WHITE PAPER

Mildly Flammable Refrigerant Symbol

Understanding the impact of low-GWP refrigerants in residential and commercial applications

A practical guide to select and apply commercial and residential packaged and split systems with A2L refrigerant.

Background

The HVAC industry in the United States transitioned from ozone-depleting hydrochlorofluorocarbon (HCFC) refrigerants to hydrofluorocarbon (HFC) refrigerants in 2010, per the Montreal Protocol. This agreement prompted the conversion of packaged and split systems from using R-22 (HCFC) to R-410A (HFC). After the R-22 conversion, the Kigali Amendment of the Montreal Protocol seeks to reduce global warming by classifying and selecting refrigerants with lower global warming potential (GWP) values. The industry is now transitioning away from HFC to low-GWP hydrofluoroolefin (HFO) refrigerants. The AIM Act, passed by United States Congress in 2020, authorized the Environmental Protection Agency (EPA) to regulate the use of refrigerants. The EPA has mandated the conversion of commercial and residential packaged and split systems on January 1, 2025, to use low-GWP refrigerants.

R-22

- No Regulation
- Ozone Depletion

R-410A

- Montreal Protocol
- Focus: Ozone Protection
- HCFC → HFC
- January 1, 2010
- GWP = 2088

R-454B

- Kigali Amendment
- Focus: Global Warming Potential
- Congress AIM Act → EPA Authority
- HFC → HFO
- January 1, 2025
- GWP = 466

Figure 1. Refrigerant Migration Timeline.

The conversion from R-22 to R-410A primarily impacted product design and manufacturing, along with the service technician's tools and methods. The conversion to R-454B has a much broader impact on the industry because of its low-flammability classification. Mildly flammable refrigerants (A2L) require increased safety methods not required for R-410A, an A1-classified refrigerant.

The conversion to R-454B impacts the following:

1. Product design and manufacturing to meet efficiency and safety standards
2. Restriction of product use in buildings based on area and occupancy use
3. Implementation of new product safety testing methods, ratings and labeling
4. Implement new equipment service practices considering safety requirements

Executive Summary

The HVAC industry is migrating refrigerant-based equipment from R-410A to R-454B or R-32 refrigerants. These low-GWP refrigerants are considered "mildly" flammable. Packaged and split system air-conditioning units using R-454B refrigerant must include mitigation strategies to prevent a possible fire if the units leak refrigerant in the shipping, storing and operating of the equipment. Several industrywide standards govern the use of refrigerant, including ASHRAE Standard 15, ASHRAE Standard 34, International Mechanical Code and UL-60335-2-40 (3rd and 4th editions). The standards provide direct guidance on all aspects of refrigerant use. Standards and codes require changes to installation, operation and maintenance practices to ensure proper handling of mildly flammable refrigerants. This paper discusses the general mitigation requirements, refrigerant charge limits, detection systems and updates to field documentation, with a focus on residential and commercial packaged and split air-conditioning systems.

This white paper limits all relevant source material to ASHRAE Standard 15-2022[1], ASHRAE Standard 34-2022 and UL 60335-2-40 (4th edition).

Paper Topics

- A2L Refrigerant Properties
- General Mitigation Strategies
- Refrigerant Charge Limits
- Leak Detection Systems
- Service Considerations

A2L Refrigerant Properties

It is important to first consider the classification and properties of A2L refrigerants. ASHRAE standard 15 Section 7.5.2.1 mandates the use of A2L refrigerants for human occupancy application as shown in Figure 2.

Refrigerant Safety Classification

Higher flammability	A3	B3
Flammable	A2	B2
Lower flammability	A2L	B2L
No flame propagation	A1	B1
	Lower toxicity	**Higher toxicity**

R-454B refrigerant classification:

A = Nontoxic; no refrigerant charge limit for toxicity reasons

2L = Lower flammability means mildly flammable; requires charge limits to mitigate fire hazard

Figure 2. ASHRAE Standard 34-2022 Section 6 Safety Classification Table.

HVAC system installation practices must include mitigation strategies to prevent a fire when a ***"direct system"*** leaks refrigerant. Underwriters Laboratory Standard UL 60335-2-40[2] defines ***direct system*** to mean a refrigerating system in which a single rupture of the refrigerant circuit results in a refrigerant release to a space, irrespective of the location of the refrigerant circuit. In general, both commercial and residential equipment have 1-4 independent circuits with differing charge amounts related to design capacity. All rules, calculations and references refer to the largest single circuit within the system.

While ASHRAE Standard 34 provides many refrigerant characteristics, the following three properties are heavily used in the description of mitigation strategies:

1. Lower Flammability Limit
2. Refrigerant Concentration Limit
3. Ignition Temperatures

[1] ASHRAE Standard 15-2022 applies to commercial spaces. ASHRAE Standard 15.2–2022 applies to residential spaces.

[2] UL 60335-2-40 publishes 2nd, 3rd and 4th editions. All references in this document are sourced - 4th edition.

Lower Flammability Limit (LFL): LFL is the minimum concentration of a gaseous substance, R-454B refrigerant in this case, that can propagate a flame through an evenly spread-out mixture of the refrigerant in the air and under specified test conditions. When the limit is reached, flame or a device's surface temperature, equal to or greater than the ignition temperature, will cause the gaseous refrigerant to burn. The same ignition flame when present will NOT cause a fire when the concentration of refrigerant is lower than the limit. Please note, refrigerant can collect or pool such that a small volume could ignite yet will not be able to spread the flame to nearby refrigerant. **The LFL used in mitigation equations for R-454B is 0.296 kg/m^3 (18.4 lbs/ft^3).**[3]

Refrigerant Concentration Limit (RCL): RCL is the refrigerant concentration limit in air, intended to reduce the risks of acute toxicity, asphyxiation and flammability hazards in occupied and enclosed spaces. Allowing refrigerant concentrations to increase beyond this limit in the enclosed space, such as an office can significantly increase the risk to human occupancy. **The RCL used in mitigation equations for R-454B is 3.1 lbs/1000 ft^3 (49 g/m^3).** RCL is only used in ASHRAE Standard 15 formulas. UL-60335-2-40 does NOT use RCL; however, it is worth mentioning when a person compares the two standards.

Ignition Temperatures: Refrigerant will burn based upon two types of temperature values. The first value is the auto ignition temperature, which will cause refrigerant to ignite when flames and electrical sparks contain enough energy source in a minute space to cause the refrigerant to burn. Static charge between human contact does NOT contain enough energy to ignite the charge. More importantly, the ignition source must be sustained for the flame to propagate. Therefore, a single electrical spark may not have enough energy to produce a self-sustaining flame.

