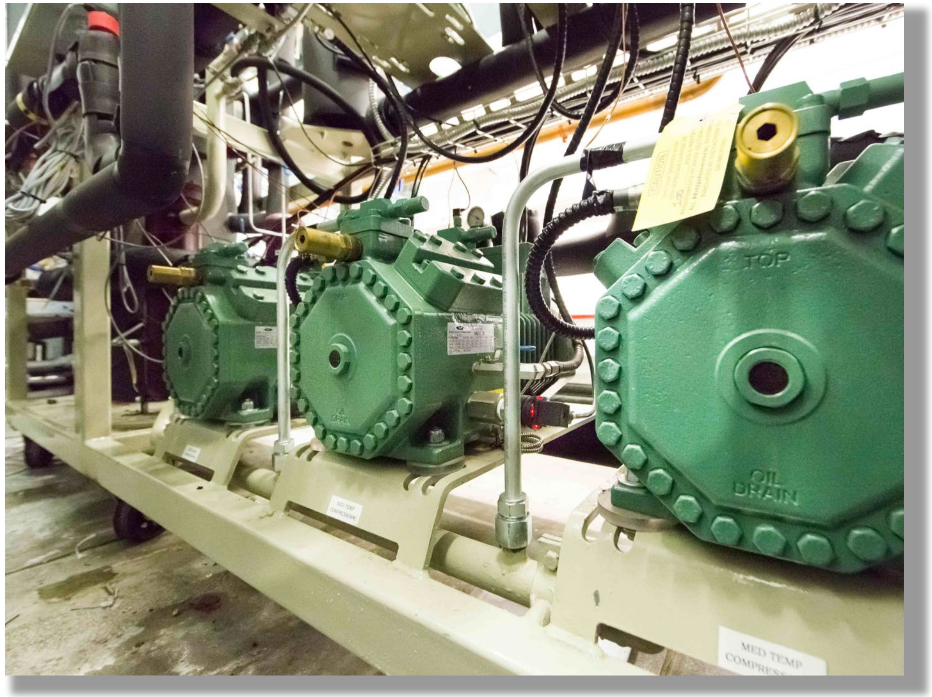
Next Generation Transcritical CO_2 Refrigeration



Oak Ridge National Laboratory
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Project Summary

Timeline:

Start date: 10/01/2020

Planned end date: 09/30/2023

Key Milestones

1. Complete modeling of subcooler and parametric analysis (09/30/2022)
2. Complete design and development of subcooler (12/31/2022)
3. Complete process optimization (06/30/2023)

Budget:

Total Project $ to Date:

- DOE: $150k
- Cost Share: $0

Total Project $850k

- DOE: $850k
- Cost Share: $0

Key Partners:

Hillphoenix

A DOVER COMPANY

Project Outcome:

Develop the next-generation energy-efficient transcritical CO_2 refrigeration system

- Modular, flexible low-GWP solution to provide subcooling of the CO_2 exiting the gas cooler
- Optimized controls to achieve maximum system efficiency and to provide grid connectivity

