



# Refrigerants are Changing

(How we got here & where we're going)

- Helen Walter-Terrinoni, VP Regulatory Affairs, Air-Conditioning, Heating, and Refrigeration Institute

<http://www.ahrinet.org/SafeRefrigerant>

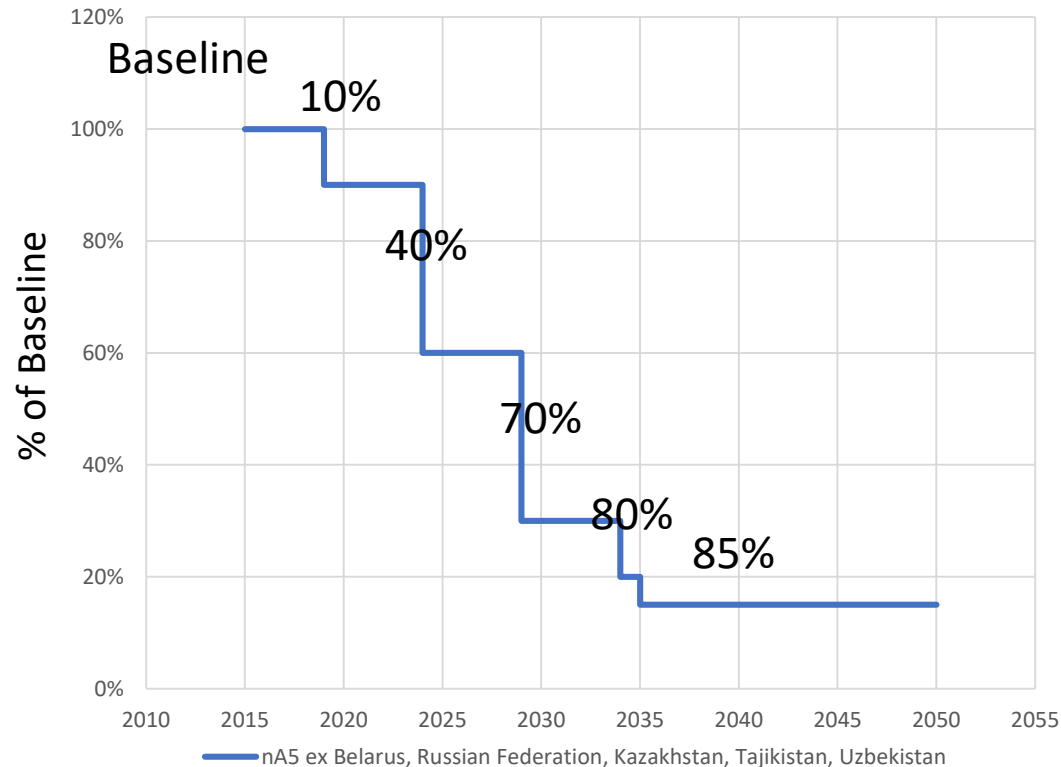
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# Overview

- Introduction
- Refrigerant regulatory landscape
- Low global warming potential (GWP) refrigerants, including the new A2L safety category
- Technical research and development informing the standards
- Safety standard upgrades for flammable refrigerants (UL60335-2-40 and ASHRAE 15/15.2)

# The Montreal Protocol Kigali HFC Amendment

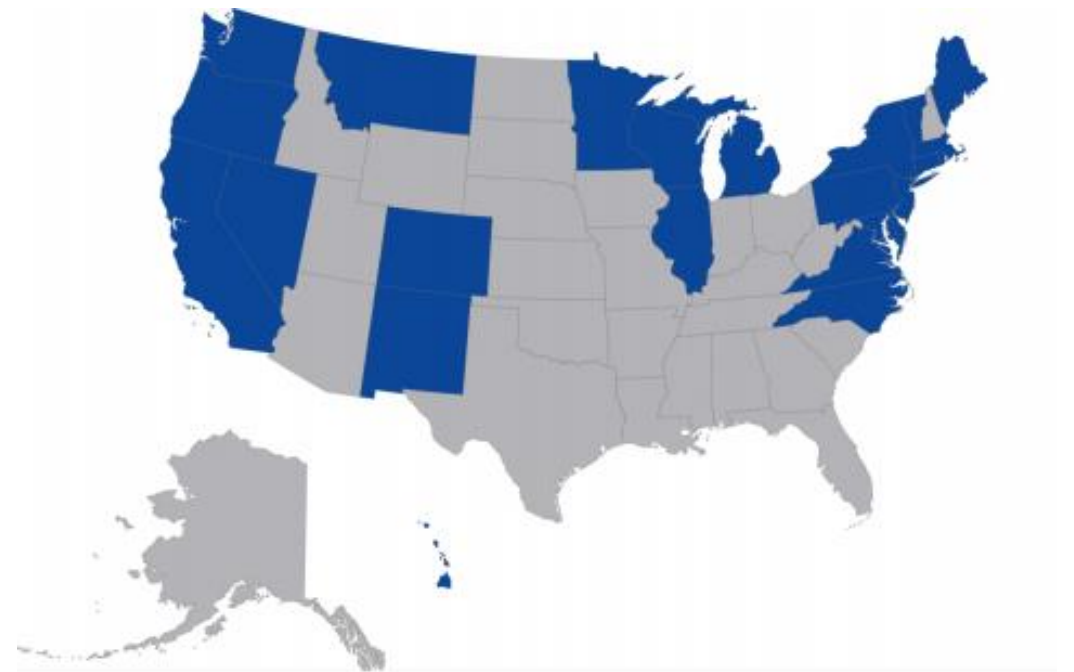
Kigali Amendment to the Montreal Protocol  
HFC Phasedown Schedule as % of Baseline (2011 – 2013)



- U.S. has not ratified the amendment (SB2754)
- The Federal Government is not phasing down HFC refrigerants
- Canada and Mexico have ratified the amendment
- States are taking action independently with some coordination through the Climate Alliance
- In 2017, California proposed transition dates:
  - Air conditioning: Jan 1, 2021
  - Commercial Refrigeration: Jan 1, 2022

# U.S. Climate Alliance: States Regulating Refrigerants

- August 4, 2017: U.S. submitted formal notice of withdrawal from Paris Climate Agreement withdrawing, at the earliest, Nov. 4, 2020
- [United States Climate Alliance](#) States commit to reduce emissions commensurate with U.S. commitment. 392 mayors also committed to the Paris Climate Agreement reductions
- 9 states have included HFCs in this effort



## Bottom Line:

To date, 9 of the 25 climate alliance states are proposing regulating refrigerants

