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New Low GWP Refrigerants for Air-Conditioning, Heat Pumps, and Refrigeration Applications

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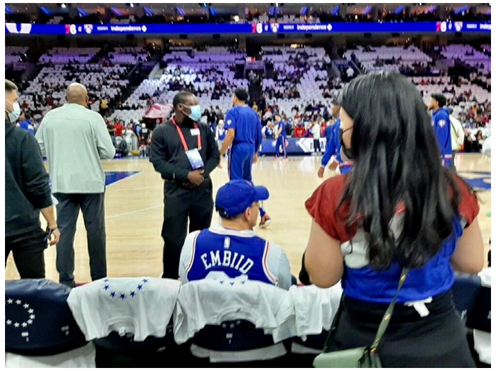
Bio

Sarah Kim, Ph.D.

– Technical Business Development Manager at Orbia

- 11 years of low GWP refrigerant development experience
- Former chair of ASHRAE Standard 34 and current chair of ISO TC86/SC8 – Refrigerants and refrigeration lubricants
- Avid coffee lover and proud fan of the Philadelphia 76ers and Eagles!



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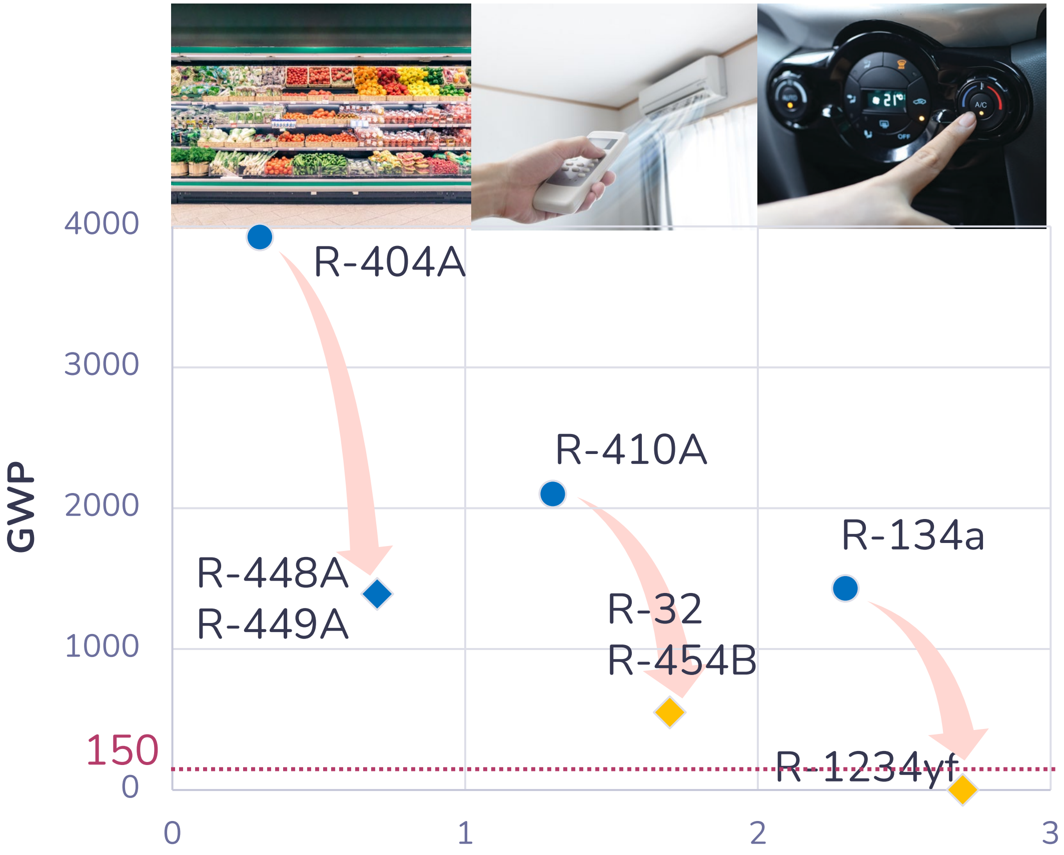
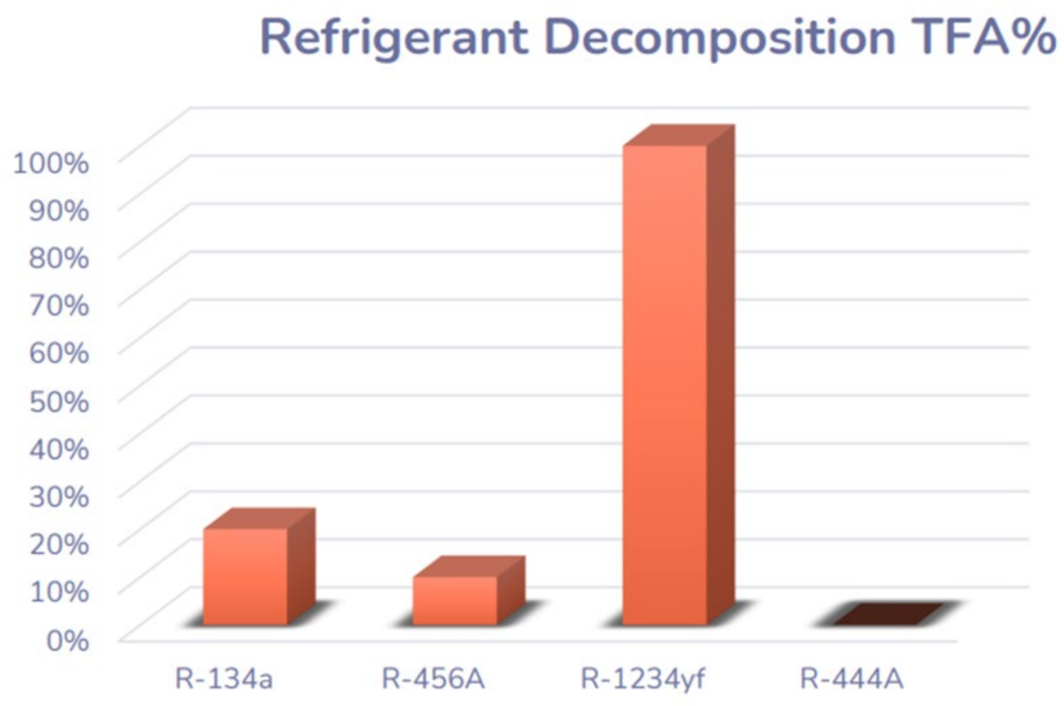
Introduction



