STANDARD

ANSI/ASHRAE Standard 15-2022
(Supersedes ANSI/ASHRAE Standard 15-2019)
Includes ANSI/ASHRAE addenda listed in Appendix G

Safety Standard for Refrigeration Systems

See Informative Appendix G for approval dates by ASHRAE and the American National Standards Institute.

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 ISSN 1041-2336

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Approved American National Standard
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Safety Standard for Refrigeration Systems

NOTE

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FOREWORD

The 2022 edition of ASHRAE Standard 15 incorporates more updates than any other edition in the standard's history. These changes are intended to ensure continued improvement in the safe design, construction, installation, and operation of refrigeration systems. One major change (Addendum d) removes from the scope of Standard 15 applications covered by the newly published ANSI/ASHRAE Standard 15.2-2022, Safety Standard for Refrigeration Systems in Residential Applications*, where one system serves one dwelling space (residential applications where one system serves more than one dwelling space still lie within the scope of Standard 15). Most of the other changes address the use of other than Group A1 refrigerants. Highlights include updates to overpressure protection (Addendum a), use of small amounts of non-A1 refrigerants in equipment listed to product safety standards (Addendum c), major revisions to piping requirements (Addendum e), introduction of the concept of releasable charge (Addendum g), clarification of connected spaces (Addendum g), major changes to volume calculations and refrigerant charge limit calculations (Addendum g), commercial refrigeration applications with non-A1 refrigerants (Addendum l), ventilation for human comfort systems using Group A2L refrigerants (Addendum m), refrigerant charge calculations for human comfort systems using Group A2L refrigerants (Addendum p), machinery room applications using Class 2L refrigerants (Addendum q), and refrigerant detector/detection and mitigation actions (Addendum s). Additional changes are noted in Informative Appendix G.*

Standard 15 is regularly updated through the continuous maintenance process, which allows additions and modifications based on feedback from users in accordance with ASHRAE's ANSI-approved procedures. In addition to feedback from users, changes in the science originating from ASHRAE and industry research, as well as changes in refrigeration technology, necessitate the continuous maintenance approach. Instructions for how to submit a change can be found on the ASHRAE website at www.ashrae.org/continuous-maintenance.

ASHRAE Standard 15 must be used with its companion standard, ANSI/ASHRAE Standard 34, Designation and Safety Classification of Refrigerants*. Standard 34 prescribes the Refrigerant Classification System, as well as refrigerant concentration limits (RCL) and lower flammability limit (LFL), which are vitally important in applying this standard. Although changes to Standard 15 are closely coordinated with those to Standard 34, users of Standard 15 should also review the most recent version of Standard 34 and its associated addenda for the latest information related to refrigerant designations and safety classifications.*

ASHRAE Standard 15 gives a method for determining the amount of refrigerant in a given space that, when exceeded, requires a machinery room. When a refrigerant is not classified in ASHRAE Standard 34 or its addenda, this standard has provisions for the authority having jurisdiction to approve a classification for use in establishing the installation requirements.

ASHRAE Standard 15 is directed toward the safety of persons and property on or near the premises where refrigeration facilities are located. It includes specifications for fabrication of refrigerating systems but does not address the effects of refrigerant emissions on the environment. For information on the environmental effects of refrigerant emissions, see ANSI/ASHRAE Standard 147, Reducing the Release of Halogenated Refrigerants from Refrigerating and Air-Conditioning Equipment and Systems*.*

The hazards of refrigerants are related to their physical and chemical characteristics and to the pressures and temperatures that occur in refrigerating and air-conditioning systems. Personal injury and property damage from inadequate precautions may originate in a number of ways:

- *Risk of flying debris from a ruptured part*
- *Release of refrigerant from a fracture, due to a leaking seal or incorrect operation*
- *Fire resulting from or intensified by burning or deflagration of escaping refrigerant or lubricant*

Personal injury resulting from the accidental release of refrigerants may also occur from the following:

- *Suffocation from heavier-than-air refrigerants in inadequately ventilated spaces*
- *Narcotic and cardiac sensitization effects*
- *Toxic effects of vapor or the decomposition products due to vapor contact with flames or hot surfaces*
- *Corrosive attack on the eyes, skin, or other tissue*
- *Freezing of tissue by contact with cold liquid*

Care should be taken to avoid stagnant pockets of refrigerant vapors by properly locating ventilation supply air inlets and exhaust outlets. All commonly used refrigerants, except ammonia (R-717) and water (R-718), are heavier than air when at room temperature. Leaked refrigerant vapor will concentrate near the floor if undisturbed. Floor-level exhaust air outlets are appropriate for heavier-than-air refrigerants.

Users of Standard 15 may refer to ASHRAE's User's Manual for ANSI/ASHRAE Standard 15-2001*, published in 2004. Though the user's manual has not been updated since the 2001 edition of the standard, and therefore does not reflect the most recent changes to the standard, it still serves to clarify the intent of many of the standard's provisions and provides some explanation of the rationale behind them. Also included are illustrations and examples of accepted industry practice, as well as explanations of and supporting references for formulas in the standard. In lieu of updating the user's manual, the 2022 edition of Standard 15 introduces a new Informative Appendix A (Addendum f) that adds explanatory context to certain sections.*

Certain terms, abbreviations, and acronyms are defined in Section 3.1 for the purposes of the standard. When the tense or plurality of the term differs from the defined term, the definition still applies. These definitions are applicable to all sections of this standard, wherever italicized. Terms that are not italicized have their ordinarily accepted meanings within the context in which they are used. Ordinarily accepted meanings are based on American standard English language usage as documented in an unabridged dictionary accepted by the adopting authority.

1. PURPOSE

This standard specifies safe design, construction, installation, and operation of refrigeration systems.

2. SCOPE

2.1 This standard establishes safeguards for life, limb, health, and property and prescribes safety requirements.

2.2 This standard applies to

a. the design, construction, test, installation, operation, and inspection of mechanical and absorption refrigeration systems, including *heat-pump* systems used in stationary applications;
b. modifications, including replacement of parts or components if they are not identical in function and capacity; and
c. substitutions of *refrigerants* having a different designation.

2.3 This standard *shall not* apply to refrigeration systems using ammonia (R-717) as the *refrigerant*.
Informative Note: See ANSI/IIAR 2 [1] for systems using ammonia (R-717).

2.4 This standard does not apply to residential refrigeration systems serving only a single dwelling unit or sleeping unit complying with ASHRAE Standard 15.2 [2].

3. DEFINITIONS

3.1 Defined Terms

administrative control: the use of human action aimed at achieving a safe level of performance from a system or subsystem. Compare to *engineering control*.

air circulation: mechanically inducing airflow within a space or spaces connected by *air ducts*.

approved: acceptable to the authority having jurisdiction (AHJ).

back pressure: the static pressure existing at the outlet of an operating *pressure relief device* due to pressure in the discharge line.

balanced relief valve: a *pressure relief valve* that incorporates means of minimizing the effect of *back pressure* on the operational characteristics of the valve (opening pressure, closing pressure, and relieving capacity).

blends: *refrigerants* consisting of mixtures of two or more different chemical compounds, often used individually as *refrigerants* for other applications.

brazed joint: a gas-tight joint obtained by the joining of metal parts with metallic mixtures or alloys that melt at liquidus temperatures above 840°F (450°C) but less than the melting solidus temperatures of the joined parts.

building code: the building code adopted by the jurisdiction.

building element: a fundamental component of building construction, including walls, partitions, floor/ceiling assemblies, roof construction, and structural framing, which may or may not be of *fire-resistance-rated* construction and is constructed of materials based on the building type of construction.

cascade refrigerating system: a *refrigerating system* having two or more *refrigerant* circuits, each with a *pressure imposing element*, a *condenser*, and an *evaporator*, where the *evaporator* of one circuit absorbs the heat rejected by another (lower-temperature) circuit.

companion valves (block valves): pairs of mating *stop valves* that allow sections of a system to be joined before opening these valves or separated after closing them.

compound refrigerating system: a *multistage refrigerating system* in which a single charge of *refrigerant* circulates through all stages of compression. See *multistage refrigerating system*.

compressor: a machine used to compress *refrigerant* vapor.

compressor unit: a *compressor* with its prime mover and accessories.

condenser: that part of the *refrigerating system* where *refrigerant* is liquefied by the removal of heat.

condenser coil: a *condenser* constructed of pipe or tubing and not enclosed in a *pressure vessel*.

condensing unit: a combination of one or more power-driven *compressors*, *condensers*, *liquid receivers* (when required), and regularly furnished accessories.

conditioned space: an area, room, or space that is enclosed within the building thermal envelope that is directly or indirectly heated or cooled. Spaces are indirectly heated or cooled where they

a. connect through openings with *conditioned spaces*;
b. are separated from *conditioned spaces* by uninsulated walls, floors, or ceilings; or
c. contain uninsulated *air ducts*, *tubing*, or other sources of heating or cooling.

connected spaces: two or more spaces connected by natural ventilation, a ducted air distribution system, or mechanical ventilation.

container (refrigerant): a cylinder for the transportation of *refrigerant*.

corridor: an enclosed passageway that limits travel to a single path.

critical pressure, critical temperature, **and** ***critical volume:*** a point on the saturation curve where the *refrigerant* liquid and vapor have identical volume, density, and enthalpy and there is no latent heat.

design pressure: the maximum gage pressure for which a specific part of a *refrigerating system* is designed.

dual pressure relief device: two *pressure relief devices* mounted on a *three-way valve* that allows one device to remain active while the other is isolated.

duct: a tube or conduit used to convey or encase.

air duct: a tube or conduit used to convey air. (Air passages in *self-contained systems* are not *air ducts*.)

pipe duct: a tube or conduit used to encase pipe or tubing.

ducted HVAC: an air conditioner, *heat pump*, whole-house dehumidifier, or whole-house dehumidifying ventilator in which conditioned air is distributed through any amount of *air duct*.

ductless HVAC: an air conditioner, *heat pump*, or dehumidifier in which conditioned air is distributed directly into the *conditioned space* from the *refrigerating system* without the use of *air ducts*.

effective dispersal volume: the volume of a space or *connected spaces* in which leaked *refrigerant* will disperse.

effective dispersal volume charge (EDVC): the maximum *refrigerant* charge permitted for an *effective dispersal volume*.

engineering control: the use of sensors, actuators, and other equipment to achieve a safe level of performance from a system or subsystem without the aid of human interaction. Compare to *administrative control*.

evaporator: that part of the *refrigerating system* designed to vaporize liquid *refrigerant* to produce refrigeration.

evaporator coil: an *evaporator* constructed of pipe or tubing and not enclosed in a *pressure vessel*.

exhaust air: air removed from a space and discharged outside of the space by means of mechanical ventilation.

exit passageway: an exit component that is separated from other interior spaces of a building or structure by *fire-resistant-rated* construction and opening protectives, and provides for a protected path of egress travel in a horizontal direction to an exit or the outside exit door.

fire-resistance-rated: a *building element* with an *approved fire-resistance rating.*

fire-resistance rating: the period of time a *building element*, component, or assembly maintains the ability to confine a fire, continues to perform a given structural function, or both, as determined by *approved* tests or *approved* methods based on tests.

fire-resistance-rated exit access corridor: a portion of a *means of egress* system that is a *fire-resistance-rated* enclosed exit access component that defines and provides a path of egress travel.

flash-gas-bypass valve: a device that regulates the removal of gas from the *flash-gas tank* for compression.

flash-gas tank: a tank provided to separate vapor from liquid on the supply side of an *evaporator*. The feed to a *flash-gas tank* is supercritical gas exiting a *gas cooler* that has been throttled to its subcritical region.

fusible plug: a plug containing an alloy that will melt at a *specified* temperature and relieve pressure.

gas cooler: a heat exchanger designed to remove heat from a *transcritical system*.

header: a pipe or tube (extruded, cast, or fabricated) to which other pipes or tubes are connected.

heat exchanger coil: a *refrigerant*-containing heat transfer component constructed of pipe or tubing.

heat pump: a *refrigerating system* used to transfer heat into a space or substance.

high side: a portion or stage of a *refrigerating system* that is subject to *condenser* or *gas cooler* pressure.

horsepower (hp): the power delivered from the prime mover to the *compressor* of a *refrigerating system*.

immediately dangerous to life or health (IDLH): the maximum concentration from which unprotected persons are able to escape within 30 minutes without escape-impairing symptoms or irreversible health effects [3].

independent circuit: a closed refrigeration circuit that is arranged in such a manner that, in the event of a single point of failure, the release of *refrigerant* is limited to only the quantity contained within the refrigeration circuit.

informative appendix: an appendix that is not part of the standard but is included for information only.

inside dimension: inside diameter, width, height, or cross-sectional diagonal.

intermediate pressure stage: a pressure stage that is sometimes present on carbon dioxide (R-744) *transcritical systems* that operates between the *high-side* and *low-side* pressure stages, is regulated by a *flash-gas-bypass valve*, and includes *flash-gas tanks* and *gas coolers*, where provided.

internal gross volume: the volume as determined from internal dimensions of the *container* with no allowance for the volume of internal parts.

labeled: equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the AHJ and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the *manufacturer* indicates compliance with appropriate standards or performance in a *specified* manner.

limited charge system: a system in which, with the *compressor* idle, the *design pressure* will not be exceeded when the *refrigerant* charge has completely evaporated.

liquid receiver: a vessel, permanently connected to a *refrigerating system* by inlet and outlet pipes, for storage of liquid *refrigerant*.

listed: equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a *specified* purpose.

lithium bromide/water absorption system: an absorption system where water (R-718) is the *refrigerant* and lithium bromide (LiBr) is the absorbent.

lobby: a waiting room or large hallway serving as a waiting room.

lower flammability limit (LFL): see ASHRAE Standard 34 [3].

low-probability pump: a pump that (a) is permanently sealed to prevent atmospheric release of the pumped fluid, (b) incorporates a static seal to prevent atmospheric release of the pumped fluid, or (c) incorporates not less than two sequential dynamic shaft seals and automatically shuts down upon failure of any seal to prevent atmospheric release of the pumped fluid.

low side: the portion of a *refrigerating system* that is subjected to approximate *evaporator* pressure.

machinery: refrigerating equipment forming a part of the *refrigerating system*, including (but not limited to) any or all of the following: *compressor*, *condenser*, *liquid receiver*, *evaporator*, and connecting *piping*.

machinery room: a designated space meeting the requirements of Sections 8.9, 8.10, and 8.11 that contains one or more *refrigerating systems* or portions thereof, such as *compressors* and *pressure vessels*.

makeup air: air added to a space from outside the building or from other indoor spaces by means of mechanical or natural ventilation.

manufacturer: the company or organization that evidences its responsibility by affixing its name, trademark, or trade name to refrigerating equipment.

means of egress: a continuous and unobstructed path of travel from any point in a building or structure to a public way.

mechanical joint: a gas-tight joint obtained by joining metal parts with a positive-holding mechanical construction such as flanged, screwed, or flared joints or compression fittings.

mitigation actions: actions taken by equipment that are initiated by detection of leaked *refrigerant* by the *refrigerant detector*.

multistage refrigerating system: a *refrigerating system* in which compression of *refrigerant* is carried out in two or more steps.

****nationally recognized testing laboratory (NRTL):*** an organization that is recognized by a national body having authority for such approval that tests for safety and lists, labels, or accepts, equipment or materials; is organized, equipped, and qualified for testing; and has a follow-up inspection service of the current production of the *listed* products.

nonpositive displacement compressor: a *compressor* in which the increase in vapor pressure is attained without changing the internal volume of the compression chamber.

normative appendix: an appendix including integral parts of the mandatory requirements of the standard, which, for reasons of convenience, are placed after all other normative elements.

occupancy: for class of *occupancy*, see Section 4.

occupational exposure limit (OEL): see ASHRAE Standard 34 [3].

occupied space: that portion of the *premises* accessible to or occupied by people, excluding *machinery rooms*.

piping: the pipe or tube used to convey fluid from one part of a refrigeration system to another. *Piping* includes pipe, flanges, bolting, gaskets, valves, fittings, pipe-supporting fixtures, structural attachments, and the pressure-containing parts of other components, such as expansion joints, strainers, filters, and devices that serve such purposes as mixing, separating, muffling, snubbing, distributing, metering, or controlling flow.

positive displacement compressor: a *compressor* in which the increase in pressure is attained by changing the internal volume of the compression chamber.

premises: a tract of land and the buildings thereon.

pressure imposing element: any device or portion of the equipment used to increase *refrigerant* pressure.

pressure limiting device: a pressure-responsive electronic or mechanical control designed to automatically stop the operation of the pressure imposing element at a predetermined pressure.

pressure relief device: a pressure (not temperature) actuated valve or *rupture member* designed to automatically relieve pressure in excess of its setting.

pressure relief valve: a pressure-actuated valve held closed by a spring or other means and designed to automatically relieve pressure in excess of its setting.

> ***pressure relief valve, pilot-operated:*** a *pressure relief valve* in which the major relieving device is combined with and is controlled by a self-actuated auxiliary *pressure relief valve*.

pressure vessel: any *refrigerant*-containing receptacle in a *refrigerating system*. This does not include *evaporators* where each separate *evaporator* section does not exceed 0.5 ft^3 (0.014 m^3) of *refrigerant*-containing volume, regardless of the maximum *inside dimension*. This also does not include *evaporator coils*, *compressors*, *condenser coils*, controls, *headers*, pumps, and *piping*.

pumpdown charge: the quantity of *refrigerant* stored at some point in the refrigeration system for operational, service, or standby purposes.

reclaimed refrigerants: *refrigerants* reprocessed to the same specifications as new *refrigerants* by any means, including distillation. Such *refrigerants* have been chemically analyzed to verify that those specifications have been met.

recovered refrigerants: *refrigerants* removed from a system in any condition without necessarily testing or processing them.

recycled refrigerants: *refrigerants* for which contaminants have been reduced by oil separation, removal of noncondensable gases, and single or multiple passes through filter driers or other devices that reduce moisture, acidity, and particulate matter.

refrigerant: the fluid used for heat transfer in a *refrigerating system*; the *refrigerant* absorbs heat and transfers it at a higher temperature and a higher pressure, usually with a change of state.

refrigerant concentration limit (RCL): see ASHRAE Standard 34 [3].

refrigerant designation: the unique identifying alphanumeric value or *refrigerant* number assigned to an individual *refrigerant* and published in ASHRAE Standard 34 [3].

****refrigerant detection system:*** a system, or portion of a combination system, that utilizes one or more devices to detect the presence of a *specified refrigerant* at a *specified* concentration and initiates one or more *mitigation actions* required by this standard.

****refrigerant detector:*** a device that is capable of sensing the presence of *refrigerant* vapor.

refrigerating system: a combination of interconnected parts forming a closed circuit in which *refrigerant* is circulated for the purpose of extracting then rejecting heat. (See Section 5 for classification of *refrigerating systems* by type.)

refrigerating system classification: *refrigerating systems* are classified according to the degree of probability, low or high, that leaked *refrigerant* from a failed connection, seal, or component could enter an occupied area. The distinction is based on the basic design or location of the components. (See Section 5 for classification of *refrigerating systems* by type.)

refrigerating system, direct: see Section 5.1.1.

refrigerating system, indirect: see Section 5.1.2.

releasable refrigerant charge (m_{rel}): a portion of the *system refrigerant charge* that can be released into a space as a result of a single point of failure.

rupture member: a device that will rupture and release *refrigerant* to relieve pressure.

safety shutoff valve: an automatically controlled *refrigerant* valve for the purpose of limiting the amount of *refrigerant* released into a space when a *refrigerant* leak is detected.

saturation pressure: the pressure at which vapor and liquid exist in equilibrium at a given temperature.

secondary coolant: any liquid used for the transmission of heat, without vaporization.

self-contained system: a complete, factory-assembled and factory-tested system that is shipped in one or more sections and has no *refrigerant*-containing parts that are joined in the field by other than *companion valves* or *block valves*.

set pressure: the pressure at which a *pressure relief device* or pressure control is set to operate.

shall (shall not): used in this standard when a provision is (or is not) mandatory.

soldered joint: a gas-tight joint formed by joining metal parts with alloys that melt at liquidus temperatures not exceeding 840°F (450°C) and above 400°F (205°C).

specified: explicitly stated in detail. *Specified* limits or prescriptions are mandatory.

stop valve: a device used to shut off the flow of *refrigerant*.

system refrigerant charge (m_c): the total mass of *refrigerant* in an *independent circuit* of a system, including both factory and field *refrigerant* charge.

three-way valve: a service valve for *dual pressure relief devices* that allows using one device while isolating the other from the system, maintaining one valve in operation at all times.

transcritical system: a refrigeration system in which evaporation occurs in the subcritical region and heat rejection can occur at a pressure exceeding the *critical pressure* of the *refrigerant*.

ultimate strength: the stress at which rupture occurs.

unit system: see *self-contained system*.

ventilated enclosure: a type of equipment enclosure that includes an integral ventilation system that will prevent *refrigerant* leaked inside the equipment enclosure from escaping into the space surrounding the equipment enclosure.

3.2 Acronyms, Abbreviations, and Initialisms

AHJ	authority having jurisdiction
EDVC	*effective dispersal volume charge*
IDLH	*immediately dangerous to life or health*
LFL	*lower flammability limit*
OEL	*occupational exposure limit*
RCL	*refrigerant concentration limit*

4. OCCUPANCY CLASSIFICATION

4.1 Locations of *refrigerating systems* are described by *occupancy* classifications that consider the ability of people to respond to potential exposure to *refrigerant* as follows.

4.1.1 *Institutional occupancy* is a premise or that portion of a premise from which, because they are disabled, debilitated, or confined, occupants cannot readily leave without the assistance of others. *Institutional occupancies* include, among others, hospitals, nursing homes, asylums, and spaces containing locked cells.

4.1.2 *Public assembly occupancy* is a premise or that portion of a premise where large numbers of people congregate and from which occupants cannot quickly vacate the space. *Public assembly occupancies* include, among others, auditoriums, ballrooms, classrooms, passenger depots, restaurants, and theaters.

4.1.3 *Residential occupancy* is a premise or that portion of a premise that provides the occupants with complete independent living facilities, including permanent provisions for living, sleeping, eating, cooking, and sanitation. *Residential occupancies* include, among others, dormitories, hotels, multiunit apartments, and private residences.

4.1.4 *Commercial occupancy* is a premise or that portion of a premise where people transact business, receive personal service, or purchase food and other goods. *Commercial occupancies* include, among others, office and professional buildings, markets (but not *large mercantile occupancies*), and work or storage areas that do not qualify as *industrial occupancies*.

4.1.5 *Large mercantile occupancy* is a premise or that portion of a premise where more than 100 persons congregate on levels above or below street level to purchase personal merchandise.

4.1.6 *Industrial occupancy* is a premise or that portion of a premise that is not open to the public, where access by authorized persons is controlled, and that is used to manufacture, process, or store goods such as chemicals, food, ice, meat, or petroleum.

4.1.7 *Mixed occupancy* occurs when two or more *occupancies* are located within the same building. When each *occupancy* is isolated from the rest of the building by tight walls, floors, and ceilings and by self-closing doors, the requirements for each *occupancy shall* apply to its portion of the building. When the various *occupancies* are not so isolated, the *occupancy* having the most stringent requirements *shall* be the governing *occupancy*.

4.2 Equipment, other than *piping*, located outside a building and within 20 ft (6.1 m) of any building opening *shall* be governed by the *occupancy* classification of the building.

Exception to 4.2: Equipment located within 20 ft (6.1 m) of the building opening for the *machinery room*.

5. REFRIGERATING SYSTEM CLASSIFICATION

5.1 Refrigerating Systems. *Refrigerating systems* are defined by the method employed for extracting or delivering heat as follows (see Figure 5-1).

5.1.1 A *direct system* is one in which the *evaporator* or *condenser* of the *refrigerating system* is in direct contact with the air or other substances to be cooled or heated.

Paragraph	Designation	Cooling or Heating Source	Air or Substance to be Cooled or Heated
5.1.1	*Direct system*		
5.1.2.1	*Indirect open spray system*		
5.1.2.2	*Double indirect open spray system*		
5.1.2.3	*Indirect closed system*		
5.1.2.4	*Indirect vented closed system*		

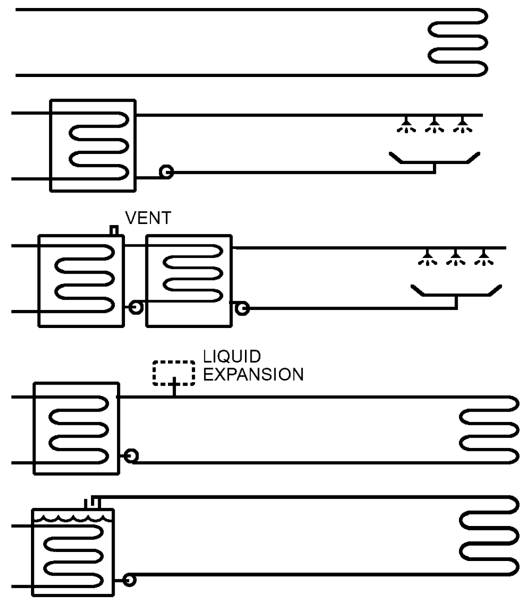


Figure 5-1 Refrigerating system designation.

5.1.2 An *indirect system* is one in which a *secondary coolant* cooled or heated by the *refrigerating system* is circulated to the air or other substance to be cooled or heated. *Indirect systems* are distinguished by the method of application given below.

5.1.2.1 An *indirect open spray system* is one in which a *secondary coolant* is in direct contact with the air or other substance to be cooled or heated.

5.1.2.2 A *double indirect open spray system* is one in which the secondary substance for an *indirect open spray system* (Section 5.1.2.1) is heated or cooled by the *secondary coolant* circulated from a second enclosure.

5.1.2.3 An *indirect closed system* is one in which a *secondary coolant* passes through a closed circuit in the air or other substance to be cooled or heated.

5.1.2.4 An *indirect vented closed system* is one in which a *secondary coolant* passes through a closed circuit in the air or other substance to be cooled or heated, except that the *evaporator* or *condenser* is placed in an open or appropriately vented tank.

5.2 Refrigeration System Classification. For the purpose of applying the data shown in ASHRAE Standard 34 [3], Table 4-1 or 4-2, a *refrigerating system shall* be classified according to the degree of probability that a leakage of *refrigerant* will enter an *occupancy*-classified area as follows.

5.2.1 High-Probability System. A high-probability system is any system in which the basic design or the location of components is such that a leakage of *refrigerant* from a failed connection, seal, or component will enter the *occupied space*. Typical high-probability systems are (a) *direct systems* or (b) *indirect open spray systems* in which the *refrigerant* is capable of producing pressure greater than the *secondary coolant*.

5.2.2 Low-Probability System. A low-probability system is any system in which the basic design or the location of components is such that leakage of *refrigerant* from a failed connection, seal, or component cannot enter the *occupied space*. Typical low-probability systems are (a) *indirect closed systems* or (b) double *indirect systems* and (c) *indirect open spray systems* if the following condition is met: In a low-probability *indirect open spray system*, the *secondary coolant* pressure *shall* remain greater than *refrigerant* pressure in all conditions of operation and standby. Operation conditions are defined in Section 9.2.1, and standby conditions are defined in Section 9.2.1.2.

5.3 Changing Refrigerant. Changes of *refrigerant* in an existing system to a *refrigerant* with a different *refrigerant designation shall* only be allowed where in accordance with Sections 5.3.1 through 5.3.4.

5.3.1* The owner or the owner's authorized agent *shall* be notified prior to making a change of *refrigerant*, and the change of *refrigerant shall not* be made where the owner objects to the change.

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

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

5.3.3 Where the replacement *refrigerant* is classified into the same safety group, requirements that were applicable to the existing system *shall* continue to apply.

5.3.4 Where the replacement *refrigerant* is classified into a different safety group, the system *shall* comply with the requirements of this standard for a new installation, and the change of *refrigerant shall* require AHJ approval.

6. REFRIGERANT SAFETY CLASSIFICATION

6.1 *Refrigerants shall* be assigned safety classifications in accordance with ASHRAE Standard 34 [3].

6.2 *Refrigerants* with a *refrigerant* number designation in the referenced edition of ASHRAE Standard 34 [3] *shall* use the indicated toxicity classification and flammability classification when a safety group classification is assigned by ASHRAE Standard 34.

6.3 *Refrigerants* without a *refrigerant* number designation or without a safety group classification in the referenced edition of ASHRAE Standard 34 [3] *shall* be classified in accordance with the criteria in ASHRAE Standard 34, whether as a single-compound *refrigerant* or a *refrigerant blend* of two or more compounds. Such safety classifications not assigned by ASHRAE Standard 34 *shall* be submitted for approval to the authority having jurisdiction. Compliance with the requirements of this standard is contingent upon use of *approved* safety classifications when not assigned by the referenced edition of ASHRAE Standard 34.

7. RESTRICTIONS ON REFRIGERANT USE

7.1 General. The *occupancy*, *refrigerating system*, and *refrigerant* safety classifications cited in this section *shall* be determined in accordance with Sections 4, 5, and 6, respectively.

7.2* Volume Calculations

7.2.1 General. The *effective dispersal volume* identified in Section 7.3 into which *refrigerant* will disperse in the event of a release *shall* be calculated in accordance with this section. Volume calculations *shall* evaluate each space or *connected spaces* relevant to each refrigeration system. The smallest volume into which *refrigerant* disperses *shall* be used to determine the *refrigerant* quantity limit in the system.

7.2.2 Refrigerant Groups

7.2.2.1 Flammability Class 1. For Group A1 and B1 *refrigerants*, the *effective dispersal volume shall* be based on the *occupied space* served by a refrigeration system. Outdoor spaces *shall not* be included.

7.2.2.2 Flammability Class 2L, 2, and 3. For Group A2L, A2, A3, B2L, B2, and B3 *refrigerants*, the *effective dispersal volume shall* be based on the *occupied space* or non-*occupied space* served by a refrigeration system.

7.2.3 Volume Calculations. The *effective dispersal volume* used to calculate the *effective dispersal volume charge* (*EDVC*) given in Section 7.3 *shall* be based on the volume calculations *specified* in Sections 7.2.3.1 through 7.2.3.4.

7.2.3.1 Room Volume. The *effective dispersal volume shall* be established by the following physical enclosure elements: walls, floors, ceilings, windows or doors which can be closed, and partitions connecting to and extending from the finished floor to more than 5.5 ft (1.7 m) above the floor. Where different stories and floor levels connect through an open atrium or mezzanine, the *effective dispersal volume shall* be determined by multiplying the floor area of the lowest floor level by 8.2 ft (2.5 m) ceiling height.

7.2.3.1.1 Exempted Spaces. The areas that contain only continuous *refrigerant piping*, or contain only joints and connections that have been tested in accordance with Section 9.13, are exempt from the *effective dispersal volume* calculation unless these areas are part of *connected spaces* per Section 7.2.3.2.

7.2.3.2 Connected Spaces via Natural Ventilation. *Connected spaces shall* be on the same floor. *Connected spaces shall* be provided with permanent natural ventilation opening(s). Permanent natural ventilation opening(s) *shall* be sized in accordance with Section 7.2.3.2.1 or 7.2.3.2.2. The lower edge of the natural ventilation opening between rooms *shall* be located a maximum of 12 in. (305 mm) above the finished floor. The area of any openings above 12 in. (305 mm) from the floor *shall not* be considered. The required size of opening(s) *shall* be based on the net free area.

7.2.3.2.1 Natural Ventilation Opening for Group A1 Refrigerants. The minimum size of the opening for a Group A1 *refrigerant* (A_{vent}) *shall* be calculated using Equation 7-1a or 7-1b:

$$A_{vent} = \frac{m_{rel} - m_{room}}{RCL \times 0.833} \times \sqrt{\frac{A}{g \times m_{room}} \times \frac{M}{M - 29}} \tag{7-1a [I-P]}$$

$$A_{vent} = \frac{m_{rel} - m_{room}}{RCL \times 208} \times \sqrt{\frac{A}{g \times m_{room}} \times \frac{M}{M - 29}} \tag{7-1b [SI]}$$

where

A_{vent}	=	minimum area of a permanent opening, ft^2 (m^2)
m_{rel}	=	*releasable refrigerant charge*, lb (kg)
m_{room}	=	allowable *refrigerant* charge of an individual room, lb (kg); (V_{eff}, used to calculate *EDVC*, is the volume of an individual room.)
RCL	=	*refrigerant concentration limit*, lb/1000 ft^3 (kg/m^3)
A	=	actual area of the individual room, ft^2 (m^2)
M	=	relative molar mass of the *refrigerant*, dimensionless
g	=	acceleration due to gravity, 32.2 ft/s^2 (9.81 m/s^2)
0.833	=	I-P conversion factor
208	=	SI conversion factor
29	=	relative molar mass of air, dimensionless

Equations 7-1a and 7-1b are not applicable for *refrigerants* with a relative molar mass less than 42.

7.2.3.2.2 Natural Ventilation Opening for Group A2L, A2, or A3 Refrigerants. The minimum size of the opening for a Group A2L, A2, or A3 *refrigerant* (A_{vent}) *shall* be calculated using Equation 7-2a or 7-2b:

$$A_{vent} = \frac{m_{rel} - m_{room}}{LFL \times 0.417} \times \sqrt{\frac{A}{g \times m_{room}} \times \frac{M}{M - 29}} \tag{7-2a [I-P]}$$

$$A_{vent} = \frac{m_{rel} - m_{room}}{LFL \times 104} \times \sqrt{\frac{A}{g \times m_{room}} \times \frac{M}{M - 29}} \tag{7-2b [SI]}$$

where

A_{vent}	=	minimum area of a permanent opening, ft^2 (m^2)
m_{rel}	=	*releasable refrigerant charge*, lb (kg)
m_{room}	=	allowable *refrigerant* charge of an individual room, lb (kg); (V_{eff}, used to calculate *EDVC*, is the volume of an individual room.)
LFL	=	*lower flammability limit*, lb/1000 ft^3 (kg/m^3)
A	=	actual area of the individual room, ft^2 (m^2)
M	=	relative molar mass of the *refrigerant*, dimensionless
g	=	acceleration due to gravity, 32.2 ft/s^2 (9.81 m/s^2)
0.417	=	I-P conversion factor
104	=	SI conversion factor
29	=	relative molar mass of air, dimensionless

Equations 7-2a and 7-2b is not applicable for *refrigerants* with a relative molar mass less than 42.

