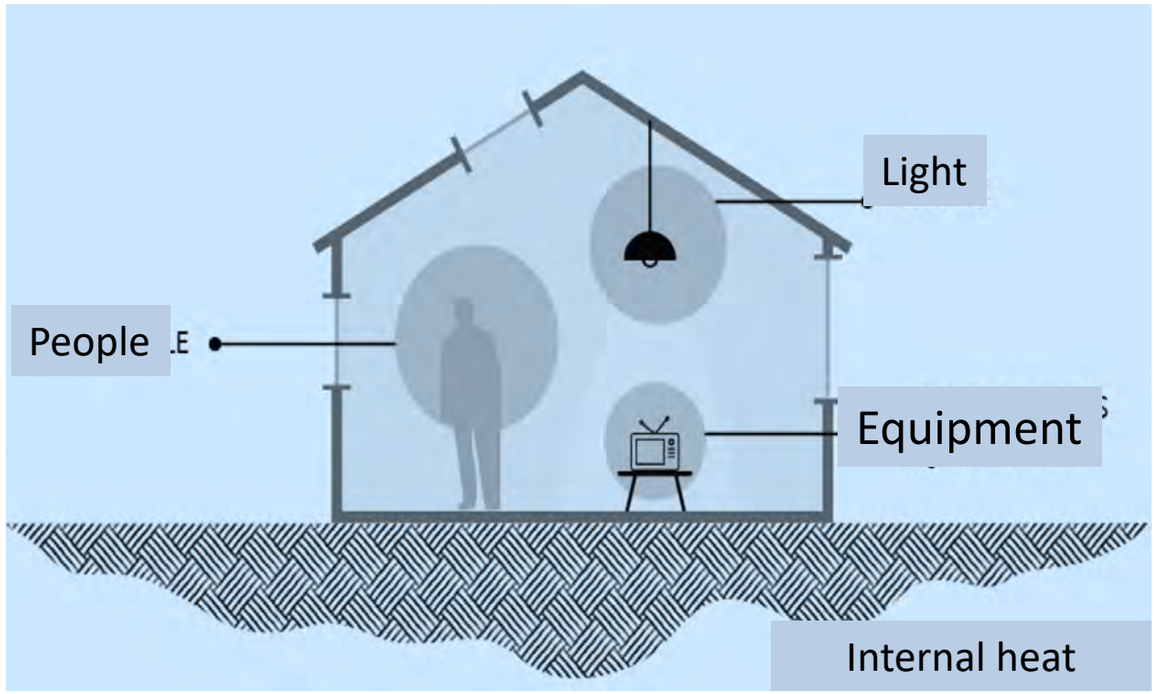
- **Maximum R-290 Charge in kg: 2.5 x $(LFL)^{5/4}$ x 2.1 m x (room floor area area (m^2))$^{1/2}$**

For Example:
Room Area: 6 m × 5 m = 30 m^2
installation height 2.1 m,
charge quantity= 480g.

HAT – Cooling Capacity

- ❑ **External Heat gain is proportional to difference in ambient and indoor temperature;**
- ❑ **Cooling requirement per sq m floor area increase with the increase in ambient temperature;**

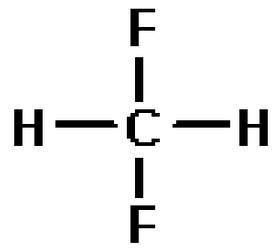




- ➢ **In HAT conditions, the cooling load of a conditioned space can be up to three times that for moderate climates;**
- ➢ **Larger capacity refrigeration systems will be needed which implies a higher refrigerant charge.**

Characteristics of HFC-32

- **Single component fluid;**
- **Boiling point: -51.7°C;**
- **Sensitive to contamination;**
- **Miscible with Polyol Easter oils;**
- **Higher Discharge Temperature;**
- **Mildly Flammable (A2L)**



