Low GWP Refrigerant Safety

Flammable and Mildly Flammable Refrigerants

Jason Obrzut, CMHE

PREVIEW

esco institute

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PRINTING SECTOR UNION CWA LABEL CHICAGO, IL

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This manual was developed by The ESCO INSTITUTE
Mount Prospect, IL 60056

ESCO Institute
P.O. Box 521
Mount Prospect, IL 60056

Phone: (800) 726-9696 **Fax:** (800) 546-3726
Website: www.escogroup.org **E-Mail:** customerservice@escogroup.org

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Printed in the United States of America

ISBN Print Edition: 978-1-930044-67-8
ISBN Ebook Edition: 978-1-930044-81-4

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Ver: 1.0-021721

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Additional Resources

In addition to this training manual, practice questions are available on the ESCO website (www.escogroup.org) to help technicians prepare for the certification examination.

Once you have thoroughly prepared for the examination, please contact your instructor for testing dates/details, or contact ESCO at 800-726-9696 for a testing location in your area or to discuss remote testing options.

Liability

Working with all refrigerants involves a degree of liability. It is recommended that technicians and contractors discuss these issues with their insurance carrier before commencing work on systems that contain flammable refrigerants.

Acknowledgements

ESCO would like to recognize the following individuals/companies for their contributions to this publication:

Chemours Company—Wilmington, DE
Quinn-Murphy Consulting, LLC—Wall Township, NJ
Refrigeration Service Engineers Society (RSES)—Rolling Meadows, IL

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Supporting Organizations

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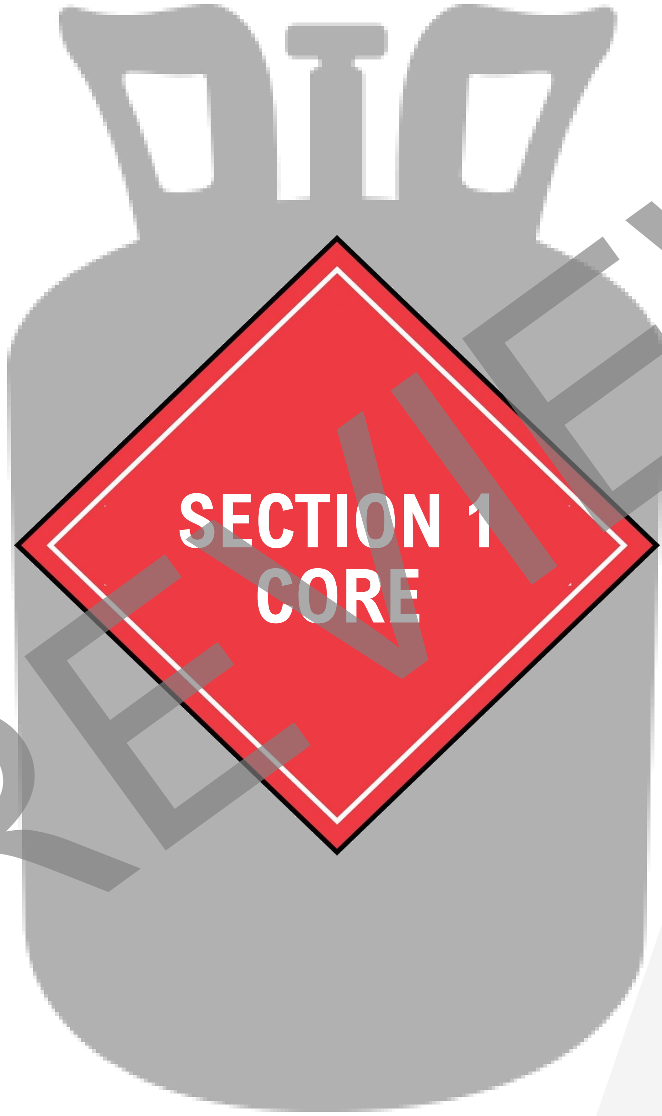

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Before You Begin

This guide was written to aid in the training of HVACR students and technicians in preparation for certification in the safe handling of modern refrigerants and the performance of service on systems utilizing these refrigerants. As the HVACR industry moves toward environmentally friendlier low GWP refrigerants, the keys to student, technician, and consumer safety are education, training, and certification.

As you read this guide, the term "flammable refrigerant" is used as a generic term. It includes the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) refrigerant flammability designations of 2, 2L, and 3. In some instances, a service procedure, refrigerant property, or industry standard may apply to only one of these refrigerant classes and will be noted as such.

Throughout this guide, this note is used to indicate that a flammable refrigerant may have additional safety, service, or installation requirements. Pay close attention to these notes as the additional requirements may differ from those used for non-flammable refrigerants.

Information for this guide was provided by many industry organizations, manufacturers, contractors, authors, and educators. The following industry codes, standards, and regulations were also referenced in the preparation of this guide:

- US Environmental Protection Agency (EPA) Clean Air Act Amendments, Sections 608 and 612
- ASHRAE Standard 15 -2019, ASHRAE Standard 15.2
- ASHRAE Standard 34 -2019
- United Laboratories (UL) Standards, especially 60335-2-40 3rd edition (2019)
- Air Conditioning Heating and Refrigeration Institute (AHRI) Guideline N
- Department of Transportation (DOT) regulations (various)
- DOT 49 CFR HAZMAT Transportation Regulations – 2019
- American Society for Testing and Materials (ASTM International) E681-85
- National Fire Protection Association (NFPA) 55
- OSHA guidelines and standards (various)

The information presented in this guide is accurate and current as of the date printed. When existing standards are updated or new standards are developed, this guide will be updated to reflect any relevant changes. There may be instances where a local code or the manufacturer's literature differ from what is printed here. Always defer to the manufacturer's requirements and local building codes.

Refrigerant Safety and Awareness

When working with or transporting any refrigerant, care must be taken to avoid serious injury and/or death. Refrigerants are heavier than air and can displace oxygen, leading to suffocation or asphyxiation. Some refrigerants can be very toxic. In the event of a large refrigerant leak, the area should be vacated and ventilated down to a safe level before re-entry. Liquid refrigerant splashed onto the skin or into the eyes can cause serious burns or blindness. Proper gloves and safety goggles should always be worn.

Refrigerant cylinders are pressurized and can rupture when exposed to high temperatures. Cylinders should be stored at temperatures under 125°F. Refillable cylinders (recovery tanks) should not be filled beyond 80% of their maximum capacity. This is to allow room for refrigerant expansion and prevents the tank from rupturing.

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When working with flammable refrigerants, the area should be well ventilated and a fire extinguisher (typically a dry-powder Class B) should be onsite. It is important to note that additional safety precautions may be necessary when working with flammable refrigerants such as using specialized tools.

Transportation

Refrigerant cylinders should be transported in the upright position so that the pressure relief valve is in contact with the vapor space of the cylinder. Cylinders should be secured to prevent excessive movement while in transit. When manually moving large cylinders, they should be secured upright to a cart and have a valve cap in place.

When transporting flammable refrigerants, the Department of Transportation (DOT) requires that the vehicle be equipped with the appropriate fire extinguisher (Class B Dry Powder). DOT rules also prohibit smoking within 25 feet of flammable gases, a written inventory of the gases being transported, and some form of security to prevent theft or unauthorized access. Carrying the safety data sheets (SDS) for each refrigerant is also recommended.

Depending on state or local codes, vehicle placards and ventilation may also be required. These requirements can vary depending on the volume of gas being transported. Always follow the manufacturer's recommendations when working with flammable refrigerants, and all applicable codes when transporting them.

Jobsite Safety

When working with refrigerants on a jobsite, safety should always be a priority. A proper lockout/tagout procedure should be used when the equipment is de-energized. The person performing the work should carry the only key. A multimeter should be used to verify that there is no voltage present before beginning work. The area should be well ventilated to prevent oxygen displacement and suffocation in the event of a refrigerant leak.

With proper jobsite ventilation, flammable refrigerants can be kept below their lower flammability limit (LFL) should a leak occur. Accumulation of a flammable refrigerant in a confined space can lead to a severe ignition event, resulting in a fire or explosion. The jobsite should be evaluated for safety hazards, such as possible ignition sources or the presence of flammable vapors, _prior to beginning the work_.