7.2.3.3 Connected Spaces via Ducted Air Distribution System. Where a refrigeration system or a part thereof is located within an air distribution *duct* system or in a space served by an air distribution *duct* system, the entire air distribution system *shall* be analyzed to determine the worst-case distribution of leaked *refrigerant*. The *effective dispersal volume* in which the leaked *refrigerant* disperses *shall* be used to determine the *EDVC* in the system, subject to the criteria in the following subsections.

7.2.3.3.1 Closures. Closures in the air distribution system *shall* be considered. If one or more spaces of several arranged in parallel can be closed off from the source of the *refrigerant* leak, their volumes *shall not* be used in the calculation. Smoke dampers, fire dampers, and combination smoke/fire dampers that close only in an emergency not associated with a *refrigerant* leak *shall not* be classified as closure devices. Dampers, such as variable-air-volume (VAV) boxes, *shall not* be considered a closure provided the airflow is not reduced below 10% of its maximum.

7.2.3.3.2 Plenums. The volume of an air ceiling plenum or floor plenum *shall* be included when calculating the *effective dispersal volume* where the plenum space is a part of the refrigeration system air distribution system.

7.2.3.3.3 Supply and Return Ducts. The volume of the supply and return *ducts shall* be included when calculating the *effective dispersal volume*.

7.2.3.4 Connected Spaces via Mechanical Ventilation. Where two or more spaces are connected by a mechanical ventilation system complying with the requirements of Section 7.6.4, the volume of all such *connected spaces shall* be included in the *effective dispersal volume* used to calculate the *EDVC* in Section 7.3.

7.2.3.4.1 Ductwork. The volume of the transfer air ductwork *shall* be included when calculating the *effective dispersal volume*.

7.3 Refrigerant System Charge Limits. The *EDVC shall* be calculated in accordance with this section. All refrigeration system*s shall* follow the compliance path in Figure 7-1 and Figure 7-2 and the limitation of Section 7.3.2.

7.3.1 EDVC Calculation. The maximum charge permitted for an *effective dispersal volume shall* be calculated using Equation 7-3a or 7-3b:

$$EDVC = RCL \times V_{eff} \times F_{occ} \qquad \text{(7-3a [I-P])}$$

$$EDVC = RCL \times V_{eff} \times F_{occ}/1000 \qquad \text{(7-3b [SI])}$$

where

$EDVC$	=	*effective dispersal volume charge*, lb (kg)
RCL	=	*refrigerant concentration limit*, lb/ft^3 (g/m^3)
V_{eff}	=	*effective dispersal volume*, ft^3 (m^3), established using Sections 7.2.1 through 7.2.3
F_{occ}	=	*occupancy* adjustment factor (For all *occupancies* other than institutional, F_{occ} has a value of 1. For *institutional occupancies*, F_{occ} has a value of 0.5.)

7.3.2* Institutional Occupancies Refrigerant Systems Charge Limits. For *institutional occupancies*, the total *refrigerant* charge of all refrigeration systems containing Group A2, A3, B2, and B3 *refrigerants* in occupied areas and *machinery rooms shall not* exceed 550 lb (250 kg).

7.3.3* Industrial Occupancies and Refrigerated Rooms. *Industrial occupancies* and refrigerated rooms *shall* comply with the following conditions:

a. Spaces containing the *machinery* are separated from other *occupancies* by tight construction with tight-fitting doors.
b. *Access* is restricted to authorized personnel.
c. *Refrigerant detectors* are installed with the sensing location and alarm level as required in refrigeration *machinery rooms* in accordance with Section 8.9.5.
d. Surfaces exceeding 800°F (426.7°C), or open flames, are not permitted where any Group A2, A3, B2, or B3 *refrigerant* is used.
e. Surfaces exceeding 1290°F (700°C), or open flames, are not permitted where any Group A2L or B2L *refrigerant* is used.
f. Where loss of the *releasable refrigerant charge* of Group A2, A3, B2, or B3 *refrigerant* would result in an average *refrigerant* concentration that exceeds 25% of the *lower flammability limit* (*LFL*), electrical equipment in the space is Class I, Division 2, in accordance with NFPA 70 [4].
g. *Refrigerant*-containing parts in systems exceeding 100 *hp* (74.6 kW) *compressor* drive power, except *evaporators* used for refrigeration or dehumidification, *condensers* used for heating, control and *pressure relief valves* for either, *low-probability pumps*, and connecting *piping*, are located either in a *machinery room* or outdoors.

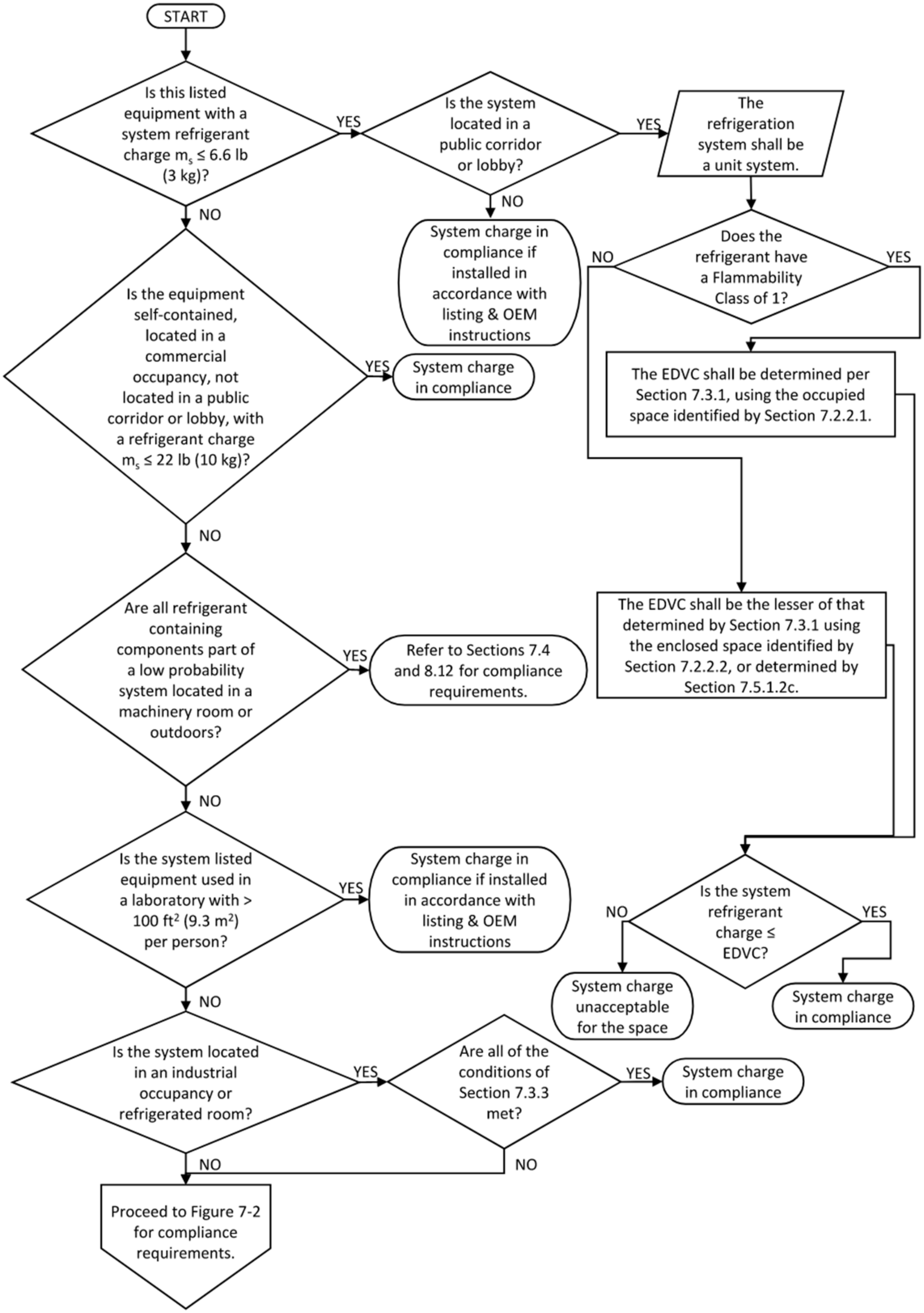


Figure 7-1 Refrigerant system charge limit compliance path—Part 1.

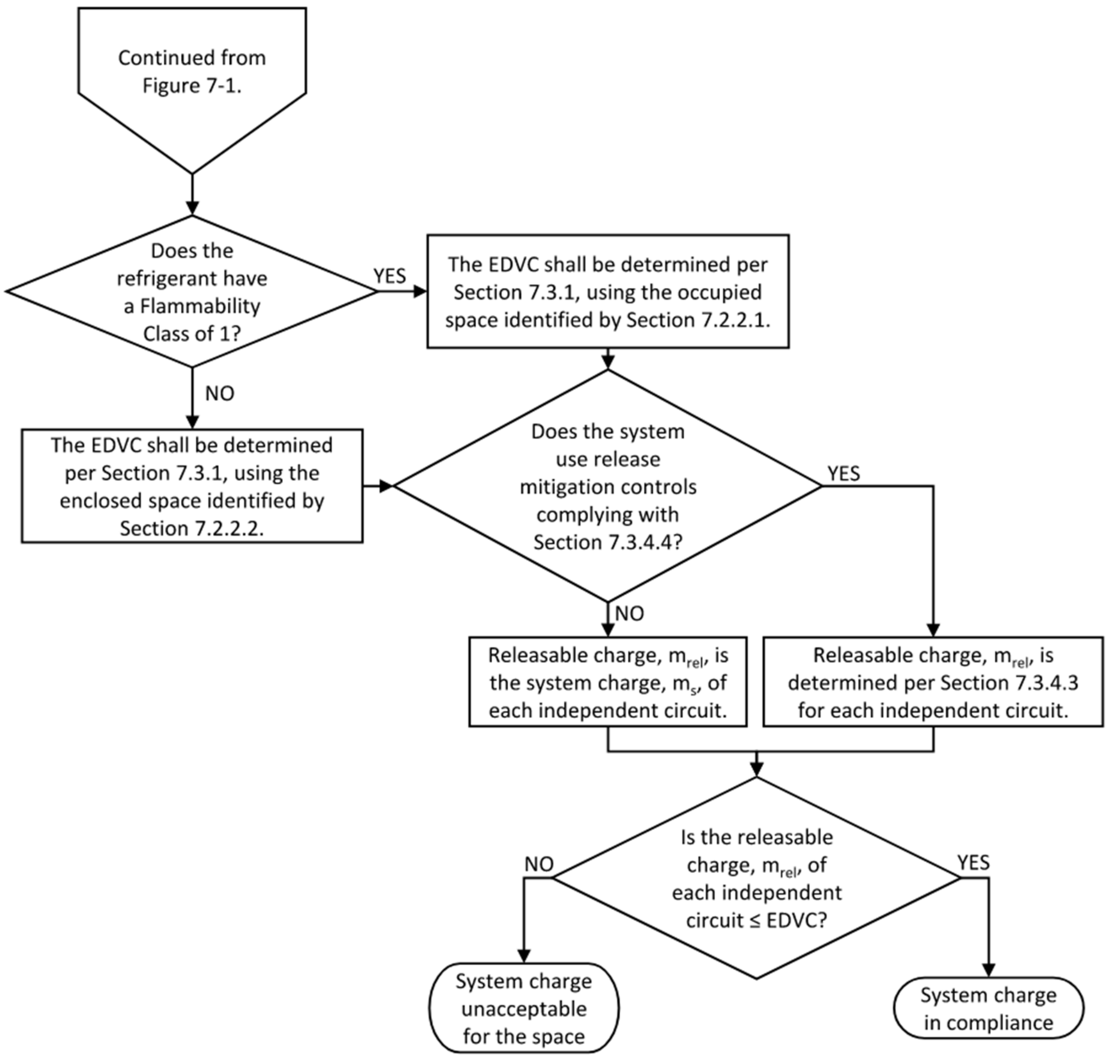


Figure 7-2 Refrigerant system charge limit compliance path—Part 2.

7.3.4* Releasable Refrigerant Charge (m_{rel}) Determination. The *releasable refrigerant charge* (m_{rel}) *shall* comply with the requirements of Section 7.3.1. The *releasable refrigerant charge shall* be determined in accordance with Sections 7.3.4.1 through 7.3.4.4. *Releasable refrigerant charge* determination in accordance with Sections 7.3.4.3 and 7.3.4.4 *shall not* be permitted for *institutional occupancies*.

7.3.4.1 Single Circuit. For single-circuit systems, the *releasable refrigerant charge* (m_{rel}) *shall* be the *system refrigerant charge*, unless release mitigation controls are provided in accordance with Section 7.3.4.4.

7.3.4.2 Multiple Independent Circuits. For systems with multiple *independent circuits*, the *releasable refrigerant charges shall* be the *refrigerant charges* in each *independent circuit*, unless release mitigation controls are provided in accordance with Section 7.3.4.4.

7.3.4.3 Calculating Releasable Refrigerant Charge. For *releasable refrigerant charge*, release mitigation controls complying with Section 7.3.4.4 *shall* be provided to limit a release by automatically isolating leaking *piping* or equipment. The *releasable refrigerant charge* (m_{rel}) *shall* be determined based on a release of the volume of *refrigerant* that will occur prior to operation of the release mitigation control plus the volume of *refrigerant* contained downstream of a release mitigation control in accordance with Equation 7-4a or 7-4b:

$$m_{rel} = (t_{r1} \times 0.0062) + m_{r2} + m_{r3} \tag{7-4a [I-P]}$$

$$m_{rel} = (t_{r1} \times 0.0028) + m_{r2} + m_{r3} \tag{7-4b [SI]}$$

where

t_{r1}	=	time before the leak is detected per Section 7.6.2.4
0.0062	=	leakage rate in lb/s
0.0028	=	leakage rate in kg/s
m_{r2}	=	leakage between the detection of the leak and the closing of the *safety shutoff valve*, lb (kg)
m_{r3}	=	leakage in the *piping* downstream of the *safety shutoff valve* after the valve is closed, lb (kg)

$$m_{r2} = t_{close} \times 0.0062 \tag{7-5a [I-P]}$$

$$m_{r2} = t_{close} \times 0.0028 \tag{7-5b [SI]}$$

where

t_{close}	=	time from when a leak is detected until the *safety shutoff valve* closes
0.0062	=	leakage rate in lb/s
0.0028	=	leakage rate in kg/s

$$m_{r3} = \Sigma V_{pipe} \times \rho_{ref} \tag{7-6}$$

where

V_{pipe}	=	internal volume of each section of the *piping* and *heat exchanger coil* downstream of the *safety shutoff valve*, ft^3 (m^3)
ρ_{ref}	=	density of the *refrigerant* in each section of pipe downstream of the *safety shutoff valve*, lb/ft^3 (kg/m^3)

7.3.4.4 Release Mitigation Controls. Release mitigation controls used to limit the *releasable refrigerant charge* (m_{rel}) *shall* comply with the following:

a. Release mitigation systems *shall* be components of a refrigeration system that is *listed* per UL 60335-2-40 [5]/CSA C22.2 No. 60335-2-40 [6] or UL 60335-2-89 [7]/CSA C22.2 No. 60335-2-89 [8] and evaluated by the *nationally recognized testing laboratory* as part of the listing.
b. Release mitigation controls *shall* only be permitted for reducing the *releasable refrigerant charge* (m_{rel}) on a refrigeration system where each indoor unit has a cooling capacity of 5 tons (17.5 kW) or less.
c. Release mitigation controls *shall* be activated by a *refrigerant detection system*. A *refrigerant detector shall* be located either in all refrigeration equipment serving the spaces or in all spaces served by the release-mitigation-controlled circuit. The *refrigerant detector shall* activate the release mitigation controls and isolate all possible paths of *refrigerant* that can leak into the space(s).
d. In the event of a failure of the release mitigation controls or a *refrigerant detector*, the release mitigation controls *shall* isolate all possible paths of *refrigerant* that can leak into the space(s).
e. *Refrigerant detectors shall* comply with Section 7.6.2.4 and *shall* activate the mitigation controls per Section 7.6.2.5. For Group A1 *refrigerants*, 100% of *RCL shall* be substituted in place of 25% of *LFL*.

f. The location of *refrigerant* mitigation controls *shall* be marked in accordance with the requirements of ASME A13.1 [9].
g. Release mitigation controls *shall* be tested in accordance with Section 9.13.

7.4 Location in a Machinery Room or Outdoors. All components containing *refrigerant shall* be located either in a *machinery room* or outdoors, where the quantity of *refrigerant* needed exceeds the limits defined by Sections 7.2 and 7.3. Refrigeration systems located outdoors *shall* comply with Section 8.12.

Exception to 7.4: *Listed self-contained systems* are permitted outside of a *machinery room*, provided that such systems are not located in public hallways or *lobbies* and are limited to the following *occupancies* and *refrigerant* quantities:

a. 6.6 lb (3 kg) of *refrigerant* where located in *residential occupancies*
b. 22 lb (10 kg) of *refrigerant* where located in *commercial occupancies*

7.4.1 Direct-fired absorption equipment *shall* be located in a *machinery room* or outdoors.

7.4.2 Class 1 Refrigerants. *Machinery rooms* required by Section 7.4 and containing only Group A1 or B1 *refrigerants shall* be constructed and maintained in accordance with Section 8.9.

7.4.3* Class 2L, Class 2, and Class 3 Refrigerants. *Machinery rooms* required by Section 7.4 and containing any Group A2, A3, B2, or B3 flammable *refrigerants shall* be constructed and maintained in accordance with Sections 8.9 and 8.10. *Machinery rooms* required by Section 7.4, containing any Group A2L or B2L flammable *refrigerants* and containing no Group A2, A3, B2, or B3 flammable *refrigerants*, *shall* be constructed and maintained in accordance with Sections 8.9.1 through 8.9.4 and Section 8.11.

7.5 Additional Restrictions

7.5.1 All Occupancies. Sections 7.5.1.1 through 7.5.1.9 apply to all *occupancies*.

7.5.1.1 Flammable Refrigerants. The total of all Group A2, A3, B2, and B3 *refrigerants shall not* exceed 1100 lb (500 kg) without approval by the AHJ.

7.5.1.2 Corridors and Lobbies. *Refrigerating systems* in a public *corridor* or *lobby shall* comply with the following:

a. *Refrigeration systems shall* be limited to *unit systems*.
b. The *refrigerant* charge *shall* be limited based on the *refrigerant* charge quantity as *specified* in Section 7.3.
c. *Refrigeration systems* containing Class 2L, 2, or 3 *refrigerants shall* be *listed*, and the *refrigerant* charge *shall* be limited for each *unit system*, calculated in accordance with Equation 7-7a or 7-7b:

$$m_s = 0.106 \times LFL \quad \text{(7-7a [I-P])}$$

$$m_s = 3 \times LFL \quad \text{(7-7b [SI])}$$

where

m_s = *system refrigerant charge*, lb (kg)
LFL = *lower flammability limit* per ASHRAE Standard 34 [3], lb/1000 ft^3 (kg/m^3)
0.106 = a constant with units of 1000 ft^3
3 = a constant with units of m^3

7.5.1.3 Refrigerant Type and Purity. *Refrigerants shall* be of a type *specified* by the equipment *manufacturer* unless converted in accordance with Section 7.5.1.8. *Refrigerants* used in new equipment *shall* conform to AHRI 700 [10] in purity unless otherwise *specified* by the equipment *manufacturer*.

7.5.1.4 Recovered Refrigerants. *Recovered refrigerants shall not* be reused except in the system from which they were removed, or as provided in Sections 7.5.1.5 or 7.5.1.6. When contamination is evident by discoloration, odor, acid test results, or system history, *recovered refrigerants shall* be reclaimed in accordance with Section 7.5.1.6 before reuse.

7.5.1.5 Recycled Refrigerants. *Recycled refrigerants shall not* be reused except in systems using the same *refrigerant* and lubricant designation and belonging to the same owner as the systems from which they were removed. When contamination is evident by discoloration, odor, acid test results, or system history, *recycled refrigerants shall* be reclaimed in accordance with Section 7.5.1.6.

Exception to 7.5.1.5: Drying is not required in order to use *recycled refrigerants* where water is the *refrigerant*, is used as an absorbent, or is a deliberate additive.

7.5.1.6 Reclaimed Refrigerants. Used *refrigerants shall not* be reused in a different owner's equipment unless tested and found to meet the requirements of AHRI 700 [10]. Contaminated *refrigerants shall not* be used unless reclaimed and found to meet the requirements of AHRI 700.

7.5.1.7 Mixing of Refrigerants. *Refrigerants* with different *refrigerant designations shall* only be mixed in a system in accordance with both of the following:

a. The addition of a second *refrigerant* is allowed by the equipment *manufacturer* and is in accordance with the *manufacturer*'s written instructions.
b. The resulting mixture does not change the *refrigerant* safety group.

7.5.1.8 Refrigerant or Lubricant Conversion. The type of *refrigerant* or lubricant in a system *shall not* be changed without evaluation for suitability, notification to the AHJ and the user, due observance of safety requirements, and replacement or addition of signs and identification as required in Section 10.1.2.

7.5.1.9 Addition of Doors to Open Refrigerated Display Cases Containing Flammable Refrigerants. It is acceptable for doors to be added to open display cases containing flammable *refrigerants* only when in accordance with all of the following:

a. The owner or the owner's authorized agent *shall* be notified prior to addition of one or more doors, and the addition of a door *shall not* be made where the owner objects to the change.
b. Flammable *refrigerant* charge sizes *shall not* exceed the limits for closed refrigerated display cases as defined by UL 60335-2-89 [7]/CSA C22.2 No. 60335-2-89 [8]. All construction, testing, and marking requirements for a new installation of closed cases, as defined in UL 60335-2-89/CSA C22.2 No. 60335-2-89, *shall* also apply.
c. Validation of safety and suitability of the addition of doors through one of the following:
   1. Written instructions of the original equipment *manufacturer* and approval of the AHJ
   2. Evaluation of the system by a registered design professional and approval of the AHJ
   3. Evaluation by a *nationally recognized testing laboratory*

7.5.2 Application Restrictions by Refrigerant Safety Group

7.5.2.1 Refrigeration Systems for Human Comfort. Group A2, A3, B1, B2L, B2, and B3 *refrigerants shall not* be used in *high-probability systems* for human comfort. Use of Group A2L *refrigerants shall* be in accordance with Section 7.6.

Exceptions to 7.5.2.1:

1. These restrictions do not apply to *unit systems* having *refrigerant* quantities less than
   a. 6.6 lb (3 kg) of *refrigerant* where located in *residential occupancies* or
   b. 22 lb (10 kg) of *refrigerant* where located in *commercial occupancies*.
2. These restrictions do not apply to *industrial occupancies*.

7.5.2.2 Refrigeration Systems Other Than Human Comfort. *High-probability systems* for other than human comfort applications *shall not* use Class B *refrigerants*. Use of Group A2L *refrigerants shall* be in accordance with Section 7.7. Use of Group A2 *refrigerants shall* be in accordance with Section 7.8. Use of Group A3 *refrigerants shall* be in accordance with Section 7.5.3.

Exception to 7.5.2.2: These restrictions do not apply to *industrial occupancies*.

7.5.3 Higher-Flammability Refrigerants. Group A3 and B3 *refrigerants shall not* be used except where *approved* by the AHJ.

Exceptions to 7.5.3:

1. This restriction does not apply to laboratories with more than 100 ft^2 (9.3 m^2) of space per person.
2. This restriction does not apply to *industrial occupancies*.
3. This restriction does not apply to *listed self-contained systems* containing no more than 0.331 lb (150 g) of Group A3 *refrigerant*, provided that the equipment is installed in accordance with the listing and the *manufacturer*'s installation instructions.
4. This restriction does not apply to equipment *listed* to UL 60335-2-89 [7]/CSA C22.2 No. 60335-2-89 [8] containing no more than 0.459 × *LFL* (lb), where *LFL* is in lb/1000 ft^3 (13 × *LFL* [kg], where *LFL* is in kg/m^3) of Group A3 *refrigerant*, provided that the equipment is installed in accordance with the listing and the *manufacturer*'s installation instructions. Refrigeration systems containing more than 0.141 × *LFL* (lb) (4 × *LFL* [kg]) in an *independent circuit shall not* be installed within 20 ft (6 m) of an open flame.
5. This restriction does not apply to equipment *listed* to UL 60335-2-40 [5]/CSA C22.2 No. 60335-2-40 [6] containing no more than 0.106 × *LFL* (lb) (3 × *LFL* [kg]) of Group A3 *refrigerant*, provided that the equipment is installed in accordance with the listing and the *manufacturer*'s installation instructions.
6. This restriction does not apply to refrigeration systems located in *machinery rooms* or outdoors.

7.6 Group A2L Refrigerants for Human Comfort. *High-probability systems* using Group A2L *refrigerants* for human comfort applications *shall* comply with this section.

7.6.1 Refrigerant Quantity Limits. The maximum *refrigerant* charge of any *independent circuit* of each refrigeration system *shall* be as *specified* in Sections 7.6.1.1 and 7.6.1.2.

7.6.1.1* Refrigeration Systems with Air Circulation. Where a *high-probability system* for human comfort using Group A2L *refrigerants* has either

a. *air circulation* initiated by a *refrigerant detector* in compliance with Section 7.6.2.4 or
b. continuous *air circulation*,

the *refrigerant* charge quantity *shall* be limited per Equation 7-8. Control of continuous *air circulation shall* be performed by the *listed* equipment and *shall* operate continuously other than short periods for maintenance and service:

$$EDVC = V_{eff} \times LFL \times \mathrm{CF} \times F_{occ} \tag{7-8}$$

where

$EDVC$	=	*effective dispersal volume charge*, lb (kg)
V_{eff}	=	*effective dispersal volume*, ft^3 (m^3)
LFL	=	*lower flammability limit*, lb/ft^3 (kg/m^3)
CF	=	concentration factor, value of 0.5
F_{occ}	=	*occupancy* adjustment factor; (For all *occupancies* other than *institutional occupancies*, F_{occ} has a value of 1. For *institutional occupancies*, F_{occ} has a value of 0.5.)

7.6.1.2* Other Refrigeration Systems. For any refrigeration system not meeting the requirements of Section 7.6.1.1, the *refrigerant* charge of the largest *independent circuit* of the system (m_s) *shall not* exceed the value from Equation 7-9:

$$EDVC = M_{def} \times F_{LFL} \times F_{occ} \tag{7-9}$$

where

$EDVC$	=	*effective dispersal volume charge*, ft^3 (m^3)
M_{def}	=	*refrigerant* charge from Table 7-1 (lb) or Table 7-2 (kg)
F_{LFL}	=	*LFL* conversion factor from Table 7-3
F_{occ}	=	*occupancy* adjustment factor; (For all *occupancies* other than *institutional occupancies*, F_{occ} has a value of 1. For *institutional occupancies*, F_{occ} has a value of 0.5.)

When determining M_{def}, the floor area *shall* be the floor area of the volume of space established in accordance with Section 7.2 in cubic feet (cubic metres). The height *shall* be the lowest point of any opening in the supply *air duct*, the return *air duct*, or the equipment providing *air circulation*. Heights below 2.0 ft (0.6 m) *shall* use the first height column. Heights greater than 9.0 ft (2.75 m) *shall* use the last height column. For floor areas or heights in between the values listed, linear interpolation or the next lower value *shall* be used. For spaces with varying floor elevations, the highest floor level relative to an opening *shall* be used to determine height. For floor areas less than 50 ft^2 (5 m^2), use 4.0 lb (1.8 kg).

7.6.2 Listing and Installation Requirements. Refrigeration systems *shall* be *listed* in accordance with UL 484 [11] or UL 60335-2-40 [5]/CSA C22.2 No. 60335-2-40 [6]. The *refrigeration system shall* be installed in accordance with Sections 7.6.2.1 through 7.6.2.5, the listing, the *manufacturer*'s instructions, and any markings on the equipment restricting the installation.

7.6.2.1 The nameplate required by Section 9.17 *shall* include a symbol indicating that a flammable *refrigerant* is used, as *specified* by the product listing.

7.6.2.2 A label indicating a flammable *refrigerant* is used *shall* be placed adjacent to service ports and other locations where service involving components containing *refrigerant* is performed, as *specified* by the product listing.

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*

Table 7-1 Refrigerant Charge Limit (M_{def}), lb (I-P)

Floor Area, ft²	Height, ft ≤2.0	3.3	4.6	5.9	6.6	7.2	8.0	≥9.0
50	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.3
100	4.0	4.0	4.4	5.6	6.3	6.9	7.7	8.6
125	4.0	4.0	5.5	7.0	7.8	8.6	9.6	10.7
150	4.0	4.7	6.5	8.4	9.3	10.3	11.4	12.8
175	4.0	5.0	7.1	9.1	10.1	11.1	12.4	13.8
200	4.0	5.4	7.6	9.7	10.8	11.9	13.2	14.8
225	4.0	5.7	8.0	10.3	11.4	12.6	14.0	15.7
250	4.0	6.0	8.4	10.9	12.1	13.3	14.8	16.5
300	4.0	6.6	9.3	11.9	13.2	14.5	16.2	18.1
350	4.3	7.1	10.0	12.8	14.3	15.7	17.5	19.6
400	4.6	7.6	10.7	13.7	15.3	16.8	18.7	20.9
450	4.9	8.1	11.3	14.6	16.2	17.8	19.8	22.2
500	5.1	8.5	11.9	15.4	17.1	18.8	20.9	23.4
600	5.6	9.3	13.1	16.8	18.7	20.6	22.9	25.6
700	6.1	10.1	14.1	18.2	20.2	22.2	24.7	27.7
800	6.5	10.8	15.1	19.4	21.6	23.7	26.4	29.6
900	6.9	11.4	16.0	20.6	22.9	25.2	28.0	31.4
1000	7.2	12.1	16.9	21.7	24.1	26.5	29.6	33.1
1200	7.9	13.2	18.5	23.8	26.4	29.1	32.4	36.3
1400	8.6	14.3	20.0	25.7	28.6	31.4	35.0	39.2
1600	9.2	15.3	21.4	27.5	30.5	33.6	37.4	41.9
1800	9.7	16.2	22.7	29.1	32.4	35.6	39.7	44.4
2000	10.2	17.1	23.9	30.7	34.1	37.5	41.8	46.8
2250	10.9	18.1	25.3	32.6	36.2	39.8	44.3	49.6
2500	11.4	19.1	26.7	34.3	38.2	42.0	46.7	52.3
2750	12.0	20.0	28.0	36.0	40.0	44.0	49.0	54.9
3000	12.5	20.9	29.3	37.6	41.8	46.0	51.2	57.3
3500	13.5	22.6	31.6	40.6	45.1	49.7	55.3	61.9
4000	14.5	24.1	33.8	43.4	48.3	53.1	59.1	66.2
4500	15.4	25.6	35.8	46.1	51.2	56.3	62.7	70.2
5000	16.2	27.0	37.8	48.6	54.0	59.4	66.1	74.0
6000	17.7	29.6	41.4	53.2	59.1	65.0	72.4	81.1
7000	19.2	31.9	44.7	57.5	63.8	70.2	78.2	87.6
8000	20.5	34.1	47.8	61.4	68.3	75.1	83.6	93.6
9000	21.7	36.2	50.7	65.2	72.4	79.6	88.7	99.3
10000	22.9	38.2	53.4	68.7	76.3	83.9	93.5	104.7
15000	28.0	46.7	65.4	84.1	93.5	102.8	114.5	128.2
20000	32.4	54.0	75.5	97.1	107.9	118.7	132.2	148.0
25000	36.2	60.3	84.5	108.6	120.7	132.7	147.8	165.5
28000	38.3	63.8	89.4	114.9	127.7	140.5	156.4	175.1

Table 7-2 Refrigerant Charge Limit (M_{def}), kg (SI)

Floor Area, m^2	Height, m							
	≤0.60	1.00	1.40	1.80	2.00	2.20	2.45	≥2.74
5	1.8	1.8	1.8	18	1.8	1.8	1.9	2.1
10	1.8	1.8	2.1	2.8	3.1	3.4	3.7	4.2
15	1.8	2.2	3.1	4.0	4.4	4.8	5.4	6.0
20	1.8	2.5	3.6	4.6	5.1	5.6	6.2	7.0
25	1.8	2.8	4.0	5.1	5.7	6.3	7.0	7.8
30	1.9	3.1	4.4	5.6	6.2	6.9	7.6	8.5
35	2.0	3.4	4.7	6.1	6.7	7.4	8.2	9.2
40	2.2	3.6	5.0	6.5	7.2	7.9	8.8	9.9
45	2.3	3.8	5.3	6.9	7.6	8.4	9.4	10.5
50	2.4	4.0	5.6	7.2	8.0	8.9	9.9	11.0
60	2.6	4.4	6.2	7.9	8.8	9.7	10.8	12.1
70	2.9	4.8	6.7	8.6	9.5	10.5	11.7	13.1
80	3.1	5.1	7.1	9.2	10.2	11.2	12.5	14.0
90	3.2	5.4	7.6	9.7	10.8	11.9	13.2	14.8
100	3.4	5.7	8.0	10.2	11.4	12.5	13.9	15.6
125	3.8	6.4	8.9	11.5	12.7	14.0	15.6	17.4
150	4.2	7.0	9.8	12.5	13.9	15.3	17.1	19.1
175	4.5	7.5	10.5	13.5	15.1	16.6	18.4	20.6
200	4.8	8.0	11.3	14.5	16.1	17.7	19.7	22.1
225	5.1	8.5	11.9	15.4	17.1	18.8	20.9	23.4
250	5.4	9.0	12.6	16.2	18.0	19.8	22.0	24.7
300	5.9	9.9	13.8	17.7	19.7	21.7	24.1	27.0
350	6.4	10.6	14.9	19.2	21.3	23.4	26.1	29.2
400	6.8	11.4	15.9	20.5	22.8	25.0	27.9	31.2
450	7.2	12.1	16.9	21.7	24.1	26.6	29.6	33.1
500	7.6	12.7	17.8	22.9	25.4	28.0	31.2	34.9
600	8.4	13.9	19.5	25.1	27.9	30.7	34.1	38.2
700	9.0	15.1	21.1	27.1	30.1	33.1	36.9	41.3
800	9.7	16.1	22.5	29.0	32.2	35.4	39.4	44.1
900	10.2	17.1	23.9	30.7	34.1	37.6	41.8	46.8
1000	10.8	18.0	25.2	32.4	36.0	39.6	44.1	49.4
1200	11.8	19.7	27.6	35.5	39.4	43.4	48.3	54.1
1400	12.8	21.3	29.8	38.3	42.6	46.8	52.2	58.4
1600	13.7	22.8	31.9	41.0	45.5	50.1	55.8	62.4
1800	14.5	24.1	33.8	43.5	48.3	53.1	59.1	66.2
2000	15.3	25.4	35.6	45.8	50.9	56.0	62.3	69.8
2200	16.0	26.7	37.4	48.0	53.4	58.7	65.4	73.2
2400	16.7	27.9	39.0	50.2	55.7	61.3	68.3	76.5
2600	17.4	29.0	40.6	52.2	58.0	63.8	71.1	79.6

Table 7-3 LFL Conversion Factor

Refrigerant	F_{LFL}
R-32	1.00
R-452B	1.02
R-454A	0.92
R-454B	0.97
R-454C	0.95
R-457A	0.71

7.6.2.4* The *refrigerant detection system shall* comply with the following:

a. Utilize a set point, nonadjustable in the field, to generate an output signal to initiate *mitigation actions.*
b. Field recalibration of the *refrigerant detection system shall not* be permitted.
c. Be capable of detecting the presence of a *specified refrigerant* corresponding to the *refrigerant designation* of the *refrigerant* contained in the refrigeration system.
d. Have access for replacement of *refrigerant detection system* components.
e. Have self-diagnostics to determine operational status of the sensing element.
f. Energize *air circulation* fans of the equipment upon failure of a self-diagnostic check.
g. Generate an output signal in not more than 30 seconds when exposed to a *refrigerant* concentration of 25% *LFL* (+0%, –1%).

