Flammable Refrigerants (A2s and A3s):

What You Need to Know

February 10, 2025

Moderator: Rajan Rajendran, Five Rivers Consulting

Speakers: Kashif Nawaz, Oak Ridge National Laboratory

Brian Rodgers, UL Solutions

Jim Vershaw, Chair of the ASHRAE Standard 15.2

Xudong Wang, Air-Conditioning, Heating, and Refrigeration Institute

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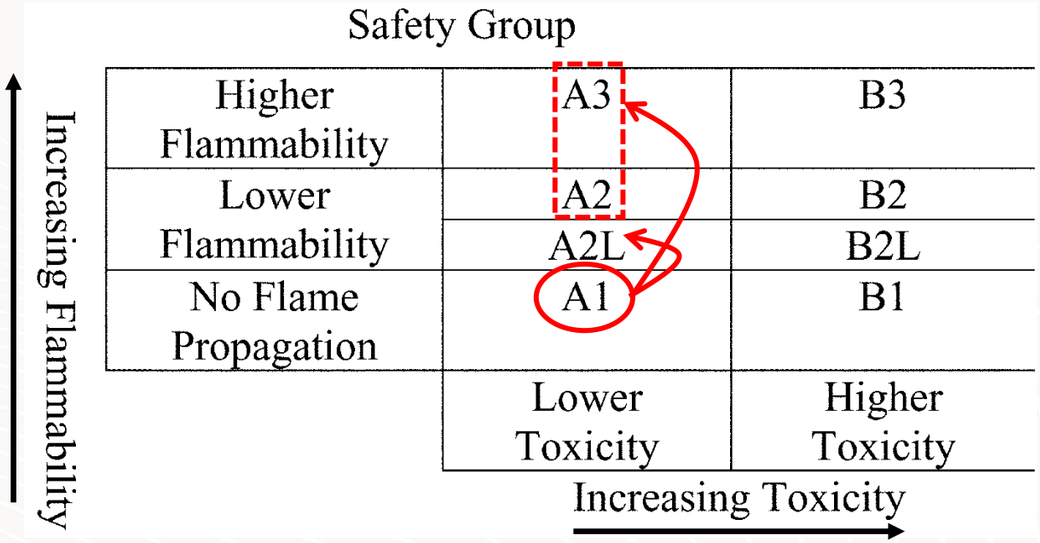
ANSI/ASHRAE Flammability Classifications

- Class 2L vs. 2 Flammability Classification Based on:
  - Burning velocity
    - Maximum velocity at which a flame propagates in a normal direction relative to unburned gas ahead of it
    - Lower burning velocity <10 cm/s = 2L
    - Higher burning velocity >10 cm/s = 2 or 3

- Class 2 vs. 3 Flammability Classification Based on:
  - Heat of combustion and lower flammability limit (LFL)

- Refrigerants like HCFC-22, R-410A, R-404A and R134a are classified A1

- Refrigerants like R-32, R-454B are A2L and R-290 (Propane) are classified A3



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Flammable Refrigerants (A2s and A3s) – What You Need to Know

ORNL Presentation

February 10, 2025

Kashif Nawaz

Oak Ridge National Laboratory

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Safe Implementation of Next-gen Refrigerants for Energy Efficiency and Resiliency

Kashif Nawaz

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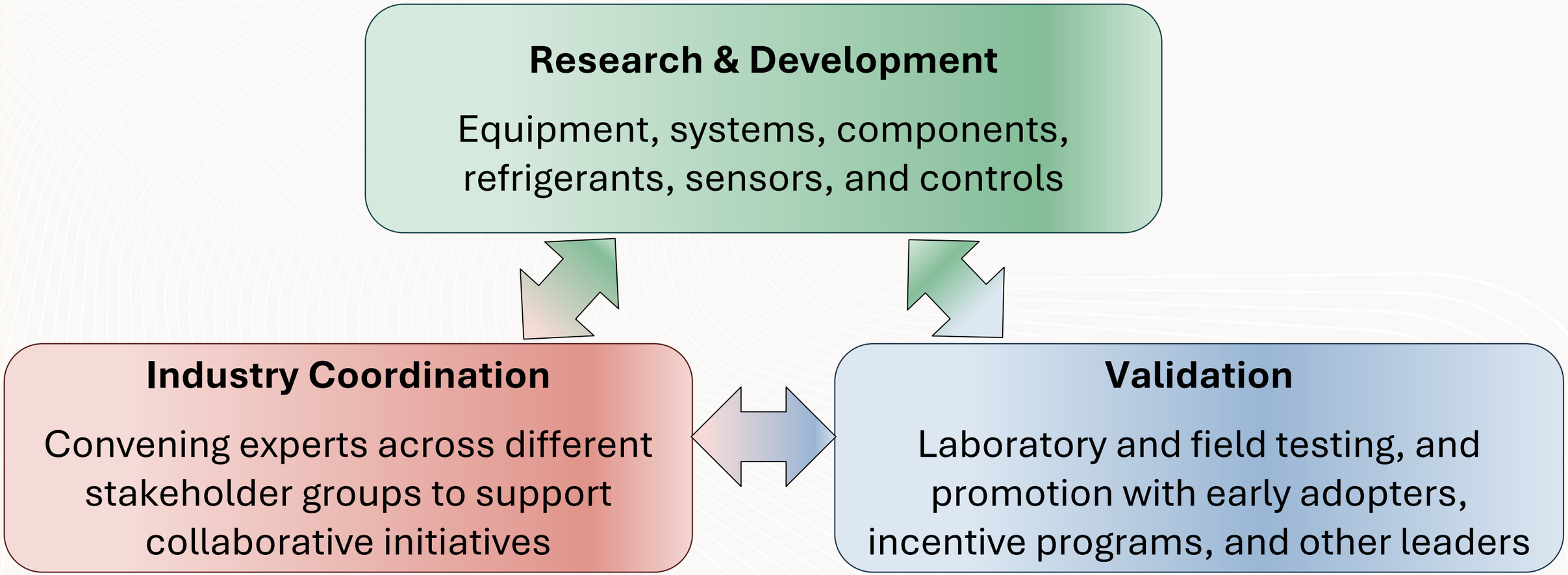
FRAMEWORK FOR SUCCESSFUL IMPLEMENTATION



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STAKEHOLDER ENGAGEMENT

Workshop 1
Commercial HVAC&R
April 1st and 2nd, 2024
EPRI Washington D.C.