Team

ORNL Team

Experienced in CO_2 refrigeration system design, system modeling and CFD

Brian Fricke

Ahmed Elatar

Kashif Nawaz

Vishal Sharma

Hillphoenix Team

Leading manufacturer of CO_2 refrigeration systems

Scott Martin

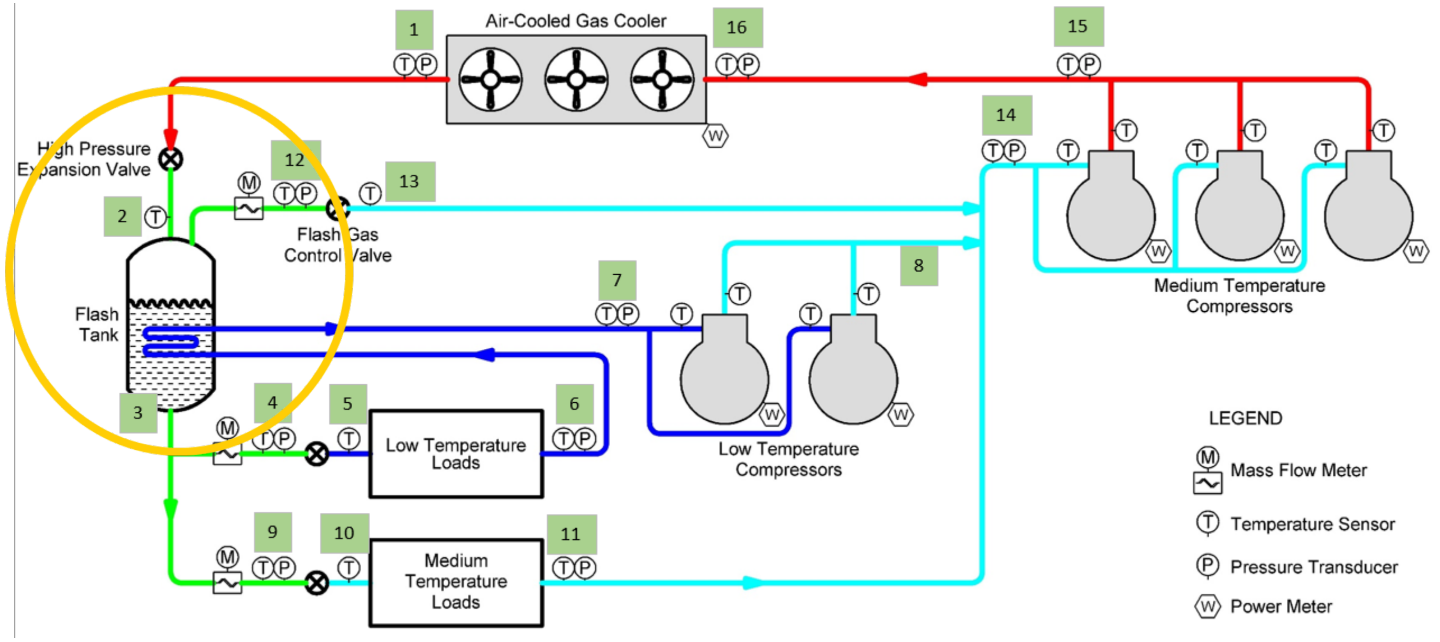
Jeff Newell

Challenge

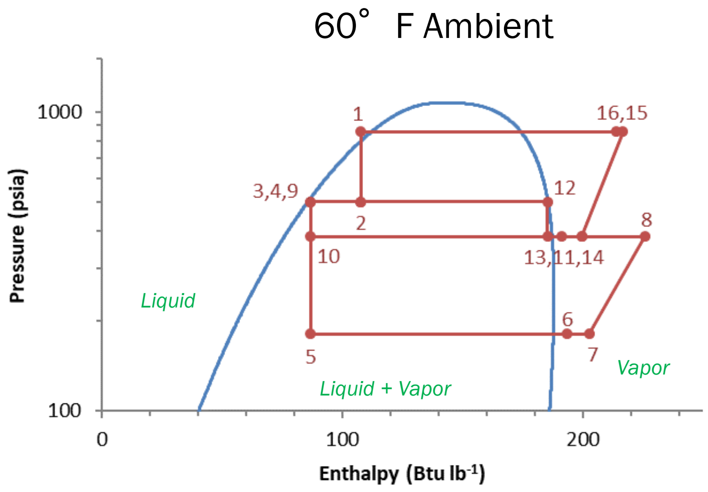
- **Many supermarket refrigeration systems use high Global Warming Potential (GWP) refrigerants**
  - R-404A: GWP = 3900
  - R-407C: GWP = 1800
- **Direct emissions ≈ Indirect Emission**
  - Annual refrigerant leakage on the order of 25%
- **Deploy low GWP refrigerants to reduce direct emissions**
  - Carbon dioxide is an attractive option
  - Non-toxic, GWP = 1
- **CO_2 refrigeration system efficiency suffers at high ambient temperatures**

