UNDERSTANDING A2L REFRIGERANTS

Honeywell

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HONEYWELL REFRIGERANT DEVELOPMENT

Honeywell has been at the forefront of every major development of fluorocarbon refrigerants technology. As the world seeks new, lower Global Warming Potential (GWP) solutions, Honeywell delivers again, with its Solstice® brand of hydrofluoroolefins (HFOs). This family of unique products offers comparable performance to today's most widely used stationary and mobile refrigerants, blowing agents, and aerosol propellants. However, unlike their more common counterparts, the molecular structure of Solstice products causes them to have short atmospheric lifetimes, which means they have very low GWP.

Honeywell's Solstice brand reflects the products' break-through environmental properties, including their superior cooling capabilities for air conditioning and stationary refrigerant applications.

Solstice L40x (R-455A), Solstice 454C (R-454C), and Solstice 454B (R-454B) are state-of-the-art long-term refrigeration and HVAC refrigerants that are mildly flammable (A2L). These refrigerants promise to have significant use in HVAC and refrigeration in the coming years.

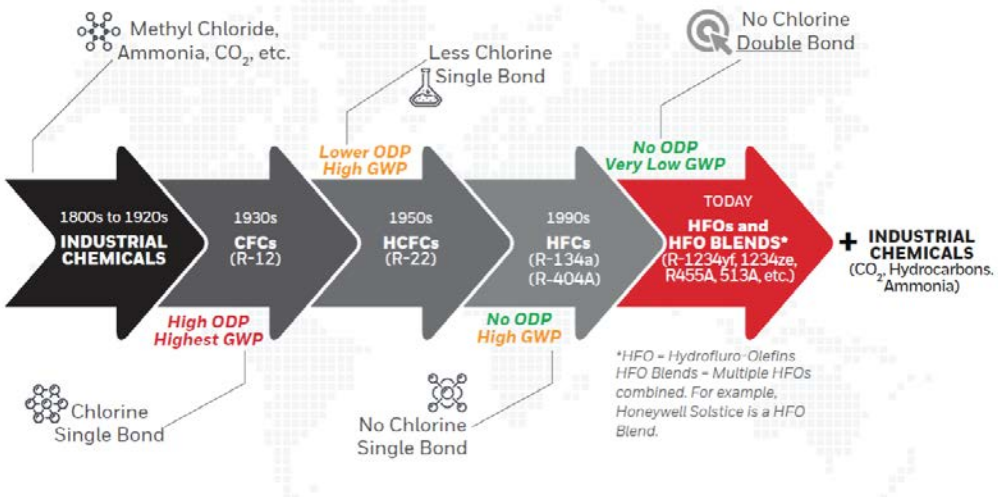
REGULATIONS DRIVING CHANGE

Since the first use of industrial chemicals in the 1800s, to today's use of HFO-based refrigerants, the evolution of refrigerants and refrigeration has followed a need for being safe, efficient, and environmentally friendly.

The largescale adoption of refrigeration and air conditioning has benefitted society through the development of a safe food chain as well as comfort cooling.

Identification of the hazards of industrial chemicals, as well as Ozone Depletion Potential (ODP) and global warming, has led to regulations to ensure safe and environmentally friendly refrigerants.

HISTORY OF REFRIGERANT TRANSITIONS

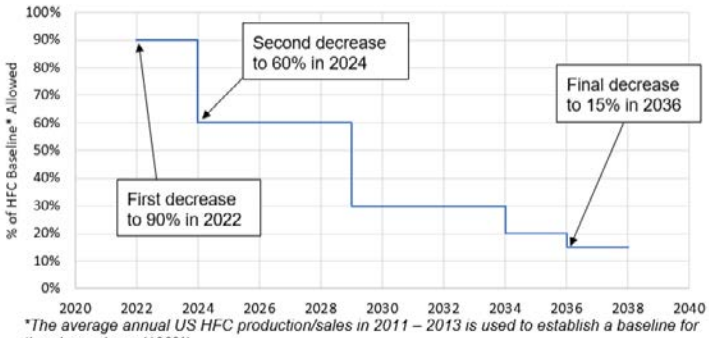


The Montreal Protocol removed chlorofluorocarbon (CFC) and hydrochlorofluorocarbon (HCFC) refrigerants from production in the United States. The final stage of this regulation for the United States took place Jan. 1, 2020.