# California

- In 2017, the California Air Resources Board (CARB) proposed high global warming potential refrigerant bans\*:
  - Air conditioning: Jan 1, 2021
  - Commercial Refrigeration: Jan 1, 2022
  - Chillers Jan 1, 2024 (Finalized)
- AHRI counterproposals:
  - Air Conditioning: 2023
    - Safety Standards ASHRAE 15 (2019) and UL 60335-2-40 3<sup>rd</sup> edition (November 2019) have been published
    - Harmonize with new minimum energy efficiency standards going into effect in 2023
  - Commercial Refrigeration: Maintain a medium GWP (seems to be rejected by CARB)
  - Commercial Refrigeration: 2024 low GWP (No feedback from CARB to date)
    - The harmonized Canada / U.S. working group (CANENA) for commercial refrigeration safety standard started evaluation of IEC 60335-2-89 and initiated 2H 2019
    - ASHRAE 15 commercial refrigeration upgrades are starting soon

\* Public Workshop on Rulemaking Proposal: High Global Warming Potential Refrigerant Emissions Reductions California Air Resources Board October 24-25-17  
[https://ww3.arb.ca.gov/cc/shortlived/meetings/10242017/public\\_workshop\\_snap-california\\_10-24-17\\_presentation.pdf?\\_ga=2.182187808.621576105.1573738237-276427812.1563094111](https://ww3.arb.ca.gov/cc/shortlived/meetings/10242017/public_workshop_snap-california_10-24-17_presentation.pdf?_ga=2.182187808.621576105.1573738237-276427812.1563094111)

# Regulatory Policy “Writing on the Wall”



- Millions of dollars in research internationally and in U.S.
- Safety standards development internationally and in U.S.
- AHRI Safe Refrigerant Transition Task Force developing training resources for organizations that would like to use it
  - A2L refrigerant training programs already in place in Europe, Australia, and Japan; several companies are training in the U.S.
  - Several companies have already started training technicians in the U.S.

# Transition to Low-GWP Refrigerants

## What's the same?

- The majority of the physical and chemical properties of these new Class A2L refrigerants are no different from traditional A1 (CFC, HCFC, and HFC) refrigerants



## What's different?

- Low-GWP refrigerants include some lower flammability (Class A2L) and higher toxicity refrigerants

## What do I need to do about it?

- Stakeholders must be aware of and properly trained in the mitigation of risks due to the lower flammability or higher toxicity properties associated with the new refrigerants

# ASHRAE 34 and ISO 817 Refrigerant Classification

Increasing Flammability 	Higher Flammability	<b>A3</b>	<b>B3</b>
	Lower Flammability	<b>A2</b>	<b>B2</b>
		<b>A2L</b>	<b>B2L</b>
	No Flame Propagation	<b>A1</b>	<b>B1</b>
	Lower Toxicity	Higher Toxicity	
	Increasing Toxicity 		

<u>Class 3 Requirements</u> 1. Exhibit flame propagation @ 60°C & 101.3 kPa 2. $LFL \leq 0.10 \text{ kg/m}^3$ or $HOC \geq 19,000 \text{ kJ/kg}$
<u>Class 2 Requirements</u> 1. Exhibit flame propagation @ 60°C & 101.3 kPa 2. $LFL > 0.10 \text{ kg/m}^3$ 3. $HOC < 19,000 \text{ kJ/kg}$
<u>Class 2L Requirements</u> 1. Same as Class 2 requirements & $S_u \leq 10 \text{ cm/s}$
<u>Class 1 Requirements</u> 1. No flame propagation @ 60°C & 101.3 kPa



# Refrigerant Concentration Limit (RCL)

- Refrigerant Concentration Limits are used to determine the maximum concentration limit allowed in an occupied space of a refrigerant
  - The RCL is based on either toxicity or flammability (lower flammability limit) or both.

## What's the same?

- RCLs are still used to determine allowed concentrations in occupied spaces
- Mitigation is required at a percentage of the RCL as determined by safety standards

## What's different?

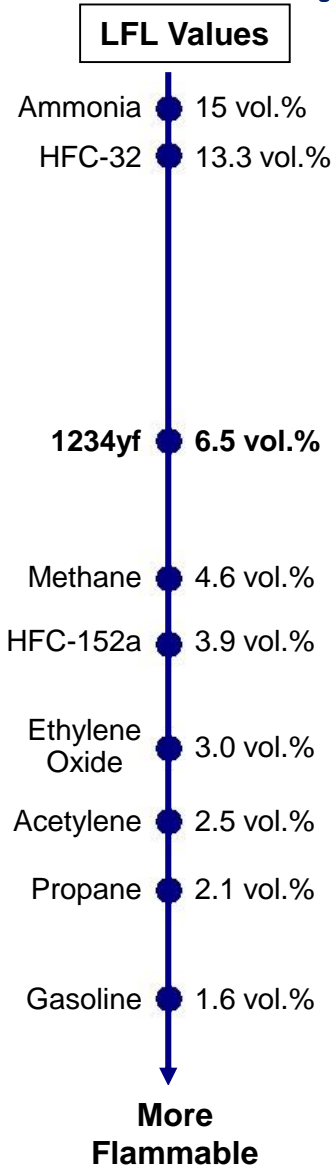
- R-410A has an RCL of 140,000 ppm
- Low global warming potential replacements for air conditioning have RCLs between 30,000 and 50,000 ppm.

## What do I need to know?

- Mitigation will be needed if 25% of LFL is reached.
- Refrigerants with RCLs based on toxicity limits may required similar mitigation



# ASTM E-681: Flammability Limits

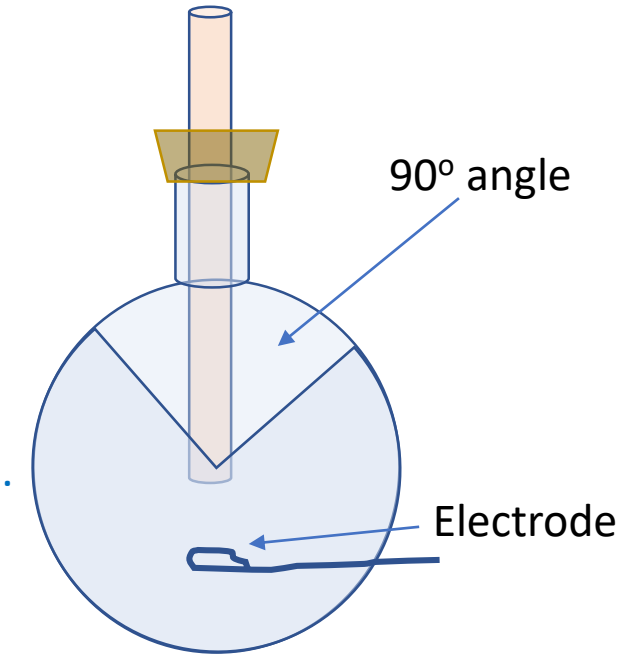


## Apparatus

- 12L glass flask
- Ignition- 15 kV/30 ma, 0.4 sec duration

## Testing

- 23°C and at 60°C, with RH of 50%  $\pm$  0.1% at 23.0°C.
- Absolute humidity of air-0.0088 grams H<sub>2</sub>O/dry air @ 23°C.
- Tested increments of 1 vol % or less of refrigerant in air.