7.6.2.5* Mitigation Action Requirements. The following *mitigation actions shall* be completed in not more than 15 seconds after the initiation of the output signal of Section 7.6.2.4(g), and *shall* be maintained for at least 5 minutes after the output signal has reset:

a. Energize the *air circulation* fan(s) of the equipment per the *manufacturer*'s instructions.
b. Open zoning dampers, or set zone dampers to full airflow set point, that are installed in the *air ducts* connected to the *refrigeration system*._
c.* Activate mechanical ventilation if required by Section 7.6.4.
d. De-energize electric resistance heat installed in the *air duct* that is connected to the *refrigeration system*.
e.* Activate *safety shutoff valves* utilized to reduce *releasable refrigerant charge*.
f.* De-energize potential ignition sources, including open flames and unclassified electrical sources of ignition with apparent power rating greater than 1 kVA, where the apparent power is the product of the circuit voltage and current rating.

7.6.3 Ignition Sources Located in Ductwork

7.6.3.1 Open-flame-producing devices *shall not* be permanently installed in the ductwork that serves the space.

7.6.3.2 Unclassified electrical devices *shall not* be located within the ductwork that serves the space.

7.6.3.3* Refrigeration Systems with Ductwork. Devices containing hot surfaces exceeding 1290°F (700°C) *shall not* be located 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(s) is energized. Average airflow velocity *shall* be determined by volumetric airflow rate divided by *duct* flow area.

7.6.4* Mechanical Ventilation. Mechanical ventilation for *refrigerant* safety mitigation *shall* comply with this section. Where a *ventilated enclosure* is provided to control a *refrigerant* leak, the refrigeration system and *ventilated enclosure shall* be *listed* and installed in accordance with UL 60335-2-40 [5]/CSA C22.2 No. 60335-2-40 [6] and *shall not* be required to comply with this section.

a. Mechanical ventilation *shall* be provided that will remove leaked *refrigerant* from the space where *refrigerant* leaking from the refrigeration system is expected to accumulate. The space *shall* be provided with an exhaust or transfer fan. Fans used to *exhaust air* from the space or transfer air to a separate indoor space *shall* comply with Equation 7-10:

$$Q_{min} = \frac{Q_{req}}{C_{LFL}} \qquad (7\text{-}10)$$

where

Q_{min} = minimum mechanical ventilation airflow rate, ft^3/min (m^3/h)

Q_{req} = required ventilation as determined from Table 7-4

C_{LFL} = *lower flammability limit* conversion factor as determined from Table 7-5

When the *refrigerant* charge necessary to be removed by ventilation is known, in order to be compliant with Section 7.3, an alternative method to determine Q_{req} uses Equation 7-11a or 7-11b. This alternative method *shall* be used for all A2L *refrigerants* not *listed* in Table 7-5.

$$Q_{req} = \frac{m_s - EDVC}{4 \times LFL} \times \mathrm{SF}_{vent} \qquad \text{(7-11a [I-P])}$$

$$Q_{req} = \frac{m_s - EDVC}{4 \times LFL} \times \mathrm{SF}_{vent} \times 60 \qquad \text{(7-11b [SI])}$$

where

Q_{req} = required minimum mechanical ventilation airflow rate, ft^3/min (m^3/h)

m_s = largest *system refrigerant charge* from *independent circuit*, lb (kg)

$EDVC$ = *effective dispersal volume charge*, lb (kg)

LFL = *lower flammability limit*, lb/ft^3 (kg/m^3)

4 = assumed leak time (4 minutes)

SF_{vent} = safety factor, value of 2

60 = conversion of minutes to hours

b.* Mechanical ventilation *shall* be permitted to be continuous or activated by a *refrigerant detector*. Building fire and smoke systems *shall* be permitted to override this function.

1. **Continuous Ventilation.** Where continuous ventilation is provided, ventilation function *shall* be continuously verified per Section 7.6.4(b)(3).
2. **Refrigerant Detector Activated Ventilation.** Where ventilation is activated by a *refrigerant detector*, the *refrigerant detector shall* be in accordance with Section 7.6.2.4. Upon *refrigerant detector* activation, the mechanical ventilation *shall* be activated and *shall* continue to operate for at least 5 minutes after the *refrigerant detector* has sensed a drop in the *refrigerant* concentration below the set point value. For mechanical ventilation systems used solely for *refrigerant* safety mitigation, ventilation function of *refrigerant detector* activated ventilation *shall* be verified in accordance with Section 7.6.4(b)(3) by a monthly self test.
3. **Verification of Ventilation Function.** Ventilation function *shall* be verified by a method that confirms operation of the required fans. On detection of a ventilation system failure, *compressor* operation *shall* be stopped and a notification *shall* be provided. The notification *shall* be to an operator workstation through a building automation system or by a local audible alarm.

c. While the ventilation system is operating, *makeup air shall* be provided, and the volume of *makeup air shall not* exceed the volume of air being exhausted or transferred out of the space. Openings for *makeup air shall* be positioned to facilitate mixing of *makeup air* with leaked *refrigerant*. Inlets for *exhaust air*, and inlets used to mechanically transfer air to a separate indoor space, *shall* be located such that the bottom of the inlet is within 12 in. (30 cm) of the lowest elevation in the space where leaked *refrigerant* would be expected to accumulate.

d. The *refrigerant* concentration of an indoor *effective dispersal volume shall not* exceed the limit *specified* in Sections 7.6.1.

e. In addition to the requirements of Sections 7.6.3, there *shall* be no open-flame-producing devices that do not contain a flame arrestor, or hot surfaces exceeding 1290°F (700°C), installed within the space where the equipment is located.

f. Electric motors larger than 1 *hp* (0.7 kW) driving fans located in the airstream of the discharge side of the ventilation system *shall* be of the totally enclosed or hermetically sealed type.

g. Fan rotating elements *shall* be nonferrous or nonsparking, or the casing *shall* consist of or be lined with such material.

h. Ventilation fans *shall* be *listed* in accordance with UL 507 [12] or UL 705 [13].

i. The discharge air openings of the ventilation system *shall* be located so as to prevent recirculation of *exhaust air* back into the space.

Table 7-4 Required Ventilation for A2L Systems [a]

Excluded Charge ($m_s - EDVC$)[b]		Q_{req}		Excluded Charge ($m_s - EDVC$)[b]		Q_{req}	
lb	kg	ft³/min	m³/h	lb	kg	ft³/min	m³/h
3.8	1.7	100	170	91.8	41.6	2400	4080
7.6	3.5	200	340	95.6	43.4	2500	4250
11.5	5.2	300	510	99.4	45.1	2600	4420
15.3	6.9	400	680	103.2	46.8	2700	4590
19.1	8.7	500	850	107.1	48.6	2800	4760
22.9	10.4	600	1020	110.9	50.3	2900	4930
26.8	12.1	700	1190	114.7	52.0	3000	5100
30.6	13.9	800	1360	118.5	53.8	3100	5270
34.4	15.6	900	1530	122.4	55.5	3200	5440
38.2	17.3	1000	1700	126.2	57.2	3300	5610
42.1	19.1	1100	1870	130.0	59.0	3400	5780
45.9	20.8	1200	2040	133.8	60.7	3500	5950
49.7	22.5	1300	2210	137.6	62.4	3600	6120
53.5	24.3	1400	2380	141.5	64.2	3700	6290
57.4	26.0	1500	2550	145.3	65.9	3800	6460
61.2	27.7	1600	2720	149.1	67.6	3900	6630
65.0	29.5	1700	2890	152.9	69.4	4000	6800
68.8	31.2	1800	3060	156.8	71.1	4100	6970
72.6	32.9	1900	3230	160.6	72.8	4200	7140
76.5	34.7	2000	3400	164.4	74.6	4300	7310
80.3	36.4	2100	3570	168.2	76.3	4400	7480
84.1	38.1	2200	3740	172.1	78.0	4500	7650
87.9	39.9	2300	3910	175.5	79.6	4590	7803

a. Charge sizes and ventilation rates shown in this table are based on R-32.
b. ($m_s - EDVC$) is the amount of *refrigerant* charge that is removed by mechanical ventilation and is therefore not included in calculations to determine compliance with Section 7.3. m_s and $EDVC$ are as defined in Section 7.6.4(a).

Table 7-5 Lower Flammability Limit Conversion Factor

Refrigerant Number	C_{LFL}
R-32	1.00
R-452B	1.02
R-454A	0.92
R-454B	0.97
R-454C	0.95
R-457A	0.71

7.7 Group A2L Refrigerants for Refrigeration Systems Other Than Human Comfort. *High-probability systems* using Group A2L *refrigerants* for other than human comfort applications *shall* comply with Sections 7.7.1 through 7.7.5.

7.7.1 Refrigerant Charge Limits. *Refrigerant* charge *shall* be limited as follows:

a. Refrigeration systems containing more than 0.141 × *LFL* (lb) (4 × *LFL* [kg]) in an *independent circuit shall not* be installed within 20 ft (6 m) of an open flame.
b. Refrigeration systems *shall* contain a *releasable refrigerant charge* no more than 9.2 × *LFL* (lb), where *LFL* is in lb/1000 ft^3 (260 × *LFL* [kg], where *LFL* is in kg/m^3) of Group A2L *refrigerant* per *independent circuit*.

Exceptions to 7.7.1:

1. This restriction does not apply to laboratories with more than 100 ft^2 (9.3 m^2) of space per person.
2. This restriction does not apply to *industrial occupancies*.
3. This restriction does not apply to systems located in *machinery rooms* or outdoors.

7.7.2 Refrigerant Concentration Limits

7.7.2.1 *Occupied spaces shall* comply with Section 7.3.

7.7.2.2 Non-*occupied spaces* with *refrigerant*-containing equipment, including but not limited to *piping* or tubing, *shall* comply with Section 7.3 except as permitted by Section 7.7.5.

7.7.3 Listing and Installation Requirements. Refrigeration systems *shall* be *listed* to UL 60335-2-89 [7]/ CSA C22.2 No. 60335-2-89 [8] and *shall* be installed in accordance with the listing and the *manufacturer*'s instructions.

Exception to 7.7.3: These requirements do not apply to *industrial occupancies*.

7.7.3.1 The nameplate required by Section 9.17 *shall* include a symbol indicating that a flammable *refrigerant* is used, as *specified* by the product listing.

7.7.3.2 A label indicating a flammable *refrigerant* is used *shall* be placed adjacent to service ports and other locations where service involving components containing *refrigerant* is performed, as *specified* by the product listing.

7.7.3.3 A *refrigerant detector shall* be provided in accordance with Section 7.6.2.4 except where either of the following apply:

a. When the *refrigerant* charge of any *independent circuit* is less than or equal to 0.459 × *LFL* (lb), where *LFL* is in lb/1000 ft^3 (13 × *LFL* [kg], where *LFL* is in kg/m^3)

   or

b. When the complete discharge of *refrigerant* from any *independent circuit* will not exceed 50% of the *RCL* of the space, and the lowest point from which leak *refrigerant* will disperse into the space is greater than or equal to 14.5 ft (4.4 m)

7.7.3.4 When a *refrigerant detector* required by Section 7.7.3.3 senses a rise in *refrigerant* concentration above the value *specified* in Section 7.6.2.4(g), the actions of Section 7.6.2.5 *shall* be taken.

7.7.4 Ignition Sources Located in Ductwork. Any ductwork serving the space *shall* comply with Section 7.6.3.

7.7.5 Compressors and Pressure Vessels Located Indoors. For refrigeration *compressors* and *pressure vessels* located in an indoor space that is accessible only during service and maintenance, it *shall* be permissible to exceed maximum *refrigerant* charge calculated in accordance with Section 7.3, provided a mechanical ventilation system is used to prevent exceeding the *RCL* and all of the following provisions are met:

a. The *releasable refrigerant charge* of the largest *independent circuit shall not* exceed 9.2 × *LFL* (lb) (260 × *LFL* [kg]). Releasable charges greater than 9.2 × *LFL* (lb) (260 × *LFL* [kg]) *shall* comply with the *machinery room* requirements of Section 8.11.
b. A mechanical ventilation system *shall* be provided that will mix air with leaked *refrigerant* and remove it from the space where the equipment is located. The space *shall* be provided with an exhaust fan. The exhaust fan *shall* remove air from the space where the equipment is located in accordance with Section 8.11.11.4.
c. The space and mechanical ventilation system is in compliance with Section 7.6.4(b) through (e) and Section 7.6.4(i).
d. Electric motors driving fans *shall not* be placed inside the exhaust *ducts*; fan rotating elements *shall* be nonferrous or nonsparking, or the casing *shall* consist of or be lined with such material.

7.8 Group A2 Refrigerants for Refrigeration Systems Other than Human Comfort. *High-probability systems* using Group A2 *refrigerants* for other than human comfort applications *shall* comply with this section. *Refrigeration systems* using Group A2 *refrigerants shall* be limited to *listed self-contained systems* containing no more than 0.459 × *LFL* (lb), where *LFL* is in lb/1000 ft^3 (13 × *LFL* [kg], where *LFL* is in kg/m^3), provided that the system is installed in accordance with the listing and the *manufacturer*'s installation instructions. Refrigeration systems containing more than 0.141 × *LFL* (lb), (4 × *LFL* [kg]) in an *independent circuit shall not* be installed within 20 ft (6 m) of an open flame.

Exceptions to 7.8:

1. This restriction does not apply to laboratories with more than 100 ft^2 (9.3 m^2) of space per person.
2. This restriction does not apply *industrial occupancies*.
3. This restriction does not apply to systems located in *machinery rooms* or outdoors.

8. INSTALLATION RESTRICTIONS

8.1 Foundations. Foundations and supports for *condensing units* or *compressor units shall* be of noncombustible construction and capable of supporting loads imposed by such units. Isolation materials, such as rubber, are permissible between the foundation and *condensing units* or *compressor units*.

8.2 Guards. Moving *machinery shall* be guarded in accordance with *approved* safety standards [14].

8.3 Safe Access. A clear and unobstructed approach and space *shall* be provided for inspection, service, and emergency shutdown of *condensing units*, *compressor units*, *condensers*, *stop valves*, and other serviceable components of refrigerating *machinery*. Permanent ladders, platforms, or portable access equipment *shall* be provided in accordance with the requirements of the authority having jurisdiction (AHJ).

8.4 Water Connections. Water supply and discharge connections *shall* be made in accordance with the requirements of the AHJ.

8.5 Electrical Safety. Electrical equipment and wiring *shall* be installed in accordance with the *National Electric Code*® [4] (NFPA 70) and the requirements of the AHJ.

8.6 Gas Fuel Equipment. Gas fuel devices and equipment used with *refrigerating systems shall* be installed in accordance with *approved* safety standards and the requirements of the AHJ.

8.7 Air Duct Installation. *Air duct* systems of air-conditioning equipment for human comfort using mechanical refrigeration *shall* be installed in accordance with *approved* safety standards, the requirements of the AHJ, and the requirements of Section 8.9.7.

8.8 Refrigerant Parts in Air Duct. All field-installed *refrigerant*-containing parts, including joints, of a *refrigerating system* located in an *air duct* carrying conditioned air to and from an *occupied space shall* be constructed to withstand a temperature of 700°F (371°C) without leakage into the airstream.

8.8.1 Installation of Piping, Joints, Valves, and Related Parts. See Sections 9.10 through 9.13 for installation restrictions and other requirements related to *refrigerant piping* and tubing. See NFPA 70 [4].

8.9 Refrigerating Machinery Room, General Requirements. When a *refrigerating system* is located indoors and a *machinery room* is required by Section 7.4, the *machinery room shall* be in accordance with the following provisions.

8.9.1 *Machinery rooms* are not prohibited from housing other mechanical equipment unless specifically prohibited elsewhere in this standard. A *machinery room shall* be so dimensioned that parts are accessible with space for service, maintenance, and operations. There *shall* be clear head room of not less than 7.25 ft (2.2 m) below equipment situated over passageways.

8.9.2 Each refrigerating *machinery room shall* have a tight-fitting door or doors opening outward, self-closing if they open into the building and adequate in number to ensure freedom for persons to escape in an emergency. With the exception of access doors and panels in *air ducts* and air-handling units conforming to Section 8.9.3, there *shall* be no openings that will permit passage of escaping *refrigerant* to other parts of the building.

8.9.3 There *shall* be no airflow to or from an *occupied space* through a *machinery room* unless the air is ducted and sealed in such a manner as to prevent any *refrigerant* leakage from entering the airstream. Access doors and panels in ductwork and air-handling units *shall* be gasketed and tight fitting.

8.9.4 Access. Access to the refrigerating *machinery room shall* be restricted to authorized personnel. Doors *shall* be clearly marked, or permanent signs *shall* be posted at each entrance to indicate this restriction.

8.9.5 Each refrigerating *machinery room shall* contain a detector, located in an area where *refrigerant* from a leak will concentrate, that actuates an alarm and mechanical ventilation in accordance with Section 8.9.7 at a set point not greater than the *occupational exposure limit* (*OEL*) value as published in ASHRAE Standard 34 [3]. For *refrigerants* that do not have a published *OEL* value in Standard 34, a set point determined in accordance with the *OEL* as defined by Standard 34 *shall* be *approved* by the AHJ. The alarm *shall* annunciate visual and audible alarms inside the refrigerating *machinery room* and outside each entrance to the refrigerating *machinery room*. The alarms required in this section *shall* be of the manual reset type with the reset located inside the refrigerating *machinery room*. Alarms set at other levels (such as *IDLH*) and automatic reset alarms are permitted in addition to those required by this section. The meaning of each alarm *shall* be clearly marked by signage near the annunciators.

Exception to 8.9.5: Detectors are not required when only systems using R-718 (water) are located in the refrigerating *machinery room*.

8.9.6 *Machinery rooms shall* be vented to the outdoors, using mechanical ventilation in accordance with Sections 8.9.7 and 8.9.8.

8.9.7 Mechanical ventilation referred to in Section 8.9.6 *shall* be by one or more power-driven fans capable of exhausting air from the *machinery room* at least in the amount given in the formula in Section 8.9.8. To obtain a reduced airflow for normal ventilation, multiple fans or multispeed fans *shall* be used. Provision *shall* be made for inlet air to replace that being exhausted. Openings for inlet air *shall* be positioned to avoid recirculation. Air supply and exhaust *ducts* to the *machinery room shall* serve no other area. The discharge of the air *shall* be to the outdoors in such a manner so as not to cause a nuisance or danger. The mechanical exhaust inlets *shall* be located in an area where *refrigerant* from a leak is likely to concentrate, in consideration of the location of the replacement air paths, refrigerating machines, and the density of the *refrigerant* relative to air.

8.9.8 Ventilation Airflow. For Group A1, A2, A3, B1, B2, and B3, the airflow *shall* comply with Section 8.9.8.1.

8.9.8.1 The mechanical ventilation required to exhaust an accumulation of *refrigerant* due to leaks or a rupture of the refrigeration system *shall* be capable of removing air from the *machinery room* in not less than the quantity calculated using Equation 8-1a or 8-1b:

$$Q = 100 \times G^{0.5} \tag{8-1a [I-P]}$$

$$Q = 0.070 \times G^{0.5} \tag{8-1b [SI]}$$

where

Q = airflow, ft^3/min (m^3/s)

G = mass of *refrigerant* in the largest refrigeration system (*independent circuit*), any part of which is located in the *machinery room*, lb (kg)

A part of the refrigerating *machinery room* mechanical ventilation *shall* be

a. operated, when occupied, to supply at least 0.5 $ft^3/min/ft^2$ (0.00254 $m^3/s/m^2$) of *machinery room* area or 20 ft^3/min (0.00944 m^3/s) per person and
b. operable when occupied at a volume required to not exceed the higher of a temperature rise of 18°F (10°C) above inlet air temperature or a maximum temperature of 122°F (50°C).

8.9.9 No open flames that use combustion air from the *machinery room shall* be installed where any *refrigerant* is used. Combustion equipment *shall not* be installed in the same *machinery room* with *refrigerant*-containing equipment except under one of the following conditions:

a. Combustion air is ducted from outside the *machinery room* and sealed in such a manner as to prevent any *refrigerant* leakage from entering the combustion chamber.
b. A *refrigerant detector*, conforming to Section 8.9.5, is employed to automatically shut down the combustion process in the event of *refrigerant* leakage.

Exception to 8.9.9: *Machinery rooms* where only carbon dioxide (R-744) or water (R-718) is the *refrigerant*.

8.10 Machinery Room, Special Requirements. In cases *specified* in the rules of Section 7.4, a refrigerating *machinery room shall* meet the following special requirements in addition to those in Section 8.9:

a. There *shall* be no flame-producing device or continuously operating hot surface over 800°F (427°C) permanently installed in the room.
b. Doors communicating with the building *shall* be *approved*, self-closing, tight-fitting fire doors.

c. Walls, floor, and ceiling *shall* be tight and of noncombustible construction. Walls, floor, and ceiling separating the refrigerating *machinery room* from other *occupied spaces shall* be of at least one-hour fire-resistive construction.
d. Exterior openings, if present, *shall not* be under any fire escape or any open stairway.
e. All pipes piercing the interior walls, ceiling, or floor of such rooms *shall* be tightly sealed to the walls, ceiling, or floor through which they pass.
f. When *refrigerants* of Groups A2, A3, B2, and B3 are used, the *machinery room shall* conform to Class 1, Division 2, of the *National Electric Code*® [4] (NFPA 70). When *refrigerant* Groups A1 and B1 are used, the *machinery room* is not required to meet Class 1, Division 2, of the NFPA 70.
g. Remote control of the mechanical equipment in the refrigerating *machinery room shall* be provided immediately outside the *machinery room* door solely for the purpose of shutting down the equipment in an emergency. Ventilation fans *shall* be on a separate electrical circuit and have a control switch located immediately outside the *machinery room* door.

8.11 Machinery Room, Special Requirements, A2L and B2L. When a refrigeration system is located indoors, and a *machinery room* is required by Section 7.4.3, *machinery rooms shall* comply with Sections 8.11.1 through 8.11.7.

8.11.1 There *shall* be no flame-producing device or hot surface over 1290°F (700°C) in the room, other than that used for maintenance or repair, unless installed in accordance with Section 8.9.9.

8.11.2 Doors communicating with the building *shall* be *approved*, self-closing, tight-fitting fire doors.

8.11.3 Walls, floor, and ceiling *shall* be tight and of noncombustible construction. Walls, floor, and ceiling separating the refrigerating *machinery room* from other *occupied spaces shall* be of at least one-hour fire-resistive construction.

8.11.4 Exterior openings, if present, *shall not* be under any fire escape or any open stairway.

8.11.5 All pipes piercing the interior walls, ceiling, or floor of such rooms *shall* be tightly sealed to the walls, ceiling, or floor through which they pass.

8.11.6 When any *refrigerant* of Groups A2, A3, B2, or B3 are used, the *machinery room shall* be designated as Class I, Division 2 hazardous (classified) electrical location in accordance with the *National Electric Code*® [4] (NFPA 70). When the only flammable *refrigerants* used are from Group A2L or B2L, the *machinery room shall* comply with both Section 8.11.6.1 for ventilation and Section 8.11.6.2 for *refrigerant* detection, or *shall* be designated as Class I, Division 2 hazardous (classified) electrical location in accordance with the NFPA 70.

8.11.6.1 The *machinery room shall* have a mechanical ventilation system in accordance with Section 8.11.11. The mechanical ventilation system *shall*

a. run continuously, and failure of the mechanical ventilation system actuates an alarm, or
b. be activated by one or more *refrigerant detectors*, conforming to requirements of Section 8.11.8.

8.11.6.2 Detection of *refrigerant* concentration that exceeds 25% of the *lower flammability limit* (*LFL*) or the upper detection limit of the *refrigerant detector*, whichever is lower, *shall* automatically de-energize the following equipment in the *machinery room*:

a. *Refrigerant compressors*
b. *Refrigerant* pumps
c. Normally closed automatic *refrigerant* valves
d. Other unclassified electrical sources of ignition with apparent power rating greater than 1 kVA, where the apparent power is the product of the circuit voltage and current rating

8.11.7 Remote control of the mechanical equipment in the refrigerating *machinery room shall* be provided immediately outside the *machinery room* door solely for the purpose of shutting down the equipment in an emergency. Ventilation fans *shall* be on a separate electrical circuit and have a control switch located immediately outside the *machinery room* door.

8.11.8 Each refrigerating *machinery room* in accordance with Section 8.11 *shall* contain one or more *refrigerant detectors* in accordance with Section 8.11.9, with sensing element located in areas where *refrigerant* from a leak will concentrate, with one or more set points that activate responses in accordance with Section 8.11.10 for alarms and Section 8.11.11 for mechanical ventilation. Multiport-type devices *shall* be prohibited.

8.11.9 *Refrigerant detectors* required by Section 8.11.6 *shall* meet all of the following conditions:

a. A *refrigerant detector shall* be capable of detecting each of the specific *refrigerant designations* in the *machinery room*.

Table 8-1 Refrigerant Detector Set Points, Response Times, Alarms, and Ventilation Levels

Limit Value	Response Time, seconds	Alarm Type	Alarm Reset Type	Ventilation Level	Ventilation Reset Type
Set point ≤ *OEL*	≤300	Trouble alarm	Automatic	Level 1	Automatic
Set point ≤ *RCL*	≤15	Emergency alarm	Manual	Level 2	Manual

Table 8-2 Level 1 Ventilation Rate for Class 2L Refrigerants

Status	Airflow
Operated when occupied, and operated when activated in accordance with Section 8.11.9(c) and Table 8-1	The greater of a. 0.5 $ft^3/min/ft^2$ (0.00254 $m^3/s/m^2$) of *machinery room* area or b. 20 ft^3/min (0.00944 m^3/s) per person
Operable when occupied	With or without mechanical cooling of the *machinery room*, the greater of a. the airflow rate required to not exceed a temperature rise of 18°F (10°C) above inlet air temperature or b. the airflow rate required to not exceed a maximum air temperature of 122°F (50°C) in the *machinery room*

b. The *refrigerant detector shall* activate responses within a time not to exceed a limit *specified* in Sections 8.11.10 and 8.11.11 after exposure to *refrigerant* concentration exceeding a limit value *specified* in Sections 8.11.10 and 8.11.11.
c. The *refrigerant detector shall* have a set point not greater than the applicable *OEL* value as published in ASHRAE Standard 34 [3]. The applicable *OEL* value *shall* be the lowest *OEL* value for any *refrigerant designation* in the *machinery room*. For *refrigerants* that do not have a published *OEL* value in Standard 34, use a value determined in accordance with the *OEL* as defined by Standard 34 where *approved* by the AHJ.
d. The *refrigerant detector shall* have a set point not greater than the applicable *refrigerant concentration limit* (*RCL*) value as published in ASHRAE Standard 34 [3]. The applicable *RCL* value *shall* be the lowest *RCL* value for any *refrigerant designation* in the *machinery room*. For *refrigerants* that do not have a published *RCL* value in Standard 34, use a value determined in accordance with the *RCL* as defined by Standard 34 where *approved* by the AHJ.
e. The *refrigerant detector shall* provide a means for automatic self testing and *shall* be in accordance with Section 8.11.10.4. The *refrigerant detector shall* be tested during installation and annually thereafter, or at an interval not exceeding the *manufacturer*'s installation instructions, whichever is less. Testing *shall* verify compliance with the alarm set points and response times per Sections 8.11.10 and 8.11.11.

8.11.10 Alarms required by Section 8.11.8 *shall* comply with the following.

8.11.10.1 The alarm *shall* have visual and audible annunciation inside the refrigerating *machinery room* and outside each entrance to the refrigerating *machinery room*.

8.11.10.2 The *refrigerant detector* set points *shall* activate an alarm in accordance with the type of reset in Table 8-1. Manual reset type alarms *shall* have the reset located inside the refrigerating *machinery room*.

8.11.10.3 Alarms set at levels other than Table 8-1 (such as *IDLH*), and automatic reset alarms, are permitted in addition to those required by Section 8.11.10. The meaning of each alarm *shall* be clearly marked by signage near the annunciators.

8.11.10.4 In the event of a failure during a *refrigerant detector* self test in accordance with Section 8.11.9(e), a trouble alarm signal *shall* be transmitted to an *approved* monitored location.

8.11.11 Ventilation. *Machinery rooms*, in accordance with Section 8.11, *shall* be vented to the outdoors using mechanical ventilation in accordance with Sections 8.11.11.1 through 8.11.11.3.

8.11.11.1 Mechanical ventilation referred to in Section 8.11.11 *shall* be in accordance with all of the following:

a. Include one or more power-driven fans capable of exhausting air from the *machinery room*; multispeed fans *shall* be permitted.
b. Electric motors driving fans *shall not* be placed inside *ducts*; fan rotating elements *shall* be nonferrous or nonsparking, or the casing *shall* consist of or be lined with such material.

Table 8-3 Calculation Method Equations [a]

Charge Quantity	Airflow	Equation Number
$G < 0.1 \times G'$	$Q \geq Q' \times 0.102$ and $Q \geq Q_1$	8-3
$0.1 \times G' \leq G \leq G'$	$Q \geq Q' \times [1 + 0.39 \times \ln(G/G')]$ and $Q \geq Q_1$	8-4
$G > G'$	$Q \geq Q'$	8-5

where

$Q' = 646 \times P^{0.62}$ (I-P)

$Q' = 0.400 \times P^{0.62}$ (SI)

$G' = 21200 \times P^{-0.72}$ (I-P)

$G' = 267 \times P^{-0.72}$ (SI)

$P = DP + 14.70$ (I-P)

$P = DP + 0.1013$ (SI)

G = mass of *refrigerant* in the largest refrigeration system (*independent circuit*), any part of which is located in the *machinery room*, lb (kg)
G' = a threshold value where the airflow requirement changes, lb (kg)
Q = airflow rate, conversion to other units of measure is permitted, ft^3/min (m^3/s)
Q' = an airflow rate independent of charge quantity, ft^3/min (m^3/s)
Q_1 = Level 1 Ventilation in accordance with Section 8.11.11.2, ft^3/min (m^3/s)
P = *refrigerant* pressure (absolute), psia (MPa)
DP = *design pressure* (gage) of the refrigeration system *high side*, psi (MPa)

a. The natural logarithm of x is written as $\ln(x)$.

c. Include provision to supply *makeup air* to replace that being exhausted; *ducts* for supply to and exhaust from the *machinery room shall* serve no other area; the *makeup air* supply locations *shall* be positioned relative to the *makeup air* locations to avoid short circuiting.
d. Inlets to the exhaust *ducts shall* be located in an area where *refrigerant* from a leak will concentrate, in consideration of the location of the replacement supply air paths, refrigerating machines, and the density of the *refrigerant* relative to air.
e. Inlets to exhaust *ducts shall* be within 1 ft (0.3 m) of the lowest point of the *machinery room* for *refrigerants* that are heavier than air and *shall* be within 1 ft (0.3 m) of the highest point for *refrigerants* that are lighter than air.
f. The discharge of the *exhaust air shall* be to the outdoors in such a manner as not to cause a nuisance or danger.

8.11.11.2 Level 1 Ventilation. The refrigerating *machinery room* mechanical ventilation in Section 8.11.11.1 *shall* exhaust at an airflow rate not less than shown in Table 8-2.

8.11.11.3 Level 2 Ventilation. A part of the refrigerating *machinery room* mechanical ventilation referred to in Section 8.11.11.1 *shall* exhaust an accumulation of *refrigerant* due to leaks or a rupture of a *refrigerating system*, or portion thereof, in the *machinery room*. The *refrigerant detectors* required in accordance with Section 8.11.8 *shall* activate ventilation at a set point and response time in accordance with Table 8-1, at an airflow rate not less than the value determined in accordance with Section 8.11.11.4.

When multiple *refrigerant designations* are in the *machinery room*, evaluate the required airflow according to each *refrigerating system*, and the highest airflow quantity *shall* apply.

Ventilation reset *shall* be in accordance with the type of reset in Table 8-1. Manual-type ventilation reset *shall* have the reset located inside the refrigerating *machinery room*.

8.11.11.4* Safety Group A2L, B2L. When required by Section 8.11.11.3, the total airflow for Level 2 ventilation *shall* be not less than the airflow rate determined by either the graphical method of Figures 8-1 (I-P) and 8-2 (SI) or the calculation method using the equations in Table 8-3. The total airflow rate for Level 2 ventilation *shall not* be less than Level 1 ventilation. The airflow rate (Q) per the calculation method *shall* be rounded up to the nearest value to two significant figures.