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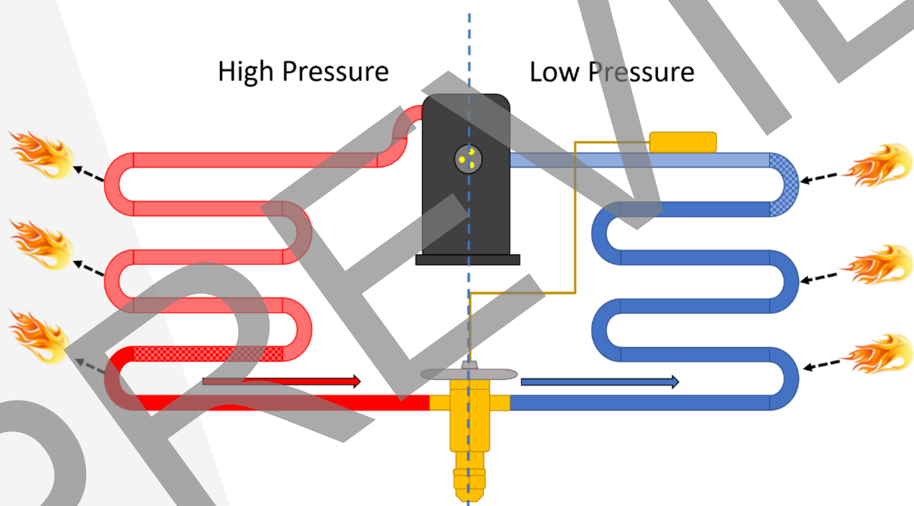
Refrigeration Cycle Fundamentals

This section is intended to provide an overview of refrigeration theory, the basic refrigeration cycle, system components, and the pressure/temperature relationship of refrigerants.

Refrigeration and air conditioning systems are designed to transfer heat by circulating refrigerant through a piping arrangement and a number of heat transfer surfaces. In the basic refrigeration cycle, refrigerant absorbs unwanted heat from one location and moves it to a remote location. The refrigerant absorbs heat through evaporation, then releases it through condensation.

Vapor-compression systems are relatively simple, but mastery of them requires a basic understanding of heat transfer theory and the components that make up the system. A malfunction in one component can affect the operation of others in the system. As refrigerant flows through the system, it undergoes the processes of expansion, vaporization, compression, and condensation. Liquid refrigerant under high pressure is fed to a metering device. As the refrigerant flows from the metering device to the evaporator the pressure is reduced. This reduced pressure lowers the temperature of the refrigerant and causes it to vaporize as it absorbs heat from the space being conditioned. The refrigerant vapor then passes through the suction line and into the compressor, where the pressure and temperature of the refrigerant increases. The compressed refrigerant then travels out to the condenser, where it begins to cool. When the refrigerant is



cool enough, it condenses and becomes liquid. It then travels through the liquid line to the metering device, and the refrigeration cycle is repeated. *The basic refrigeration cycle does not change if the refrigerant is flammable.*

A closed-loop (sealed) refrigeration system can be divided into two sides: the high-pressure side (red) and the low-pressure side (blue). Whatever is done on one side of the system must be undone on the other side. Heat that is absorbed on the low-pressure side must be expelled on the high-pressure side. Refrigerant that is boiled (vaporized) on the low-pressure side must be condensed to a liquid on the high-pressure side. The repeating cycle continues until the space being conditioned reaches the desired temperature.

Refrigeration system components such as the evaporator, condenser, compressor, and metering device must be designed, tested, and UL listed in order to be installed on a system that is charged with a flammable refrigerant.

Equipment with flammable refrigerant requires a red-colored marking on all process tubes and service connections. The colored marking must extend one inch in both directions from service locations.

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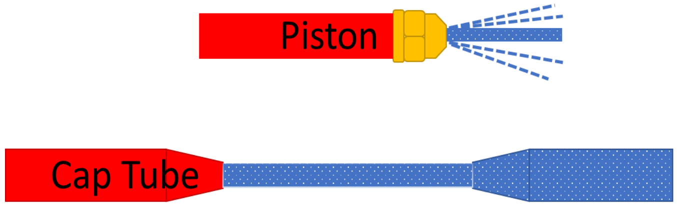
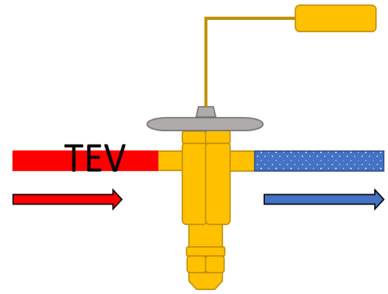
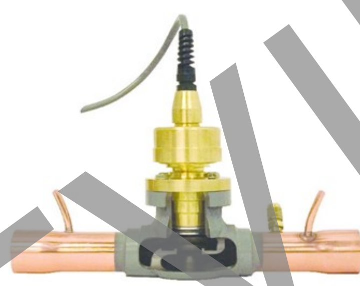




Metering Device

The metering device is the component that regulates (and restricts) the amount of refrigerant entering the evaporator. It separates the low-pressure side of the system from the high-pressure side of the system. It can have a fixed opening, such as a piston or capillary tube, or can be adjustable such as a thermostatic expansion valve (TEV), automatic expansion valve (AEV), or an electronic expansion valve (EEV). The metering device is fed high-pressure, subcooled liquid refrigerant and it feeds low-pressure, low-temperature liquid to the evaporator. A small percentage of the liquid refrigerant leaving the metering device will immediately flash to a vapor, called flash gas. This flash gas lowers the temperature of the remaining liquid refrigerant.

A piston with a fixed orifice



An electronic expansion valve
Courtesy Parker Sporlan

A thermostatic expansion valve

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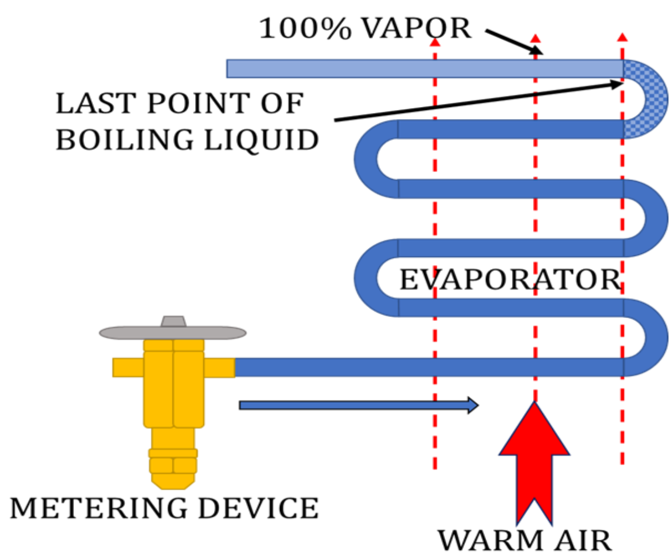
Evaporator

The evaporator is a heat transfer component located on the low-pressure side of the system. Low-pressure/low-temperature liquid refrigerant is fed into the evaporator by a metering device. The refrigerant is boiled to a vapor by heat from the air or water passing over it. This heat is absorbed by the refrigerant and ultimately removed from the system by the condenser. The heat absorbed into the refrigerant during the change in state, from liquid to vapor, is a latent heat process. (Latent heat, also referred to as hidden heat, cannot be measured with a thermometer and is instead measured in BTUs.) Once all the liquid has boiled to a vapor, the heat added to the refrigerant is sensible heat, also called superheat. In a system with the proper refrigerant charge and appropriate flow of air or water, the last point of liquid typically occurs near the end of the evaporator, just before the refrigerant enters the suction line.



Another function of the evaporator in comfort cooling applications is the removal of humidity. The evaporator coil temperature of an air conditioner or heat pump is typically between 40°F- 45°F, which is below the dew point of the air being cooled. As the warm air encounters the cooler surface of the coil, moisture in the air will condense on the coil's

Proper Airflow

In air conditioning applications, the industry standard for airflow across the evaporator is 400 cubic feet per minute (CFM), per ton of cooling. In areas with a high latent heat load, or high humidity climates, slightly lower airflow (325-350 CFM) can be used across the evaporator for additional humidity removal. In areas with a high sensible heat load, slightly higher airflow (425-450 CFM) can be used to satisfy the conditioned space requirements. Always refer to the manufacturer's literature for airflow recommendations for the equipment being used. On a system that is properly installed, has the correct charge, and is clean, the temperature split (difference in temperature between the supply and return ducts) should be between 16°F - 22°F, depending on the system's efficiency and the latent load on the system.

Condensing units are designed with either a top or a side air discharge. Package and split systems typically have a top air discharge, while mini-splits are designed with a side air discharge. The coil must be cleaned regularly to ensure proper airflow and heat transfer. There are many coil cleaning chemicals on the market, some of which contain acid. Before applying a cleaner to a coil, it should first be verified that the chemical is compatible with the coil design. Some condenser coils have a special coating to reduce long term corrosion and may react with the different type coil cleaners.

Depending on the installation, some systems that are charged with a flammable refrigerant may require an indoor fan to be energized (by an active refrigerant sensor) as a mitigation step. In the event of a leak, running the fan will move enough air to keep the leaking flammable refrigerant below its lower flammability level (LFL). Follow the manufacturer's instructions for applications where mitigation steps are required. (Mitigation is minimizing or reducing the possibility of an ignition event or accident.)

