CalFIRE A2L 2022

JUNE 2020

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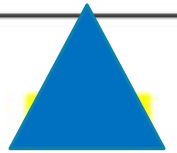
Disclosure

- Although Helen Walter-Terrinoni is a member of the United Nations Montreal Protocol Technical and Economic Assessment Panel (TEAP), this presentation and work is independent of the work of the TEAP

AHRI SAFE REFRIGERANT TRANSITION TASK FORCE

New HVAC Installation with New Line-set

R-410A Residential System	A2L Residential System	A2L vs. R-410A Differences
Follow OEM guidelines for line sizing, length	Follow OEM guidelines for line sizing, length	
Field joints exposed for visual inspection prior to covering/enclosing per ASHRAE 15 and Bldg Codes	Field joints exposed for visual inspection prior to covering/enclosing per ASHRAE 15 and Bldg Codes	
Field joint made at the unit - Brazed, welded or mech connections	Field joint made at the unit - Brazed, welded or mech connections - Indoor mechanical connections must comply with ISO 14903, or other reqs	
Testing - Pressure test - Vacuum test - Leak check (handheld leak detector)	Testing - Pressure test - Vacuum test - Leak check (handheld leak detector)	

New Install with Existing Line-set –Exposed Piping

R-410A Residential System	A2L Residential System	A2L vs. R-410A Differences
Follow OEM guidelines for line sizing, length	Follow OEM guidelines for line sizing, length	IDENTICAL
Inspect lines for condition/cleanliness	Inspect lines for condition/cleanliness	IDENTICAL
Flush lines, if necessary	Flush lines, if necessary	IDENTICAL
Field joints exposed for visual inspection prior to covering/enclosing per ASHRAE 15 and Bldg Codes**	Field joints exposed for visual inspection prior to covering/enclosing per ASHRAE 15 and Bldg Codes**	IDENTICAL
Field joint made at the unit - Brazed, welded or mech connections	Field joint made at the unit - Brazed, welded or mech connections - Indoor mechanical connections must comply with ISO 14903, or other reqs	A2L more stringent
Testing - Pressure test - Vacuum test - Leak check (handheld leak detector)	Testing - Pressure test - Vacuum test - Leak check (handheld leak detector)	IDENTICAL

** If there are joints in existing line-set in walls , those joints would have been inspected prior to cover up in original installation.

New Install with Existing Line-set – Hidden Piping

R-410A Residential System	A2L Residential System	A2L vs. R-410A Differences
Follow OEM guidelines for line sizing, length	Follow OEM guidelines for line sizing, length	✓
Testing - Pressure test - Vacuum test - Leak check (handheld leak detector)	Testing - Pressure test - Vacuum test - Leak check (handheld leak detector)	✓

- **California Building Code has required visible inspection of piping upon installation as far back as could be confirmed.**
- **Verify piping integrity (whether existing or new): pressure test, vacuum check, and leak check**

Research

Completed Research on Flammable Refrigerants*

Testing

- **AHRTI-9007: Benchmarking Risk by Whole Room Scale Leaks and Ignitions Testing**
- AHRTI-9013: A2L Consequence Study
- AHRTI-9012/Oak Ridge National Laboratory (ORNL): Real-world Leak Assessments of Alternative Flammable Refrigerants-Phase I
- AHRTI-9008: Investigation of Hot surface Ignition Temperature (HSIT) for A2L Refrigerants
- AHRI-8017: Investigation of Energy Produced by Potential Ignition Sources in Residential Application
  - NFPA: Evaluation of the Fire Hazard of ASHRAE Class A3 Refrigerants in Commercial Refrigeration Applications
  - Carrier: Electric Heater Testing
  - Carrier: Turbulent deflagrations of mildly flammable refrigerant-air mixtures

Modeling

- ORNL: Investigate the Proper Basis for Setting Charge Limits of A2L, A2, and A3 for Various Types of Products

Servicing

- ASHRAE-1807:Guidelines for Flammable Refrigerant Handling, Transporting, Storing and Equipment Servicing, Installation and Dismantling
- ASHRAE-1808: Servicing and Installing Equipment using Flammable Refrigerants: Assessment of Field-made Mechanical Joints
  - AHAM Safe Servicing of Household Appliances with Flammable Refrigerants: Recommended Practices
  - NFPA: Flammable refrigerants firefighter training: Hazard assessment and demonstrative testing

Detection

- AHRTI-9009: Leak Detection of A2L Refrigerants in HVACR Equipment

*This is not a comprehensive list (Japan, Europe and Manufacturers have done extensive studies)

Research on Flammable Refrigerants*

Completed - Risk Assessment

- AHRI-8004: Risk Assessment of Residential Heat Pump Systems Using 2L Flammable Refrigerants
- AHRI-8009: Risk Assessment of Refrigeration Systems Using A2L Flammable Refrigerants
- AHRI-8016: Risk Assessment of Rooftop Units Using A2L Refrigerants

- Ongoing projects in US
  - AHRTI-9014: Assess Refrigerant Detector Characteristics for Use in HVACR Equipment
  - AHRTI-9015: Assessment of Mitigation Effectiveness for Air-Conditioning and Refrigeration Equipment
  - AHRI 8023: Risk Assessment of Transport Refrigeration Systems Using Flammable Refrigerants
  - Oak Ridge National Laboratory (ORNL): Real-world Leak Assessments of Alternative Flammable-Phase II
  - NIST: Modeling tools for low-GWP Refrigerant Blends Flammability
  - ASHRAE-1806: Flammable Refrigerants Post-Ignition Simulation and Risk Assessment Update
  - ASHRAE-1855: Determination of the Impact of Combustion Byproducts on the Safe Use of Flammable Fluorinated Refrigerants

Research outside US

- Japanese Industry Risk Assessment of Mildly Flammable Refrigerants
- Japanese Industry Risk Assessment for Safe Use of A3 Refrigerants

*This is not a comprehensive list (Japan, Europe and Manufacturers have done extensive studies)

Research 9007-01

http://www.ahrinet.org/App_Content/ahri/files/RESEARCH/Technical%20Results/AHRI_9007-01_Final_Report.pdf

AHRTI 9007-01

Final report AHRTI Project 9007-01 Benchmarking Risk by Whole Room Scale Leaks and Ignitions Testing of A2L Refrigerants

The project investigation plan is presented in Figure 1.