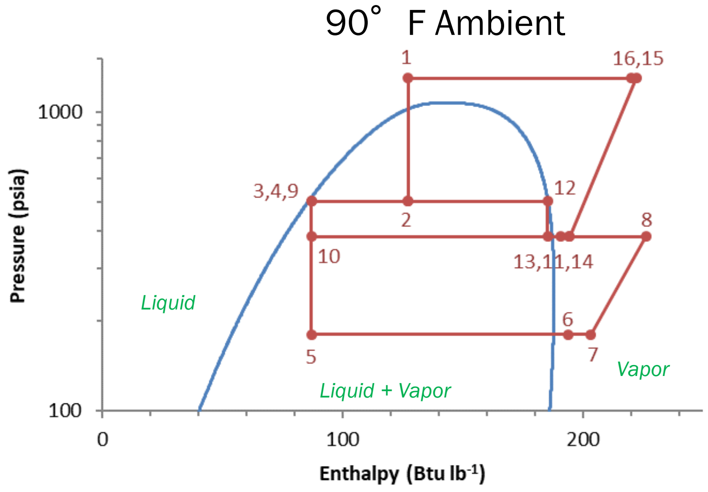

Photo by Michael Burrows from Pexels

Challenge

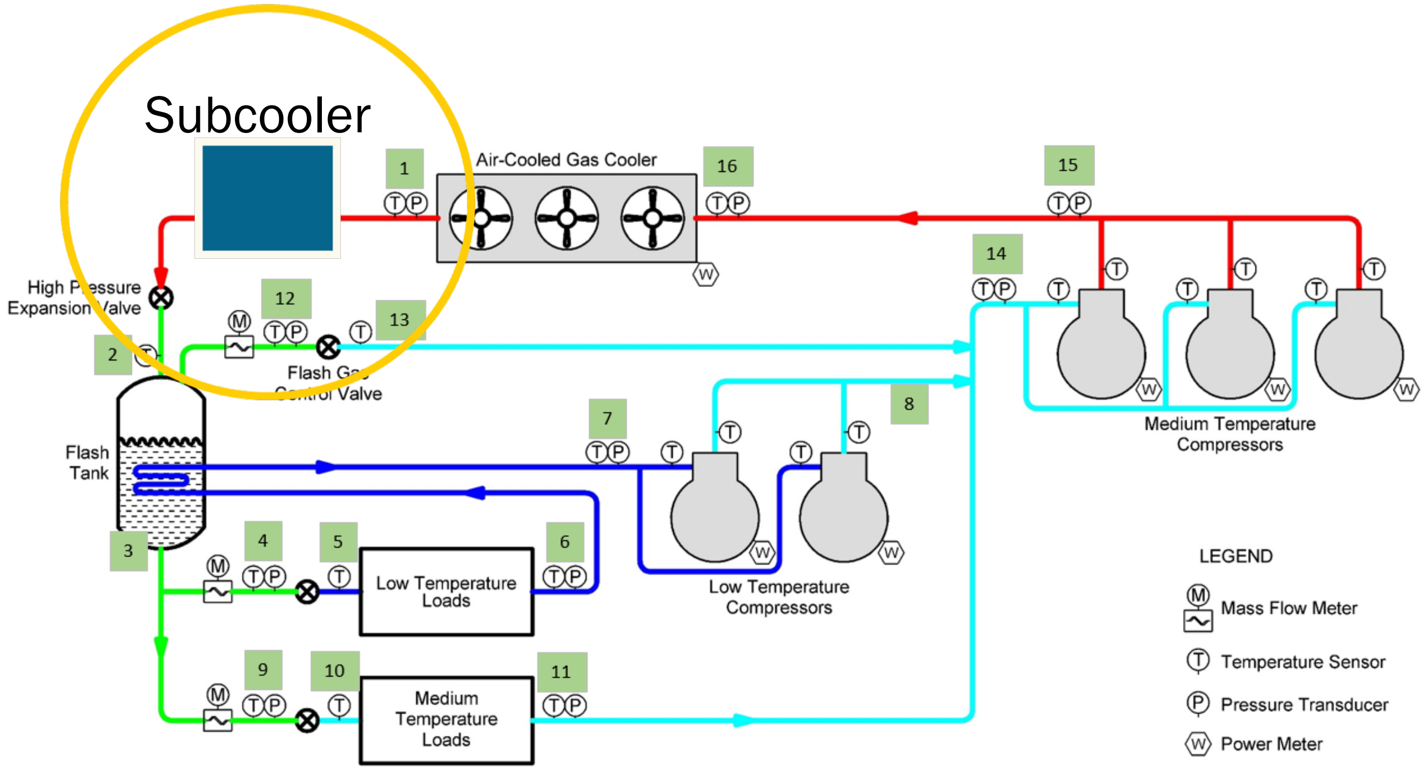


- At higher ambient temperatures, more flash gas is produced
- Flash gas does not participate in the refrigeration effect
- It only gets compressed, thus requiring energy