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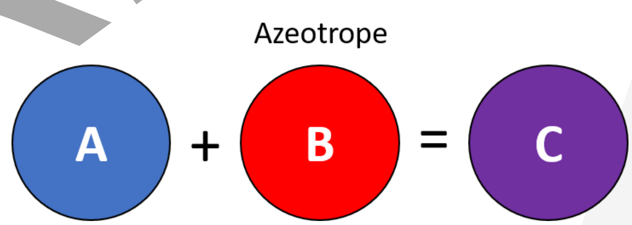
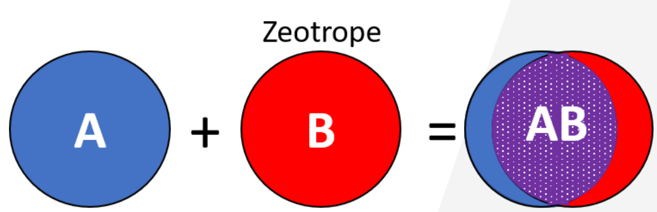
Refrigerant Blends

A blended refrigerant is a mixture of two or more refrigerants that is classified as azeotropic, near-azeotropic, or zeotropic. Blends can be binary, consisting of two refrigerants, or ternary, consisting of three refrigerants. Blends are created in the factory by chemists and engineers, not in the field by technicians.

An azeotropic refrigerant blend behaves like a single compound refrigerant. It follows a single pressure/temperature chart and does not separate into its component parts, or *fractionate*, with a change in pressure, temperature, or both. Azeotropic refrigerant blends are numbered in the 500 series (R-500, R-502, etc.).



A zeotropic refrigerant blend is a mixture of two or more refrigerants that can separate, or fractionate, into its original components. The components of these blends have a range of different boiling temperatures at a given pressure. This temperature range is known as *temperature glide*. The larger the range of boiling points, the larger the temperature glide will be. Zeotropic refrigerants will have two pressure/temperature charts; one for the vapor phase (dew point), and one for the liquid phase (bubble point).



Superheat and Subcooling – Blends

When calculating the **superheat** of a system charged with a zeotropic or near-azeotropic refrigerant blend, the **vapor phase** (dew point) values are used. For example, a system charged with R-422D has a low-side pressure of 74 psig and a vapor line temperature of 60°F. Using the chart, it can be seen that 74 psig converts to a saturation temperature of 45°F. Subtracting the evaporator saturation temperature from the vapor line temperature (60°F – 45°F) results in a superheat of 15°F.

When calculating the **subcooling** of a system charged with a zeotropic or near-azeotropic refrigerant blend, the **liquid phase** (bubble point) values are used. For example, a system charged with R-422D has a high-side pressure of 281 psig and a liquid line temperature of 105°F. Using the chart, it can be seen that 281 psig converts to a saturation temperature of 120°F. Subtracting the liquid line temperature from the condenser saturation temperature (120°F – 105°F) results in a subcooling of 15°F.

Midpoint

When sizing and selecting system components for equipment that is charged with a zeotropic or near-azeotropic refrigerant blend, the midpoint should be used. Midpoint is the average temperature of a coil, either condenser or evaporator, in a system charged with a blended refrigerant. It is important to know the average coil temperature to accurately calculate the difference between refrigerant temperature in the coil and the air or water temperature that the coil is exchanging heat with (temperature difference or TD). To calculate midpoint, the dew (vapor) and bubble (liquid) temperatures at a single pressure must be known. Condenser and evaporator coils use different calculations to arrive at the midpoint.

Temp °F	R-422D		R-410A	R-407C	
	Liquid	Vapor		Liquid	Vapor
0	27.9	21.7	48.6	29.9	19.6
5	32.5	25.8	55.2	34.7	23.6
10	37.5	30.4	62.3	39.9	28.0
15	42.8	35.3	70.0	45.6	32.8
20	48.5	40.7	78.3	51.6	38.0
25	54.7	46.4	87.3	58.2	43.6
30	61.3	52.6	96.8	65.2	49.6
35	68.4	59.3	107	72.6	56.1
40	75.9	66.4	118	80.7	63.1
45	84.0	74.0	130	89.2	70.6
50	92.6	82.2	142	98.3	78.7
55	102	90.9	155	108	87.3
60	111	100	170	118	96.9

Temp °F	R-422D		R-410A	R-407C	
	Liquid	Vapor		Liquid	Vapor
0	27.9	21.7	48.6	29.9	19.6
5	32.5	25.8	55.2	34.7	23.6
10	37.5	30.4	62.3	39.9	28.0
15	42.8	35.3	70.0	45.6	32.8
20	48.5	40.7	78.3	51.6	38.0
25	54.7	46.4	87.3	58.2	43.6
30	61.3	52.6	96.8	65.2	49.6
35	68.4	59.3	107	72.6	56.1
40	75.9	66.4	118	80.7	63.1
45	84.0	74.0	130	89.2	70.6
50	92.6	82.2	142	98.3	78.7
55	102	90.9	155	108	87.3
60	111	100	170	118	96.9
65	122	110	185	129	106
70	133	121	201	141	117
75	144	132	217	153	128
80	156	144	235	166	140
85	169	156	254	180	153
90	183	170	274	195	166
95	197	184	295	210	181
100	212	198	317	226	196
105	228	214	340	243	211
110	245	231	365	261	229
120	281	266	418	299	266

All pressures in above tables are in PSIG.

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An uppercase letter (A, B, C) designation is used when refrigerant blends are composed of the same refrigerants, but with different percentages of each. For example, R-407A, R-407B, and R-407C all contain R-125, R-134a, and R-32. Each letter designation of R-407 indicates that a different percentage of each refrigerant is used in the blend.

R-407 Blend	R-125	R-134a	R-32
R-407A	40%	40%	20%
R-407B	70%	20%	10%
R-407C	25%	52%	23%

Hydrofluorocarbons (HFCs)

HFCs contain hydrogen, fluorine, and carbon and do not deplete the ozone as they have no chlorine. However, many of the most common HFCs have global warming potentials (GWP) over 1,500. HFCs are used in a wide variety of cooling systems; from refrigerators and freezers to automotive and residential air-conditioning units. HFC-134a has been used as a replacement refrigerant for most CFC-12 applications including medium-temperature coolers and automobiles. HFC-407C is used as a retrofit refrigerant for HCFC-22 in comfort cooling applications. HFC-404A is mainly used in low-temperature refrigeration applications. Due to the high GWP of HFC-404A (3920) and HFC-134a (1430), they have been scheduled for a phase down in some states. HFC-410A is primarily used in residential and light commercial air-conditioning and heat pump systems and is classified as a "super-polluter" with a GWP of 2088. HFC-32 has pressures and temperatures that are similar to HFC-410A, but it is mildly flammable. It has a low GWP of 675 and is widely used across Europe, Japan, and Australia in comfort cooling systems.

R-Number	Chemical Name	Boiling Point	GWP (AR5)
R-32	Difluoromethane	-62°F	675
R-134a	Tetrafluoroethane	-15.3°F	1430
R-404A	R-125/143a/134a blend	-46.2°F	3920
R-407C	R-32/125/134a blend	-43.6°F	1770
R-410A	R-32/125 blend	-55.3°F	2088

Hydrofluoroolefins (HFOs)

HFOs are chemically similar to HFCs as they contain hydrogen, fluorine, and carbon. The only difference is that they are unsaturated, meaning that they have at least one double carbon bond. These molecules are named olefins or alkenes. Unlike HFCs, these refrigerants have a very low, single digit, global warming potential (GWP) and most are mildly flammable (A2L). HFOs also have an ozone depletion potential (ODP) of zero (0). HFOs are being used in a number of different temperature applications, such as automotive air-conditioners and commercial refrigeration systems and are being tested for expanded use. It should be noted that HFO refrigerants are not compatible with some gaskets or seals. Always follow the manufacturer's recommendations when replacing any gaskets or seals.

R-Number	Chemical Name	Boiling Point	GWP (AR5)
R-1234yf	Tetrafluoropropene	-22°F	<1
R-1234ze	Tetrafluoroprop-1-ene	49.6°F	6
R-1233zd	trifluoropropene	66°F	4.7 - 7

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Working with Refrigerant Oil

All refrigerant oils are hygroscopic, meaning that they absorb moisture. Care should be taken to limit their exposure to the atmosphere, no more than 15 minutes is recommended. In some cases, as with POE, the moisture cannot be removed from the oil with a deep vacuum. The oil must be flushed from the system and replaced if it becomes saturated with moisture. Some of the more highly hygroscopic oils can pull moisture through plastic containers and must be stored in glass or metal containers. Refrigerant oils can be a skin irritant and should be handled appropriately. Gloves and goggles are recommended. If oil gets on the skin, the affected area should be washed thoroughly with soap and water.

Systems that have been subjected to moisture, air, or other contaminates, may experience a chemical reaction that produces acid when exposed to excessive heat. A compressor burnout may also cause the formation of acid. An acid test should be done on any system suspected of being acidic. If a system is found to contain acid, the refrigerant should be recovered into a separate recovery tank, the oil drained, and the system components flushed with an approved line flush. New suction and liquid line filter driers should also be installed. Once cleaned, new oil and refrigerant can be added to the system.