The second value is surface temperature. If a surface such as a hot plate or stove top reaches a high enough temperature, the surface then contains enough energy to cause the refrigerant to burn. The auto ignition temperature for R-454B is 928 °F (498 °C). The surface temperature limit for R-454B is 1290 °F (700 °C)[4]. For comparison, a cigarette burns at 752-1652 °F (400-900 °C), depending upon puffs of air drawn through the cigarette. A cigarette lighter's yellow flame burns at 700 °F (371-482 °C), yet the blue interior of the flames can reach 1700 °F (927 °C). A laboratory hot plate develops surface temperatures from 212-1382 °F (100 to 750 °C). An electric duct heater can also develop ignition-level temperatures when low airflows are present. ASHRAE Standard 15 provides the following summarized rules:

- NO open-flame-producing devices should be installed in the air ductwork.
- NO unclassified electrical devices shall be located within the ductwork that serves the space. Unclassified electrical devices do not follow UL fuse and current limiting practices, thereby allowing more available ignition energy than normal.
- Devices containing hot surfaces exceeding 1290 °F (700 °C) shall not be in the ductwork that serves the space unless there is an average airflow velocity not less than 200 ft/min (1.0 m/s) across the heating device(s) and there is proof of airflow before the heating device is energized, i.e., *electric and gas duct heater.*

Mitigation strategies use LFL, RCL and ignition temperatures to describe and quantify requirements. The major fire prevention strategies are:

- Reduce and prevent leaked refrigerant contact with surfaces and devices at ignition temperatures (928 °F and 1290 °F).
- Limit available refrigerant leak amounts (lbs.) per given application volume.
- Provide continuous acceptable circulation air rate, which dissipates the concentration of leaked refrigerant (natural and/or mechanical).
- Provide refrigerant leak detection systems and provide circulation air upon activation, which dissipates the concentration of leaked refrigerant.
- Add barriers to prevent leaked refrigerant migration to occupied spaces.
- Update electrical devices to be A2L compliant and/or intrinsically safe for the application.
- Continuously exhaust air from the space to dissipate the concentration of refrigerant, or exhaust air from the space upon a detection of a refrigerant leak to dissipate the concentration of refrigerant.
- Add barriers to prevent complete release of refrigerant charge amount to spaces.

The most prevalent mitigation strategies will be limiting refrigerant for a given space, adding leak detection to the units and exhausting air from the space. Product electrical systems must also comply with UL 60335-2-40, which further reduces fire hazard.

General Mitigation Strategies

If a unit leaks refrigerant and the refrigerant concentration reaches the lower flammability limit (LFL) a single ignition source can cause all airborne refrigerant to burn. The previously mentioned mitigation methods can be reduced to the following three scenarios to prevent fire hazard:

- **Scenario #1: No Further Mitigation Required**
  Apply HVAC equipment to condition a large enough area so that a refrigerant leak detection system (RDS) is not required.
- **Scenario #2: RDS or Continuous Supply Air Circulation Required**
  Use refrigerant detector system to activate the supply fan, which dilutes concentrations of leaked refrigerant in the space with air circulation. Use an RDS when the conditioned area is too small to use scenario #1. Scenario #2 also requires the space to be larger than a minimum total applied area.
- **Scenario #3: RDS or Continuous Supply Air Circulation Required and Additional Exhaust Air System**
  When the area of the conditioned space is less than the minimum areas required for scenario #1 and for scenario #2, use an RDS along with additionally exhausting air from the conditioned space to reduce the potential of collecting refrigerant.

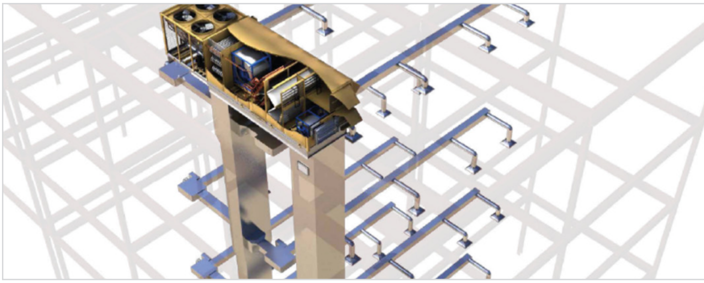


Figure 3. RDS calculations only apply to the lowest elevation level of the ductwork system and its volume.

[3] *UL 60335-2-40, LFL defined in Table BB.1DV, lower flammability limit at worst-case formulation at 25 °C; LFL = 0.296 lg/m^3 or 18.4 lbs./1000 ft^3. The international mechanical code 2021 published 0.356 kg/m^3 or 22.0 lbs/1000 ft^3 for the LFL value – TABLE 1103.1 REFRIGERANT CLASSIFICATION, AMOUNT AND OEL.*

[4] *ASHRAE standard 15, round the temperature values.*

Each one of the scenarios relates to product that is applied to "condition" an occupied space. Within the occupied space are zones where the refrigerant can collect and obtain its highest concentration. The zones are conditioned, enclosed areas that do not allow the free flow of air to another part of the building, e.g., rooms, offices, closets. The HVAC equipment can be located in the conditioned space, or the equipment can be remote mounted with connecting ductwork to each zone.

In the event of a refrigerant leak, the heavier-than-air gas can theoretically collect in the lowest elevation of the building in the smallest zone. The smallest zone could theoretically collect enough refrigerant equal to the LFL, thereby causing a potential hazard. ASHRAE Standard 15 section 7.2.3 is interpreted that all calculations pertaining to area apply only to the lowest elevation in the building associated with a particular piece of equipment. Figure 3 (above) shows a building with a unit that serves multiple floors. The applicable zones are individual offices, break rooms, conference centers and other conditioned spaces at the lowest level.

When applying product, the square foot area of each zone must be equal to or larger than the minimum required by the calculations shown in UL 60335-2-40. The combined area of ALL the lowest-level zones is considered the total applied area for the unit. The total applied area must be equal to or larger than required by UL 60335-2-40. In addition, the potential refrigerant leak applies to the single largest circuit of the equipment. If more than 1 piece of HVAC equipment serves a room, the unit with the largest refrigerant circuit amount is used.

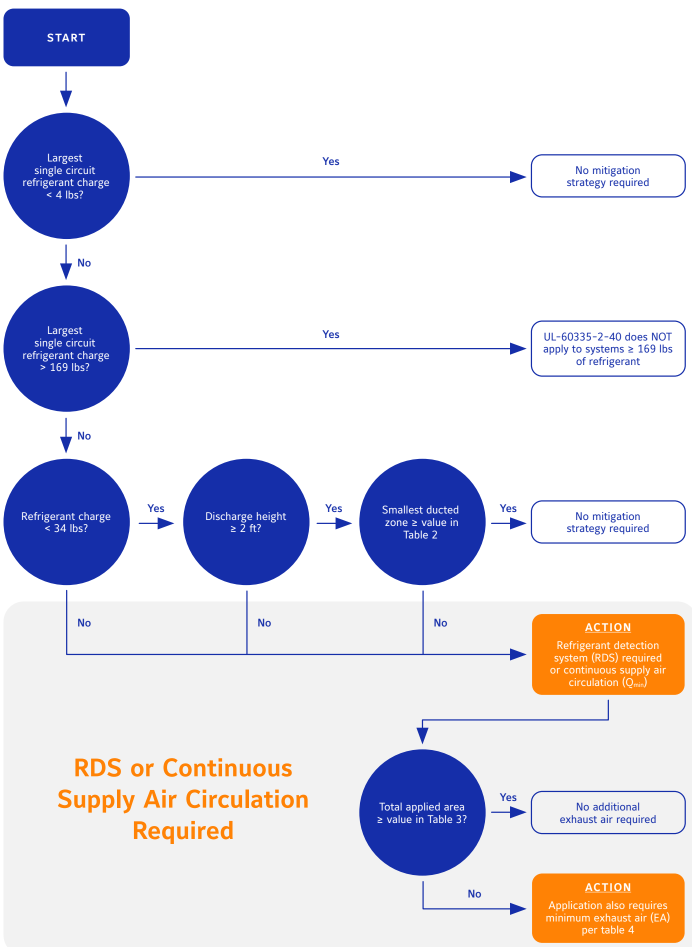


Figure 4. Flow Chart To Determine Required Mitigation.