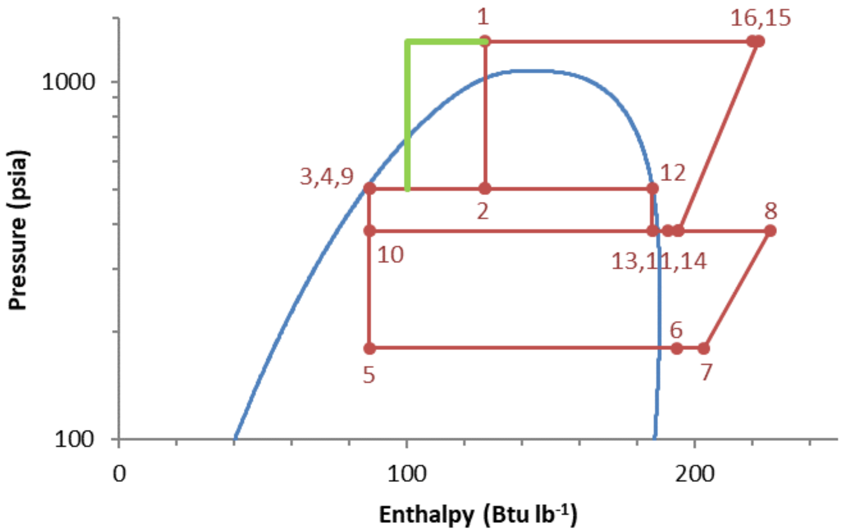




Approach

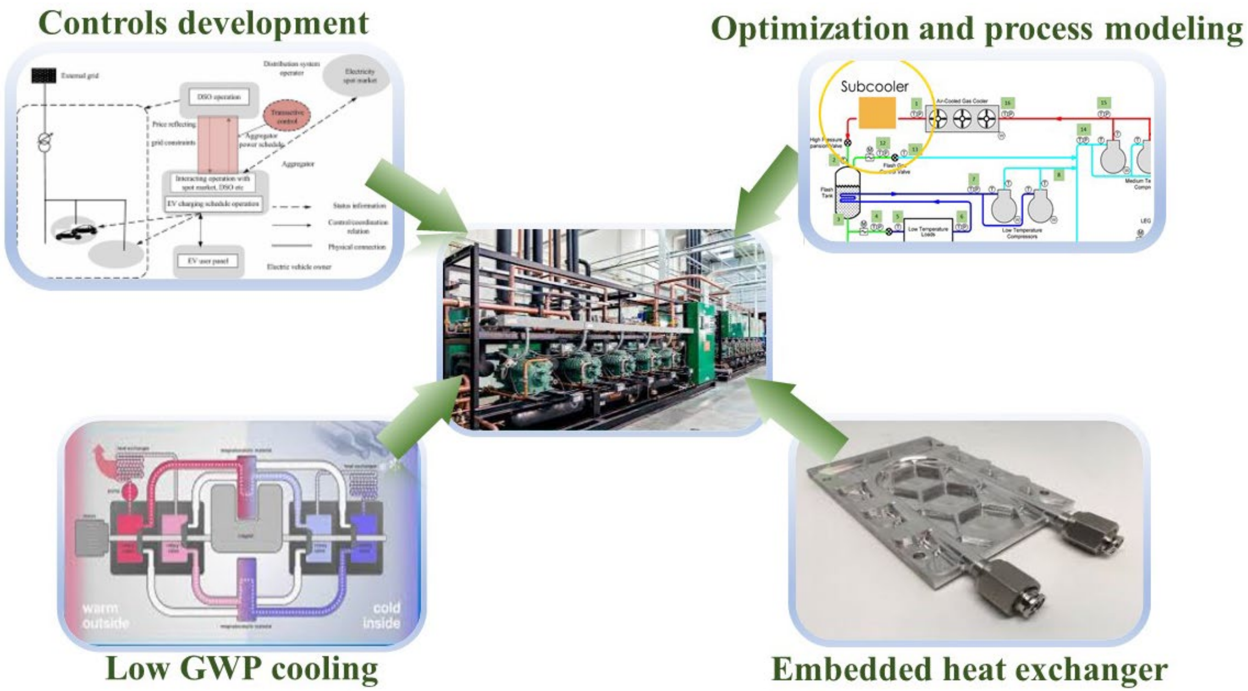


- Provide subcooling (green line on pH diagram)
- Less flash gas produced
- More refrigerant participates in the cooling process
- Improved COP (~20%)



Innovation and Impact

- **Integration for flexible operation due to modular approach**
  - Optimal subcooling degree
  - Required capacity of subcooler
- **Embedded heat exchanger design for subcooler integration**
- **Controls and grid connectivity**



Impact

- **Current impact of refrigeration in food retail**
  - Primary energy: 550 TBtu
  - Indirect emissions: 23 Mt CO_2 emissions
  - Direct emissions: $\approx$ Indirect Emission
    - Refrigerant leakage
    - Use of high Global Warming Potential (GWP) refrigerants (GWP = 1800 to 4000)
- **Impact of subcooler technology**
  - Decrease CO_2 refrigeration system energy consumption by 10-20%
  - Promote widespread use of CO_2 as a low-GWP refrigerant (GWP = 1)
  - Significantly reduce indirect and direct emissions (50%)

Progress

- **Determined baseline refrigeration system performance**
  - ORNL's laboratory-scale transcritical CO_2 refrigeration system
  - System performance data over range of operating conditions
    - Refrigerant temperatures/pressures
    - Compressor power
    - Ambient conditions ranging from 25°F to 97°F
- **Identified, reviewed and analyzed potential subcooler solutions**
