Energy Efficient Refrigerated Food Processing and Dispensing Machines for Quick Service Restaurants

Oak Ridge National Laboratory
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Project Summary

Timeline:

Start date: 10/01/2019

Planned end date: 9/30/2022

Key Milestones

1. Complete hardware-based component model: 3/31/2021
2. Complete experimental evaluation of R454C based soft-serve ice-cream machine: 09/30/2021

Budget:

Total Project $ to Date:

- DOE: $180K (FY21)

Total Project $:

- DOE: $510K (FY20- FY22)

Key Partners:

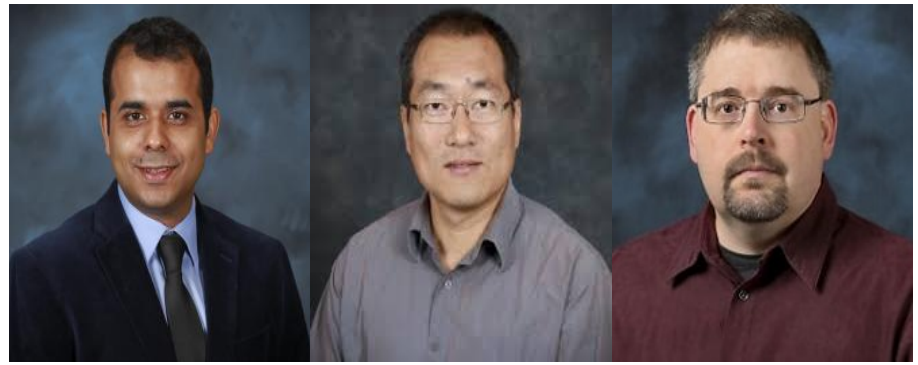
Taylor Company (CRADA FY20-FY21)

Project Outcome:

At the end of this project, a low GWP refrigerant based soft-serve ice-cream will be developed using **IEC60335-2-89**

Team

- **Oak Ridge National Laboratory**
  - **Research Team**
    - Vishaldeep Sharma
    - Bo Shen
    - Brian Fricke
  - **Service & Safety Team**
    - Jeff Chambers, Jeff Taylor and Gerald Barth
- **Taylor Company**
  - Stephen Wadle (Senior Project Engineer)
  - Jim Minard (COO)