Scenario #1 applies to refrigerant circuits with a refrigerant charge amount between 4 and 34 pounds. (1.8-15.4 kg). Applying product in a large enough space prevents leaked charge amounts from collecting in amounts greater than the LFL. Table 2 shows pounds of refrigerant and the minimum applied area required to properly apply the product. In this scenario, no other mitigation is required. Most light commercial products (5-25 tons) fall within the given refrigerant range.

Scenario #2 applies to circuits between 4 and 169 lbs. (1.8-76.7 kg) and can be used when any of the following is true.

- The refrigerant quantity is greater than **34 lbs**.
- The smallest ducted zone area is smaller than allowed in Table 2.
- The supply air discharge height from the floor to the diffuser is less than 2 ft.

In scenario #2, the refrigerant detection system activates the supply fan to dilute the refrigerant concentrations, thereby preventing a fire hazard. The RDS activates at 25% of the LFL value. In addition, scenario #2 requires a minimum applied area. The total applied area must be equal to or larger than the required size specified by UL 60335-2-40 shown in Table 3. The table also specifies the minimum circulation airflow rates.

Scenario #3 is used when the total applied area is smaller than the required value per scenario #2. The mitigation strategy still requires an RDS, as well as adding mechanical exhaust airflow rate to the space. Therefore, the excessive amount of refrigerant that could accumulate in the space is diluted and exhausted before a hazardous condition can occur.

Refrigerant Charge Limits

Refrigerant charge limits are based on LFL/RCL principles and application type: LFL/RCL limits the amount of refrigerant charge releasable in each space. ASHRAE Standard 15 lists several application types that require additional considerations when A2L refrigerants are used. Application types are grouped as "occupied human comfort" or "other." Within each of the two groups are building functional uses such as institutional, public assembly, residential, commercial, large mercantile, industrial, laboratory, machinery rooms and mixed occupancy. ASHARE Standard 15 provides general and specific guidance for the different applications.

For packaged and 1-1 split systems that use **ductwork**, ASHRAE Standard 15-2022[5] requires an integral refrigerant leak detection system when uniquely different spaces use the same supply air ductwork (see Figure 5). Unique space refers to isolating walls, doors, etc., that prevent natural ventilation between the spaces such that they are considered refrigerant collection points. Figure 8 illustrates the common ductwork definition. Spaces like gyms, churches, banquet halls using ductwork serving a single space or connected spaces with large free-flowing openings do NOT automatically require a factory-installed leak detection system. Units discharging supply air into an underfloor delivery system require a factory-installed leak detection system because refrigerant can pool in the ductwork. UL 60335-2-40 addresses the same requirements slightly differently at a PRODUCT LEVEL, which may cause an interpretation question. When there is a conflict between the standards, which one applies? It is difficult to say the more stringent rule applies, because in some cases the rules are dissimilar in nature. The application of the product, not just the product itself, must meet requirements described in ASHRAE 15. An example is the refrigerated room application, covered in ASHRAE Standard 15, in Section 7.3.3. The application requires restriction of personnel in the space and devices in the room, which may need to be rated for Class 1 Division 2 hazardous duty. To reduce confusion, product functionality is certified to UL 60335-2-40. Product refrigerant charge limits are also defined by UL-60335-2-40. Building or application functionality should follow ASHRAE 15.

[5] *ASHRAE Standard 15-2022, Section 7.6.2.3, Manufacturer's Refrigerant Detection System Requirements.*

ASHRAE Standard 15-2022:
Example of Building Rules Not Covered by UL 60335-2-40

ASHRAE Standard 15 Section 7.6.2.3 Manufacturer's Refrigerant Detection System Requirements. The following refrigeration systems shall have an integral refrigerant detection system:

a. Ducted HVAC systems with a releasable refrigerant charge (m_{rel}) more than 4.0 lb. (1.8 kg) and with any duct openings **less** than 5.9 ft (1.8 m) above the finished floor.

b. Ducted HVAC systems where spaces connected to the same supply air duct are used as the dispersal floor area to calculate volume, per Section 7.2.

c. Refrigeration systems installed where the occupancy classification is institutional occupancy.

Figure 5. ASHRAE Standard 15-2022, Applications using ductwork and requirement for integral leak detection system.

Packaged units and split systems are certified to UL 60335-2-40. However, the standard does NOT attempt to list all application or building-level requirements shown in ASHRAE 15. The standard focuses on refrigerant charge amount, applied room area, circulation air rates and exhaust air flow rates.

Figure 6 puts into tabular form the governing section that limit the product refrigerant amount based upon product location and product charge amount. The column headings list product applied based on a given room area, applied based on room area with addition mitigation and a third column of additional ventilation. Each row defines the product refrigerant charge ranges as m_1, m_2, m_3 and are further defined in Table 1. The charge ranges are a function of the LFL. The maximum single circuit charge of a product is designated as m_c. The previous discussed flow chart and scenarios are derived from the formulas in each section shown here. This section discusses the formulas that provide the values found in table 2 thru 5 for the different scenarios.

UL 60335-2-40 Summary of Governing Rules
Outline of Annex GG (informative)

<table>
<tr><th rowspan="3">Refrigerant charge</th><th colspan="4">Direct system[a,e]</th><th rowspan="3">Indirect system[b]</th></tr>
<tr><th colspan="3">Indoor space</th><th>Outdoors</th></tr>
<tr><th>Refrigerant charge and room area</th><th>Refrigerant charge, room area and additional requirements</th><th>Additional ventilation</th><th></th></tr>
<tr><td>$m_c \le m_1$ or $m_{rel} \le m_1$</td><td>No room size restriction</td><td></td><td></td><td rowspan="4">No room size restriction</td><td rowspan="5">No room size restriction, GG.2.1DV; GG.6</td></tr>
<tr><td>$m_c < m_c \le 2 \times m_1$ (appliances which are not FIXED APPLIANCES)</td><td>Not allowed</td><td>GG.7</td><td>Not allowed</td></tr>
<tr><td>$m_1 < m_c \le m_2$</td><td>GG.2.1</td><td>GG.2.2[c], GG.2.3[e], GG.9[c], GG.10[c]</td><td>GG.3, GG.8[c], GG.10[c,d]</td></tr>
<tr><td>$m_2 < m_c \le m_3$</td><td>Not allowed</td><td>GG.10[c,d]</td><td>GG.3, GG.8[c], GG.10[c,d]</td></tr>
<tr><td>$m_c > m_3$</td><td colspan="4">ITE Annex 101.DVN; Machinery Room; Clause GG.2.1DV</td></tr>
</table>

[a] Direct system means a REFRIGERATING SYSTEM in which a single rupture of the refrigerant circuit results in a refrigerant release to an indoor space, irrespective of the location of the refrigerant circuit.