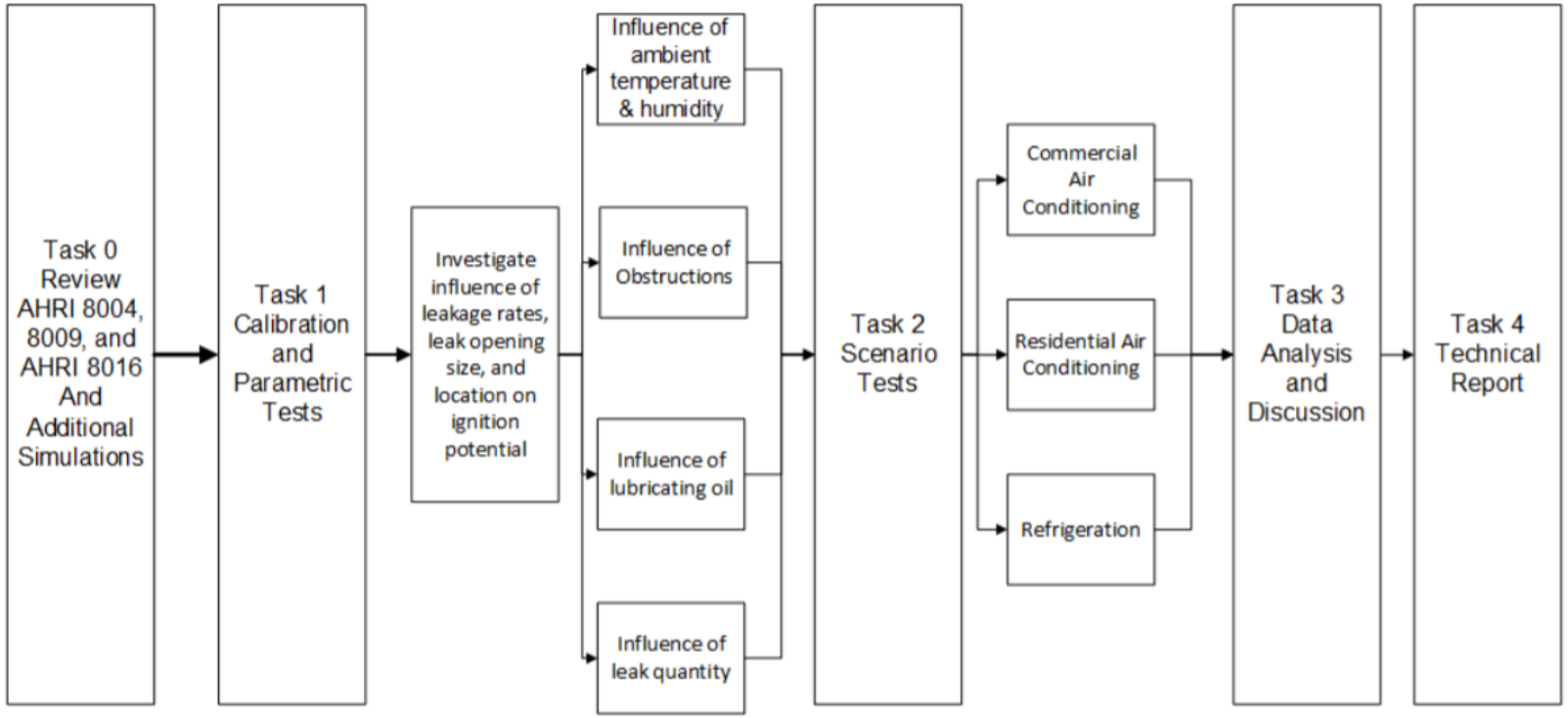


Figure 1 – Technical Plan

Flammable Zones - Initial Research Observations

High (8ft) release: Concentrations **below** LFL due to mixing

Low release: Concentrations above UFL

Mid-range without barrier: Concentrations **below** LFL due to mixing

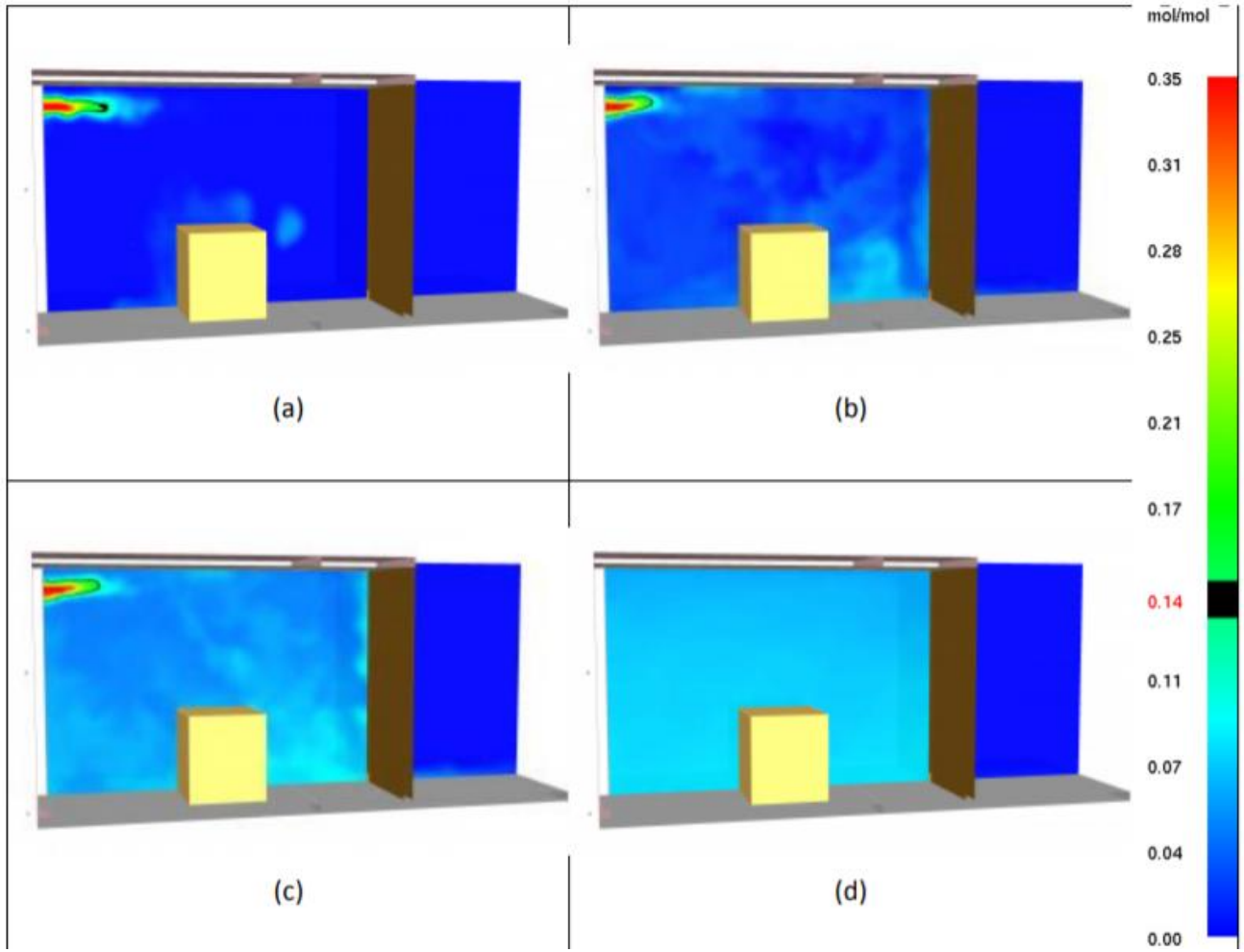
Mid-range with barrier with air circulation: Concentrations **below** LFL due to mixing

Mid-range with barrier with no circulation: **can result in** concentrations between LFL and UFL

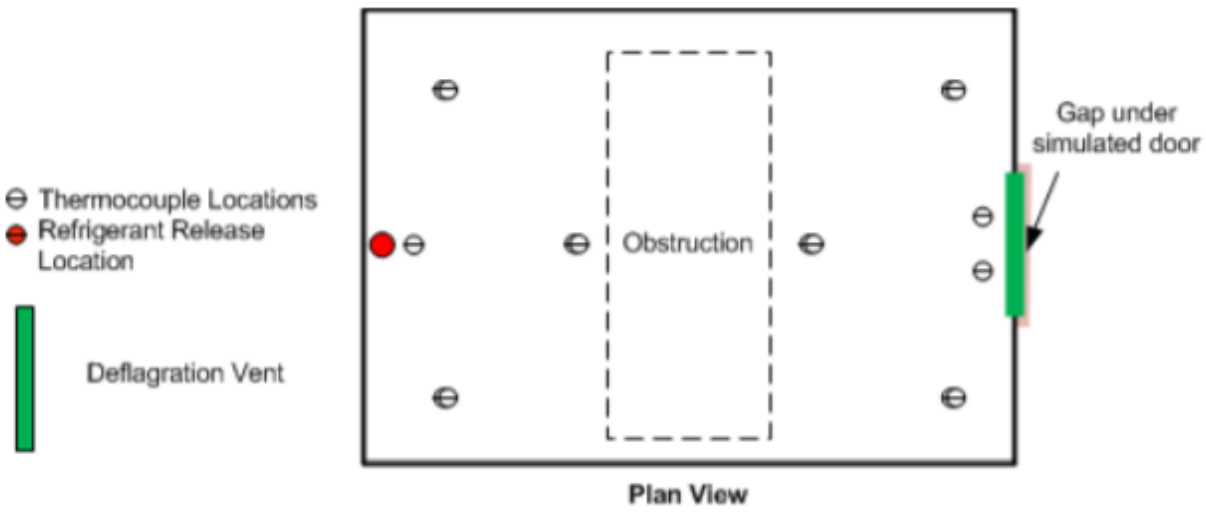
How safety standards were updated -

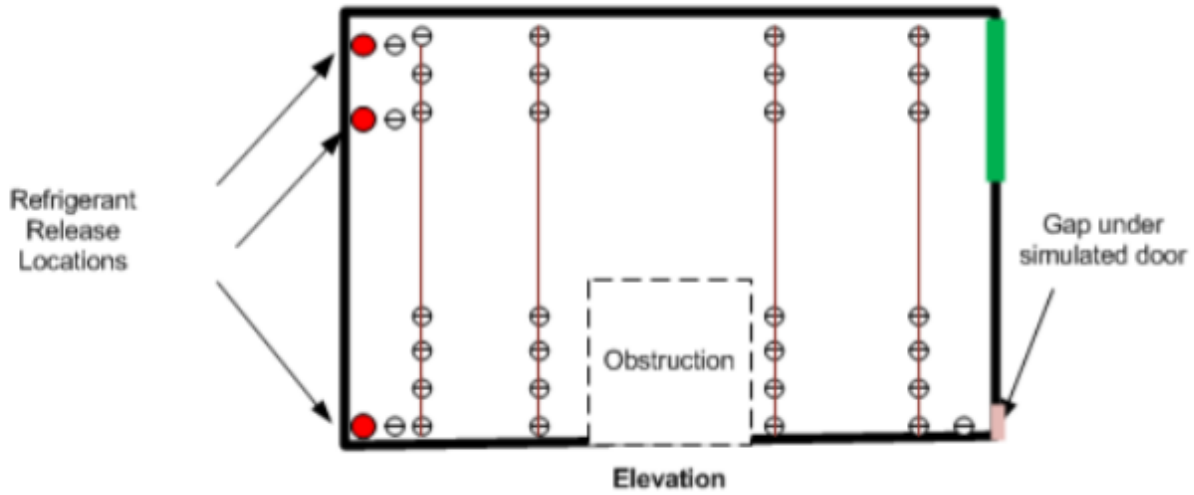
Charge size without sensor or ductwork requires use of gravity equation and mixing equations address these learnings

Simulation 1(Figure 2) shows that a high velocity (e.g., 100 g/s and 50 mm release opening) release results in a jet in the test room that causes turbulent mixing with the ambient air and yields relatively low concentrations of the refrigerants in the test room. The region of gas above LFL is confined to a small volume in front of the release location.



Release from 8 ft





Modeling showed that room setup required an obstruction to achieve concentration between LFL and UFL with no circulation/ mitigation

PTAC Unit in Motel Room

The PTAC tests were designed to emulate the release of refrigerant from the evaporator into a typical motel room sized 1660 ft³, 47.1 m³ with ignition devices representing those sources that could be expected to occur.

The refrigerant quantity released in the tests corresponds to proposed m1 size charge of (6 m3 × LFL kg/m3), where LFL is the lower flammable limit in kg/m3 from for the refrigerant used.

Nine tests were conducted for this scenario using R-32 and R-452B refrigerants. The ignition sources were tea candles (open flame) placed at floor level or electric arc sources which continually arced once energized at the various locations.

In some of the tests, the candle ignition source failed to either ignite or stay ignited. Refrigerant concentrations measured in the test room did not show values above the LFL and ignition did not occur. One test using R-452B resulted in a low energy ignition near the PTAC power cord plug lasting no more 3 seconds.

There was no secondary ignition of the cheesecloth for either refrigerant in this test. An additional test was added placing the electric arcs directly in front of the PTAC in the refrigerant discharge zone. This test resulted in ignition of the refrigerant.

IEC 60335-2-40 uses 50% LFL to initiate mitigation

IEC uses 50% LFL to initiate mitigation to account for:

- Furniture / obstacles
- Refrigerant density
- Safety factor

- IEC uses 50% LFL while UL uses 25% LFL in standards to initiate mitigation

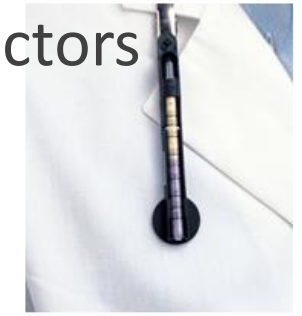
How do I know if there is a leak?

- **There is a detector inside the equipment that will turn on fan** at 25% LFL (or lower) and turn off cooling, heating and electrostatic ignition sources
- **The fan will be running and will not turn off.**
- **The** unit **will not** cool or heat.
- Bottom line: No cooling or heating + fan running --> There may be a leak

Portable Gas or Oxygen detectors

What should the sensor detect? The technology is known and there are many detectors available including intrinsically safe ones.