Refrigerant Designations and Classifications

There are many classifications used to identify refrigerants. For example, there are alphanumeric *designations* such as R-22 and HFC-134a, which are based on a refrigerant's chemical formula and/or thermodynamic properties. There are also *classifications* based on a refrigerant's toxicity and/or flammability, such as A1, B2, A2L and B3. These identifiers are assigned by ASHRAE in Standard 34 and are the focus of this section.

ANSI/ASHRAE Standard 34-2019/ISO 817-2020

ASHRAE Standard 34 is used to classify a refrigerant according to the potential hazards involved with its use, specifically toxicity and flammability. Toxicity, a term used to describe the poisonous quality of a substance, is represented by a letter, with "A" representing a low toxicity and "B" indicating a higher level of toxicity. Flammability, which indicates a substance's ability to burn, is represented by a number, with 1 being no flame propagation. Flame propagation can be simply understood as the spread of a flame outward from the point at which the combustion started, but is fully defined as combustion which causes a continuous flame that moves upward and outward from the point of ignition without assistance from the original ignition source.

The higher the flammability, the higher the number a refrigerant is assigned. An A1 refrigerant, for example, would have low toxicity and no flame propagation.

High Flammability (3)	**R-290/R-600a A3**	**NA B3**
Low Flammability (2)	**R-152a A2**	**R-611/R-40 B2**
Lower Flammability (2L)	**R-32/R-1234yf A2L**	**R-717 B2L**
No Flame Propagation (1)	**R-22/R-410A A1**	**R-123 B1**
	Lower Toxicity (A)	**Higher Toxicity (B)**

2L refrigerants have a burning velocity of 10 cm/s or slower.

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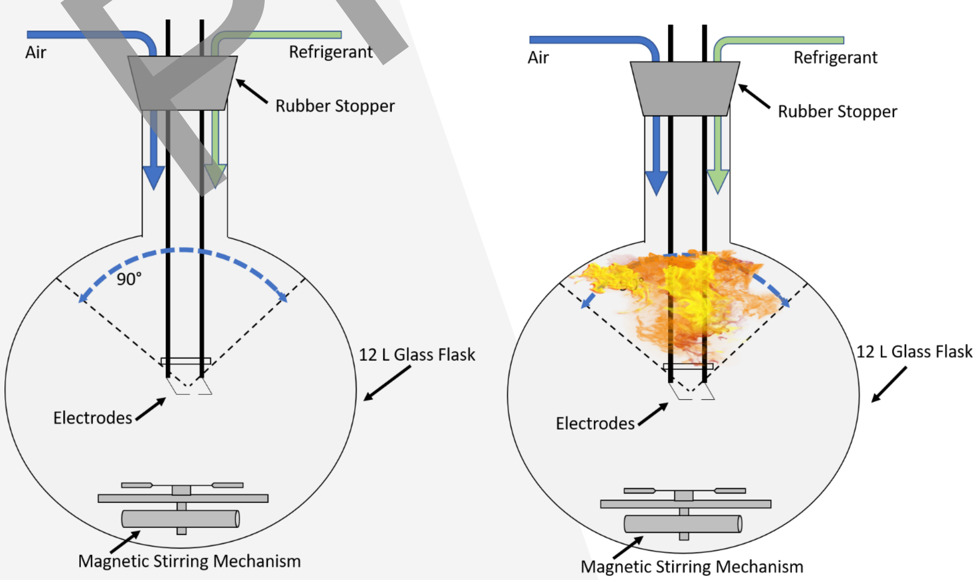
The lower flammability designation (Class 2) has been divided into two categories, 2 and 2L. The 2L refrigerants are mildly flammable with a maximum burning velocity of less than 10 cm/s, or centimeters per second. It should be noted that at very high temperatures, even A1 refrigerants can become flammable. For example, R-410A at a high temperature and humidity level, can ignite when exposed to an ignition source.

The lower flammability limit (LFL) of a refrigerant is the minimum concentration of a refrigerant that can propagate a flame through a consistent mixture of the refrigerant and air under specified test conditions. The LFL is expressed as refrigerant percentage by volume. Refrigerant flammability is determined by the ASHRAE-modified ASTM E-681 Flammability test.

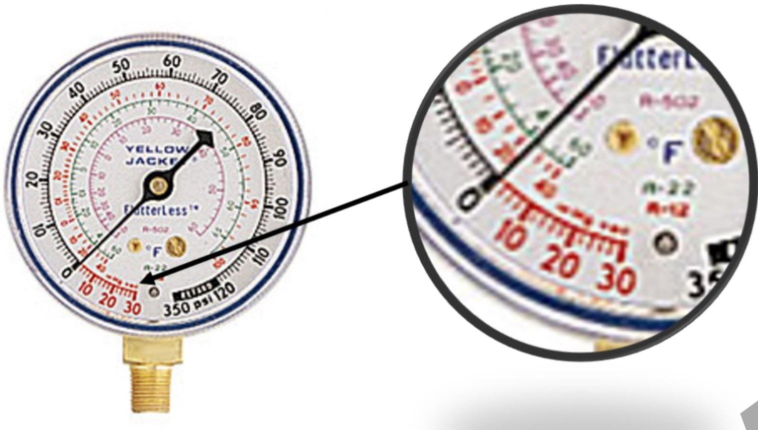
The following is a general summary of the criteria that are used during refrigerant flammability testing to assign a refrigerant to a flammability class:

Type of Refrigerant	Class	Criteria
Single-Compound Refrigerant	**Class 1**	Does not show flame propagation when tested in air at 140°F (60°C) and 14.7 psia (0 psig).
	Class 2L	Exhibits flame propagation when tested at 140°F (60°C) and 14.7 psia (0 psig), Has a lower flammability (LFL) greater than 0.0062 lb/ft³, Has a heat of combustion less than 8,169 Btu/lb, Has a maximum burning velocity of 10 cm/s when tested at 73.4°F (23.0°C) and 14.7 psia (0 psig) in dry air.
	Class 2	Exhibits flame propagation when tested at 140°F (60°C) and 14.7 psia (0 psig), Has a lower flammability limit (LFL) greater than 0.0062 lb/ft³ Has a heat of combustion less than 8169 Btu/lb.
	Class 3	Exhibits flame propagation when tested at 140°F (60°C) and 14.7 psia (0 psig), Has a lower flammability (LFL) less than or equal to 0.0062 lb/ft³ or, Has a heat of combustion that is greater than or equal to 8,169 Btu/lb.
Refrigerant Blends		Assigned a flammability classification based on their worst case of formulation for flammability (WCF) and worst case of fractionation for flammability (WCFF), as determined from a fractionation analysis.

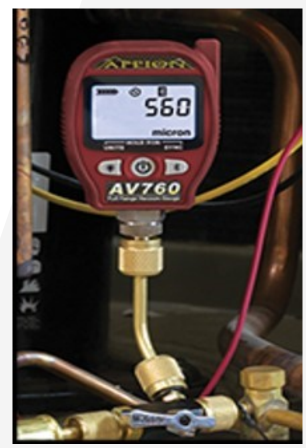


ASTM E-681 Flammability testing apparatus – the flame must be a solid flame stretching out over a 90° span. If the flame breaks on one side or the other, only the largest degree span is counted. The flammability classification is determine by how wide the flame stretches from the center, up to 90°F.

PREVIEW



A micron is a very small unit of measurement, used in the HVACR industry to measure a deep vacuum. Atmospheric pressure (0 psig) is equal to 760,000 microns. Most refrigerant gauge manifolds measure a vacuum in inches of mercury (inHg). This unit of measurement is too large to be used for a deep vacuum. Note the vacuum scale on the gauge in the image. At 28 inHg, the system is at 50,800 microns; at 29 inHg it is at 25,400 microns; and at 29.90 the system is at 2,540 microns. The industry standard target for evacuation is 500 microns (29.98 inHg). Trying to measure a deep vacuum with this scale (inHg) is impossible. Technicians must instead rely on a digital micron gauge.



A micron gauge should be attached as close to the system as possible. Placing the micron gauge on or near the vacuum pump only proves the pump is able to create a vacuum. The gauge port on the side of the core removal tool is an ideal location. It should be mounted in the upright position to prevent any oil from entering the gauge.

There are several models of micron gauges, each with a slightly different operation. Some gauges will not begin to display a reading until the vacuum pressure has been reduced to 20,000 microns or less. Other gauges will start at 760,000 microns and continue to measure for the entire evacuation. Refer to the manufacturer's instructions for proper use, cleaning, and storage of the gauge.

The quality of the vacuum being pulled is directly related to the quality of the oil in the vacuum pump. Vacuum pump oil creates seals across the vanes of the pump, lubricates the mechanical components inside of the pump, and, in some pumps, can help cool the pump by conducting heat from the motor to the pump housing where it can be dissipated. Moisture and contaminants from the system being evacuated will collect in the pump oil, degrading it, requiring the oil to be changed. Oil that contains moisture and contaminants from the system will not form quality seals in the pump's vanes and will not lubricate well. Contaminated oil will negatively affect the evacuation level and the vacuum pump itself. The color of the oil can indicate when a change is necessary. It is also possible that if the system evacuation stalls, the oil may need to be changed.

