Leak Detection in Commercial Units Using A3 Refrigerants

NAMA Vending machines at ORNL for leak testing

Retail freezer using R-290

Performing Organization(s): Oak Ridge National Laboratory
PI Name and Title: Moonis Ally, Senior Research Staff
PI Tel and/or Email: 865-576-8003, allymr@ornl.gov

Project Summary

Timeline:

Planned Start date: 10/01/2020 (**New Start**)

Start date: 03/01/2021

Planned end date: 09/30/2022

Key Milestones

1. FY 2021: Analyze Propane leak; sensor selection & preliminary tests; 9/30/2021
2. FY 2022: Sensor self-check/diagnostics/mitigation capability and testing; 9/30/2022

Budget:

Total Project $ to Date:

- DOE: $250K
- Cost Share: $0K (liaise with separate NAMA CRADA)

Total Project $:

- DOE: $600K
- Cost Share: $0K

Key Partners:

Liaise with National Automatic Merchandising Assoc (NAMA) with whom ORNL has a CRADA on a stand-alone project on propane leak detection & mitigation steps in vending machines (VMs)

Project Outcome:

- Leak profile in propane systems;
- Propane leak detection at 10% Lower Flammability Limit (LFL) with 10s response time with
- Inexpensive sensors with hourly-self check, self-diagnostics, no field calibration.

BTO MYPP FY 2016-2020: Low-GWP refrigerants, Strategy 2: Next Generation Technology Development, pp.63.

Team

- ORNL R&D staff:

Moonis Ally

Senior R&D Staff - project coordination and planning, sensor selection assembly and developing protype, report preparation, communication with project team and partners

Viral Patel

R&D Staff – main liaison with NAMA team members and coordinating the sensor needs for vending machines.

Tugba Turnaoglu

Postdoctoral Research Associate – assisting with experimental work, data analysis, report preparation

Ahmad Abu-Heiba

R&D Staff – assisting with sensor hardware configuration testing, communication with project team and partners

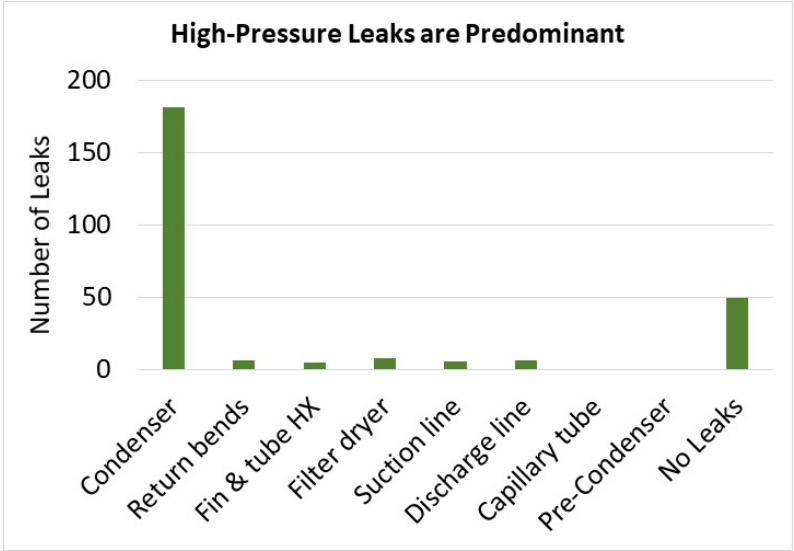
- ORNL facilities and operations staff, craft personnel
- NAMA members: Represents manufacturers and distributors of automatic vending machines in North America