The Kigali amendment to the Montreal Protocol adds hydrofluorocarbons (HFCs) to the regulated substances. The amendment strives to reduce HFC usage to 15% of the baseline levels by 2036.

The United States approved the AIM Act in 2020, which mimics the requirements of the Kigali amendment as shown in the graph below. As part of the AIM Act, producers of fluorinated refrigerants are given specific GWP-based quotas based on a phase-down schedule.

Figure 1: U.S. AIM HFC Phase-Down Schedule



The average annual US HFC production/sales in 2011 – 2013 is used to establish a baseline for the phase-down (100%)

The U.S. Environmental Protection Agency (EPA), under authority of the AIM Act, enacted sector-specific regulations in the Technology Transition Program in October 2023. These sector-specific regulations are intended to eliminate higher GWP refrigerants for use in specific applications. Some of the proposed sector regulations and their A2L replacements are in the table below:

INDUSTRIES AND APPLICATIONS	AIM ACT REGULATORY GWP LIMIT	Solstice® yf (R-1234yf) GWP <1	Solstice® ze (R-1234ze) GWP <1	Solstice® L40X (R-455A) GWP-148	Solstice® 454C (R-454C) GWP-148	Solstice® 454B (R-454B) GWP-466
Food Retail						
Supermarket system	150 (>200lb), 300 (<200lb)	■	■	■	■	
Condensing unit	150 (>200lb), 300 (<200lb)	■	■	■	■	
Stand-alone refrigerator	150	■	■	■	■	
High side of cascade	300 (<200lb)	■	■	■	■	
Buildings						
Chillers - Comfort cooling and heating	700		■			■
Residential/ light commercial AC/ heat pumps	700					■
Variable Refrigerant Flow (VRF) systems	700					■
Industrial Process						
Chillers – Low and medium temperature	700[2]	■	■	■	■	■
Industrial process - non chiller	150 (>200lb), 300 (<200lb), 700 (-58F > -22F)[2]	■	■	■	■	
Industrial high temperature heating	NA	■	■			
Data Centers						
Room and precision air conditioning	700		■			■
Liquid Cooling (cold plates, etc)			■			
Cold Storage	150 (>200lb), 300 (<200lb)	■	■	■	■	
Commercial Ice Machines	150[1]	■		■	■	
Household Refrigerators/ Freezers	150	■	■			
Ice Rinks	700	■		■	■	
Organic Rankine Cycle	NA					
Non-Mechanical Heat Transfer	NA					
Refrigerated Transport	700[1,2]	■		■	■	■

■ NEW SYSTEMS - OEM PRODUCT AVAILABLE EARLY 2024
■ NEW SYSTEMS - CONTACT HONEYWELL FOR OEM AVAILABILITY

[1] See technology transition rule for specific refrigerant exclusions.
[2] See technology transition rule for ultra low temp rules.

These regulations effectively eliminate refrigerants such as R-410A, R-404A, R-448A, and R-449A in new refrigeration and HVAC equipment as early as Jan. 1, 2025.

Refer to the EPA Technology Transition Program Fact Sheet for specific dates and limits.

EPA's Significant New Alternatives Policy (SNAP) Program is approving new refrigerants that adhere to these lower GWP limits. The majority of these refrigerants are mildly flammable (A2L) and are the subject of this paper.

Some examples of EPA's proposed SNAP 26 include:

- R-455A; Similar to R-404A GWP<150, A2L
- R-454B: Similar to R-410A GWP<700, A2L
- R-454C: Similar to R-404A GWP<150, A2L

For more information, view the EPA's SNAP Fact Sheet.

Though A2Ls will be a key component of refrigerant strategies of the future, Honeywell does offer a medium-temperature A1 <150 GWP refrigerant. For details, read the Honeywell N-71 (R-471A) application guide.