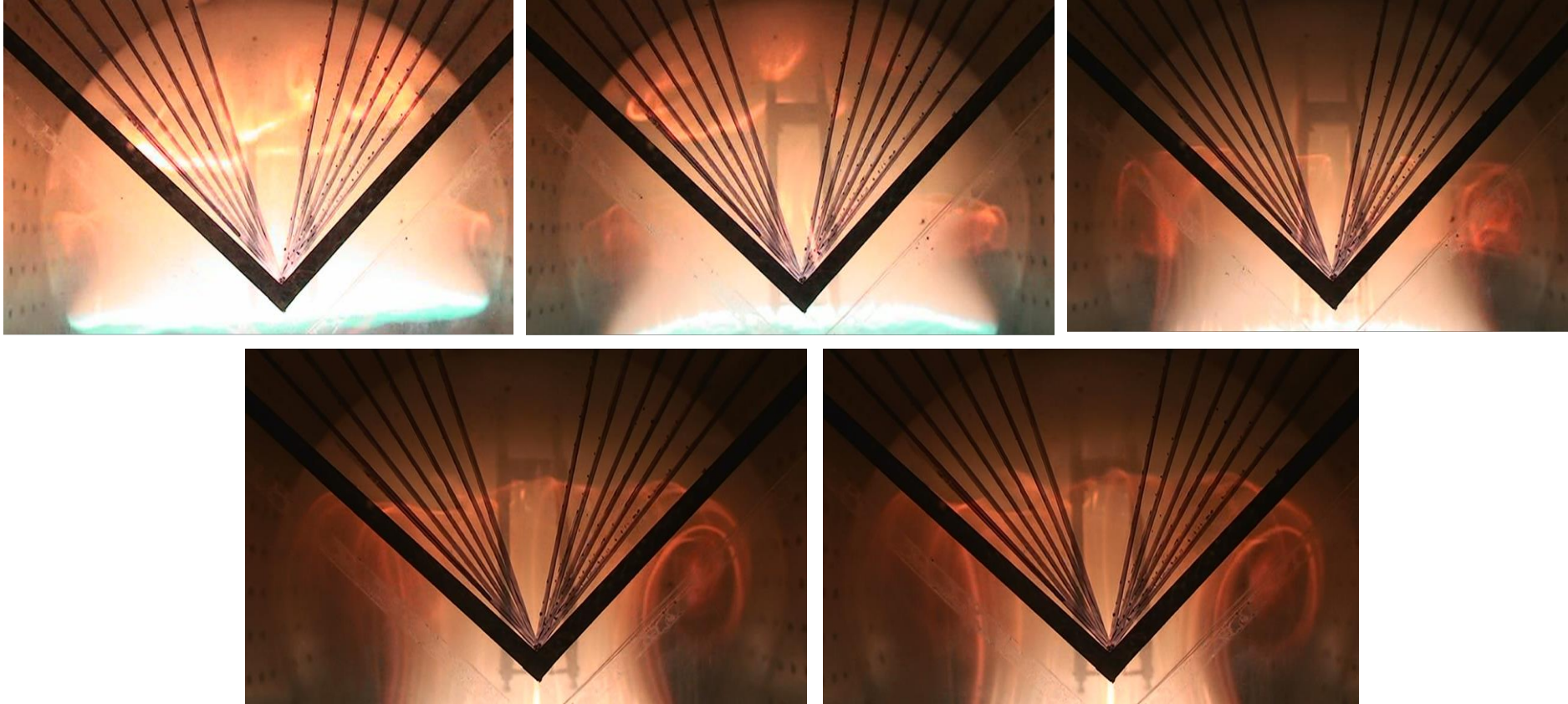


## Lower Flammability Limits (LFL)

LFL R-32 (A2L) = 14.4%

LFL Propane (A3) = 2.1%

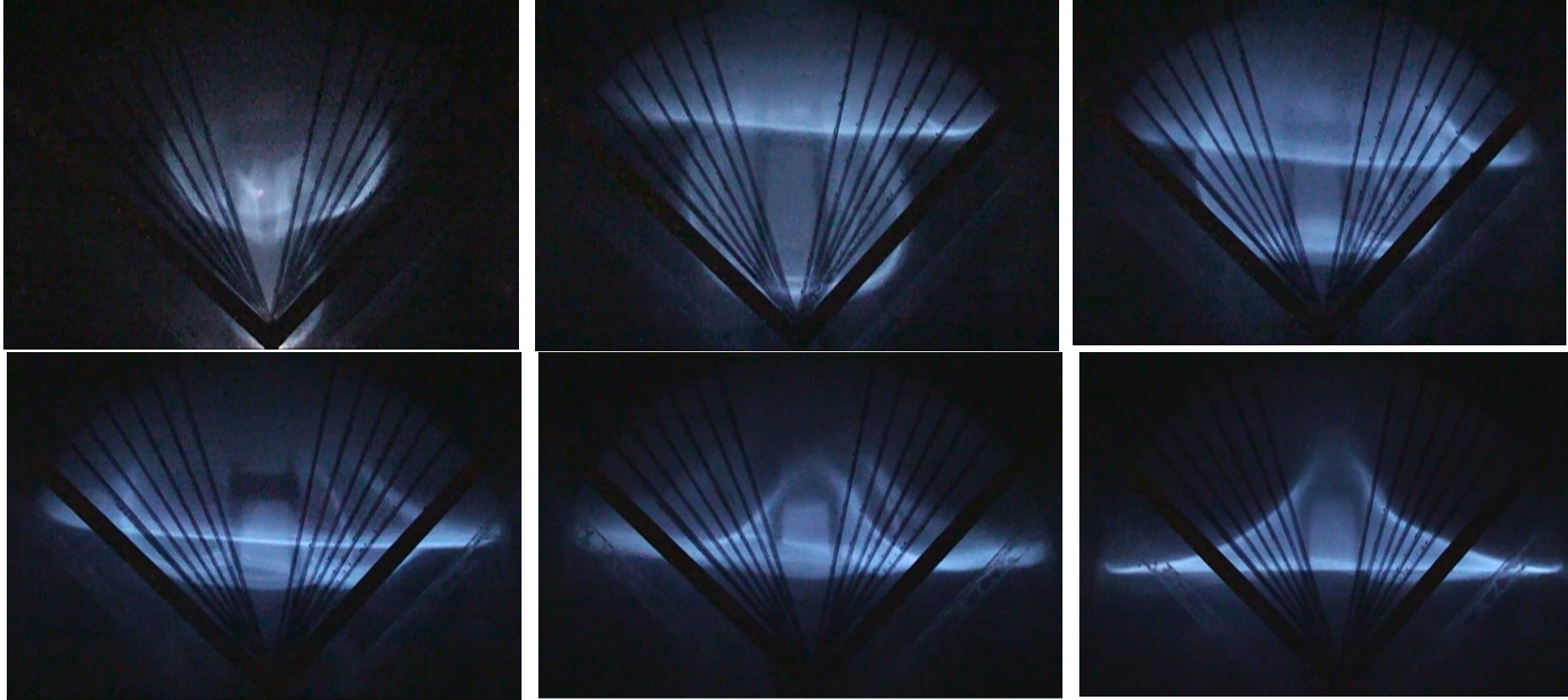
# ASTM E681- Class 3



The flame must be a solid flame stretching out over a 90 degree span. If the flame breaks on one side or the other only the largest degree span is counted.