Left to right: dirty oil, clean oil, moisture-saturated oil

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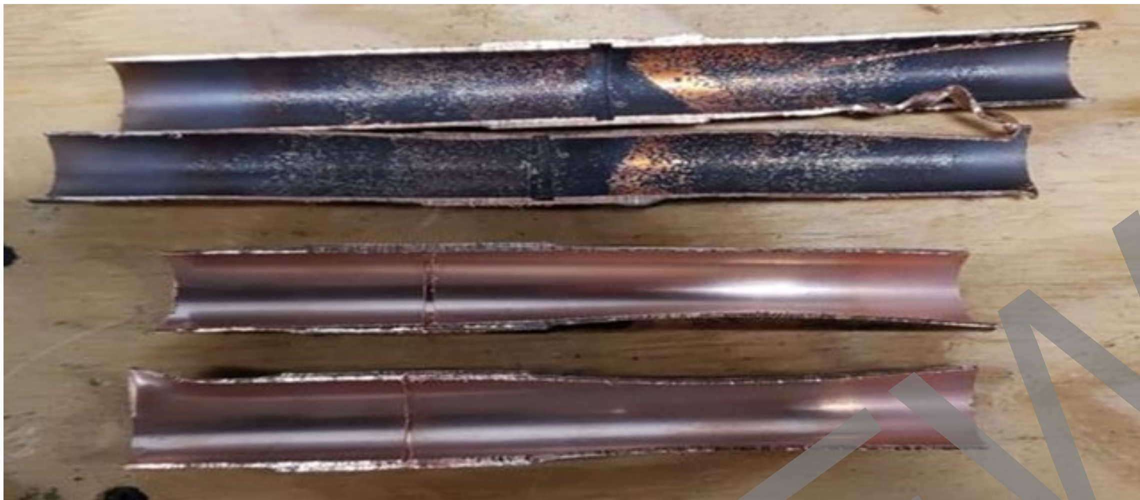
During the brazing process, an inert gas, such as nitrogen, should be purged at low pressure through the tubing being joined. This will displace any oxygen in the tubing and prevent oxidation or scale formation.



The manufacturer's installation manual and local codes should be followed when joining the copper lines of a system that is to be charged with a flammable refrigerant. Some jurisdictions allow brazing only, while others may allow soldering, compression, flare, or press fittings.

Brazing Tools and Equipment

The torch kits most commonly used during the brazing process are oxyacetylene and air acetylene. Both setups require pressure regulators, hoses, torch tips and handles, and a spark ignitor. A key difference between the two kits is how the acetylene is burned. An oxyacetylene setup requires a tank of acetylene as well as a tank of oxygen. These gases are combined and ignited which will produce a narrow, sharp flame at a very high temperature, about 5400°F. An air acetylene setup only requires a single acetylene tank and gets oxygen from the ambient air. It produces a wider heat distribution and a somewhat cooler flame when compared to oxyacetylene, about 3000°F. To produce higher temperatures with air acetylene, the ratio of air to acetylene must be increased.

Portable oxyacetylene kits typically use an "MC" tank (10 cubic feet) for the acetylene and an "R" tank (20 cubic feet) for the oxygen. The pressure regulators on the tanks are typically set at a 1:1 ratio when brazing copper to copper. Regulator pressures of 5psig (acetylene) and 5psig (oxygen) are commonly used in the HVACR industry for brazing.

Air acetylene torches typically use either an "MC" tank or a "B" tank (40 cubic feet). If the tank is equipped with a pressure regulator, it should be adjusted to no higher than 14-15psig. If a gauge is not present, the regulator should be

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2L Refrigerant Safety Considerations

Low GWP, 2L refrigerants are similar, from a chemical-composition standpoint, to the A1 refrigerants that have been widely used in nearly all segments of the HVACR industry. While transitioning to 2L refrigerants, field service personnel will notice that there are some significant differences with regards to the handling, charging, and labeling of refrigerants and the systems that contain them. Many of the safe work practices employed while working with A1 refrigerants are still relevant when working with 2Ls, however, an additional layer of safety has been added to lower the probability of an accident or ignition event. There are currently millions of systems around the world that are operating safely using 2L refrigerants.

From the outside, most residential and light commercial 2L systems look no different than other systems in use today, with one obvious difference: system labeling. The refrigeration components have been specifically designed for use with flammable refrigerants and the electrical components have been designed to safely operate in a flammable atmosphere. Larger commercial and industrial equipment designed for use with flammable refrigerants will have more obvious changes and system modifications for safe operation. Most, if not all, 2L refrigerants still fall under the jurisdiction of EPA Section 608. As such, they must still be recovered and do require a 608 certification to purchase, handle, or transport.

Transportation

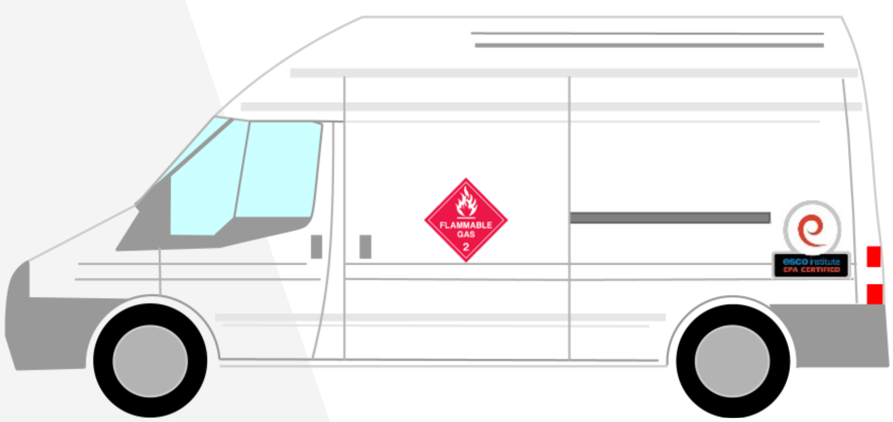
The following list outlines some of the code requirements, manufacturer recommendations, and industry best practices for transporting 2L refrigerants. As it would be impossible to cover every code, standard, piece of equipment, refrigerant, or scenario, it is strongly recommended that the Department of Transportation (DOT) and/or the local authority having jurisdiction be consulted for more detailed and complete information.

- In most circumstances, 2Ls can typically be transported from a storage area to the jobsite in the same manner as other flammable gases such as oxygen and acetylene in a service vehicle.

- Depending on state or local codes, placards and ventilation may be required on the service vehicle. These requirements vary depending on the volume of gas being transported. Always follow the manufacturer's recommendations for transporting flammable refrigerants and refer the safety data sheets (SDS) for specific hazards and hazard mitigation actions.

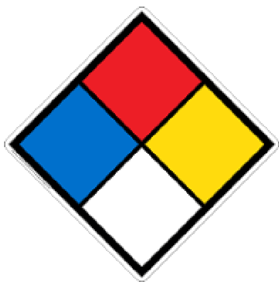
- Refrigerant cylinders should be transported in the upright position so that the pressure relief valve is in contact with the vapor space of the cylinder. Cylinders should be secured to limit movement while in transit. When manually moving, transferring, or repositioning larger cylinders, they should be secured upright to a cart and have a valve cap in place.

PREVIEW



The National Fire Protection Association (NFPA) fire safety storage requirements mandate that a storage facility must:

- have a permit from a local fire code official;
- have no open flames, high temperature devices, or combustion appliances in the storage area;
- post visible hazard identification signs around the storage area (NFPA 704 placard);
- post "No Smoking" signs within a certain distance of the storage area;
- maintain a Hazardous Materials Management plan for the site;
- maintain a Hazardous Materials Inventory Statement onsite;
- maintain the SDS sheets for each type of gas stored onsite.



The NFPA 704 placard is used to warn occupants of specific hazards. The blue diamond is used for health hazards, the red for flammability hazards, the yellow for chemical reactivity, and the white for special hazards.

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Jobsite Safety

When working with refrigerants on a jobsite, safety should always be a priority. A proper lockout/tagout procedure should be used when the equipment is de-energized. The person performing the work should carry the only key. A multimeter should be used to verify that there is no voltage present before beginning work. The area should be well ventilated to prevent oxygen displacement and suffocation in the event of a refrigerant leak.