As we continue the push to lower GWP products, refrigerant efficiency becomes a key driver of total emissions

Why *Another* Refrigerant?
EU PFAS Regulations and TFA

- Five European countries (Germany, the Netherlands, Denmark, Norway, Sweden) proposed a restriction to ECHA, the European Chemicals Agency in January 2023[1]
  - Proposal would restrict ~10,000 materials, many of which we use every day
  - The ECHA scientific committee is evaluating the proposal for risks to people and the environment
  - 5,600 comments from over 4,400 companies submitted
- Tri-fluoro acetic acid (TFA) is a decomposition product of many refrigerants and is a major contributor to PFAS burden[2]
  - TFA is present in nature, though is persistent
- PFAS definitions that include TFA further limit options



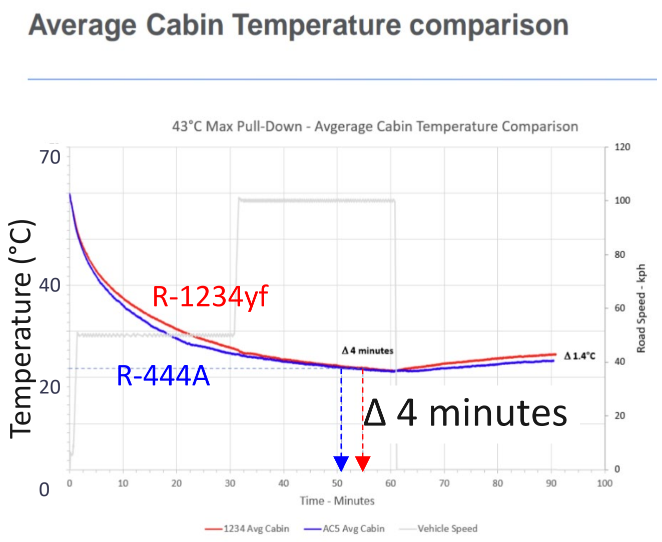
Due to its high TFA decomposition, R-1234yf could be banned as early as 2028-9