Class 3 has addl parameters (LFL<0.1kg/m<sup>3</sup> and HOC> 19,000kJ/kg)

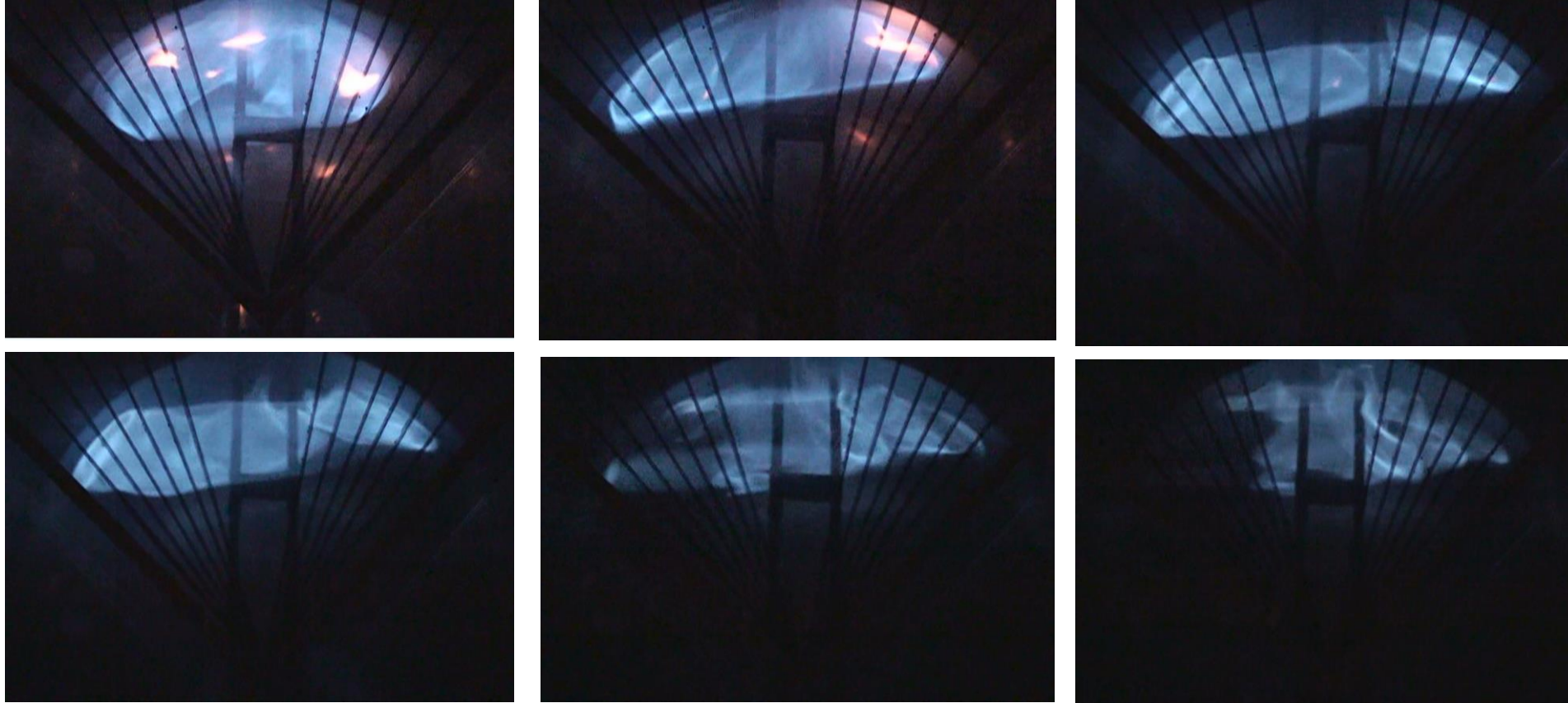
# ASTM E681- Class 2



The flame must be a solid flame stretching out over a 90 degree span. If the flame breaks on one side or the other only the largest degree span is counted.

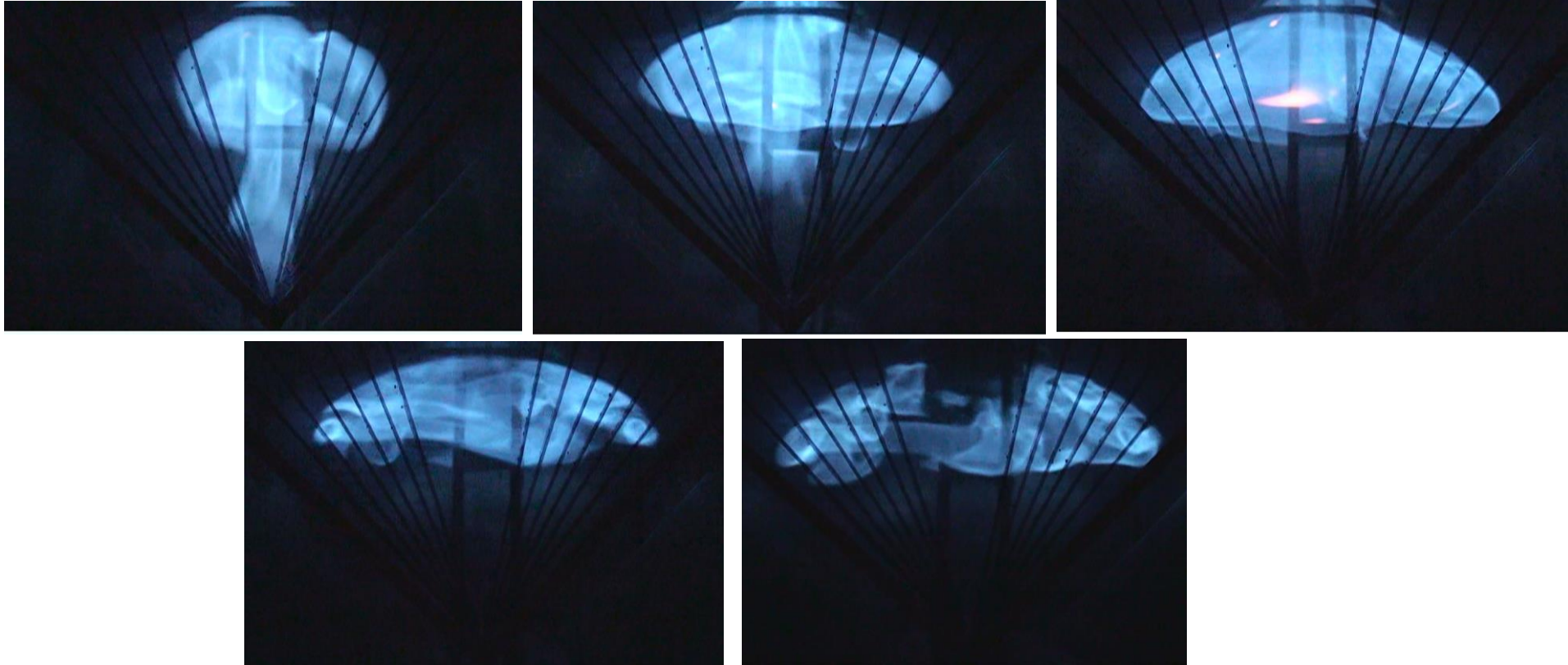
Class 2 has addl parameters (LFL>0.1kg/m<sup>3</sup> and HOC <19,000kJ/kg)

