ET Summit 2024

Presented by

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Ammonia Vapor Compression with CO_2 Convection

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Ammonia-Carbon Dioxide Cooling System

Ammonia chilling coupled to a CO_2 convective loop

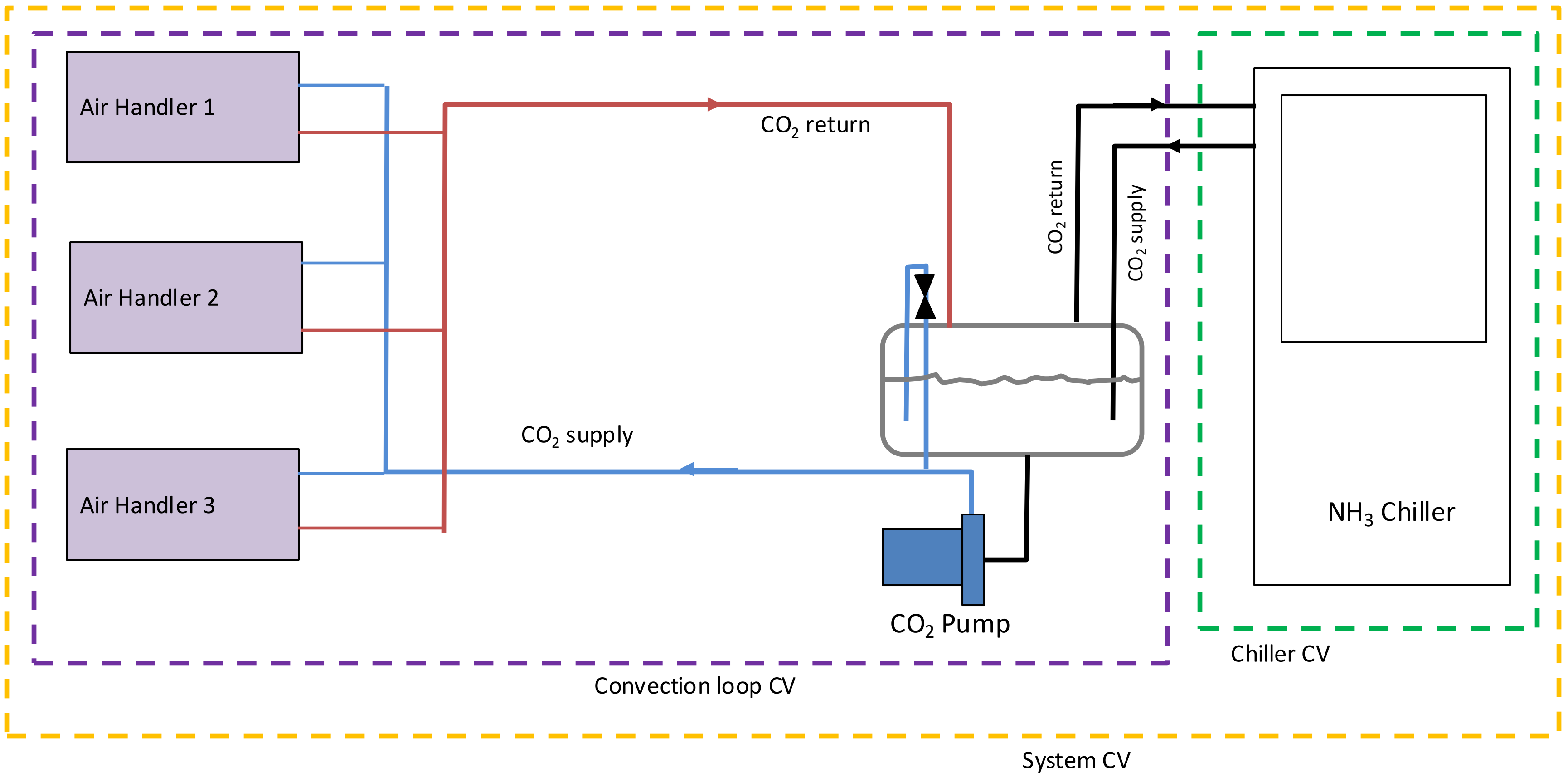
Project Overview

Environmentally Friendly Refrigerants for HVAC

Background & Goals