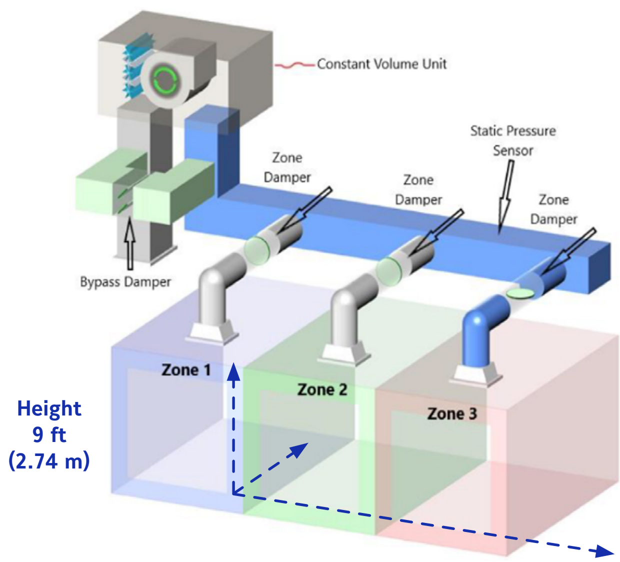
[b] Indirect system means a REFRIGERATING SYSTEM in which a single rupture of the refrigerant circuit does not leak into an indoor space, irrespective of the location of the refrigerant circuit.

[c] These clauses are only applicable to appliances with A2L REFRIGERANT.

[d] Refrigerant charge is limited to $m_1 < m_c \le M_3$.

[e] For ITE COOLING APPLIANCES using A2L REFRIGERANTS with REFRIGERANT CHARGE $m_c > m_1$, Annex 101.DVN shall apply as applicable.

Figure 6. UL 60335-2-40 Annex GG Refrigerant Limits. Provides direct guidance on charge limits, ventilation requirements and the use of leak detection system for product using A2L refrigerants.



Zones
Zone 1 = 15 x 15 = 225 ft^2 (20.9 m^2)
Zone 2 = 20 x 20 = 400 ft^2 (37.2 m^2)
Zone 3 = 5 x 5 = 25 ft^2 (2.3 m^2)
Zone 3 is a closet or small room.
Total Area = 650 ft^2 (60.4 m^2)

Figure 7. Common ductwork between unique spaces requires unit-installed refrigerant leak detector.

Table 1
Refrigerant Charge Ranges for R-454B[6]

Charge Limits	Charge Ranges
$m_1 = 6 \times LFL$ 6×0.296 kg/m^3 ≈ 1.8 kg, 4 lbs.	$m_c \leq m_1$ **$m_c \leq 4$ lbs.**
	$m_1 < m_c \leq m_2$ **4 lbs. $< m_c \leq 34$ lbs.**
$m_2 = 52 \times LFL$	$m_1 < m_c \leq m_3$ **4 lbs. $< m_c \leq 169$ lbs.**
$m_3 = 260 \times LFL$	$m_c > m_3$ **$m_c > 169$ lbs.**
Charge amount rounded to nearest whole pound. Convert kg to lbs. by multiplying kg × 2.20462	

Commercial Examples of Refrigerant Detection System (RDS) Calculations

Scenario #1 → Let us examine each of the three scenarios. In each of the scenarios we will use a 7.5-ton packaged unit with a 6-lb. (2.72 kg) refrigerant charge amount in its largest circuit. And, we are conditioning a space like Figure 7, where the conditioned air is discharged into the spaces at a height 9 ft above the floor. For systems with the largest circuit size between 4 lbs. and 34 lbs., the product can be applied in an unventilated area (scenario #1). “Unventilated” is defined by applications without an air circulation fan or the requirement of a refrigerant detection system (RDS). The product can be applied in a space that is equal to or larger than the area shown in equation #1. The primary minimum area equation #1 governs most circumstances; however, a secondary equation #2 provides a limit to equation #1. As the charge becomes large or the discharge height becomes small, equation #2 limits equation #1. Therefore, each application must have an area larger than the smaller of the two equations.

$$\textit{Minimum Applied Area} \quad A_{min} = \left(\frac{m_c}{2.5 \times LFL^{\frac{5}{4}} \times h_o} \right)^2 \qquad \text{(equation 1)}^7$$

$$A_{min}\,(m^2) = \left(1.83 \, \frac{m_c}{h_o} \right)^2, \quad A_{min}\,(ft^2) = \left(8.546 \, \frac{m_c}{h_o} \right)^2 \qquad \textit{(simplified eq 1)}$$

[6] UL Standard 60335-2-40, Annex GG, Section GG.1.2, Determination of the case applicable, definition of m_1, m_2 and m_3. Equation GG.4, GG.5 and GG.6, where LFL = 0.296 kg/m^3.

[7] UL-60335-2-40 lists equations in metric form only; this paper provides simplified equations in both empirical and metric for quick use by the readers.

but minimum area not less than

$$\textit{Minimum Applied Area (Limits 2)} \quad A_{min} = \frac{m_c}{SF \times LFL \times h_o} \qquad \text{(equation 2)}$$

$$A_{min}\,(m^2) = 6.76\,\frac{m_c}{h_o}\;,\; A_{min}\,(ft^2) = 108.2\,\frac{m_c}{h_o} \qquad \textit{(simplified eq 2)}$$

where

A_{min}	=	Minimum applied area expressed in sq meter (m^2) and sq feet (ft^2)
m_c	=	Largest refrigerant circuit expressed in kilograms (kg) or pounds (lbs.); ex. 6.0 lbs., 2.72 kg
h_o	=	Air discharge height from point of entering the room to the floor. Limited between 2–9 ft (0.6-2.74 m); ex. 9 ft, 2.74 m
SF	=	Safety factor = 0.75
LFL	=	Lower flammability limit = 0.296 kg/m^3 (18.5 lbs./1000 ft^3)
Constant	=	1.83, 6.76, 8.546 and 108.2 derived from fixed values for R-454B/R-32

Example: 7.5-ton packaged rooftop unit with 6 lbs. of R-454B refrigerant and the conditioned air discharge 9 ft above the space floor.

$$A_{min}\,(m^2) = \left(1.83\,\frac{m_c}{h_o}\right)^2 = \left(1.83\,\frac{2.72}{2.74}\right)^2 = 3.3\,m^2\;,\; A_{min}\,(ft^2) = \left(8.546\,\frac{m_c}{h_o}\right)^2 = \left(8.546\,\frac{6.0}{9.0}\right)^2 = 32.5\,ft^2 \qquad \textit{(eq 1)}$$

$$A_{min}\,(m^2) = 6.757\,\frac{m_c}{h_o} = 6.757\,\frac{2.72}{2.74} = 6.7\,m^2\;,\; A_{min}\,(ft^2) = 108.2\,\frac{m_c}{h_o} = 108.2\,\frac{6.0}{9.0} = 72.1\,ft^2 \qquad \textit{(eq 2)}$$

The results of equation 1 are smaller than the results of equation 2. Therefore, equation 1 results dictate the application of the product. If the room area is greater than 32.5 ft^2 (3.0 m^2) with a conditioned air discharge height of 9 ft (2.74m), the product can be used and does NOT require the use of continuous air circulation nor a refrigerant leak detection system. The conditioned air discharge height values used in the equation must be equal to or greater than 2 ft and less than or equal to 9 ft. The ductwork area and height from the unit to the room is also NOT used in the equations. UL-60335-2-40 requires the product installation instructions to show the minimum applied area in a table format. Tables 2 through 5 are a typical set of tables that govern the three scenarios. Table 2 shows that a **34-lb.** system requires a minimum of 409 ft^2 when the discharge of conditioned air into the space is 9 ft from the floor. This minimum area is roughly a 20 ft x 20 ft room. And, similarly, the same 34-lb. system requires a 42 ft x 42 ft room or, more precisely, a 1,840 ft^2 minimum area when the discharge height is 2 ft, as shown in Table 2. The example used a ducted system with multiple rooms. Does scenario #1 still apply? We must consider scenario #2.