# ASTM E681- Class 1 – Non-Flammable



The flame must be a solid flame stretching out over a 90 degree span. If the flame breaks on one side or the other only the largest degree span is counted.

# ASTM E681- Class 2L



The flame must be a solid flame stretching out over a 90 degree span. If the flame breaks on one side or the other only the largest degree span is counted.

Class 2 has addl parameters ( $BV < 10 \text{ cm/sec}$ ,  $LFL > 0.1 \text{ kg/m}^3$  and  $HOC > 19,000 \text{ kJ/kg}$ )

# Safety Standards Updated Based on Extensive Research

- More than a decade of research is available from testing for Japan and Europe
  - Nearly \$7 million has been invested in the U.S. to understand low-GWP refrigerants
- Research informed conservative modifications to safety standards. For example:
  - Test results from AHRI research showed that a sensor trip time of 30 seconds was not fast enough for residential units, so a shorter period is required in the safety standard
  - The charge size for cord-connected equipment was reduced in the U.S. and Canada by 50%
  - Isolation valves are now required for VRF systems and refrigerant leaks
  - Refrigerant charge for A2 and A3 refrigerants in appliances was reduced to 114 g from 150 g approved by EPA compared to Europe which just approved 500 g
- Research also showed that the MIE of common household items like electric heaters do not ignite the A2L refrigerants
- Current research all over the world will support optimization for future products



# Extensive 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
- 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

## • Modeling

- ASHRAE-1806: Flammable Refrigerants Post-Ignition Simulation and Risk Assessment Update
- ORNL: Investigate the Proper Basis for Setting Charge Limits of A2L, A2, and A3 for Various Types of Products
- NIST: Modeling tools for low-GWP Refrigerant Blends Flammability