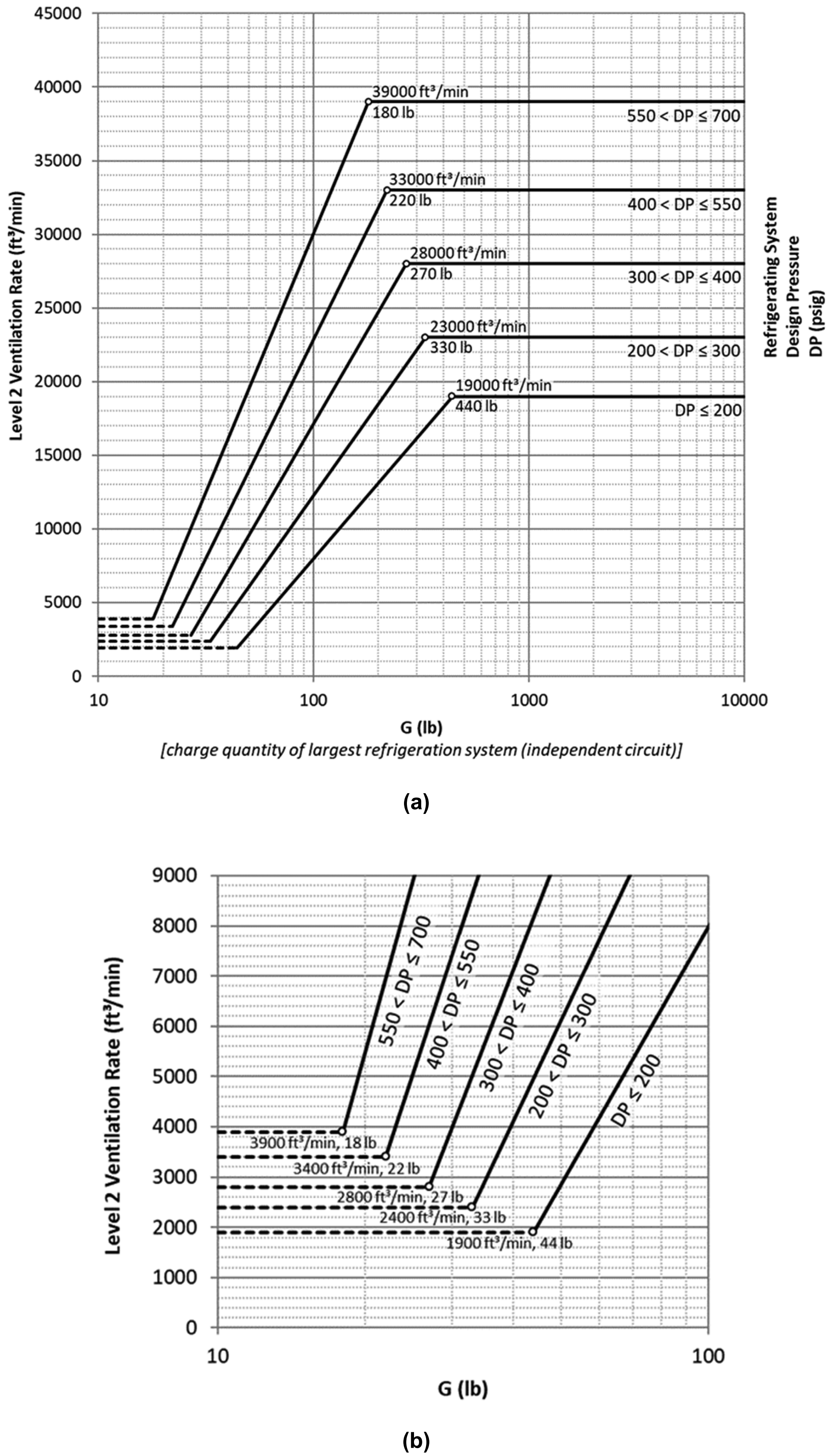
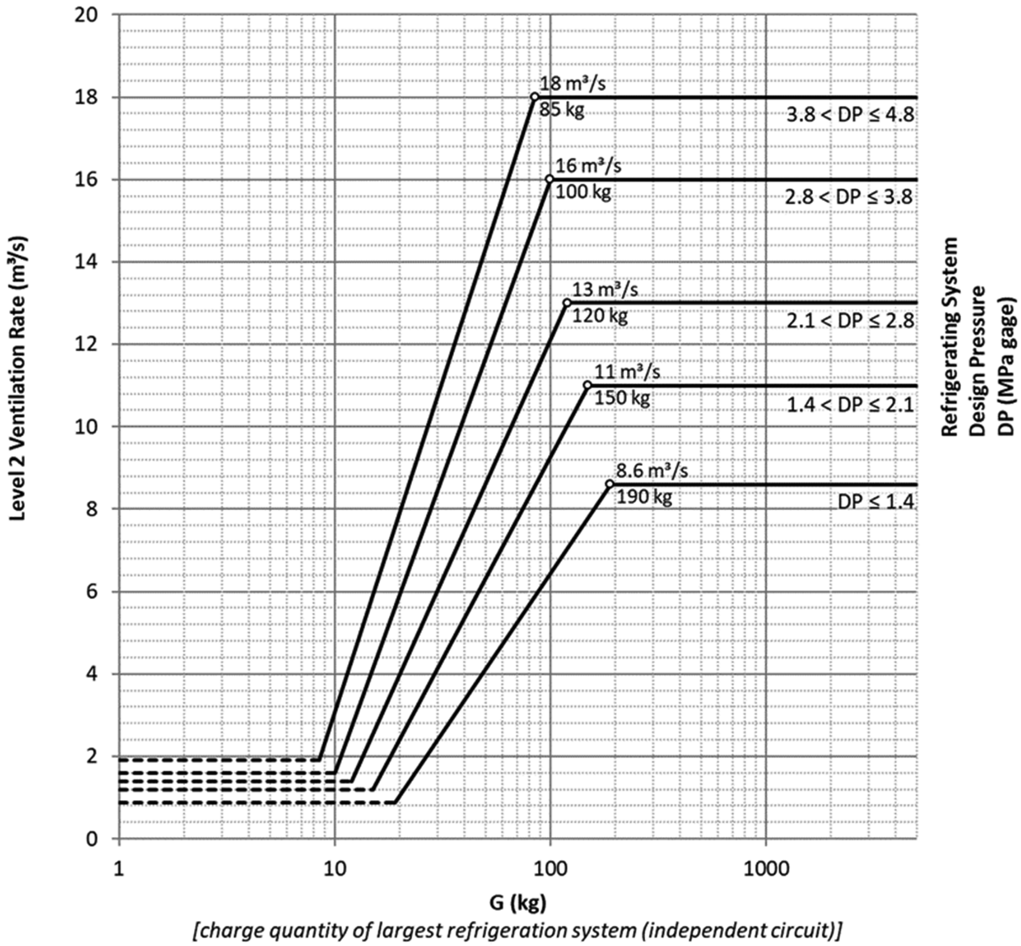
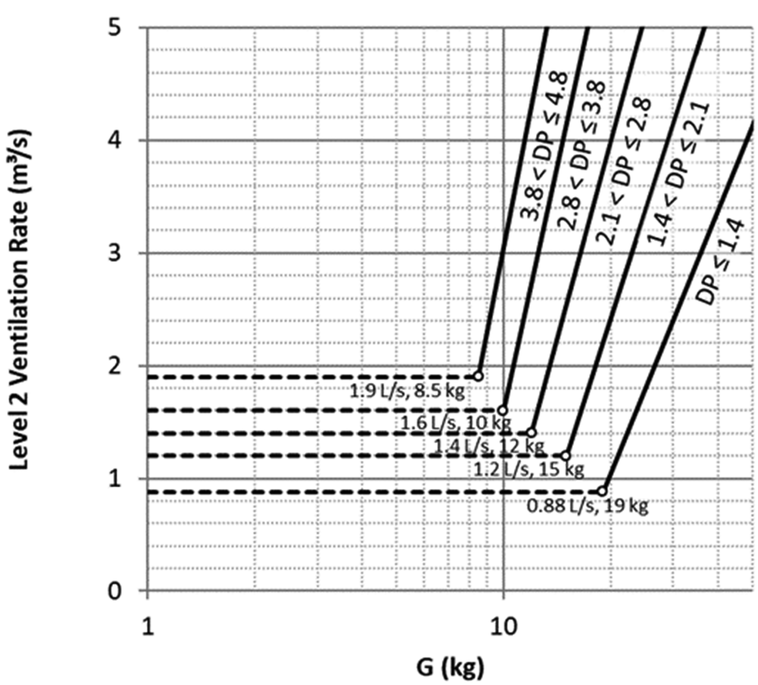


Figure 8-1 (a) Level 2 ventilation rate for Class 2L refrigerants (I-P) with (b) detail.



(a)



(b)

Figure 8-2 (a) Level 2 ventilation rate for Class 2L refrigerants (SI) with (b) detail.

8.12 When a *refrigerating system* is located outdoors more than 20 ft (6.1 m) from building openings and is enclosed by a penthouse, lean-to, or other open structure, natural or mechanical ventilation *shall* be provided. The requirements for such natural ventilation are as follows:

a. The free-aperture cross section for the ventilation of a *machinery room shall* be at least

$$F = G^{0.5} \qquad \text{(8-2a [I-P])}$$

$$F = 0.138 \times G^{0.5} \qquad \text{(8-2b [SI])}$$

where

F = the free opening area, ft^2 (m^2)

G = the mass of *refrigerant* in the largest system, any part of which is located in the *machinery room*, lb (kg)

b. Locations of the gravity ventilation openings *shall* be based on the relative density of the *refrigerant* to air.

8.13 Purge Discharge. The discharge from purge systems *shall* be governed by the same rules as *pressure relief devices* and *fusible plugs* (see Section 9.7.8) and *shall* be piped in conjunction with these devices.

Exception to 8.13: When R-718 (water) is the *refrigerant*.

9. DESIGN AND CONSTRUCTION OF EQUIPMENT AND SYSTEMS

9.1 Materials

9.1.1 General. Materials used in the construction and installation of *refrigerating systems shall* be suitable for conveying the *refrigerant* used. Materials *shall not* be used that will deteriorate because of the *refrigerant*, the lubricant, or their combination in the presence of air or moisture to a degree that poses a safety hazard.

9.1.1.1 Refrigerant Piping, Valves, and Fittings. *Refrigerant piping*, valves, and fittings *shall* comply with the requirements of Sections 9.10 through 9.13.

9.1.2* Alloy Restriction. Aluminum, zinc, magnesium, or their alloys *shall not* be used in contact with methyl chloride. Magnesium alloys *shall not* be used in contact with any halogenated *refrigerants*.

9.1.3 Discharge Line. *Piping* material used in the discharge line of a *pressure relief device* or *fusible plug shall* comply with Section 9.10.

9.2 System Design Pressure

9.2.1 *Design pressures shall not* be less than pressure arising under maximum operating, standby, or shipping conditions. When selecting the *design pressure*, allowance *shall* be provided for setting *pressure limiting devices* and *pressure relief devices* to avoid nuisance shutdowns and loss of *refrigerant*. *ASME Boiler and Pressure Vessel Code* [15], Section VIII, Division I, Appendix M, contains information on the appropriate allowances for *design pressure*.

Refrigerating equipment *shall* be designed for a vacuum of 29.0 in. Hg (32°F). *Design pressure* for *lithium bromide absorption systems shall not* be less than gage pressure 5.00 psi (34.5 kPa). *Design pressure* for mechanical refrigeration systems *shall not* be less than gage pressure 15.0 psi (103 kPa) and, except as noted in Sections 9.2.2, 9.2.3, 9.2.4, 9.2.5, and 9.2.6, *shall not* be less than the *saturation pressure* (gage) corresponding to the following temperatures:

a. *Low sides* of all systems: 80°F (26.7°C)
b. *High sides* of all water-cooled or evaporatively cooled systems: 30°F (16.7°C) higher than the summer 1% wet-bulb temperature for the location, as applicable, or 15°F (8.3°C) higher than the highest design leaving condensing water temperature, or 104°F (40°C), whichever is greatest
c. *High sides* of all air-cooled systems: 30°F (16.7°C) higher than the summer 1% design dry-bulb temperature for the location but not lower than 122°F (50°C)

Informative Note: See Informative Reference 16 for sources of information relating to summer 1% wet-bulb and summer 1% dry-bulb temperature data for a specific location.

9.2.1.1 The *design pressure* selected *shall* exceed maximum pressures attained under any anticipated normal operating conditions, including conditions created by expected fouling of heat exchange surfaces.

9.2.1.2 Standby conditions are intended to include normal conditions that are capable of being attained when the system is not in operation (e.g., maintenance, shutdown, power failure). Selection of the *design pressure* for *low-side* components *shall* also consider pressure developed in the *low side* of the system from equalization, or heating due to changes in ambient temperature, after the system has stopped.

9.2.1.3 The *design pressure* for both *low-side* and *high-side* components that are shipped as part of a gas- or *refrigerant*-charged system *shall* be selected with consideration of internal pressures arising from exposure to maximum temperatures anticipated during the course of shipment.

9.2.2 The *design pressure* for either the *high side* or *low side* need not exceed the *critical pressure* of the *refrigerant* unless such pressures are anticipated during operating, standby, or shipping conditions.

9.2.3 When part of a *limited charge system* is protected by a *pressure relief device*, the *design pressure* of the part need not exceed the setting of the *pressure relief device*.

9.2.4 When a *compressor* is used as a booster and discharges into the suction side of another *compressor*, the booster *compressor shall* be considered a part of the *low side*.

9.2.5 Components connected to *pressure vessels* and subject to the same pressure as the *pressure vessel shall* have a *design pressure* no less than the *pressure vessel*.

9.2.6 Components of *refrigerating systems* that use carbon dioxide (R-744) as a heat transfer fluid *shall* comply with the minimum *design pressure* requirements in Sections 9.2.6.1 through 9.2.6.4. The pressure at maximum operating conditions referenced by Sections 9.2.6.1 through 9.2.6.3 *shall* be the highest pressure experienced during the following conditions:

a. Start-up
b. Full-load operation at the warmest heat-rejection design condition
c. Defrost, for systems designed with defrost capability

9.2.6.1 For circuits without a *compressor*, the *design pressure shall* be not less than 120% of the circuit pressure at maximum operating conditions.

9.2.6.2 Cascade *refrigerating systems shall* comply with all of the following:

a. The *high-side design pressure shall* be not less than 120% of the maximum pressure developed by a *pressure imposing element*.
b. The *low-side design pressure shall* be not less than 120% of the pressure at maximum operating conditions, corresponding to the warmest location in the circuit.

9.2.6.3 Transcritical *refrigerating systems shall* comply with all of the following:

a. The *high-side design pressure shall* be not less than 110% of the maximum pressure developed by a *pressure imposing element*.
b. The *low-side design pressure shall* be not less than 120% of the pressure at maximum operating conditions.
c. The *intermediate pressure stage*, where present, *shall* have a *design pressure* that is not less than 120% of the pressure at maximum operating conditions.

9.2.6.4 Where the *design pressure* calculated in Sections 9.2.6.1 through 9.2.6.3 will be exceeded in the event of *refrigerant* warming to ambient temperature during normal standstill or emergency standstill conditions, one of the following means *shall* be provided to maintain pressure at or below the *design pressure*:

a. A pressure-relieving connection that will relieve excess pressure to a lower pressure part of the system
b. A *pressure relief valve* in accordance with Section 9.7.5

9.3 Refrigerant-Containing Pressure Vessels

9.3.1 Inside Dimensions 6 in. (152 mm) or Less. These vessels have an inside diameter, width, height, or cross-sectional diagonal not exceeding 6 in. (152 mm), with no limitation on length of vessel.

9.3.1.1 *Pressure vessels* having *inside dimensions* of 6 in. (152 mm) or less *shall* be

a. *listed* either individually or as part of an assembly by a *nationally recognized testing laboratory*;
b. marked directly on the vessel or on a nameplate attached to the vessel with a "U" or "UM" symbol signifying compliance with *ASME Boiler and Pressure Vessel Code* [15], Section VIII; or
c. when requested by the authority having jurisdiction (AHJ), the *manufacturer shall* provide documentation to confirm that the vessel meets the design, fabrication, and testing requirements of *ASME Boiler and Pressure Vessel Code*, Section VIII.

Pressure vessels having *inside dimensions* of 6 in. (152 mm) or less *shall* be protected by either a *pressure relief device* or a *fusible plug*.

Exception to 9.3.1.1: Vessels having an internal or external *design pressure* of 15 psig (103.4 kPa gage) or less.

9.3.1.2 If a *pressure relief device* is used to protect a *pressure vessel* having an *inside dimension* of 6 in. (152 mm) or less, the *ultimate strength* of the *pressure vessel* so protected *shall* be sufficient to withstand a pressure at least 3.0 times the *design pressure*.

9.3.1.3 If a *fusible plug* is used to protect a *pressure vessel* having an inside diameter of 6 in. (152 mm) or less, the *ultimate strength* of the *pressure vessel* so protected *shall* be sufficient to withstand a pressure 2.5 times the *saturation pressure* of the *refrigerant* used at the temperature stamped on the *fusible plug*, or 2.5 times the *critical pressure* of the *refrigerant* used, whichever is less.

9.3.2 Inside Dimensions Greater than 6 in. (152 mm). *Pressure vessels* having an inside diameter exceeding 6 in. (152 mm) and having an internal or external *design pressure* greater than 15 psig (103.4 kPa gage) *shall* be directly marked, or marked on a nameplate, with a "U" or "UM" symbol signifying compliance with the rules of *ASME Boiler and Pressure Vessel Code* [15], Section VIII.

9.3.3 Pressure Vessels for 15 psig (103.4 kPa gage) or Less. *Pressure vessels* having an internal or external *design pressure* of 15 psig (103.4 kPa gage) or less *shall* have an *ultimate strength* to withstand at least 3.0 times the *design pressure* and *shall* be tested with a pneumatic test pressure no less than 1.25 times the *design pressure* or a hydrostatic test pressure no less than 1.50 times the *design pressure*.

9.4 Pressure Relief Protection

9.4.1 *Refrigerating systems shall* be protected by a *pressure relief device* or other *approved* means to safely relieve pressure due to fire or other abnormal conditions.

9.4.2 *Pressure vessels shall* be protected in accordance with Section 9.7. *Pressure relief devices* are acceptable if they either bear a nameplate or are directly marked with a "UV" or "VR" symbol signifying compliance with *ASME Boiler and Pressure Vessel Code* [15], Section VIII.

9.4.3 Hydrostatic Expansion. Pressure rise resulting from hydrostatic expansion due to temperature rise of liquid *refrigerant* trapped in or between closed valves *shall* be addressed by the following.

9.4.3.1 If trapping of liquid with subsequent hydrostatic expansion can occur automatically during normal operation or during standby, shipping, or power failure, *engineering controls shall* be used that are capable of preventing the pressure from exceeding the *design pressure*. Acceptable *engineering controls* include but are not limited to a

a. *pressure relief device* to relieve hydrostatic pressure to another part of the system and
b. reseating *pressure relief valve* to relieve the hydrostatic pressure to an *approved* treatment system.

9.4.3.2 If trapping of liquid with subsequent hydrostatic expansion can occur only during maintenance—i.e., when personnel are performing maintenance tasks—either engineering or *administrative controls shall* be used to relieve or prevent the hydrostatic overpressure.

9.4.4 *Heat exchanger coils* located downstream, or upstream within 18 in. (460 mm), of a heating source and capable of being isolated *shall* be fitted with a *pressure relief device* that discharges to another part of the system in accordance with Section 9.4.3 or outside any enclosed space in accordance with Section 9.7.8. The *pressure relief device shall* be connected at the highest possible location of the heat exchanger or *piping* between the heat exchanger and its manual isolation valves.

Exceptions to 9.4.4:

1. Relief valves *shall not* be required on *heat exchanger coils* that have a *design pressure* greater than 110% of *refrigerant saturation pressure* when exposed to the maximum heating source temperature.
2. A relief valve *shall not* be required on self-contained or *unit systems* if the volume of the *low side* of the system, which is shut off by valves, is greater than the specific volume of the *refrigerant* at critical conditions of temperature and pressure as determined Equation 9-1:

$$V_1/[W_1 - (V_2 - V_1)/V_{gt}] \text{ shall be greater than } V_{gc} \tag{9-1}$$

where

V_1 = *low-side* volume, ft^3 (m^3)
V_2 = total volume of system, ft^3 (m^3)
W_1 = total weight of *refrigerant* in system, lb (kg)
V_{gt} = specific volume of *refrigerant* vapor at 110°F (43.5°C), ft^3/lb (m^3/kg)
V_{gc} = specific volume at *critical temperature* and *critical pressure*, ft^3/lb (m^3/kg)

9.4.5 *Pressure relief devices shall* be direct-pressure actuated or pilot operated. *Pilot-operated pressure relief valves shall* be self actuated, and the main valve *shall* open automatically at the *set pressure* and, if some essential part of the pilot fails, *shall* discharge its full rated capacity.

9.4.6 *Stop valves shall not* be located between a *pressure relief device* and parts of the system protected thereby. A *three-way valve*, used in conjunction with the dual relief valve requirements of Section 9.7.2.3, is not considered a *stop valve*.

9.4.7 When relief valves are connected to discharge to a common discharge *header*, as described in Section 9.7.9.3, a full area *stop valve* is not prohibited from being installed in the discharge pipe between the relief valve and the common *header*. When such a *stop valve* is installed, a locking device *shall* be installed to ensure that the *stop valve* is locked in the open position. This discharge *stop valve shall not* be shut unless one of the following conditions exists:

a. A parallel relief valve is installed that protects the system or vessels.
b. The system or vessels being protected have been depressurized and are vented to the atmosphere.

9.4.8 *Pressure relief devices shall* be connected directly to the *pressure vessel* or other parts of the system protected thereby. These devices *shall* be connected above the liquid *refrigerant* level and installed so that they are accessible for inspection and repair and so that they cannot be readily rendered inoperative.

Exception to 9.4.8: When *fusible plugs* are used on the *high side*, they *shall* be located either above or below the liquid *refrigerant* level.

9.4.9 The seats and discs of *pressure relief devices shall* be constructed of suitable material to resist *refrigerant* corrosion or other chemical action caused by the *refrigerant*. Seats or discs of cast iron *shall not* be used. Seats and discs *shall* be limited in distortion, by pressure or other cause, to a *set pressure* change of not more than 5% in a span of five years.

9.5 Setting of Pressure Relief Devices

9.5.1 Pressure Relief Valve Setting. *Pressure relief valves shall* start to function at a pressure not to exceed the *design pressure* of the parts of the system protected.

Exception to 9.5.1: See Section 9.7.8.3 for relief valves that discharge into other parts of the system.

9.5.2 Rupture Member Setting. *Rupture members* used in lieu of, or in series with, a relief valve *shall* have a nominal rated rupture pressure not to exceed the *design pressure* of the parts of the system protected. The conditions of application *shall* conform to the requirements of *ASME Boiler and Pressure Vessel Code* [15], Section VIII, Division 1, paragraph UG-127. The size of *rupture members* installed ahead of relief valves *shall not* be less than the relief valve inlet.

9.6 Marking of Relief Devices and Fusible Plugs

9.6.1 *Pressure relief valves* for *refrigerant*-containing components *shall* be set and sealed by the *manufacturer* or an assembler as defined in *ASME Boiler and Pressure Vessel Code* [15], Section VIII, Division 1. Each *pressure relief valve shall* be marked by the *manufacturer* or assembler with the data required in *ASME Boiler and Pressure Vessel Code*, Section VIII, Division 1.

Exception to 9.6.1: Relief valves for systems with *design pressures* of 15 psig (103.4 kPa gage) or less *shall* be marked by the *manufacturer* with the pressure setting capacity.

9.6.2 Each *rupture member* for *refrigerant pressure vessels shall* be marked with the data required in *ASME Boiler and Pressure Vessel Code* [15], Section VIII, Division 1, paragraph UG-129(e).

9.6.3 *Fusible plugs shall* be marked with the melting temperatures in Fahrenheit or Celsius.

9.7 Pressure Vessel Protection

9.7.1 *Pressure vessels shall* be provided with overpressure protection in accordance with rules in *ASME Boiler and Pressure Vessel Code* [15], Section VIII, Division 1.

9.7.2 *Pressure vessels* containing liquid *refrigerant* that are capable of being isolated by *stop valves* from other parts of a *refrigerating system shall* be provided with overpressure protection. *Pressure relief devices* or *fusible plugs shall* be sized in accordance with Section 9.7.5.

9.7.2.1 *Pressure vessels* with an *internal gross volume* of 3 ft^3 (0.085 m^3) or less *shall* use one or more *pressure relief devices* or a *fusible plug*.

9.7.2.2 *Pressure vessels* of more than 3 ft^3 (0.085 m^3) but less than 10 ft^3 (0.285 m^3) *internal gross volume shall* use one or more *pressure relief devices*. *Fusible plugs shall not* be used.

9.7.2.3 *Pressure vessels* of 10 ft^3 (0.285 m^3) or more *internal gross volume shall* use one or more *rupture members* or dual *pressure relief valves* when discharging to the atmosphere. Dual *pressure relief valves* *shall* be installed with a *three-way valve* to allow testing or repair. When dual relief valves are used, each valve must meet the requirements of Section 9.7.5.

Exceptions to 9.7.2.3: A single relief valve is permitted on *pressure vessels* of 10 ft^3 (0.285 m^3) or more *internal gross volume* when all of the following conditions are met:

1. The relief valves are located on the *low side* of the system.
2. The vessel is provided with shutoff valves designed to allow pumpdown of the *refrigerant* charge of the *pressure vessel*.
3. Other *pressure vessels* in the system are separately protected in accordance with Section 9.7.2.

9.7.3 For *pressure relief valves* discharging into the *low side* of the system, a single relief valve (not *rupture member*) of the required relieving capacity *shall not* be used on vessels of 10 ft^3 (0.283 m^3) or more *internal gross volume* except under the conditions permitted in Section 9.7.8.3.

9.7.4 Large vessels containing liquid *refrigerant shall not* be prohibited from using two or more *pressure relief devices* or *dual pressure relief devices* in parallel to obtain the required capacity.

9.7.5 The minimum required discharge capacity (C) of the *pressure relief device* or *fusible plug* for each *pressure vessel shall* be determined using the methods in this section.

The minimum required discharge capacity (C) *shall* be the largest value determined by consideration of potential thermal exposure from both external heat sources in accordance with Section 9.7.5.1 and internal heat sources in accordance with Section 9.7.5.2, with each case calculated using Equation 9-2. The calculated value of the minimum required relief device discharge capacity *shall* be rounded up to not less than two (2) significant figures.

When one *pressure relief device* or *fusible plug* is used to protect more than one *pressure vessel*, the required capacity *shall* be the sum of the capacities required for each *pressure vessel*.

The *pressure relief device set pressure shall* be in accordance with Section 9.5, and the relieving pressure for calculations in this section *shall* be 1.1 times the *pressure relief device set pressure*. When the relieving pressure exceeds 90% of the *refrigerant*'s *critical pressure*, an engineering analysis *shall* determine the value of the pressure relief capacity factor (f) as calculated using Equation 9-2:

$$C = f \times A \tag{9-2}$$

where

C = minimum required discharge capacity of the relief device expressed as mass flow of air, lb/min (kg/s)

f = pressure relief capacity factor that is dependent on type of *refrigerant* and vessel *design pressure* or protected equipment, lb/(ft^2·min) [kg/(m^2·s)]

A = area of the pressure vessel or protected equipment (per Section 9.7.5.1 or 9.7.5.2), ft^2 (m^2)

Tables 9-1 through 9-6 provide values of *pressure relief device* capacity factors (f) for specific *refrigerants* and *pressure vessel design pressures* calculated in accordance with this section. The tables are arranged according to the *refrigerant designation* and the *design pressure* of the *pressure vessel* or protected equipment. Linear interpolation *shall* be used for determining capacity factors for intermediate *design pressure* values between tabulated values. Capacity factor values from Tables 9-1 through 9-6 *shall not* be extrapolated. Capacity factor values for other *refrigerants* or *design pressures* outside the range of the tables *shall* be calculated per the method in this section.

The area (A) *shall* be calculated in accordance with Section 9.7.5.1 and 9.7.5.2. The capacity factor (f) *shall* be calculated using Equation 9-3 when the relieving pressure of the vessel does not exceed 90% of the *refrigerant critical pressure*.

$$f = \frac{H}{h_{fg}} \times r_w \tag{9-3}$$

where

H = the heat flux from a thermal energy source originating from an external source or internal source in accordance with Section 9.7.5.1 and 9.7.5.2, respectively, Btu/[ft^2·min] (kW/m^2)

h_{fg} = the *refrigerant*'s latent heat of vaporization evaluated at the relieving pressure (1.1 times the component *design pressure*), Btu/lb (kJ/kg)

r_w = *refrigerant* to air mass flow rate conversion factor, dimensionless

The *refrigerant* to air mass flow rate conversion factor (r_w) *shall* be calculated using Equations 9-4 and 9-5.

Table 9-1 Relief Device Refrigerant Capacity Factors (f) lb/[ft^2·min] (I-P)

	Design Pressure (psi, gage)							
Refrigerant	50	100	150	200	300	400	500	600
R12	1.24	1.38	1.51	1.64	1.91	2.3	—	—
R22	0.98	1.09	1.18	1.26	1.43	1.62	1.88	—
R23	0.95	1.05	1.13	1.21	1.38	1.56	1.84	—
R32	0.73	0.80	0.86	0.91	1.02	1.13	1.26	1.45
R115	1.48	1.69	1.89	2.2	2.7	—	—	—
R134a	1.05	1.18	1.29	1.40	1.65	1.97	—	—
R143a	1.05	1.18	1.30	1.42	1.69	2.1	—	—
R152a	0.84	0.94	1.02	1.10	1.27	1.47	1.79	—
R170	0.70	0.77	0.83	0.89	1.01	1.14	1.33	—
R290	0.78	0.87	0.95	1.03	1.20	1.41	—	—
R401A	1.01	1.12	1.22	1.31	1.51	1.75	2.2	—
R401B	1.00	1.11	1.21	1.30	1.49	1.72	2.1	—
R401C	1.04	1.16	1.27	1.37	1.60	1.88	2.5	—
R402A	1.11	1.25	1.36	1.48	1.73	2.1	—	—
R402B	1.06	1.18	1.28	1.39	1.60	1.86	2.3	—
R403A	1.05	1.18	1.28	1.38	1.60	1.86	2.4	—
R403B	1.16	1.30	1.42	1.55	1.82	2.2	—	—
R404A	1.12	1.26	1.38	1.51	1.80	2.3	—	—
R405A	1.10	1.22	1.34	1.45	1.70	2.1	—	—
R406A	0.98	1.09	1.19	1.28	1.47	1.70	2.1	—
R407A	0.98	1.09	1.19	1.28	1.48	1.72	2.2	—
R407B	1.08	1.21	1.33	1.44	1.69	2.1	—	—
R407C	0.95	1.05	1.15	1.23	1.41	1.63	1.99	—
R407D	0.97	1.08	1.18	1.27	1.46	1.71	2.2	—
R407E	0.93	1.03	1.12	1.20	1.38	1.58	1.90	—
R407F	0.93	1.03	1.12	1.20	1.37	1.58	1.89	—
R407G	1.03	1.15	1.26	1.37	1.60	1.90	—	—
R407H	0.91	1.00	1.09	1.16	1.33	1.51	1.79	—
R408A	1.03	1.15	1.25	1.36	1.57	1.84	—	—
R409A	1.02	1.13	1.23	1.32	1.52	1.75	2.2	—
R409B	1.02	1.13	1.23	1.32	1.51	1.74	2.1	—
R410A	0.90	0.99	1.07	1.15	1.31	1.48	1.74	—
R410B	0.92	1.02	1.10	1.18	1.35	1.54	1.82	—
R411A	0.95	1.05	1.14	1.22	1.39	1.58	1.84	—
R411B	0.97	1.07	1.16	1.24	1.41	1.60	1.86	—
R412A	1.00	1.10	1.20	1.28	1.47	1.68	1.99	—

Table 9-1 Relief Device Refrigerant Capacity Factors (*f*) lb/[ft^2·min] (I-P) [Continued]

	Design Pressure (psi, gage)							
Refrigerant	**50**	**100**	**150**	**200**	**300**	**400**	**500**	**600**
R413A	1.07	1.20	1.32	1.44	1.71	2.1	—	—
R414A	1.03	1.14	1.25	1.34	1.55	1.81	2.3	—
R414B	1.05	1.17	1.27	1.37	1.58	1.85	2.3	—
R415A	0.94	1.04	1.13	1.21	1.38	1.57	1.83	—
R415B	0.87	0.96	1.05	1.13	1.29	1.49	1.79	—
R416A	1.11	1.25	1.37	1.49	1.77	2.2	—	—
R417A	1.10	1.24	1.36	1.49	1.77	2.2	—	—
R417B	1.17	1.32	1.45	1.59	1.90	2.4	—	—
R417C	1.06	1.19	1.31	1.43	1.69	2.1	—	—
R418A	0.97	1.08	1.17	1.25	1.42	1.61	1.87	—
R419A	1.11	1.24	1.37	1.49	1.76	2.2	—	—
R419B	1.07	1.20	1.32	1.43	1.68	2.1	—	—
R420A	1.05	1.18	1.29	1.40	1.64	1.97	—	—
R421A	1.12	1.26	1.39	1.51	1.80	2.3	—	—
R421B	1.19	1.34	1.48	1.61	1.93	2.5	—	—
R422A	1.19	1.34	1.48	1.62	1.95	2.5	—	—
R422B	1.11	1.26	1.38	1.51	1.80	2.3	—	—
R422C	1.16	1.31	1.45	1.59	1.91	2.5	—	—
R422D	1.14	1.28	1.41	1.54	1.85	2.3	—	—
R422E	1.12	1.26	1.39	1.52	1.81	2.3	—	—
R423A	1.19	1.35	1.50	1.65	1.99	2.6	—	—
R424A	1.11	1.24	1.37	1.49	1.78	2.2	—	—
R425A	0.97	1.07	1.17	1.26	1.45	1.69	2.1	—
R426A	1.05	1.18	1.30	1.41	1.66	2.00	—	—
R427A	0.99	1.10	1.20	1.29	1.50	1.75	2.3	—
R428A	1.18	1.33	1.47	1.61	1.93	2.5	—	—
R429A	0.77	0.86	0.93	1.00	1.15	1.33	1.60	—
R430A	0.87	0.98	1.07	1.16	1.36	1.62	—	—
R431A	0.81	0.91	0.99	1.07	1.25	1.48	—	—
R432A	0.74	0.82	0.89	0.96	1.10	1.27	1.51	—
R433A	0.77	0.86	0.94	1.01	1.18	1.38	1.75	—
R433B	0.78	0.87	0.95	1.03	1.19	1.41	—	—
R433C	0.77	0.86	0.94	1.02	1.18	1.38	1.76	—
R434A	1.14	1.29	1.42	1.55	1.86	2.4	—	—
R435A	0.74	0.82	0.88	0.95	1.08	1.22	1.40	1.77
R436A	0.79	0.88	0.96	1.05	1.23	1.48	—	—

