# Safe Refrigerant Transition to lower Global Warming Potential Refrigerants

# A2L Safety Standards for Direct Residential Systems

# Standards Goal: Prevent Ignition

- In order for a refrigerant ignition to occur, there must be 2 failures:
  - The refrigerant leak must exceed the lower flammability limit (LFL) and be lower than the Upper Flammability Limit *
    - ➢10 to 14%  LFL concentration
    - ➢Large refrigerant release
  - There must be a “competent” ignition source (minimum ignition energy) in an area that exceed LFL
    - ➢Open flame or very high energy ignition source
- Goal of the standards:
  - Prevent the LFL concentration from being reached
    - ➢Refrigerant charge limits or mitigation requirements
    - ➢Mitigation may include circulation or ventilation to reduce refrigerant concentration
  - Remove “competent” ignition sources

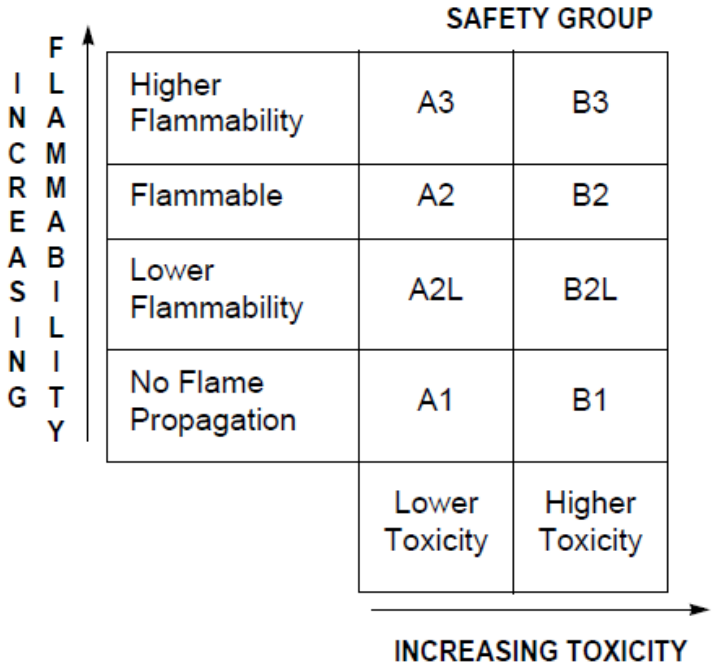
# How do the relationship between charge limit and room size impact safety?

1. **$m_1$**
2. **6 times LFL**
3. Maximum capacity
4. **Room size**

# Refrigerant Charge Limits – Current Requirements

There may be confusion about charge limits with the use of the new lower flammability A2L refrigerants as well as current A1 refrigerants

- Current refrigerants are mainly classified as A1 where the “A” is used to define level of toxicity and
  “1” is used to define level of flammability.
- “A” or the first character, is the toxicity classification two classes being used to define exposure limits using the OEL limit
  - Class A refrigerants have an OEL of 400 ppm or greater.
  - Class B refrigerants have an OEL of less than 400 ppm.
  - OEL is the occupational exposure limit. It is the time-weighted average (TWA) concentration for a normal eight-hour workday and a 40-hour workweek to which nearly all workers can be repeatedly exposed without adverse effect, based on the OSHA PEL, ACGIH TLV-TWA, TERA OARS-WEEL, or consistent value.
- “1” or the second character is used to define flammability
  - “1” No flame propagation when tested at 140°F and 14.7 psia
  - “2L” Flame propagation when tested at 140°F and 14.7 psia and LFL > 0.0062 lb/ft3 and heat of combustion < 8,169 Btu/lb and burning velocity when tested at 73.4°F 14.7 psia in dry air 2, and3 are also used and have a greater flame propagation metrics



# Refrigerant Charge Limits – Current Requirements

- Most refrigerants are heavier than air and safety standards include requirements to protect against exposure and asphyxiation and the safety standards like ASHRAE 34, and ASHRAE 15 use the refrigerant concentration limit (“RCL”) as defined by ASHRAE 34.
- The refrigerant concentration limit, in air, determined in accordance with ASHRAE 34 is intended to reduce the risks of acute toxicity, asphyxiation, and flammability hazards in normally occupied, enclosed spaces.
- The refrigerant concentration limit (RCL) for each refrigerant is the lowest of the following;
  1. Acute Toxicity Exposure Limit (ATEL) which is the lowest of the Mortality exposure test results, Cardiac Sensitization tests, , Anesthetic or Central Nervous System Effects test results, or Escape Impairing Effects and Permanent Injury results
  2. Oxygen Deprivation Limit (ODL)
  3. Flammable Concentration Limit (FCL)
- ASHRAE divides refrigeration systems into two main classification based on the method employed for extracting or delivering heat to the building space.
  - Direct System - is one in which the evaporator or condenser of the refrigerating system is in direct contact with the air or other substances to be cooled or heated.
  - Indirect System - is one in which a secondary coolant cooled or heated by the refrigerating system is circulated to the air or other substance to be cooled or heated.  There are further subclasses
- The RCL limits is used to determine the charge limits for the direct and indirect applications and is also used for the new A2L refrigerants with some additional requirements.

# Refrigerant Charge Limits – Current Requirements

- For direct systems, ASHRAE 15 requires that each application be checked for the concentration of refrigerant in a complete discharge of each independent circuit of high-probability systems shall not exceed the RCL limits.
- The requirements for space volume are defined in section 7.3 and state that the volume shall be based on the volume of space to which refrigerant disperses in the event of a refrigerant leak.  It includes additional requirements for;
  - Non-connecting Spaces
  - Ventilated Spaces
  - Plenums
  - Supply and return ducts

- The requirements for machine rooms defined requirements for ventilation and the use of sensors with the ventilation being $100^* G^{0.5}$
- **Machines rooms are required when the charge exceeds the RCL limits for the space**

# Refrigerant RCL Limits

| Refrigerant | Classification | RCL |
|---|---|---|
| R-410A | A1 | 140,000 |
| R-134A | A1 | 50,000 |
| R-407C | A1 | 81,300 |
| R-466A | A1 | 30,000 |
| R-513A | A1 | 72,000 |
| R-32 | A2L | 36,000* |
| R-452B | A2L | 30,000* |
| R-454B | A2L | 30,000* |

* RCL is based on 25% of the LFL

# Refrigerant Charge Limits – What is New

**Machine Rooms**

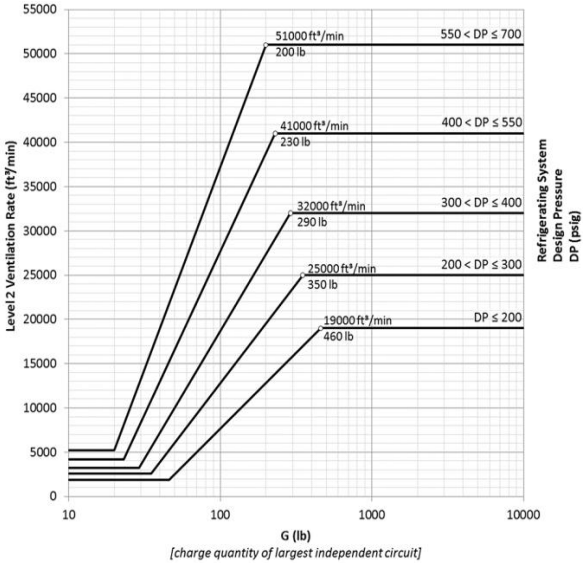
- The A2L refrigerants modifications for machine rooms was completed in ASHRAE 15 addendum h which revised the ventilation requirements for A2L refrigerants based on research and testing done by the industry.

- Note, that UL60335-2-40 does not address ventilation requirements and allowable charge levels for machine rooms and just addresses the requirements for the equipment.  UL60335-2-40 refers to ASHRAE 15-2019 for machine rooms charge levels and ventilation.

- The new ASHRAE 15 requirements call for higher ventilation levels that are a function of charge and operating pressure as shown in the figure

- <u>The requirements for A2L were not directly adopted in the CMC but table 1106.2.5.2 was modified based on the ASHRAE 15 procedures</u>

ASHRAE 15-2109




California Mechanical Code

TABLE 1106.2.5.2
REQUIRED AIRFLOW FOR GROUP A2L REFRIGERANTS

| REFRIGERANT | MINIMUM AIR FLOW* (CFM) |
|---|---|
| R32 | 32 500 |
| R143a | 28 600 |
| R444A | 13 700 |
| R444B | 22 400 |
| R445A | 16 400 |
| R446A | 50 500 |
| R447A | 50 200 |
| R447B | 29 600 |
| R451A | 14 900 |
| R451B | 14 900 |
| R452B | 31 500 |
| R454A | 4290 |
| R454B | 6650 |
| R454C | 32 800 |
| R455A | 4770 |
| R457A | 31 400 |
| R1234yf | 16 500 |
| R1234zeE | 12 600 |

# Refrigerant Charge Limits – What is New

- For direct systems where the charge can be released into an occupied room UL60335-2-40 added new requirements for equipment that are more restrictive than the RCL limits defined in ASHRAE 15.
- This were based on the IEC60335-2-40 that is in wide use globally for the application of A2L refrigerants but for the US additional conservative requirements were added.
- ASHRAE 15 requires listed products so the requirements of UL60335-2-40 apply to the actual application and not just the design of the equipment
- The UL60335-2-40 requires both charge limits and additional requirements for the volume of the occupied space
- Charge limits are based on the m1, m2, and m3 charge level
- The volume limits are a function of the type of equipment and the air delivery system to the room.  For ease of application the volume limits are translated to floor area and there are additional restrictions on the allowable height of the room based on the application and air delivery system
- The details of the requirements are summarized in the following slide