INTRODUCTION TO A2Ls

A2Ls AS A REFRIGERANT CLASSIFICATION

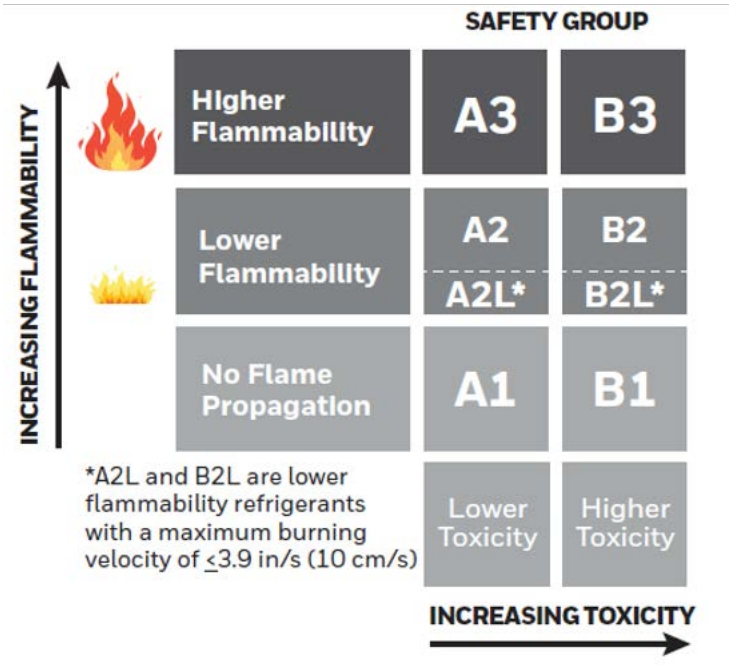
ASHRAE Standard 34 classifies refrigerants into toxicity and flammability groups. These range from non-toxic and non-flammable (no flame propagation) to toxic and highly flammable.

Added in recent years, the A2L class allows for the use of refrigerants that have lower flammability than A2 and A3 refrigerants and are suited to many A1 refrigerant applications such as R-404A and R-410A. A2L refrigerants are significantly lower in flammability than A2, and particularly A3, refrigerants.

Toxicity:
- Low: A
- High: B

Flammability:
- No Flame propagation: 1
- Lower Flammability: 2L
- Flammable: 2
- Higher Flammability: 3

Examples:
- A3: Hydrocarbons (R-290, R-600a)
- A2: R-142b, R-143a, R-152a
- A1: R-22, R-404A, R-407C, R-410A, R-448A. R-744A
- A2L: R-1234yf, R-1234ze, R-455A, R-454B, R-454C
- B1: R-123, R-245fa
- B2L: Ammonia (R-717)



Industry organizations such as the Air Conditioning, Heating, and Refrigeration Institute (AHRI) have done safety testing on these refrigerants. This testing determined that A2L refrigerants are safe for use in commercial and residential systems with the addition of mitigation measures. (See Leak Mitigation section below.)

FLAMMABILITY MEASURES AND COMPARISONS

Refrigerant flammability is determined by the American Society for Testing and Materials (ASTM) test E681 "Standard test for concentration limits of flammability of chemicals." Refrigerant flammability class (1, 2, 2L, 3) is based on the values for:

- Flame propagation
- Heat of combustion
- Burning velocity

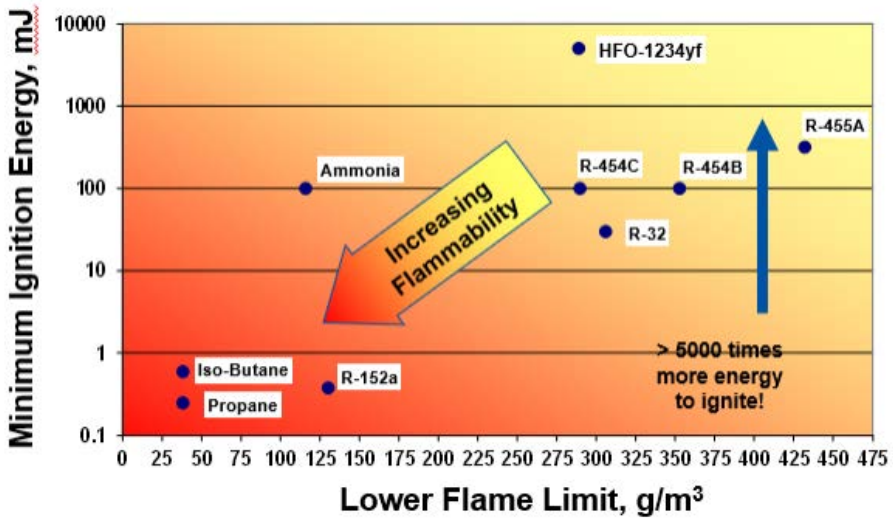
The values of these properties are used to assign a refrigerant to each class and are determined by American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) standard 34, "Designation and safety classifications for refrigerants."