  - Mechanical subcooling technologies
    - Refrigerant options
  - Thermoelectric and other technologies (vortex tubes, adiabatic subcooling, absorption systems)
- **Parametric cycle analysis**
  - Determine optimum subcooler performance characteristics
- **Heat exchanger design**
  - Compact heat exchanger design options for coupling subcooler to refrigeration system

Stakeholder Engagement

- **Collaboration with Hillphoenix**
  - Previous CRADA between Hillphoenix and ORNL
    - Introduced CO_2 refrigeration systems to the North American market
  - Assist with development of the subcooler technology and provide design requirements
  - Ensure cost-effective solution
  - Prototype subcooler development and fabrication
  - Provide a path to commercialization
- **Future engagement plans**
  - Attend meetings with experts at technical forums
  - ASHRAE (TC 10.7)
  - Conferences (Purdue Conferences, IIR Conference on Ammonia and CO_2 Refrigeration, IIR Gustav Lorentzen Conference)

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ASHRAE

HERRICK CONFERENCES

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INTERNATIONAL INSTITUTE OF REFRIGERATION

Remaining Project Work

- **System performance modeling and subcooler design**
- **Fabricate subcooler prototype**
- **Laboratory evaluation of subcooler performance**
  – Integration with ORNL's laboratory-scale transcritical CO_2 refrigeration system
- **Field evaluation of subcooler**