- Significant leak required to reach LFL
  - • LFL (A2Ls) = 118,000 to 144,000 ppm
  - •LFL (Butane) = 18,000 ppm
- Sufficient O2- O2 Sensor
- Leak of fluorinated refrigerant- Hand-held leak detectors
  - ($200-$300) (10 to 1000 ppm)
- HF- Draeger tubes or HF monitors
  - ($200-$600) (10 to 1000 ppm)



Draeger Tubes

Crowcon HF Detector

Concentrations must be very high to reach LFL

Parameter	R-22	R-32	R-410A	R-452B	R-455A
Lower Flammability Limit (LFL, % volume)	no flame propagation	14.4	no flame propagation	11.9	11.8
(LFL, kg/m³) Sea Level		0.307		0.310	0.423
(LFL, kg/m³) 200 m (650 feet)		0.301		0.304	0.415
Upper Flammability Limit (UFL, % volume)	no flame propagation	29.3	no flame propagation	22.0	12.9
Refrigerant Concentration Limit (RCL, ppm v/v)	59,000	36,000	130,000	30,000	22,000
Laminar Burning Velocity (cm/s)	no flame propagation	6.7	no flame propagation	<4.0	<1.5
Composition (% mass)	100% R-22	100% R-32	50% R-32 50% R-125	67% R-32 26% R-1234yf 7% R-125	75.5% R-1234yf 21.5% R-32 3.0% R-744

AHRTI 9007-01

Sensing Leaks

Conditions at the end of refrigerant release

Release 25% LFL

60s after end of release (no ignition)

- An odorant (e.g. mercaptan) is added to some highly flammable fluids (e.g. natural gas) to provide a single way to sense the presence of odorless, colorless gases with LFLs at or below 5% and very low ignition energies (natural gas <0.5 milliJoules) that have been involved in severe incidents. Odorant potential usage in AC is still under investigation.
- Large volumes of refrigerant must be released in order reach a flammable concentration (greater than 10%), so a high flow rate of refrigerant is needed:
  - Loud (sound)
  - Refrigerant cloud (sight)
  - Cold temperature as refrigerant is released (feel)

UL/AHRI Demonstration Project

- Review proposal through June 1
- 6 weeks from commencement to draft report
- 8 weeks to final report

Scenario	Test #1	Refrigerant	Scenario	Refrigerant
1	1	Baseline	Baseline 60 kW calorimeter measurements	None
	2	A1 #1	Discharge into open flame from various distances	R-410A
	3	A2L #1		R-32
	4	A2L #2		R-454B
	5	A1 #2		R-466A
2	6	Baseline	Flashover fire A1 room	None
	7	A1	Flashover fire with refrigerant line break	R-410A
	8	A2L #1		R-32
	9	A2L #2		R-454B
If Needed 3	10	A1	Flashover fire with fully charged system (no forced break)	R-410A
	11	A2L #1		R-32
	12	A2L #2		R-454B
4	13	Baseline	Combustibles fire in A1 Room	None
	14	A1	Forced line break during overhaul	R-410A
	15	A2L #1		R-32
	16	A2L #2		R-454B
5	17	Baseline	Kitchen gas fire in Room	None
	18	A1	Kitchen cooktop gas fire with refrigerant line break	R-410A
	19	A2L #1		R-32
	20	A2L #2		R-454B

AHRI Safe Refrigerant Transition Task Force

AHRI has formed a **Safe Transition Task Force** which has 7 working groups that are open to interested participants

Goals are to **evaluate end-to-end supply chain to enable the safe commercialization of low GWP refrigerants** in a timely manner and support the effort to reverse the **global warming trend**.

- Communications
- Safety Training
- Codes and Standards
- Transportation/Storage/Packaging/Handling
- Bulk Storage and Manufacturing Facilities
- Installation/Operation/Maintenance
- Recovery/Reclaim/Destruction

http://www.ahrinet.org/SafeRefrigerant

Contact one of the following people if interested in the Safe Refrigerant Transition Task Force

Helen Water-Terrinoni HWalter-Terrinoni@ahrinet.org
Christophe Bresee CBresee@ahrinet.org

Establish structure to ensure continuous improvement

- Incident investigation
- Continuous maintenance standards
- Training upgrades

Leverage learnings around the world

- **Widespread use of A2L refrigerants already in global HVAC&R industry** in European Union, Japan, India and Australia and auto industry (including US and Canada)

END CHARTS FROM MAY MEETING

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JUNE 11 2020

EPA Significant New Alternatives Policy (SNAP) Program Rule 23

Signed by EPA Administrator Wheeler May 29th

45-day public comment commences when proposed rule is published in the *Federal Register* (likely later this month).

- Residential and light commercial air conditioning and heat pumps—Proposed listing of R-32, R-452B, R-454A, R-454B, R-454C, and R-457A as acceptable, subject to use conditions, for use in residential and light commercial air conditioning and heat pumps end-use for new equipment;
- Total flooding: Proposed removal of Powdered Aerosol E from the list of substitutes acceptable subject to use conditions

https://www.epa.gov/sites/production/files/2020-06/documents/pre-publication_snap_listing_rule_23_nprm_5_29_2020_signed_.pdf

EPA Significant New Alternative Policy (SNAP) Program

SNAP program is required to complete a comparative analysis of alternate refrigerants based on safety, toxicity, environmental properties etc.

- FYI. EPA also lists fire suppressants as acceptable or unacceptable based on the same criteria and has experts in fire suppression alternatives.
- The EPA SNAP program experts have a wide breadth of experience with many of them having been analyzing alternatives for decades. They have expertise in the products using chemicals, toxicity, safety etc.

New refrigerants are only listed as “acceptable” if they can be used without increasing risk compared to the original refrigerant based on this set of criteria.

Historically, EPA has listed flammable refrigerants as “acceptable only subject to use conditions” which generally include requirements to adhere to a product safety standard such as UL 60335-2-40. There are often charge limits included in EPA’s listing regulations.

Why 2023 date for AC when SB1383 requires 40% reduction in 2030

- SB1013 mandates based on the *consumption or use* of certain refrigerants →

2019: Aerosols can no longer use HFC-134a

2021: Self-contained units can no longer use R-404A

2024: Chillers can no longer use R-410A

- SB1383 mandates CARB to reduce ***emissions*** instead of consumption
  - *Emission regulations require early action:*

2010 -2023 R-410A Equipment installed

2030 R-410A emissions come from AC equipment installed 2010 – 2023

40% emissions reduction based on lower GWP AC refrigerants installed from 2023-2030

ASHRAE RP-1808: Durability and Leak Rates of Field-made Mechanical Joints

- Press fittings, compression fittings and flare fittings.
  - 2 different fitting sizes between 3/8” and 1-1/8”
  - Two different materials (Cu-Cu and Cu-Al).
  - 100 fittings of each type underwent the evaluation procedure.
  - Brazed joints were used as a baseline
- Evaluation
  - Fitting assembly time,
  - Leaks after initial assembly
  - Assembly failures for which the fitting required replacement
  - Fitting durability through a series of harshness tests
    - Pressure-temperature cycling,
    - freezing-thawing cycling and
    - vibration testing
  - Leak rates of different fittings
    - positive pressure with R32 vapor
    - Vacuum

Conclusions

- Pressure (at not less than the design pressure of the setting of the pressure relief device) and vacuum tests as well as leak check are required in the safety standards
  - Leak checks are important after assembly especially for press fittings and compression fittings.
  - More experienced technicians assembled fittings faster and there were less leaks from their fittings
  - Experience level more important than assembly location and fitting size.
- High failure rates of smaller flare fittings at very cold temperatures indicate that they should be avoided in temperatures below freezing
- Suggest that care be exercised when using compression and flare (threaded-type) fittings under vibrating application conditions. Fittings may have been damaged during vibration testing.
- No significant leaks under vacuum conditions for any of the fittings relative to brazed fittings

RECALL: 4 lbs would need to be released in a space of less than 212 sq ft to reach LFL

M1 for A2L refrigerants (R-32 & R-454B) is ~ 4 lbs.

- A typical 12K PTAC has less than 2 lbs of R410A (this would go to about 1.7 lbs of R32).
- Old rule of thumb – 80s or 90s construction - **400 ft^2 per ton**
- New rule of thumb - More recent construction - **600 to 1,000 ft^2 per ton**

In order to reach the lower flammability limit, 4 lbs of an A2L would need to be released into a room smaller than 6 m^3 or 211.9 ft^3 or a 5.1 by 5.1 ft room (8 ft ceiling).

Even with the most conservative estimate, a 26.5 square ft. room would only need a much smaller AC unit with a much smaller charge.

Note that mitigation requirements for ignition sources, labeling, and safe application are still required for m1 systems.

AHRTI research examined m1 charged equipment

Bottom Line: A complete release from even a reasonably oversized “m1” unit is unlikely to reach LFL

m_1 A2L Air Conditioning Units have been marketed and sold in US since 2016

https://www.coolingpost.com/world-news/lg-supply-r32-air-conditioners-in-the-us/

https://perfectaire.us/2019/03/22/switching-to-r32-from-r410a-why-manufacturers-are-switching-refrigerants/

Lowe's R32 window units - https://www.lowes.com/pd/LG-550-sq-ft-Window-Air-Conditioner-115-Volt-12000-BTU-ENERGY-STAR/1000925326

Summary ASHRAE RP-1808

Fitting Type		Assembly Failures (/100)	Leaks Found (/100)	Pressure/ Temperature and Freeze/Thaw	Vibration	Observed leak rate g/yr *
Press Fitting	Fastest	1		0/100		1 g/yr
Compression Fitting	Second	8	33	5-10% (could be re-tightened)		0.4 g/ yr (near zero leak rate observed for many fittings)
Flare Fittings	Third	5	56		Large flare fittings failed 50%	0.2 g/ yr (near zero leak rate observed for many fittings)

* Recall 4 lbs charge would need to be released suddenly into less than 212 sq ft to reach LFL.