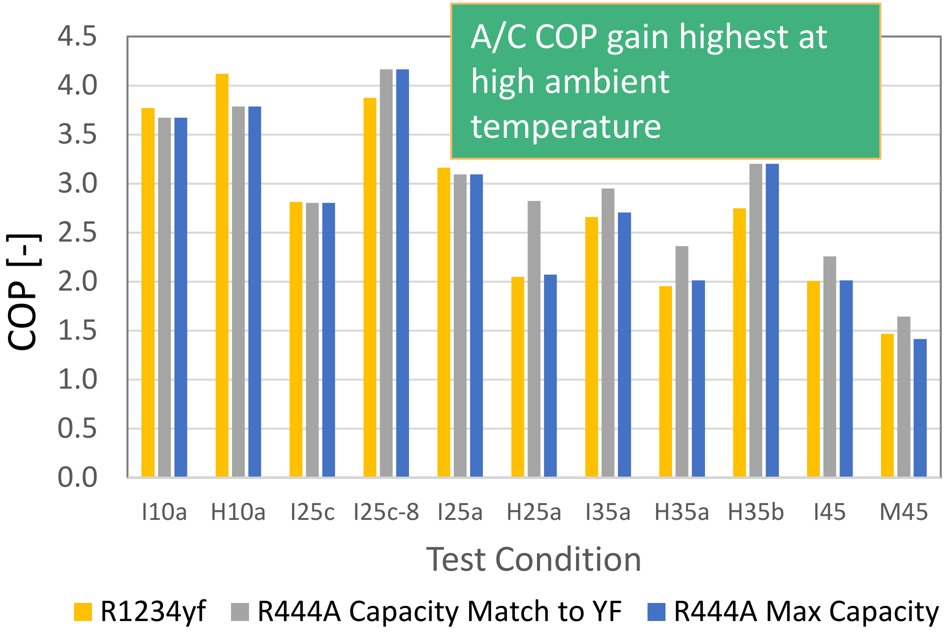
*Sources: 1 https://echa.europa.eu/-/echa-publishes-pfas-restriction-proposal
2 Tropospheric photolysis of CF3CHO - ScienceDirect