Table 9-1 Relief Device Refrigerant Capacity Factors (*f*) lb/[ft^2·min] (I-P) [Continued]

	Design Pressure (psi, gage)							
Refrigerant	**50**	**100**	**150**	**200**	**300**	**400**	**500**	**600**
R436B	0.79	0.88	0.97	1.05	1.24	1.49	—	—
R437A	1.06	1.19	1.31	1.43	1.68	2.1	—	—
R438A	1.04	1.17	1.28	1.38	1.62	1.93	—	—
R439A	0.90	0.99	1.08	1.15	1.31	1.50	1.77	—
R440A	0.84	0.94	1.02	1.10	1.27	1.47	1.80	—
R441A	0.73	0.82	0.89	0.96	1.12	1.33	1.71	—
R442A	0.93	1.03	1.12	1.20	1.38	1.58	1.90	—
R443A	0.76	0.85	0.92	1.00	1.15	1.34	1.67	—
R444A	1.00	1.11	1.22	1.32	1.54	1.83	2.4	—
R444B	0.87	0.96	1.04	1.11	1.26	1.43	1.66	2.1
R445A	0.95	1.06	1.16	1.26	1.46	1.73	2.3	—
R446A	0.81	0.89	0.96	1.02	1.15	1.29	1.46	1.73
R447A	0.82	0.90	0.97	1.03	1.16	1.29	1.47	1.74
R447B	0.82	0.90	0.97	1.03	1.16	1.30	1.48	1.76
R448A	0.97	1.08	1.18	1.27	1.46	1.70	2.1	—
R449A	0.98	1.09	1.19	1.28	1.48	1.73	2.2	—
R449B	0.97	1.08	1.18	1.27	1.46	1.70	2.2	—
R449C	1.00	1.11	1.21	1.31	1.52	1.79	2.4	—
R450A	1.10	1.24	1.36	1.49	1.77	2.2	—	—
R451A	1.19	1.35	1.50	1.65	2.1	—	—	—
R451B	1.19	1.35	1.50	1.65	2.1	—	—	—
R452A	1.11	1.24	1.36	1.48	1.74	2.2	—	—
R452B	0.83	0.92	0.99	1.06	1.20	1.35	1.55	1.96
R452C	1.10	1.23	1.35	1.46	1.72	2.1	—	—
R453A	0.97	1.07	1.17	1.26	1.45	1.69	2.1	—
R454A	0.96	1.07	1.16	1.25	1.44	1.68	2.1	—
R454B	0.83	0.91	0.99	1.05	1.19	1.34	1.54	1.92
R454C	1.02	1.14	1.24	1.35	1.57	1.88	—	—
R455A	0.98	1.09	1.19	1.28	1.48	1.74	2.2	—
R456A	1.04	1.16	1.27	1.38	1.62	1.94	—	—
R457A	1.00	1.11	1.22	1.32	1.53	1.83	—	—
R458A	0.96	1.07	1.17	1.26	1.45	1.68	2.1	—
R459A	0.83	0.91	0.99	1.05	1.19	1.33	1.53	1.90
R459B	1.02	1.14	1.24	1.34	1.57	1.87	2.6	—
R460A	1.05	1.17	1.28	1.38	1.61	1.91	2.6	—
R460B	0.95	1.05	1.14	1.22	1.40	1.61	1.93	—

Table 9-1 Relief Device Refrigerant Capacity Factors (*f*) lb/[ft^2·min] (I-P) [Continued]

	Design Pressure (psi, gage)							
Refrigerant	**50**	**100**	**150**	**200**	**300**	**400**	**500**	**600**
R500	1.11	1.24	1.35	1.47	1.71	2.1	—	—
R501	1.04	1.15	1.25	1.34	1.53	1.75	2.1	—
R502	1.20	1.34	1.47	1.60	1.87	2.3	—	—
R503	1.14	1.27	1.38	1.49	1.72	2.00	—	—
R504	0.99	1.10	1.20	1.29	1.48	1.72	2.2	—
R507A	1.13	1.27	1.40	1.53	1.83	2.3	—	—
R508A	1.25	1.41	1.55	1.69	2.1	2.6	—	—
R508B	1.21	1.36	1.49	1.62	1.91	2.4	—	—
R509A	1.29	1.46	1.62	1.77	2.2	2.8	—	—
R510A	0.73	0.81	0.88	0.94	1.07	1.22	1.41	—
R511A	0.77	0.87	0.95	1.02	1.19	1.40	—	—
R512A	0.85	0.95	1.03	1.11	1.28	1.49	1.82	—
R513A	1.14	1.29	1.42	1.56	1.87	2.4	—	—
R513B	1.14	1.29	1.43	1.57	1.88	2.4	—	—
R515A	1.16	1.32	1.46	1.60	1.94	2.5	—	—
R1150	0.69	0.76	0.81	0.87	0.98	1.10	1.27	—
R1234yf	1.21	1.37	1.53	1.69	2.1	—	—	—
R1234ze(E)	1.14	1.29	1.42	1.56	1.87	2.4	—	—
R1270	0.75	0.84	0.91	0.98	1.13	1.31	1.58	—

Table 9-2 Relief Device Refrigerant Capacity Factors (*f*) kg/[m^2·s] (SI)

	Design Pressure (kPa, gage)							
Refrigerant	**350**	**700**	**1000**	**1500**	**2000**	**2500**	**3000**	**4000**
R12	0.101	0.113	0.122	0.137	0.153	0.173	0.199	—
R22	0.080	0.089	0.095	0.105	0.115	0.126	0.138	—
R23	0.078	0.086	0.092	0.101	0.111	0.121	0.134	—
R32	0.060	0.066	0.070	0.076	0.082	0.088	0.095	0.114
R115	0.121	0.138	0.152	0.178	0.22	—	—	—
R134a	0.086	0.096	0.104	0.118	0.132	0.149	0.174	—
R143a	0.086	0.097	0.105	0.119	0.135	0.155	—	—
R152a	0.069	0.077	0.083	0.092	0.102	0.113	0.127	—
R170	0.057	0.063	0.067	0.074	0.081	0.089	0.098	—
R290	0.063	0.071	0.077	0.086	0.096	0.108	0.123	—
R401A	0.082	0.092	0.099	0.110	0.121	0.134	0.151	—
R401B	0.082	0.091	0.098	0.108	0.120	0.132	0.148	—
R401C	0.085	0.095	0.103	0.115	0.128	0.143	0.164	—
R402A	0.091	0.102	0.110	0.124	0.138	0.156	0.180	—
R402B	0.086	0.096	0.104	0.116	0.128	0.143	0.161	—
R403A	0.086	0.096	0.103	0.116	0.128	0.143	0.161	—
R403B	0.094	0.106	0.115	0.130	0.146	0.166	0.196	—
R404A	0.091	0.103	0.112	0.127	0.144	0.167	—	—
R405A	0.090	0.100	0.108	0.122	0.136	0.153	0.178	—
R406A	0.080	0.089	0.096	0.107	0.118	0.130	0.146	—
R407A	0.080	0.089	0.096	0.107	0.119	0.132	0.149	—
R407B	0.089	0.099	0.107	0.121	0.135	0.153	0.178	—
R407C	0.078	0.086	0.093	0.103	0.114	0.126	0.141	—
R407D	0.079	0.088	0.095	0.106	0.118	0.131	0.148	—
R407E	0.076	0.084	0.091	0.100	0.111	0.122	0.136	—
R407F	0.076	0.084	0.091	0.100	0.110	0.122	0.136	—
R407G	0.084	0.094	0.102	0.115	0.128	0.145	0.168	—
R407H	0.074	0.082	0.088	0.097	0.107	0.117	0.130	—
R408A	0.084	0.094	0.101	0.113	0.126	0.141	0.161	—
R409A	0.083	0.093	0.099	0.110	0.122	0.135	0.151	—
R409B	0.083	0.092	0.099	0.110	0.121	0.134	0.150	—
R410A	0.073	0.081	0.087	0.096	0.105	0.115	0.127	—
R410B	0.075	0.083	0.089	0.099	0.108	0.119	0.132	—
R411A	0.078	0.086	0.092	0.102	0.112	0.123	0.135	—
R411B	0.079	0.087	0.094	0.103	0.113	0.124	0.137	—
R412A	0.081	0.090	0.097	0.107	0.118	0.130	0.144	—

Table 9-2 Relief Device Refrigerant Capacity Factors (*f*) kg/[m^2·s] (SI) [Continued]

	Design Pressure (kPa, gage)							
Refrigerant	**350**	**700**	**1000**	**1500**	**2000**	**2500**	**3000**	**4000**
R413A	0.087	0.098	0.107	0.121	0.137	0.157	0.189	—
R414A	0.084	0.093	0.101	0.112	0.125	0.139	0.157	—
R414B	0.086	0.095	0.103	0.114	0.127	0.141	0.160	—
R415A	0.077	0.085	0.091	0.101	0.111	0.121	0.134	—
R415B	0.071	0.079	0.085	0.094	0.104	0.115	0.128	—
R416A	0.091	0.102	0.111	0.125	0.142	0.162	0.195	—
R417A	0.090	0.101	0.110	0.125	0.141	0.162	0.197	—
R417B	0.095	0.108	0.117	0.134	0.152	0.176	—	—
R417C	0.087	0.098	0.106	0.120	0.135	0.154	0.182	—
R418A	0.079	0.088	0.094	0.104	0.114	0.125	0.138	—
R419A	0.091	0.102	0.110	0.125	0.141	0.160	0.191	—
R419B	0.087	0.098	0.106	0.120	0.135	0.153	0.180	—
R420A	0.086	0.096	0.104	0.117	0.132	0.149	0.174	—
R421A	0.091	0.103	0.112	0.127	0.144	0.165	0.200	—
R421B	0.097	0.109	0.119	0.136	0.154	0.179	—	—
R422A	0.097	0.110	0.120	0.136	0.156	0.181	—	—
R422B	0.091	0.103	0.112	0.127	0.144	0.166	0.21	—
R422C	0.095	0.107	0.117	0.134	0.152	0.177	—	—
R422D	0.093	0.105	0.114	0.130	0.148	0.171	0.22	—
R422E	0.091	0.103	0.112	0.128	0.145	0.167	0.21	—
R423A	0.098	0.111	0.121	0.139	0.159	0.188	—	—
R424A	0.090	0.102	0.111	0.125	0.142	0.163	0.199	—
R425A	0.079	0.088	0.095	0.105	0.117	0.130	0.147	—
R426A	0.086	0.096	0.105	0.118	0.133	0.151	0.178	—
R427A	0.080	0.090	0.097	0.108	0.120	0.134	0.153	—
R428A	0.096	0.108	0.118	0.135	0.154	0.179	—	—
R429A	0.063	0.070	0.075	0.084	0.093	0.103	0.115	—
R430A	0.071	0.080	0.086	0.097	0.109	0.123	0.143	—
R431A	0.066	0.074	0.080	0.090	0.100	0.113	0.130	—
R432A	0.060	0.067	0.072	0.080	0.089	0.098	0.109	—
R433A	0.063	0.070	0.076	0.085	0.094	0.105	0.120	—
R433B	0.063	0.071	0.076	0.086	0.096	0.107	0.123	—
R433C	0.063	0.070	0.076	0.085	0.095	0.106	0.120	—
R434A	0.093	0.105	0.115	0.130	0.148	0.172	—	—
R435A	0.060	0.067	0.071	0.079	0.087	0.095	0.104	0.135
R436A	0.064	0.072	0.078	0.088	0.098	0.112	0.130	—

Table 9-2 Relief Device Refrigerant Capacity Factors (*f*) kg/[m²·s] (SI) [Continued]

	Design Pressure (kPa, gage)							
Refrigerant	**350**	**700**	**1000**	**1500**	**2000**	**2500**	**3000**	**4000**
R436B	0.064	0.072	0.078	0.088	0.099	0.112	0.132	—
R437A	0.087	0.098	0.106	0.120	0.135	0.154	0.182	—
R438A	0.085	0.095	0.103	0.116	0.130	0.146	0.170	—
R439A	0.073	0.081	0.087	0.096	0.106	0.116	0.128	—
R440A	0.069	0.077	0.083	0.092	0.102	0.113	0.127	—
R441A	0.060	0.067	0.072	0.080	0.090	0.101	0.116	—
R442A	0.076	0.084	0.091	0.100	0.111	0.122	0.136	—
R443A	0.062	0.069	0.075	0.083	0.092	0.103	0.117	—
R444A	0.081	0.091	0.098	0.111	0.124	0.139	0.160	—
R444B	0.071	0.079	0.084	0.093	0.101	0.111	0.122	0.160
R445A	0.077	0.087	0.094	0.105	0.117	0.132	0.152	—
R446A	0.066	0.073	0.078	0.085	0.093	0.100	0.109	0.135
R447A	0.067	0.073	0.078	0.086	0.093	0.101	0.110	0.136
R447B	0.067	0.074	0.079	0.086	0.094	0.101	0.110	0.137
R448A	0.079	0.088	0.095	0.106	0.117	0.130	0.147	—
R449A	0.080	0.089	0.096	0.107	0.119	0.132	0.150	—
R449B	0.080	0.089	0.095	0.106	0.118	0.131	0.148	—
R449C	0.082	0.091	0.098	0.110	0.122	0.136	0.156	—
R450A	0.090	0.101	0.110	0.125	0.141	0.162	0.198	—
R451A	0.097	0.111	0.121	0.139	0.161	0.192	—	—
R451B	0.097	0.110	0.121	0.139	0.161	0.191	—	—
R452A	0.090	0.101	0.110	0.124	0.139	0.159	0.189	—
R452B	0.068	0.075	0.080	0.088	0.096	0.105	0.115	0.150
R452C	0.090	0.101	0.109	0.123	0.138	0.156	0.185	—
R453A	0.079	0.088	0.094	0.105	0.116	0.129	0.146	—
R454A	0.078	0.087	0.094	0.104	0.116	0.129	0.146	—
R454B	0.068	0.075	0.080	0.088	0.096	0.104	0.114	0.147
R454C	0.083	0.093	0.101	0.113	0.126	0.142	0.166	—
R455A	0.080	0.089	0.096	0.107	0.119	0.133	0.152	—
R456A	0.085	0.095	0.103	0.116	0.130	0.147	0.172	—
R457A	0.081	0.091	0.098	0.110	0.123	0.139	0.161	—
R458A	0.079	0.088	0.094	0.105	0.116	0.129	0.146	—
R459A	0.068	0.075	0.080	0.088	0.095	0.104	0.114	0.146
R459B	0.083	0.093	0.100	0.112	0.126	0.142	0.165	—
R460A	0.086	0.096	0.103	0.116	0.129	0.145	0.168	—
R460B	0.077	0.086	0.092	0.102	0.113	0.124	0.139	—

Table 9-2 Relief Device Refrigerant Capacity Factors (*f*) kg/[$m^2 \cdot s$] (SI) [Continued]

	Design Pressure (kPa, gage)							
Refrigerant	**350**	**700**	**1000**	**1500**	**2000**	**2500**	**3000**	**4000**
R500	0.090	0.101	0.109	0.123	0.137	0.154	0.177	—
R501	0.085	0.094	0.101	0.112	0.123	0.135	0.150	—
R502	0.098	0.110	0.119	0.134	0.150	0.169	0.198	—
R503	0.093	0.104	0.112	0.124	0.138	0.153	0.174	—
R504	0.081	0.090	0.097	0.108	0.119	0.132	0.149	—
R507A	0.092	0.104	0.113	0.129	0.146	0.169	—	—
R508A	0.102	0.115	0.125	0.142	0.161	0.187	—	—
R508B	0.099	0.111	0.120	0.136	0.153	0.176	—	—
R509A	0.105	0.119	0.130	0.149	0.171	0.21	—	—
R510A	0.060	0.066	0.071	0.079	0.086	0.095	0.104	0.138
R511A	0.063	0.071	0.076	0.086	0.096	0.107	0.122	—
R512A	0.069	0.077	0.083	0.093	0.103	0.114	0.129	—
R513A	0.093	0.105	0.115	0.131	0.149	0.174	—	—
R513B	0.093	0.106	0.115	0.132	0.150	0.175	—	—
R515A	0.095	0.108	0.118	0.135	0.155	0.181	—	—
R1150	0.056	0.062	0.066	0.072	0.079	0.085	0.094	0.125
R1234yf	0.099	0.112	0.123	0.142	0.165	0.198	—	—
R1234ze(E)	0.093	0.105	0.115	0.131	0.150	0.174	—	—
R1270	0.061	0.068	0.074	0.082	0.091	0.101	0.113	—

Table 9-3 Relief Device Refrigerant Capacity Factors (*f*) lb/[ft^2·min] (I-P)

Refrigerant	Design Pressure (psi, gage)			
	15	50	100	150
R11	1.05	1.18	1.32	1.44
R113	1.21	1.38	1.57	1.75
R114	1.25	1.42	1.62	1.81
R123	1.09	1.24	1.40	1.55
R124	1.10	1.25	1.41	1.56
R142b	0.94	1.07	1.20	1.31
R245fa	0.99	1.12	1.27	1.41
R600	0.74	0.84	0.94	1.04
R600a	0.76	0.87	0.98	1.09
R718	0.24	0.26	0.28	0.29
R764	0.64	0.70	0.76	0.81
R1224yd(Z)	1.09	1.25	1.43	1.59
R1233zd(E)	1.02	1.16	1.31	1.45
R1336mzz(Z)	1.12	1.29	1.49	1.68

Table 9-4 Relief Device Refrigerant Capacity Factors (*f*) kg/[m^2·s] (SI)

Refrigerant	Design Pressure (kPa, gage)			
	100	350	700	1000
R11	0.086	0.096	0.107	0.116
R113	0.098	0.112	0.128	0.141
R114	0.101	0.116	0.133	0.146
R123	0.089	0.101	0.115	0.125
R124	0.089	0.102	0.115	0.126
R142b	0.077	0.087	0.098	0.106
R245fa	0.080	0.092	0.104	0.114
R600	0.060	0.068	0.077	0.084
R600a	0.062	0.071	0.080	0.088
R718	0.0195	0.021	0.023	0.023
R764	0.052	0.057	0.062	0.066
R1224yd(Z)	0.089	0.102	0.117	0.128
R1233zd(E)	0.083	0.094	0.107	0.117
R1336mzz(Z)	0.091	0.105	0.121	0.135

Table 9-5 Relief Device Refrigerant Capacity Factors (*f*) lb/[ft^2·min] (I-P)

Refrigerant	Design Pressure (psi, gage)							
	100	300	400	500	600	700	800	850
R744	0.75	0.93	1.01	1.09	1.18	1.30	1.48	1.63

Table 9-6 Relief Device Refrigerant Capacity Factors (*f*) kg/[m^2·s] (SI)

Refrigerant	Design Pressure (kPa, gage)											
	700	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	5900
R744	0.061	0.065	0.070	0.075	0.080	0.084	0.089	0.095	0.101	0.109	0.120	0.134

$$r_w = \frac{C_a}{C_r}\sqrt{\frac{T_r}{T_a}}\sqrt{\frac{M_a}{M_r}} \tag{9-4}$$

$$C_r = 520\sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} \tag{9-5}$$

where

C_a = 356, a dimensionless constant for air

T_r = the absolute dew-point temperature of *refrigerant* evaluated at a relieving pressure of 1.1 times the relief device *set pressure*, °R (K)

T_a = the absolute temperature of standard air, 520°R (289 K)

M_r = the relative molar mass of the *refrigerant* in accordance with ASHRAE Standard 34 [3]

M_a = the relative molar mass of air, 28.97

k = the ratio of specific heats (c_p/c_v) for saturated *refrigerant* vapor evaluated at a relieving pressure of 1.1 times the relief device *set pressure*

9.7.5.1 External Heat Sources. The area (A) *shall* be the largest *refrigerant*-containing, projected external surface area of the *pressure vessel* when viewed from any orientation. See Figure 9-1 for examples. The value of heat flux (H) *shall* be not less than 150 Btu/(min·ft^2) (28.4 kW/m^2). Where combustible materials are within 20 ft (6.1 m) of a pressure vessel, the value of heat flux (H) *shall* be not less than 375 Btu/(min·ft^2) (71.0 kW/m^2). Where a heat source other than an external fire has potential to generate a larger heat flux (H) during operating conditions and standby conditions as defined in Sections 9.2.1 and 9.2.1.2, or during other abnormal conditions, the *pressure relief device shall* be sized based on the other heat source.

9.7.5.2 Internal Heat Sources. The area (A) *shall* be the applicable *refrigerant*-containing area for the *pressure vessel* or pressure-protected equipment that corresponds to the greatest internal heat flux (H) expected during operating conditions or standby conditions as defined in Sections 9.2.1 and 9.2.1.2.

9.7.6 The rated discharge capacity of a *pressure relief device* expressed in lb of air/min (kg of air/s) *shall* be determined in accordance with *ASME Boiler and Pressure Vessel Code* [15], Section VIII, Division 1, paragraph UG-131. All pipe and fittings between the *pressure relief valve* and the parts of the system it protects *shall* have at least the area of the *pressure relief valve* inlet area.

9.7.7 The rated discharge capacity of a *rupture member* or *fusible plug* discharging to the atmosphere under critical flow conditions in lb of air/min (kg of air/s) *shall* be determined using Equation 9-6a or 9-6b:

$$C = 0.64P_1d^2 \qquad d = 1.25(C/P_1)^{0.5} \tag{9-6a [I-P]}$$

$$C = 1.09\times10^{-6}P_1d^2 \qquad d = 958.7(C/P_1)^{0.5} \tag{9-6b [SI]}$$

where

C = rated discharge capacity expressed as mass flow of air, lb/min (kg/s)

d = smallest of the internal diameter of the inlet pipe, retaining flanges, *fusible plug*, and *rupture member*, in. (mm)

where for *rupture members*,

P_1 = (rated pressure psig [kPa gage] × 1.10) + 14.7 (101.33)

where for *fusible plugs*,

P_1 = absolute *saturation pressure* corresponding to the stamped temperature melting point of the *fusible plug* or the *critical pressure* of the *refrigerant* used, whichever is smaller, psia (kPa)

9.7.8 Discharge from Pressure Relief Devices. Pressure relief systems designed for vapor *shall* comply with Section 9.7.8. Pressure relief systems designed for liquid *shall* comply with Section 9.4.3.

Different *refrigerants shall not* be vented into a common relief *piping* system unless the *refrigerants* are included in a *blend* that is recognized by ASHRAE Standard 34 [3].

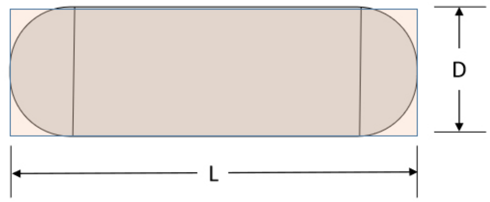
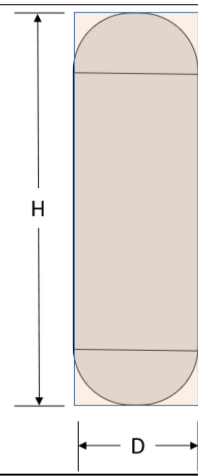
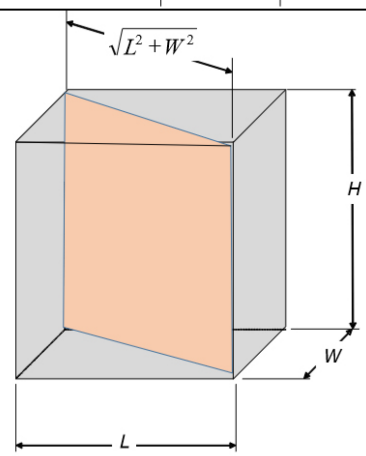
Component	Example	Area
Pressure vessel, horizontal, without waterboxes		$A = D \cdot L$
Pressure vessel, horizontal, with waterboxes		$A = D \cdot L$
Pressure vessel, vertical		$A = D \cdot H$
Plate heat exchanger		$A = \sqrt{L^2 + W^2} \cdot H$

Figure 9-1 External projected area examples for common pressure equipment.

9.7.8.1 Discharging Location Interior to Building. *Pressure relief devices*, including *fusible plugs*, serving refrigeration systems *shall* be permitted to discharge to the interior of a building only when all of the following apply:

a. The system contains less than 110 lb (50 kg) of a Group A1 or A2L *refrigerant*.
b. The system contains less than 6.6 lb (3 kg) of a Group A2, B1, B2L, or B2 *refrigerant*.
c. The system does not contain any quantity of a Group A3 or B3 *refrigerant*.
d. The system is to be installed in a *machinery room* as required by Section 7.4.
e. The *refrigerant* charge quantity in Section 7.3 is not exceeded.

Refrigeration systems that do not meet the above requirements *shall* meet the requirements of Sections 9.7.8.2, 9.7.8.3, and 9.7.8.4.

9.7.8.2 Discharging Location Exterior to Building. *Pressure relief devices* designed to discharge external to the refrigeration system *shall* be arranged to discharge outside of a building and comply with all of the following:

a. The point of vent discharge *shall* be located not less than 15 ft (4.57 m) above the adjoining ground level.

   Exception to (a): Outdoor systems containing Group A1 *refrigerant shall* be permitted to discharge at any elevation where the point of discharge is located in an access controlled area accessible to authorized personnel only.

b. The point of vent discharge *shall* be located not less than 20 ft (6.1 m) from windows, building ventilation openings, pedestrian walkways, or building exits.

c. For heavier-than-air *refrigerants*, the point of vent discharge *shall* be located not less than 20 ft (6.1 m) horizontally from below-grade walkways, entrances, pits, or ramps if a release of the entire system charge into such a space would yield a concentration of *refrigerant* in excess of the *refrigerant concentration limit* (*RCL*). The direct discharge of a relief vent into enclosed outdoor spaces, such as a courtyard with walls on all sides, *shall not* be permitted if a release of the entire system charge into such a space would yield a concentration of *refrigerant* in excess of the *RCL*. The volume for the *refrigerant* concentration calculation *shall* be determined using the gross area of the space and a height of 8.2 ft (2.5 m), regardless of the actual height of the enclosed space.

d. The termination point of a vent discharge line *shall* be made in a manner that prevents discharged *refrigerant* from spraying directly onto personnel that might be in the vicinity.

e. The termination point of vent discharge lines *shall* be made in a manner that prevents foreign material or debris from entering the discharge *piping*.

f. Relief vent lines that terminate vertically upward and are subject to moisture entry *shall* be provided with a drip pocket having a minimum of 24 in. (0.6 m) in length and having the size of the vent discharge pipe. The drip pocket *shall* be installed to extend below the first change in vent pipe direction and *shall* be fitted with a valve or drain plug to permit removal of accumulated moisture.

9.7.8.3 Internal Relief. *Pressure relief valves* designed to discharge from a higher-pressure vessel into a lower-pressure vessel internal to the system *shall* comply with all of the following:

a. The *pressure relief valve* that protects the higher-pressure vessel *shall* be selected to deliver capacity in accordance with Section 9.7.5 without exceeding the maximum allowable working pressure of the higher-pressure vessel accounting for the change in mass flow capacity due to the elevated *back pressure*.

b. The capacity of the *pressure relief valve* protecting the part of the system receiving a discharge from a *pressure relief valve* protecting a higher-pressure vessel *shall* be at least the sum of the capacity required in Section 9.7.5 plus the mass flow capacity of the *pressure relief valve* discharging into that part of the system.

c. The *design pressure* of the body of the relief valve used on the higher-pressure vessel *shall* be rated for operation at the *design pressure* of the higher-pressure vessel in both pressure-containing areas of the valve.

9.7.8.4 Discharge Location, Special Requirements. Additional requirements for *pressure relief device* discharge location and allowances *shall* apply for specific *refrigerants* as *listed* in this section.

9.7.8.4.1 Water (R-718). Where water is the only *refrigerant*, discharge to a floor drain *shall* be permitted where all of the following conditions are met:

a. The *pressure relief device set pressure* does not exceed 15 psig.

b. The floor drain is sized to handle the flow rate from a single broken tube in any *refrigerant*-containing heat exchanger.

c. Either

   1. the AHJ finds it acceptable that the working fluid, corrosion inhibitor, and other additives used in this type of refrigeration system may infrequently be discharged to the sewer system, or

   2. a catch tank, sized to handle the expected discharge, is installed and equipped with a normally closed drain valve and an overflow line to drain.

9.7.9 Relief Discharge Piping. The *piping* used for *pressure relief device* discharge *shall* meet the requirements of the following subsections.

9.7.9.1 Discharge Piping, General. *Piping* connected to the discharge side of a *fusible plug* or *rupture member shall* have provisions to prevent plugging of the pipe upon operation of a *fusible plug* or *rupture member*.

9.7.9.2 The size of the discharge pipe from a *pressure relief device* or *fusible plug shall not* be less than the outlet size of the *pressure relief device* or *fusible plug*.

9.7.9.3 The maximum length of the discharge *piping* installed on the outlet of *pressure relief devices* and *fusible plugs* discharging to the atmosphere *shall* be determined using the method in this section.

See *Normative Appendix* E, Table E-1, for the allowable flow capacity of various equivalent lengths of single discharge *piping* vents for conventional *pressure relief valves*.

9.7.9.3.1 The design *back pressure* due to flow in the discharge *piping* at the outlet of *pressure relief devices* and *fusible plugs*, discharging to atmosphere, *shall* be limited by the allowable equivalent length of *piping* determined using Equation 9-7a or 9-7b:

$$L = \frac{0.2146 d^5 (P_0^2 - P_2^2)}{f C_r^2} - \frac{d \ln\left(\frac{P_0}{P_2}\right)}{6f} \qquad \text{(9-7a [I-P])}$$

$$L = \frac{7.4381 \times 10^{-15} d^5 (P_0^2 - P_2^2)}{f C_r^2} - \frac{d \ln\left(\frac{P_0}{P_2}\right)}{500f} \qquad \text{(9-7b [SI])}$$

where

L	=	equivalent length of discharge *piping*, ft (m)
C_r	=	rated capacity as stamped on the *pressure relief device* in lb/min (kg/s), or in standard cubic feet per minute multiplied by 0.0764, or as calculated in Section 9.7.7 for a *rupture member* or *fusible plug*, or as adjusted for reduced capacity due to *piping* as *specified* by the *manufacturer* of the device, or as adjusted for reduced capacity due to *piping* as estimated by an *approved* method
f	=	Moody friction factor in fully turbulent flow (***Informative Note:*** See typical values in *Informative Appendix* D.)
d	=	inside diameter of pipe or tube, in. (mm)
ln	=	natural logarithm
P_2	=	absolute pressure at outlet of discharge *piping*, psia (kPa)
P_0	=	allowed *back pressure* (absolute) at the outlet of *pressure relief device* (see Section 9.7.9.3.2), psia (kPa)

9.7.9.3.2 Unless the maximum allowable *back pressure* (P_0) is *specified* by the relief valve *manufacturer*, the following maximum allowable *back pressure* values *shall* be used for P_0, where P is the *set pressure* and P_a is atmospheric pressure at the nominal elevation of the installation (Informative Table 9-7):

a. For conventional relief valves: 15% of *set pressure*

$$P_0 = (0.15 \times P) + P_a \qquad \text{(9-8)}$$

b. For *balanced relief valves*: 25% of *set pressure*

$$P_0 = (0.25 \times P) + P_a \qquad \text{(9-9)}$$

c. For rupture disks alone, *fusible plugs*, or pilot-operated *pressure relief devices*: 50% of *set pressure*

$$P_0 = (0.5 \times P) + P_a \qquad \text{(9-10)}$$

For *fusible plugs*, *P shall* be the saturated absolute pressure for the stamped temperature melting point of the *fusible plug* or the *critical pressure* of the *refrigerant* used, whichever is smaller.

9.7.9.3.3 When outlets of two or more relief devices or *fusible plugs*, which are expected to operate simultaneously, connect to a common discharge pipe, the common pipe *shall* be sized large enough to prevent the *back pressure* at each *pressure relief device* from exceeding the maximum allowable *back pressure* in accordance with Section 9.7.9.3.2.

9.8 Positive Displacement Compressor Protection. Every *positive displacement compressor* with a *stop valve* in the discharge connection *shall* be equipped with a *pressure relief device* of adequate size and pressure setting, as *specified* by the *compressor manufacturer*, to prevent rupture of the *compressor* or to prevent the pressure from increasing to more than 10% above the maximum allowable working pressure of any other component located in the discharge line between the *compressor* and the *stop valve* or in accordance with

Informative Table 9-7 Atmospheric Pressure at Nominal Installation Elevation (P_a)

Elevation above Sea Level, ft	P_a, psia	Elevation above Sea Level, m	P_a, kP
0	14.7	0	101
500	14.4	150	99.5
1000	14.2	300	97.8
1500	13.9	450	96.0
2000	13.7	600	94.3
2500	13.4	750	92.6
3000	13.2	900	91.0
3500	12.9	1050	89.3
4000	12.7	1200	87.7
4500	12.5	1350	86.1
5000	12.2	1500	84.6
6000	11.8	1800	81.5
7000	11.3	2100	78.5
8000	10.9	2400	75.6
9000	10.5	2700	72.8
10000	10.1	3000	70.1

Section 9.7.5, whichever is larger. The *pressure relief device shall* discharge into the low-pressure side of the system or in accordance with Section 9.7.8.

The relief devices *shall* be sized based on *compressor* flow at the following conditions:

a. *Compressors* in single-stage systems and high-stage *compressors* of other systems. Flow *shall* be calculated based on 50°F (10°C) saturated suction temperature at the *compressor* suction.
b. Low-stage or booster *compressors* in *compound refrigerating systems*. For those *compressors* that are capable of running only when discharging to the suction of a high-stage *compressor*, flow *shall* be calculated based on the saturated suction temperature equal to the design operating intermediate temperature.
c. Low-stage *compressors* in *cascade systems*. For those *compressors* that are located in the lower-temperature stages of *cascade systems*, flow *shall* be calculated based on the suction pressure being equal to the pressure setpoint of the pressure relieving devices that protect the *low side* of the stage against overpressure.

Exceptions to (a) (b) and (c): The discharge capacity of the *pressure relief device* is allowed to be the minimum regulated flow rate of the *compressor* when all of the following conditions are met:

1. The *compressor* is equipped with capacity regulation.
2. Capacity regulation actuates to minimum flow at 90% of the *pressure relief device* setting.
3. A *pressure limiting device* is installed and set in accordance with the requirements of Section 9.9.