## • 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

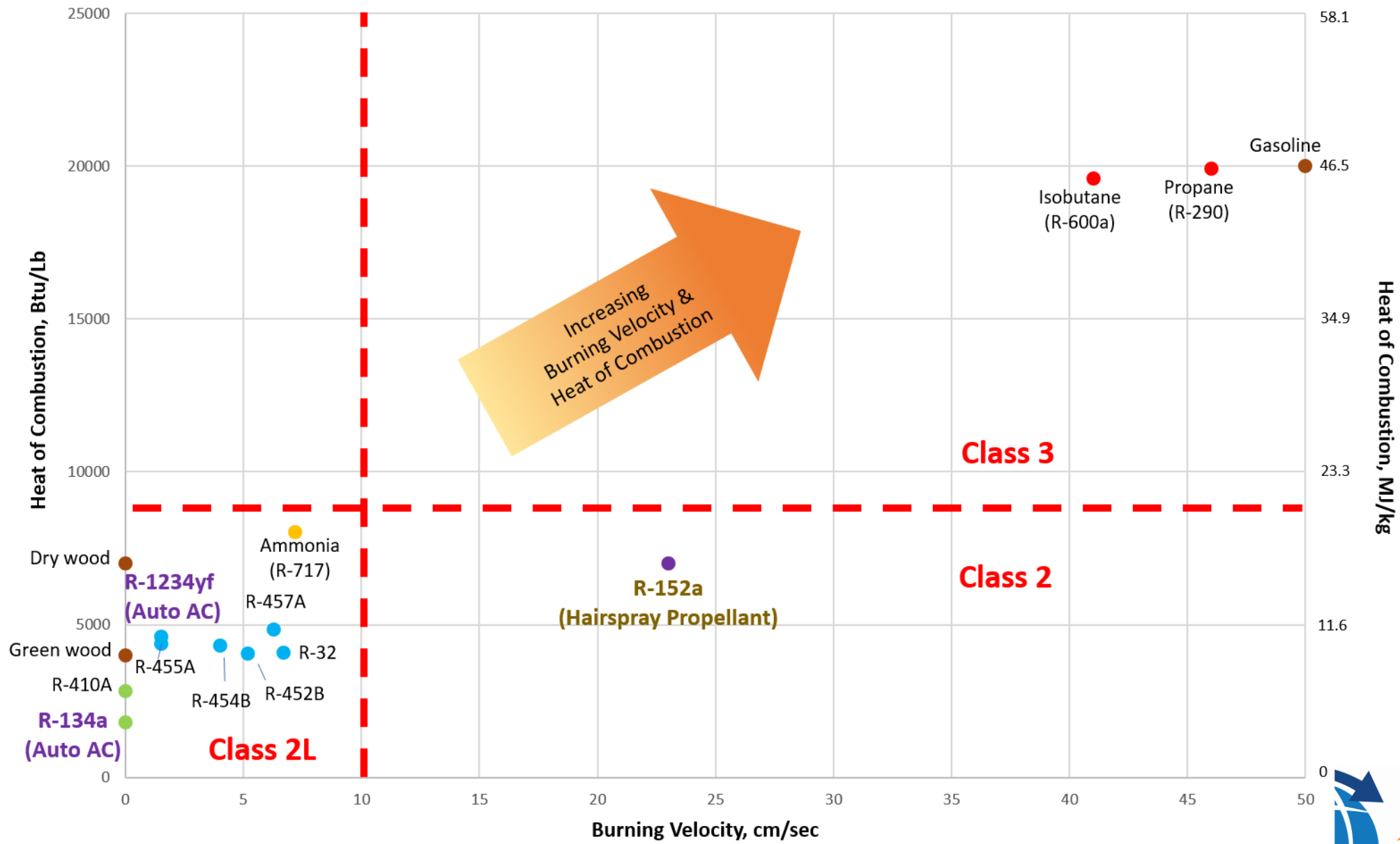
## • Detection

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





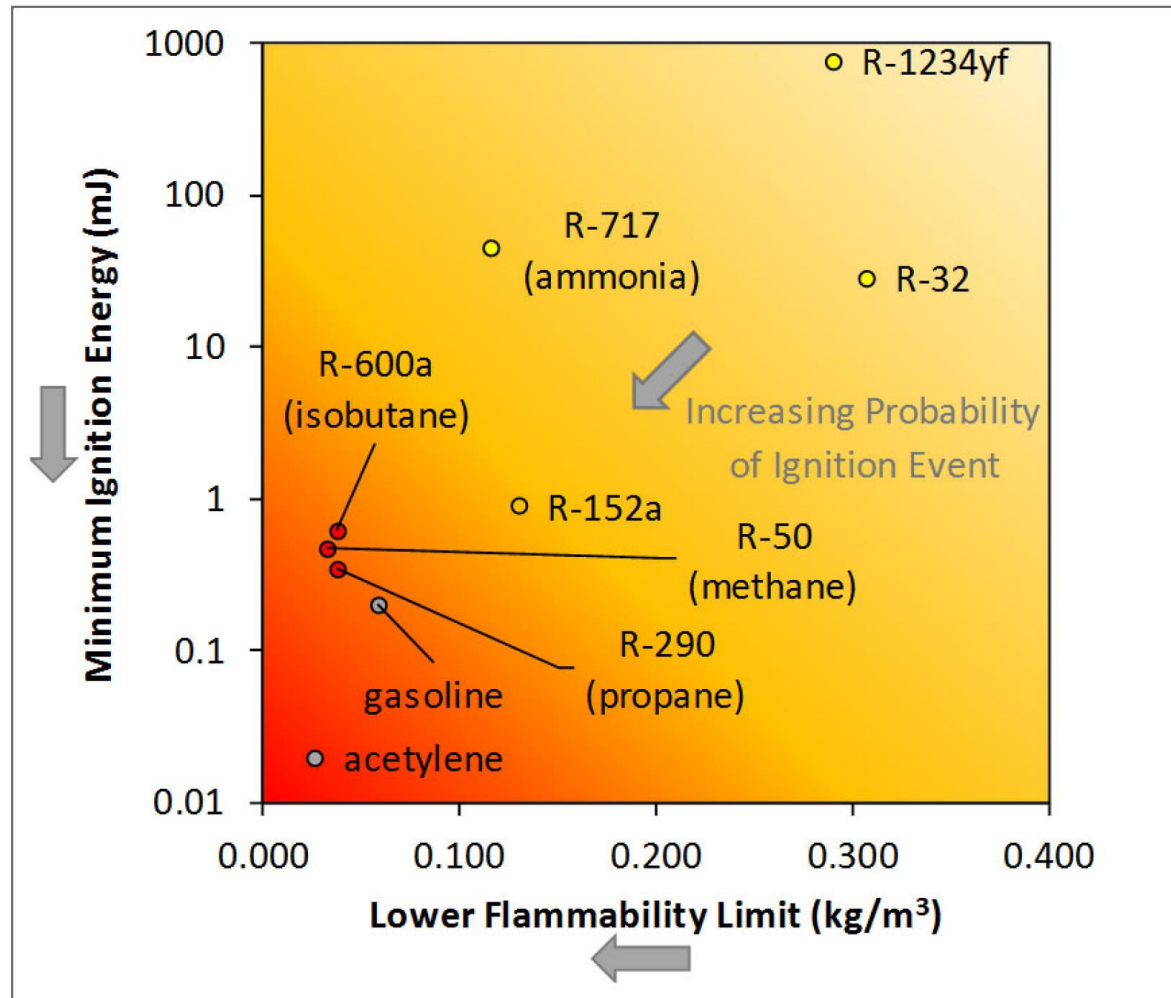
# Flammability Properties



● A3 ● A2 ● B2L ● A2L ● A1 ● Fuels



# Flammability – Minimum Ignition Energy (MIE)



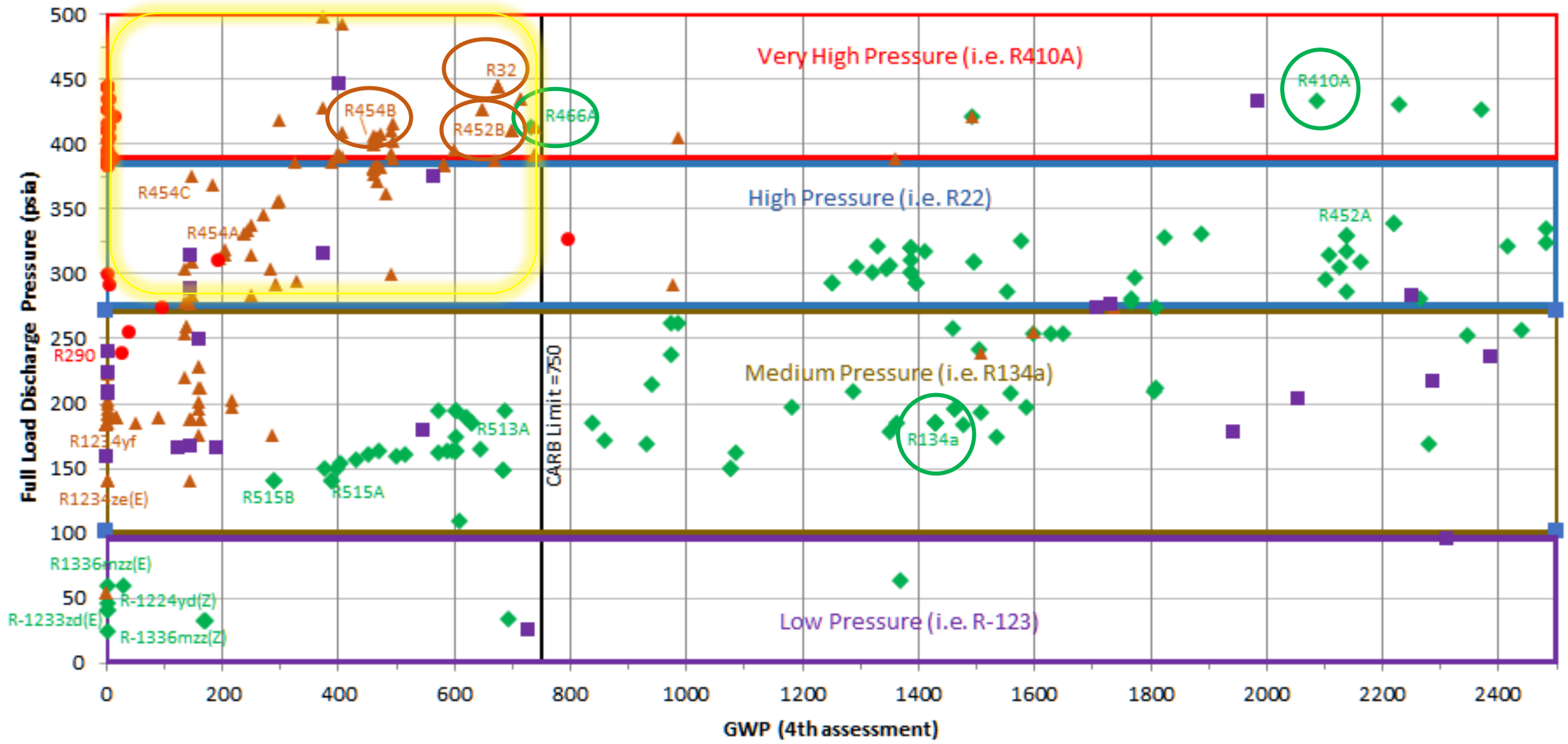
- Hydrocarbons require relatively low energy levels to ignite
- MIEs of A2Ls are much higher than hydrocarbons
- Many potential ignition sources for hydrocarbons (e.g., static spark) will not ignite A2Ls
- Many common household items (toasters, electric heaters, etc.) will not ignite A2Ls

