Carrier

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ATMOsphere AMERICA business case natural refrigerants

CO_2 Commercialization In Refrigerated Transport

Efficient and sustainable container refrigeration applications using CO_2

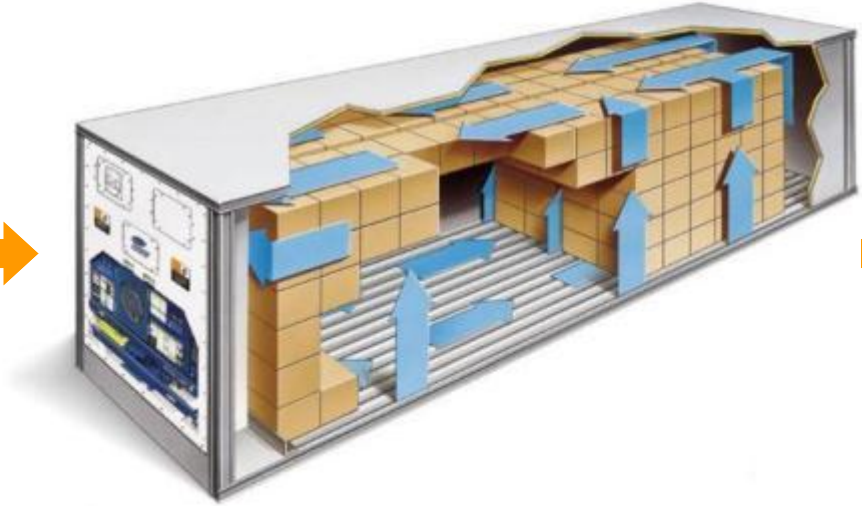
Jim Taeckens, Senior Product Manager, Global Container Refrigeration

San Francisco - June 19, 2014

Refrigerated container shipping

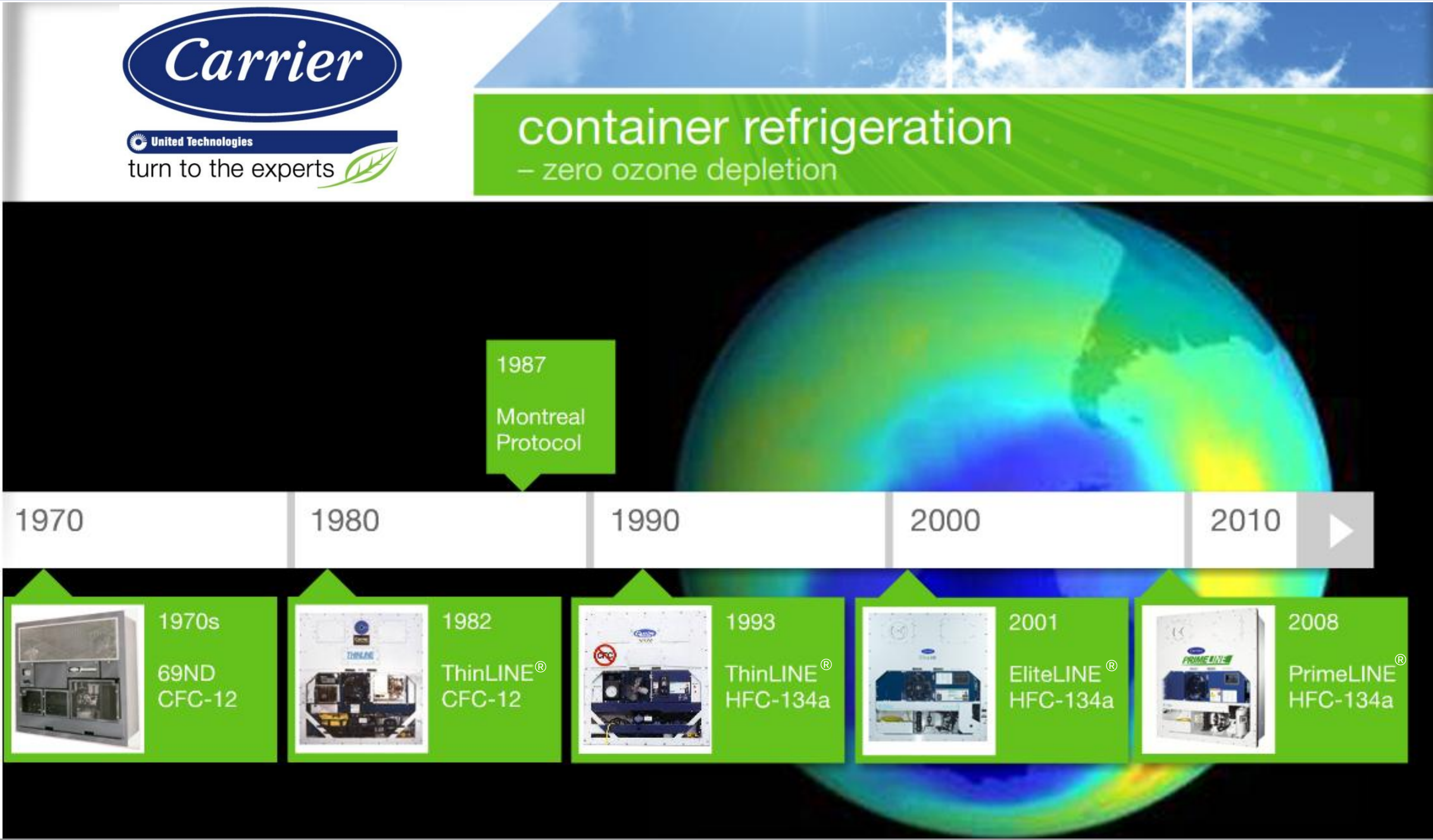
NaturaLINE™ refrigeration machine (reefer)