Exception to 9.8: Hermetic *refrigerant* motor-compressors that are *listed* and have a displacement less than or equal to 50 ft^3/min (1.42 m^3/min).

Informative Note: *Informative Appendix* C describes one acceptable method of calculating the discharge capacity of *positive displacement compressor* relief devices.

9.9 Pressure Limiting Devices

9.9.1 When Required. *Pressure limiting devices* complying with Section 9.9 *shall* be provided for *compressors* on all systems operating above atmospheric pressure.

Exception to 9.9.1: *Pressure limiting devices* are not required for *listed* factory-sealed systems containing less than 22 lb (10 kg) of Group A1 *refrigerant*.

9.9.2 Setting. *Pressure limiting devices shall* be set in accordance with one the following:

a. For *positive displacement compressors*:

1. When systems are protected by a *high-side pressure relief device*, the *compressor*'s *pressure limiting device shall* be set at or below 90% of the operating pressure for the *high-side pressure relief device*.
2. When systems are not protected by a *high-side pressure relief device*, the *compressor*'s *pressure limiting device shall* be set at or below the system's *high-side design pressure*.

b. For *nonpositive displacement compressors*:

1. When systems are protected by a *high-side pressure relief device*, the *compressor*'s *pressure limiting device shall* be set at or below 90% of the operating pressure for the *high-side pressure relief device.*
2. When systems are protected by a *low-side pressure relief device* that is only subject to *low-side* pressure and is provided with a permanent relief path between the systems' *high side* and *low side*, without intervening valves, the *compressor*'s *pressure limiting device shall* be set at or below the systems' *high-side design pressure*.

9.9.3 Location. *Stop valves shall not* be installed between the *pressure imposing element* and *pressure limiting devices* serving *compressors*.

9.9.4 Emergency Stop. Activation of a *pressure limiting device shall* stop the action of the *pressure imposing element*.

9.10 Refrigerant Piping, Valves, Fittings, and Related Parts

9.10.1 General. *Refrigerant piping*, valves, fittings, and related parts *shall* conform to the requirements of Sections 9.10 through 9.13.

9.10.1.1 *Refrigerant piping*, valves, fittings, and related parts having a maximum internal or external *design pressure* greater than 15 psig (103.4 kPa gage) *shall* be *listed* either individually or as part of an assembly or a system by a *nationally recognized testing laboratory*, or *shall* comply with ASME B31.5 [17] where applicable.

9.10.1.2 Refrigerant Parts in Air Duct. All *refrigerant*-containing parts of a *refrigerating system* and joints located in an *air duct* carrying conditioned air to and from an *occupied space shall* be constructed to withstand a temperature of 700°F (371°C) without leaking into the airstream.

9.10.2 Reuse of Piping Materials on Existing Systems. Reused pipe, fittings, valves, or other materials on existing *refrigerant* systems being renovated or modified *shall* be clean and free of foreign materials and *shall* comply with the requirements of Section 9.10.

9.10.3 Piping Materials Standards. Pipe or tube utilized as *refrigerant piping shall* either be *listed* or demonstrate conformance to one or more of the standards in Table 9-8. The exterior of the *piping shall* be protected from corrosion and degradation.

9.10.3.1 Type F Steel Pipe Limitation. ASTM A53/A53M [18], Type F steel pipe *shall* only be permitted for discharge lines in pressure relief systems.

9.10.4 Pipe Fittings. *Refrigerant* pipe fittings *shall* be *approved* for installation with the *piping* materials to be installed and *shall* demonstrate conformance to one or more of the standards in Table 9-9 or *shall* be *listed* as complying with UL 207 [19].

9.10.4.1 Copper Field Swaged. The minimum and maximum cup depth of field fabricated copper swaged fitting connections *shall* comply with Table 9-10.

9.10.5 Flexible Connectors, Expansion and Vibration Compensators. Flexible connectors and expansion, vibration control devices or other similar components *shall* be *listed* to UL 207 [19] or CSA C22.2 No. 140.3 [20] for the specific *refrigerant* of the *refrigerating system* for which the components are installed, and *shall* have *design pressure* in accordance with Section 9.2.

9.11 Joints and Connections

9.11.1 Approvals. Joints and connections *shall* be either *listed* or an *approved* type. Joints and connections *shall* be tight for the pressure of the *refrigerating system* when tested in accordance with Section 9.13.

9.11.1.1 Joints Between Different Piping Materials. Joints between different *piping* materials *shall* be made with either *listed* or *approved* adapter fittings. Joints between dissimilar metallic *piping* materials *shall* be designed to prevent galvanic action, which includes (but is not limited to) the use of a dielectric fitting or a dielectric union conforming to dielectric tests of ASSE 1079 [21]. Adapter fittings with threaded ends between different materials *shall* be lubricated in accordance with Section 9.11.4.4.

9.11.2 Allowable Joints. The allowable joints for a specific *piping* material *shall* be in accordance with Table 9-11.

9.11.3 Preparation of Pipe Ends. Pipe *shall* be cut square, reamed, and chamfered and *shall* be free of burrs and obstructions. Pipe ends *shall not* be undercut to reduce pipe wall below the minimum thickness as required for the application.

Table 9-8 Refrigerant Piping Materials

Piping Material	Standard
Aluminum tube	ASTM B210/B210M [22], ASTM B491/B491M[23]
Brass (copper alloy) pipe	ASTM B43 [24]
Copper pipe	ASTM B42 [25], ASTM B302 [26]
Copper tube	ASTM B68 [27], ASTM B75 [28], ASTM B88 [29], ASTM B280 [30], ASTM B819 [31]
Copper linesets	ASTM B1003 [32], ASTM B280 [30]
Stainless steel pipe	ASTM A312/A312M [33]
Stainless steel tube	ASTM A269/A269M [34], ASTM A632 [35]
Steel pipe	ASTM A53/A53M [18], ASTM A106/A106M [36], ASTM A333/A333M [37]
Steel tube	ASTM A254/A254M [38], ASTM A334/A334M [39]

Table 9-9 Refrigerant Pipe Fittings

Fitting Material	Standard
Aluminum	ASTM B361 [40], ASME B16.52 [41]
Brass (copper alloy)	ASME B16.15 [42], ASME B16.24 [43]
Copper	ASME B16.15 [42], ASME B16.18 [44], ASME B16.22 [45], ASME B16.26 [46], ASME B16.50 [47]
Stainless steel	ASTM A403/A403M [48], ASME B16.11 [49]
Steel	ASTM A105/A105M [50], ASTM A181/A181M [51], ASTM A193/A193M [52], ASTM A234/A234M [53], ASTM A420/A420M [54], ASTM A707/A707M [55]

Table 9-10 Copper Swaged Cup Depths

Nominal Fitting Size		Brazed Cup Depths				Solder Cup Depths	
		Minimum		Maximum		Minimum	
in.	mm	in.	mm	in.	mm	in.	mm
1/8	6	0.15	3.81	0.23	5.84	0.25	6,4
3/16	7	0.16	4.06	0.24	6.10	0.31	7.9
1/4	8	0.17	4.32	0.26	6.60	0.31	7.9
3/8	10	0.20	5.08	0.30	7.62	0.38	9.7
1/2	15	0.22	5.59	0.33	8.38	0.50	12.7
5/8	18	0.24	6.10	0.36	9.14	0.62	15.7
3/4	20	0.25	6.35	0.38	9.65	0.75	19.1
1	25	0.28	7.11	0.42	10.67	0.91	23.1
1 1/4	32	0.31	7.87	0.47	11.94	0.97	24.6
1 1/2	40	0.34	8.64	0.51	12.95	1.09	27.7
2	50	0.40	10.16	0.60	15.24	1.34	34.0
2 1/2	65	0.47	11.94	0.71	18.03	1.47	37.3
3	80	0.53	13.46	0.80	20.32	1.66	42.2
3 1/2	90	0.59	14.99	0.89	22.61	1.91	48.5
4	100	0.64	16.26	0.96	24.38	2.16	54.9

Table 9-11 Allowable Joints

	Brazed	Mechanical	Flared	Press-Connect	Soldered	Threaded	Welded
Applicable Section	**9.11.4.1**	**9.11.4.2**	**9.11.4.2.1**	**9.11.4.2.2**	**9.11.4.3**	**9.11.4.4**	**9.11.4.5**
Material							
Aluminum tube	●	●		●			●
Brass pipe	●	●		●		●	●
Copper pipe	●	●		●	●	●	●
Copper tube	●	●	●	●	●		
Stainless steel pipe	●	●		●		●	●
Stainless steel tube	●	●	●	●			●
Steel pipe	●	●		●		●	●
Steel tube	●	●	●	●			●

9.11.4 Joint Preparation and Installation. The preparation and installation of brazed, flared, mechanical, press-connect, soldered, threaded, and welded joints *shall* comply with Sections 9.11.4.1 through 9.11.4.5.

9.11.4.1 Brazed Joints. Surfaces of *brazed joints shall* be cleaned prior to brazing. An *approved* flux *shall* be applied where required by the braze filler-metal *manufacturer*. The *piping* being brazed *shall* be purged of air to remove the oxygen and filled with one of the following inert gases: oxygen-free nitrogen, helium, or argon. The *piping* system *shall* be prepurged with an inert gas for a minimum time corresponding to five volume changes through the *piping* system prior to brazing. The prepurge rate *shall* be a minimum velocity of 100 ft/min (30.5 m/min). The inert gas *shall* be directly connected to the tube system being brazed to prevent the entrainment of ambient air. After the prepurge, the inert gas supply *shall* be maintained through the *piping* during the brazing operation at a minimum gage pressure of 1.0 psi (6.9 kPa) and a maximum gage pressure of 3.0 psi (21 kPa). The joint *shall* be brazed with a filler metal conforming to AWS A5.8M/A5.8 [56].

9.11.4.2 Mechanical Joints. *Mechanical joints shall* be installed in accordance with the *manufacturer*'s instructions.

9.11.4.2.1* Flared Joints. Single-flare fittings *shall not* be used in any part of a *refrigerating system* with a *low-side refrigerant* saturation temperature that is less than 35.6°F (2.0°C) under any anticipated normal operating conditions. Flared fittings *shall* be installed in accordance with the *manufacturer*'s instructions. The flared fitting *shall* be used with the tube material *specified* by the fitting *manufacturer*. The flared tube end *shall* be made by a tool designed for that operation.

9.11.4.2.2 Press-Connect Joints. Press-connect joints *shall* be installed in accordance with the *manufacturer*'s instructions.

9.11.4.3 Soldered Joints. Joint surfaces *shall* be cleaned. A flux conforming to ASTM B813 [57] *shall* be applied. The joint *shall* be soldered with a solder conforming to ASTM B32 [58]. Solder joints *shall* be limited to *refrigerant systems* using Group A1 *refrigerant* and *shall* not exceed the pressure rating *specified* in Appendix I of ASME B16.22 [45].

9.11.4.4 Threaded Joints. Threads *shall* conform to ASME B1.20.1 [59], ASME B1.20.3 [60], ASME B1.13M [61], or ASME B1.1 [62]. Thread lubricant, pipe-joint compound, or tape *shall* be applied on the external threads only and *shall* be *approved* for application on the *piping* material.

9.11.4.5 Welded Joints. Welded joints *shall* use qualified and *approved* weld procedure specifications that include operator qualifications, surface preparation requirements, and, when required for the application, the filler-metal specifications.

9.12 Refrigerant Pipe Installation

9.12.1 Piping Location. *Refrigerant piping* fabricated, assembled, installed, or erected on the *refrigerating system*'s *premises shall* comply with the installation location requirements of Sections 9.12.1.1 through 9.12.1.8. *Refrigerant piping* for Group A2L, A2, A3, B2L, B2, and B3 *shall* also comply with the requirements of Section 9.12.2.

9.12.1.1 Minimum Height. Exposed *refrigerant piping* installed in open spaces that afford passage *shall* be not less than 7 ft 3 in. (2.2 m) above the finished floor.

9.12.1.2 Pipe Protection. *Refrigerant piping shall* be located in one or more of the following:

a. Within either the *building elements* or protective enclosure. In concealed locations where aluminum tube, copper tube, or steel tube is installed through holes or notches in studs, joists, or similar members less than 1.5 in. (38 mm) from the nearest edge of the member, the tube *shall* be protected by steel shield plates having a minimum thickness of 0.0575 in. (1.461 mm). Protective steel shield plates *shall* cover the area of the tube where the member is notched or bored, and *shall* extend not less than 2.0 in. (51 mm) above sole plates and below top plates. (***Informative Note:*** Considering ASTM dimensional tolerances, number 16 gage galvanized steel meets the minimum thickness requirement, and number 15 gage plain steel meets the minimum thickness requirement.)
b. More than 7 ft 3 in. (2.21 m) above the finished floor.
c. Inside the building exposed within 6 ft 0 in. (1.83 m) of the *refrigerant* unit or appliance.
d. In a *machinery room* complying with Section 8.9 and, as applicable, Section 8.10 or 8.11.
e. In an attic or crawl space, aluminum tube, copper tube, or steel tube *shall* be protected in accordance with Item (a) when located within 1.5 in. (38 mm) from the nearest edge of the member.
f. Outside the building,
   1. protected from damage from the weather, including (but not limited to) hail, ice, and snow loads,
   2. protected from damage within the expected foot or traffic path, and
   3. if underground, installed not less than 8 in. (200 mm) below finished grade and protected against corrosion.

9.12.1.3 Prohibited Locations. *Refrigerant piping shall not* be installed in any of the following locations:

a. Exposed within a *fire-resistance-rated exit access corridor*
b. Exposed within an interior exit stairway
c. Interior exit ramp
d. Exit passageway
e. Elevator, dumbwaiter, or other shaft containing a moving object

9.12.1.4 Piping in Concrete Floors. *Refrigerant piping* installed in concrete floors *shall* be encased in *pipe duct*. The *piping shall* be protected to prevent damage from vibration, stress, and corrosion.

9.12.1.5 Refrigerant Pipe Shafts. *Refrigerant piping* that penetrates two or more floor/ceiling assemblies *shall* be enclosed in a *fire-resistance-rated* shaft enclosure. The *fire-resistance-rated* shaft enclosure *shall* comply with the requirements of the *building code*. Other building utilities or *piping* systems *shall* be allowed in the *refrigerant piping* shaft.

9.12.1.5.1 Shaft Alternative. A shaft enclosure *shall not* be required for the *refrigerant piping* for any of the following *refrigerating systems*:

a. Systems using R-718 (water) *refrigerant*
b. *Piping* in a high-probability system where the *refrigerant* concentration does not exceed the amounts shown in ASHRAE Standard 34 [3], Table 4-1 or 4-2, for the smallest *occupied space* through which the *piping* passes
c. *Piping* located on the exterior of the building where vented to the outdoors

9.12.1.6 Exposed Piping Surface Temperature. Exposed *piping* with ready access to nonauthorized personnel having temperatures greater than 120°F (49°C) or less than +5°F (–15°C) *shall* be protected from contact or have thermal insulation that limits the exposed insulation surface temperature to a range of +5°F (–15°C) to 120°F (49°C).

9.12.1.7 Pipe Support. *Piping shall* be supported in accordance with ANSI/MSS SP-58 [63].

9.12.1.8 Pipe Identification. *Refrigerant piping* located in areas other than the room or space where the refrigerating equipment is located *shall* be identified in accordance with ANSI/ASME A13.1 [9]. The pipe identification *shall* be located at intervals not exceeding 20 ft (6.1 m) on the *refrigerant piping* or pipe insulation. The minimum height of lettering of the identification label *shall* be 0.50 in. (12.7 mm). The identification *shall* indicate the *refrigerant designation* and safety group classification of *refrigerant* used in the *piping* system.

a. For Group A2L and B2L *refrigerants,* the identification *shall* also include the following statement: “WARNING—Risk of Fire. Flammable Refrigerant.”
b. For Group A2, A3, B2, and B3 *refrigerants* the identification *shall* also include the following statement: “DANGER— Risk of Fire or Explosion. Flammable Refrigerant.”

Table 9-12 Shaft Ventilation Velocity

Shaft Cross-Sectional Area, *A*		Minimum Ventilation Velocity, *V*	
in.^{2}	m^2	ft/min	m/min
$A \le 20$	$A \le 0.0129$	$100 \le V$	$30.5 \le V$
$20 < A \le 250$	$0.0129 < A \le 0.161$	$200 \le V$	$61 \le V$
$250 < A \le 1250$	$0.161 < A \le 0.806$	$300 \le V$	$91 \le V$
$1250 < A$	$0.806 < A$	$400 \le V$	$122 \le V$

c. For any Group B *refrigerant*, the identification *shall* also include the following statement: "DANGER—Toxic Refrigerant."

9.12.2 Installation Requirements for Flammable Refrigerants. *Refrigerant piping* for *refrigerating systems* using Group A2L, A2, A3, B2L, B2, or B3 *refrigerant shall* comply with the requirements of Section 9.12.2.1 through 9.12.2.2.

9.12.2.1 Pipe Protection. In addition to the requirements in Section 9.12.1.2, aluminum tube, copper tube, or steel tube for Group A2, A3, B2L, B2, and B3 *refrigerants* located in concealed locations where tubing is installed in studs, joists, rafters, or similar member spaces and located less than 1.50 in. (38 mm) from the nearest edge of the member, *shall* be continuously protected by shield plates. Protective steel shield plates having a minimum thickness of 0.0575 in. (1.461 mm) *shall* cover the area of the tube and *shall* extend a minimum of 2.0 in. (51 mm) beyond the outside edge of the tube.

Informative Note: Considering ASTM dimensional tolerances, number 16 gage galvanized steel meets the minimum thickness requirement, and number 15 gage plain steel meets the minimum thickness requirement.

9.12.2.2 Shaft Ventilation. *Refrigerant* pipe shafts with systems using only Group A2L or B2L *refrigerants shall* be naturally or mechanically ventilated. *Refrigerant* pipe shafts with one or more systems using any Group A2, A3, B2, or B3 *refrigerant shall* be continuously mechanically ventilated and *shall* include a *refrigerant detector*. The shaft ventilation exhaust outlet *shall* comply with the discharge location requirement *specified* in Section 9.7.8.2.

a. Naturally ventilated shafts *shall* have a minimum of a 4.0 in. (102 mm) diameter pipe, *duct*, or conduit that connects at the lowest point of the shaft and connects to the outdoors. The pipe, *duct*, or conduit *shall* be level or pitched down to the outdoors. A *makeup air* opening *shall* be provided at the top of the shaft.
b. When active, mechanically ventilated shafts *shall* have a minimum air velocity in accordance with Table 9-12. *Makeup air shall* be provided at the inlet to the shaft for mechanically ventilated shafts. The mechanical ventilation *shall* either be continuously operated or, for pipe shafts containing only systems using Group A2L or B2L *refrigerants*, activated by a *refrigerant detector*. *Refrigerant* pipe shafts utilizing a *refrigerant detector shall* have a set point not exceeding the *occupational exposure limit* (*OEL*) of the *refrigerant*. The detector, or a sampling tube that draws air to the detector, *shall* be located in an area where *refrigerant* from a leak will concentrate.
c. The shaft *shall not* be required to be ventilated for double-wall *refrigerant* pipe where the interstitial space of the double-wall pipe is vented to the outdoors in accordance with the discharge location requirements *specified* in Section 9.7.8.2.

9.12.3 Refrigerant Pipe Penetrations. In other than *industrial occupancies*, the annular space between the outside of a *refrigerant* pipe and the inside of a pipe sleeve or opening in a building envelope, wall, floor, or ceiling assembly penetrated by a *refrigerant* pipe *shall* be sealed in an *approved* manner with caulking material, foam sealant, or closed with a gasketing system. The caulking material, foam sealant, or gasketing system *shall* be designed for the conditions at the penetration location and *shall* be compatible with the pipe, sleeve, and building materials in contact with the sealing materials. *Refrigerant* pipes penetrating required *fire-resistance-rated* assemblies or membranes of *fire-resistance-rated* assemblies *shall* be sealed or closed in accordance with the *building code*.

9.12.4 Stress and Strain. *Refrigerant piping shall* be installed so as to prevent strains and stresses that exceed the structural strength of the pipe. Where necessary, provisions *shall* be made to protect *piping* from damage resulting from vibration, expansion, contraction, and structural settlement.

9.12.5 Stop Valves. *Stop valves shall* be installed in *specified* locations when required in accordance with Section 9.12.5.1 and 9.12.5.2. *Stop valves shall* be identified in accordance with Section 9.12.5.3. This requirement *shall not* apply to the following:

a. Systems that have a *refrigerant* pump-out function capable of storing the entire *refrigerant* charge in a receiver or heat exchanger
b. Systems that are equipped with provisions for pump out of the *refrigerant* using either portable or permanently installed *refrigerant* recovery equipment
c. *Self-contained listed systems*

9.12.5.1 Refrigerating Systems Containing More Than 6.6 lb (3.0 kg) of Refrigerant. *Stop valves shall* be installed in the following locations on *refrigerating systems* containing more than 6.6 lb (3.0 kg) of *refrigerant*:

a. The suction inlet of each *compressor*, *compressor unit*, or *condensing unit*
b. The discharge outlet of each *compressor*, *compressor unit*, or *condensing unit*
c. The outlet of each *liquid receiver*

9.12.5.2 Refrigerating Systems Containing More Than 110 lb (50 kg) of Refrigerant. In addition to *stop valves* required by Section 9.12.5.1, systems containing more than 110 lb (50 kg) of *refrigerant shall* have *stop valves* installed in the following locations:

a. Each inlet of each *liquid receiver*
b. Each inlet and each outlet of each *condenser* when more than one *condenser* is used in parallel

Stop valves shall not be required on the inlet of a receiver in a *condensing unit* or on the inlet of a receiver that is an integral part of the *condenser* or systems utilizing *nonpositive displacement compressors*.

9.12.5.3 Identification. *Stop valves shall* be *labeled* if the components regulated by the valve are not in view at the valve location. Numbering or lettering labels *shall* be a minimum of 0.50 in. (12.7 mm) in height. When valve numbering or lettering systems are used, the key *shall* be located in accordance with the requirements of the AHJ.

9.13 Refrigerating System Testing

9.13.1 General. *Refrigerating systems* fabricated, assembled, or erected on the *premises shall* be tested to the applicable requirements of this section. Tests *shall* include both the *high sides* and *low sides* of each system. System components that have been strength tested under pressure by the component *manufacturer*, fabricator, or assembler are not required to be strength tested again on the *premises* unless modified or repaired. *Listed* equipment not modified or repaired *shall not* be required to be strength tested on the *premises*. After installation and before being placed in operation, system components not previously strength tested *shall* be strength tested under pressure in accordance with Section 9.13.5. After successful completion of the required strength tests and before being placed in operation, system components and field installed connections *shall* be leak tested for tightness in accordance with Section 9.13.6.

Informative Note: System components that are strength tested prior to field assembly include (but are not limited to), *compressors*, *condensers*, precharged linesets, *pressure vessels*, *evaporators*, *refrigerant* bulk storage tanks, safety devices, pressure gages, and control mechanisms.

9.13.2* Exposure of Refrigerant Piping System. *Refrigerant piping* and joints installed on the *premises shall* be exposed for visual inspection and testing prior to being covered or enclosed.

9.13.3 Test Gases. The medium used for pressure testing the *refrigerant* system *shall* be one of the following inert gases: oxygen-free nitrogen, helium, argon, or premixed nonflammable oxygen-free nitrogen with a tracer gas of hydrogen or helium. For R-744 *refrigerant* systems, carbon dioxide *shall* be allowed as the test medium. For R-718 *refrigerant* systems, water *shall* be allowed as the test medium.

9.13.3.1 Test Gases not Permitted. Oxygen, air, *refrigerants* other than those identified in Section 9.13.3, combustible gases, and mixtures containing such gases *shall not* be used as the pressure test medium.

9.13.4 Field Test Apparatus. The means used to pressurize the *refrigerant piping* system *shall* have either a *pressure limiting device* or a pressure reducing device and a test pressure measuring device on the outlet side. The test pressure measuring device *shall* have an accuracy of ±3% or less of the test pressure and *shall* have a resolution of 3% or less of the test pressure.

9.13.5 Piping System Strength Test. *Refrigerating system* components and *refrigerant piping shall* be tested in accordance with ASME B31.5 [17] or this section. Separate tests for isolated portions of the system are permitted, provided that all required portions are tested at least once. Pressurize with test gas for a minimum of ten (10) minutes to not less than the lower of (a) the lowest *design pressure* for any system component or (b) the lowest value of *set pressure* for any *pressure relief devices* in the system. The *design pressures* for determination of test pressure *shall* be the pressure identified on the label nameplate of the *condensing unit*, *compressor*, *compressor unit*, *pressure vessel*, or other system component with a nameplate. A passing test result *shall* have no rupture or structural failure of any system component or *refrigerant piping*.

Table 9-13 Duration of Leak Test

Leak Test	Pipe Length, L ft	Pipe Length, L m	Maximum Nominal Pipe Size NPS, in.	Maximum Nominal Pipe Size DN, mm	Minimum Period of Test hours
Pressure test	$L \le 100$	$L \le 30$	NPS ≤ 3/4	DN ≤ 20	0.25
			3/4 < NPS ≤ 3	20 < DN ≤ 75	1.0
			3 < NPS	75 < DN	24
	$100 < L \le 200$	$30 < L \le 61$	NPS ≤ 3	DN ≤ 75	1.0
			3 < NPS	75 < DN	24
	$200 < L$	$61 < L$	Any	Any	24
Vacuum test	$L \le 100$	$L \le 30$	NPS ≤ 3/4	DN ≤ 20	1.0
			3/4 < NPS ≤ 3	20 < DN ≤ 75	8.0
			3 < NPS	75 < DN	24
	$100 < L \le 200$	$30 < L \le 61$	NPS ≤ 3	DN ≤ 75	8.0
			3 < NPS	75 < DN	24
	$200 < L$	$61 < L$	Any	Any	24

Informative Note: The maximum nominal pipe size is the largest interconnecting field *piping* installed.

Pressure relief devices may need to be temporarily removed and replaced with plugs during the strength test.

Informative Note: Stored energy due to pressure is hazardous, and sudden release of that energy can cause serious damage. Take appropriate safety measures to protect life, limb, health, and property in the event of a test failure.

9.13.6 Leakage Test. The leak test *shall* be in accordance with ASHRAE Standard 147 [64], ASME B31.5 [17], or this section.

9.13.6.1 Leak Testing Protocol. After the time to complete the strength test, continue to pressure test in accordance with Section 9.13.5 for a minimum period as *specified* in Table 9-13. The system *shall* show no loss in pressure on the pressure measuring device during the pressure test. Calculation of the pressure differential based on a change in ambient temperature *shall* be permitted. A vacuum of 0.0097 psi (67 Pa) absolute or lower *shall* be achieved (0.0197. in Hg [32°F]; 500 microns Hg [0°C]; 500 microns). After achieving a vacuum, the system *shall* be isolated from the vacuum pump. The system pressure *shall not* rise above 0.029 psi (200 Pa) absolute (0.059 in. Hg [32°F]; 1500 microns Hg [0°C]; 1500 microns) for a minimum period as *specified* in Table 9-13.

Informative Note: The vacuum pump should gradually create a vacuum to avoid freezing of any moisture in the *piping* system.

9.13.7 Contractor or Engineer Declaration. The installing contractor or registered design professional of record *shall* issue a certificate of test, verifying strength test in accordance with Section 9.13.5 and leakage test in accordance with Section 9.13.6, to the AHJ for all systems containing 55 lb (25 kg) or more of *refrigerant*. The certificate *shall* give the test date, photograph of the pressure gage at the test pressure, *refrigerant designation*, test medium, and the field test pressure applied to the *high side* and the *low side* of the system. The certification of test *shall* be signed by the installing contractor or registered design professional and *shall* be made part of the public record.

9.14 Components Other than Pressure Vessels and Piping

9.14.1 Every pressure containing component of a *refrigerating system*, other than *pressure vessels*, *piping*, pressure gages, and control mechanisms, *shall* be *listed* either individually or as part of a complete *refrigerating system* or a subassembly by a *nationally recognized testing laboratory*, or *shall* be designed, constructed, and assembled to have an *ultimate strength* sufficient to withstand 3.0 times the *design pressure* for which it is rated.

Exception to 9.14.1: Water-side components designed to operate at a temperature not exceeding 210°F (99°C) *shall* be exempted from the rules of *ASME Boiler and Pressure Vessel Code* [15], Section VIII and *shall* be designed, constructed, and assembled to have an *ultimate strength* to withstand 150 psig (1034 kPa) or 2.0 times the *design pressure* for which it is rated, whichever is greater.

9.14.2 Liquid-level-gage glass columns *shall* have automatic closing shutoff valves. All such glass columns *shall* be protected against external damage and properly supported.

Exception to 9.14.2: Liquid-level-gage glasses of the bull's-eye type.

9.14.3 When a pressure gage is permanently installed on the *high side* of a *refrigerating system*, its dial *shall* be graduated to at least 1.2 times the *design pressure*.

9.14.4 *Liquid receivers*, if used, or parts of a system designed to receive the *refrigerant* charge during pumpdown *shall* have sufficient capacity to receive the *pumpdown charge*. The liquid *shall not* occupy more than 90% of the volume when the temperature of the *refrigerant* is 90°F (32°C).

Informative Note: The receiver volume is not required to contain the total system charge but is required to contain the amount being transferred. If the environmental temperature is expected to rise above 122°F (50°C), the designer *shall* account for the specific expansion characteristics of the *refrigerant*.

9.15 Service Provisions

9.15.1 All serviceable components of *refrigerating systems shall* be provided with safe access.

9.15.2 *Condensing units* or *compressor units* with enclosures *shall* be provided with safe access without the need to climb over or remove any obstacles or to use portable access devices to get to the equipment.

9.15.3 All systems *shall* have provisions to handle the *refrigerant* charge for service purposes. When required, there *shall* be liquid and vapor transfer valves, a transfer *compressor* or pump, and *refrigerant* storage tanks or appropriate valved connections for removal by a reclaim, recycle, or recovery device.

9.16 Factory Tests

9.16.1 All *refrigerant*-containing parts or *unit systems shall* be tested and proved tight by the *manufacturer* at not less than the *design pressure* for which they are rated. *Pressure vessels shall* be tested in accordance with Section 9.3.

9.16.1.1 Testing Procedure. Tests *shall* be performed with dry nitrogen or another nonflammable, nonreactive, dried gas. Oxygen, air, or mixtures containing them *shall not* be used. The means used to build up the test pressure *shall* have either a *pressure limiting device* or a pressure reducing device and a gage on the outlet side. The *pressure relief device shall* be set above the test pressure but low enough to prevent permanent deformation of the system's components.

Exceptions to 9.16.1.1:

1. Mixtures of dry nitrogen, inert gases, and Class 1 *refrigerants* [3] are allowed for factory tests.
2. Mixtures of dry nitrogen, inert gases, or a combination of these with Class 2L, Class 2, or Class 3 *refrigerants* [3] in concentrations not exceeding the lesser of a *refrigerant* weight fraction (mass fraction) of 5% or 25% of the *lower flammability limit* (*LFL*) are allowed for factory tests.
3. Compressed air without added *refrigerant* is allowed for factory tests, provided the system is subsequently evacuated to less than 1000 microns (132 Pa) before charging with *refrigerant*. The required evacuation level is atmospheric pressure for systems using R-718 (water) or R-744 (carbon dioxide) as the *refrigerant*.

9.16.2 The test pressure applied to the *high side* of each factory-assembled *refrigerating system shall* be at least equal to the *design pressure* of the *high side*. The test pressure applied to the *low side* of each factory-assembled *refrigerating system shall* be at least equal to the *design pressure* of the *low side*.

The pressure test on the complete unit *shall not* be conducted at the *low-side design pressure* per Section 9.2 unless the final assembly connections are made per ASME B31.5 [17]. In this case, parts *shall* be individually tested by either the unit *manufacturer* or the *manufacturer* of the part at not less than the *high-side design pressure*.

9.16.3 Units with a *design pressure* of 15 psig (103.4 kPa gage) or less *shall* be tested at a pressure not less than 1.33 times the *design pressure* and *shall* be proved leak-tight at not less than the *low-side design pressure*.

9.17 Nameplate. Each *unit system* and each separate *condensing unit*, *compressor*, or *compressor unit* sold for field assembly in a *refrigerating system shall* carry a nameplate marked with the *manufacturer*'s name, nationally registered trademark or trade name, identification number, *design pressures*, and *refrigerant* for which it is designed. The *refrigerant shall* be designated by the *refrigerant* number ("R-" number) as shown in ASHRAE Standard 34 [3], Table 4-1 or 4-2.

10. GENERAL REQUIREMENTS

10.1 Signs and Identification

10.1.1 Installation Identification. Each *refrigerating system* erected on the *premises shall* be provided with a legible permanent sign, securely attached and easily accessible, indicating

a. the name and address of the installer,
b. the *refrigerant* number and amount of *refrigerant*,
c. the lubricant identity and amount, and
d. the field test pressure applied.

10.1.2 Changes in Refrigerant or Lubricant. When the kind of *refrigerant* or lubricant is changed as provided in Section 7.5.1.8, the signs required by Sections 10.1.1 and 9.12.1.8 *shall* be replaced, or added if not present, to identify the *refrigerant* and lubricant used.

10.1.3 Each entrance to a refrigerating *machinery room shall* be provided with a legible permanent sign, securely attached and easily accessible, reading "Machinery Room—Authorized Personnel Only." The sign *shall* further communicate that entry is forbidden except by those personnel trained in the emergency procedures required by Section 10.6 when the *refrigerant* alarm, required by Section 8.9.5, has been activated.

10.2 Charging, Withdrawal, and Disposition of Refrigerants. No service *containers shall* be left connected to a system except while charging or withdrawing *refrigerant*. *Refrigerants* withdrawn from *refrigerating systems shall* be transferred to *approved containers* only. Except for discharge of *pressure relief devices* and *fusible plugs*, incidental releases due to leaks, purging of noncondensables, draining oil, and other routine operating or maintenance procedures, no *refrigerant shall* be discharged to the atmosphere or to locations such as a sewer, river, stream, or lake.

10.2.1 Refrigerant Access. *Refrigerant* circuit access ports located outdoors *shall* be secured to prevent unauthorized access.

10.3 Containers. *Containers* used for *refrigerants* withdrawn from a *refrigerating system shall* be as prescribed in the pertinent regulations of the U.S. Department of Transportation and *shall* be carefully weighed each time they are used for this purpose, and *containers shall not* be filled in excess of the permissible filling weight.