# UL60335-2-40 Charge Limits - New

| Refrigerant Charge | Direct Systems | | | | Indirect Systems |
|---|---|---|---|---|---|
| | Indoor Space | | | Outdoors | |
| | Refrigerant charge and room area | Refrigerant charge and room area and additional requirements | Additional ventilation | | |
| $m_c<m_1$ | no room size restrictions but other mitigation requirements still apply | | | no area restrictions but there are additional limits in ASHRAE 15 | refer to ASHRAE 15 machine room requirements |
| $m_1<m_c\leq 2 \times m_1$ (No-fixed appliances) | not allowed | For non-fixed factory seal single package appliances **$m_{max}=0.25 \times A \times LFL \times 2.2$** | not allowed | | |
| $m_1<m_c\leq m_2$ | **$m_{max}=2.5 \times (LFL)^{(5/4)} \times h_o \times (A)^{1/2}$** and charge not to exceed $0.25 \times LFL \times h_o \times A$ | If the a fixed appliance fan is continuously operated or is initiated by a refrigerant detector system **$m_{max}= 0.25 \times LFL \times h_{ra} \times A$**<br><br>For units connected via air duct systems to one or more rooms **$m_{max}=.25 \times LFL \times 2.2 \times TA$** | When $m_c>m_{max}$ additional ventilation can be used with limits defined in the standard | | |
| $m_1<m_c\leq$ number of indoor units $\times m_2$, not to exceed $4 \times m_2$ indoor unit cooling capacity <35 kW | not allowed | For units employing multiple evaporators complying with enhanced tighness, with continuous fans and Qmin >135 x CAP, or non-continuous fans with sensors then **$m_{max}=0.25 \times A \times LFL \times 2.2$ and $A<250\ m^2$**<br><br>If one or two additional measures are used which includes, safety shut-off valves, alarms, or ventilation then | When $m_c>m_{max}$ additional ventilation can be used with limits defined in the standard | | |
| $m_1<m_c\leq m_3$ | Not allowed | If the a fixed appliance fan is continuously operated or is initiated by a refrigerant detector system **mmax= 0.25 xLFL x hra x A**<br><br>For units connected via air duct systems to one or more rooms **mmax=.25 x LFL x 2.2 x TA** | When $m_c>m_{max}$ additional ventilation can be used with limits defined in the standard | | |
| $m_c> m_3$ | Beyond the scope of UL60335-2-40. National standards apply | | | | |

# How are m1 A2L systems without sensors acceptable?

- M1 for A2L refrigerants (R-32 & R-454B) is ~ 4 lbs.
  - 3 lbs. of charge provides a capacity of 1 ton in small units
  - A one-ton air conditioner can cool **400 square feet per ton** of air conditioning capacity in an environment with higher humidity.
- 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.

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

- Note that mitigation requirements for ignition sources, labeling, and safe application are still required for m1 systems.
- AHRTI research examined m1 charged equipment

# Units with Less than $m_1$ Charge

- Per UL60335-2-40 units with a charge below $m_1$ are not required to have a refrigerant sensor, but must comply with all the other A2L requirements
- For a permanently installed units $m_1$ is 6 x LFL (about 4 lbs.) and for a portable and cord connected unit $m_1$ is 3 x LFL (about 2 lbs.)
- The LFL values for A2L lower flammability refrigerants are around .30 kg/m3 (0.187 lb/ft3)
- Typical small HVAC systems have a charge or around 3 lbs. per ton.
- This would translate into a space having 156 ft2/ton of capacity which is 256% the capacity that normally would be used for an occupied space
- Also the charge is very small at 4 lbs. for a permanently installed system and was further decreased to 2 lbs for cord connected and portable systems

# Room Size

- The approach used in the standards is to insure a minimum room size that can accommodate the refrigerant charge with a **safety factor of 4**. There are a few product and application specific exceptions

- The room area is a surrogate for room volume but for simplification the floor area was used with a maximum room height in UL60335-2-40 and ASHRAE 15.2P.

  - ASHRAE 15 instead uses the full room volume and RCL calculation which is not as restrictive but requires HVAC products to be listed.

  - ASHRAE 15.2 uses some simplification approaches for residential applications

  - There are some special requirements for VRF systems

  - The minimum room area is also a function of the application and air delivery system

  - There are also some special requirements for connected spaces/rooms

Sample Label

Minimum installation height – X ft
Minimum room area – X $m^2$ ($ft^2$)
Note: for minimum room areas at higher installation heights, see instructions (note is optional)

- The requirements will be part of the installation instructions and defined on a label on the unit

# Room Size Evaluation – UL60335-2-40

- The UL60335-2-40 standard used floor area as a surrogate for room volume with a maximum allowable height of 7.2 ft but may be lower based on release height. ASHRAE 15.2P is closely aligned with UL60335-2-40 but may be slightly more conservative due to some simplification revisions
- Requirements are defined in UL 60335-2-40 section GG.1.3

  For the purpose of determination of room area (A) when used to calculate the MAXIMUM allowable REFRIGERANT CHARGE ($m_{max}$) in an unventilated space, the following shall apply.

  The room area (A) shall be defined as the room area enclosed by the projection to the floor of the walls, partitions and doors of the space in which the appliance is installed.

  Spaces connected by only drop ceilings, ductwork, or similar connections shall not be considered a single space.

  For units mounted higher than 1.6 m, and in compliance with GG.2.2, spaces divided by partition walls which are no higher than 1.6 m shall be considered a single space.

  For FIXED APPLIANCES, rooms on the same floor and connected by an open passageway between the spaces can be considered a single room when determining compliance to Amin, if the passageway complies with all of the following.

  - It is a permanent opening.
  - It extends to the floor.
  - It is intended for people to walk through.

  For FIXED APPLIANCES, the area of the adjacent rooms, on the same floor, connected by permanent opening in the walls and/or doors between occupied spaces, including gaps between the wall and the floor, can be considered a single room when determining compliance to Amin, provided all of the following are met .

  - The space shall have appropriate openings according to GG.1.4.
  - The minimum opening area for natural ventilation $Anv_{min}$ shall not be less than the following:

$$Anv_{min} = \frac{m_c - m_{max}}{LFL \times 104} \times \sqrt{\frac{A}{g \times m_{max}} \times \frac{M}{M - 29}}$$

There are other detailed application requirements depending on the product and application. Also ASHRAE 15.2P and ASHRAE 15 have some variations on the rules for calculation room size but UL60335-2-40 is the most conservative

# Maximum Room Size – (details)

- The approach of the UL60335-2-40 and ASHRAE 15.2P standard is to define a minimum room area tied to the refrigerant charge of the product per refrigerant circuit. ASHRAE 15 uses a similar approach based on RCL which is 25% of the LFL and the room volume instead of floor area
- The standard requires a label be placed on the unit defining the minimum floor area.
- The standard also requires that the charge label be updated for additional charge adding during installation for split system longer line sets
  The minimum floor area is intended to a surrogate for the room volume but was simplified for enforcement and also includes limits on the allowable height of the space plus the release height of the product.
- The UL Standard is used in product design, testing and certification by the manufacturers. Details on the product specific requirements for room area will be defined in the literature for the products and on a label on the units as shown
- The minimum area is a function of the product and application and there are additional prescriptive requirements and are based on a safety factor of 4 except for some special requirements for VRF when used with additional measures.
- UL60335-2-40 Amin Requirements depend on the application and unit type and are summarized below and outlines in the flowchart on the following page. Application app's are also being developed and training information and Users Guide.
  - Fixed Appliances with no ductwork (GG2.1) - $A_{min} = (m_c / (2.5 \times (LFL)^{5/4} \times h_o)^2$
  - Fixed Applainces with Ductwork (GG.9) – $TA_{min} = mc / (0.25x\ LFL \times hra)$
  - Ventilated (GG.8) – $Anv_{min} = 0.14 \times (m_c \times 0.04/LFL)^{0.5}$
  - Non-fixed Appliances (GG.7) – Amin = mc / (0.25x LFL x hra)
  - Ducted Units with Sensor (GG9.3) or continuous fan (GG9.2) – $TA_{min} = m_c / (0.25x\ LFL\ x\ h_{ra})$
  - Multisplit Requirements (Annex 101 DVG) - $A_{min} = m_c / (0.50x\ LFL\ x\ h_{ra})$