Mated to ISO insulated containers (20’ or 40’-long)



Transports virtually all perishable and frozen cargoes

Transition to zero ozone depleting refrigerants



Container refrigerant transition

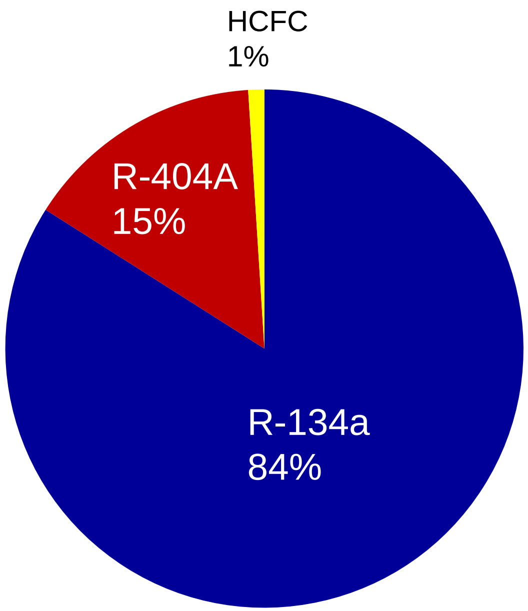
Transition from CFCs to HFCs

Early decision to focus on HFCs

Today 99% HFCs in container application

Main drivers

- Performance
- Safety
- Lower GWP
- Availability
- Cost



Container installed base refrigerants

EU F-gas regulation

Revision prompted by 2006 regulation (MAC)

HFC cap and phase-down mechanism is central pillar of new regulation

Proposal finalized last April (coming on-line starting 2020):

- Ban of HFCs with GWP > 2500 in stationary refrigeration
- Ban of HFCs with GWP > 150 in centralized multipack and hermetic refrigeration
- Ban of HFCs with GWP > 750 in single split AC systems (charge > 3kg)
- Mandatory leakage checks for refrigerated trucks / trailers