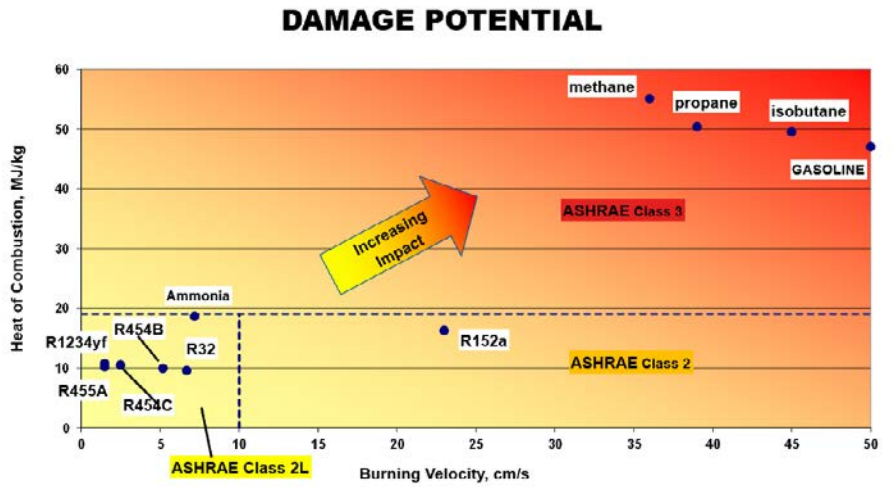
A2L refrigerants are significantly lower in flammability as indicated in the following graphs.

Flammability is evaluated by 'Chance of Flame occurring' and 'Effect of Flame occurring' whereas:

- Chance of Flame occurring -> Lower Flame Limit, Minimum Ignition Energy
- Effect of Flame occurring -> Burning Velocity, Heat of Combustion

PROBABILITY OF IGNITION





RECOMMENDED A2L FLUIDS FOR REFRIGERATION

The refrigerants listed below are applicable to many applications. The usage is based on environmental regulations, safety codes (UL, CSA, etc.), and mechanical codes (ASHRAE, UMC, IMC, etc.).

In general, these refrigerants will find large usage in commercial, residential, and industrial applications and will replace legacy A1 refrigerants for new equipment in the near future.

A2L REFRIGERANTS

Solstice® L40x (R-455A) is a mildly flammable (A2L) refrigerant having a boiling point of -50oF (average of dew and bubble) at 0 psig. R-455A is suitable for medium- and low-temperature refrigeration applications. The environmental properties of Solstice® L40x include a low GWP of 146 (AR5) and zero ODP. L40x also has a high Lower Flame Limit (LFL) as compared to other similar refrigerants in its class. This makes a flame occurrence much harder to occur. Due to this, L40x has much larger charge limits than other refrigerants in its class. Refer to the Underwriters Laboratories (UL) codes section below.

Solstice® 454C (R-454C) is a mildly flammable (A2L) refrigerant having a boiling point of -43oF (average of dew and bubble) at 0 psig. R-454C is suitable for both medium- and low-temperature refrigeration. The environmental properties of Solstice 454C include a GWP of 146 (AR5) and a zero ODP.

A2L REFRIGERANT COMPARISONS

REFRIGERANT	SAFETY CLASSIFICATION	LFL (KG/M3)	MAX CHARGE SIZE POUNDS (LBS.)*	CAPACITY VS R-404A**
R-290 (Propane)	A3	0.038	1.1	95%
R-454C	A2L	0.291	165	91%
R-455A	A2L	0.43	247	101%

*Maximum charge size refers to UL listing for commercial equipment. Non-commercial may have higher limits per ASHRAE 15

** Thermodynamic analysis

CODES AND STANDARDS

DISCLAIMER

Codes and regulations are in steady flux. The following interpretations are Honeywell's best assessment as of this publication. As manufacturers and code officials acclimate to the use of A2L refrigerants, we expect to see modifications to the codes and their interpretations.

ASHRAE

ASHRAE Standard 15, which is the safety standard for refrigeration systems, is the code generally referred to by local codes such as the International Mechanical Code (IMC) and the Uniform Mechanical Code (UMC). While local jurisdictions may make modifications to the ASHRAE standard to meet local needs, it is by and large the document to use to determine safety codes for refrigeration.