Leak Rate Comparison

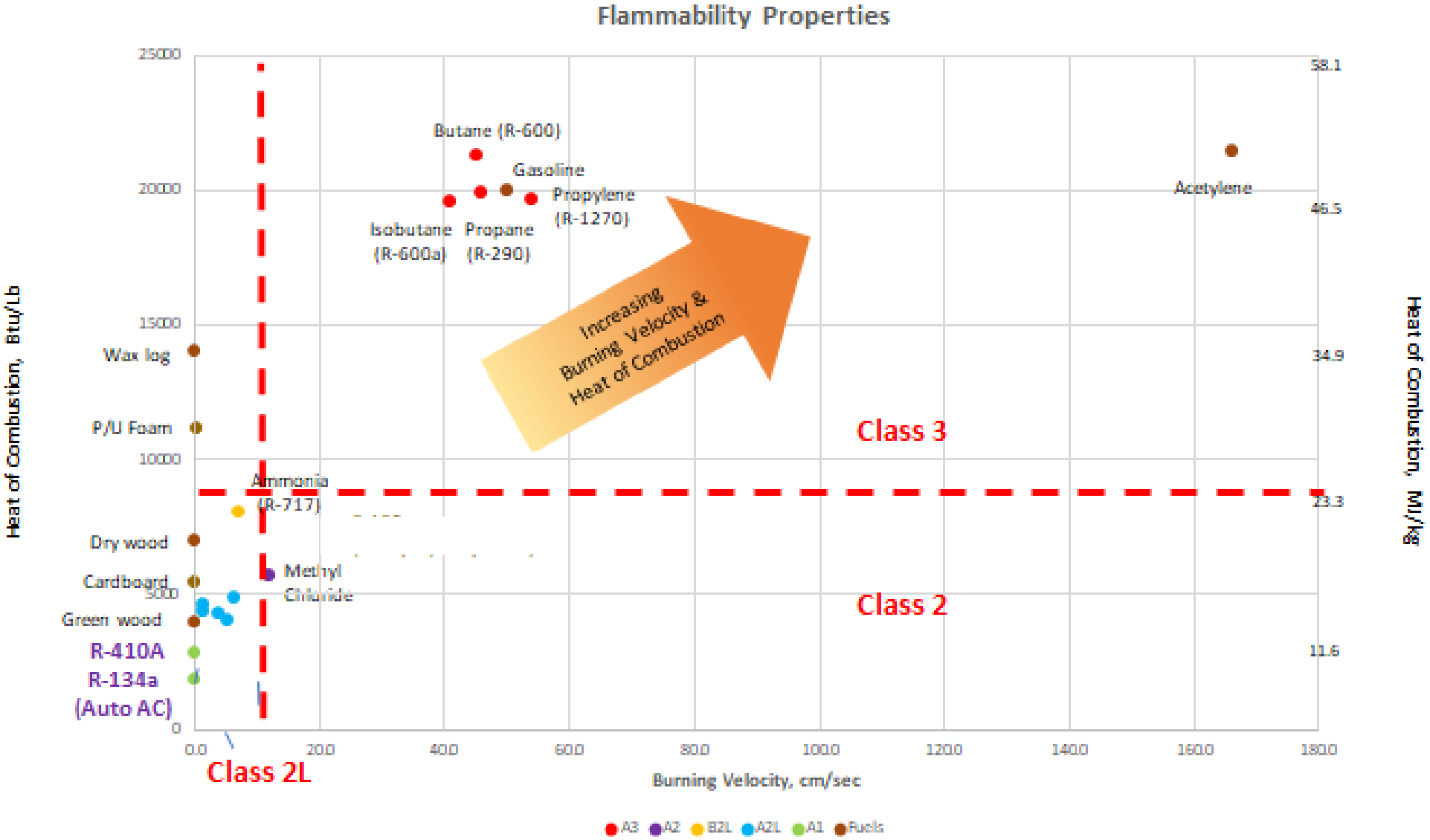
Annual Leak Rate			Time to reach LFL in 10' x 10' x 8' room	
gram	ounce	pound	months	years
1	0.0	0.0	83,134	6,928
4	0.1	0.0	20,784	1,732
100	3.5	0.2	831	69
1000	35.3	2.2	83	7

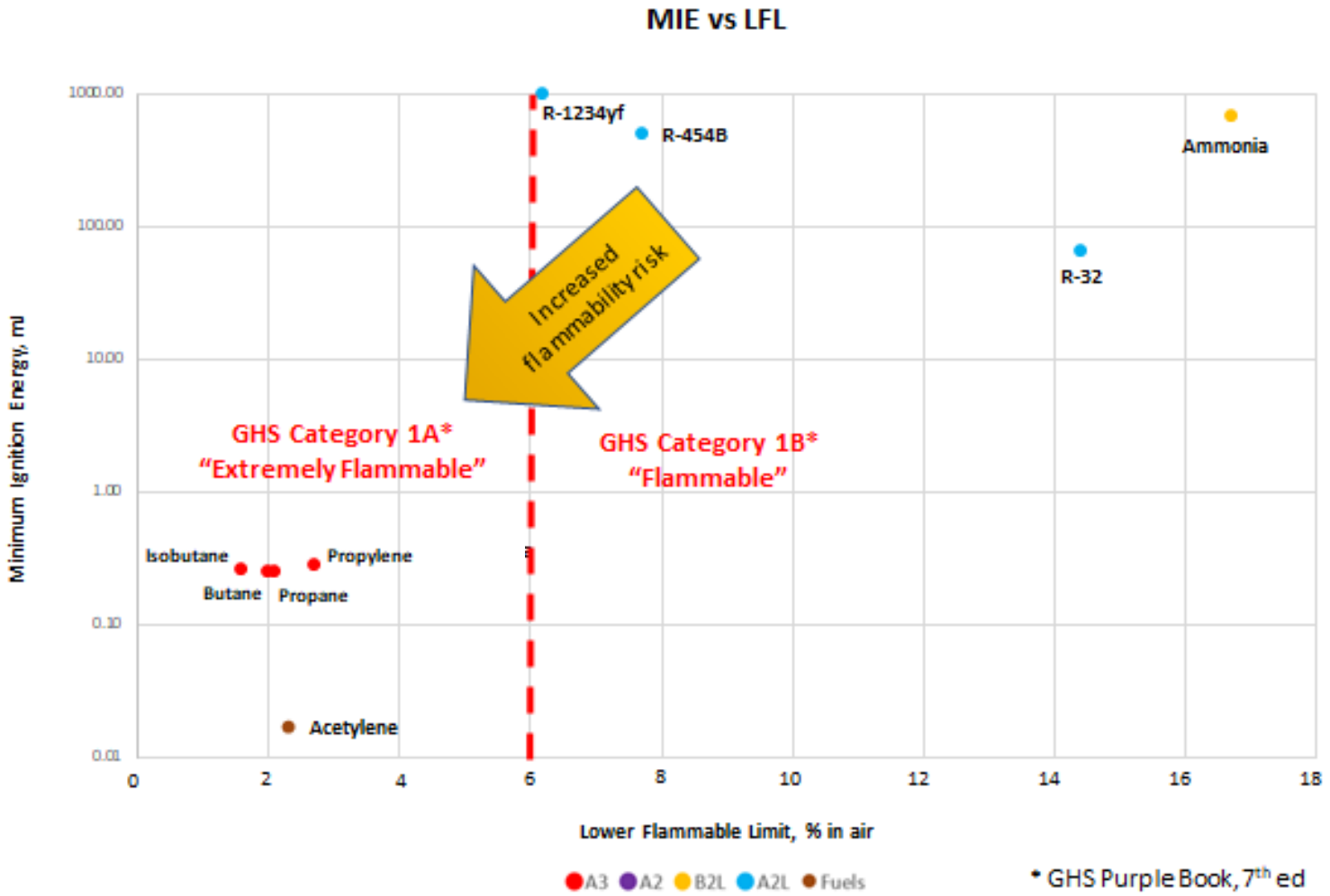
Different flammable fluids are regulated differently in building codes and other regulations.

- NFPA storage limits are different for acetylene, ammonia, methylene chloride and propane.
- Global Harmonized System differentiates between refrigerant classes.

- It takes orders of magnitude higher energy to ignite ASHRAE Class 2L flammable refrigerants versus commonly used hydrocarbons like acetylene, propane and butane
- Higher concentrations are needed to reach flammable concentrations compared to A3 refrigerants
- Heat of combustion and burning velocity are lower for A2L refrigerants

Is there any difference between flammable fluids?





It takes 2-6x higher A2L concentration to reach flammable concentrations versus A3 refrigerants

Minimum Ignition Energy: Note the logarithmic scale.

Research Project 9007-1 (cont)

Rooftop Unit in Commercial Kitchen

This test consisted of a roof top unit with duct work connected to the kitchen space below. The kitchen size was 14 x 16 x 8 ft. high (4.3m x 4.9m x 2.4m). The release quantities for R-32 and R-452B were based on a IEC SC 61D Working Group 9 draft version of IEC 60335-2-40 (Annex GG section: GG.10.1).

Five tests were conducted for this scenario using R-32 and R-452B refrigerants. Tests represented a refrigerant leak in the evaporator in the air handler.

This location was approximately 9 ft. (2.7m) above the work surfaces. In these tests, the HVAC unit fan was turned on 30s or 60s after the start of refrigerant release as a mitigation technique.

There was accumulation of the leaked refrigerant in the evaporator condensate drain pan and therefore not all the refrigerant entered the test room. This resulted in lower concentrations of refrigerants and no ignition was observed.

In these tests, the candle ignition source was extinguished by the fan-induced flow of the air-refrigerant mixture in the test room.

Split HVAC unit in utility closet – Internal Leak

9007-01 Figure 143 – Results residential A/C Res06, R410A

9007-01 Figure 144 – Results for residential A/C Res07, R32

The residential A/C application test scenario involved an HVAC unit located in a 24ft 2in x 30ft x 8ft (7.4 x 9.1 x 2.4m) residential arrangement with the air conditioning unit located in a 8 x 4 x 8 ft. (2.4 x 1.2 x 2.4m) closet. In this scenario, three tests were conducted using R-410A, R-32 and R-452B refrigerants. The refrigerant charge used was the same as that used in the A-coil experiments.

The refrigerant was released under natural pressure decay to represent a servicing scenario such as a mistake during joint brazing. In all of these scenarios 30g lubricating oil was mixed with each refrigerant prior to release.

Ignition was not observed with R-410A refrigerant. However, ignition occurred for both R-32 and R-452B refrigerants near the release location which was located inside the closet.

There was no ignition of the refrigerant outside the utility closet for either refrigerant. The candle ignition sources were placed near the point of release.