Workshop 2
Refrigeration and Water Heating
May 1st and 2nd, 2024
University of Maryland

Workshop 3
Code and Standards for Low GWP Refrigerants
May 6th , 2024
California Energy Commission

Major objectives of the workshops:

- Gain insight into current refrigerant technologies
- Facilitate collaboration among key stakeholders
- Identify gaps and opportunities for research and development
- Define actionable steps for future initiatives

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STAKEHOLDERS WORKSHOPS

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PRIORITIZATION FOR CODES AND STANDARDS WORKING GROUP

- The intent has been to focus on product areas with lower barriers and larger applicability in order to make headway in moving high efficiency refrigerants through the codes and standards process.
- Top three priorities in smaller working groups to identify and develop action items for each of these product categories:
    1. Indirect A3 systems in commercial chillers and air-to-water heat pumps
    2. Direct small charge A3 systems for window units, PTAC/PTHPs, HPWH, etc.
    3. Indirect A3 systems for residential monobloc air-to-water heat pumps

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OVERVIEW OF CODES & STANDARDS A3 REFRIGERANT SUBGROUPS

- **These subgroups began meeting in July 2024 to review current risk assessment literature and characterize the proposed research activities:**
  - Specific activities to be conducted
  - Organizations to perform these activities
  - Potential sponsors or funders
  - Additional resources needed (e.g., equipment, facilities)
  - Estimated timeline
  - Risks to be considered
- **The subgroups have identified a comprehensive list of research topics, with several cross-cutting topics applicable for multiple subgroups.**

Commercial Indirect A3 Systems
Focused on Chillers and Air-to-Water Heat Pumps

Residential Indirect A3 Systems
Focused on Monobloc Air-to-Water Heat Pumps

Small Charge, Self-Contained A3 Systems
Focused on HPWHs, PTAC, window, room, dehumidifiers, HP clothes dryers

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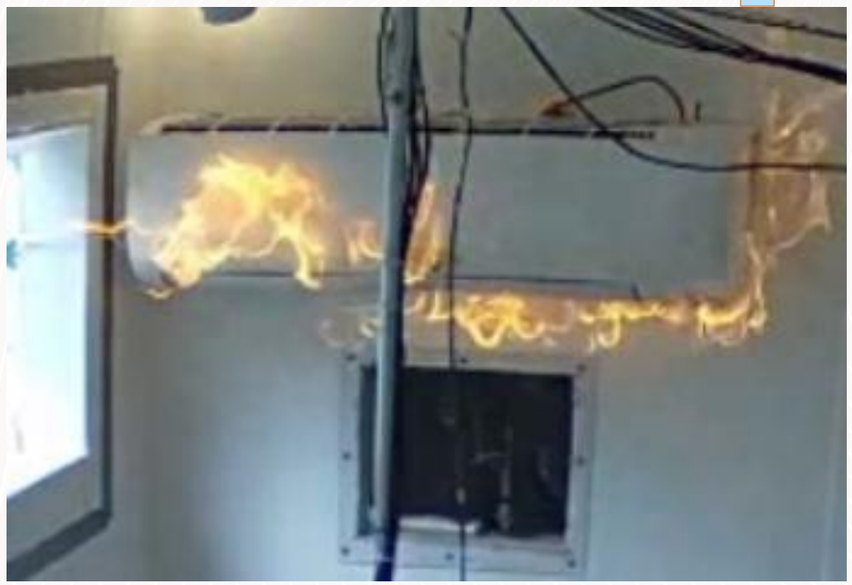
RESEARCH TOPICS PRIORITIZATION

Tier	Project Title	Applicable Product Area
1	Risk Assessments Specific to Commercial Small-to-Medium Size Chillers and Air-to-Water Heat Pumps	Commercial indirect
1	Risk Assessments Specific to Residential Monobloc A2W HP Configurations	Residential indirect
1	Risk Assessments Specific to Heat Pump Water Heaters	Direct, small charge, self contained
1	Investigation of Whether the 114g A3 Charge Limit Could Be Raised for Window/Portable AC/HP, PTAC/PTHP, Dehumidifiers, and HP Dryers	Direct, small charge, self contained
2	Safe Distances between Different Commercial HVAC Units in an Exterior or Interior Location	Crosscutting (all)
2	Investigation of A3 Leak Collection on Rooftops and Machine Rooms, and Potential Structural Effects from Ignition	Commercial indirect
2	Evaluation of Risks Posed by Leaks between Secondary Fluid and Primary A3 Working Fluid Loop	Crosscutting (commercial indirect and residential indirect)
2	Investigation of How Installation Height Affects A3 Refrigerant Leak and Ignition Risks	Direct, small charge, self contained
3	Evaluating How A3 Equipment Responds When Involved in Fires	Crosscutting (all)
3	Investigation of How to Safely Test A3 Systems in Lab Settings	Crosscutting (all)
3	Preparations for Future Training and Certification of Field Technicians for the Handling, Installation, and Maintenance of A3 Systems	Crosscutting (commercial indirect and residential indirect)

RISK ASSESSMENT- REFRIGERANT LEAKAGE

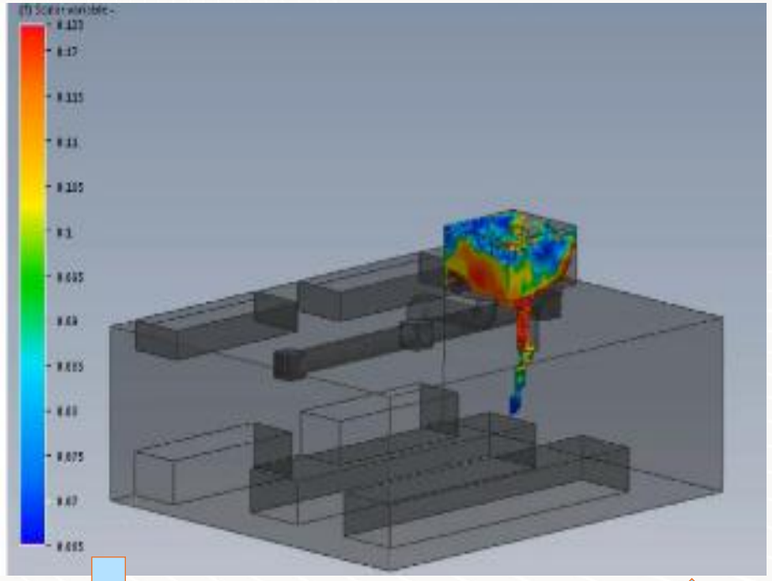
Propane Leak Testing



Source: AHRTI 9007-2 [UL]

Physical testing is conducted to assist development of models and to calibrate models.