# Key Points About the Transition

- Most of the basic chemical/physical properties of next-generation refrigerants are very similar to previous generation (CFC/HCFC/HFC) refrigerants
  - Many new refrigerants are blends which include refrigerants that are currently part of Class A1 refrigerant blends (e.g., R-410A is 50% R-32, a Class A2L refrigerant)
- Compared to propane and natural gas, A2L refrigerants have much lower flammability risk due to:
  - Higher Lower Flammability Limit – Higher concentration to become flammable
  - Higher Minimum Ignition Energy – harder to ignite
  - Lower Heat of Combustion – less energy released if burned
  - Lower Burning Velocity – more difficult for flames to spread
- Flammability risks from A2L refrigerants will be mitigated by a variety of equipment design changes, applicable codes and standards, and training of installers and service technicians
- Class A2L refrigerants are already being used safely
  - Global auto industry (including U.S. and Canada)
  - Air conditioning and refrigeration equipment in the European Union, Australia, Japan, Thailand and other countries
  - Small appliances as approved by the Environmental Protection Agency (EPA)

LFL R-32 (A2L) = 14.4%  
LFL Propane (A3) = 2.1%

# Future Refrigerant Options for Residential and Light Commercial



◆ A1      ▲ A2L      ■ A2      ● A3

# Refrigerant Safety Classifications Properties

Refrigerant	Components Composition%	Safety Classification ASHRAE 34	Exposure Limit (RCL)	GWP (4th)	Operating Pressure @ 120 F SDT	LFL nominal composition	UFL nominal composition	Burning Velocity (Su)	Minimum Ignition Energy (MIE)	Heat of Combustion (HOC)	Auto Ignition Temperature (AIT)	Hot Surface Temperature (HOC)
			ppm	CO <sub>2</sub> e	psia	% v/v	% v/v	cm/sec	mJ	KJg	°C	°C
R-410A	R-32/R-125 50/50	A1	140,000	2,088	433.6	-	-	-	-	5.91	>750	-
R-134a	1,1,1,2-tetrafluoroethane 10000%	A1	50,000	1,430	185.9	-	-	-	-	?	>750	-
R-404A	R-125/R-134a/R-143a 44/4/52	A1	126,000	3,922	325.8	-	-	-	-	?	<750	
R-466A	R-32/R-125/CF3I 49/11.5/39.5	A1	30,000	733	412.6	-	-	-	-	?	?	
R-513A	R-134a/R-1234yf 44/56	A1	72,000	629	184.98	-	-	-	-	?	?	
R-1234yf	2,3,3,3-tetrafluoropropene 100%	A2L	16,000*	0.31	185.0	6.20%	12.30%	1.5	8000	10.7	405	700
R-32	difluoroemethane 100%	A2L	36,000*	675	444.0	14.4%	29.30%	6.7	21-24	9.38	648	700
R-452B	R32/R125/R1234yf 67/7/26	A2L	30,000*	697	410.1	11.9%	21.60%	3.3	100-300	9.45	?	700
R-454B	R-32/R-1234yf 68.9/31.1	A2L	30,000*	465	405.5	11.8%	21.50%	5.2	100-300	10.3	?	700
R-152a	1,1 difluoroethane 100%	A2	12,000*	124	166.1	4.80%	8.0%	23	0.38	16.3	455	355
R-290	propane 100%	A3	5,300*	3.30	242.5	2.10%	9.5%	46	0.25	46.3	470	370



# Safety Standard Safe Application of A2L Refrigerant Approach

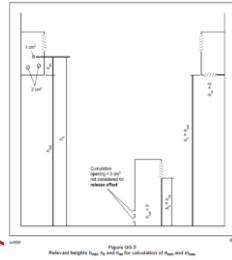
- There has been confusion concerning the safety standard and how they are intended to be used
- The overall approach involves the following for direct systems (residential and light commercial);
  0. Fundamental Approach is to prevent ignition and combustion (Baseline strategy)
  1. Control of competent ignition sources and isolation from flammable refrigerants
  2. Refrigerant Charge limits (m1, m2, m3) combined with item 7
  3. Refrigerant Piping Design qualification and protection
  4. Labeling and Literature
  5. Factory Installed UL60335-2-40 application approved Refrigerant Detectors in all units above m1 charge
  6. Active mitigation using circulation and dilution (not just an alarm like fire and smoke detectors)
  7. Minimum occupied area ( $A_{min}$ ) checks combined with charge limits in item 2
  8. Service Training and Education and likely technician certification

# Safe Application of A2L Refrigerants Summary

UL60335-2-40 3<sup>rd</sup> Edition Summary for a **Residential Ducted Unit (direct system)** A2L Refrigerant Requirements

## Minimum Area Check ( $A_{min}$ )

- Safety factor of 4
- Or safety factor of 2 with additional measures
- Per Annex GG