10.4 Storing Refrigerant. The total amount of *refrigerant* stored in a *machinery room* in all *containers* not provided with relief valves and *piping* in accordance with Section 9.4 *shall not* exceed 330 lb (150 kg). *Refrigerant shall* be stored in *approved* storage *containers*. Additional quantities of *refrigerant shall* be stored in an *approved* storage facility.

10.5 Maintenance. *Refrigerating systems shall* be maintained by the user in a clean condition, free from accumulations of oily dirt, waste, and other debris, and *shall* be kept accessible at all times.

10.5.1 Stop Valves. *Stop valves* connecting *refrigerant*-containing parts to atmosphere during shipping, testing, operating, servicing, or standby conditions *shall* be capped, plugged, blanked, or locked closed when not in use.

10.5.2 Calibration of Pressure Measuring Equipment. Pressure measuring equipment *shall* be checked for accuracy and calibrated prior to test and immediately after every occasion of unusually high (full scale) pressure, either by comparison with master gages or a dead-weight pressure gage tester, over the operating range of the equipment.

10.5.3 Periodic Tests. Detectors, alarms, and mechanical ventilating systems *shall* be tested in accordance with *manufacturers*' specifications and the requirements of the authority having jurisdiction (AHJ).

10.6 Responsibility for Operation and Emergency Shutdown. It *shall* be the duty of the person in charge of the *premises* on which a *refrigerating system* containing more than 55 lb (25 kg) of *refrigerant* is installed to provide a schematic drawing or panel giving directions for the operation of the system at a location that is convenient to the operators of the equipment.

Emergency shutdown procedures, including precautions to be observed in case of a breakdown or leak, *shall* be displayed on a conspicuous card located as near as possible to the *refrigerant compressor*. These precautions *shall* address

a. instructions for shutting down the system in case of emergency;
b. the name, address, and day and night telephone numbers for obtaining service; and
c. the names, addresses, and telephone numbers of all corporate, local, state, and federal agencies to be contacted as required in the event of a reportable incident.

When a refrigerating *machinery room* is used, the emergency procedures *shall* be posted outside the room, immediately adjacent to each door.

The emergency procedures *shall* forbid entry into the refrigerating *machinery room* when the *refrigerant* alarm required by Section 8.9.5 has been activated, except by persons provided with the appropriate respiratory and other protective equipment and trained in accordance with jurisdictional requirements.

11. PRECEDENCE WITH CONFLICTING REQUIREMENTS

Where there is a conflict between this standard and local building, electrical, fire, mechanical, or other adopted codes, their provisions *shall* take precedence unless otherwise stated in those codes. No provision in this standard *shall* be deemed to restrict the authority of local building, electrical, fire, mechanical, or other officials from approving plans, performing inspections, allowing use of alternative methods and/or materials, or otherwise enforcing adopted codes.

12. LISTED EQUIPMENT

Equipment *listed* by a *nationally recognized testing laboratory*, and identified as part of the listing as being in conformance with this standard, is deemed to meet the design, construction of equipment, and factory test requirement sections of this standard for the *refrigerant* or *refrigerants* for which the equipment was designed.

13. NORMATIVE REFERENCES

This section contains a complete list of normative references. A complete list of references that are solely informative is included in *Informative Appendix* B. References in this standard are numbered in the order in which they appear in the document, so the numbers for the informative references are shown for the convenience of the user.

1. See *Informative Appendix* B, "Informative References."
2. ASHRAE. 2022. ANSI/ASHRAE Standard 15.2, *Safety Standard for Refrigeration Systems in Residential Applications*. Peachtree Corners, GA: ASHRAE.
3. ASHRAE. 2019. ANSI/ASHRAE Standard 34, *Designation and Safety Classification of Refrigerants*. Peachtree Corners, GA: ASHRAE.
4. NFPA. 2020. NFPA 70, *National Electrical Code*®. Quincy, MA: National Fire Protection Association.
5. UL. 2019. ANSI/UL 60335-2-40, *Standard for Household and Similar Electrical Appliances—Safety—Part 2-40: Particular Requirements for Electrical Heat Pumps, Air-Conditioners and Dehumidifiers*. Northbrook, IL: UL, LLC.
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9. ASME. 2015. ANSI/ASME A13.1, *Scheme for the Identification of Piping Systems*. New York: American Society of Mechanical Engineers.
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14. UL. 2015. UL 1995, *Heating and Cooling Equipment*, 5th Edition. Northbrook, IL: UL LLC.
15. ASME. 2019. *Boiler and Pressure Vessel Code*. New York: American Society of Mechanical Engineers.
16. See *Informative Appendix* B, "Informative References."
17. ASME. 2016. ANSI//ASME B31.5, *Refrigeration Piping and Heat Transfer Components*. New York: American Society of Mechanical Engineers.

18. ASTM. 2018. ASTM A53/A53M, *Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless*. West Conshohocken, PA: American Society for Testing and Materials.
19. UL. 2014. UL 207, *Standard for Refrigerant-Containing Components and Accessories, Nonelectrical—Eighth Edition*. Northbrook, IL: Underwriters Laboratories, Inc.
20. CSA. 2015 (RA2020). CSA 22.2 No. 140.3:15, Refrigerant-containing components for use in electrical equipment. Toronto, Canada: CSA Group.
21. ASSE. 2012. ASSE 1079, *Performance Requirements for Dielectric Pipe Unions*. Mokena, IL: American Society of Sanitary Engineering.
22. ASTM. 2019. ASTM B210/B210M, *Standard Specification for Aluminum and Aluminum-Alloy Drawn Seamless Tubes*. West Conshohocken, PA: American Society for Testing and Materials.
23. ASTM. 2015. ASTM B491/B491M, *Standard Specification for Aluminum and Aluminum-Alloy Extruded Round Tubes for General-Purpose Applications*. West Conshohocken, PA: American Society for Testing and Materials.
24. ASTM. 2015. ASTM B43, *Standard Specification for Seamless Red Brass Pipe, Standard Sizes*. West Conshohocken, PA: American Society for Testing and Materials.
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43. ASME. 2016. ANSI/ASME B16.24, *Cast Copper Alloy Pipe Flanges, Flanged Fittings, and Valves: Classes 150, 300, 600, 900, 1500 and 2500*. New York, NY: American Society of Mechanical Engineers.
44. ASME. 2018. ANSI/ASME B16.18, *Cast Copper Alloy Solder Joint Pressure Fittings*. New York, NY: American Society of Mechanical Engineers.
45. ASME. 2018. ANSI/ASME B16.22, *Wrought Copper and Copper Alloy Solder-Joint Pressure Fittings*. New York, NY: American Society of Mechanical Engineers.
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47. ASME. 2013. ANSI/ASME B16.50, *Wrought Copper and Copper Alloy Brazed-Joint Pressure Fittings*. New York, NY: American Society of Mechanical Engineers.
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63. MSS. 2018. MSS SP-58, *Pipe Hangers and Supports—Materials, Design, Manufacture, Selection, Application, and Installation*. Vienna, VA: Manufacturers Standardization Society.
64. ASHRAE. 2019. ANSI/ASHRAE Standard 147, *Reducing the Release of Halogenated Refrigerants from Refrigerating and Air-Conditioning Equipment and Systems*. Peachtree Corners, GA: ASHRAE.
65. See *Informative Appendix* B, "Informative References."
66. See *Informative Appendix* B, "Informative References."
67. See *Informative Appendix* B, "Informative References."

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INFORMATIVE APPENDIX A
EXPLANATORY MATERIAL

Sections of the standard with associated explanatory information in this appendix are marked with an asterisk "*" after the section number.

Section 3.1

nationally recognized testing laboratory (NRTL): For the U.S., the Occupational Safety and Health Administration (OSHA) is one such national body. Refer to 29 CFR 1910.7 [65].

refrigerant detection system: The product safety standard addresses both *refrigerant detection systems* and leak detection systems. In the product safety standard, a leak detection system is defined as "a sensing system which responds to *refrigerant* leaking from a *refrigerating system*." A leak detection system may include gas sensing, ultrasonic, or other such methods that meet the standards UL 60335-2-40 [5]/CSA C22.2 No. 60335-2-40 [6] or UL 60335-2-89 [7]/CSA C22.2 No. 60335-2-89 [8].

refrigerant detector: "*Refrigerant* sensor" is another term for *refrigerant detector*. A *refrigerant* sensor is a sensing element combined with electronic circuitry that provides a digital output or an analog signal output that corresponds to the sensed *refrigerant* gas concentration.

Section 5.3.1

The intent of notifying the owner or owner's agent is to ensure that the owner of the building is aware of the change and can address any consequences to the building or occupancy that might be tied to the change of *refrigerant*. The owner notification can be made by the designer, contractor, installer, or any other party involved in the proposed *refrigerant* change.

Section 7.2

The *effective dispersal volume* used to calculate compliance with the *EDVC* is based on the volume into which *refrigerant* is expected to disperse in the event of a *refrigerant* leak. Section 7.2, "Volume Calculations," describes how to select the appropriate spaces to be included when determining the dispersal volume, either individual or *connected spaces*, and the smallest space where *refrigerant* from a single leak event might concentrate establishes the *EDVC* that is used in Section 7.3, "*Refrigerant* System Charge Limits."

Section 7.3.2

When a refrigeration system does not have a *refrigerant detector*, there will not necessarily be circulation (or ventilation) airflow. Thus, systems in accordance with Section 7.3.2 (no *refrigerant* detection and/or no continuous airflow), must use the worst-case distribution of leaked *refrigerant*.

Section 7.3.3

For refrigeration systems that do have a *refrigerant detector* but do not have ventilation, the airflow will mix leaked *refrigerant* throughout the spaces connected to ductwork; therefore, the volume of all rooms connected by ductwork is used.

Section 7.3.4

For refrigeration systems with *refrigerant* detection and ventilation, circulation will distribute leaked *refrigerant* throughout the rooms connected to the ductwork as well as locations connected to the ventilation.

Section 7.4.3

Use of any Class 2 or Class 3 flammable *refrigerants* in a *machinery room* will trigger the special requirements of Section 8.10 in addition to the general requirements of Section 8.9, regardless of whether or not the *machinery room* also makes use of any Class 2L flammable *refrigerants* or any Class 1 *refrigerants* with no flame propagation. Use of Class 2L flammable *refrigerants* in a *machinery room* will trigger the special requirements of Section 8.11 in addition to the general requirements of Sections 8.9.1 through 8.9.4, regardless of whether the *machinery room* also makes use of any Class 1 *refrigerants*.

Section 7.6.1.1

Equation 7-8: In the equation, *LFL* is *specified* as lb/ft^3 (kg/m^3), while ASHRAE Standard 34 [3] specifies *LFL* in Table 4-1 and Table 4-2 as $lb/1000\ ft^3$ (g/m^3). Appropriate conversion is necessary. The user should refer to addenda to the most recent published edition of ASHRAE Standard 34 for the most current values of *LFL*.

Continuous Air Circulation: Continuous *air circulation* will be performed by the *listed* equipment. The airflow will be detected continuously or monitored continuously. As *specified* by the product safety standard, within ten seconds of the event that the airflow is reduced below a certain quantity, the user is warned and *compressor* operation may be disabled. Continuous *air circulation* by means other than the *listed* equipment is not acceptable. The minimum continuous *air circulation* airflow rate is established in the product safety standard and does not require the fan to operate at full speed.

Section 7.6.1.2

Opening: Cumulative openings smaller than 0.8 $in.^2$ (5 cm^2) and openings with a single dimension of not more than 0.004 in. (0.1 mm) are not considered as openings from where leaking *refrigerant* can escape.

Tables 7-1 and 7-2: The numbers in these table are derived from the product safety standards UL 60335-2-40 [5]/CSA C22.2 No. 60335-2-40 [6]. For R-32, this is the maximum of 4.0 lb (1.8 kg), which is m_1 *refrigerant* quantity, and the dispersal volume calculated *refrigerant* quantity. The dispersal volume calculated *refrigerant* quantity is the lower of a fixed percentage of total dispersal volume and the quadratic equation of Clause GG.2 of the product safety standard.

Section 7.6.2.3

The requirements of Section 7.6.2.3 are intended to harmonize Standard 15 with the requirements of ASHRAE Standard 15.2, *Safety Standard for Refrigeration Systems in Residential Applications* and UL 60335-2-40 [5]/CSA C22.2 No. 60335-2-40 [6]. A *refrigerant detection system* of equipment *listed* to UL 60335-2-40/CSA C22.2 No. 60335-2-40 meets the requirements of this section.

Section 7.6.2.4

Validation of meeting requirements (a) to (c) and (e) to (g) can be accomplished by verifying that the *refrigerant detector* meets the requirements of UL 60335-2-40 [5]/CSA C22.2 No. 60335-2-40 [6], Annex LL.

Section 7.6.2.5

The *manufacturer*'s instructions can be reviewed to determine which of these requirements are performed by the equipment.

Section 7.6.2.5(c): The ventilation requirements in Standard 15 are different from those in ASHRAE Standard 62.1, *Ventilation and Acceptable Indoor Air Quality*, in that they are not intended to control indoor air quality. Rather, ventilation in Standard 15 serves as a safety mitigation method for reducing the *refrigerant* concentration within a space.

Section 7.6.2.5(e): *safety shutoff valves* located on the *low side* of the refrigeration system may remain open during pumpdown to reduce *releasable refrigerant charge*. The pumpdown cycle should not reduce the *low-side* pressure below atmospheric pressure, and the *safety shutoff valves* must close at the end of the pumpdown cycle to be considered to meet this requirement.

Section 7.6.2.5(f): Potential ignition sources include those items that are defined in UL 60335-2-40 [5]/CSA C22.2 No. 60335-2-40 [6], including arcs and sparks from electrical components in Clause 22.115 and hot surfaces and flames in Clause 22.117.

Section 7.6.3.3

The volumetric airflow rate can be determined from the airflow tables supplied in the instructions and the static pressure in the ductwork. If this is not available, use field measurement. The average airflow velocity can then be calculated as the volumetric airflow rate through the *duct* containing the hot surface divided by the cross-sectional area of ductwork in which the heating device is located.

Section 7.6.4

Note that in Equations 7-11a and 7-11b, *LFL* is *specified* as lb/ft^3 (kg/m^3), while ASHRAE Standard 34 [3] specifies *LFL* in Table 4-1 and Table 4-2 as lb/1000 ft^3 (g/m^3). Appropriate conversion is necessary. The user should refer to the most current addenda to ASHRAE Standard 34 for the most current values of *LFL*.

Section 7.6.4(b): The continuous ventilation system can be shut down for short periods of time during service and maintenance of the ventilation system. Fan failure switches can be used to determine that the ventilation fan is not operating properly. Examples of fan failure switches include the following:

a. Hall effect switch on the fan shaft or blade pass
b. Pressure switch across the fan
c. Sail switch on the outlet of the fan
d. On direct drive, a Hall effect switch on the motor shaft
e. On direct drive ECM and similar, a digital output indicating the motor is not turning, current draw, etc.

Section 8.11.11.4

For the graphical method, where the *design pressure* falls into the range of the inequality, the line above that region of the chart applies.

Example 1:
For *DP* = 150 psi (*DP* = 1.0 MPa) gage pressure, the line for *DP* ≤ 200 psi (*DP* ≤ 1.4 MPa) applies to determine the minimum Level 2 ventilation airflow rate. The graphical method does not apply when the *design pressure* exceeds 700 psi (4.8 MPa) gage pressure.

Example 2:
For *DP* = 600 psi (*DP* = 4.1 MPa) gage pressure, the line for 550 psi ≤ *DP* ≤ 700 psi (3.8 MPa ≤ *DP* ≤ 4.8 MPa) applies to determine the minimum Level 2 ventilation airflow rate.

For both the graphical method and the calculation method, check that the Level 2 ventilation airflow rate is not less than the Level 1 ventilation airflow rate determined per Section 8.11.11.2. Where the applicable charge quantity *G* is relatively low (lower left corners of Figure 8-1 or Figure 8-2), the Level 1 ventilation airflow rate may determine the Level 2 ventilation airflow rate (i.e., for a relatively small refrigeration system in a sufficiently large *machinery room*, when Level 2 ventilation is triggered the airflow rate may not need to increase above the Level 1 ventilation airflow rate).

Section 9.1.2

The restriction on magnesium alloys for halogenated *refrigerants* applies to alloys where the principal component metal is magnesium. The requirement does not apply to aluminum, copper, and steel alloys that contain magnesium.

Section 9.11.4.2.1

Double flare fittings are not restricted by the *low-side refrigerant* saturation temperature limit.

Section 9.13.2

Reused *piping shall not* be required to be exposed.

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INFORMATIVE APPENDIX B
INFORMATIVE REFERENCES

This appendix contains a full list of informative references. A full list of normative references is included in Section 13, "Normative References." References in this standard are numbered in the order in which they appear in the document, so the numbers for the normative references are shown for the convenience of the user.

1. IIAR. 2019. ANSI/IIAR 2-2014 with addendum A, *American National Standard for Safe Design of Closed-Circuit Ammonia Refrigeration Systems*. Alexandria, VA: International Institute of Ammonia Refrigeration.
2. See Section 13, "Normative References."
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8. See Section 13, "Normative References."
9. See Section 13, "Normative References."
10. See Section 13, "Normative References."
11. See Section 13, "Normative References."
12. See Section 13, "Normative References."
13. See Section 13, "Normative References."
14. See Section 13, "Normative References."
15. See Section 13, "Normative References."
16. ASHRAE. 2017. *ASHRAE Handbook—Fundamentals*. Peachtree Corners, GA: ASHRAE.
17. See Section 13, "Normative References."
18. See Section 13, "Normative References."
19. See Section 13, "Normative References."
20. See Section 13, "Normative References."
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62. See Section 13, "Normative References."
63. See Section 13, "Normative References."
64. See Section 13, "Normative References."
65. GPO. 2022. 29 CFR 1910.7, *Definition and Requirements for a Nationally Recognized Testing Laboratory.* Washington, DC: U.S. Government Publishing Office.
66. NIST. 2013. NIST REFPROP, Standard Reference Database 23, Version 9.1. National Institute of Standards and Technology, Gaithersburg, MD.
67. IUPAC. 2013. Atomic Weights of the Elements 2013 (IUPAC Technical Report). International Union of Pure and Applied Chemistry, Research Triangle Park, NC.

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INFORMATIVE APPENDIX C
METHOD FOR CALCULATING DISCHARGE CAPACITY OF POSITIVE DISPLACEMENT COMPRESSOR PRESSURE RELIEF DEVICE

The following calculation method provides the required discharge capacity of the *compressor pressure relief device* in Section 9.8.

(***Note:*** Section 9.8 permits the discharge capacity of the *pressure relief device* to be the minimum regulated flow rate of the *compressor* when the following conditions are met: (a) the *compressor* is equipped with capacity regulation, (b) capacity regulation actuates to minimum flow at 90% of the *pressure relief device* setting, and (c) the *pressure limiting device* is installed and set in accordance with the requirements of Section 9.9.)

$$W_v = \frac{Q \times \mathrm{PL} \times \eta_v}{v_g} \qquad \text{(C-1)}$$

where

W_r = mass flow of *refrigerant*, lb/min (kg/s)

Q = swept volume flow rate of *compressor*, ft^3/min (m^3/s)

PL = fraction of *compressor* capacity at minimum regulated flow

η_v = volumetric efficiency (assume 0.9 unless actual volumetric efficiency at relieving pressure is known)

v_g = specific volume of *refrigerant* vapor as *specified* in Section 9.8, ft^3/lb (m^3/kg)

Next, find the relieving capacity in mass flow of air W_a for an ASME-rated [14] *pressure relief device*:

$$W_a = W_r \times r_w \qquad \text{(C-2)}$$

$$r_w = \frac{C_a}{C_r}\sqrt{\frac{T_r}{T_a}}\sqrt{\frac{M_a}{M_r}} \qquad \text{(C-3)}$$

where

r_w = *refrigerant*-to-standard-air-mass-flow conversion factor (see Table C-1)

M_a = molar mass of air = 28.97

M_r = molar mass of *refrigerant* (see Table C-1)

T_a = absolute temperature of the air = 520°R (289 K)

T_r = absolute temperature of the *refrigerant* = 510°R (283 K)

C_a = constant for air = 356

C_r = constant for *refrigerant* as determined from Equation C-4

$$C_r = 520\sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} \qquad \text{(C-4)}$$

where

k = ratio of specific heats (C_p/C_v)

C_p = constant-pressure specific heat of *refrigerant* at a *refrigerant* quality of 1 at 50°F (10°C)

C_v = constant-volume specific heat of *refrigerant* at a *refrigerant* quality of 1 at 50°F (10°C)

Constants for several *refrigerants* are listed in Table C-1.

Example

Determine the flow capacity of a *pressure relief device* for a R-410A *compressor* with a swept volume (Q) of 341 ft^3/min (0.1609 m^3/s). The *compressor* is equipped with capacity control that is actuated at 90% of the *pressure relief device set pressure* and has a minimum regulated flow of 10%.

Q = 341 ft^3/min

Q = 0.16095 m^3/s

Table C-1 Constants for Calculating Discharge Capacity

Refrigerant	k [a]	Molar Mass [b]	C_r	r_w
R-11	1.137	137.4	330.7	0.49
R-12	1.205	120.9	337.7	0.51
R-13	2.053	104.5	403.6	0.46
R-22	1.319	86.5	348.8	0.59
R-23	2.742	70.0	439.3	0.52
R-113	1.081	187.4	324.7	0.43
R-114	1.094	170.9	326.1	0.45
R-123	1.104	152.9	327.1	0.47
R-134a	1.196	102.0	336.8	0.56
R-236fa	1.101	152.0	326.8	0.47
R-245fa	1.107	134.0	327.5	0.50
R-290	1.235	44.1	340.8	0.84
R-404A	1.279	97.6	345.0	0.56
R-407C	1.270	86.2	344.1	0.59
R-410A	1.434	72.6	359.0	0.62
R-500	1.236	99.3	340.8	0.56
R-502	1.264	111.6	343.6	0.52
R-507A	1.284	98.9	345.5	0.55
R-600	1.122	58.1	329.2	0.76
R-718	1.328	18.0	349.6	1.28
R-744	2.690	44.0	437.0	0.65

a. Source: NIST REFPROP, Standard Reference Database, v9.1, 2013 [66]
b. Source: IUPAC Atomic Weights, 2013 [67]

η_v = 0.90, assumed
PL = 0.1
$v_{g@50°F}$ = 1.1979 ft^3/lb (I-P)
$v_{g@10°C}$ = 0.0748 m^3/kg (SI)

$$W_r = \frac{341\ \frac{\text{ft}^3}{\text{min}} \times 0.1 \times 0.9}{1.1979\frac{\text{ft}^3}{\text{lb}}} = 25.62\ \frac{\text{lb}}{\text{min}} \qquad \text{(I-P [see C-1])}$$

$$W_r = \frac{0.1609\ \frac{\text{m}^3}{\text{s}} \times 0.1 \times 0.9}{0.0748\ \frac{\text{m}^3}{\text{kg}}} = 0.1936\ \frac{\text{kg}}{\text{s}} \qquad \text{(SI [see C-1])}$$

$$W_a = W_r \times r_w = 25.62 \times 0.62 = 15.88\ \frac{\text{lb}}{\text{min}}\text{ of air} \qquad \text{(I-P [see C-2])}$$

$$W_a = W_r \times r_w = 0.1936 \times 0.62 = 0.12\ \frac{\text{kg}}{\text{s}}\text{ of air} \qquad \text{SI [see C-2])}$$

Converting to standard ft^3/min, where V_a = specific volume of air = 13.1 ft^3/lb (0.818 m^3/kg) for dry air at 60°F (15.6°C):

SCFM = 13.1 (15.88) = 208.02 ft^3/min (I-P)
SCFM = 0.818 (0.12) = 0.098 m^3/s (SI)

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INFORMATIVE APPENDIX D
TYPICAL MOODY FRICTION FACTORS FOR USE IN RELIEF PIPING LINE LENGTH LIMIT

Table D-1 Typical Moody Friction Factors (*f*) for Fully Turbulent Flow

Tubing OD, in.	DN, mm	ID, in.	*f*
3/8	8	0.315	0.0136
1/2	10	0.430	0.0128
5/8	13	0.545	0.0122
3/4	16	0.666	0.0117
7/8	20	0.785	0.0114
1 1/8	25	1.025	0.0108
1 3/8	32	1.265	0.0104
1 5/8	40	1.505	0.0101

Piping NPS, in.	DN, mm	ID, in.	*f*
1/2	15	0.622	0.0259
3/4	20	0.824	0.0240
1	25	1.049	0.0225
1 1/4	32	1.380	0.0209
1 1/2	40	1.610	0.0202
2	50	2.067	0.0190
2 1/2	65	2.469	0.0182
3	80	3.068	0.0173
4	100	4.026	0.0163
5	125	5.047	0.0155
6	150	6.065	0.0149

(This is a normative appendix and is part of this standard.)

NORMATIVE APPENDIX E
ALLOWABLE EQUIVALENT LENGTH OF DISCHARGE PIPING

Table E-1 Pressure Relief Valve Discharge Line Capacity (lb/min of air) of Various Discharge Line Lengths

Set Pressure, psig	Length, ft	Nominal Pipe Size, NPS in. (DN mm)											Set Pressure, psig	Length, ft	Nominal Pipe Size, NPS in. (DN mm)										
		0.5 (15)	0.75 (20)	1 (25)	1.25 (32)	1.5 (40)	2 (50)	2.5 (65)	3 (80)	4 (100)	5 (125)	6 (150)			0.5 (15)	0.75 (20)	1 (25)	1.25 (32)	1.5 (40)	2 (50)	2.5 (65)	3 (80)	4 (100)	5 (125)	6 (150)
5	2	2.8	5.8	10.7	21.3	31.4	57.8	88.8	148.0	278.9	469	704	15	15	1.9	3.9	7.3	14.8	22.1	41.7	65.3	111.6	218.0	379	583
5	3	2.3	4.8	9.0	18.1	26.8	49.9	77.3	130.4	249.8	426	647	15	20	1.6	3.4	6.4	13.0	19.4	36.8	57.9	99.4	195.8	344	532
5	4	2.0	4.2	7.9	16.0	23.7	44.5	69.4	117.8	228.2	393	601	15	25	1.5	3.1	5.7	11.7	17.5	33.3	52.5	90.5	179.3	316	492
5	5	1.8	3.8	7.1	14.4	21.5	40.6	63.5	108.3	211.4	367	564	15	30	1.3	2.8	5.3	10.7	16.1	30.7	48.4	83.6	166.3	295	460
5	6	1.7	3.5	6.6	13.3	19.8	37.5	58.9	100.8	197.8	346	533	15	40	1.2	2.4	4.6	9.4	14.0	26.8	42.4	73.5	147.1	262	411
5	8	1.5	3.0	5.7	11.6	17.4	33.1	52.0	89.5	177.0	312	484	15	60	1.0	2.0	3.8	7.7	11.6	22.1	35.1	61.0	122.7	220	347
5	10	1.3	2.7	5.1	10.5	15.7	29.9	47.1	81.3	161.7	286	446	15	100	0.7	1.5	2.9	6.0	9.0	17.3	27.5	47.9	96.8	175	276
5	15	1.1	2.2	4.2	8.6	12.9	24.7	39.2	67.9	135.9	243	380	15	160	0.6	1.2	2.3	4.7	7.1	13.7	21.8	38.1	77.3	140	222
5	20	0.9	1.9	3.7	7.5	11.3	21.6	34.2	59.4	119.5	214	337	15	250	0.5	1.0	1.9	3.8	5.7	11.0	17.5	30.6	62.3	113	179
5	25	0.8	1.7	3.3	6.7	10.1	19.4	30.8	53.5	107.9	194	306	25	2	5.7	11.3	20.0	37.6	53.5	93.2	137.5	219.2	390.5	628	918
5	30	0.8	1.6	3.0	6.2	9.3	17.8	28.2	49.1	99.1	179	282	25	3	4.9	9.9	17.8	34.0	48.8	86.5	128.8	207.5	374.4	608	893
5	40	0.7	1.4	2.6	5.3	8.0	15.4	24.5	42.8	86.5	156	247	25	4	4.4	8.9	16.2	31.3	45.3	81.0	121.6	197.6	360.1	589	869
5	60	0.5	1.1	2.1	4.4	6.6	12.6	20.1	35.1	71.2	129	205	25	5	4.0	8.2	14.9	29.1	42.3	76.4	115.5	188.9	347.3	572	848
5	100	0.4	0.9	1.7	3.4	5.1	9.8	15.6	27.3	55.6	101	160	25	6	3.7	7.6	13.9	27.4	39.9	72.6	110.2	181.3	335.8	556	828
5	160	0.3	0.7	1.3	2.7	4.0	7.8	12.4	21.7	44.1	80	127	25	8	3.3	6.7	12.4	24.6	36.1	66.4	101.5	168.5	315.9	529	791
5	250	0.3	0.6	1.0	2.1	3.2	6.2	9.9	17.4	35.3	64	102	25	10	3.0	6.1	11.3	22.6	33.3	61.5	94.6	158.1	299.1	505	759
15	2	4.6	9.3	16.7	32.0	46.0	81.6	121.8	196.5	355.2	577	849	25	15	2.5	5.1	9.5	19.1	28.3	52.9	82.1	138.7	266.6	457	694
15	3	3.9	8.0	15.5	28.3	41.0	74.0	111.6	182.3	334.5	550	815	25	20	2.1	4.5	8.3	16.8	25.0	47.1	73.5	125.0	242.9	420	643
15	4	3.5	7.1	13.0	25.6	37.4	68.1	103.6	170.8	317.1	526	784	25	25	1.9	4.0	7.5	15.2	22.7	42.9	67.1	114.7	224.5	391	602
15	5	3.1	6.5	11.9	23.6	34.6	63.5	97.1	161.2	302.2	506	757	25	30	1.8	3.7	6.9	14.0	20.9	39.6	62.2	106.6	209.8	367	568
15	6	2.9	6.0	11.0	22.0	32.3	59.7	91.7	153.1	289.2	487	732	25	40	1.5	3.2	6.0	12.2	18.3	34.8	54.9	94.5	187.3	331	514
15	8	2.5	5.2	9.7	19.5	28.9	53.8	83.2	140.0	267.5	455	689	25	60	1.3	2.6	4.9	10.1	15.1	28.9	45.7	79.1	158.0	281	440
15	10	2.3	4.7	8.8	17.8	26.3	49.3	76.7	129.7	250.1	429	683	25	100	1.0	2.0	3.8	7.9	11.8	22.7	36.0	62.5	125.8	226	356

SI Conversions: kPa = psig × 6.895; mm = in. × 25.4; kg/s = lb/min × 0.007559; m = ft × 0.3048

Table E-1 Pressure Relief Valve Discharge Line Capacity (lb/min of air) of Various Discharge Line Lengths [Continued]

Set Pressure, psig	Length, ft	Nominal Pipe Size, NPS in. (DN mm)										
		0.5 (15)	0.75 (20)	1 (25)	1.25 (32)	1.5 (40)	2 (50)	2.5 (65)	3 (80)	4 (100)	5 (125)	6 (150)
25	160	0.8	1.6	3.1	6.3	9.4	18.1	28.7	50.0	101.1	183	289
25	250	0.6	1.3	2.4	5.0	7.6	14.5	32.1	40.3	81.7	148	235
50	2	7.6	14.7	25.4	46.5	65.3	111.7	162.8	256	451	718	1045
50	3	6.8	13.2	23.2	43.4	61.4	106.3	156.1	248	439	704	1027
50	4	6.1	12.2	21.6	40.8	58.1	101.6	150.2	240	429	691	1011
50	5	5.7	11.3	20.2	38.6	55.2	97.4	144.9	233	419	678	996
50	6	5.3	10.6	19.1	36.7	52.8	93.8	140.1	226	410	666	981
50	8	4.7	9.5	17.3	33.6	48.7	87.5	131.8	215	393	644	953
50	10	4.3	8.7	15.9	31.2	45.5	82.4	124.8	205	378	624	927
50	15	3.6	7.4	13.6	26.9	39.6	72.7	113.3	185	347	582	872
50	20	3.1	6.5	12.0	24.0	35.5	65.8	101.4	170	323	547	825
50	25	2.8	5.9	10.9	21.9	32.4	60.5	93.8	158	303	517	785
50	30	2.6	5.4	10.0	20.3	30.1	56.3	87.6	148	286	492	750
50	40	2.3	4.7	8.8	17.8	26.6	50.1	78.3	133	260	451	692
50	60	1.9	3.9	7.3	14.8	22.1	42.0	66.0	113	224	393	608
50	100	1.4	3.0	5.7	11.6	17.4	33.3	52.6	91	182	323	504
50	160	1.1	2.4	4.5	9.3	13.9	26.7	42.3	73	148	265	416
50	250	0.9	1.9	3.6	7.5	11.2	21.5	34.2	59	120	217	342
75	2	9.1	17.2	29.4	53.3	74.3	126.0	182.7	286	501	795	1154
75	3	8.2	15.8	27.3	50.4	70.7	121.2	176.9	279	491	783	1140
75	4	7.5	14.6	25.7	47.8	67.6	116.9	171.6	272	482	772	1127
75	5	7.0	13.7	24.3	45.7	64.8	113.1	166.8	266	474	762	1114
75	6	6.5	13.0	23.1	43.7	62.4	109.6	162.3	260	466	751	1101
75	8	5.9	11.8	21.1	40.6	58.3	103.4	154.4	249	450	732	1077
75	10	5.4	10.8	19.6	38.0	54.9	98.2	147.5	240	437	714	1054
75	15	4.5	9.2	16.9	33.2	48.4	88.0	133.7	220	407	675	1004
75	20	4.0	8.2	15.1	29.9	43.8	80.5	123.1	204	383	641	960
75	25	3.6	7.4	13.7	27.4	40.3	74.6	114.8	192	363	612	921
75	30	3.3	6.8	12.7	25.4	37.6	69.8	107.9	181	345	587	887
75	40	2.9	6.0	11.2	22.5	33.4	62.5	97.2	164	317	544	828
75	60	2.4	5.0	9.3	16.8	28.0	52.9	82.8	141	276	481	739
75	100	1.9	3.9	7.3	14.8	22.2	42.2	66.5	115	227	401	623
75	160	1.5	3.1	5.8	11.9	17.8	34.0	53.8	93	186	332	520
75	250	1.2	2.5	4.7	9.6	14.4	27.5	43.6	76	153	274	432
100	2	10.3	19.4	32.9	59.3	82.2	138.8	200.8	314	547	868	1258
100	3	9.4	17.9	30.9	56.4	78.9	134.4	195.4	307	539	857	1246
100	4	8.7	16.8	29.2	54.0	75.9	130.3	190.4	301	531	847	1234
100	5	8.1	15.8	27.8	51.8	73.2	126.6	185.9	295	523	837	1222
100	6	7.6	15.0	26.5	49.9	70.8	123.2	181.7	289	515	828	1210
100	8	6.9	13.7	24.5	46.6	66.6	117.2	174.0	279	501	810	1188
100	10	6.3	12.7	22.8	43.9	63.1	112.0	167.2	270	488	793	1167
100	15	5.4	10.9	19.9	38.7	56.3	101.4	153.1	250	459	756	1120
100	20	4.7	9.7	17.8	35.1	51.3	93.4	142.1	234	435	723	1077
100	25	4.3	8.8	16.3	32.3	47.4	87.0	133.2	221	415	694	1039
100	30	4.0	8.2	15.1	30.1	44.3	81.8	125.8	210	397	668	1005
100	40	3.5	7.2	13.3	26.7	39.5	73.7	114.0	192	367	625	946
100	60	2.9	5.9	11.1	22.4	33.4	62.7	97.9	166	323	558	853
100	100	2.2	4.7	8.7	17.8	26.6	50.4	79.2	136	268	471	728
100	160	1.8	3.7	7.0	14.3	21.4	40.7	64.3	111	222	393	614
100	250	1.4	3.0	5.6	11.5	17.3	33.0	52.3	91	182	326	513