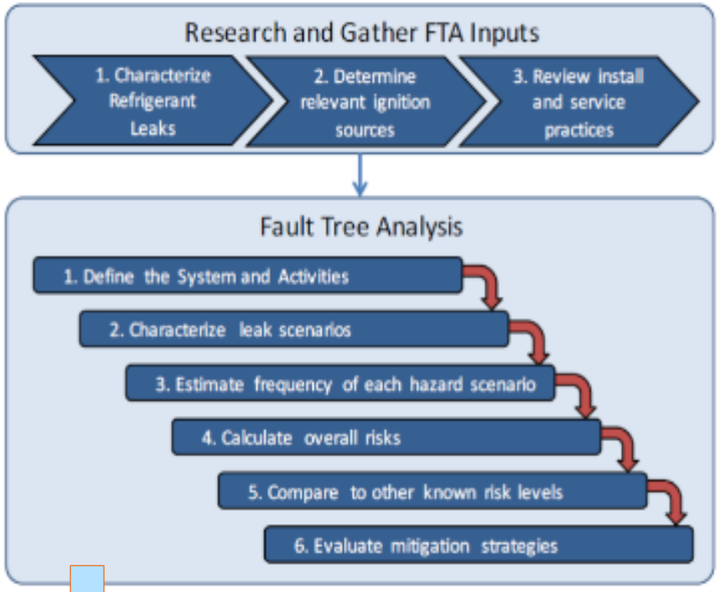
CFD of Evaporator Leak



Source: AHRI 8016 [Guidehouse/Navigant]

CFD modelling will help determine which physical testing needs to be completed.

Fault Tree Analysis



Source: AHRI 8016 [Guidehouse/Navigant]

Results from testing and modelling help the development of the fault tree analysis.

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Kashif Nawaz

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Flammable Refrigerants (A2s and A3s) – What You Need to Know

ASHRAE Standard 15.2: Safety Standard for Refrigeration Systems in Residential Applications

February 10, 2025

Jim Vershaw, Chair of the ASHRAE SSPC 15.2

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ASHRAE 15.2

1. PURPOSE

This standard specifies the minimum requirements for the safe design and installation of *refrigeration systems* used in residential applications.

2.* SCOPE

2.1 This standard applies to *listed refrigeration systems* in the following residential applications that are limited to serving only a single *dwelling unit* or *sleeping unit*:

a. One- and two-family *dwellings* and townhouses
b. Detached outbuildings associated with a one- or two-family *dwelling* or townhouse and located on the same property included in Section 2.1(a)
c. Individual *dwelling units* and *sleeping units* located in a *multifamily dwelling*

6. REFRIGERANT CLASSIFICATION AND REQUIREMENTS

6.1* Permissible Refrigerants. Only *refrigerants* having an *approved refrigerant designation* of ASHRAE Standard 34 [1] safety group A1 or A2L *shall* be used in conjunction with this standard.

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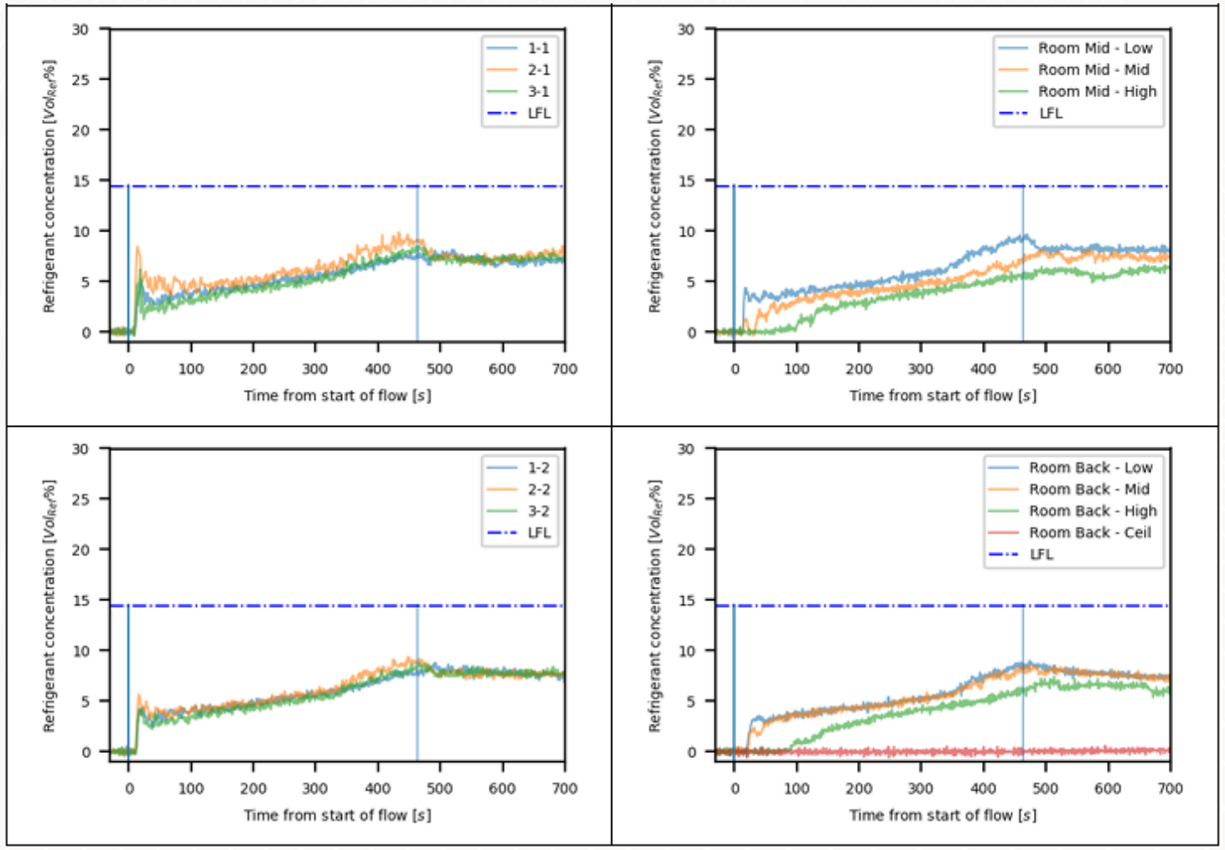
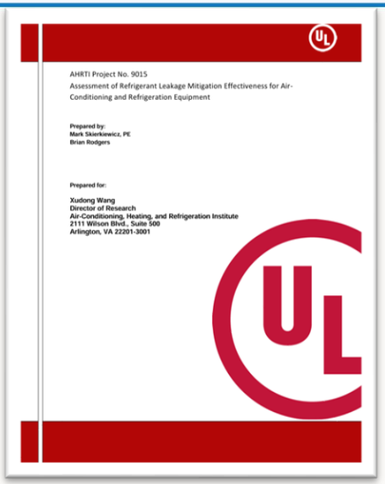
ASHRAE 15.2 - History