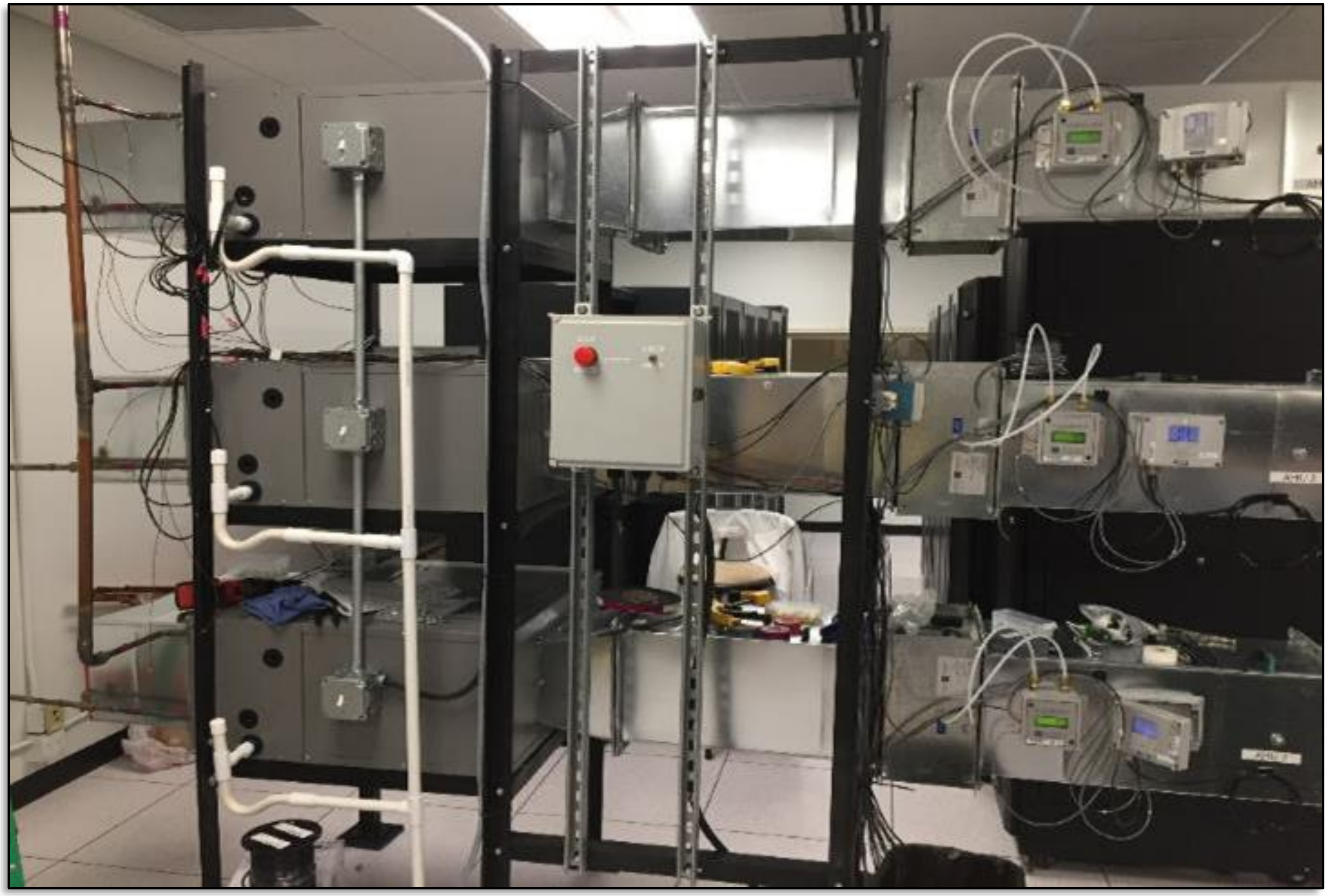
- Refrigerant regulations (CARB, EPA) are phasing-out the current refrigerants (R-134a, R-410A, R-22) used in commercial HVAC equipment
- Environmentally friendly refrigerants are being developed for commercial HVAC.
- Explore alternative refrigerants, in line with changing requirements in CA.
- Design and evaluate candidate technologies
  - Ammonia vapor compression
  - Carbon dioxide convection