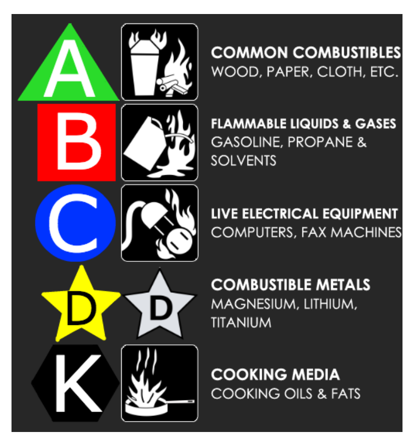
The following is a partial list of code requirements, manufacturer recommendations, and industry best practices for jobsite safety when working with 2L refrigerants. As this list cannot cover every situation and condition, defer to OSHA requirements, local building codes, and the authority having jurisdiction for proper work environment requirements.

- With proper ventilation on a jobsite or work area, flammable refrigerants can be stored below their lower flammability limit (LFL). Accumulation of a flammable refrigerant in a confined space can lead to a severe ignition event, resulting in a fire or explosion. The jobsite should be evaluated for safety hazards, such as possible ignition sources or the presence of flammable vapors, *prior to beginning the work*.

- Designate a safe perimeter around the work area using cones, construction horses or barriers, etc. This will reduce the chances of a possible ignition source from being introduced into the area while work is being performed.

- When working on 2L equipment, keep a Class B (or ABC), dry powder fire extinguisher nearby, and know how to use it, in case of an emergency.

- Make sure that the 2L equipment being used is approved for installation and use in the designated area or space. The manufacturer's literature (installation manual) for 2L systems will list specific applications and use limitations for their equipment. A system "swap out", where the existing equipment is removed and a new system installed in its place, may require additional considerations. Not only must the system be sized correctly and fit in the existing space, but the installation area must also be evaluated for the installation of a 2L system to ensure it meets the manufacturer's specifications and local building codes.



Fire extinguisher ratings

Burning Velocity

Burning velocity of a combustible gas is the rate at which a flame front spreads relative to the unburned gas ahead of the flame. For most applications, burning velocity is measured in centimeters per second, cm/s. 2L refrigerants have a burning velocity of 10 cm/s (3.9 inches per second) or less, making them less likely to sustain combustion after the initial ignition source has been removed.

Refrigerant	R-32	R-454B	R-1234yf	R-717 Ammonia	R-152a	R-290 Propane	R-600a Isobutane
Safety Group	A2L	A2L	A2L	B2L	A2	A3	A3
LFL	14.4%	11.8%	6.2%	15%	3.9%	2.1%	1.8%
Auto Ignition Temperature	648°C 1,198.4ºF	496°C 924.8ºF	405°C 761ºF	651°C 1,203.8ºF	440°C 824ºF	455°C 851ºF	460°C 860ºF
Minimum Ignition Energy (MIE)	30 – 100 mJ	100-300 mJ	5,000 – 10,000 mJ	100 – 300 mJ	0.38 mJ	0.25 mJ	0.6 – 0.7 mJ
Burning Velocity	6.7 cm/s	5.2 cm/s	1.5 cm/s	7.2 cm/s	23 cm/s	46 cm/s	41 cm/s
Heat of Combustion (HOC)	3,869 Btu/lb	4,420 Btu/lb	4,408 Btu/lb	9,673 Btu/lb	2,708 Btu/lb	19,905 Btu/lb	19,000 – 19,200 Btu/lb

Refrigerant Concentration Limit (RCL) and Lower Flammability Limit (LFL)

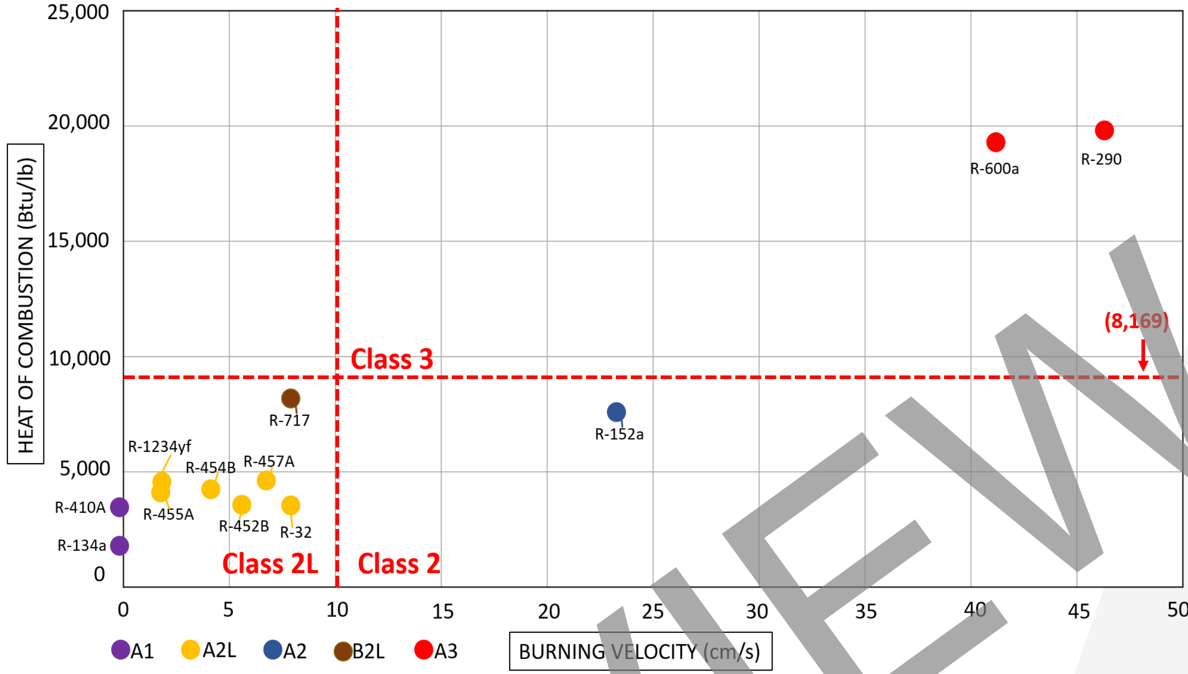
Refrigerant Concentration Limits (RCL) are used to determine the maximum concentration of a refrigerant allowed in an occupied space. The RCL is the lowest of three calculated limits for: toxicity, oxygen deprivation (asphyxiation), and/or flammability. The toxicity calculation is given as the acute toxicity exposure limit (ATEL). ATEL values are comparable to the Immediately Dangerous to Life or Health (IDLH) concentrations, established by the National Institute of Occupational Safety and Health (NIOSH). Mitigation measures, such as mechanical ventilation, are required when concentrations exceed RCL limits. Ideally, these measures should be employed before the maximum RCL concentration is reached.

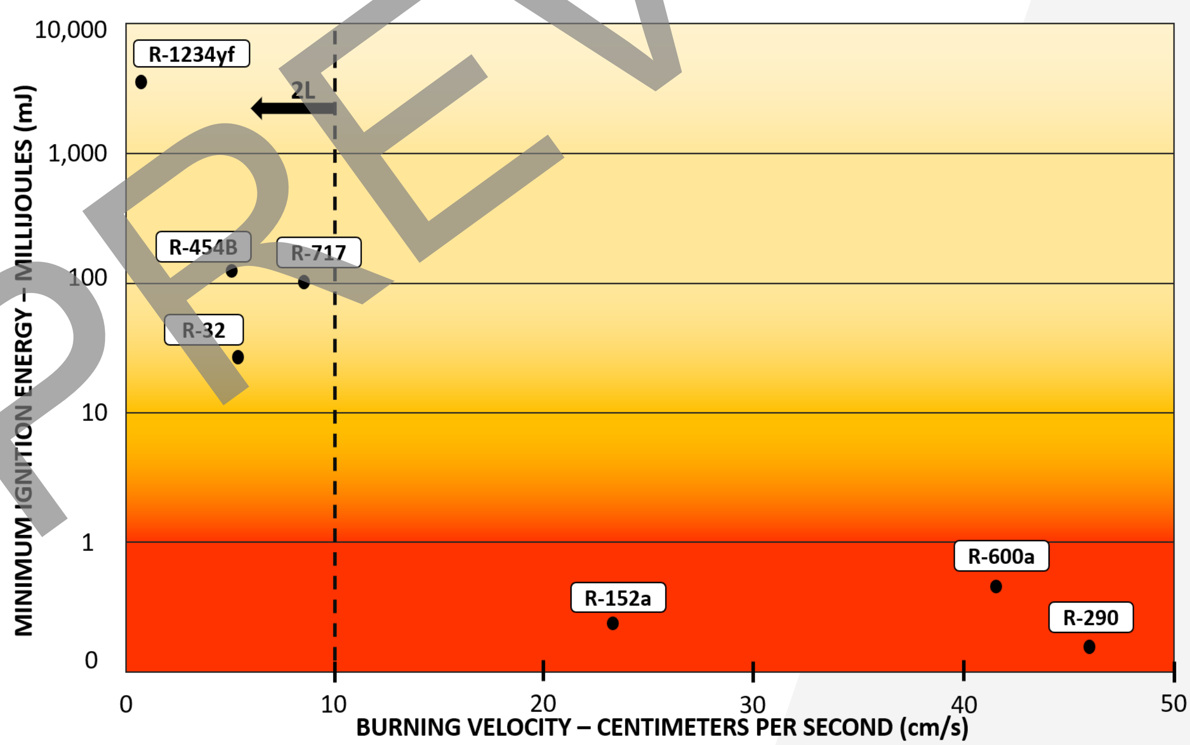
The lower flammability limit (LFL) is the minimum concentration of a flammable substance, in this case a refrigerant, that is capable of ignition when there is a sufficient mixture of air and the substance. The LFL is expressed as refrigerant percentage by volume. Refrigerant flammability is determined by the ASHRAE-modified ASTM E-681 Flammability test.