Scenario #2 → For **DUCTED SYSTEMS**, UL-50335-2-40 requires each ducted room location (isolated) to also meet the minimum area limit. In the example of a 7.5-ton packaged rooftop with 6 lbs. of refrigerant, the minimum allowable applied area was 32.5 ft^2 (3.3 m^2). If this is NOT true for all zones, the application does NOT meet the rule[8]. This is why the rule is labeled the minimum area for the smallest room. Figure 7, zone 3 is a 25 ft^2 space; therefore, it does not meet the minimum area rule. Unlike ASHRAE Standard 15, Section 7.6.2.3, which requires a factory-installed leak detector for ducted systems, UL 60335-2-40 does not directly require an RDS, except through the above rule. When the space does NOT meet the minimum area requirement, **or** the charge is greater than **34 lbs.**, scenario #2 applies. In Scenario #2, the application requires a minimum circulation air flow rate Q_{min} and a minimum TOTAL applied area, TA_{min}, as shown in the given equations #3 and #4[9]. The minimum airflow rate can be achieved using an RDS, which activates the supply fan when a leak occurs, or the supply fan can run continuously. Another important distinction is the discharge height is no longer a variable value. The discharge height is a constant value of 7.2 feet, even though the application height may be different. The lowest elevation level rule applies.

[8] *Source UL 60335-2-40 4th edition, Annex GG.9 Charge limits for appliances using A2L refrigerants connected via an air duct system to one or more rooms. This document does NOT address the use of natural ventilation. Please refer to UL 60335-2-40, ASHRAE Standard 62.1 and ASHRAE Standard 15 to harmonize the use of natural ventilation.*

[9] *Source UL 60335-2-40 4th edition, Annex GG.9.1DV.2, equation GG.15DV and GG.17DV.*

$$\text{Minimum Air Circulation Rate to the Space} \rightarrow Q_{min} = 6.76 \frac{30 \times m_c}{LFL} \qquad \text{(equation 3)}$$

$$Q_{min}\left(\frac{m^3}{h}\right) = 101.4 \times m_c \ , \ Q_{min}\left(\frac{ft^3}{m}\right) = 27.1 \times m_c \qquad \text{(simplified eq 3)}$$

$$\text{Minimum Total Applied Area} \rightarrow TA_{min} = \frac{m_c}{CF \times LFL \times H} \qquad \text{(equation 4)}$$

$$TA_{min}\ (m^2) = 3.1 \times m_c \ , \ TA_{min}(ft^2) = 15.0 \times m_c \qquad \text{(simplified eq 4)}$$

where

TA_{min}	=	Minimum total applied area expressed in sq meter (m^2) and sq feet (ft^2)
m_c	=	Largest refrigerant circuit expressed in kilograms (kg) or pounds (lbs.); ex. 6.0 lbs., 2.72 kg
H	=	Air discharge height is a constant 2.2 m or 7.2 ft.
LFL	=	Lower flammability limit 0.296 kg/m^3
CF	=	Concentration factor = 0.5 (metric equation)
Constant	=	3.1, 15.0, 27.1 and 101.4 are derived from fixed values for R-454B and R-32 refrigerants

Using the same example above where the refrigerant is 6 lbs. for the largest circuit:

$$Q_{min}\left(\frac{m^3}{h}\right) = 101.4 \times m_c = 101.4 \times 2.72 = 275.8 \frac{m^3}{h} \ , \ Q_{min}\left(\frac{ft^3}{m}\right) = 27.1 \times m_c = 27.1 \times 6 = 162.6 \ cfm$$

$$TA_{min}\ (m^2) = 3.1 \times m_c = 3.1 \times 2.72 = 8.4\ m^2 \ , \ TA_{min}(ft^2) = 15.0 \times m_c = 15.0 \times 6 = 90\ ft^2$$

Using the same example with 6 lbs. of refrigerant, the minimum air circulation rate for a leak detection system is 162.6 cfm or 275.8 m^3/h. Upon a refrigerant leak, an RDS would activate the supply fan to provide at least 162.6 CFM of air to the space to dilute the refrigerant. The designer can also choose to run the supply fan continuously instead of using an RDS. The required combined minimum applied area (TA_{min}) is 90 ft^2 or 8.4 m^2. Note the applied area increased from 34.2 ft^2 to 90 ft^2; however, the rule requiring each zone to meet the minimum area is dropped. For Figure 7, the total applied area is zone 1 plus zone 2 plus zone 3, equaling 650 ft^2 (225 ft^2 + 400 ft^2 + 25 ft^2 = 650 ft^2). Assuming the fan can circulate more than 162.6 cfm, the product can be applied.

Scenario #3 → When the system charge (m_c) is larger than allowed for a given space per scenario #2, scenario #3 applies, i.e., $m_c > m_{max}$. This rule can also be stated as the TOTAL area is smaller than allowed by scenario #2. In the 6-lb. example, the minimum area provided by scenario #1 was 32.5 ft^2, or a 6' x 6' room. Let us assume the only room being served is Zone 3 from Figure 7, 25 ft^2. When the space is too small for the refrigerant charge, the product can be applied if the application includes exhaust air from the space. UL-60335-2-40 section 8.0 provides a set of equations for circulation air rates, exhaust airflow rate and adjacent exhaust room volume shown here[10]. Scenario #3 does NOT have a new total applied area. Equation 5 provides minimum circulation air flow rates and equation 6 provides a **minimum exhaust air flow rate**. Equations 5 and 6 compare the maximum allowed refrigerant charge from scenario #2 to the actual charge. The maximum charge value is found by solving equation 4 for refrigerant charge instead of area. The exhaust air can be delivered to an adjacent room if the room volume meets the minimum shown in equation 7. Tables 4 and 5 shown below are the tabular form of the equations listed here.

$$\text{Minimum Ventilation Rate} \rightarrow Q = \frac{m_c - m_{max}}{4 \times LFL} \times 2 \times 60 \qquad \text{(equation 5)}$$

$$Q\left(\frac{m^3}{h}\right) = 202.7 \times (m_c - m_{max}) \ , \ Q\left(\frac{ft^3}{h}\right) = 54.1 \times (m_c - m_{max}) \qquad \text{(simplified eq 5)}$$

[10] Source UL 60335-2-40 4th edition, Annex GG.8.3, equation GG.13DV, GG.14DV and GG.20.

$$\text{Minimum Exhaust Rate} \rightarrow EA_{min} = \frac{m_c - m_{max}}{CF \times LFL \times H} \quad \text{(equation 6)}$$

$$EA\left(\frac{m^3}{h}\right) = 1.6 \times (m_c - m_{max}) \;,\; EA\left(\frac{ft^3}{min}\right) = 0.43 \times (m_c - m_{max}) \quad \text{(simplified eq 6)}$$

$$\text{Adjacent Application Volume} \rightarrow V = \frac{2 \times m_c}{LFL} \quad \text{(equation 7)}$$

$$V\,(m^3) = 13.5 \times m_c \;,\; V\,(ft^3) = 216.7 \times m_c \quad \text{(simplified eq 7)}$$

where

V	=	Application volume in ft^3 or m^3
Q_{min}	=	Ventilation air rate m^3/h or CFM
EA_{min}	=	Exhaust air rate m^3/h or CFM
CF	=	Concentration factor = 0.25 (metric only)
LFL	=	Lower flammability limit = 0.296 kg/m^3
$(m_c - m_{max})$	=	The difference in charge above the allowed maximum
m_{max}	=	Refrigerant charge allowed **per a given area per equations 1-4**

Scenario #3 Example 5 ft x 5 ft room = 25 ft^2

Let's assume the room is 25 ft^2. The example in scenario #1 required a minimum room area of 32.5 ft^2 and no circulation requirement. Scenario #2's example required a minimum combined, or total, area of 90 ft^2 and constant air circulation or leak detector activating circulation. Scenario #3 is used because a 25 ft^2 room does NOT meet the requirements of #2.

$$\text{Using equation 1, } A_{min} = (8.546 \times \frac{m_c}{h_o})^2 \rightarrow m_c = \sqrt{A_{min}} \times \frac{h_o}{8.546}$$

$$m_c = \sqrt{25} \times \frac{9}{8.546} = 5.27 \text{ lbs}$$

5.27 lbs. is the maximum refrigerant charge for a 25 ft^2 room with 9 ft discharge height.