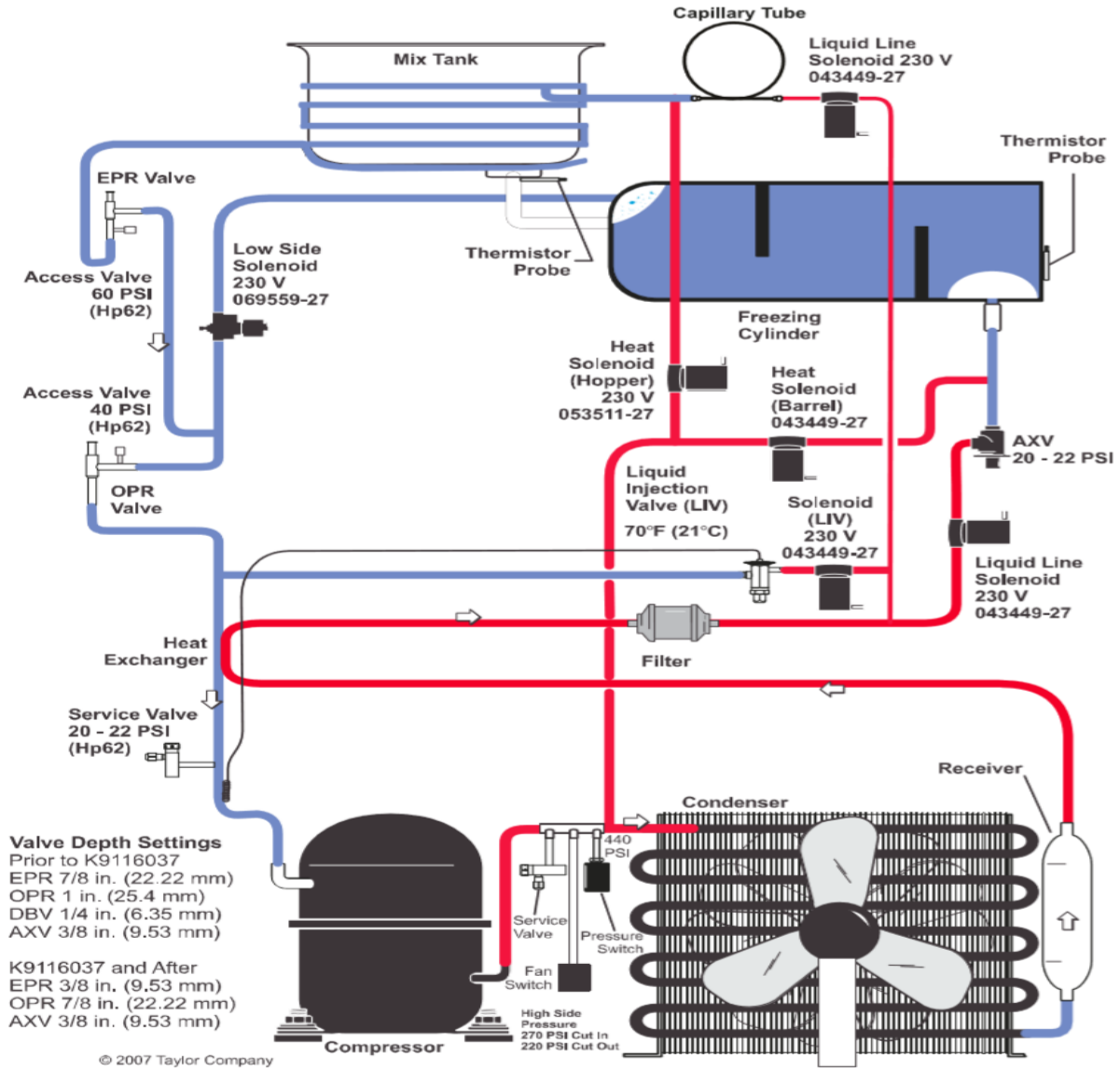
Challenge

- **Carbon emission**
  - 420,000 metric tons of carbon emission reduction potential
- **Low GWP Alternatives**
  - Natural- CO_2, Propane
  - Synthetic- R-454C (GWP:146)
- **Significance for Taylor Company**
  - Global Company with 500 employees
  - Industry leader in the US, 25% share in EU


Gdańsk; Touristenfotos 2009

Approach

- **Two Evaporators**
  - Hopper
  - Freezing Cylinder
- **Heat treatment cycle**
  - 150°C for 30mins



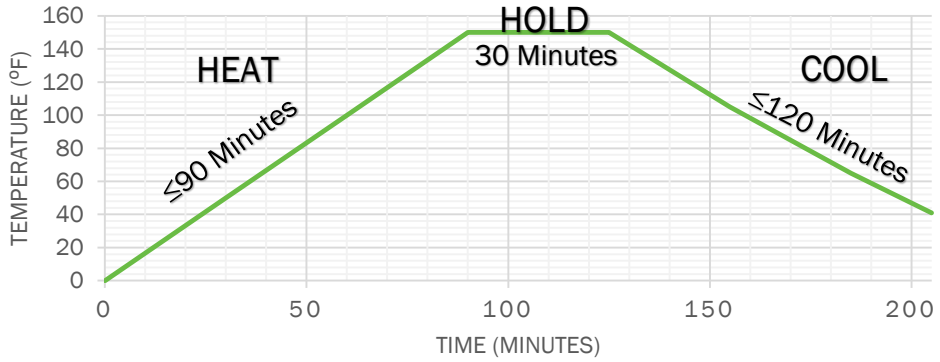
Approach

- **Complete evaluation of baseline soft-serve ice-cream machine**
  - R449A based machine
- **Modeling Prototype Low GWP based Soft-Serve Ice-cream machine**
  - Investigate Refrigerant Option
  - Thermodynamic Analysis
  - Evaporator and Condenser Modeling
- **Fabricate Prototype Soft-Serve Ice-cream machine**

- **Laboratory Evaluation**
  - Environmental chamber at different ambient temperatures

Approach

- **Baseline Testing**
  - Continuous Run Test
    - Product Quality
    - Product Draw Rate
  - Capacity and Hopper Cooling Test
    - Refrigeration Capacity
    - Recovery time
  - Heat Treatment Test
    - NSF/ANSI 6- Dispensing Freezers
    - Product temperature > 150°C for 30minutes



Approach

- **CO_2 system analysis**
  - Thermodynamic Model development
  - Heat Pump Design Model
- **Issues**
  - High Operating Pressure
  - Inefficient
- **Flammable refrigerants**
  - R454C (Mildly Flammable): GWP-146
  - R290 (Highly Flammable): GWP-3

	System	Coefficient of Performance	Discharge Temperature (˚F)	Condenser Pressure (psia)	Refrigerant Charge (lb/hr)	System Complexity	Store Retrofit
Single Stage System	CO_2 Direct Expansion (DX) System	1.18	284	1350	196	Simple	NO
	CO_2 DX system with SLHX	1.25	326	1310	170	Simple	NO
	CO_2 DX with Gas Bypass	1.21	273	1345	198	Simple	NO
Two Stage System	CO_2 DX system with SLHX (2 stage expansion)	1.24	283	1331	189	Moderate	NO
	CO_2 DX system with 2 stage compression (intercooler)	1.49	188	1335	167	Moderate	NO
	CO_2 system with 2 stage compression and 2 stage expansion	1.4	186	1335	189	Moderate	NO
	CO_2 Booster System	1.42	232	1229	214	Moderate	NO

Failed Pressure Test

Impact

- 200,000 quick service restaurants in the US
- Current Refrigerant: R449A (GWP= 1400)
- Future Refrigerant: R290 (GWP = 3)
- Direct CO_{2e} emission reduction = 99%
- Replacing refrigerant in all soft serve machines would reduce carbon equivalent by 420,000 metric tons
- Increases global footprint of US OEM