Once the discharge started, these candles were immediately extinguished by the discharge. Ignition was observed once the electric arc was energized.

The location of the electric arc and the discharge rate combined to limit the ignited volume to the immediate vicinity of the electric arc.

Walk-in Cooler

The walk-in cooler scenario involved the use of a ceiling mounted commercial refrigeration unit with the refrigerant leak in the evaporator. The refrigerant release quantities were based on 13 m3 × LFL kg m3 (from draft version of IEC 60335-2-89) for R-455A and R-457A.

The first two tests were for R455A and R457A at a target charge level with the walk-in door closed. The leak was created at the coil return band.

This would be the worst case scenario when leaked refrigerants were trapped inside the walk-in box, and refrigerant has the tendency to pool when the refrigerant was forced to leave the unit cooler through the condensate drain and drop to the floor. Ignition occurred for both tests.

The tests were repeated with the walk-in door open to see if the refrigerants ignition may be mitigated due to the fact that they can dissipate outside the walk-in box. The position of the test room door, open or closed, appeared to have little impact on ignition results.

Testing results indicated that 13*LFL charge limit without mitigation may have risk under catastrophic refrigerant release.

The published 2-89 3ED is currently set an upper limit: *“The refrigerant charge of flammable refrigerant in appliances with an incorporated refrigerant unit or motor-compressor* ***shall not exceed 13 times the LFL of the flammable refrigerant or 1,2 kg in any refrigerating circuit, whichever is smaller****.”*

Reach-in Cooler

The reach-in cooler scenario involved a product display refrigerator having an internal volume of 21 ft³ (0.59 m³), located in a convenience store with dimensions of 30 x 30 x 8-ft. high (9.1m x 9.1m x 2.4m). Tests with release quantities of 300g, 400g, and 500g were performed. The 500 g value is the current limit for class 2 flammable refrigerant in UL 471 edition 10 including revisions through November 2014. Four tests were conducted for this scenario using R-455A and R-457A refrigerants.

The reach-in cooler tests showed that ignition of the refrigerant occurs with a refrigerant release quantity greater than 300g.

The fire spread indicated that walls and corners in proximity of the reach-in cooler facilitate higher concentrations of refrigerants.

In those cases where ignition occurred, the highest temperatures attained were near the floor level.

The 300 gram test showed some flaring of the candles due to the presence of refrigerant, but there was no visible spread of flame into the surrounding air.

Maximum temperatures from the events increased with increasing charge size. Both 400 and 500 gram charge sizes resulted in ignition.

R-455A had approximately 150 ºF lower maximum temperatures than R-457A for the same release mass of 500 grams.

Hermetic Electrical Pass-Through Terminal Failure

The Hermetic Electrical Terminal failure scenario involved the use of the outdoor section of a residential compressor/condenser unit. Four tests were conducted for this scenario using R-32, R-452B, and R-410A refrigerants. Each test was conducted using a new factory-built compressor charged with refrigerant and lubricating oil. A 1/8 inch hole was drilled in the Hermetic Electrical Terminal plug to represent a terminal failure

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The results from the Hermetic Electrical Terminal failure tests showed that R-452B ignited under these test conditions.

In the R-452B experiment, it was observed that the molded plug remained attached to the terminal which was different from all other experiments where the molded plug was completely ejected.

The experiment with R-410A was repeated because of concern about the seating of the terminal plug on the electrical terminals. In both R-410A tests, there was no ignition.

It was anticipated that R-32 would ignite under these same conditions, but an electrical interference from the electric arc influenced the solenoid valve controlling the refrigerant discharge and caused reduction in the overall rate of R-32 discharge. This slower rate of the R-32 discharge resulted in refrigerant/air mixtures that were not ignitable.

AHRI Guidelines M and N

Guideline M: Unique Fittings and Service Ports for Flammable Refrigerant Use

- A2L and A3 cylinders have left-hand threads.
- Technician would have to make a modification to the cylinder or tool to charge an A1 system with a flammable refrigerant

Guideline N: A red band on the shoulder or top of the container should designate flammable compounds, or mixtures that could become flammable in the event of a leak

- Submitted to UL CSDS system for resolution regarding right-hand and left-thread threads.

Guideline N, Assignment of Refrigerant Container Colors

AHRI announced significant changes to refrigerant paint color designations in the revised version of AHRI Guideline N, Assignment of Refrigerant Container Colors. Revisions now specify that all refrigerant containers should have one uniform paint color, a light-green grey (RAL 7044), and **that existing individually assigned container paint colors should be transitioned to that color by 2020.**

AHRI

we make life better®

Unlicensed Contractors?

- California State Law requires that all contractors be licensed by the California Contractors State License Board (CSLB).
- Various classifications. HVAC is C-20 "Warm Air Heating, Ventilating, and Air Conditioning". There are over 12,000 licensed HVAC contractors in CA.
- CSLB has enforcement authority.
  - CSLB has a Statewide Investigative Fraud Team (SWIFT)
  - Cities separately enforce – like San Francisco
- Consumers can easily check if a contractor is licensed or not.
  - https://www2.cslb.ca.gov/OnlineServices/CheckLicenseII/CheckLicense.aspx
- Consumers can easily file complaints.
  - https://www.cslb.ca.gov/Consumers/Filing_a_Complaint/
- Many cities actively promote use of, and checking for, licensed contractors.
  - https://www.riverbank.org/182/Building
  - https://www.ci.patterson.ca.us/140/Building-Division
  - https://www.lacityattorney.org/unlicensed-contractor-fraud **PUBLIC CAMPAIGN**

Technician Training

Training Programs are available or in progress

- ACCA found at: https://www.acca.org/certification
- NATE found at: https://www.natex.org/site/1/Home
- RSES found at: https://www.rses.org/hydrocarbons.aspxhttps://www.rses.org/hydrocarbons.aspxhttps://www.rses.org/hydrocarbons.aspx
- OEMs will have training and/or detailed service manuals in order for products to be listed (UL 60335-2-40 Annex DD)
- The refrigeration market has already transitioned to A3s (vending machines, refrigerators)
  - IHACI Training (California contractor association):

http://www.ihaci.org/education-training/

http://www.ihaci.org/education-training/class-description/

Sensor Mitigation Strategy: Prevent Ignition

- Internal sensors detect refrigerant inside equipment before an external leak occurs.
- UL 60335-2-40 requires an internal sensors and controls to mitigate leak if the charge is above m1 where the greatest concentration will be so that it is detected.

Sensor Life

- What happens if expected sensor life is shorter than expected product life?
- UL 60335-2-40 addresses this situation.
- Sensors are either “refrigerant sensor” or “limited life refrigerant sensor.”
- Annex LL .8 addresses this situation by mandating that if a sensor would need to be replaced, it must take by going into continuous circulation mode at a minimum airflow.

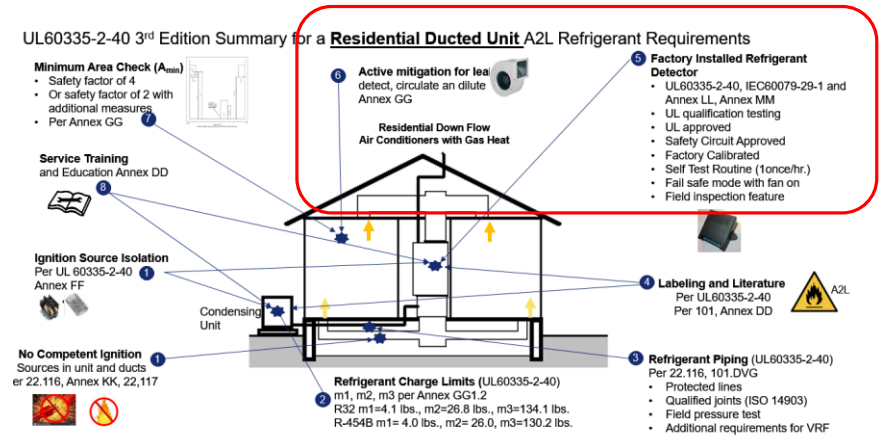
Lifetime depends on which product the manufacturer selects. Many have reported that sensors can outlast equipment.

Similar to smoke detectors, self-test is required to detect failure just in case there is a premature failure

The same requirement applies for failure of self-check.

Leak Sensing and Mitigation Operation

- The approach used by Safety Standards for the application of A2L refrigerants is to sense the leaking refrigerant inside the unit and automatically mitigate using circulated airflow before the refrigerant reaches 25% of LFL in the occupied space outside the unit.
  - ✓ Refrigerant sensors/detectors are required to factory installed in the unit and qualified and certified for settings and accuracy as well as location
  - ✓ When the sensor/detector detects a refrigerant leak, inside the units the indoor fan is turned on to circulate airflow and dilute the refrigerant. The fan continues to run until the detector resets plus and additional 5 mins.
  - ✓ Alternate approach is continuous fan operation, but that increases energy use
- Annex MM of UL60335-2-40 has defined requirements for qualification of the sensor/detector location



UL60335-2-40 Sensor Location Requirements

As per annex MM 2.6

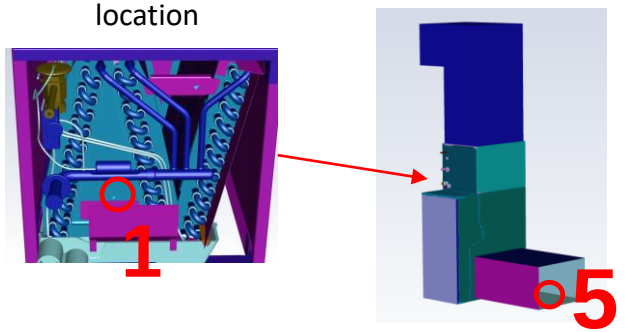
The measured concentration of refrigerant gas at the location of the REFRIGERANT DETECTION SYSTEM sensor shall exceed the set point of the detection system used within 90 s from the start of the release. Where multiple sensors are applied with the REFRIGERANT DETECTION SYSTEM, if the concentration at any single sensor location exceeds the set point of the detection system used within 90 s from the start of the release, the REFRIGERANT DETECTION SYSTEM sensor location shall be considered in compliance.

The purpose of this test is to determine if the selected location of the sensor is in a good place to detect a leak inside the unit and acceptable to detect a leak.