- Advent of A2Ls created need for a residentially focused safety standard.
- Found that there was limited research into A2L risks and how to mitigate those risks.
- AHRTI test programs at UL and ORNL were carried out to provide a basis for setting the maximum safe charge based on room size

Ductless: No mitigation / Release 50% of LFL

Test Summary	Baseline - no mitigation		
Release Amount	6.85 kg	Release Time	466 s
Release Quality	Liquid	Time to Qmin	N/A
Installation Height	1.8 m	Fan Speed	N/A




AHRTI Project No. 9015
Assessment of Refrigerant Leakage Mitigation Effectiveness for Air-Conditioning and Refrigeration Equipment

Prepared by:
Mark Skierkowicz, PE
Brian Rodgers

Prepared for:
Xudong Wang
Director of Research
Air-Conditioning, Heating, and Refrigeration Institute
2111 Wilson Blvd., Suite 500
Arlington, VA 22201-3001

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Adding A2/A3 Refrigerants to ASHRAE 15.2

Risks of R-290

- Flammability Range: 2.1% to 9.5% (R-32 is 14.4% to 29.3%)
- MIE 0.25 millijoules (MIE of R-32 is 60 times higher)
- Typical static electricity discharges are 1-10 millijoules

What's currently allowed in US?

- UL 60335 2-40: Maximum charge 114g
- ASHRAE 15: Direct systems limited to 150g; Indirect systems unlimited.
- ASHRAE 15.2: No A2 or A3 allowed

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Adding A2/A3 Refrigerants to ASHRAE 15.2

Standards in use for refrigeration systems using A2/A3s

- EN 378: general design
- ATEX Directive 2014/34/EU: Overpressure control and Explosive atmospheres
- Local rules vary across the EU
- No agency certification of equipment

Other standards

- NFPA 58, Liquefied Petroleum Gas Code,

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First Attempt to add A2/A3 fluids to 15.2

Proposed an addendum to allow indirect systems with propane

Used NFPA rules on 20-pound LP tanks to set building spacing

Set a maximum charge limit of 5 Kg

Public review comments pointed out

- lack of technical basis for maximum charge level
- multi-family buildings were not adequately covered

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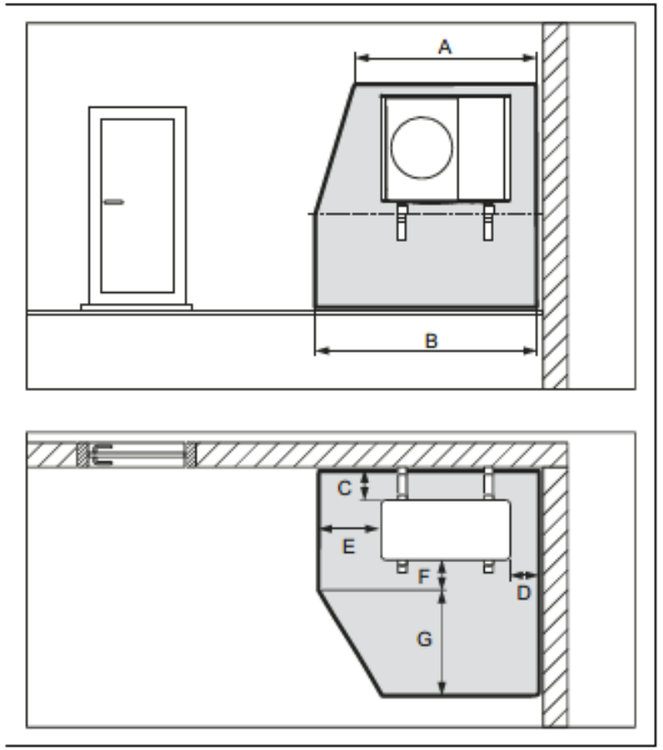
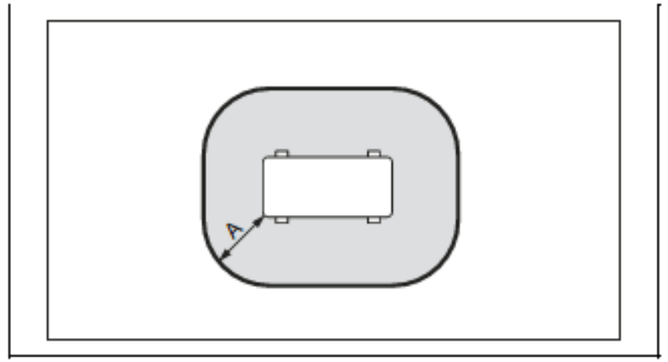
Residential Installation Restrictions in EU