System Control Volumes for Characterization



Outdoor System

Indoor System—Air Handlers



Heat Transfer Capacity of CO_2

Boiling heat capacity of CO_2 vs sensible capacity of water

- **CO_2~500psig (saturated)**

Δh = $h_v - h_l$ = 136.8 Btu/lbm – 37.5 Btu/lbm = **99.3 Btu/lbm**

- **Water**
- 1 Btu/lbm °F
  ~10 °F ΔT for typical chilled water system
- ~**10 Btu/lbm**

99.3 vs. 10 □ CO_2 ~ 10x Water

Piping Requirements and Costs

CO2

- Copper high pressure tubing with standard brazing
- (Mueller *Streamline XHP™*)

Example 8-ton system:
7/8" Copper XHP
0.43 in^2 cross-section
~1000 lbm/hr
~2.1 gpm

Water

- Welded or threaded black steel pipe

Example 8-ton system:
2.5" steel pipe
4.79 in^2 cross-section
9600 gal/hr
~19.2 gpm

Flow ~10x water vs CO_2 (liquid)

Piping

Mueller Streamline XHP (130 Bar) Copper/Iron Alloy
(90 Bar option would have been sufficient)

Piping Comparison
Copper (CO_2) vs. Welded Steel (Chilled Water)

1-3/8” Copper vs 4” Steel

7/8” and 1-1/8” Copper vs 2” Steel

Piping Requirements and Cost

Tubing/Pipe Size	Raw Material	Raw Labor	Total Installed (with O&P)
Type K Copper (ACR)		***Cost ($) per linear foot***	
7/8”	$4.97	$2.83	$10.10
1 1/8”	$7.00	$3.2	$12.95
1 3/8”	$9.35	$3.68	$16.35
Schedule 40 Welded Steel		***Cost ($) per linear foot***	
1 ½”	$5.70	$8.50	$21.06
2”	$11.25	$10.60	$30.76
3”	$16.55	$15.05	$44.14
4”	$17.00	$17.45	$48.87

Source: R.S. Means April, 2019

Traditional vs NH_3/CO_2 Comparison

Halocarbon/Pumped Chilled Water		NH_3 Chiller/Pumped CO_2	
Pro	***Con***	***Pro***	***Con***
Familiarity to industry and trades	Large piping, high install cost	High inherent NH_3 efficiency	NH_3 toxicity, familiarity of trades
Many products available	GWP of refrigerants e.g. R134a	Lower pumping energy for CO_2	CO_2 pressure, familiarity of trades
Air or water source	Higher pumping energy for water	High heat capacity of CO_2	Limited product availability for HVAC applications
Many configurations possible (positive displacement or centrifugal)	Water treatment chemicals	Adjustable evaporator temperature	Limited knowledge of system lifetime issues
Scalable		Lower piping installation cost	High operating pressure
		Near zero GWP of refrigerants	CO_2 management (leaks & maintenance)