Thank you

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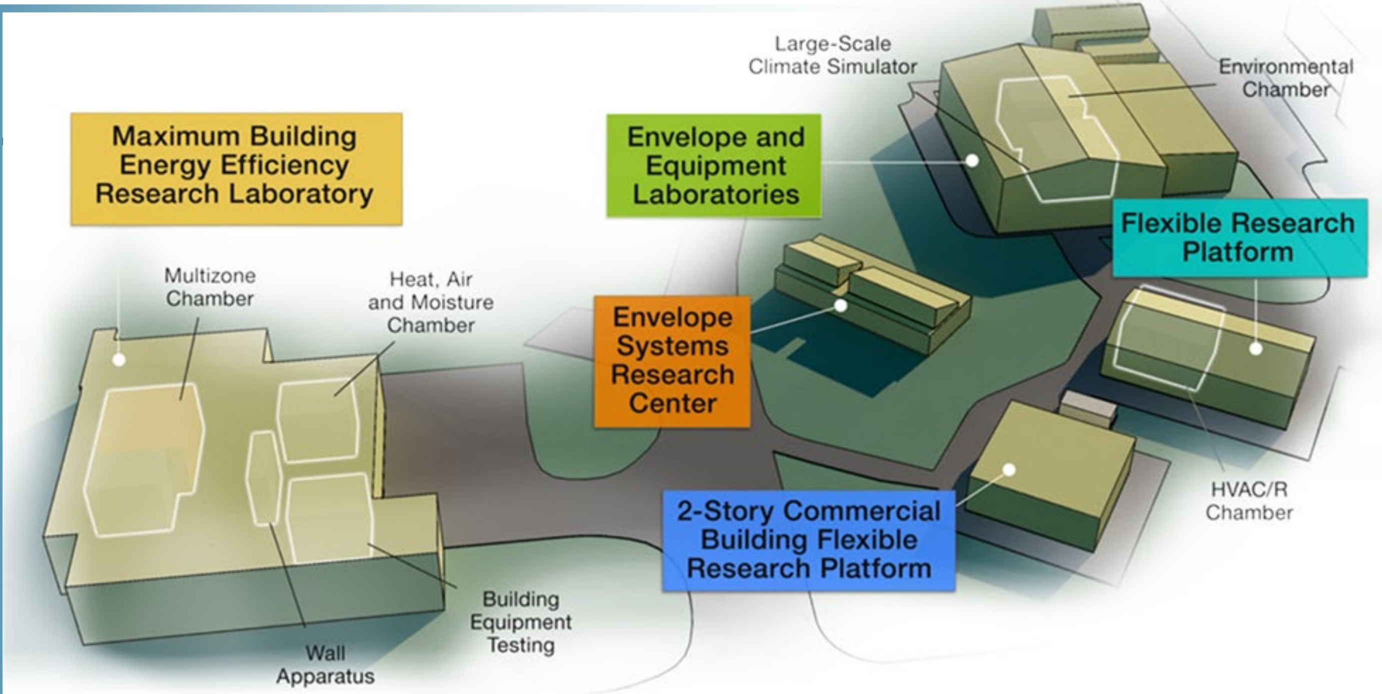

ORNL's Building Technologies Research and Integration Center (BTRIC) has supported DOE BTO since 1993. BTRIC is comprised of 50,000+ ft^2 of lab facilities conducting RD&D to support the DOE mission to equitably transition America to a carbon pollution-free electricity sector by 2035 and carbon free economy by 2050.

Scientific and Economic Results

238 publications in FY20
125 industry partners
27 university partners
10 R&D 100 awards
42 active CRADAs

BTRIC is a DOE-Designated National User Facility

REFERENCE SLIDES

Project Budget

Project Budget: $850k.
Variances: None
Cost to Date: $150k
Additional Funding: None

Budget History					
FY 2021 – 10/01/2020 (current)		FY 2022 (planned)		FY 2023 – 09/30/2023 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$250k	$0	$300k	$0	$300k	$0

Project Plan and Schedule