4.1.5 Protective zone for wall installation in a building corner



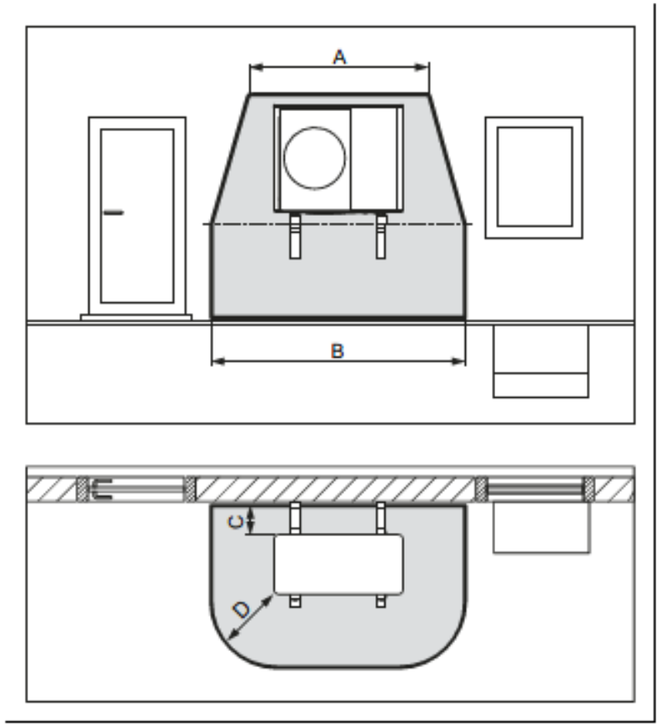
A	2100 mm	E	1000 mm
B	2600 mm	F	500 mm
C	200 mm/250 mm	G	1800 mm
D	500 mm		

4.1.6 Protective zone for flat-roof installation



A 1000 mm

4.1.4 Protective zone for wall installation in front of a building wall



A	2100 mm	C	200 mm/250 mm
B	3100 mm	D	1000 mm

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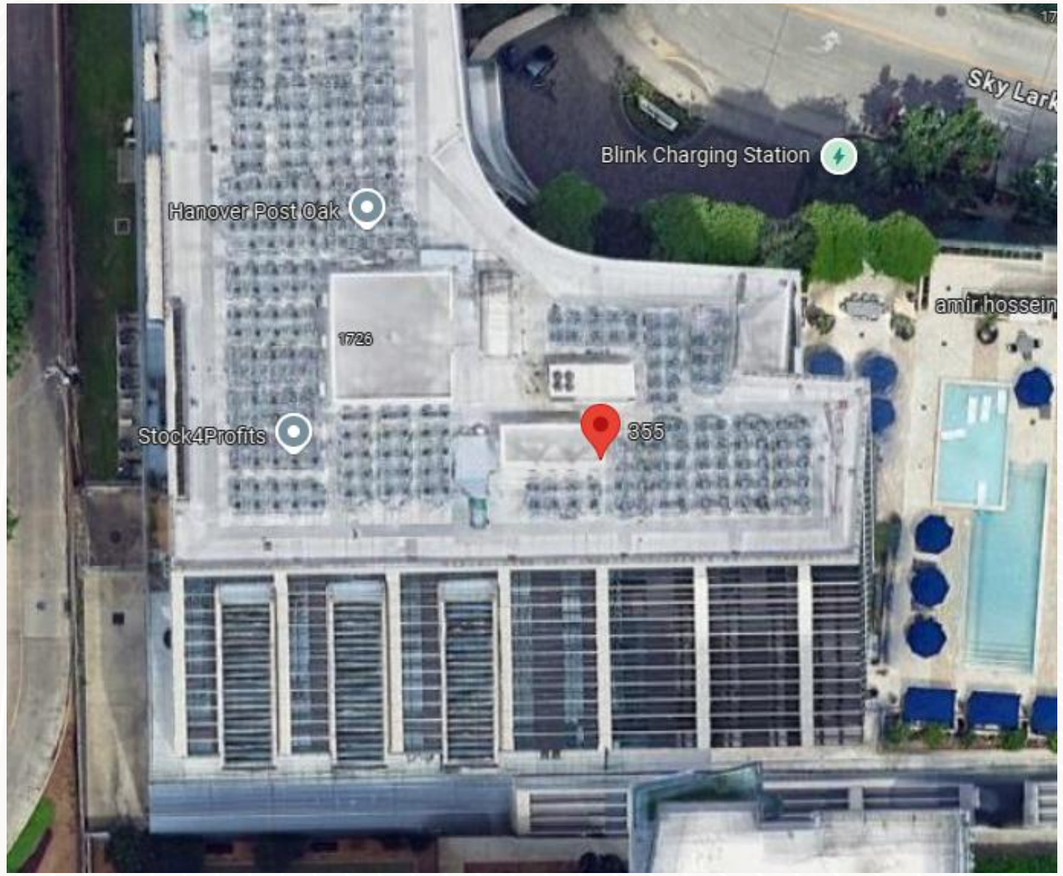
Multi-Family Installation Questions



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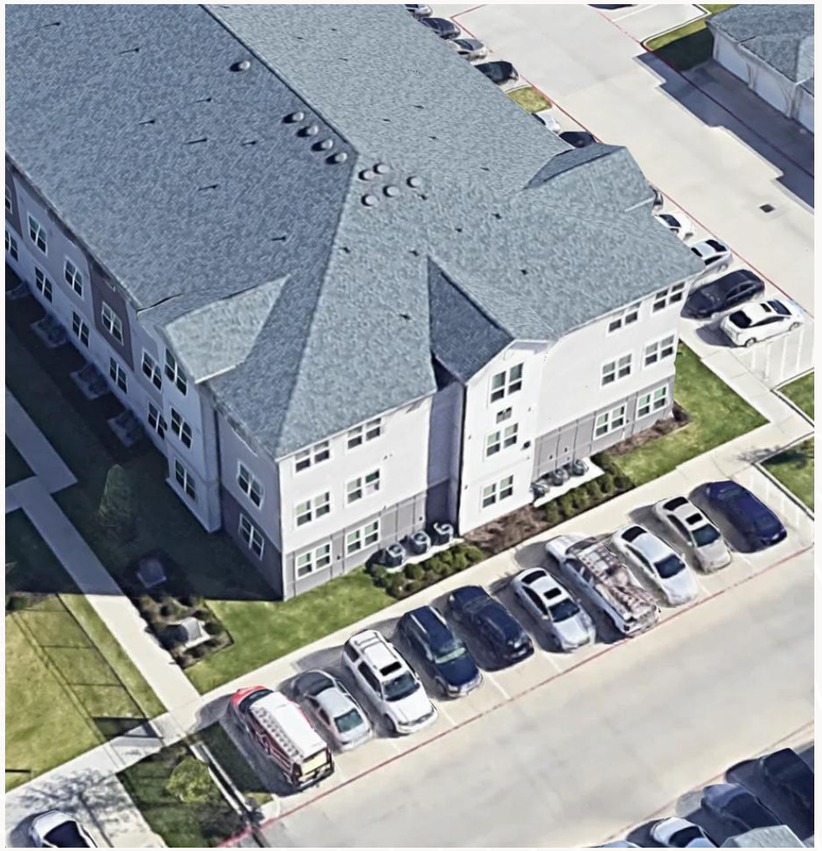
Multi-Family Installation Questions