The product has a 6-lb. charge, therefore 6 - 5.27 = 0.73 lbs. difference.

$$Q_{min}\left(\frac{ft^3}{h}\right) = 54.1 \times (6 - 5.27) = 39.5 \text{ CFM circulation air} \quad \text{(equation 5)}$$

$$EA\left(\frac{ft^3}{min}\right) = 0.43 \times (6 - 5.27) = 0.31 \text{ CFM exhaust air rate} \quad \text{(equation 6)}$$

$$\text{Adjacent Room Volume } (ft^3) = 216.5 \times 6 = 1299\ ft^3 \quad \text{(equation 7)}$$

The example used a 0.73 lbs. difference, using Table 4. We can see results for a 1-lb. difference requiring 38 CFM circulation rate with exhaust airflow of 0.45 CFM. The room's air can be exhausted to the outdoors or to an adjacent room larger than 1299 ft^3. More importantly, scenario #3 requires constant exhaust air.

If the application can NOT meet the requirements of scenario #3, the application should be reviewed by the specifying agents for standards and code compliance.

Table 2
Minimum Applied Area to Apply R-454B Unit
No RDS Required

Maximum Single Circuit Charge (m_c)	Discharge Height (h_o) From Floor to Diffuser							
	ft	ft	ft	ft	ft	ft	ft	ft
lbs.	2.0	3.3	4.6	5.9	6.6	7.2	8.0	9.0
4	292.2	107.3	55.2	33.6	26.8	22.5	18.3	14.4
6	657.3	241.4	124.3	75.5	60.4	50.7	41.1	32.5
8	1168.6	429.2	220.9	134.3	107.3	90.2	73.0	57.7
10	1825.9	670.7	345.2	209.8	167.7	140.9	114.1	90.2
12	2629.4	965.8	497.0	302.1	241.4	202.9	164.3	129.8
16	4674.4	1717.0	883.6	537.1	429.2	360.7	292.2	230.8
18	5916.0	2173.0	1118.3	679.8	543.3	456.5	369.8	292.2
20	7303.8	2682.7	1380.7	839.3	670.7	563.6	456.5	360.7
22	8837.5	3246.1	1670.6	1015.5	811.5	681.9	552.3	436.4
24	10517.4	3863.1	1988.2	1208.6	965.8	811.5	657.3	519.4
26	12343.3	4533.8	2333.3	1418.4	1133.5	952.4	771.5	609.5
28	14315.4	5258.2	2706.1	1645.0	1314.5	1104.6	894.7	706.9
30	16433.5	6036.2	3106.5	1888.4	1509.0	1268.0	1027.1	811.5
32	18697.6	6867.8	3534.5	2148.5	1717.0	1442.7	1168.6	923.3
34	21107.9	7753.1	3990.1	2425.5	1938.3	1628.7	1319.2	1042.4
Maximum Single Circuit Charge (m_c)	Discharge Height (h_o) From Floor to Diffuser							
	m	m	m	m	m	m	m	m
kg	0.6	1.0	1.4	1.8	2.0	2.2	2.4	2.7
1.8	29.7	10.9	5.6	3.4	2.7	2.3	1.9	1.5
2.7	66.7	24.5	12.6	7.7	6.1	5.1	4.2	3.3
3.6	118.6	43.6	22.4	13.6	10.9	9.2	7.4	5.9
4.5	185.3	68.1	35.0	21.3	17.0	14.3	11.6	9.2
5.4	266.9	98.0	50.4	30.7	24.5	20.6	16.7	13.2
7.3	474.4	174.3	89.7	54.5	43.6	36.6	29.7	23.4
8.2	600.4	220.5	113.5	69.0	55.1	46.3	37.5	29.7
9.1	741.3	272.3	140.1	85.2	68.1	57.2	46.3	36.6
10.0	896.9	329.5	169.6	103.1	82.4	69.2	56.1	44.3
10.9	1067.4	392.1	201.8	122.7	98.0	82.4	66.7	52.7
11.8	1252.8	460.2	236.8	144.0	115.0	96.7	78.3	61.9
12.7	1452.9	533.7	274.7	167.0	133.4	112.1	90.8	71.7
13.6	1667.9	612.6	315.3	191.7	153.2	128.7	104.2	82.4
14.5	1897.7	697.0	358.7	218.1	174.3	146.4	118.6	93.7
15.4	2142.3	786.9	405.0	246.2	196.7	165.3	133.9	105.8

Simplified equation 1: $A_{min} = (8.546 \times m_c/h_o)^2$ (IP); $Amin = (1.83 \times m_c/h_o)^2$ (SI).

Simplified equation 2: $A_{min} = (108.236 \times m_c/h_o)^2$ (IP); $Amin = (6.75 \times m_c/h_o)^2$ (SI).

m_c = refrigerant charge in lbs. or kg, h_o = discharge height from the entry point in the room to the floor in feet or meters.

Table equations sourced from UL-60335-2-40 Annex GG, Section 2.0.

Table 3
Refrigerant Detector Required
Total Applied Area and Air Circulation Rates for R-454B HVAC System

Maximum Single Circuit Refrigerant Charge (m_c)		Minimum Applied Area (TA) Minimum Air Circulation Rate (Q) Range: 4-169 lbs. of refrigerant			
		$TA_{min} = 15.0 \times m_c$ $Q_{min} = 27.1 \times m_c$		$TA_{min} = 3.1 \times m_c$ $Q_{min} = 101.4 \times m_c$	
		TA	Q_{min}	TA	Q_{min}
lbs.	kg	ft^2	CFM	m^2	m^3/h
4	1.8	60.0	108	5.6	184
6	2.7	90.0	163	8.4	276
8	3.6	120.0	217	11.2	368
10	4.5	150.0	271	14.1	460
12	5.4	180.0	325	16.9	552
16	7.3	240.0	434	22.5	736
18	8.2	270.0	488	25.3	828
20	9.1	300.0	542	28.1	920
22	10.0	330.0	596	30.9	1012
24	10.9	360.0	650	33.7	1104
26	11.8	390.0	705	36.6	1196
28	12.7	420.0	759	39.4	1288
30	13.6	450.0	813	42.2	1380
32	14.5	480.0	867	45.0	1472
34	15.4	510.0	921	47.8	1564
35	15.9	525.0	949	49.2	1610
40	18.1	600.0	1084	56.2	1840
45	20.4	675.0	1220	63.3	2070
50	22.7	750.0	1355	70.3	2300
60	27.2	900.0	1626	84.4	2760
70	31.8	1050.0	1897	98.4	3220
80	36.3	1200.0	2168	112.5	3680
90	40.8	1350.0	2439	126.6	4139
100	45.4	1500.0	2710	140.6	4599
110	49.9	1650.0	2981	154.7	5059
120	54.4	1800.0	3252	168.7	5519
130	59.0	1950.0	3523	182.8	5979

Equations #3 and #4:
TA = Total minimum applied area of the product, where height is a constant 7.2 ft/2.2 m.
m_c = Refrigerant charge in lbs. or kg.
h_o = Discharge height from the entry point in the room to the floor in feet or meters.
Q = Minimum ventilation airflow rate.
Table equations sourced from UL-60335-2-40 Annex GG, Section 2.0.