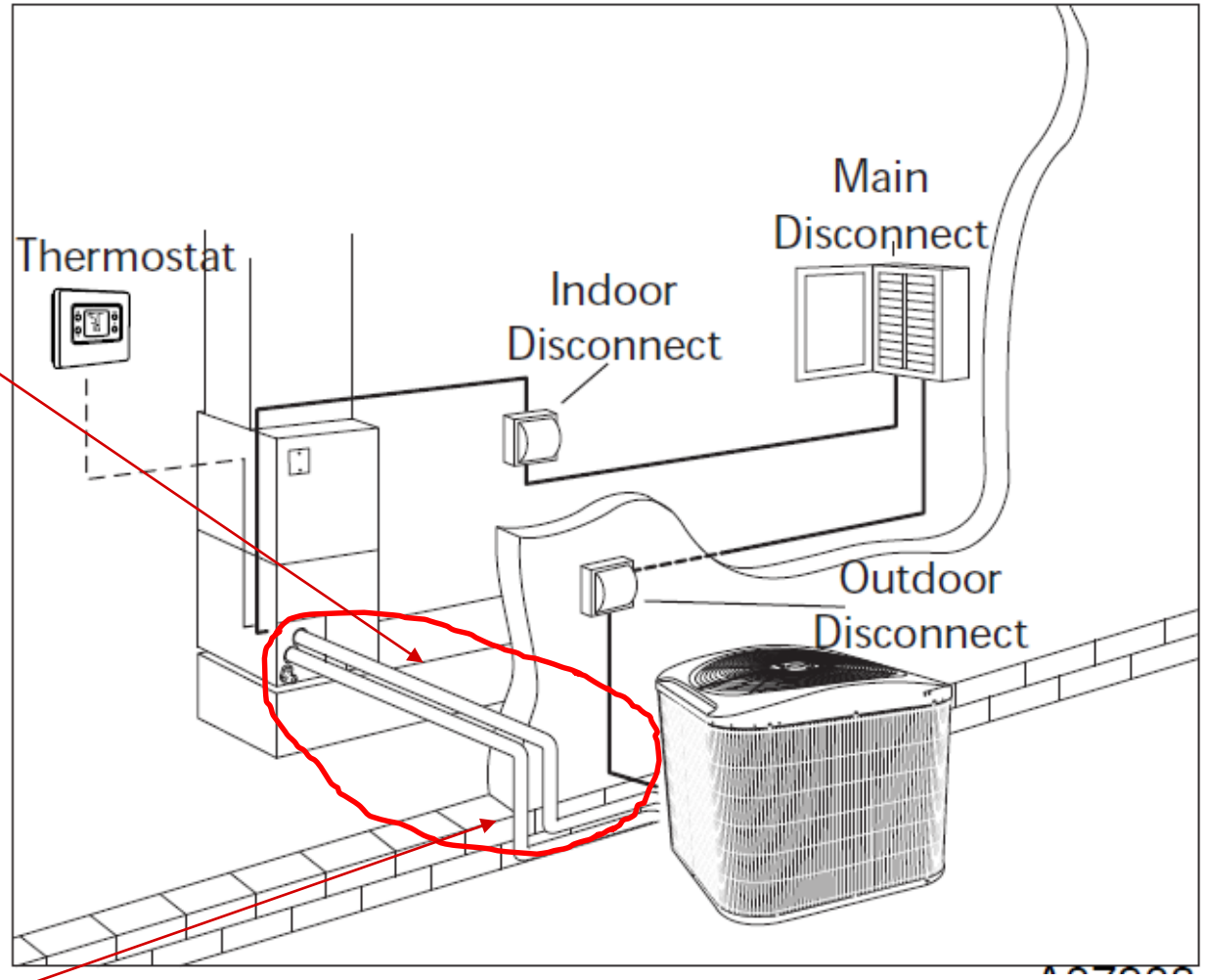
Sample Label

Minimum installation height – X ft
Minimum room area – X $m^2$ ($ft^2$)
Note: for minimum room areas at higher installation heights, see instructions (note is optional)

# Piping and Concealed Spaces

# Field Piping Design Requirements

Low side or Vapor line




High side or Liquid line

# Question 5 - Concealed Space (Additional requirements for concealed spaces have been addressed in UL60335-2-40, and ASHRAE 15)

- **UL60335-2-40**
  - The standard has requirements for **piping inside the unit and connected to the unit**.
    - Protected from potential damage during normal operation, service or maintenance
    - Refrigerant systems shall use only permanent joints indoors except for site-made joints directly connecting the indoor unit to the refrigerant piping, or factory mechanical joints in compliance with ISO14903,
    - **Be in compliance with national and local codes and standards, such as ASHRAE 15, IAPMO Uniform Mechanical Code, ICC International Mechanical Code, or CSA B52.**
    - Filed piping shall be pressure tested at the design pressure and tightness tested at 25% design pressure, and standing vacuum tested.
- **ASHRAE 15**
  - Requires listed products (i.e. UL60335-2-40)
  - Refrigerant pipe joints erected on the premises shall be exposed to view for visual inspection prior to being covered or enclosed. Note for existing piping this was required when the piping was first installed.
  - For Group A2L, refrigerants, protective enclosures or covers shall be provided for annealed copper tube erected on the premises between the condensing unit and the house. No enclosures shall be required for connections between a condensing unit and the nearest protected riser if such connections are not longer than 6.6 ft (2 m) in length.
- **ASHRAE 15.2P**
  - A2L refrigerants located in concealed locations where tubing is installed in studs, joists, rafters or similar member spaces and located less than 1-1/2 inches (38 mm) from the nearest edge of the member, shall be continuously protected by shield plates. Protective steel shield plates having a minimum thickness of 0.0575 inch (1.463 mm) (No. 16 gage) shall cover the area of the tube, and shall extend a minimum of 2 inches (50 mm) beyond the outside edge of the tube.
  - When a Refrigeration System is installed with field applied joints at the indoor section, the joints shall be in compliance with ISO 14903 or enclosed to vent to the appliance where a leak would be detected .
- **California Mechanical Code**
  - Chapter 11 of the California Mechanical code includes requirements on piping in section 1109 but does need some updates
  - In 1109.8 current code has required visual inspection of the field erected piping as far back as could be confirmed.

**Article 300.4 National Electrical Code** Piping is protected with a stud-guard or steel-plate protector

# How does a building code inspector ensure that a new A2L system in an existing building has safe piping?

## Summary of piping / installation requirements

| | 15 | 15.2 | 2-40 |
|---|---|---|---|
| Material- | Listed (UL 207)[1]<br>Material spec<br>*Section 9.10*<br>*Section 9.13* | Listed (UL 207)[1]<br>Material spec<br>Fitting spec<br>Swage<br>*Section 8* | ASHRAE 15 applies<br>*DD.3.1.DV.2* |
| Joints | Stop valve requirements<br>*Section 9.12* | Types given<br>*Section 8* | ISO 14903<br>*22.121.DV* |
| Location | Height<br>Not in duct<br>*Section 9* | Several items [2]<br>Stud protection [3]<br>Open joints UL 207 [3]<br>Shaft ventilation[3]<br>*Section 8* | Full list of requirements<br>*DD.3.1.DV.2* |
| Factory check | Design pressure<br>*Section 9.14, 9.14.2* | *Refer to UL 2-40* | Design proved through elevated pressures / cycling<br>*Annex EE, ADV.101.2*<br>Design pressure – 100%<br>*ADV.101.3* |
| Pressure check [6] | Design pressure [4]<br>*Section 10.1* | Design pressure [4] (60min)<br>*Section 10.1* | ASHRAE 15 applies<br>*21.1DV.1*<br>Design pressure [4] (60min)<br>*DD.3.1DV.2* |
| Vacuum check [6] | | 1500 micron for 10 min [5]<br>*Section 10.1* | 1500 micron for 10 min [5]<br>*DD.3.1DV.2* |



Field Piping Requirements

[1] Includes valves, connected, etc., if 15 psig or greater

[2] applies to all systems UOS:

- Height
- Protection (6')
- Prohibited spaces
- In concrete floor
- Pipe shaft
- Insulation (if contact possible)
- Supported
- Pipe penetrations sealed

[3] A2L only

[4] or pressure relief device setting

[5] must achieve 500 microns while evacuating

[6] to be specified in literature

VERIFICATION :

1 - Stud protection for pipes and wires already exists in CMC.

2 – Open joints can be verified by markings

3 – shaft ventilation (if required) can be visually verified

# Standards Goal: Prevent Ignition

- In order for a refrigerant ignition to occur, there must be 2 failures:
  - The refrigerant leak must exceed the lower flammability limit (LFL)
    - ➢10 to 14%  LFL concentration
    - ➢Large refrigerant release
  - There must be a “competent” ignition source (minimum ignition energy) in an area that exceed LFL
    - ➢Open flame or very high energy ignition source
- Goal of the standards:
  - Prevent the LFL concentration from being reached
    - ➢Refrigerant charge limits or mitigation requirements
    - ➢Mitigation may include circulation or ventilation to reduce refrigerant concentration
  - Remove “competent” ignition sources

# How are A2L detectors and controls safe?

- Detector listing?
- Calibration
- End of Life of Sensor

# Refrigerant Leak Mitigation

- One of the risks associated with UL 60335-2-40 equipment is refrigerant leakage.
- Refrigerant leak detection systems, that are a factory-installed integral component of the equipment, are required to mitigate this risk.
- Refrigerant leak detectors that sense loss of pressure are required for all systems in the occupied space exceeding a prescribed refrigerant charge limit (approximately four pounds for most permanently installed applications).
- Refrigerant leak detection systems are required to have both sensors and control logic electronics that activate the evaporator fan and use circulated air to quickly disperse and dilute refrigerant in the event of a leak. This is intended to prevent the formation of refrigerant concentrations.

# Refrigerant Leak Detection Systems

- The refrigerant leak detection system is unique for the specific HVAC equipment in which it is factory installed. The system is positioned within the equipment based on testing.

- Refrigerant leak detection systems are more than just a detector or sensor.  The system also includes the detector logic, the protective electrical circuit, as well as the location sensor in the unit.

- Detectors and sensors that are part of the refrigerant leak detection system are evaluated and tested as required by UL60335-2-40 3rd edition, and thus are a component of the product listing of the HVAC equipment.  Routine factory inspections are conducted by UL as part of the listing requirements for the equipment.

- UL60335-2-40 requires sensors to be factory calibrated and not be adjustable in the field.  This is required because field calibration is not the most reliable approach especially in appliance type applications and in residential applications. If the detector has a defined life and requires replacement after a given period, the detection system shall initiate an alarm or indication that replacement is required.

- For specific explanation of the refrigerant leak detection system requirements within UL 60335-2-40, go to https://www.ul.com/news/understanding-ul-60335-2-40-refrigerant-detector-requirements

# Refrigerant Leak Detection Systems Requirements

1. Factory-installed indicating type detectors with sensors optimally located to detect any leaks.
2. Refrigerant leak detector sensor set point is factory set and sealed with no field adjustment permitted.
3. Detector markings identify the manufacturer and refrigerants used.
4. Leak detection system activates at a maximum concentration of < 25% of the LFL of the refrigerant being used in the equipment. This 4-times safety factor helps ensure flammable concentrations are not reached.
5. Detectors turn on available mitigation devices such as circulation fans to provide dilution.
6. Self-test protocols run every hour to ensure proper operation and function. In the event of detector failure, the circulation fans activate and maintain a required airflow to prevent flammable concentrations from forming. This fail-safe mode is maintained until the detector is replaced.
7. Detector software is considered part of a Protective Electronic Circuit, which is evaluated for robustness, functionality and reliability.
8. The sensor shall not be subject to poisoning due to common household and workplace contaminants that shall not damage the sensor or produce false alarms or nuisance trips.
9. These systems are required to pass testing designed to address long term stability, vibration, range and setpoint verification, and response time.
10. If the detector has a defined life and requires replacement after a given period, the detection system shall initiate an alarm or indication that replacement is required.