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Adding A2/A3 Refrigerants to ASHRAE 15.2

Plan

- Start with indirect systems
- Develop comprehensive risk assessment
- Carry out a program combining CFD analysis and actual tests.
- Develop and publish installation rules for indirect systems using ASHRAE Standards process

Timing

- Program to start 1Q25
- 3-year duration

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Flammable Refrigerants (A2s and A3s) – What You Need to Know

A2 and A3 Flammable Refrigerants and Navigating the Differences Between UL/IEC 60335-2-40 and UL/IEC 60335-2-89 and The Path Forward

February 10, 2025

Brian Rodgers, UL Solutions

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A2 and A3 Flammable Refrigerants and Navigating The Differences Between UL/IEC 60335-2-40 and UL/IEC 60335-2-89 and The Path Forward.

ASHRAE 2025

Brian Rodgers
Principal engineer, HVAC/R
UL Solutions

Brian Rodgers
Principal engineer – HVAC and Commercial Refrigeration

Background

- +35 years of experience in standards
- Leadership roles with multiple standards:
  - Voting member of ASHRAE 15, 15.2, 37, MTG. LowGWP
  - Corresponding member of ASHRAE TC 2.9 and TC 8.11.
  - Convener of IEC 61C MT1 for (IEC 60335-2-34 for motor compressors)
  - Member of IEC SC 61C WG 4 and MT5
  - Member of IEC SC 61D, MT28 (IEC 60335-2-40)
  - Convenor of IEC SC 61D MT29 for refrigerant leak sensors
  - Chair of the US TAGs for IEC SC61 C and D
  - Member of CANENA SC61D WG14 for UL1995/CSA 236 and UL/CSA 60335-2-40 and SC61C WG16 for UL 60335-2-89
- William Henry Merrill Society distinguished member. He has extensive experience in the development of U.S., regional and international safety standards and was recognized with the "1906 Award" for his work on IEC SC61C MT1 for motor compressors.
- He was called to the White House Climate Policy Office and the Department of Energy in March 2024. He was asked to join a committee that is developing risk assessments and research to develop requirements for adding ultra-low GWP refrigerants (less than 10 on the GWP).

Introduction

Impacts:

- Transition to environmentally friendly but Highly flammable refrigerants (A2 & A3)
- Redesign of models to accommodate new safety requirement
- Incorporation of flammable refrigerants into standards development cycles
- Redefinition of building codes considering new risks for people

Today we are going to take a look at the impacts in regards to:

- UL/IEC 60335-2-40, the Standard for Household and Similar Electrical Appliances – Safety – Part 2-40: Particular Requirements for Electrical Heat Pumps, Air-Conditioners and Dehumidifiers
- UL/IEC 60335-2-89, the Standard for Household and Similar Electrical Appliances – Safety – Part 2-89: Particular Requirements for Commercial Refrigerators

How did we get to 4 X LFL limit for A2 and A3 Refrigerants

- From IEC 60335-2-89; it was determined that the average size of a small commercial kitchen was 2 m^3.
- That room volume has been determined keep the room below the LFL when the entire refrigerant charge is leaked into that space.
- IEC 60335-2-40 adapted this limit for the m_1 Charge limit.
- UL60335-2-89 accepted the requirements in the IEC standard
- UL 60335-2-40 did not accept 4 X LFL as the members understand that cord connected equipment, will be stored in confined spaces in the offseason, smaller than 2 m^3 so 3 x LFL was selected confirmed through research.

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What's next for UL/IEC 60335-2-89

- Third edition IEC 60335-2-89
- Increased the charge limit to 13 X LFL for all A2L, A2, and A3 refrigerants
- Added Annex CC to determine if we reach the LFL outside the equipment enclosure.
- UL60335-2-89 accepted the requirements in the IEC standard for open coolers but only accepted 8 X LFL for doored coolers as the IEC standard allows the test to be above the LFL for 5 minutes
- Larger charge are not being considered today for commercial Refrigeration

UL Solutions

What’s next for UL/IEC 60335-2-40

- UL 60335-2-40 did not accept 4 X LFL as the members understand that cord connected equipment, will be stored in confined spaces in the offseason, smaller than 2 m^3 so 3 x LFL was selected confirmed through research.
- Today IEC 60335-2-40 allows up to 1KG with two forms of mitigation.
- ASHRAE 15 is proposing a 100% indirect system with up to 10Kg’s of an A2 or A3 refrigerant.
- The current requirements require the propane the fuel gas to be 20 feet from building or garage as dose NFPA 1.
- (Propane the fuel gas) Propane cylinders can not be on the roof of a building, NFPA1.

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SC61D/MT29

- TS-63542 Refrigerant Leak detectors
- The eighth edition of IEC 60335-2-40 has removed Annex LL from IEC 60335-2-40 and will reference TS-63542.
- MT29 is resolving the comments received from the CVD that separated Annex LL from IEC 60335-2-40.
- MT29 is also modifying the requirements to align with the requirements in UL 60335-2-40 Annex LL (CRD) to move towards one set of requirements.
- Once TS-63542 is published, it can be referenced by IEC 60335-2-89 and IEC 61010-2-011 as well.
- Timeline for TS 63542 Ed. 2, For a TS the CDV is skipped. Assuming a Committee Draft is available June 2025, DTS draft available June 2026 (FDIS is called DTS). Publication expected October 2026.
- MT29 is seeking experts to join the maintenance team

What is needed to go forward? Research!