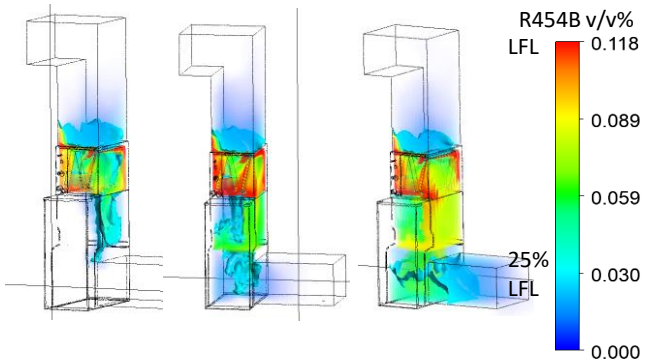
Leak Sensing and Mitigation Operation

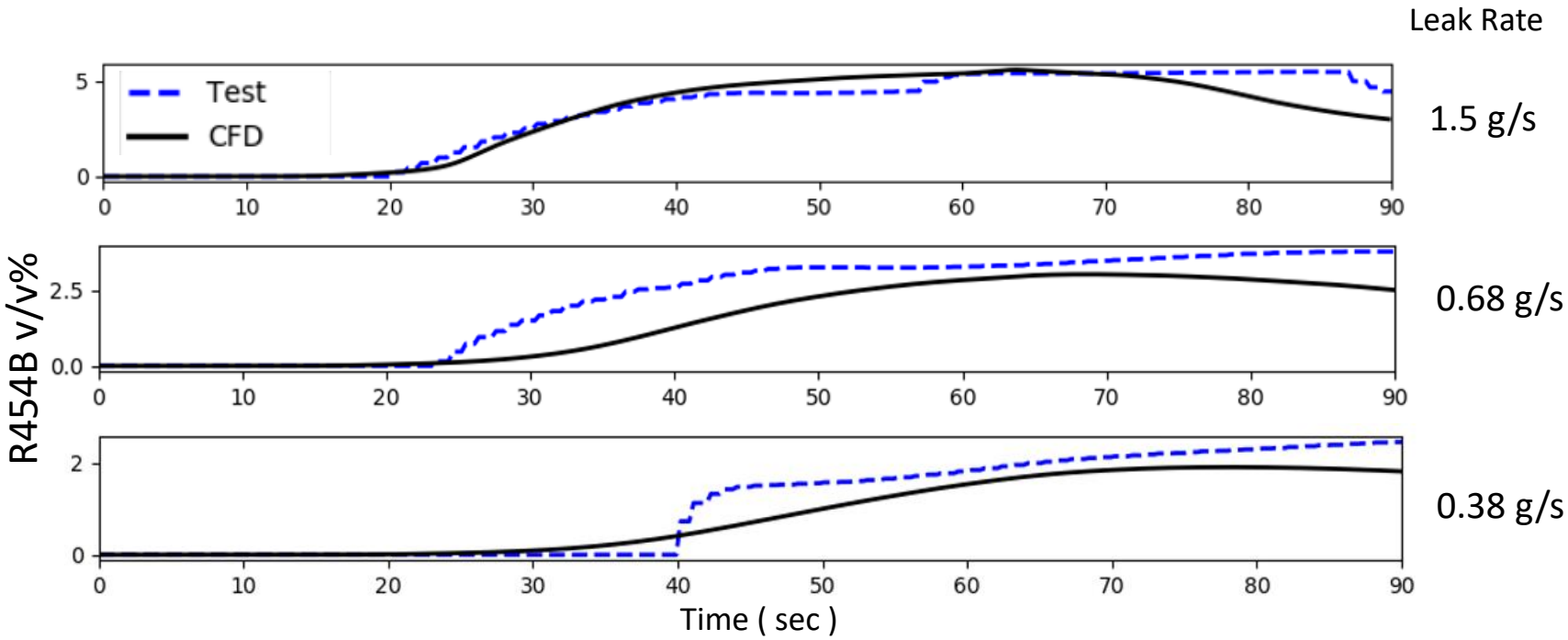
The figures show the results of the CFD and testing at the entrance to the short return duct (location 5)

Leak and Sensor location



CFD Results (1.5 g/s)





Fluorocarbon combustion products

Hydrogen fluoride (HF) is a combustion product of old A1 refrigerants (in use for 90 years) and new A2L refrigerants

- HF forms when any fluorocarbon refrigerant, including those used today, undergoes combustion, partial combustion, or thermal decomposition
- HF gas is a lung irritant and HF acid, depending on concentration, is a skin irritant

Hydrogen Iodide (HI) and HFC-23 are additional combustion products R-466A

- R-466A contains CF_3I
- HI gas is a lung irritant and HI acid, depending on concentration, is a skin irritant

Wild Fire Concerns

A2L RESIDENTIAL AC SYSTEM

Less than 4 gallons of an A2L refrigerant

Difficult to ignite (High MIE)

Low heat of combustion

PROPANE

120 gallon tank of propane allowed 10 feet from house.

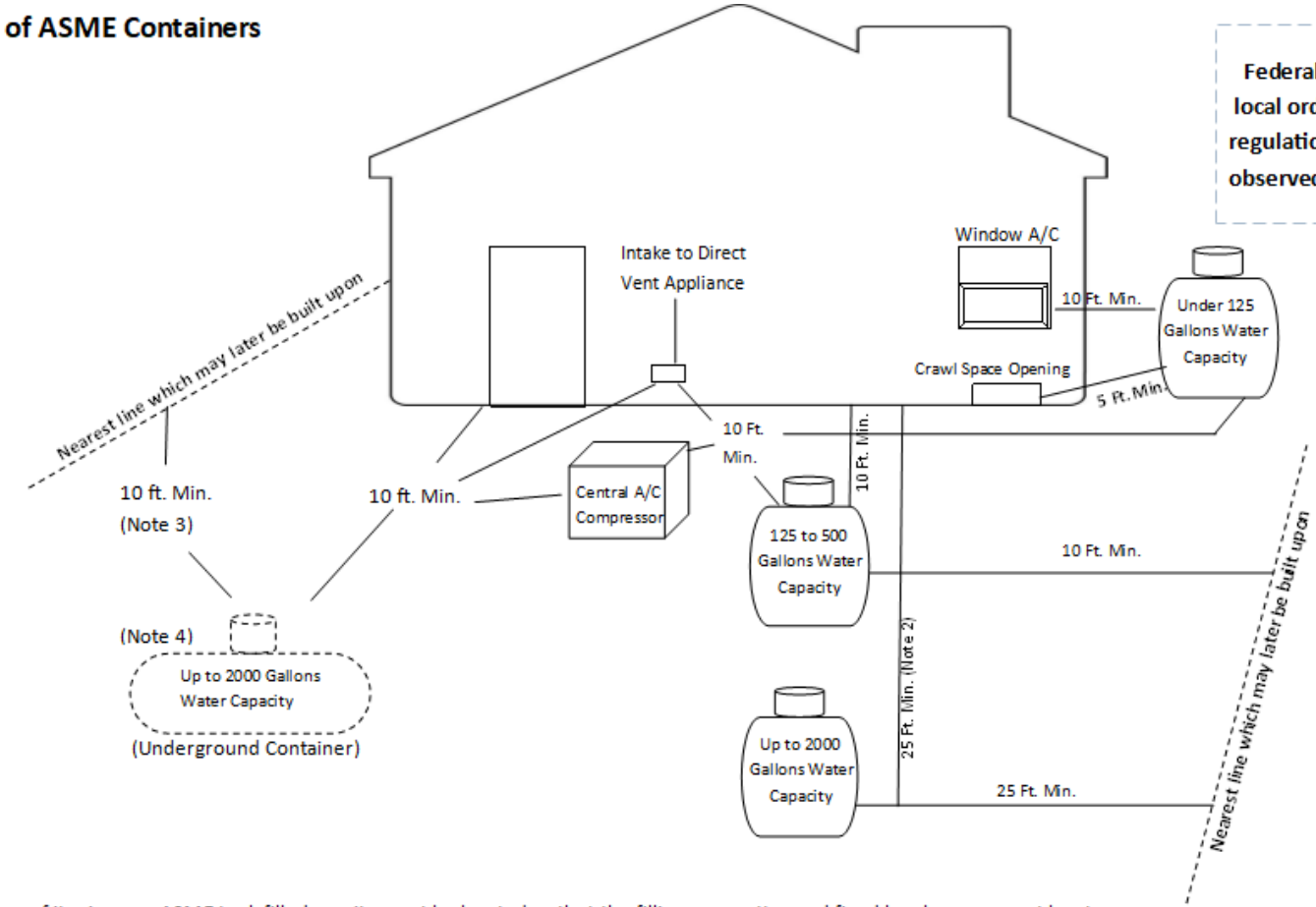
Low minimum ignition energy (MIE)

Higher heat of combustion

Did you know?

Olive oil, a Class IIIB combustible liquid has a heat of combustion of over 17,000 Btu/lb. Difluoromethane (R-32), a Category 2 flammable gas, has a heat of combustion of 4,041 Btu/lb or one fourth that of olive oil.

Location of ASME Containers



Federal, state, and local ordinances and regulations should be observed at all times.

Notes:

1) Regardless of its size, any ASME tank filled on-site must be located so that the filling connection and fixed level gauge are at least 10 feet from external source of ignition (i.g. open flame). Intake to direct vented gas appliance, or intake to a mechanical ventilation system.

2) May be reduced to 10 feet minimum for a single container of 1200 gallons water capacity or less if it is located at least 25 feet from any other LP-Gas container of more than 125 gallons water capacity.

3) Minimal distances from underground containers should be measure from the relief valve and filling or level gauge vent connection at the container, except that no part of an underground container shall be less than 10 feet from a building or line of adjoining property which may be built upon.

4) Where the container may be subject to abrasive action or physical damage due to vehicular traffic or other causes it must be either a) placed no less than 2 feet below grade or b) otherwise protected against such physical damage.