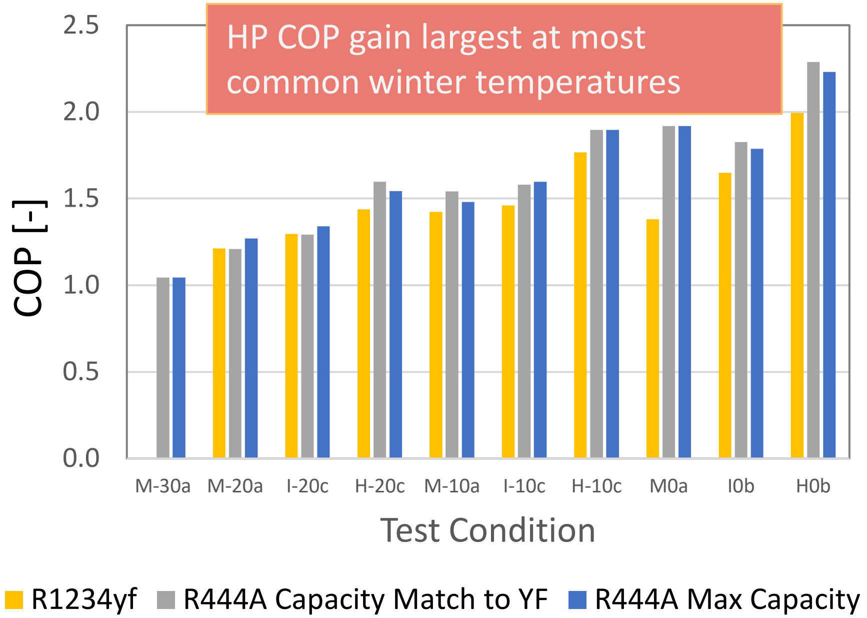
Medium Pressure Refrigerants

Property	Units	R-134a	R-456A	R-513A	R-1234yf	R-444A
GWP (AR4)		1430	687	631	4	93
ASHRAE 34 class		A1	A1	A1	A2L	A2L
Avg dew & bubble point	°C	-26.1	-28.1	-29.5	-29.5	-30.0
Molecular mass	g/mol	102	101.4	108.4	114	96.7
Critical temperature	°C	101.1	102.7	94.9	94.7	103.2
Critical pressure	kPa	4059	4175	3648	3382	4278
Liquid density (@0°C)	kg/m^3	1295	1249	1222	1176	1204
Bubble pressure (@0°C)	kPa	292.8	337.8	325.0	315.8	390.1
Glide	K	0	~3	0	0	~7

R-444A Performance comparison vs R-1234yf

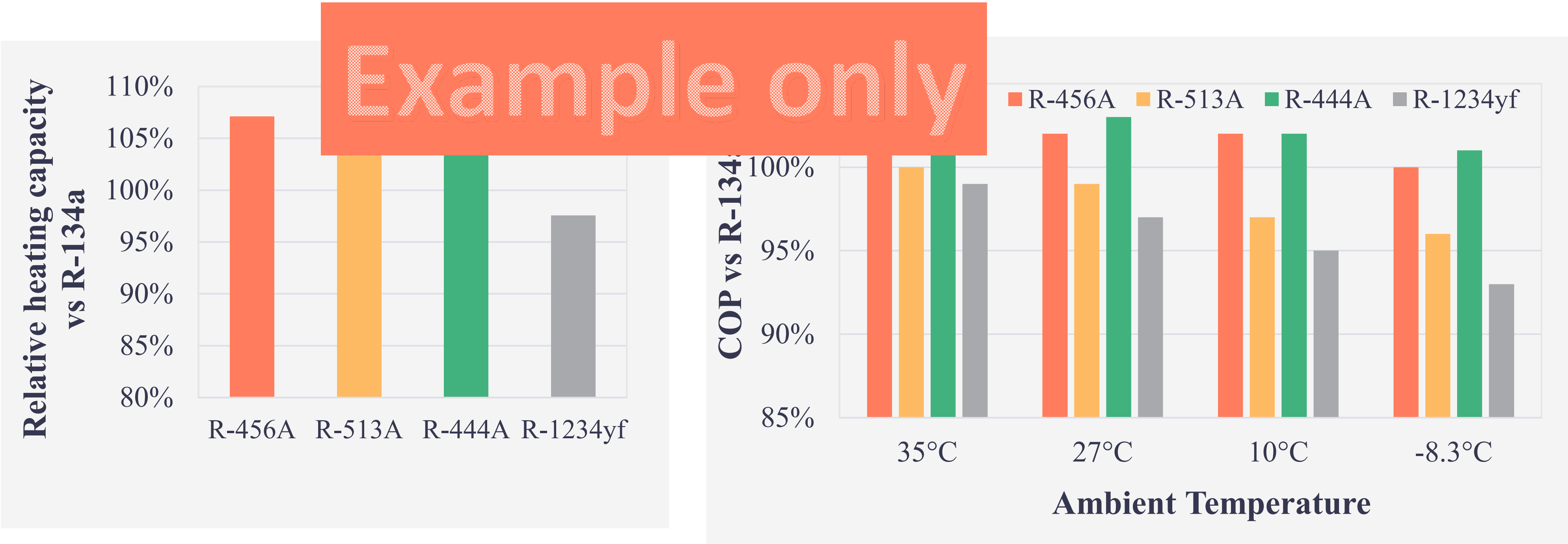






- R-444A pulls down faster than R-1234yf in drop-in test on ICE car
- Also offers higher energy efficiency in both AC and heat pump mode for electric vehicle thermal management systems
- Able to run well over a broader ambient temperature range

Refrigerant Performance comparison vs R-134a



- Waiting for full test data set, but expected to be similar and in agreement with modeled results (shown above)