Member state taxation in place or pending based on GWP

Global phase down agreements

2013 U.S. / China Summit

- Multilateral approach to phase down HFCs
    - Production
    - Consumption
- Proposed amendment to Montreal Protocol for HFCs
- Gradual reduction framework

2013 G-20 Summit – St. Petersburg

- Agreement on global HFC phase-down per Montreal Protocol
- Global GHG emission reduction of 90b tons by 2050

Impact

- Potential move from regional HFC regulation to global
- Potential to be similar to CFC phase down

Source: http://www.reuters.com/article/2013/09/06/us-g20-climate-idUSBRE9850WU20130906

Impact to container industry

Currently no direct regulation on container equipment

Servicing container equipment will likely become more expensive

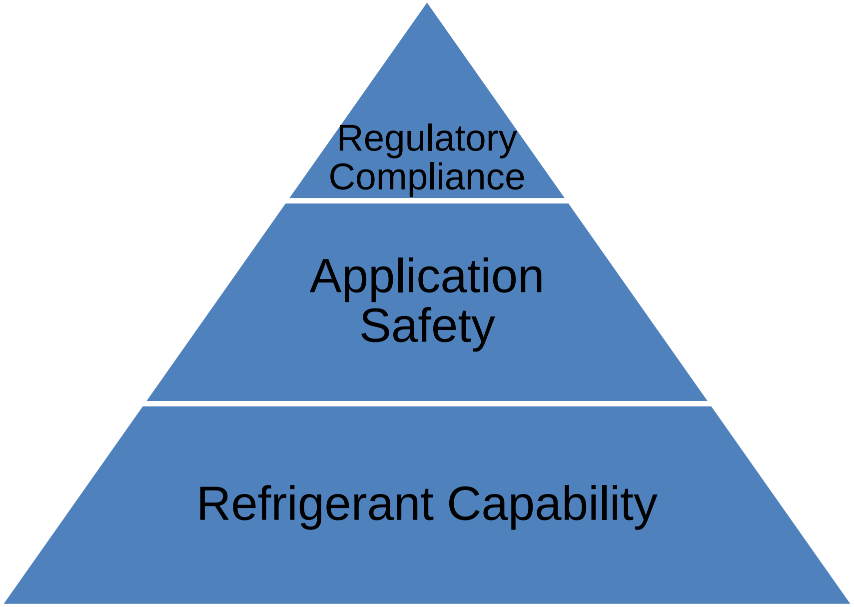
Refrigerant pricing will likely be much higher globally

Alternatives

- HFO chemical blends
- Natural refrigerants

Container refrigerant suitability

	Low Toxicity	High Toxicity
High Flammability	A3 propane propene isobutane	B3
Low Flammability	A2 A2L HFO-1234yf AC-5 R-32	B2 ammonia
No Flame Propagation	A1 R-134a R-404A R-407C R-407F CO_2	B1



Flammable refrigerants in transport

ISO 5149: Safety and Environmental Requirements

Flammability Limits ~ Refrigerant Concentration Limit (RCL) g/m^3
40 ft. container / 80% loaded / available volume: 25 m^3

a) Propane (A3): 9.5 RCL
b) R32 (A2L): 77 RCL
c) R1234yf (A2L): 75 RCL

Resulting RCL if leak from evaporator with charge lost inside 40 ft. container

a) Propane:	2 kg / $25m^3$ = 0.08 or $80g/m^3$	8.5X RCL (34X allowed by std)
b) R32:	4 kg / $25m^3$ = 0.16 or $160g/m^3$	2.1X RCL (8.5X allowed by std)
c) R1234yf:	4 kg / $25m^3$ = 0.16 or $160g/m^3$	2.1X RCL (8.5X allowed by std)

NOTE: RCL would be 2X higher for a 20 ft. container for each refrigerant

Conclusion: For A2L and A3 refrigerants - a leak in the container brings us above the flammability limit