(Source: NFPA 58. Appendix I)

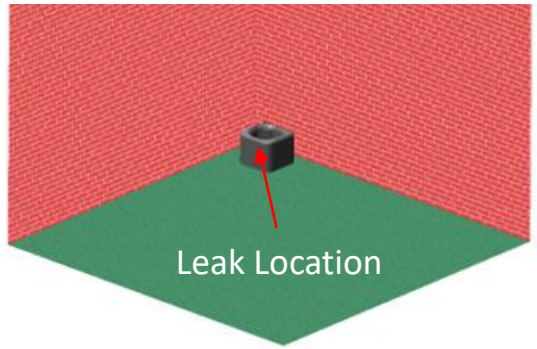
Wild Fire

- Concerns have been raised about the increase risk to a structure exposed to a wild fire
- At the temperatures of a fire 600 C to 1,100 C the A2L and A1 refrigerants will be flammable as well as the oil in HVAC systems
- If a leak occurs near an active fire are there additional risk with A2L refrigerants
- The heat of combustion for typical A1 and A2L refrigerants are;
  - Nominal A2L refrigerant Heat of Combustion = 4,400 BTU/lb.
  - R-410A refrigerant Heat of Combustion = 2,800 BTU/lb.
- In a fire 100% combustion typically does not occur but if we assume 100% combustion and a charge of 15 lbs. the difference in fuel value is;
  - (4,400 – 2,800) x 15 = 24,000 BTU
- This difference (A2L vs A1) is equivalent to additional fuel value of:
  - 3.4 lbs. dry wood (~30% of an 8 ft. length of kiln-dried 2x4)
  - 1.7 lbs. Duraflame™ wax fire log (~38% of a single fire log)

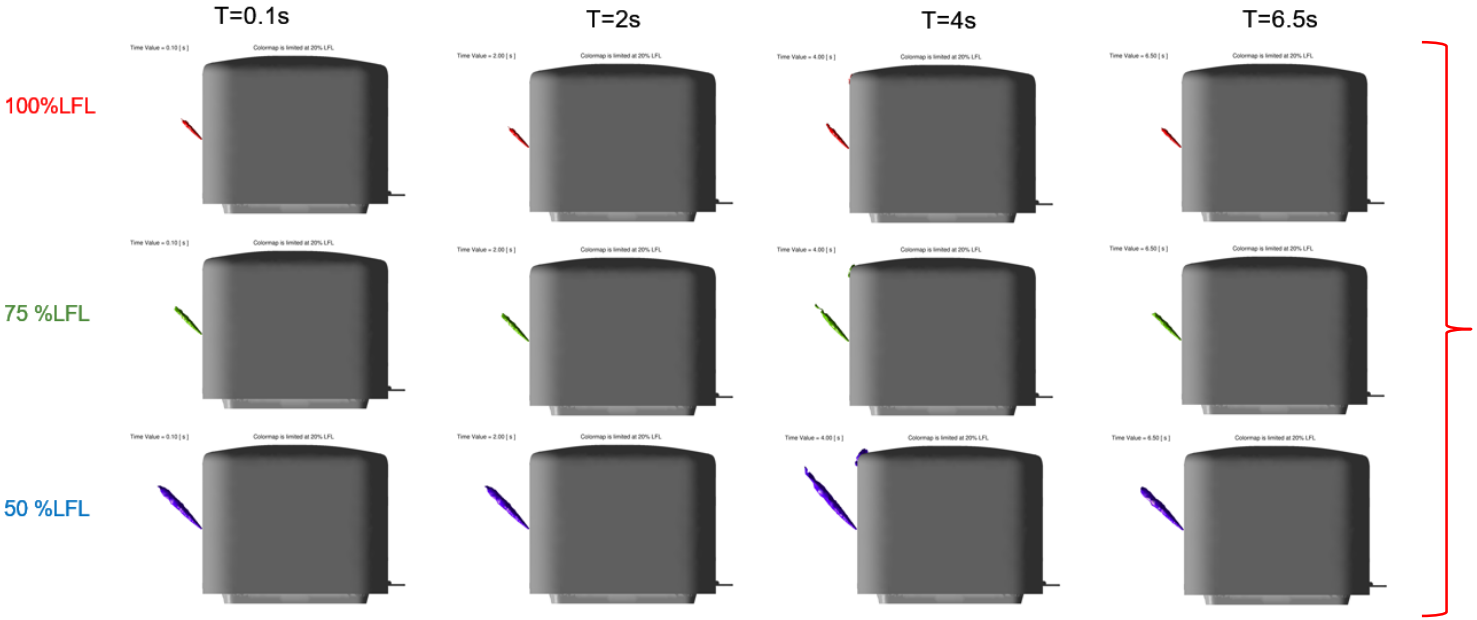
There is negligible added fuel value in this scenario due to A2L refrigerant usage

What about a leak in an outdoor condensing unit during a wildfire?

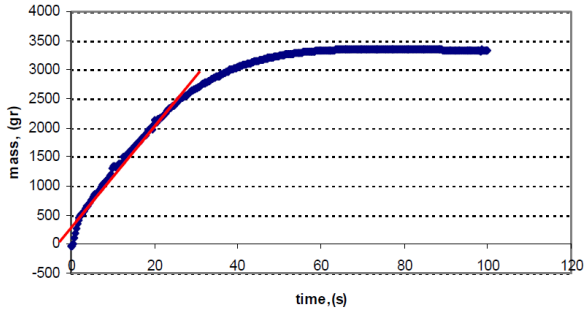
- The evaluate this we are doing CFD studies of various leak scenarios for an outside condensing unit
- The following are the results for a ¼ hole in a condenser tube angled up at 45 degrees which results in a full loss of charge in 1 minute. There is no wind and the unit is in a corner of a building structure



Leak rate include pressure degradation
¼ hole results in full charge loss in 1 minute



As you can see at this very high leak rate the flammable mass region is very small



What is different in a house fire? (HVAC unit not involved)

Situation	Result	R-410A Systems	A2L Systems	
Leak of refrigerant, hitting hot surface *(inside house)*	**Decomposition Products**	Can generate HF	Can generate HF	Same Impact (less HF with many A2L products)
	Ignition (without oil)	Can start to ignite when temps > 1000C	Can start to ignite when temps > 800C	Similar Impact
	Ignition (with oil)	Can ignite if there is oil (410A/oil systems known to ignite)	Can ignite if there is oil (A2L/oil systems known to ignite)	Same Impact (oil level drives ignitions as it has AIT of about 250C)

Scenarios:

- First responder enters house during fire, HVAC line is leaking onto hot surface (no fire at leak site)
- First responder enters house after fire, HVAC line is leaking onto hot surface (no fire at leak site)

What is different in a house fire? (HVAC unit not on fire)

Situation	Result	R-410A Systems	A2L Systems	
Leak of refrigerant, due to rupture of equipment line *(inside house)*	Decomposition Products	Can generate HF	Can generate HF	Same Impact (less HF with many A2L products)
	Ignition (without oil)	Can ignite if refrigerant is exposed to fire (temps> 1000C	Can ignite if refrigerant is exposed to fire (temps> 1000C	Similar Impact
	Ignition (with oil)	Can ignite if there is oil	Can ignite if there is oil	Same Impact (oil level drives ignitions)
	Pressure Rise	**UL60335-2-40 22.112DV.4** "Appliances shall have protective means such as a fusible plug, a rupture member, soldered or brazed tubing joints, special terminals, or pressure relief valves, or shall be so constructed that some part of the system will safely relieve the pressure in case of fire." DV.9 – pressure relief valve or a fusible plug that still has to relieve safely and cannot exceed specific pressures. DV.10 – No shut off valve between device and point of relief DV.6-8 – Greater than 6 inch must have devices	**UL60335-2-40 22.112DV.4** "Appliances shall have protective means such as a fusible plug, a rupture member, soldered or brazed tubing joints, special terminals, or pressure relief valves, or shall be so constructed that some part of the system will safely relieve the pressure in case of fire." DV.9 – pressure relief valve or a fusible plug that still has to relieve safely and cannot exceed specific pressures. DV.10 – No shut off valve between device and point of relief DV.6-8 – Greater than 6 inch must have devices	**Similar Impact** **Changes in UL 2-40 require pressure relief.** **(R-410A pressure is similar to many A2Ls. 1234yf lower pressure than R-410A)**

Scenarios

- First responder severs line during house fire
- Equipment line breaks due to line failure while first responder is nearby

Potential Refrigerant Fuel Load

Safety Class	Example Refrigerant	Heat of Combustion MJ/kg
A1	R-410A	5.91
A2L	R-32	9.38
A2L	R-454B	10.3
A3	R-290 (Propane)	46.3

Worst case scenario = externally fueled fire, complete charge loss (typical residential ducted split unit charge ~ 15 lbs.)

- Nominal A2L refrigerant — Heat of Combustion = 4,400 BTU/lb.
- R-410A refrigerant — Heat of Combustion = 2,800 BTU/lb.

Assuming all refrigerant leaked and burned, fuel value difference between the A2L and R-410A would be:

- (4,400 – 2,800) x 15 = 24,000 BTU

This difference (A2L vs A1) is equivalent to additional fuel value of:

- 3.4 lbs. dry wood (~30% of an 8 ft. length of kiln-dried 2x4)
- 1.7 lbs. Duraflame™ wax fire log (~38% of a single fire log)

There is negligible added fuel value in this scenario due to A2L refrigerant usage

What is different? Wildfire with 410A, A2L or a Propane tank?

120 Gallon Vertical Propane Tank – ASME
https://www.kleen-ritecorp.com/p-37891-120-gallon-vertical-propane-tank-asme.aspx

Propane Tank Fire

Charge is unlikely to exceed 35 lbs. A2L in a single residential split system.

120 gallon propane tank contains up to 60 lbs.

Image from report - - - >
https://virginiabeach.legalexaminer.com/legal/defective-dangerous-products/injuries-caused-by-propane/

https://www.kcrg.com/content/news/Central-City-house-fire-re-routing-traffic-493532011.html

What is different in a wildfire igniting a 410A unit vs HC tank?