- Research is needed!
- We need financial support for the research to ensure safety.
- The first step is indirect systems! We need to determine a realistic distance that an A2 or A3 refrigerant must be from the building or homes door, window or pit. Then language can be drafted in UL 60335-2-40 and ASHRAE 15.
- Research on the RDS (refrigerant detection system) using A2 and A3 refrigerants if we are to consider higher charges for direct system.
- Response times may be critical for A2 and A3 refrigerants!

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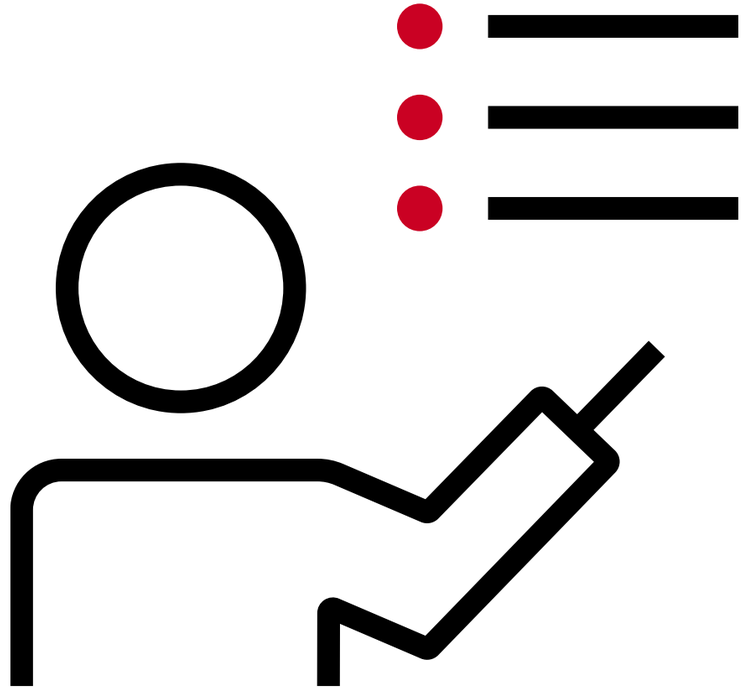
Training

UL Solutions offers general and custom training packages for all HVACR platforms for Safety Standards, including:

- UL/IEC 60335-1
- UL/IEC 60335-2-40
- UL/IEC 60335-2-89
- UL/IEC 60335-2-24
- UL/IEC 60335-2-34



Questions?

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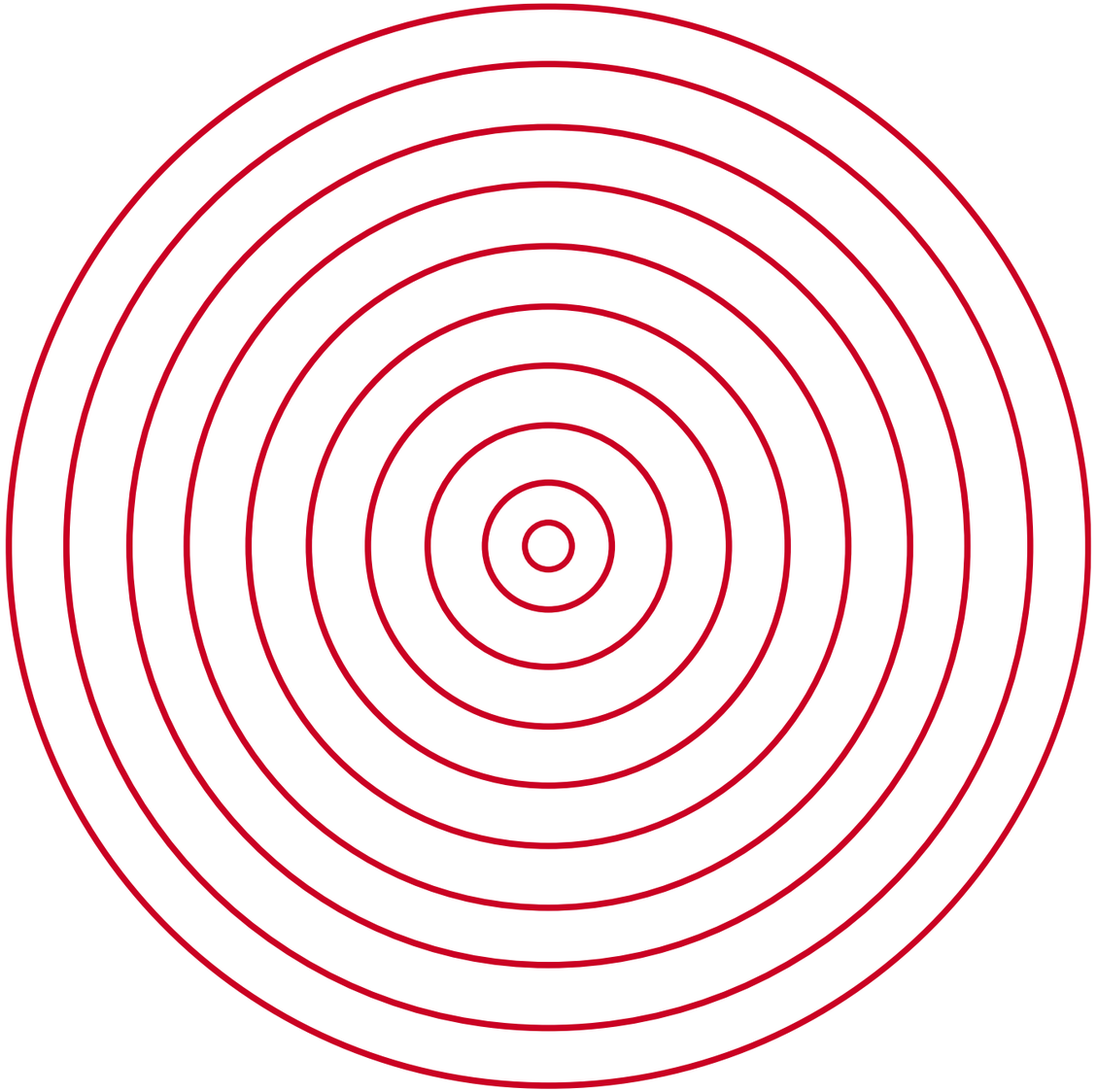