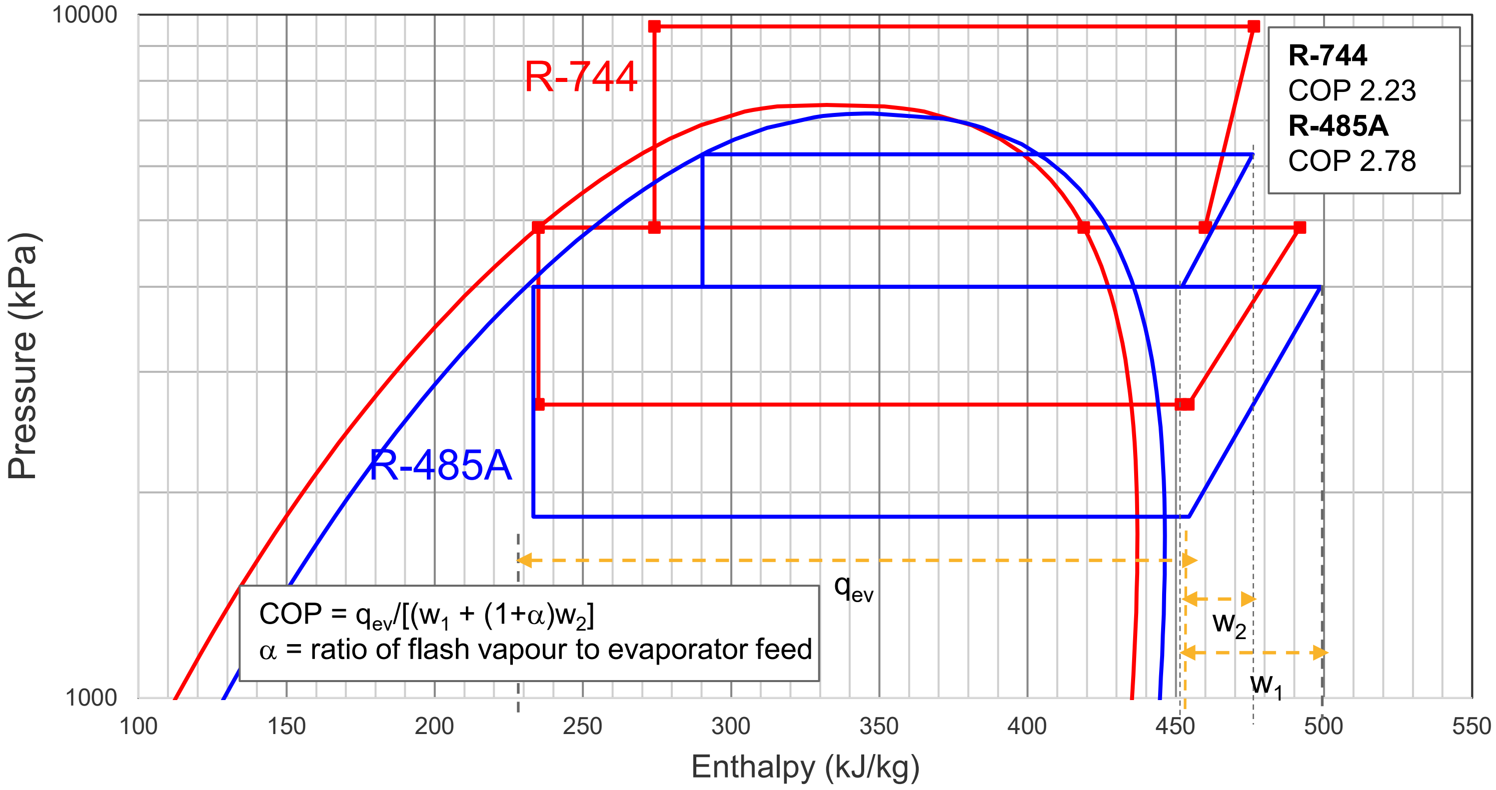
Expanding R-744's effectiveness beyond its limits