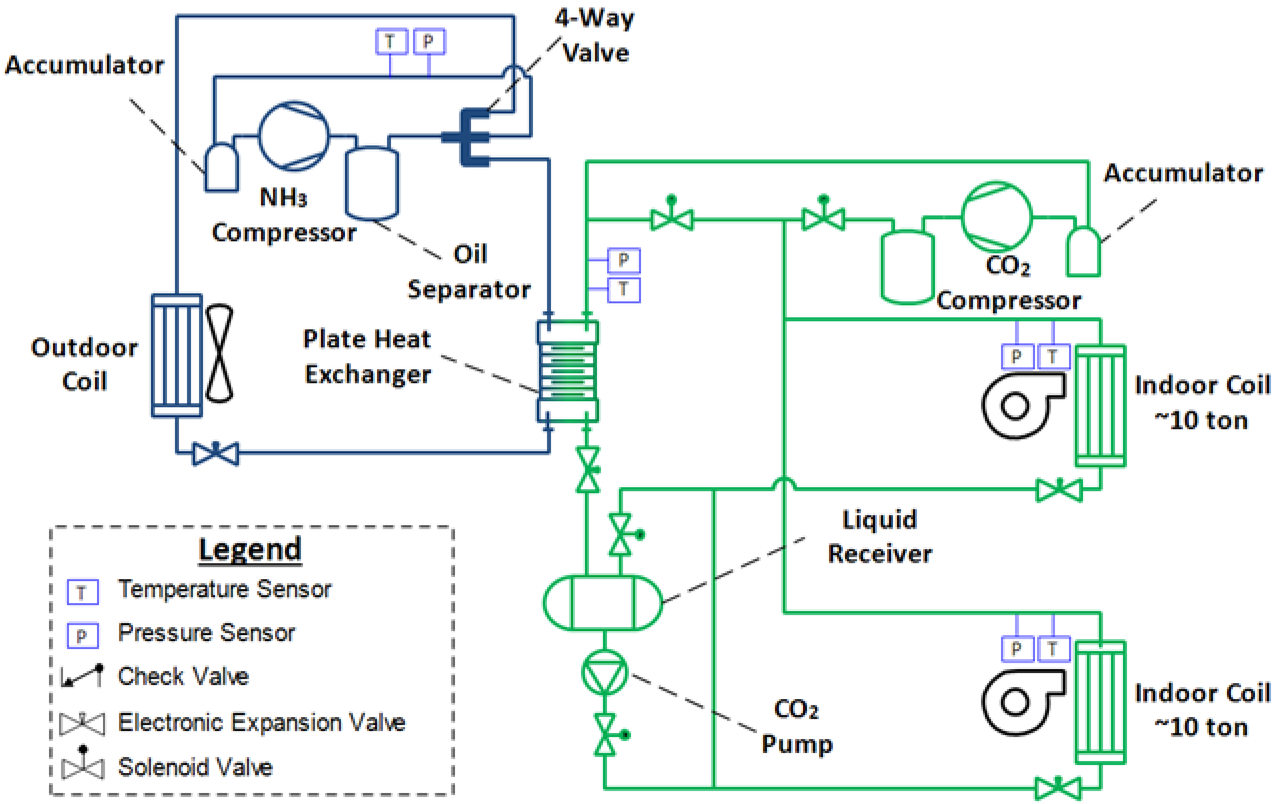
Outcomes & Recommendations

- Project constructed and demonstrated a novel approach to the application of zero GWP refrigerants for commercial space cooling
- Demonstrated an alpha prototype cooling system using low-charge ammonia as the primary vapor compression fluid and carbon dioxide as the secondary convection fluid
- COPs in the range of 2 – 3 as various operating states with a non-optimized system is considered promising.
- Potential cost reduction from the elimination of halocarbon refrigerant and high install cost of large water piping
- The prototype represents a first step in developing a field deployable prototype
- Leading to development of a heat pump version

Follow-on Project

Reversible Heat Pump for California Climate

- CEC-funded project based on SCE-funded NH_3 chiller with liquid CO_2 distribution
- Uses NH_3 as the refrigerant and CO_2 as the distribution fluid
- Potential for lower installation and lower maintenance costs
- Novel use of supercritical CO_2 as a heating distribution fluid allows smaller piping and lower pumping costs compared to hydronic
- Reduces risks associated with increasingly stringent regulations on refrigerants
- Reduces risk to atmosphere associated with unintentional leakage



Project Partners

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Thank You!

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