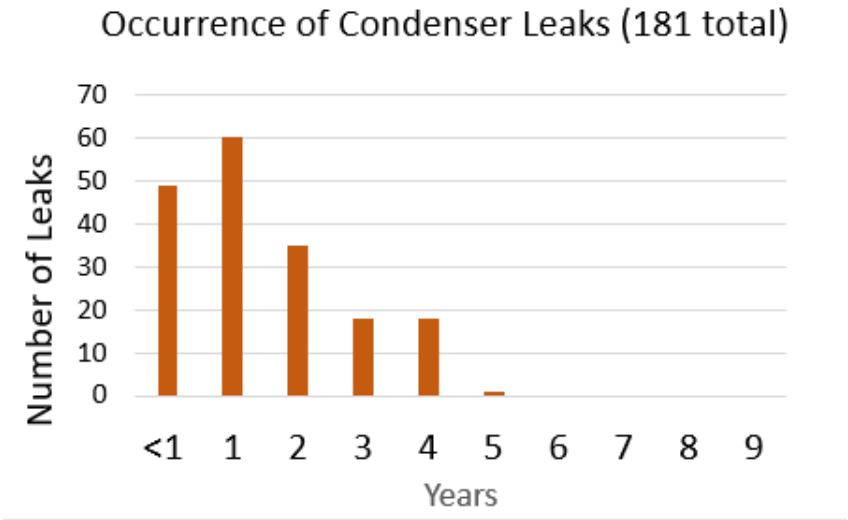
Challenge

- In the US, R-134A (GWP=1430) is allowable in VMs except in California. EU and Asia use R-290 extensively –No R-134A.
- Current use of R-134A or HFOs in VMs is not tenable (compressors/lubricants compatibility, efficiency standards, ban on refrigerant blends)
- NAMA concludes no alternative to R-290 (GWP=3) in VMs; HFOs, A2L not an option
- ASHRAE, UL standards and building safety codes restrict placement of VMs containing R-290; limit of 114g for VMs (ASHRAE 34 addendum) but bottle coolers need 150g.
- OEMs don't want stop-gap fix. Want predictable refrigerant use for >15years (equipment life); wary of tighter regulations/safety standards in the US and in the EU
- NAMA's position: current sensors are too expensive and too bulky for use in VMs.
  - No practical/economical solution on the horizon.
- R-290 sensor with self-check and self-diagnostics is critically important to cope with safety and operations up to 150g.
  - key to markets, GHG mitigation, energy efficiency, product acceptance and sales.

Approach

- FY 21:
  1. **Leak occurrence, frequency, location**? Most leaks occur on the high-pressure side*. Completed March/April 2021
  2. Inexpensive sensors with good detection and response times identified. Mar/Apr 2021
  3. Sensor performance tests with 50%, 28.6%, 5% LFL Propane LFL (May/August 2021)
     - detection limit (<10% LFL) and response time (<10s).
  4. Completed test with 50% LFL; 3s response times; sensor cost<$4
  5. Develop plug-in sensor package (5 cm x 5 cmx 2 cm), analog/digital output to trigger alarm, take remedial action
- FY 22:
  - Develop sensor package with non-adjustable set point; no field calibration; self-diagnostics; hourly self-check and reporting, etc. (9/2022)
- ORNL Team: Buildings Technology, Sensors and Controls, technicians
- Outside participants: NAMA members





*http://lifefront.eu/refrigerant-leakage-database/

Impact

Regulatory/Policy Impact:

- HCs are approved for use under the EPA's Significant New Alternatives Policy (SNAP) program.
- Serves DOE energy efficiency (MDEC, kWh/day), GHG reduction (80% by 2050), and climate change objectives (<2°C rise by 2100)
- The US is lagging in adoption of R-290 for refrigeration relative to EU's F-Gas regulations
- US OEMs want long-term solution to R-290 refrigerant use in VMs. Be prepared if ISO, ASHRAE impose special requirements
- Supports the US administration's new target for the United States to achieve a 50-52 percent reduction from 2005 levels in economy-wide net greenhouse gas pollution in 2030

Business Impact:

- Too expensive for US OEMs to make one type of vending machines with HFOs for US and another with R-290 for EU; At best, HFOs are a temporary measure
- Improve market penetration through enhanced safety.