Progress: Modeling and Fabrication

- **Evaluated baseline R449A Soft-Serve Machine**
- **Developed System Model using different Heat Exchangers**
  - Flooded Evaporator
  - Wrapped Tank Coil
  - Microchannel Heat Exchanger (**Propane**)
- **Developed Liquid injection model**
- **Fabricated and Evaluated R454C based Soft-Serve Machine**
  - 17% reduced capacity

Refrigerant	Classification	GWP	Capacity	Operating Pressure	Minimum Room Size (m^2)	Spark Free Components
R-404A	A1	3922	Acceptable	Low	No Restriction	N/A
R-449A	A1	1400	Acceptable	Low	No Restriction	N/A
R-454C	A2L	148	Low	Low	No Restriction	65 components
R-290	A3	3	Acceptable	Low	23.6	65 components
R-744	A1	1	Low	High	No Restriction	N/A

Stakeholder Engagement

- **CRADA with Taylor Company (12/11/19)**
  - Leading manufacturer of soft-serve machines
  - Commercialize technology for global market
    - Durability test
    - Spark proof components (≥ 65)


IEC 60335-2-89

Edition 3.0 2019-06

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Household and similar electrical appliances – Safety –
Part 2-89: Particular requirements for commercial refrigerating appliances and ice-makers with an incorporated or remote refrigerant unit or motor-compressor

Appareils électrodomestiques et analogues – Sécurité –
Partie 2-89: Exigences particulières pour les appareils de réfrigération et fabriques de glace à usage commercial avec une unité de fluide frigorigène ou un motocompresseur incorporés ou à distance

Remaining Project Work

- Fabricate Prototype R290 Soft-serve ice-cream machine
- Leakage testing of Prototype R-290 Soft-serve ice-cream machine

Thank you

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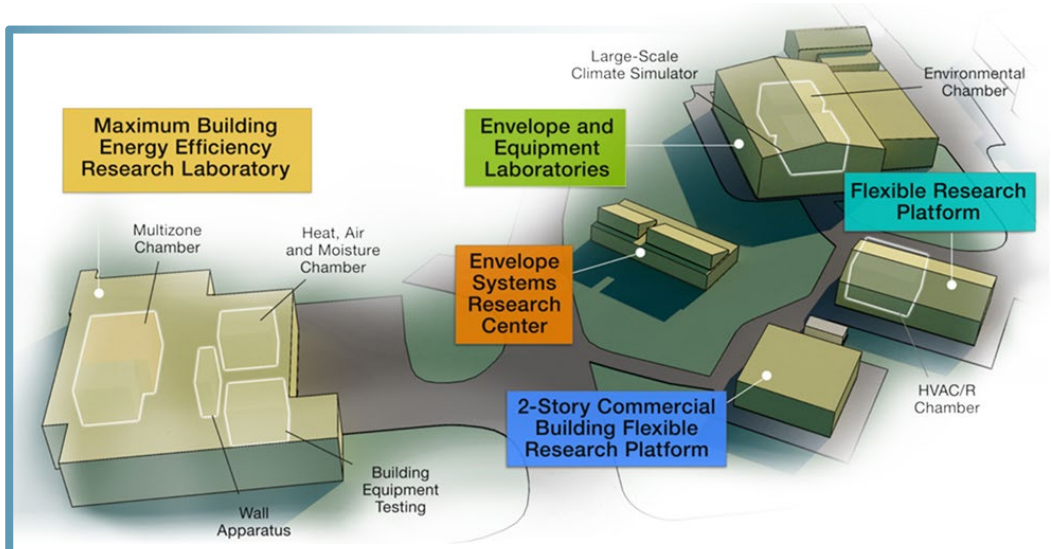

ORNL's Building Technologies Research and Integration Center (BTRIC) has supported DOE BTO since 1993. BTRIC is comprised of 50,000+ ft^2 of lab facilities conducting RD&D to support the DOE mission to equitably transition America to a carbon pollution-free electricity sector by 2035 and carbon free 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: 510K
Variances: No
Cost to Date: $180K
Additional Funding: NO.

Budget History					
FY 2020 (past)		FY 2021 (current)		FY 2022 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
180K	90K	180K	90K	150K	90K

Project Plan and Schedule

Project Schedule															
Project Start: 10/1/2020	Completed Work														
Projected End: 9/30/2022	Active Task (in progress work)														
	Milestone/Deliverable (Originally Planned) use for missed														
	Milestone/Deliverable (Actual) use when met on time														
	FY2020				FY2021				FY2022						
Task	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)			
Past Work															
Complete evaluation of baseline shake and soft-serve ice-cream machine															
Complete modelling of the prototype machine															
Complete fabrication of prototype CO2 based refrigerated shake and soft-serve ice-cream machine															
Complete comparative performance evaluation of the two machines															
Complete modelling of a R454C based liquid injection machine and a vapor injection machine															
Complete Experimental Evaluation of R454C based liquid injection integrated soft-serve ice cream machine															
Complete Experimental Evaluation of R454C based vapor injection integrated soft-serve ice cream machine															
Current/Future Work															