The latest edition of ASHRAE Standard 15, published in 2022, includes specific requirements for the A2L refrigerant class. Previous editions included A2L as a sub-class of A2 refrigerants, which at that time included the stricter A2 usage requirements.

For systems other than human comfort, ASHRAE Standard 15 allows for the use of A2Ls in accordance with section 7.7. This allows use of 260 x LFL [kg/m3], which is in sync with the UL 60335-2-89 standard.

ASHRAE also stipulates that a system be "listed" unless used in industrial applications (section 7.7.3). To be listed, a piece of equipment adheres to UL 60335-2-40 (HVAC) or 60335-2-89 (Refrigeration).

For industrial systems, ASHRAE Tables 7-1 and 7-2 should be followed. These charges can be significantly larger than the commercial systems. It is also important to understand the (higher charge) exceptions made for industrial and storage coolers and freezers within the code.

A free view-only version of ASHRAE Standard 15 is available here.

EQUIPMENT SAFETY (UL)

As noted above, ASHRAE Standard 15 requires UL listing for commercial refrigeration equipment, which is why the UL codes generally drive the refrigerant charge quantities.

The international IEC 60335-2-89 is the basis for the development of the UL standard 60335-2-89 and the Canadian Standards Association (CSA) Standard 22.2, both of which contain the same language.

1. Partial Systems

The UL/CSA versions of these standards include the use of partial units. UL defines a partial unit as "a remote condensing (or condenser) unit or remote evaporator unit which is part of a total connected assembly of a refrigeration system where not all assemblies that create the refrigeration system are specified by the manufacturer."

This, in effect, adds supermarket and convenience store systems to the standard.

Due to the nature of partial systems having the potential to come from different manufacturers, the safety codes evaluate these "partial units" independently. For example, in one complete refrigeration system, you may have a condensing unit by manufacturer "x," a display case by manufacturer "y," and a walk-in cooler evaporator by manufacturer "z." The UL/CSA safety standards assess each of these partial units independently. Each unit may have different requirements. The condensing unit may not need any mitigation while the walk-in may need leak detection, shut off valves, and air circulation or evacuation, depending on the charge and cooler size.

For partial field-erected systems such as condensing units (compressor + condenser) or supermarket "rack" systems employing an A2L refrigerant, the system shall comply with the requirements in Annex 101.DVG and Annex 101.DVU of the latest UL 6035-2-89 (refrigeration) or 60335-2-40 (HVAC). (Field-erected systems in this context do not include appliances with refrigerated compartments, packaged refrigerating (cassette) units for walk-in coolers and walk-in freezers, or ice makers.)

The standard defines several refrigerant mass variables defined as follows (refrigeration 2-89 values given below):

m_1 = 13 m^3 X LFL (except for products with doors or drawers for which the limit is 8 m3 X LFL)

m_2 = 52 m^3 X LFL

m_3 = 260 m^3 X LFL

Where LFL is the Lower Flammable Limit in kg/m^3 for the refrigerant used. Be aware this calculation will provide charges in kg and should be converted to lbs. using a "lbs. = kg x 2.205" calculation.

Based on the calculations above, view the charge limits for each refrigerant:

A2L REFRIGERANT COMPARISONS

REFRIGERANT	M1 (LB.)	M2 (LB.)	M3 (LB.)
Propane	1.1	NA	NA
R454B	8.7	34.7	173.7
R454C	8.3	33.4	166.8
R455A	12.4	49.4	247.1

Leak mitigation
Each charge calculation (m_1, m_2, m_3) is associated with specific leak-mitigation requirement(s) based on the type of partial unit (condenser, display case, walk-in, etc.).

A comprehensive listing of charges and mitigation measures is premature at this point due to the ongoing revision of the UL standards.

However, some general takeaways can be gleaned from the codes:

- A charge of 260 x LFL (kg/m3) will certainly be allowed, and potentially higher charges for individual circuits (247+ lbs. for R-455A).
- Evaporators in displays cases will need leak detection and shut-off valves in most instances.
- Evaporators for walk-in coolers and freezers will likely require some combination of leak detection, air circulation, and/or air ventilation.
- Outdoor compressor systems <m3 will have little, if any, mitigation required.