# Will people charge A1 systems with A2Ls

- EPA maintains lists of refrigerants as acceptable, unacceptable, acceptable subject to use conditions, and acceptable subject to narrow use limits.
- EPA only lists flammable refrigerants as acceptable with restrictions such as requirements to follow UL safety standards.
- EPA also specifies which refrigerants can be used to “retrofit” existing equipment with a different refrigerant.
- EPA has never allowed retrofits of existing equipment with a refrigerant with a higher flammability safety classification.

- The EPA SNAP rules are well-managed with a significant history of enforcement.

# DIFFERENCES IN SAFETY STANDARDS

# Safety Standards Evaluated

- Published product standard UL 60335-2-40 (2019) for equipment manufacturers
- Published commercial/residential application standard ASHRAE 15 for installation
- Proposed residential application standard ASHRAE 15.2(P) for installation

# Safety Standards Evaluation Findings

- Standards will always have differences
  - Serve different purposes (product vs application/installation)
  - Current process has different review schedules
- Agreement that only an analysis of direct systems in residential settings was needed.
- All require the most stringent requirement to be followed

Although there are differences in the safety standards, none were identified as unresolvable for direct air conditioning systems

# Residential Application/Installation Requirements only in ASHRAE 15.2 (P)

- Does not allow consideration of connected rooms with a door with louvres in the calculation of allowed charge quantity.
  - UL 60335-2-40 allows a door with louvres; ASHRAE 15.2 does not
  - UL Collaborated Standard Development System (CSDS) could be submitted to align standards

- Allows 3-4 lbs additional charge more than 25% LFL in a ductless system
  - Allowance based on ventilation limit of 200 cfm
  - <u>This restriction is unlikely to impact residential settings.</u>

# Equipment Design Requirements only in ASHRAE 15.2 (P)

- Split system indoor coil must always have a sensor
  - Split system with an air handler and package unit do not require detection with a charge less than 4 lbs*

* This was noted as being of limited practical significance because line-set would likely increase charge above 4lb limit which would require sensor for most systems

- UL Collaborated Standard Development System request has been submitted to add this requirement to UL60335-2-40 now

# Equipment Design Requirements UL/CSA 60335-2-40

- UL Certification Requirement Decision (CRD) requires Protected Electronic Circuit (PEC) guidelines to be followed in UL 60335-2-40.
  - Petition needs to be completed for CSA to add this requirement
  - Needs to be communicated to all listing organizations

# Equipment Design Requirements UL/CSA 60335-2-40

- UL/CSA 60335-2-40 interpretation question: multi-split systems do not require safety shut-off valves to be closed to minimize releasable charge
  - Will be submitted to UL CSDS system for resolution

# Residential Application/Installation Requirements only in ASHRAE 15.2 (P)

- ASHRAE 15.2 (P): M2 or ~32 to 35 pound charge limit for residential systems in a single circuit
  - This was noted as being of limited practical significance as residential systems rarely, if ever, exceed 30 lbs per circuit.

Note : There is no limitation of square footage on residential buildings.

Note:  VRF will be limited by the releasable quantity rather than charge limit

# Retrofit

- ASHRAE 15.2(P): Does not allow retrofit of system to refrigerant in a different ASHRAE safety class
  - This was noted as being of no practical significance as EPA has never allowed retrofit to refrigerant of a more hazardous ASHRAE flammability safety class

# 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.

# Summary

- UL60335-2-40 informs equipment design
- ASHRAE 15 inform installation requirements
- ASHRAE 15.2 P would also inform installation requirements

- There are 2 more stringent requirements in the installation requirements in ASHRAE 15.2.

# ASHRAE 15.2(P) Process

- Current draft
  - ASHRAE SSPC 15 Committee will vote for public review
    - Majority of committee members must vote with 2/3 of those voting in favor (7.2.4.2)
  - ASHRAE editorial review will likely be complete mid-April
  - Public Review mid-April to end May
- ASHRAE 15.2 would resolve comments and update draft
- Committee chair goal is to publish in December for inclusion in ICC code proposal January 8, 2021

# Supporting Documents

# A1 systems w/ A2L

- Both the **UL60335-2-40** and **ASHRAE 15** have defined requirements on approvals for replacement refrigerants

- **UL60335-2-40** will require that the retrofit be UL approved to UL60335-2-40 including all the mitigation
  - Some may develop retrofit kits that allow a new condensing unit to be used with an existing fan coil or the reverse, but they would require UL60335-2-40 approval and modifications and inspection by UL.

- **ASHRAE 15** has the following statements in section 5.3;

  5.3.1 The change of refrigerant shall be approved by the owner.

  5.3.2 The change of refrigerant shall be in accordance **with one of the following**:

  a. Written instructions of the original equipment manufacturer
  b. An evaluation of the system by a registered design professional or by an approved nationally recognized testing laboratory that validates safety and suitability of the replacement refrigerant
  c. Approval of the AHJ

# What is the charge limit / room size and how is it determined?

Equipment containing flammable refrigerants need to meet UL 60335-2-40 standard.

The m1 refrigerant charge level is applicable for all room sizes.

| | Example Refrigerant | m1 (Refrig Amt) | Max Charge charge (#) | Actual charge (kg) | Heat of Combustion MJ/kg | Total Energy Burden |
|---|---|---|---|---|---|---|
| A1 | R-410A | typical | | | 5.91 | 0.0 |
| A2L | R-32 | 6 x LFL | 4.08 | 1.85 | 9.38 | 17.4 |
| A2L | R-454B | 6 x LFL | 4.65 | 2.11 | 10.3 | 21.7 |
| A3 | R-290 (Propane) | 3 x LFL | 0.25 | 0.114 | 46.3 | 5.3 |

# Refrigerant Safety Classifications Properties

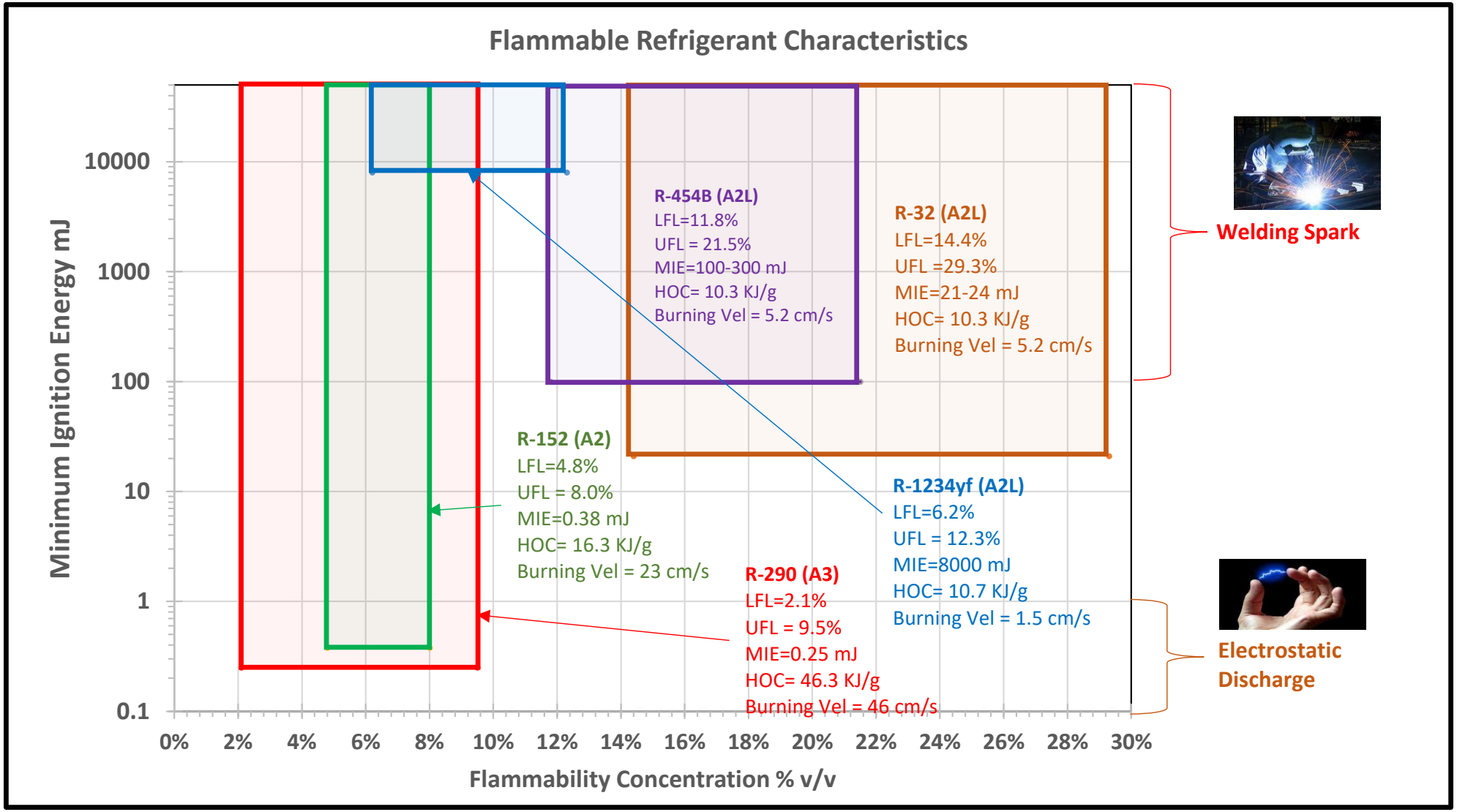
| Refrigerant | Components Composition% | Safety Classification ASHRAE 34 | Exposure Limit (RCL) | GWP (4th) | Applied GWP relative to R-410A | Operating Pressure @ 120 F SDT | LFL nominal composition | UFL nominal composition | Burning Velocity (Su) | Minimum Ignition Energy (MIE) | Heat of Combustion (HOC) | Auto Ignition Temperature (AIT) | Hot Surface Temperature (HOC) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ppm | $CO_2e$ | $CO_2e$ | psia | % v/v | % v/v | cm/sec | mJ | KJg | °C | °C |
| R-410A | R-32/R-125 50/50 | A1 | 140,000 | 2,088 | 2,088 | 433.6 | - | - | - | - | 5.91 | >750 | - |
| R-134a | 1,1,1,2-tetrafluoroethane 10000% | A1 | 50,000 | 1,430 | 1,632 | 185.9 | - | - | - | - | ? | >750 | - |
| R-404A | R-125/R-134a/R-143a 44/4/52 | A1 | 126,000 | 3,922 | 3,878 | 325.8 | - | - | - | - | ? | <750 | |
| R-466A | R-32/R-125/CF3I 49/11.5/39.5 | A1 | 30,000 | 733 | 855 | 412.6 | - | - | - | - | ? | ? | |
| R-513A | R-134a/R-1234yf 44/56 | A1 | 72,000 | 629 | 679 | 184.98 | - | - | - | - | ? | ? | |
| R-1234yf | 2,3,3,3-tetrafluoropropene 100% | A2L | 16,000* | 0.31 | 0.32 | 185.0 | 6.20% | 12.30% | 1.5 | 8000 | 10.7 | 405 | 700 |
| R-32 | difuoroemethane 100% | A2L | 36,000* | 675 | 612 | 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 | 612 | 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 | 433 | 405.5 | 11.8% | 21.50% | 5.2 | 100-300 | 10.3 | ? | 700 |
| R-152a | 1,1 difluoroethane 100% | A2 | 12,000* | 124 | 106 | 166.1 | 4.80% | 8.0% | 23 | 0.38 | 16.3 | 455 | 355 |
| R-290 | propane 100% | A3 | 5,300* | 3.30 | 1.55 | 242.5 | 2.10% | 9.5% | 46 | 0.25 | 46.3 | 470 | 370 |