Compared to A3s such as propane (R-290) and isobutane (R-600a), most 2L refrigerants have a much lower flammability risk due to:

- Higher minimum ignition energy (MIE) – They are harder to ignite than class 2 or 3 refrigerants.
- Higher lower flammability limit (LFL) – They require a higher concentration to become flammable.
- Lower heat of combustion (HOC) – There is less energy released if they are burned.
- Lower burning velocity – This makes it more difficult for flames to spread during an ignition event.

PREVIEW


25,000
20,000
15,000
10,000
5,000
0
HEAT OF COMBUSTION (Btu/lb)
0
5
10
15
20
25
30
35
40
45
50
BURNING VELOCITY (cm/s)
A1
A2L
A2
B2L
A3
R-600a
R-290
(8,169)
Class 3
R-717
R-152a
R-1234yf
R-454B
R-457A
R-410A
R-455A
R-452B
R-32
R-134a
Class 2L
Class 2


10,000
1,000
100
10
1
0
MINIMUM IGNITION ENERGY – MILLIJOULES (mJ)
R-1234yf
2L
R-454B
R-717
R-32
R-600a
R-152a
R-290
0
10
20
30
40
50
BURNING VELOCITY – CENTIMETERS PER SECOND (cm/s)

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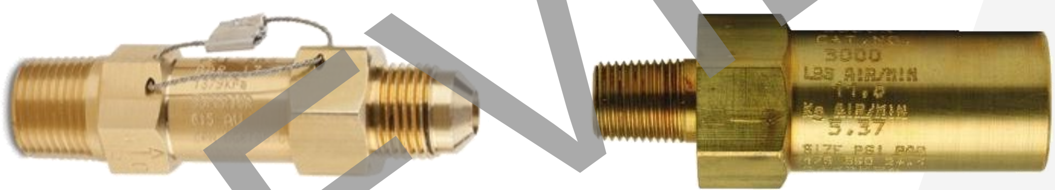
- The maximum charge size for the A2L equipment being installed will be limited by the cubic feet of airspace served by the equipment. The space must be large enough, and have enough air, to keep the refrigerant at or below a percentage of the lower flammability limit (LFL) should the entire charge leak into the space (referred to as dispersal volume). **Refer to the installation manual and industry standards (ASHRAE 15, 15.2) to calculate the maximum allowable charge for a space.

- Upon completion of system installation, the manufacturer's literature (install/service manuals) must be left with the equipment or the equipment owner. Technicians should also take time to review the documentation with the owner.

- A permanent label, required by UL, must be filled out by the installing technician. This label must contain, at a minimum, the contractor/technician contact information, date of the installation, and final charge (refrigerant type/ weight) of the system upon completion of the installation.

Many A2L systems are equipped a with a pressure relief device. There are many different types of refrigerant pressure relief valve designs. There are also several different requirements for the installation of the discharge piping connected to it. Pipe diameter, length, pitch, and termination location all must be considered. Pressure relief valves and relief valve piping will vary from one manufacturer to next and will differ depending on system capacity. After a pressure relief valve has been actuated, it should be replaced with a new one with the same ratings. The best sources of information for the proper installation of relief valve piping are the manufacturer's installation manual and the local codes.



Examples of refrigerant pressure relief valves

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Mitigation Requirements

On some installations, when permissible by the appropriate codes, a larger charge size may be deemed acceptable if mitigation strategies are installed. Mitigation strategies are designed to prevent accumulation and/or ignition of flammable refrigerant vapors should a leak occur. They are not "one size fits all" solutions and are specific to the occupancy classification, type of system, size of the charge, location of the system (indoor/outdoor), and the manufacturer's requirements. Mitigation strategies may include, but are not limited to:

- Active refrigerant alarms (room sensors)
- Permanent space ventilation
- Constant airflow (blower operation)
- Systems with an automatic refrigerant pumpdown (isolation valve)

Refrigerant detector/alarms, or room sensors, have long been a code requirement in many occupancy classifications where refrigerant is present, either in a system or for storage. They are designed to alert occupants when refrigerant concentration in a particular area has reached a specific threshold.

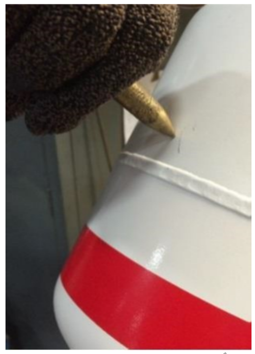
Traditionally, these sensors would emit an audible alarm and are referred to as *passive* sensors. Room sensors installed where flammable refrigerants are present, are required to be *active* sensors.

- When charging a new system, the total charge weight (and date of charge) must be recorded on a label affixed to the unit by the installing technician. Any additional refrigerant added on a future date must also be recorded.

- Patterns of adding refrigerant (at least once per three-year period) should be considered proof of a leak. The leak should be identified, repaired, and leak tested prior to recharging.

- When empty, A2L refrigerant cylinders should be disposed of as shown below.

Locking refrigerant caps



Placement of non-sparking pick for piercing

An A2L refrigerant cylinder

System Repairs

A2L systems are designed with electrical components that are intrinsically safe (IS). Intrinsically safe equipment is defined as "equipment and wiring which is incapable of releasing sufficient electrical or thermal energy under normal or abnormal conditions to cause ignition of a specific hazardous atmospheric mixture in its most easily ignited concentration." Simply stated, components such as the contactor or capacitor are designed to be enclosed, isolating the electrical contacts from the atmosphere. If heat or a spark is generated, it will be contained within the protective enclosure. This will prevent these components from being an ignition source if there is a leak of A2L refrigerant.

The following are additional considerations to be aware of when performing work on an A2L system:

- When performing repairs on a system that is charged with an A2L refrigerant, start by ensuring that the unit is properly grounded.

- Discharge capacitors in a way that will not cause a spark. (Shorting a capacitor's terminals with a screwdriver, for example, is dangerous as it can create a spark.)

- Reassemble sealed enclosures properly. If seals are worn, replace them.

- When troubleshooting, intrinsically safe components are the only types that can be worked on while live within a flammable atmosphere.

- Replace components only with parts specified by the manufacturer (OEM). Other parts may result in the ignition of refrigerant in the atmosphere from a leak.

- Check all equipment and components to verify proper installation before putting the system back into service.

The technician should keep a record of all service and maintenance performed on the system. This service record should be kept on site with the equipment and should be protected from weather and moisture.

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Summary of Standards and Codes

There are several codes and/or standards that cover the installation and service of different types of HVACR equipment. Some of them have been updated or revised to include systems that are charged with a flammable refrigerant. The following is a brief summary of some of the revised standards and the equipment covered. For more specific information regarding flammable refrigerant use, transport, disposal, etc., technicians should refer to the complete text of these standards as well as the local code requirements for their area.

ANSI/ASHRAE Standard 15

ASHRAE Standard 15 covers the design, construction, installation, and operation of light commercial and commercial HVACR equipment and machine/equipment rooms. Standard 15 was updated in 2019 to cover A2L refrigerants and now contains restrictions for A2L refrigerant equipment use, installation, service, and disposal.

ANSI/ASHRAE Standard 15.2

ASHRAE Standard 15.2 is a new standard and is the "residential" companion to the existing ANSI/ASHRAE Standard 15, Safety Standard for Refrigeration Systems. This standard focuses on residential applications and contains restrictions for residential A2L refrigerant equipment installation, service, and disposal.

ANSI/ASHRAE Standard 34

ASHRAE Standard 34 covers refrigerant designations and assigns safety classifications and refrigerant concentration limits based on a substance's toxicity and flammability. The 2019 edition of the standard incorporates 24 approved and published addenda to the 2016 edition. Standard 34 is typically packaged and sold with Standard 15.

UL Standard 60335-2-40

Referred to as "2-40", this standard covers the design and test specifications for heat pumps, air conditioners, and dehumidifiers. The 3rd edition, published in 2019, added specifications for A2L equipment design. There are also recommended service practices for A2L systems listed in the appendices.

UL Standard 60335-2-89

Referred to as "2-89", this standard covers the design and test specifications for split-type, commercial refrigeration appliances (systems equipped with remote condensing units).