Property	Units	R-744	R-485A	R-473A
Global Warming Potential		1	142	142
Composition			R-744/1132a/**32** (69/10/21%)	R-744/1132a/**23/125** (60/20/10/10)
Flammability (ASHRAE/ISO classification)		A1	A1/A2L	A1
Critical temperature	°C	31.0	41.2	29.7
Critical pressure	kPa	7377	7170	6287
Dry ice onset temperature	°C	-56.6	ND	-71 ~ -81
Liquid density (0°C)	kg/m^3	927	935	907
(mean) saturation pressure (0°C)	kPa	3485	2540	3083
Typical T_{evap} glide (with zero pressure drop)	K	0	4-5	4

Benefit of higher critical point

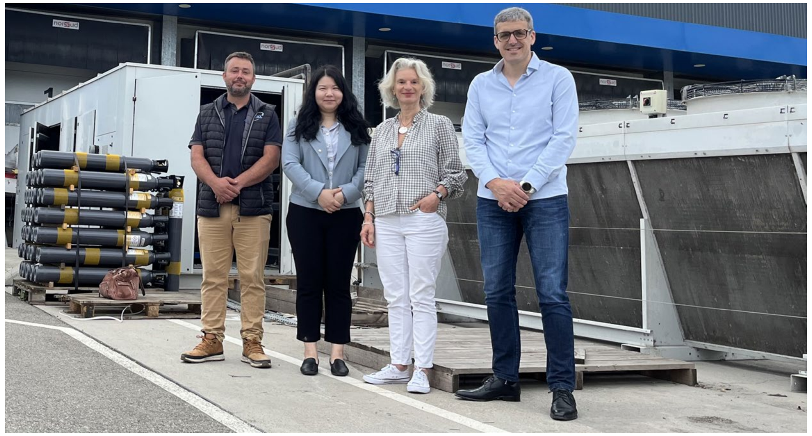
- Application of R-485A for medium temperature refrigeration
- Economized cycle with two-stage compression commonly used in commercial R-744 packaged condensing units
- Cycle diagram shows benefit of operating in subcritical mode with R-485A
  - Lower operating pressures
  - Condensation in the gas cooler
  - Increase in net refrigeration effect
- COP gain over R-744 for this set of cycle conditions is 25%

Comparison of R-744 and R-485A Economized Cooling Cycles
-10°C evaporator temperature; +32°C ambient temperature



Field testing in a cold storage warehouse

- Large medium temperature system for a refrigerated produce warehouse in Southern France
- Strong customer interest in R-485A as a blend with non-PFAS components
- 400kg charge of refrigerant
- Ambient temperature during testing in range 24-34°C
- Gas cooler control set to allow subcritical operation with R-485A where possible
- Equivalent cooling performance
- Observed COP improvement of 19%
- All but two of logged data points with R-485A were in subcritical mode
- Pressure levels at 32°C ambient
  - R-485A ~80 bar maximum
  - R-744 ~110 bar (system cutoff)
- Further trials planned



Ultra Low Temperature Refrigeration

- **Solution for ultra low temperature refrigeration**
  - Non-flammable
  - 85% GWP reduction vs R-23 (14,800)
- **Industry recognition**
  - Adopted by leading logistics company
  - “Refrigeration Innovation of the year: Technology” RAC Cooling Industry Awards 2022
  - Innovation Award, ACREX India, 2024

- **Applications**
  - High value cold chain, pharmaceutical, test chambers, medical

Japan Customer Case Study

Conversion of R-23 environmental test chamber

Placeholder for customer image

- First in Japan to adopt low-GWP refrigerants for environmental test chambers
- Operating range: -70 to 180°C
- With minor adjustment to the expansion valve setting, R-473A was able to meet the extreme temperature ramp rate and pull-down/heat-up time

Tuna Cold Storage Warehouse

Placeholder for customer image

- Conversion of R-22 air-cooled two-stage system to water-cooled cascade R-32/R-473A system
- Facility upgrades avoided by installing R-32 circuit outdoors and R-473A circuit indoors
- Reduced energy consumption by 31% while maintaining target storage temperature

Conclusion

- Environmental impact and efficiency must be considered alongside GWP as the industry continues the HFC phasedown journey
- Zeotropic refrigerants can enhance performance with proper system design and engineering
- Thoughtful selection and addition of fluorinated refrigerants helps address limitations of “natural” refrigerants, such as high flammability, high pressure, and restricted operating range

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