Situation	Result	R-410A Systems	A2L Systems	Propane Tank	
HVAC unit is on fire *(outside house)*	Decomposition Products	Can generate HF	Can generate HF	No HF, but possibly more CO, soot	**Same Impact (less HF with many A2L products)**
	Ignition (without oil)	Can ignite if refrigerant is exposed to fire (temps> 1000C	Can ignite if refrigerant is exposed to fire (temps> 1000C	Can ignite if refrigerant is exposed to fire (temps> 250C)	**Similar Impact**
	Ignition (with oil)	Can ignite if there is oil	Can ignite if there is oil	N/A	**Same Impact (oil level drives ignitions)**
	Pressure Rise	**UL60335-2-40 22.112DV.4** "Appliances shall have protective means such as a fusible plug, a rupture member, soldered or brazed tubing joints, special terminals, or pressure relief valves, or shall be so constructed that some part of the system will safely relieve the pressure in case of fire." DV.9 – pressure relief valve or a fusible plug that still has to relieve safely and cannot exceed specific pressures. DV.10 – No shut off valve between device and point of relief DV.6-8 – Greater than 6 inch must have devices	**UL60335-2-40 22.112DV.4** "Appliances shall have protective means such as a fusible plug, a rupture member, soldered or brazed tubing joints, special terminals, or pressure relief valves, or shall be so constructed that some part of the system will safely relieve the pressure in case of fire." DV.9 – pressure relief valve or a fusible plug that still has to relieve safely and cannot exceed specific pressures. DV.10 – No shut off valve between device and point of relief DV.6-8 – Greater than 6 inch must have devices	**Can ignite if line is severed and pressure rise is much faster leading to larger event**	**R-410A and A2L systems are approximately same and depends on pressure of refrigerant. Propane can have extremely high pressure release if inadvertantly releaseed**

Scenarios

- First responder comes to house and HVAC unit is on fire and proceeds to put out HVAC unit
- First responder comes to house and Propane tank is on fire and first responder takes appropriate action (?)

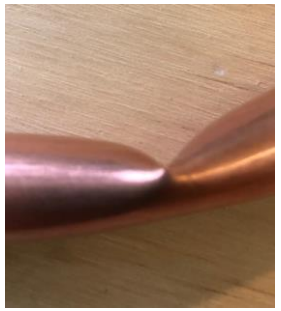
Damage to Refrigerant Lines During a Fire

- There has been concerns expressed about damage to refrigerant lines inside a wall during fire fighting
- UL demonstration project will show impact of a leak
- To determine the potential for line damage we have done some experiments on damage to a line from an ax where we evaluated a ¼ copper line and a ½ copper line
- With a direct hit from an ax the lines were damaged but a leak did not occur.
- For the ¼ inch line with a little post stressing the line did break but the resulting hole size was only 0.002 x .30 slot which at 500 F temperatures for R-32 would result in a 0.049 lb/min leak rate

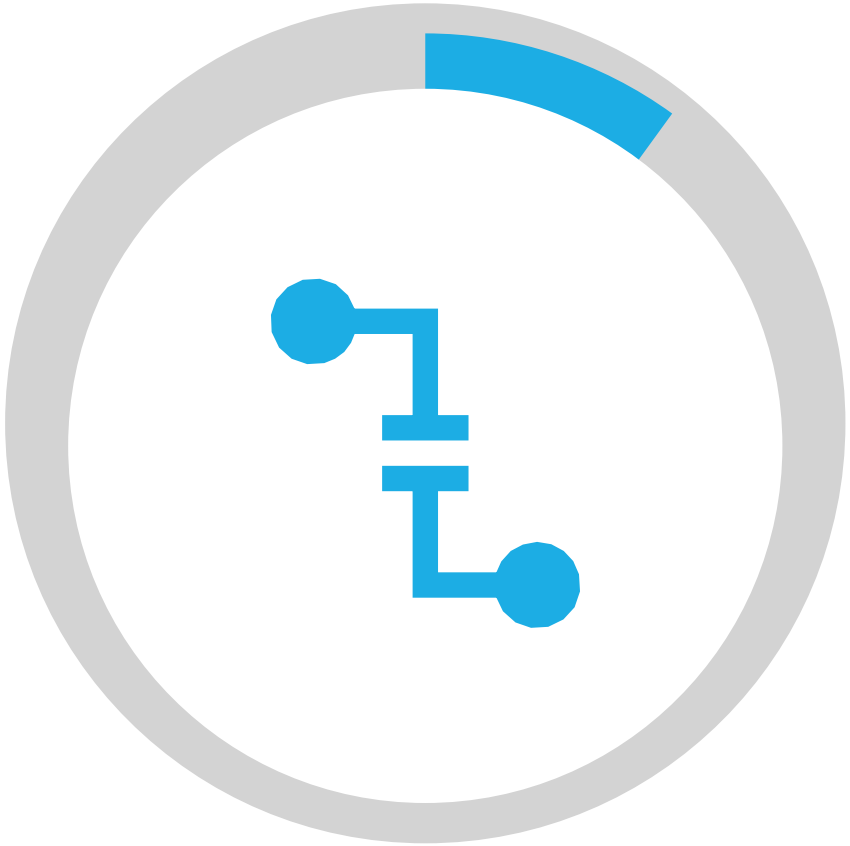
¼ inch line (no leak)

¼ line with post stressing

½ inch line (no leak)



What if there is a catastrophic leak **and** there is a power outage **and** there is an external fire?



Non-causative, multiple failures that each have low probability of occurring

No power → no ignition source within unit

+ Catastropic leak must be sufficient to reach LFL (10x higher than propane)

+ External fire

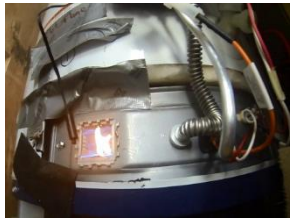
Bottom line: Less than 4 gallons of A2L refrigerant is present which is difficult to ignite and has low heat of combustion

Water Heater in a Closet

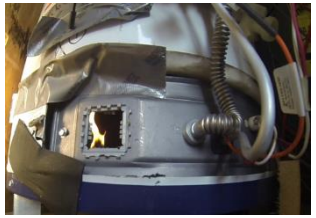
- This has been considered in UL60335-2-40 with requirements on the joints at the fan coil
  - Joints either must be ISO 14903 qualified or inside the fan coil
- This also has been addressed in standard for water heaters which require flame arrestors after 2004 to protect against exposure to flammable gas mixtures in a garage
- So the potential for a leak in the closet has been address but testing has been done in the industry to evaluate if a leak did occur
- Shown is a test setup where a water heater and a fan coil were installed in a small closet and a leak was introduced that resulted in a flammable concentration around the water heat with a standing pilot. The flame arrestor was removed for this testing
- Tests were run with R-32 (A2L), R-1234ze(E) and R-410A (A1) and no external combustion was seen and only extension of the pilot flame occurred

R-410A
(A1)

R-1234ze(E)
A2L



R--32
A2L



Seismic: AC units are highly qualified for vibration

AC units highly qualified for vibration

- Shipping vibration
- Steady State operational vibration
- VRF has additional requirements in UL/CSA 60335-2-40 for vibration

Piping

- Copper tubing is robust in vibration.
  - Expansion loops
  - Not rigidly mounted
  - Seismic isolators are required in California Building Code

What are the requirements today?

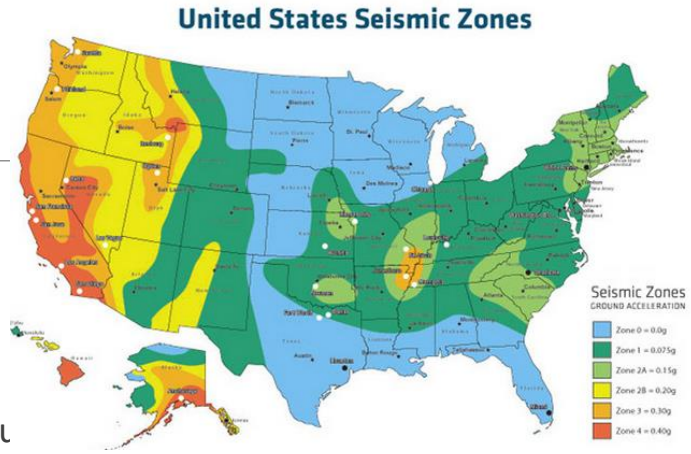
- Only Category 4 (e.g. hospitals, disaster relief) Certificate of seismic code compliance
  - There are no seismic requirements for boilers in residential
  - Water heaters must be secured in residential setting

Question - Seismic

This is not a new concern and is covered in the existing IBC commercial code in section 1705.2 and 1705.2 and in the Residential in Chapter 4, 6, 10

The requirements for construction of the building depend on the Seismic Design Categories of C, Do, D1, and D2 for residential building in section R301.2.2 of the 2019 California Residential code.

- In active zones, additional requirements are required for walls, floors
- We did not see specific requirements for HVAC systems.



For commercial buildings the IBC code refer to the ASCE-7 standard and California OSHPD who interprets the requ

- For critical buildings like public assembly there are certification requirements that include verification of durability and operability in a seismic event
- ASCE-7 allow for qualification one of the following three method which will continue to be used as required;
    1. Calculations
    2. Shaker Table Testing for transport testing completed in y and z
    3. Historical

The UL60335-2-40 and ASHRAE 15 standard do not address seismic qualification, but do require vibration, shipping testing as well as most manufactures internal qualification testing

The new A2L systems do have more robust requirements for piping and joints and field testing of piping and are likely more durable than current A1 based refrigerants units.

Shaker Table Testing

- Shaker Table testing for transport is in y and z direction
- Higher frequency
- Longer test (hours)

- Seismic test is low frequency, high displacement test in y direction only

AHRI Research to Verify IEC 60335-2-40

- US TAG wanted to verify the IEC 60335-2-40 --> $7 million by AHRI and ASHRAE
  - US AC industry is more conservative
  - Different built environment in US
  - Individual companies and international research also invested in testing
  - Research completed to inform the safety standards
  - AHRI created videos of some of the research related to A2L and A3 refrigerants.
  - Still photos of the videos can be found in the final reports on the AHRTI website
- 8 hours to walk through research to provide context .
  - AHRI willing to start this process now through a virtual forum
  - When pandemic conditions allow for an in-person, we can complete the process.
- AHRI has presented videos jointly with UL in Northbrook Illinois
  - Oct 2018: Invitations sent to fire service with more than 100 attendees for 2-day session on research for both air conditioning and commercial refrigeration -
  - Jan 2020: Private session on air conditioning research inviting only specific members of fire service as directed by and including Jim Dominik

Wildfire Concerns

A2L RESIDENTIAL AC SYSTEM

Less than 4 gallons of an A2L refrigerant

Difficult to ignite (High MIE)

Low heat of combustion

PROPANE

120 gallon tank of propane allowed 10 feet from house.

Low minimum ignition energy (MIE)

Higher heat of combustion

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