Table 4
R-454B HVAC Units Where $m_c > m_{max}$
RDS and Exhaust Air Flow Required

Maximum Single Circuit Charge (m_c - m_{max})		(Refrigerant charge greater than allowed by room area per UL-60335-2-40 Annex 2.1 and 2.2) Minimum Air Circulation (Q) and Exhaust Airflow Rates (EA)			
		$Q (cfm) = 54.1 \times (m_c - m_{max})$ $EA (cfm) = 0.43 \times (m_c - m_{max})$		$Q (m^3/h) = 202.7 \times (m_c - m_{max})$ $EA (m^3/h) = 1.6 \times (m_c - m_{max})$	
lbs.	kg	Q_{CFM}	EA_{CFM}	$Q_{m^3/h}$	$EA_{m^3/h}$
1	0.45	54	0.4	10966	0.7
2	0.91	108	0.9	21932	1.5
3	1.36	162	1.3	32898	2.2
4	1.81	216	1.7	43864	2.9
5	2.27	271	2.2	54830	3.6
6	2.72	325	2.6	65796	4.4
7.5	3.40	406	3.2	82246	5.4
10	4.54	541	4.3	109661	7.3
12	5.44	649	5.2	131593	8.7
14	6.35	757	6.0	153525	10.2
16	7.26	866	6.9	175457	11.6
18	8.16	974	7.7	197389	13.1
20	9.07	1082	8.6	219321	14.5
22	9.98	1190	9.5	241254	16.0
24	10.89	1298	10.3	263186	17.4
26	11.79	1407	11.2	285118	18.9
28	12.70	1515	12.0	307050	20.3
30	13.61	1623	12.9	328982	21.8

Equations #5 and #6:
Refrigerant charge greater than allowed by room area per UL-60335-2-40 Annex 2.1 and 2.2.
Table equations sourced from UL-60335-2-40 Annex GG.8, GG13DV and GG14DV.

Table 5
Exhaust Air Minimum Adjacent Volume Size

Maximum Single Circuit Charge (m_c - m_{max})		(Refrigerant charge greater than allowed by room area Annex eq 1-4) Adjacent Room Volume	
		$Volume (m^3) = 13.5 \times m_c$ $Volume (f^3) = 216.5 \times m_c$	
lbs.	kg	ft^3	m^3
4	1.81	866	54.0
6	2.72	1299	81.0
8	3.63	1732	108.0
10	4.54	2165	135.0
12	5.44	2598	162.0
16	7.26	3464	216.0
18	8.16	3897	243.0
20	9.07	4330	270.0
22	9.98	4763	297.0
24	10.89	5196	324.0
26	11.79	5629	351.0
28	12.70	6062	378.0
30	13.61	6495	405.0

Equation #7:
Equations sourced from UL-60335-2-40 Annex GG.8, GG20.

Residential Examples of RDS Calculations

Figure 8. Typical Residential Applications.

Residential Systems

Let us look at two scenarios. Both assume the equipment is properly sized for the application. Charge information is pulled from the Tabular Data Sheets supplied with the equipment.

Scenario #1 → In this scenario, the system consists of a 14.3 SEER2 2-ton capacity AC with matching indoor coil and gas furnace. The conditioned air is discharged into the space at floor level. The AC unit ships with 2.75 lb., the selected coil adder is 0 lb. and line set is 30 ft with a charge adder of 0.537 lb. Total system charge in this scenario is 3.287 lbs., which is less than 4 lbs. Therefore, a refrigerant detection system is not required. The application does NOT have area limits, as well.

Scenario #2 → In this scenario, the unit is a 13.4 SEER2 5-ton capacity AC with matching indoor coil and gas furnace. The conditioned air is discharged into the space at floor level. The AC unit ships with 3.635 lbs., the selected coil adder is 1.187 lbs. and line set is 25 ft with a charge adder of 0.625 lb. Total system charge in this scenario is 5.447 lbs., which is more than 4 lbs. Therefore, a refrigerant detection system is required.

As illustrated in these two examples, residential calculations are straightforward.

Unit charge + coil adder charge + additional line set charge = total system charge. If the total system charge is less than 4 lbs., a refrigerant detection system will not be required. If the total system charge is more than 4 lbs. in a residential application, JCI requires an RDS for the system.

Special Consideration for Commercial Split Systems

Split systems have an undefined refrigerant charge amount until properly installed in the field. A split system can use nearly double the amount of refrigerant than a comparable, same-tonnage packaged system. The minimum area limits must be specifically calculated for the equipment. JCI-matched products can be purchased with a factory-installed leak detection system. Customers also can purchase condensers and air handlers from different vendors that are assembled in the field to work as one system. Split systems can rely on continuous ventilation strategies in lieu of a leak detector, or the installing agent can properly coordinate a field-installed leak detection system. The field-installed piping must also adhere to national and local codes.

Refrigerant Charge Limit

Leak Detector or Continuous Fan Option?

The next logical question: why would an application select a leak detector system over a continuous circulation strategy? Most packaged and split systems are set to run continuously in the occupied mode, thereby providing continuous ventilation and meeting the needs of air quality and A2L mitigation. However, the standard can be interpreted to require airflow in the unoccupied mode. Most HVAC equipment runs intermittently in the unoccupied mode.

One question not addressed by the standards is changing the mitigation strategy in the field. Let's assume a factory-installed leak detector was chosen. Let us further assume the leak detection system failed. Can the equipment be allowed to run using the continuous fan mitigation strategy? The simple answer is "yes," as a temporary condition, because the continuous fan operation for space ventilation reasons far exceeds the requirements for fire hazard. This is not an ideal situation and should be monitored by technical service personnel to quickly restore the unit to proper operation.

Leak Detection Systems (RDS)

When required, the leak detection system will sense R-454B refrigerant and activate an alarm sequence when the sensed concentration reaches no greater than 25% of the LFL per UL 60335-2-40 Annex LL. The leak detection system will work as follows:

- The factory preset and calibrated leak detection system will sense the rated concentration amount within 30 seconds of being exposed to certified test gas at 295 ft/min flow rates. The system has an accuracy of ±20% at the factory. The RDS activation point is published in IOMs and user manuals. This rate is equivalent to a major leak. The RDS is NOT designed to react to small cracks and pin out leaks.

- Upon sensing an alarm condition, the alarm will turn off compressors, de-energize attached ignition sources (electric heaters, gas furnaces, etc.) and activate the supply fan to provide circulation air to the space to dilute the refrigerant concentration. The system must provide at least the minimum circulation air rate per UL 60335-2-40 Annex GG using equation #3 or #5 shown in this document. JCI systems activate the supply fan at 50-100%, thereby far exceeding the required minimum CFM. In addition, electric circuits and appliances with 1 kVA ignition value that are not intrinsically safe, or explosion-proof, should also be de-energized upon an alarm condition. For JCI systems, only the supply fan will run, while all other systems will be OFF.