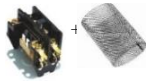


## Service Training and Education Annex DD, Annex HH



## Ignition Source Isolation

Per UL 60335-2-40 Annex FF



## No Competent Ignition Sources in unit and ducts

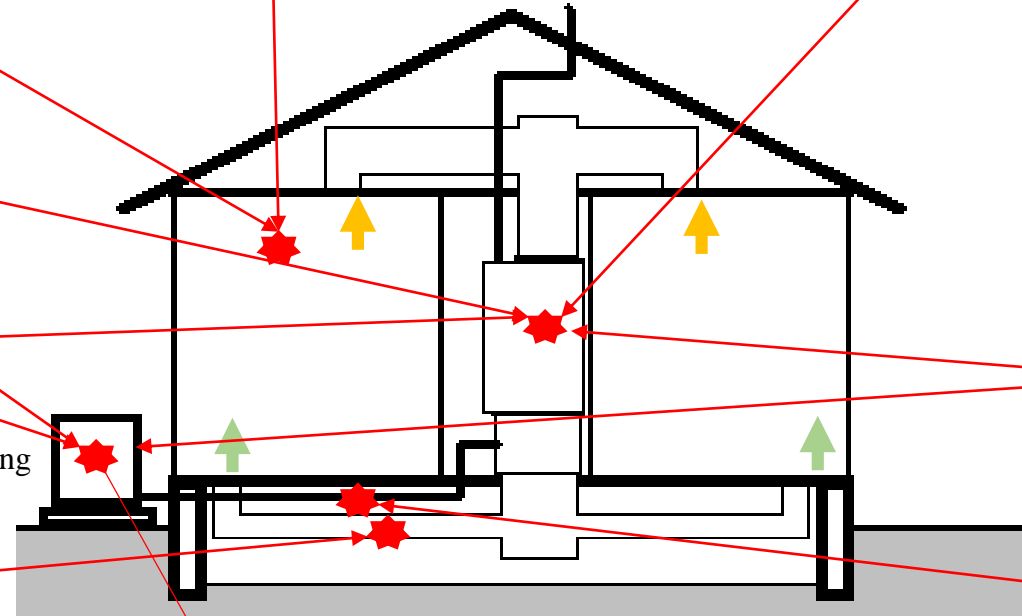
Per 22.116, Annex KK, 22,117



## Active mitigation for leaks detect, circulate and dilute Annex GG



Residential Down Flow Air Conditioners with Gas Heat



## Factory Installed Refrigerant Detector

- UL60335-2-40, IEC60079-29-1 and Annex LL, Annex MM
- UL qualification testing
- UL approved
- Safety Circuit approved
- Factory Calibrated
- Self Test Routine (one time/hr.)
- Fail safe mode with fan on
- Field inspection enable feature



## Labeling and Literature

Per UL60335-2-40 Per 101, Annex DD



## Refrigerant Piping (UL60335-2-40)

Per 22.116, 101.DVG

- Protected lines
- Qualified joints (ISO 14903)
- Field pressure test
- Additional requirements for VRF

## Refrigerant Charge Limits (UL60335-2-40)

m1, m2, m3 per Annex GG1.2  
 R-32 m1=4.1 lbs., m2=26.8 lbs., m3=134.1 lbs.  
 R-454B m1= 4.0 lbs., m2= 26.0, m3=130.2 lbs.

# Storage

- National Fire Safety Storage Requirements

- Permit from fire code official

- Hazardous Materials Management Plan
    - Hazardous Material Inventory Statement

- Requires visible hazard identification signs (NFPA 704 sign)

- No smoking signs

- No open flames or high temperature devices (could include warehouse heaters)

- Empty tanks/cylinders (Heels)

- Must be free of residual material and vapor before storage for reuse

- Safety Data Sheets

- SDS must be available on site

- Upright storage

- Exception for nonflammable gases secured to a pallet



Sample NFPA 704 Sign





# Service Training

- There has been confusion about service training availability
- UL 60335-2-40 includes a new annex DD which outlines requirements for servicing and service training for use of A2L refrigerants.
- In addition the UL60335-2-40 includes another new annex HH defining requirements for competent service personnel
- Contrary to the confusion, a local installer and AHJ **does not have to buy** and understand UL60335-2-40, because the standards requires that the service and installation instructions for the product include the requirements of Annex DD, so they will be provided with the product. Annex DD is an outline of the requirements.
- Service training exists and the Nate Exam was developed over a year ago but was **placed on hold in the US as service firms indicated they were not ready to start training** as the first likely installations were to be in 1/1/2023 and that was 4 years away. Instead Nate moved their focus to Europe and developing countries that were ready to be trained and were beginning to use A2L and A3 refrigerants.
- Globally the industry has developed significant training material in Europe, Japan, Australia, and Canada and more is in process including work by the AHRI Safe Transition Task Force.
- Manufacturers are also updating their training programs for both in-person hands on training and for on-line training classes.
- Target audiences include: First Responders, Installers, Service Technicians, Certification/Licensing groups, AHJ's/Code officials, Property Owners, Engineers/Architects/Builders, Wholesale Distributors, Industry Organizations and shipping firms

Bottom line Service Training is well underway and has been started earlier than prior refrigerant regulatory induced changes (i.e. R22 to R-410A in 2010)

# UL60335-2-40 DD.9 Servicing Refrigerant System Summary - Example

Safety training is a key issue and requirements have been included in the 3<sup>rd</sup> Edition and is required for new installation instruction

The following is an example showing the revisions for A2L and A2/A3 refrigerants servicing

Requirement	A1	A2L	A2&A3	Comment
Safely Remove Refrigerant following local and national codes	Required	Required	Required	EPA Rule 608, which requires recovery except for Natural refrigerants
<b>Purge Circuit with Inert gas (i.e. oxygen free nitrogen)</b>	Not required	<b>Required</b>	Required	Repeat as necessary
<b>Evacuate</b>	Not required	<b>Required</b>	Required	Insure outlet of pump is not near an ignition source
Purge with Inert Gas for 5 min	Not required	Optional	Required	Second purge
Evacuate again	Not required	Optional	Required	Included in Annex HH
Open the circuit by cutting or brazing	Final step	Final step	Final step	Final repair preparation. Should also state not to leave the system open for long periods
Repair the systems and for brazing purge with nitrogen during brazing	Required	Required	Required	Included in Annex HH
<b>Leak Test and Pressure Test the unit</b>	Not required	<b>Required</b>	Required	Part of DD.10
Evacuate the system	required	required	required	Follow industry practices for evacuation
Charge the system (See DD.10)	required	required	required	See DD-10 and mfg. charging procedures

# Summary

- World is transitioning to low-GWP refrigerants, including A2L mildly flammable refrigerants.
- 9 U.S. states and Canada are actively pursuing phasedown of HFC refrigerants, with California considering proposals for actions starting as early as 2022 (commercial refrigeration).
- AHRI Safe Refrigerant Transition Task Force is actively working to provide training and other resources to help ensure a safe North American transition to A2L refrigerants.
- A1 and A2L refrigerants have similar outcomes if equipment is involved in a fire.
- Extensive research on A2L flammability has been conducted since 2006.
- Results of this research has now been incorporated into approved standards: UL 60335-2-40, 3<sup>rd</sup> ed. and ASHRAE 15.
- Service training materials are already in place in regions/countries outside U.S. where A2L refrigerants are already in active use.

# Additional Information

Task Group	Description
0	Overall Task Force
1	Installation Operation and Maintenance
2	Codes and Standards * Codes and Standard for AC * Codes and Standards for Commercial * Refrigeration/Transport * Equipment Design
3	Bulb Storage/Manufacturing Facilities
4	DOT, Shipping/Packaging and Handling/Warehouse
5	Recovery, Reclaim, and Destruction
6	Communications * Interaction with Energy Efficiency * Public Documents * Website
7	Safety Training * Technical Training * First Responders Training * Building code inspectors (AHJ) * Others

- AHRI Safe Refrigerant Transition Task Force has 7 working groups open to volunteers
- Task force is working on communications, training materials and information related to the new regulations and safe use of flammable refrigerants
- Visit [www.ahrinet.org/SafeRefrigerant](http://www.ahrinet.org/SafeRefrigerant) for more information



# Thank You for Joining Us!

- Visit the Safe Refrigerant Transition Task Force page - in the Policy section of the AHRI website - for more information:  
<http://www.ahrinet.org/SafeRefrigerant>
- Note the Terms of Use referenced in this presentation, listed under Resources:  
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