LFL = Lower Flammability Limit (%v/v)
UFL = Upper Flammability Limit (%v/v)
Su = Laminar Burning Velocity (cm/sec)
HOC = Heat of Combustion (KJ/g)
AIT = Auto Ignition Temperature (°C)
HST = Host Surface Temperature (°C)
RCL = refrigerant concentration limit doe roxicity risk reduction, * = 25% of LFL for flammable refrigerants

# Refrigerant Flammability (backup details)

A2L refrigerants do not reach flammable concentrations until there are high concentration levels vs A3 refrigerants which people are used to.

They also require high ignition energy



# Refrigerant Safety Classifications

**ASHRAE 34 and EN 378**

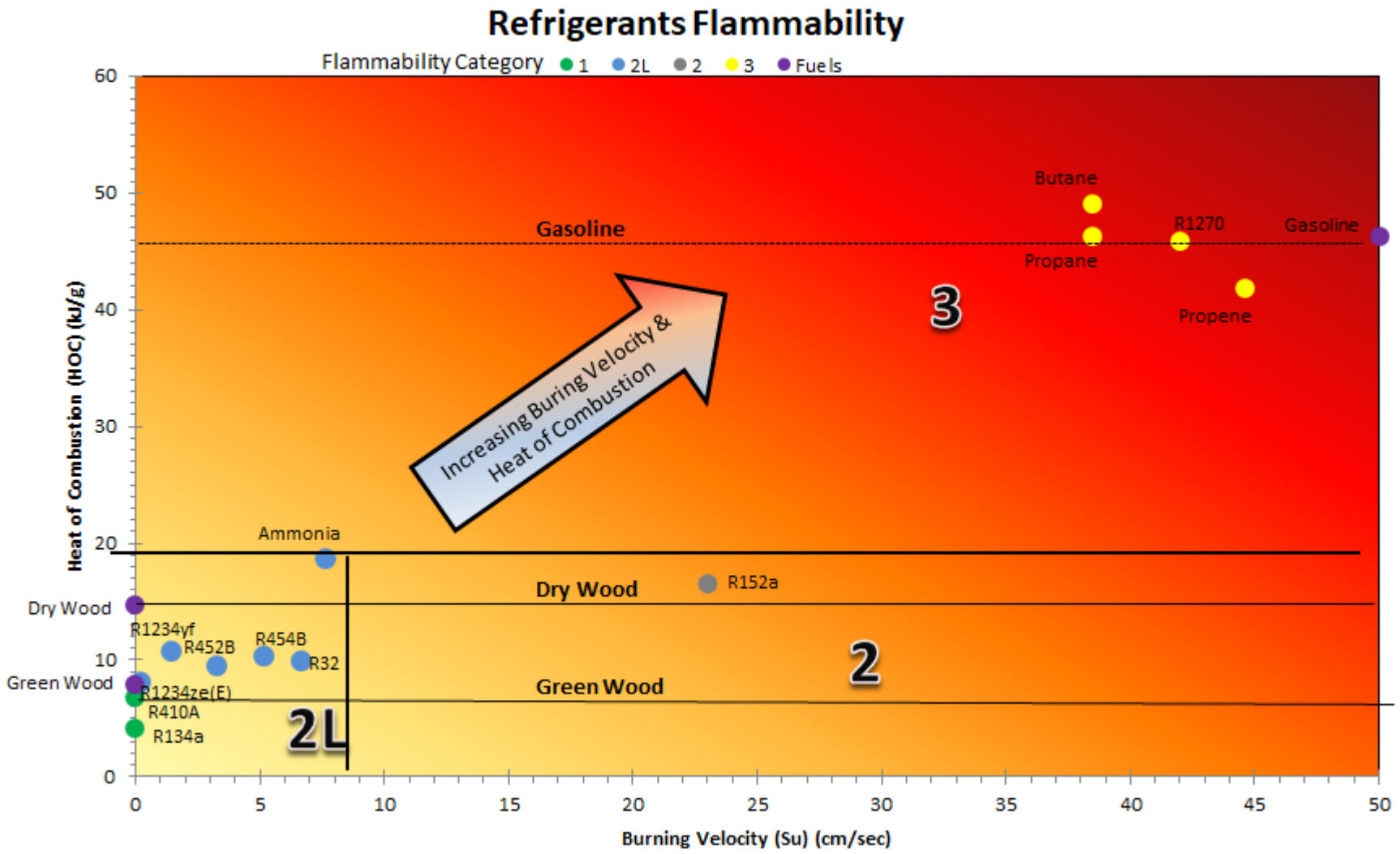
| | | | | | |
|---|---|---|---|---|---|
| **Higher Flammability (explosive)**  | Ignites very easily<br>Potentially Explosive |   | **A3**<br>R-429A, R-430A, R-431A, R-435A, R-290 (Propane), Butane, Butene, Butyne, | **B3** | **Clase 3 Requirements**<br>1. Flame propagation when tested at 60 C & 101.3 kPa<br>2. and LFL < 0.10 kg/m$^3$<br>3. or heat of combustion<19,000 kJ/kg |
| | | | **High Flammability** | | |
| **Low Flammability**  | Ignites Easily<br>Relatively High Energy Release |   | **A2**<br>R-152a, R-413A, R-439A, R-440A | **B2**<br>R40 Methyl Chloride | **Clase 2 Requirements**<br>1. Flame propagation when tested at 60 C & 101.3 kPa<br>2. and LFL > 0.10 kg/m$^3$<br>3. and heat of combustion<19,000 kJ/kg |
| | | | **Flammable** | | |
| **Lower Flammability**  | "Mildly Flammable"<br>Difficult to Ignite<br>Relatively Low Energy Release<br>Low Flame Speed |  Low Grade Coal | **maximum burning velocity of ≤10 cm/sec**<br>**A2L**<br>R-1234yf, R-1234ze(E), R-32, R-452B, R-454B, R-454A | **New**<br>**B2L**<br>R717 (Amonnia) | **Clase 2L Requirements**<br>1. Flame propagation when tested at 60 C & 101.3 kPa<br>2. and LFL > 0.10 kg/m$^3$<br>3. and heat of combustion<19,000 kJ/kg<br>4. and burning velocity ≤ 10 cm/s @ 23 C & 101.3 kPa |
| | | | **Lower Flammability** | | |
| **No Flame Proprogation**  | No Ignition at ≤63 C but still may be flammable at higher temperatures and in building fires | | **A1**<br>R-22, R-410A, R-407C, R-404A, R-134a, R-448A, R-449A, R-513A, R-452A R-1233zd(E), R-448A, R-450A, R-466A | **B1**<br>R-123, R-514A | **Clase 1 Requirements**<br>1. No flame propagation @ 140 F & 14.7 psia |
| | | | **No Flame Proprogation** | | |
| | | | **Lower Toxicity**<br>[OEL of 400 ppm or greater.] | **400 ppm**<br>**Higher Toxicity**<br>[OEL of less than 400 ppm.] | **Flammability Criteria** |