- The alarm system will open or set zone dampers, VAV boxes, etc., to full airflow set points, which are associated and/or connected via ductwork to the refrigerant system.

- Upon activation of the alarm, an alarm output will be sent to building personnel.

- The leak detection system has self-testing to ensure proper operation. Upon failure during a self-test, the system will default to alarm mode and not allow cooling operation until field-verified by personnel. Neither field recalibration nor adjustment of the activation setpoint for the refrigerant sensors is allowed.

- The alarm system will maintain airflow for an additional 5 min after the refrigerant concentration values have dropped below the alarm limit.

Service Considerations

UL Standard 60335-2-40 requires proper documentation of the application. Units are marked with area limits and identify that the unit uses an A2L refrigerant requiring fire mitigation procedures. The installation manuals should also have table-formatted area limitations. See below for a complete listing of requirement topics.

Technicians' and other service personnel's tools must be certified for use with R-454B. The list below shows the expected changes in tools. Many of the same service items can be used for servicing A2L refrigerants versus R-22 and R-410A. However, some service equipment, due to the electrical components and motors, should be specifically designed for use with mildly flammable A2L refrigerants (e.g., R-454B, R-1234yf, R-32, etc.). All service should be conducted in a safe manner and with respect to the guidelines given by the relevant codes and standards in your country/region.

Figure 9. Labeling requirement per UL 602335-2-40, Annex DD.

Service Tools	R-410A	R-454B
Gauge Manifold Set	Routine	Routine
Charging Hoses	Routine	Routine
Scales (Weight)	Routine	Routine
Flare Tool	Routine	Routine
Pipe Cutter	Routine	Routine
Vacuum Pump	Routine	Routine*
Dry Powder/CO_2 Fire Extinguisher	Not Necessary	Chemical Compatible
Gas Detector	Routine	2L Certified
Leak Detector	Routine	2L Certified
Refrigerant Recovery Cylinder	Routine	Flammable (GHS Label) Left-Hand Thread
Recovery Machines	Routine	2L Certified

** Proposed switch should be located away from work zone.*

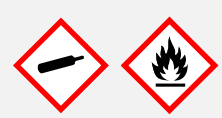
Service cylinders for use with A2L			
Service Item	**R-404A**	**R-410A**	**Opteon™ XL**
Cylinder Type	Returnable	Returnable	Returnable
Cylinder Pressure Rating			Min 42 Bar
Valve Threading	Right-Hand	Right-Hand	Left-Hand
Valve Type			Typical DIN 477-1
GHS Markings			

Figure 10. Refrigerant containment vessel comparison.

Although A2L cylinders have the same rated pressure as current R-410A cylinders, tanks are designed with several distinguishing characteristics, including:

Pressure relief valve In the event of excessively high cylinder pressure, A2L cylinders include a pressure relief valve that is designed to release only enough refrigerant to reduce the pressure in that cylinder. Upon release, the valve will reset. The point is to mitigate releasing a localized charge amount with a large enough concentration that could ignite.

Red band/stripe A2L cylinders will have a red band (stripe) or the entire top painted red to indicate the presence of the mildly flammable refrigerant.

Left-hand (LH) thread To further distinguish from other types of refrigerants, A2L cylinders will have a left-handed thread.

UL 60335-2-40 Clause	Description	Installation	Maint & Repair	Decommissioning
DD.2	Symbols showing A2L flame	Yes	Yes	Yes
DD.3.1	Exposed refrigerant piping in space labeling	Yes	Yes	-
DD.3.2	Unventilated areas – warnings and ignition sources; warning to open flames	Yes	Yes	-
DD.4	Information on servicing the equipment	-	Yes	Yes
DD.4.1	General information laid out related to 4.2 thru 4.10	-	Yes	Yes
DD.4.2	Safety checks to area – ignition sources	-	Yes	Yes
DD4.3	Work procedures, repair unit while minimizing risk to ignition	-	Yes	Yes
DD4.4	Avoid working in confined spaces	-	Yes	Yes
DD4.5	Check for presence of refrigerant	-	Yes	Yes
DD.4.6	Presence of fire extinguishers	-	Yes	Yes
DD.4.7	Ignition sources	-	Yes	Yes
DD.4.8	Working in ventilated space	Yes	Yes	-
DD.4.9	Check that refrigerant meets area limit requirements	-	Yes	-
DD.5.1	Disconnect power to repair sealed component	-	Yes	-
DD.5.2	Inspect electrical connections and insure level of protection -t damaged	-	Yes	-
DD.6	Repair to intrinsically safe components and A2L	-	Yes	-
DD.7	Inspect cabling – damage	Yes	Yes	-
DD.8	How to inspect and detect flammable refrigerant in the system	Yes	Yes	Yes
DD.9	Best practices for removal and evacuation of A2L refrigerant	Yes	Yes	Yes
DD.10	Best practices for charging units using A2L	Yes	Yes	-
DD.11	Decommissioning units with A2L – minimize ignition	-	-	Yes
DD.12	Labeling of decommissioned unit, labeling	-	-	Yes
DD.13	Best practices for refrigerant recovery for repair or decommissioning	Yes	Yes	Yes

Table 101.DVF.1
Warning label requirements (English)

Warning letter	A2L	A2 or A3	Product type [c]	Required wording	All text font size, min (mm)	Location
A (a)	X		B	WARNING - Risk of Fire. Flammable Refrigerant Used. To Be Repaired Only by Trained Service Personnel. Do Not Puncture Refrigerant Tubing.	3.2	Outside of unit
C (a)	X		B	WARNING - Risk of Fire. Dispose of Properly in Accordance With Federal or Local Regulations. Flammable Refrigerant Used.	3.2	Outside of unit
E	X		B	WARNING - Risk of Fire. Flammable Refrigerant Used. Consult Repair Manual/Owner's Guide Before Attempting To Service This Product. All Safety Precautions Must Be Followed.	3.2	Inside of unit near compressor
G	X		B	WARNING - Risk of Fire Due to Flammable Refrigerant Used. Follow Handling Instructions Carefully in Compliance With National Requlations.	3.2	On appliance packaging if factory-charged
I	X		B	Minimum installation height, X m and ft *(if applicable).* Minimum room area (operating or storage), Y m^2 and f^2. Note: For minimum room areas at higher installation heights, see instructions (note is optional).	3.2	Indoor unit near nameplate
K (b)	X	X	NF	WARNING - Risk of Fire or Explosion - Store in a well-ventilated room without continuously operating flames or other potential ignition.	6.4	Outside of appliance
N	X		NF	WARNING - Risk of Fire - Store in a well-ventilated room without continuously operating flames or other potential ignition sources.	6.4	N

Notes:
(a) Required on both indoor and outdoor sections of split systems.
(b) Not required if $m_c < m_1$.
(c) Product type: F = fixed appliance, NF = non-fixed appliance, and B = both fixed and non-fixed.

Conclusion

As the U.S. HVAC industry transitions from HFC to low-GWP HFO refrigerants, the environmental benefits are clear. However, it is critical that industry professionals understand the impact of these refrigerants in residential and commercial applications. A2L refrigerants such as R-454B have a low-flammability classification and, as such, the conversion to their use requires new safety methods for installation, operation and maintenance that were not required for A1 refrigerants like R-410A. Education and preparation in A2L refrigerant handling can help ensure HVAC professionals are ready to navigate this transition successfully in both residential and commercial applications.

Mildly Flammable Refrigerant Symbol

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