For example, on one R-455A condensing unit, you could have 10 closed cases (76lbs.) and 10 open fixtures (124lbs.), for a total of 200lbs. (assuming max releasable charges, which is unlikely). Since the 200lbs. is less than the 247lbs. allowed for the condensing unit, the charges are acceptable.

Purchasing the UL guideline provides some calculation tables, but in lieu of that, it is expected that manufactures will supply the fixture and Cooling Distribution Unit (CDU) charge calculations information in a user-friendly manner in installation guides.

2. Self-Contained Systems
For self-contained (not partial) refrigeration systems, UL 60335-2-89 stipulates the following:

- 13 x LFL (in kg.m3) for open systems
- 8 x LFL for appliances with doors or “packaged refrigerating units”
- 3 x LFL for units in public corridors or lobbies

These charge allowances, when applied to specific refrigerants, result in the charges shown in the table below:

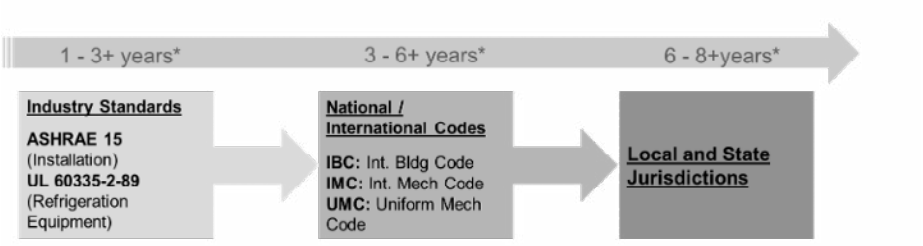
A2L REFRIGERANT COMPARISONS

CLASS	REFRIGERANT	LFL (KG/M³)	MAX CHARGE (KG)	MAX CHARGE (LB.)	
A3	Propane	0.038	0.5	1.1	open self-contained
			0.3	0.7	with doors
			0.3	0.7	Packaged Refrigerating Units*
			0.1	0.3	corridor
A2L	R454C	0.291	3.8	8.3	open self-contained
			2.3	5.1	with doors
			2.3	5.1	Packaged Refrigerating Units*
			0.9	1.9	corridor
A2L	R455A (L40X)	0.432	5.6	12.4	open self-contained
			3.5	7.6	with doors
			3.5	7.6	Packaged Refrigerating Units*
			1.3	2.9	corridor

*For this portion of the standard, "packaged refrigerating units" is not what is commonly referred to as a condensing unit. It is a unit that is mounted on the enclosure to be cooled. Sometimes referred to as a "cassette."

Mechanical codes

ASHRAE Standard 15 (safety code) was updated in 2022 to include requirements and larger charges for A2L refrigerants. This updated code can take years to be incorporated into local and state jurisdictions.



AHRI has worked to have codes updated, or legislation enacted, at the state level to allow the usage of A2Ls in the interim prior to the codes being updated in the standard process.

These approvals are constantly changing. Contact your Honeywell representative for status of specific state approvals of A2Ls for refrigeration and for air conditioning.

DESIGN CONSIDERATIONS

A2L APPLICATIONS

Systems in commercial applications with charges up to 247 lbs. (R-455A) can be utilized with A2L refrigerants. These may be distributed condensing units or even small rack systems (for larger systems, the refrigerant R-455A will have the benefit of larger charges due to its larger LFL value). These systems can be multiplexed to various loads such as display cases and walk-in coolers/freezers. As long as the charge limits for each circuit and the compressor system are adhered to, these systems can be similar to legacy systems (depending on final text and interpretation of UL standards). The fixtures would likely be required to have the mitigation measures such as leak detection and safety valves as discussed previously in this document.

Some retailers may choose a simpler route, using condensing units for each main load or lineup.

Another option is to use an A2L for low-temperature loads and a low GWP fluid like R-471A for the medium-temperature loads. The A2L system could also be cascaded with the medium-temperature systems to provide an increase in efficiency and operational stability in the low-temp systems.

System replacement impact

The A2L refrigerants for refrigeration being discussed (R-454C, R-455A) are very similar thermodynamically to R-404A.

The main difference in a commercial store design is to limit the refrigerant charge based on the refrigerant used, and to include the mitigation measures required by UL for commercial systems. The previous R-404A design may have had distributed systems, and in this case, the number of systems may not differ.