Decreased RCL

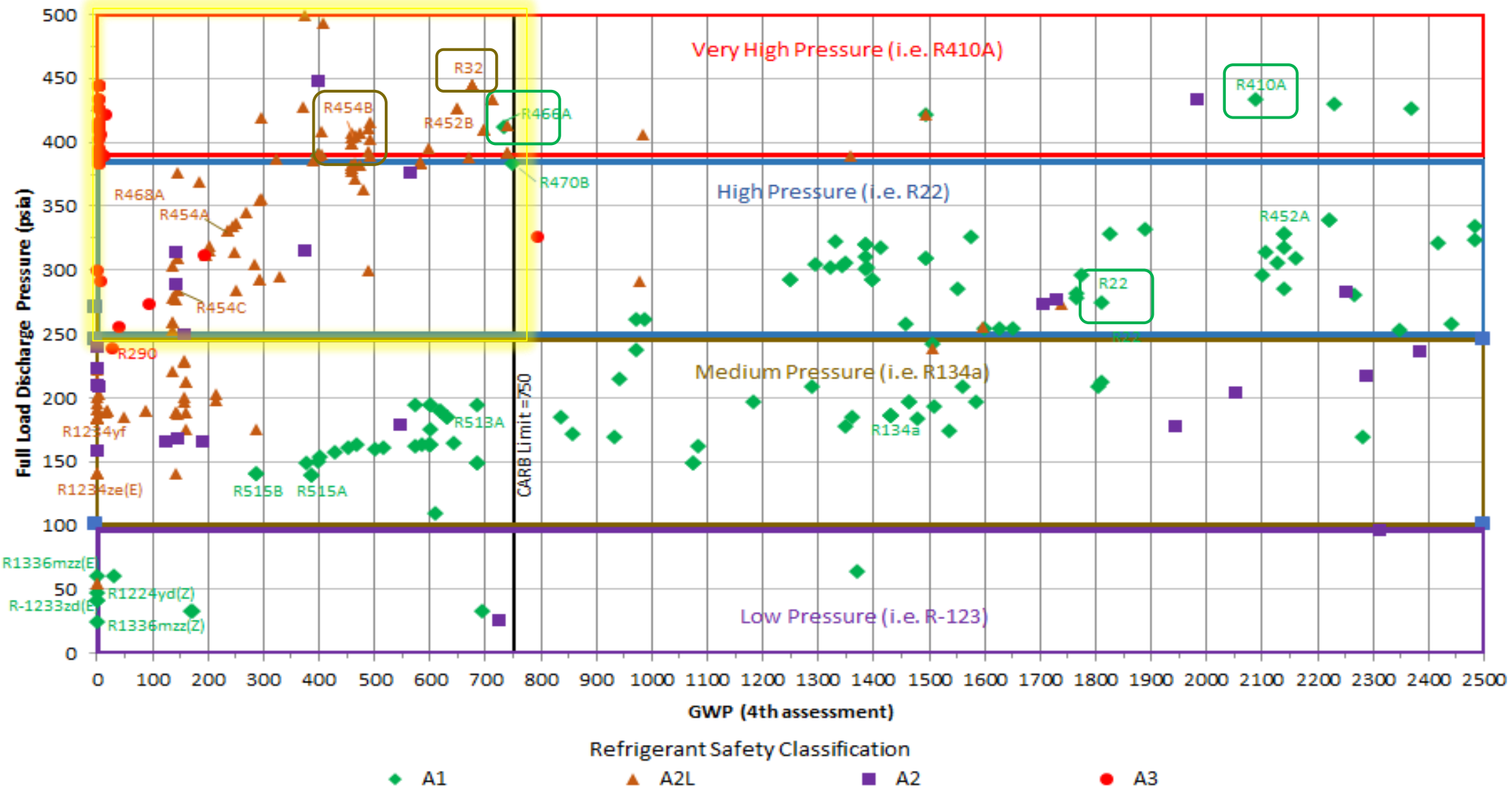
Burning Velocity and Heat of Combustion

Increase

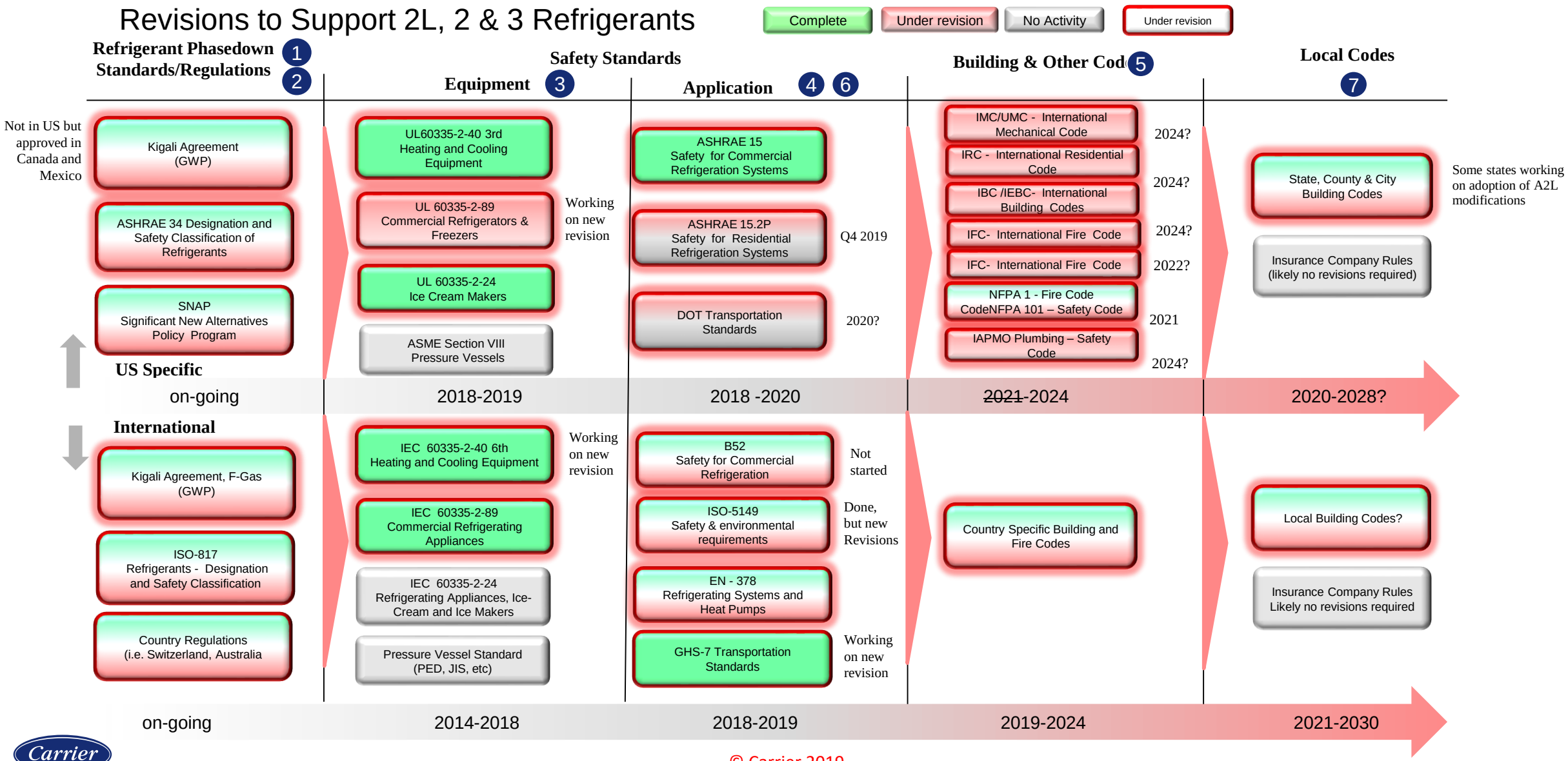
# Refrigerant Safety Classifications



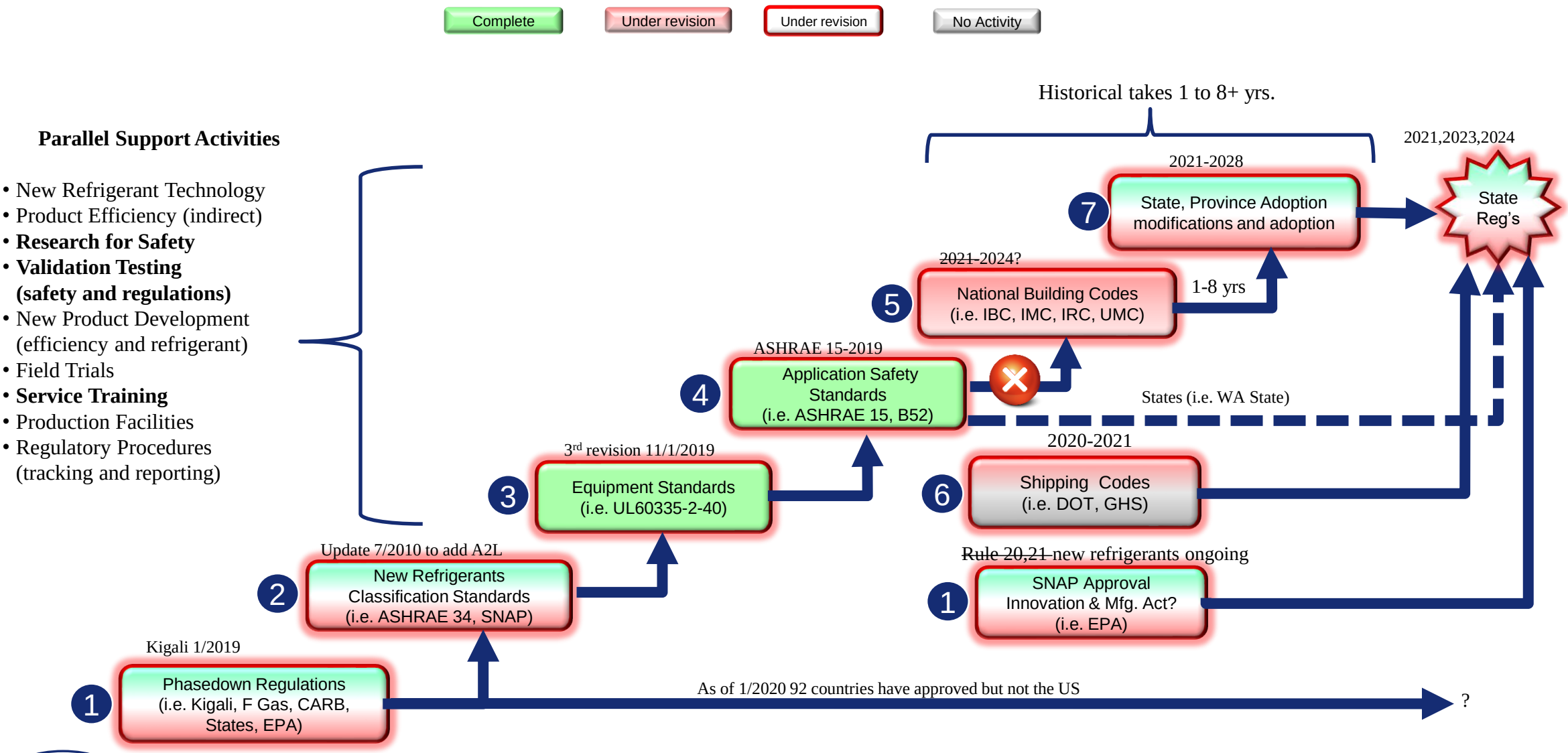
# Future Refrigerant Options for R-410A Products