CH_2F_2

Difluoromethane

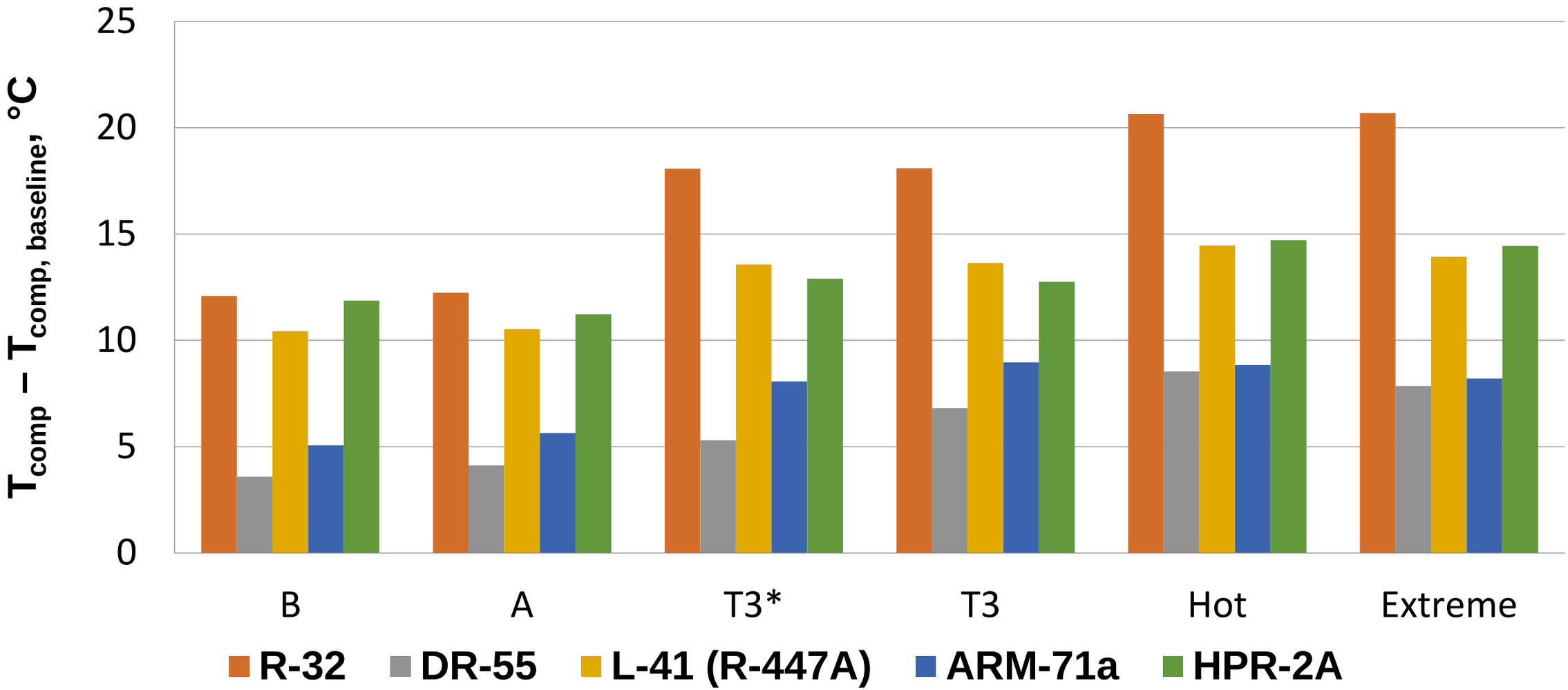
Flammability range :

14 - 31 by Vol. % in air

Ignition source temp must be (≥648°C) to catch fire

0 % **100 %**

Impact on Compressor Discharge Temperature



- Higher Discharge temperatures could be addressed through equipment design:
  - Oversizing of condenser/vapor or liquid injection compressor

Status of Lower-GWP Technical Options for HAT

- **Room Air Conditioners (RAC) - HCFC-22 &R-410A Replacements:**
  - **HFC-32 : widely accepted technical option including for HAT;**
  - **Currently commercial scale use of R-290 is limited due to limitation of charge quantity for a given space and safety considerations;**
  - **R-290 may not be a choice of refrigerant for HAT as charge quantities will be beyond the safe limit for the same floor area as in temperate climates;**
  - **HFC/ HFO blends: Several blends of HFCs, HFO but not commercially used in any market**
    - **R-452B (HFC-32/HFO-1234yf/HFC-125)**
    - **R-444B (HFC-32/HFC-152a/HFO-1234ze)**
- **No new refrigerant molecules have been reported in last 3 years**
- **HFC/ HFO blends have been reported but most of the blends have GWP above 600.**

THANK YOU

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