Climate Change/Energy Impact:

- A global phasedown of hydrofluorocarbons (HFCs) is estimated to reduce warming by 0.5 ° C by 2100. Change to Propane (GWP=3) will help meet that objective.
- Serves DOE energy efficiency (MDEC, kWh/day)

Progress

FY2021

- Project is a NEW START
- Funding was received 03/01/2021
- Project is in mid-stage.
- Propane leak analysis using Bayesian inference methods completed (Milestone delivered 7/31/2021)
- Sensor response times of <5 s with 50% LFL calibration gas (completed)
- Testing with 28.57% LFL (0.6% propane + nitrogen) and 5% LFL calibration gas scheduled for August.
- Technical metrics: detection at 10% LFL in <10s

FY2022

- Enhance Sensor module to include the following capabilities, (in case stricter Standards are developed for A3 refrigerants):
- Hourly Self-check
- Self-diagnostics
- Mitigation capability
- No field calibration
- By FY 2022, expect to have functional sensor ready for technology transfer

Stakeholder Engagement

- Project is in middle-stage
- Fully engaged with NAMA with whom ORNL has a CRADA on a stand-alone project on propane leak detection & mitigation steps in vending machines (VMs). The current sensor project on early leak detection complements existing working relationship with NAMA.
- Stakeholder engagement efforts that, among others:
  - OEMs are looking to long-term solution with equipment life >15 years; wary of tighter regulations/safety standards in the US and in the EU
  - NAMA's position is that current sensors are too expensive and too bulky for use in VMs. No practical/economical solution on the horizon.
  - There are 6.9 million VMs in the U.S (31.2% is for cold drinks). In 2018, global VM revenue topped $30 Billion
  - Refrigerant charge levels are small compared to commercial refrigeration systems.
  - R-290 sensor with self-check and self-diagnostics is critically important to cope with safety and operations with up to 150g propane. It's the key to markets, GHG mitigation, energy efficiency, product acceptance and sales.

Remaining Project Work

Sensors and detection

Objective: Identify sensors that can detect propane leaks at 10% LFL in less than 10 s

— Propane detection at the 28% and 10% LFL scheduled for August 2021

—Current sensor with electronics is about 4cm x 4 cm

Sensor self-diagnostic capability

— Hardware/software for hourly self-test, self-diagnostics capability

Sensor assembly

—Assembly plug-n-play sensor for vending machines and test using NAMA equipment (equipment on-site, instrumented with data acquisition and analysis capability)

Technology Transfer

—By end of FY 2022, expect to have functional sensor ready for technology transfer

Summary

- OEMs must transition away from high- to low-GWP refrigerants for VMs
- Propane is the refrigerant of choice for Vending Machines (NAMA conclusion)
- US OEMs have a business risk at their doorstep if appropriate sensors are not developed
- The regulatory picture is evolving in the US towards tightening safety regarding A3 refrigerants
- Due to propane flammability issues, early detection and mitigation are key to product viability
- Reliable sensors with self-check self-diagnostic capability are needed
- Project is a New Start (start date 03/01/2021)
- Our goal is to assemble the sensor module with the stated properties by the end of FY 22 (09/30/2022)

Thank You

Performing Organization: Oak Ridge National Laboratory
Moonis Ally, Senior Research Staff
865-483-4009; allymr@ornl.gov

REFERENCE SLIDES

Project Budget

Project Budget: DOE:$250K (FY21); $350K (FY22); Cost Share $0K
Variances: None
Cost to Date: $186K
Additional Funding: None

Budget History					
03/01/2021 – FY 2020 (past)		FY 2021 (current)		FY 2022 – 09/30/2022 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
0	0	$250K	0	$350K	0

Project Plan and Schedule

Project Start: 3/01/2021												
Project End: 09/30/2022												
Activity	Oct-20	Nov_2020	Dec-20	Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21	Jul-21	Aug-21	Sep-21
FY21 ($250K)												
Leak data												
Initial sensor tests on test rig or NAMA vending machine												
Milestone Report on preliminary tests												
Develop sensors to meet proposed Standards & specs.												
Activity	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22	Mar-22						
FY22 (350K)												
Package sensors with self-test & diagnostics capability												
Test fully functional sensor												
Milestone Rreport -final												
Legend:												
	Go/No-Go											