First natural refrigerant container unit

Purpose built multi-stage compressor

Zero GWP insulating foam

Gas cooler heat exchanger

Two speed gas cooler fan

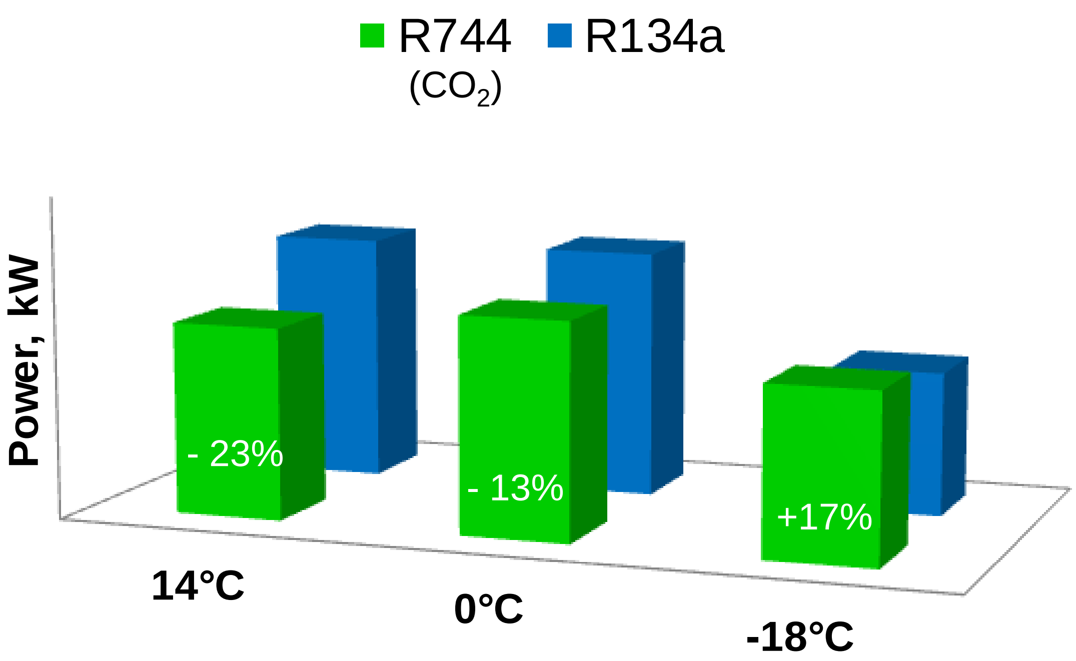
Flash tank

Variable speed drive

Advance software and controls

95% recyclable

NaturaLINE™ efficiency



Average energy use similar to R134a

Superior efficiency at part-load perishable set-points

Typical container control temperatures at 25°C ambient

70% of all container loads are carried at 25°C or less ambient temperature

Source : *Carrier internal testing*
Temperature & Humidity in Ocean Containers, David Leinberger, Xerox 2006

NaturaLINE™ field trials starting in 2008

NaturaLINE™ field trials 2012-2014

>120 shipments completed
Frozen and perishable cargo
>27,500 operating hours

Ice cream / cookie dough	Frozen	Cheese	Beer	Banana	Wine
-22°C	-18°C	5°C	12°C	13°C	

NaturaLINE™ service training

- CO_2 training part of standard offering
- Service Center training
- Technician training
- Vessel crew training
- Training content
    - Fundamentals of Refrigeration (R134a and R744)
    - Working with refrigerants
    - Operation of NaturaLINE unit
    - Servicing and trouble shooting

NaturaLINE™ timing and next steps

Announced field trial success	End of 2013
Moving into commercial phase	2014

Track units and customer feedback

- Cargo carried
- Service records
- Performance measurements

Explore other / unique applications

- NaturaLINE 2 year field trial
- Refrigerated trucks / trailers at Sainsbury's

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June 18-19, 2014 - San Francisco