# GLOBAL A2L STANDARDS AND CODES – STATIONARY PRODUCTS

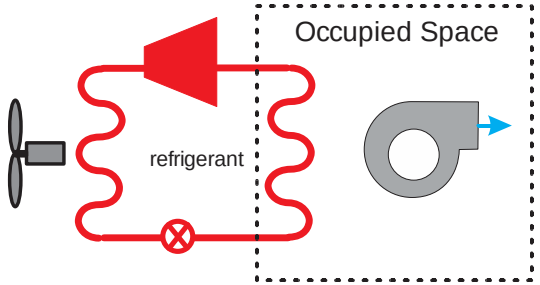


# US A2L Standards and Codes Revision Process



# Safety Standard Application Classifications

**Direct System**
Refrigerant can leak into the occupied space




Ductless

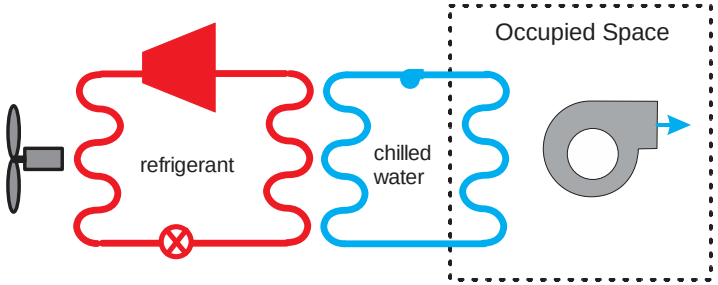
Ducted

Small Chiller

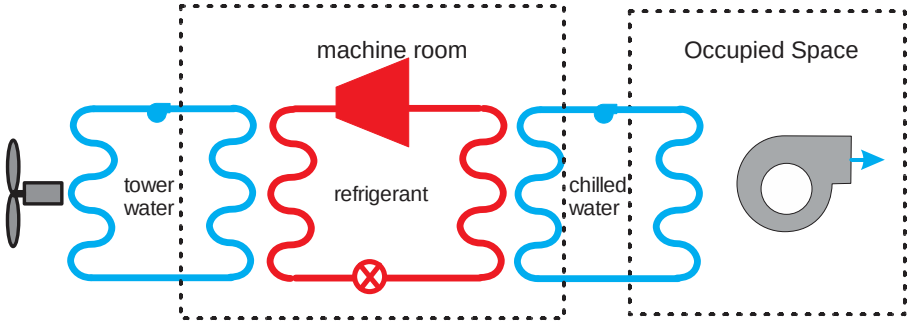
**Indirect Systems**

Refrigerant Leak Isolated by secondary loop

Equipment outdoors or in a machine room




Outdoor

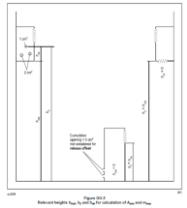



Indoor

# Safe Application of A2L Refrigerants Summary

UL60335-2-40 3rd Edition Summary for a **Residential Ducted Unit** A2L Refrigerant Requirements

**Minimum Area Check ($A_{min}$)**
- Safety factor of 4
- Or safety factor of 2 with additional measures
- Per Annex GG



7

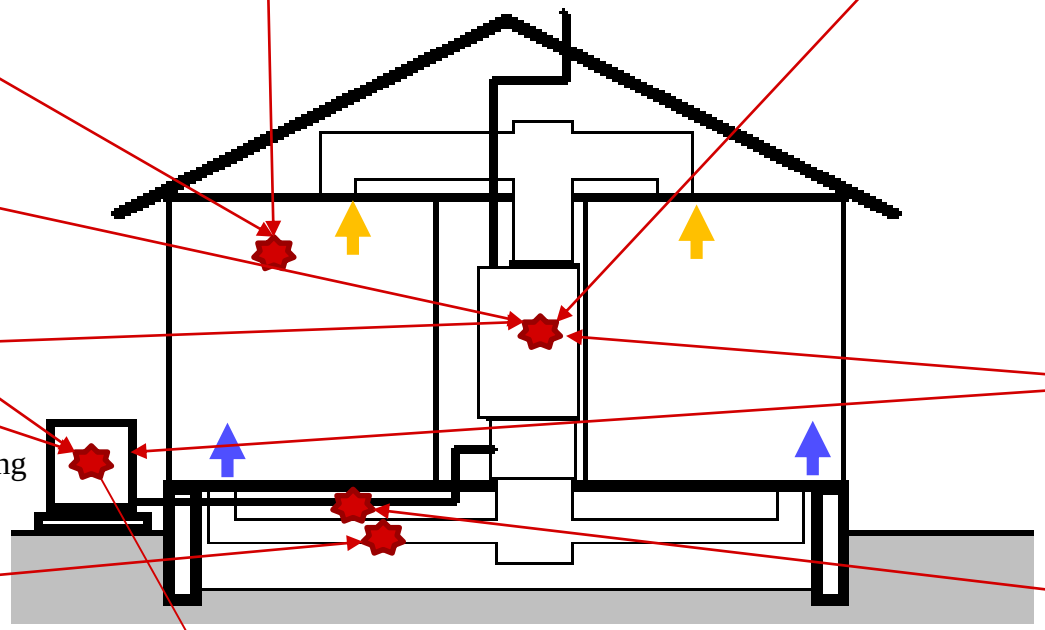
6 **Active mitigation for leaks** detect, circulate an dilute Annex GG

5 **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 (1once/hr.)
- Fail safe mode with fan on
- Field inspection feature

**Residential Down Flow Air Conditioners with Gas Heat**

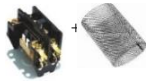
**Service Training** and Education Annex DD

8



**Ignition Source Isolation** Per UL 60335-2-40 Annex FF

1



Condensing Unit

4 **Labeling and Literature** Per UL60335-2-40 Per 101, Annex DD

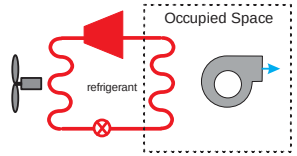

**No Competent Ignition** Sources in unit and ducts Per 22.116, Annex KK, 22,117

1

2 **Refrigerant Charge Limits** (UL60335-2-40)
m1, m2, m3 per Annex GG1.2
R32 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.

3 **Refrigerant Piping** (UL60335-2-40) Per 22.116, 101.DVG
- Protected lines
- Qualified joints (ISO 14903)
- Field pressure test, leak verification test
- Additional requirements for VRF

# A2L Refrigerant Requirements - Direct Systems




## Product and Application Requirements (UL60335-2-40/CSA 22.2, ASHRAE 15.2, ASHRAE 15, B52, EPA)

Application
Refrigerant Charge
Limits/circuit

A3 limits to 114 g (m1)

| Limit | Equation | R--32 | R-452B |
|---|---|---|---|
| <m1 | =3 or 6*LFL | 2 or 4.1lb | 2 or 4.0 lbs |
| <m2 | =52*LFL | 35.1 lb | 34.7 lbs |
| <2 x m2 | =104*LFL | 70.1 | 69.5 lbs |
| >m3 | =260*LFL | 175.4 | 173.7 lbs |

All Systems → No sensor requirements or area check, but other requirements still apply

Appliances → $A_{min} = (mc / (2.5 \times (LFL)5/4 \times ho)^2$ , not less than $A = mc / (SF \times LFL \times ho)$

Ductless → $A_{min} = m_c/(0.25 \times LFL \times h_o)$

Ductless<35kW Multisplit → *sensor and* $A_{min} = m_c/(0.50 \times LFL \times h_{ra})$

Ducted → *sensor and* $TA_{min} = m_c/(0.25 \times LFL \times H)$

Ducted/Ductless → Sensor External Mechanical ventilation

Check $A_{min}$
Validation Testing
Labeling of $h_o$
Room connection

(New Cylinder colors AHRI Guideline N and AHRI Guideline G for fittings left hand threads for flammable)

New Reclaim LH Threads

Refrigerant detector above m1 for ducted and circulation m2 or <Amin VRF in unit

Indoor airflow verification for electric heat (only if no refrigerant detector)

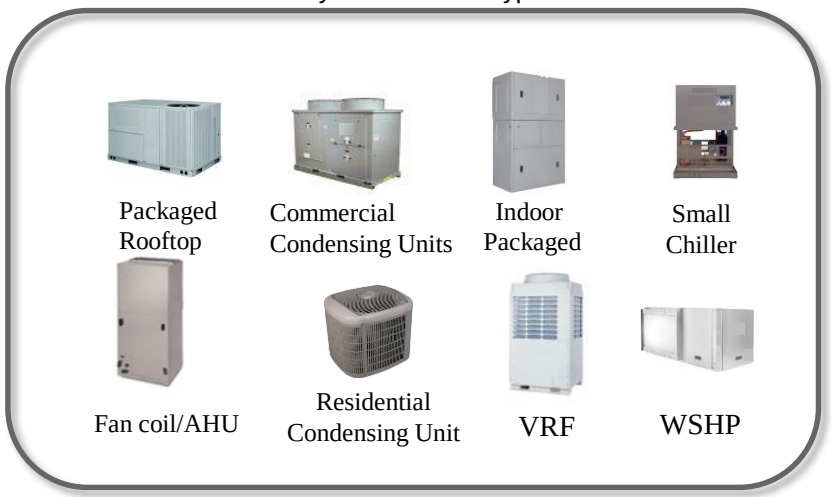
Hot surface limit of <700 C Except for heat with sensor or airflow verification

Tubing protection for exposed piping greater than 6.6 ft.