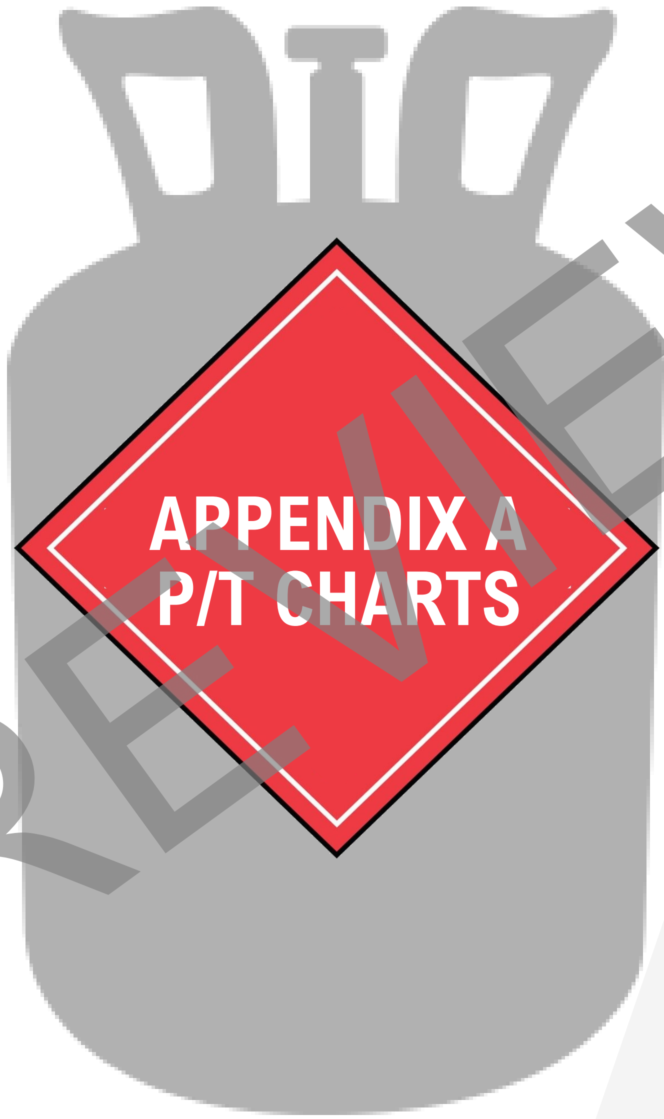
Code of Federal Regulations (CFR) Title 49

The nine-volume Code of Federal Regulations Title 49 for Transportation regulates transportation of hazardous materials for all forms of transportation to, from, and within the United States. Parts 100-185 of Title 49 cover transporting hazardous materials, which are overseen by the Pipeline and Hazardous Materials Safety Administration under the helm of the U.S. Department of Transportation (DOT).

Some of the areas addressed by CFR Title 49 include:

- Descriptions of hazardous materials by class,
- The amount of hazardous materials permitted in specific containers in addition to the total volume allowed in each shipped package,
- The types of packages and packaging required for the safe transport of hazardous materials,
- Testing requirements for reaching specific performance standards,
- Required documentation for shipping hazardous materials,
- The markings and labels required on packaging and placards required by carriers,
- Training and safety plan requirements.

PREVIEW



PREVIEW

R-1234yf	
Temperature °F	Pressure psig
-45	-6.8
-40	-5.7
-35	-4.4
-30	-2.9
-25	-1.4
-20	0.4
-15	2.3
-10	4.4
-5	6.7
0	9.2
5	12
10	14.9
15	18.1
20	21.6
25	25.4
30	29.4
35	33.8
40	38.4
45	43.4
50	48.8
55	54.5
60	60.6
65	67
70	73.9

R-1234yf	
Temperature °F	Pressure psig
75	81.3
80	89
85	97.2
90	105.9
95	115.1
100	124.9
105	135.1
110	145.9
115	157.3
120	169.2
125	181.8
130	195
135	208.9
140	223.4
145	238.7
150	254.7
155	271.4
160	288.9
165	307.3
170	326.5
175	346.6
180	367.6
185	389.7

Data Source: Genetron Properties V 1.41, by Honeywell International
https://www.fluorineproducts-honeywell.com/refrigerants/genetron-properties-suite/

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R-32	
Temperature °F	Pressure psig
-50	5.2
-45	8
-40	11
-35	14.4
-30	18.2
-25	22.3
-20	26.8
-15	31.7
-10	37.1
-5	42.9
0	49.3
5	56.1
10	63.5
15	71.4
20	80
25	89.2
30	99.1
35	109.7
40	121
45	133
50	145.8
55	159.5
60	174

R-32	
Temperature °F	Pressure psig
65	189.5
70	205.8
75	223.2
80	241.5
85	260.9
90	281.3
95	302.9
100	325.7
105	349.6
110	374.9
115	401.4
120	429.3
125	458.7
130	489.5
135	521.8
140	555.8
145	591.4
150	628.8
155	668.1
160	709.4
165	752.9
170	798.9

Data Source: Genetron Properties V 1.41, by Honeywell International
https://www.fluorineproducts-honeywell.com/refrigerants/genetron-properties-suite/

Temperature °F	R-454B Liquid Pressure psig	R-454B Vapor Pressure psig
-45	6.7	5.7
-40	9.6	8.5
-35	12.8	11.6
-30	16.3	15
-25	20.2	18.7
-20	24.4	22.8
-15	29	27.2
-10	34.1	32
-5	39.5	37.3
0	45.4	43
5	51.8	49.2
10	58.7	55.8
15	66.2	63
20	74.2	70.7
25	82.8	79
30	92	87.9
35	101.8	97.4
40	112.3	107.6
45	123.5	118.5
50	135.5	130
55	148.2	142.4
60	161.7	155.4

Temperature °F	R-454B Liquid Pressure psig	R-454B Vapor Pressure psig
65	176	169.4
70	191.1	184.1
75	207.2	199.7
80	224.1	216.3
85	242	233.8
90	260.9	252.2
95	280.8	271.7
100	301.8	292.3
105	323.8	314
110	347	336.8
115	371.4	360.9
120	397	386.2
125	423.9	412.8
130	452	440.8
135	481.6	470.2
140	512.5	501.1
145	544.9	533.7
150	578.9	567.9
155	614.5	604
160	651.7	642.2
165	690.8	682.6
170	731.6	726.2

PREVIEW

Data Source: Genetron Properties V 1.41, by Honeywell International
https://www.fluorineproducts-honeywell.com/refrigerants/genetron-properties-suite/

APPENDIX B SAFETY DATA SHEETS

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Important Information Regarding Safety Data Sheets

The safety data sheets (SDS) provided here are for sample/review purposes only, and are current as of the date of publication of this manual. SDS sheets are updated by the refrigerant manufacturer, as necessary, and it is the responsibility of the technician to ensure the most up to date information on the refrigerant being used is reviewed.

Additional Resources

Honeywell International SDS information: https://msds-resource.honeywell.com/

Chemours Company FC, LLC SDS information: https://www.opteon.com, click on SDS tab.

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SECTION 1. IDENTIFICATION

Product name	:	Solstice® yf Refrigerant (R-1234yf) (Cartridge)
Number	:	000000023794
Product Use Description	:	Refrigerant
Manufacturer or supplier's details	:	Honeywell International Inc. 115 Tabor Road Morris Plains, NJ 07950-2546
For more information call	:	800-522-8001 +1-973-455-6300(Monday-Friday, 9:00am-5:00pm)
In case of emergency call	:	**Medical: 1-800-498-5701 or +1-303-389-1414**
	:	**Transportation (CHEMTREC): 1-800-424-9300 or +1-703-527-3887**
	:	
	:	(24 hours/day, 7 days/week)

SECTION 2. HAZARDS IDENTIFICATION

Emergency Overview

Form	:	Liquefied gas
Color	:	clear
Odor	:	slight

Classification of the substance or mixture

Classification of the substance or mixture	:	Flammable gases, Category 1 Gases under pressure, Liquefied gas Simple Asphyxiant

GHS Label elements, including precautionary statements

PREVIEW

For information purposes only. Please refer to the manufacturer's website for current data.

SECTION 1. IDENTIFICATION

Product name	:	Genetron® 32
Number	:	000000009907
Product Use Description	:	Refrigerant
Manufacturer or supplier's details	:	Honeywell International Inc. 115 Tabor Road Morris Plains, NJ 07950-2546
For more information call	:	800-522-8001 +1-973-455-6300 (Monday-Friday, 9:00am-5:00pm)
In case of emergency call	:	**Medical: 1-800-498-5701 or +1-303-389-1414**
	:	**Transportation (CHEMTREC): 1-800-424-9300 or +1-703-527-3887**
	:	
	:	(24 hours/day, 7 days/week)

SECTION 2. HAZARDS IDENTIFICATION

Emergency Overview

Form	:	Liquefied gas
Color	:	colourless
Odor	:	slight sweet ether-like

PREVIEW

Low GWP Refrigerant Safety

Flammable and Mildly Flammable Refrigerants

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