If the R-404A base design was a machine-room layout, then the A2L design may require moving the systems closer to the loads and possibly having additional systems to limit the maximum charge.

Pipe sizing

Pipe sizing for R-454A and R-454C are similar to R-404A. R-455A will have a lower pressure (oF) drop than R-454C.

R-454C has a larger pressure drop. This should be taken into consideration if using R-404A line sizing for R-454C.

SUCTION SIZING COMPARISONS:

CONDITION	LOAD (BTUH)	LINE SIZE	PRESSURE DROP (°F)		
		(in)	R-404A	R-455A	R-454C
-25sst, 110sct, 100ft	6000	7/8	1.33	1.28	1.53
	24000	1-3/8	1.66	1.58	1.89
	80000	2-1/8	1.73	1.64	1.96
+20sst, 110sct, 100ft	6000	5/8	1.18	1.14	1.33
	24000	1-1/8	0.70	0.67	0.79
	60000	1-5/8	1.01	0.96	1.13

SUCTION SIZING COMPARISONS:

CONDITION	LOAD (BTUH)	LINE SIZE	PRESSURE DROP (°F)		
		(in)	R-404A	R-455A	R-454C
-25sst, 110sct, 100ft	6000	7/8	0.31	0.19	0.20
	24000	1-3/8	0.82	0.50	0.52
	80000	2-1/8	2.32	1.39	1.46
+20sst, 110sct, 100ft	6000	3/8	0.24	0.15	0.16
	24000	1/2	0.63	0.40	0.41
	80000	5/8	1.75	1.11	1.15

For HVAC systems with R-454B the line sizes will typically be the same as a R-410A system. Regardless, it is prudent to check sizing for any new installation.

Pipe protection
For A2L refrigerant piping, there are some added requirements per ASHRAE Standard 15 section 9.12.1.2.

- Indoor piping below 7'3" from floor, and further than 6' from appliance, must be protected.
- Piping through notches, studs, etc. requires protection in some instances.
- Outdoor piping must be protected from damage from the weather, including (but not limited to) hail, ice, and snow loads, and protected from damage within the expected foot or traffic path. If underground, it must be installed not less than 8 in. (200 mm) below finished grade and protected against corrosion.

Section 9.12.1.3 in ASHRAE Standard 15 cites some prohibited locations such as exit stairways. Refer to ASHRAE here.

Coordination with local authorities
We recommend coordination with local authorities be done in advance of construction to ensure being updated with the latest ASHRAE, UL, and state-specific legislation.

CONTRACTORS AND A2Ls

Equipment Selection and equipment labelling
With A2L refrigerants, it is important to select systems that are approved for the specific application. This requirement, in part, will be the responsibility of the contractor or distributer. An example is a walk-in freezer condensing unit, which will be labelled for refrigeration of a walk-in with a minimum area. Any walk-in that is smaller will not meet the UL requirements.

The manufacturers will supply a charge label with instructions on charge calculation, to be filled in by the installer

Charging and recovery
Charging lines should be as short as possible to minimize the A2L refrigerant within the lines.

Per UL, when recovering A2L refrigerants, the system shall be purged with oxygen-free nitrogen and filled with nitrogen up to working pressures and then venting.

Equipment procedures and local codes should be adhered to.

Cylinders
Cylinders shall be complete with pressure relief and shut-off valves.

Storage
For warehouse storage, refer to the AHRI Safe Refrigerant Transition Task Force document here and your local authority.

Storage within service vans is currently being determined. It is possible that cylinders may need to be vertical or at 45 degrees in service vehicles. Check with your local distributor.

RESOURCES

Technical documentation

Honeywell technical data sheets can be found on the website at www.sustainability.honeywell.com/us/en

Honeywell training

Contact your Honeywell Refrigerants representative for in person or web-based training.

AHRI resources

AHRI has a Safe Refrigerant Transition Task Force that has done a lot of the work needed to bring A2L refrigerants into the mainstream. Access their information here.

ESCO resources

ESCO Institute has an A2L training manual and online course for A2Ls. Visit the site for more information.

Honeywell Advanced Materials
115 Tabor Rd
Morris Plains, NJ 07950
USA
www.honeywell.com

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THE FUTURE IS WHAT WE MAKE IT

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