Red pantone service port (EPA Requirement)

Field Piping Design, (joints, protection) & Pressure proof test, leak verification test

Direct System Product Type

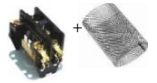



Laboratory Upgrades (Manufacturers and Certification)

Production Processes

Warehouse and Shipping (DOT/GHS)

Safety / circulation control and unit interlock (UL Safety Circuit)



Ignition Source Flame arrestors or control box qualification


New Warming labels on units and packaging

Amin, $h_o$ and charge tracking on unit nameplate

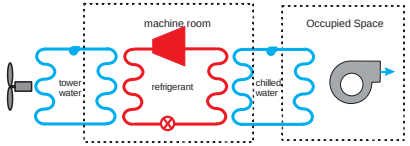
Isolation valves for multiple evaporator systems (VRF) Also additional requirements options per 101 DVG.2

Pressure Relief Requirements

New service requirements and procedures


Training, Literature and Technician Certification? (Nate, HRAI, ACCA)

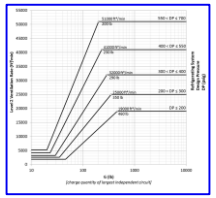
# A2L Requirements Indoor Indirect Systems




## Product and Application Requirements (UL60335-2-40/CSA 22.2, ASHRAE 15, B52, EPA)

Revised/Increased machine Room Ventilation as a function of charge

ASHRAE 15-2019



ASHRAE 15 addendum h increased ventilation as a function of charge

LH Threads

New

Reclaim

(New Cylinder colors AHRI Guideline N and AHRI Guideline G for fittings left hand threads for flammable)

Safety / ventilation control interface and Inspection

Machine Room Indoor Indirect Product Types

Red pantone service port (EPA Requirement)

Machine room requirements access controls, alarms, ventilation

No open flame combustion

Refrigerant sensor (already required for A1)

Machine Room Electrical Protection

Hot surface limit of <700 C

Relief valves vented outdoors And refrigerant relief on waterside

New Warming labels on units and packaging


Production Processes

Routine inspection & Leak checking, CARB EPA Rule 608 >50 lbs.

Laboratory Upgrades

New service requirements and procedures

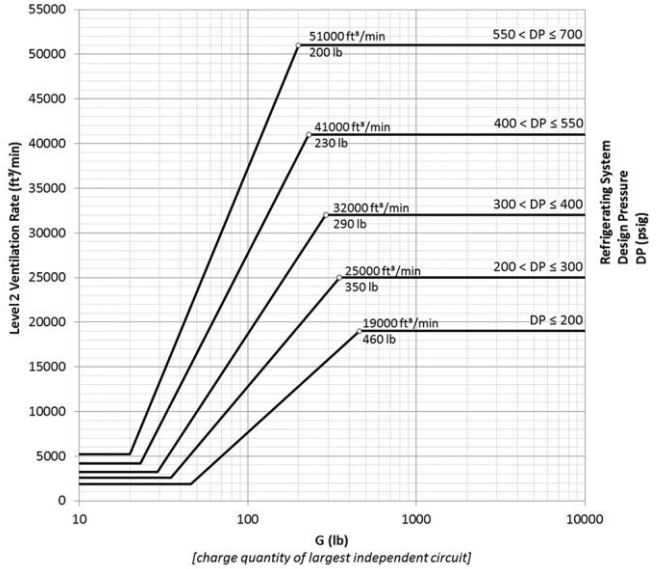
Flame arrestors or control box qualification for units and machine room


Training and Literature Machine Room Guidelines (NATE, HRAI)

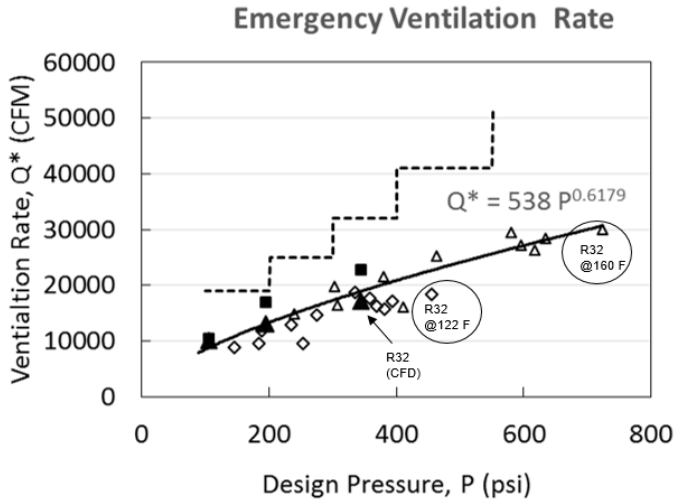
# Machine Room Ventilation

- Sensors and ventilation are already required for all machine rooms even with A1 and following the requirements of ASHRAE 15 for US and EN 378 in Europe
- The requirements for ventilation in ASHRAE 15 are based on 100* $G^{0.5}$ which was developed many years ago but is not based on any testing or analytical studies
- UTC/Carrier did considerable CFD work, which was validated by testing to develop a new correlation for use with A2L refrigerants
- This was submitted to ASHRAE 15 as a code change and they adopted the concept, but in implementation made some mistake section 8.11 and in the graphs that are in ASHRAE 15-2019
- We have found that the implemented requirements over ventilate by as much as 3X
- We have developed a modified proposal and have submitted it as a CMP change proposal to ASHRAE 15 and they are currently evaluating making a addendum change
- At this point Europe, in the ISO 5149 standard has not modified the ventilation requirements but we continue to push them to make modifications to the current equation which is a function of $G^{2/3}$

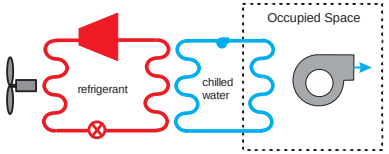
ASHRAE 15-2019 Requirements




Modified Proposal



# A2L Requirements Outdoor Indirect Systems




## Likely Product Impacts (UL60335-2-40/CSA 22.2, ASHRAE 15, B52, EPA)

No charge limits

(New Cylinder colors AHRI Guideline N and AHRI Guideline G for fittings left hand threads for flammable)

New Reclaim

LH Threads

No ventilation requirements

Refrigerant sensor (not required)

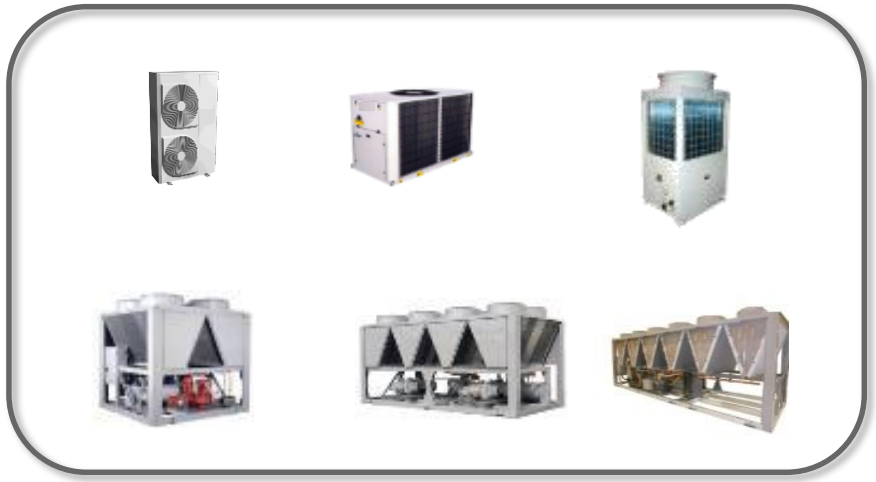
Hot surface limit of <700 C

New Warming labels on units and packaging

A2L

refrigerant relief sizing for waterside to be able to handle refrigerant

**Outdoor Indirect Systems**

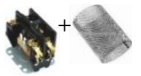


Routine Inspection & Leak checking Section 608 and CARB

Laboratory Upgrades

Located 20 ft from building intake (ASHRAE 15)

Red pantone service port (EPA Requirement)



Flame arrestors or control box qualification for units

Production Processes

New service requirements and procedures


Training and Literature & Machine Room Guidelines (NATE, ACCA, HRAI)

# Service Training

- **Claims** have been made that service training has not been started and is not available and building standards should be delayed
- **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 what was **claimed** at the code hearings 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 [illegible] ipping 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 3rd 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 |
| **Purge Circuit with Inert gas (i.e. oxygen free nitrogen)** | Not required | **Required** | Required | Repeat as necessary |
| **Evacuate** | Not required | **Required** | 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 |
| **Leak Test and Pressure Test the unit** | Not required | **Required** | 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 |

# 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 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
- 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)

There is a new website where additional information can be found at the following address;

http://www.ahrinet.org/SafeRefrigerant

- *DISCLAIMER: The information contained in the conference presentations are intended primarily to inform industry experts and code committees revising relevant national and regional safety codes.  Please confine the sharing of this information to within your company.  AHRI makes no claims, promises, or guarantees about the accuracy, completeness, or adequacy of the contents of the information, and expressly disclaims liability for errors and omissions in the content of the information.*