Flammable Refrigerants (A2s and A3s) – What You Need to Know

Industry Collaborative Approach

February 10, 2025

Xudong Wang

Air-Conditioning, Heating, and Refrigeration Institute

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A2L Refrigerants Transition

- **The industry is in the middle of transition to A2L refrigerants and has gained tremendous experience in safely using A2Ls**
- **The updated safety standards include many requirements to ensure the safe use of A2Ls**
  - Isolate competent ignition sources by removing them from inside ducts and the unit
  - Set minimum occupied areas combined with charge limits
  - Install refrigerant detectors in units above certain charge levels
  - Activate mitigation using air circulation or ventilation for units above certain charge levels
  - Protect piping from accidental damage
  - Label products with proper warnings
  - Require service training and education
- **The principle is to prevent refrigerant ignition in the first place**

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AHRTI Flammable Refrigerants Research

- **Extensive research to understand A2Ls' flammability risk**
  - Ignition source
  - Refrigerant dispersion and ignition testing
  - Refrigerant detection
  - Risk assessment and mitigation
- **Technical results to substantiate standard changes and code adoption**
- **Experience gained can be applied to understanding A2 and A3 refrigerants**

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What about A3 Refrigerants?

- **Some testing has been done to get an initial understanding**
- **Results demonstrated that A3 refrigerants require extra caution compared to A2L refrigerants**
  - Ignition
  - Severity
  - Mitigation
- **Implementing A3 refrigerants requires technically sound, and publicly available results to support the changes to safety standards and building codes**

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Expected Approach

- **Leverage the successful A2L experience and conduct collaborative research**
  - Need an industry collaborative research effort to fully address A3 refrigerants' safety concerns and understand the comparative risk to A2L refrigerants on an equivalent base
  - Main Focus:
    - Identify A3 refrigerants' safety related knowledge gaps
    - Design research to remove A3 refrigerants' implementation barriers (codes and standards)
    - Generate publicly available technical results to support standard revision and code adoption

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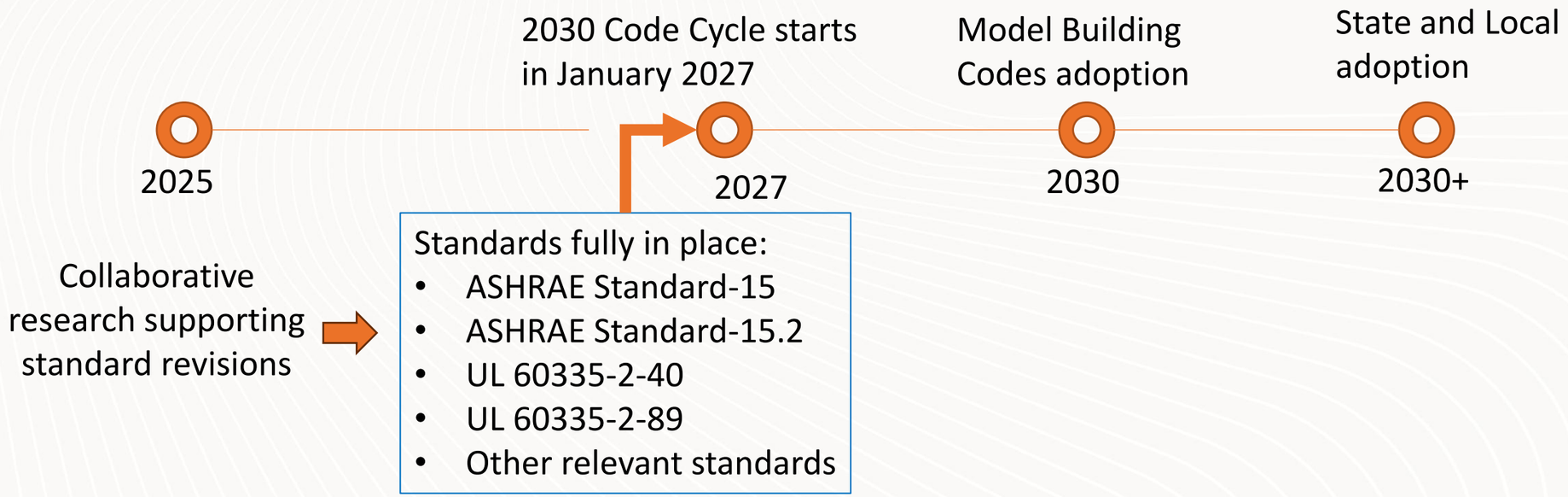
Air-to-Water Heat Pump (ATWHP): Performance and Safety Measures

- **Main Tasks:**
  - Develop a laboratory testing framework to consistently evaluate ATWHPs performance
  - Assess safety measures for ATWHPs using A3 flammable refrigerants
    - Risk assessment supported by modeling and testing for typical installation scenarios
    - Safety in laboratory testing, field installation, service, and repair
  - Identify barriers and necessary steps to address them

A Long Journey

Best case scenario:



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Key Takeaways

1. In order enable more options to meet the AIM Act, it is important to also consider the safe and efficient use of flammable (A2 & A3) refrigerants in more RACHP applications (in addition to the A2L refrigerants)
2. When considering A2 and A3 classified refrigerants, ***safety is the most important*** performance factor; other factors such as heating and cooling capacity, energy efficiency, first cost and operating & maintenance costs etc. are important as well
3. Understanding the safe use of flammable refrigerants in additional RACHP applications needs ***more fundamental research*** to develop appropriate safety standards and system design; initial focus of the effort is on indirect (secondary coolant) systems
4. The magnitude of the problem calls for a ***collaborative approach*** between all the stakeholders – *that is happening, and we are making progress!*

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Thank You!

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