SI Conversions: kPa = psig × 6.895; mm = in. × 25.4; kg/s = lb/min × 0.007559; m = ft × 0.3048

Table E-1 Pressure Relief Valve Discharge Line Capacity (lb/min of air) of Various Discharge Line Lengths [Continued]

Set Pressure, psig	Length, ft	0.5 (15)	0.75 (20)	1 (25)	1.25 (32)	1.5 (40)	2 (50)	2.5 (65)	3 (80)	4 (100)	5 (125)	6 (150)
		Nominal Pipe Size, NPS in. (DN mm)										
150	2	12.5	23.3	39.2	70.1	96.8	162.7	234.5	366	636	1006	1457
150	3	11.6	21.8	37.2	67.4	93.7	158.5	229.6	360	628	996	1446
150	4	10.8	20.6	35.5	64.9	90.8	154.7	225.1	354	621	987	1435
150	5	10.2	19.6	34.0	62.8	88.1	151.2	220.7	348	613	979	1425
150	6	9.6	18.7	32.7	60.8	85.7	147.8	216.6	343	606	970	1414
150	8	8.8	17.3	30.5	57.3	81.4	141.8	209.1	333	593	954	1394
150	10	8.1	16.1	28.7	54.4	77.7	136.5	202.3	324	581	938	1375
150	15	6.9	14.0	25.2	48.7	70.3	125.4	187.8	304	553	902	1330
150	20	6.2	12.5	22.8	44.5	64.6	116.6	176.0	288	529	870	1289
150	25	5.6	11.4	21.0	41.2	60.2	109.4	166.2	274	507	841	1251
150	30	5.2	10.6	19.5	38.6	56.5	103.4	157.9	261	488	815	1217
150	40	4.5	9.4	17.3	34.5	50.8	93.9	144.5	241	456	769	1156
150	60	3.8	7.8	14.5	29.2	43.3	80.8	125.4	212	407	696	1058
150	100	2.9	6.1	11.5	23.3	34.7	65.6	102.7	175	343	597	918
150	160	2.3	4.9	9.2	18.7	28.0	53.3	84.0	145	286	505	785
150	250	1.9	3.9	7.4	15.2	22.7	43.4	68.6	119	238	423	662
200	2	14.6	26.9	45.0	80.2	110.6	185.2	266.6	415	721	1139	1649
200	3	13.6	25.4	43.1	77.5	107.4	181.2	261.9	409	713	1130	1638
200	4	12.7	24.2	41.3	75.1	104.6	177.4	257.4	404	706	1121	1628
200	5	12.0	23.1	39.8	72.8	101.9	173.9	253.1	398	699	1113	1618
200	6	11.5	22.1	38.4	70.8	99.4	170.6	249.1	393	692	1105	1608
200	8	10.5	20.5	36.0	67.2	95.0	164.5	241.5	383	679	1089	1588
200	10	9.7	19.2	34.0	64.1	91.1	159.0	234.6	374	667	1073	1570
200	15	8.4	16.8	30.2	57.9	83.2	147.3	219.6	354	639	1038	1525
200	20	7.5	15.2	27.5	53.2	77.0	137.9	207.2	337	614	1005	1485
200	25	6.8	13.9	24.3	49.5	72.0	130.1	196.6	322	592	967	1447
200	30	6.3	12.9	23.6	46.5	67.9	123.4	187.6	309	572	949	1412
200	40	5.6	11.4	21.1	41.8	61.4	112.8	172.6	287	538	901	1349
200	60	4.6	9.6	17.7	35.5	52.5	97.7	151.1	254	484	823	1245
200	100	3.6	7.5	14.1	28.5	42.4	79.9	124.7	212	413	714	1094
200	160	2.9	6.0	11.3	23.0	34.4	65.2	102.5	176	347	610	944
200	250	2.3	4.9	9.1	18.6	27.9	53.3	84.1	145	290	514	802
250	2	16.5	30.4	50.7	89.9	123.8	207.0	297.7	463	803	1268	1836
250	3	15.5	28.8	48.6	87.2	120.7	203.0	293.0	457	796	1260	1826
250	4	14.6	27.5	46.9	84.7	117.8	199.3	288.5	452	789	1251	1815
250	5	13.8	26.4	45.2	82.4	115.1	195.7	284.2	446	782	1243	1805
250	6	13.2	25.4	43.8	80.3	112.5	192.3	280.2	441	775	1234	1795
250	8	12.2	23.6	41.3	76.6	107.9	186.1	272.5	431	762	1219	1776
250	10	11.3	22.2	39.1	73.3	103.9	180.4	265.4	422	750	1203	1757
250	15	9.8	19.6	35.0	66.7	95.4	168.2	249.8	401	721	1167	1713
250	20	8.8	17.7	31.9	61.5	88.7	158.1	236.7	383	696	1135	1672
250	25	8.0	16.3	29.5	57.5	83.3	149.7	225.5	368	673	1104	1634
250	30	7.4	15.1	27.6	54.1	78.7	142.5	215.7	354	652	1076	1598
250	40	6.5	13.4	24.7	48.8	71.5	130.7	199.5	330	616	1026	1533
250	60	5.4	11.3	20.9	41.7	61.5	114.0	175.6	294	558	944	1423
250	100	4.3	8.9	16.6	33.6	49.9	93.7	145.9	248	479	826	1261
250	160	3.4	7.1	13.4	27.2	40.6	76.8	120.5	207	406	710	1096
250	250	2.7	5.8	10.8	22.1	33.0	62.9	99.2	171	340	602	937
300	2	18.4	33.7	56.1	99.4	136.7	228.3	328	510	884	1395	2019
300	3	17.3	32.1	54.0	96.0	133.5	224.2	323	504	877	1386	2009

SI Conversions: kPa = psig × 6.895; mm = in. × 25.4; kg/s = lb/min × 0.007559; m = ft × 0.3048

Table E-1 Pressure Relief Valve Discharge Line Capacity (lb/min of air) of Various Discharge Line Lengths [Continued]

Set Pressure, psig	Length, ft	Nominal Pipe Size, NPS in. (DN mm) 0.5 (15)	0.75 (20)	1 (25)	1.25 (32)	1.5 (40)	2 (50)	2.5 (65)	3 (80)	4 (100)	5 (125)	6 (150)
300	4	16.4	30.8	52.2	94.1	130.6	220.4	319	498	869	1378	1998
300	5	15.6	29.6	50.5	91.7	127.8	216.8	314	493	862	1369	1988
300	6	14.9	28.5	49.0	89.6	125.2	213.4	310	488	856	1361	1978
300	8	13.8	26.6	46.3	85.6	120.4	206.9	302	478	843	1345	1959
300	10	12.8	25.1	44.1	82.2	116.2	201.0	295	468	830	1330	1940
300	15	11.2	22.2	39.6	75.1	107.2	188.3	279	447	801	1293	1895
300	20	10.0	20.1	36.2	69.6	100.1	177.7	265	428	775	1260	1853
300	25	9.2	18.6	33.6	65.2	94.2	168.7	253	412	751	1229	1814
300	30	8.5	17.3	31.5	61.5	89.2	160.9	243	397	729	1200	1777
300	40	7.5	15.4	28.2	55.6	81.3	148.2	225	372	691	1148	1710
300	60	6.3	12.9	23.9	47.7	70.2	129.7	199	333	639	1061	1595
300	100	4.9	10.3	19.1	38.5	57.2	107.1	167	282	544	934	1422
300	160	3.9	8.2	15.4	31.3	46.6	88.1	138	236	463	807	1243
300	250	3.2	6.6	12.5	25.4	38.0	72.3	114	196	389	687	1068
350	2	20.3	37.0	61.4	108.6	149	249	358	556	963	1519	2199
350	3	19.1	35.3	59.3	105.8	146	245	353	550	956	1510	2189
350	4	18.1	33.9	57.4	103.3	143	241	348	544	949	1502	2178
350	5	17.3	32.7	55.7	100.9	140	237	344	539	941	1493	2168
350	6	16.6	31.5	54.1	98.6	137	234	340	534	935	1484	2158
350	8	15.3	29.6	51.3	94.5	132	227	331	523	921	1468	2139
350	10	14.4	28.0	48.9	90.9	128	221	324	514	908	1452	2120
350	15	12.5	24.8	44.1	83.5	119	208	307	492	879	1414	2075
350	20	11.3	22.6	40.5	77.6	111	196	293	473	852	1379	2032
350	25	10.3	20.8	37.6	72.8	105	187	280	455	827	1347	1992
350	30	9.6	19.4	35.3	68.8	99	178	269	440	804	1317	1954
350	40	8.5	17.3	31.7	62.4	91	163	250	413	764	1262	1885
350	60	7.1	14.6	26.9	53.7	79	145	222	372	699	1170	1765
350	100	5.6	11.6	21.6	43.5	64	120	186	316	607	1034	1582
350	160	4.5	9.3	17.4	35.4	52	99	155	266	519	897	1390
350	250	3.6	7.5	14.1	28.8	43	81	128	222	438	766	1200
400	2	22.0	40.2	66.6	117.7	161.7	269.6	387	601	1041	1642	2376
400	3	20.9	38.5	64.5	114.8	158.4	265.5	382	595	1034	1633	2366
400	4	19.8	37.0	62.5	112.2	155.3	261.5	378	589	1026	1625	2355
400	5	18.9	35.7	60.7	109.7	152.4	257.7	373	584	1019	1616	2345
400	6	18.2	34.5	59.1	107.4	149.6	254.1	369	578	1012	1608	2335
400	8	16.9	32.5	56.1	103.1	144.5	247.3	360	568	999	1591	2315
400	10	15.8	30.7	53.6	99.3	139.9	241.0	353	558	986	1575	2295
400	15	13.9	27.4	48.5	91.5	130.1	227.1	335	535	955	1537	2249
400	20	12.5	24.9	44.6	85.2	122.0	215.4	320	515	927	1502	2205
400	25	11.4	23.0	41.6	80.1	115.3	205.4	307	497	902	1469	2164
400	30	10.6	21.5	39.0	75.8	109.6	196.6	296	481	878	1438	2125
400	40	9.4	19.2	35.1	68.9	100.4	182.0	276	453	836	1382	2052
400	60	7.9	16.2	26.9	59.4	87.2	160.4	246	409	767	1286	1927
400	100	6.2	12.9	24.0	48.3	71.5	133.4	207	349	669	1143	1734
400	160	5.0	10.4	19.4	39.3	58.5	110.3	173	294	574	996	1529
400	250	4.0	8.4	15.7	32.0	47.9	90.9	143	246	468	854	1324

SI Conversions: kPa = psig × 6.895; mm = in. × 25.4; kg/s = lb/min × 0.007559; m = ft × 0.3048

Table E-1 Pressure Relief Valve Discharge Line Capacity (lb/min of air) of Various Discharge Line Lengths [Continued]

Set Pressure, psig	Length, ft	Nominal Pipe Size, NPS in. (DN mm) 0.5 (15)	0.75 (20)	1 (25)	1.25 (32)	1.5 (40)	2 (50)	2.5 (65)	3 (80)
450	5	20.6	38.7	65	118	164	277	401	—
450	10	17.2	33.4	58	108	151	260	380	—
450	15	15.2	29.9	53	99	141	245	362	—
450	20	13.7	27.3	48.7	93	132	233	346	—
450	25	12.6	25.2	44.9	87	125	222	333	—
450	30	11.7	23.6	42.7	83	119	213	320	—
450	40	10.4	21.1	38.5	76	109	198	299	493
450	60	8.7	17.8	32.8	65	95	175	267	446
450	100	6.9	14.2	26.4	53	78	146	226	382
450	160	5,5	11,4	21,4	43,3	64	120	189	323
450	250	4.4	9.2	17.3	35.3	52	99	156	269
500	5	22.2	41.6	70.5	127	176	297	430	—
500	10	18.7	36.1	62.8	116	162	279	408	—
500	15	16.5	32.4	57.1	107	152	264	389	—
500	20	14.9	29.6	52.8	100	142	251	373	—
500	25	13.7	27.4	49.3	94	134	240	359	—
500	30	12.7	25.7	46.4	88	129	230	346	—
500	40	11.3	23.0	41.9	82	118	214	324	
500	60	9.5	21.0	35.8	71	103	189	290	482
500	100	7.5	15.5	28.8	58	85	158	245	414
500	160	6.0	11.2	23.3	47.3	70	131	206	352
500	250	4.8	10.1	18.8	38.6	57	108	171	295
550	5	23.8	44.5	76	135	188	316	457	—
550	10	20.1	38.8	67	124	174	298	435	—
550	15	17.8	34.9	61	115	162	282	416	—
550	20	16.1	31.9	57	108	153	269	399	—
550	25	14.8	29.6	53	102	145	258	384	—
550	30	13.8	27.7	50.0	96	139	247	370	—
550	40	12.2	24.8	45.2	88	127	230	347	—
550	60	10.2	21.0	38.7	76	111	216	312	—
550	100	8.1	16.8	31.3	62	92	171	264	447
550	160	6.5	13.5	25.3	51	75	142	227	380
550	250	5.3	10.9	20.5	42	62	117	184	319

Set Pressure, psig	Length. ft	Type L Copper Tubing Outer Diameter (OD), in. 3/8	1/2	5/8	3/4	7/8	1-1/8	1-3/8	1-5/8
100	5	2.1	4.3	7.4	11.7	16.9	30.5	48.1	69.7
100	10	—	3.4	6.1	9.8	14.3	26.6	42.8	63.0
100	15	—	2.9	5.3	8.6	12.7	24.0	39	58
100	20	—	2.6	4.7	7.7	11.5	22.0	36	54
100	25	—	—	4.3	7.1	10.6	20.3	33.7	50.7
100	30	—	—	4	6.7	9.9	19.0	31.7	48.0
100	40	—	—	3.5	5.9	8.9	17.1	28.6	43.6
100	60	—	—	2.9	4.9	7.4	14.5	26.3	37.6
100	100	—	—	2.4	3.9	5.9	11.6	19.7	30.5

SI Conversions: kPa = psig × 6.895; mm = in. × 25.4; kg/s = lb/min × 0.007559; m = ft × 0.3048

Table E-1 Pressure Relief Valve Discharge Line Capacity (lb/min of air) of Various Discharge Line Lengths [Continued]

Set Pressure, psig	Length. ft	Type L Copper Tubing Outer Diameter (OD), in.							
		3/8	1/2	5/8	3/4	7/8	1-1/8	1-3/8	1-5/8
100	160	—	—	—	3.1	4.7	9.4	16.0	24.8
100	250	—	—	—	—	3.8	7.6	13.0	20.2
150	5	—	5.3	9	14.3	20.5	36.5	57.2	82.6
150	10	—	4.4	7.6	12.2	17.8	32.6	52.0	76.1
150	15	—	3.8	6.7	10.9	16.0	29.7	48.0	73.9
150	20	—	3.4	6.1	9.9	14.6	27.5	44.8	73.9
150	25	—	3.1	5.6	9.1	13.6	25.7	42.2	63.1
150	30	—	2.9	5.2	8.5	12.7	24.2	40	60.1
150	40	—	—	4.6	7.6	11.3	21.9	36.4	55.1
150	60	—	—	3.8	6.4	9.6	18.7	31.5	48.0
150	100	—	—	3.0	5.1	7.7	15.1	25.6	39.5
150	160	—	—	—	4.1	6.2	12.2	20.9	32.3
150	250	—	—	—	3.3	5.0	10.0	17.0	26.5
200	5	3.1	6.2	10.7	16.6	23.7	42.1	65.8	94.7
200	10	—	5.2	9.1	14.4	20.8	38.1	60.5	88.2
200	15	—	4.5	8	13.0	19.0	35.1	56.3	82.8
200	20	—	4.1	7.3	11.9	17.5	32.6	52.9	78.3
200	25	—	3.6	6.7	11.0	16.2	30.7	50.0	74.5
200	30	—	3.5	6.3	10.2	15.3	29.1	47.6	71.2
200	40	—	3.1	5.6	9.2	13.8	26.4	43.6	65.7
200	60	—	—	4.7	7.8	11.7	22.7	40.5	57.8
200	100	—	—	3.7	6.2	9.4	18.4	31.2	47.9
200	160	—	—	3.0	5.0	7.6	13.6	25.5	39.5
200	250	—	—	—	4.1	6.2	12.2	20.9	32.5
250	5	3.5	7.1	12.1	18.8	26.8	47.5	73.9	106.3
250	10	—	6.0	10.4	16.5	23.9	43.3	68.5	99.6
250	15	—	5.3	9.3	14.9	21.8	40.1	64.2	94.1
250	20	—	4.8	8.5	13.7	20.2	37.5	60.6	89.4
250	25	—	4.4	7.8	12.7	18.9	35.4	57.5	85.4
250	30	—	4.1	7.3	12.0	17.7	33.6	54.9	81.8
250	40	—	3.4	6.6	10.8	16.1	30.6	50.5	75.9
250	60	—	—	6.0	9.1	13.7	26.5	44.2	67.1
250	100	—	—	4.4	7.3	11.1	21.7	36.5	55.9
250	160	—	—	3.5	5.9	9.0	17.7	30.1	46.4
250	250	—	—	—	4.8	7.3	14.5	24.7	38.2
300	5	4.0	8.0	13.5	21	29.8	52.6	81.8	117.1
300	10	—	6.8	11.7	18.6	26.8	48.4	76.3	110.7
300	15	—	6.0	10.5	16.9	24.6	45.0	71.8	105.0
300	20	—	5.4	9.6	15.5	22.8	32.2	68.0	100.1
300	25	—	5.0	9.0	14.5	21.4	39.9	64.7	95.8
300	30	—	4.7	8.4	13.6	20.2	38.0	62.0	92.1
300	40	—	4.2	7.5	12.3	18.3	34.8	57.2	85.7
300	60	—	3.5	6.3	10.5	15.7	30.3	50.3	76.1
300	100	—	—	5.1	8.4	12.7	24.8	41.7	63.8
300	160	—	—	4.1	6.8	9.3	20.3	34.5	53.1
300	250	—	—	3.3	5.5	8.4	16.6	28.4	43.9
350	5	4.4	8.9	14.9	23.1	32.8	57.7	89.6	128.5
350	10	3.6	7.6	13.1	20.6	29.6	53.3	83.9	121.1
350	15	3.2	6.7	11.8	18.7	27.3	49.8	83.9	115.6
350	20	—	6.1	10.8	17.3	25.4	46.8	75.2	110.1
350	25	—	5.6	10.0	16.2	23.8	44.4	71.8	106
350	30	—	5.2	9.4	15.2	22.5	42.3	68.9	102

SI Conversions: kPa = psig × 6.895; mm = in. × 25.4; kg/s = lb/min × 0.007559; m = ft × 0.3048

Table E-1 Pressure Relief Valve Discharge Line Capacity (lb/min of air) of Various Discharge Line Lengths [Continued]

Set Pressure, psig	Length. ft	Type L Copper Tubing Outer Diameter (OD), in.							
		3/8	1/2	5/8	3/4	7/8	1-1/8	1-3/8	1-5/8
350	40	—	4.7	8.4	13.8	20.5	38.8	66.1	95.2
350	60	—	3.9	7.1	11.8	17.7	34.0	56.2	84.9
350	100	—	3.1	5.7	9.5	14.3	28.0	46.9	71.6
350	160	—	—	4.5	7.9	11.7	22.9	38.8	59.7
350	250	—	—	3.7	6.2	9.5	18.8	32.0	49.5
400	5	4.8	9.7	16.3	25.1	35.7	62.7	97.2	139.3
400	10	4.0	8.3	14.3	22.5	32.4	58.1	91.4	132.1
400	15	3.5	7.4	12.9	20.6	29.9	54.4	86.5	126.0
400	20	—	6.7	11.9	19.1	27.9	51.4	82.3	120.7
400	25	—	6.2	11.9	19.1	27.9	51.4	82.3	120.7
400	30	—	5.8	10.4	16.8	24.9	46.5	75.6	111.8
400	40	—	5.2	9.3	15.2	22.7	42.8	70.1	104.6
400	60	—	4.4	7.9	13.1	19.6	39.9	62.1	93.6
400	100	—	3.5	6.4	10.6	15.9	31.0	52.0	79.2
400	160	—	—	5.1	8.8	13.0	26.2	43.1	66.3
400	250	—	—	4.2	7	10.6	20.9	35.6	55.0
450	5	5.2	10.5	17.6	27.1	38.5	67.5	104.7	150
450	10	4.4	9.1	15.6	24.4	35.1	62.8	98.7	143
450	15	3.8	8.1	14.1	22.4	32.5	59.0	93.6	136
450	20	3.5	7.4	13.0	20.8	30.4	55.8	89.2	130
450	25	3.2	6.8	12.1	19.5	28.6	53.1	85.4	125
450	30	—	6.4	11.4	18.4	27.2	50.7	82.1	120
450	40	—	5.2	10.2	16.7	24.8	46.8	76.4	114
450	60	—	4.8	8.7	14.3	21.5	41.1	67.9	102
450	100	—	3.8	7.0	11.6	17.5	34.0	56.9	87
450	160	—	3.1	5.7	9.4	14.3	28.0	47.4	73
450	250	—	—	4.6	7.7	11.7	23.0	39.2	59
500	5	5.7	11.3	18.9	29.1	41.3	72.4	112.1	161
500	10	4.8	9.8	16.8	26.3	37.8	67.5	105.9	153
500	15	4.2	8.8	15.2	24.2	35.1	63.5	100.6	146
500	20	3.8	8.0	14.1	22.5	32.8	60.2	96.1	141
500	25	3.5	7.4	13.1	21.1	31.0	57.3	92.1	135
500	30	3.2	6.9	12.3	20.0	29.4	54.8	88.6	130
500	40	—	6.2	11.1	18.1	26.9	50.7	82.4	123
500	60	—	5.2	9.5	15.6	23.3	44.5	73.6	111
500	100	—	4.2	7.6	12.7	19.1	37.0	61.9	94
500	160	—	3.4	6.2	10.3	15.6	30.5	51.5	79
500	250	—	—	5	8.4	12.7	25.1	42.7	65
550	5	6.1	12.1	20.2	31.1	44.1	77	119	171
550	10	5.1	10.5	18.0	28.2	40.4	72	113	163
550	15	4.5	9.4	16.4	26.0	37.5	68	107	156
550	20	4.1	8.6	15.1	24.2	35.3	64	103	150
550	25	3.7	8.0	14.1	22.8	33.3	61	98	145
550	30	3.5	7.5	13.3	21.5	31.6	59	95	140
550	40	3.1	6.5	12.0	19.6	28.9	54	89	132
550	60	—	5.6	10.3	16.9	25.1	47.9	79	119
550	100	—	4.5	8.3	13.5	20.5	40.0	67	101
550	160	—	3.6	6.7	11.2	17.4	33.1	56	85
550	250	—	3.0	5.4	9.1	13.8	27.2	46.2	71

SI Conversions: kPa = psig × 6.895; mm = in. × 25.4; kg/s = lb/min × 0.007559; m = ft × 0.3048

(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

INFORMATIVE APPENDIX F
EMERGENCIES IN REFRIGERATING MACHINERY ROOMS

This standard specifies refrigerating *machinery rooms* under some conditions to reduce risks from large *refrigerating systems* and large amounts of *refrigerant*. One purpose of the requirements is to warn of emergencies in the refrigerating *machinery room*. The *refrigerant detector* required by Section 8.9.5 or 8.11.8 triggers alarms inside and outside the refrigerating *machinery room*. Signage warns refrigeration technicians and bystanders not to enter when the alarm has activated.

This appendix provides guidance on integrating the minimum emergency warning and training requirements of this standard with measures often taken in occupational health and safety programs.

The requirements in the standard provide minimum protection to help prevent injury from refrigerating *machinery room* accidents. Minimal conformance to the standard's specifications does not necessarily facilitate the convenient handling of incidents in the room. For example, if only the minimum protective steps are taken, refrigeration technicians may not reenter the *machinery room* after an alarm has sounded (to silence the alarm and repair any damage) without calling on the services of emergency responders (generally the local hazardous materials team). Many other approaches are possible, especially in facilities that prepare sophisticated emergency response plans.

F1. ALARM LEVELS

A *refrigerant* level above the *occupational exposure limit* (*OEL*) activates the alarms required by Section 8.9.5 or 8.11.10. If personnel working in the refrigerating *machinery room* are not provided with and trained to use respiratory protection equipment appropriate for the *refrigerant* (such as canister respirators or self-contained breathing apparatus), they must leave the room immediately. Presence of *refrigerant* above the *OEL* does not by itself signal an emergency. Many routine service operations can create such levels. Local or national regulations often prescribe that steps be taken to protect the health and safety of personnel working in the *machinery room* when *refrigerant* concentrations rise above the *OEL*.

In a more sophisticated facility, with appropriate training and other measures *specified* by local regulations, refrigeration technicians might use this alarm as a signal to don respiratory protection. Evacuation of the *machinery room* may not be necessary, although warning bystanders not to enter still is. Selection of the proper respiratory protection for the particular situation may require additional information (e.g., whether or not the *refrigerant* concentration is above the *immediately dangerous to life or health* [*IDLH*] level).

Note that donning respiratory protection is a last-resort option under most industrial hygiene regimens. It is preferable to provide *engineering controls* to reduce *refrigerant* concentrations to tolerable levels. The *refrigerant detector* required by Section 8.9.5 or 8.11.8 activates the *machinery room* ventilation automatically. In many cases, this may be entirely adequate to reduce the concentration, and respiratory protection may not be needed. (An alarm silence switch is useful for situations where personnel are to remain working in the room.)

F2. ALTERNATE REFRIGERANT LEVEL MEASUREMENTS

The required alarms signal only that *refrigerant* was detected at concentrations above the *OEL*. Some facilities may find it useful to have multiple levels of alarm or to provide an instrument that indicates the actual *refrigerant* level (digital readout in parts per million of *refrigerant*). Selecting proper respiratory protection for technicians or other responders, as mentioned above, is one reason. This is perfectly acceptable, provided that the additional alarms or indicators are clearly distinguished from the main alarm. Bystanders should not be confused by the alarm arrangements.

The main alarm must be a manual-reset type as required per Section 8.9.5 or 8.11.10.2. It is unwise to rely on automatic detectors to announce that an event is over. A technician could not distinguish between an alarm that reset when the *refrigerant* concentration dropped (e.g., because ventilation fans controlled the incident) and one that reset because the *refrigerant detector* was damaged. In the latter case, anyone entering the refrigerating *machinery room* might be entering a hazardous area. Alarms or indicators intended to communicate current conditions inside the refrigeration *machinery room* may, of course, be automatically resetting.

F3. REENTRY INTO REFRIGERATING MACHINERY ROOMS

Reentering an area during an emergency requires sophisticated equipment and training; many national and local regulations govern such activities. Prepositioning emergency response equipment (e.g., self-contained breathing apparatus) should be done only by arrangement with emergency responders, and any prepositioned equipment should be clearly labeled for use by trained personnel only. Doing otherwise invites unauthorized use (or vandalism) by untrained personnel, with dangerous consequences.

Facilities should note, however, that the alarms required in this standard annunciate not that an emergency is occurring but that an abnormal situation is occurring. It may be acceptable for trained personnel to enter the refrigerating *machinery room* to investigate the situation, repair minor leaks, reset alarms tripped in error, etc. Any personnel required to enter should be provided with appropriate personal protective equipment (especially respiratory protection, if needed) and should be trained to recognize an emergency situation requiring professional emergency response.

F4. EXAMPLE EMERGENCY PROCEDURES

As an example (and there are many other possibilities), consider a facility that wishes to use its own technicians to handle minor problems in the refrigerating *machinery room*. The facility

a. provides the *refrigerant* alarm required by Section 8.9.5 or 8.11.10, along with signage warning "Authorized Personnel Only. Stay Out When Refrigerant Alarm Sounds; Call Facilities Management Immediately." This alarm triggers at the *OEL*.
b. provides a digital readout of the current *refrigerant detector* reading outside the refrigerating *machinery room*. A sign distinguishes the current-reading indicator from the alarm-activation indicator required by Section 8.9.5 or 8.11.10.
c. provides the refrigeration technicians with appropriate respiratory protection suitable for use in an atmosphere containing *refrigerant* in concentrations below the *IDLH*, in accordance with all applicable national and local regulations.
d. defines as "incidental" any *refrigerant* release that is not producing levels above the *IDLH* in the *machinery room*. (The ventilating system will render many potential releases incidental.)
e. trains the technicians to leave the refrigerating *machinery room* when the *refrigerant* alarm sounds. After donning appropriate respiratory protection (if necessary), they may reenter the *machinery room* to close valves, fix leaks, shut off alarms, etc., if and only if the current *refrigerant* level is below the *IDLH*. That is, technicians may reenter the room if the *refrigerant* release is incidental. If the level exceeds the *IDLH*, or the problem seems uncontrolled in the sense that it may unpredictably worsen or require a team of technicians to fix, they are to leave and call for emergency responders.
f. coordinates emergency procedures with the local emergency response agencies in advance.

None of these steps contradicts the requirements of the standard, but the additional procedures significantly aid the facility's efforts to handle minor maintenance problems safely.

(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

INFORMATIVE APPENDIX G
ADDENDA DESCRIPTION

ANSI/ASHRAE Standard 15-2022 incorporates ANSI/ASHRAE Standard 15-2019 and Addenda a, b, c, d, e, f, g, i, j, k, l, m, n, o, p, q, r, s, u, v, and w to ANSI/ASHRAE Standard 15-2019. Table G-1 lists each addendum and describes the way in which the standard is affected by the change. It also lists the ASHRAE and ANSI approval dates for each addendum.

Table G-1 Addenda to ANSI/ASHRAE Standard 15-2019

Addendum	Sections Affected	Description of Change*	ASHRAE Standards Approval
a	9.7.5, 9.7.5.1 (new), 9.7.5.2 (new)	Addendum *a* provides capacity factors for overpressure protection of pressure vessels and pressure equipment for a number of new refrigerants and expands the coverage of capacity factors for existing refrigerants based on the design pressure for the portion of the system being pressure protected.	February 1, 2020 (Std. Comm.) February 5, 2020 (ASHRAE BOD) February 6, 2020 (ANSI)
b	3.1	Addendum *b* changes the definition of “listed” and adds the term “labeled” to Section 3.1.	February 1, 2020 (Std. Comm.) February 5, 2020 (ASHRAE BOD) February 6, 2020 (ANSI)
c	7.2; 7.5; 7.1.5.2	Addendum *c* makes changes to allow the use of equipment using small amounts of non-A1 refrigerants only if they are listed to appropriate product safety standards.	September 1, 2020 (ASHRAE Staff) September 1, 2020 (ANSI)
d	2.4 (new)	Addendum *d* revises the scope of the standard to clarify that it does not apply to residential refrigeration systems covered by ASHRAE Standard 15.2. This change in scope coincides with the publication of ASHRAE Standard 15.2.	April 29, 2022 (ASHRAE Staff) April 29, 2022 (ANSI)
e	3.1; 7.2.2; 7.4.2; 7.4.3; 7.5.1.8; 8.7; 8.8; 8.9; 8.10; 8.11; 8.12; 8.13; 8.14; 8.15; 9.9.1; 9.10; 9.11 (new); 9.12 (new); 9.13 (new); 9.14; 9.15; 9.16 (new); 9.17 (new); 10; 11; 12; 13; Informative Appendix A; Normative Appendix B; Informative Appendix F	Addendum *e* revises requirements related to the design, installation, location, and testing of refrigerant piping.	January 27, 2022 (ASHRAE Staff) January 27, 2022 (ANSI)
f	14 (new); Informative Appendix A (new); Normative Appendix B	Addendum *f* inserts a new appendix that will be used to add clarifying, nonmandatory reference information for the purpose of improving ease of use and moves mandatory normative reference information into the body of the standard.	September 30, 2020 (ASHRAE Staff) September 30, 2020 (ANSI)

* These descriptions may not be complete and are provided for information only.

Table G-1 Addenda to ANSI/ASHRAE Standard 15-2019 [Continued]

Addendum	Sections Affected	Description of Change*	ASHRAE Standards Approval
g	3.1; 7.2; 7.3; Informative Appendix A	Addendum *g* completely rewrites Section 7.2, "Concentration Limits," and Section 7.3, "Volume Calculations," by reversing the existing sections, first addressing the volume of spaces for consideration (new Section 7.2), then determining acceptable refrigerant charge quantity (new Section 7.3).	August 31, 2022 (ASHRAE Staff) August 31, 2022 (ANSI)
i	Table 7-1; 7.4; 8.11.5; 8.11.8; 8.13; 8.13.6; 8.13.11.4; Informative Appendix A	Addendum *i* modifies ASHRAE Standard 15 by making necessary changes to defer regulation of ammonia refrigeration to ANSI/IIAR 2 (see Section 2.3).	July 31, 2020 (ASHRAE Staff) July 31, 2020 (ANSI)
j	7.4.2; 7.4.3; 9.14.1.1; 10.1.2;	Addendum *j* modifies ANSI/ASHRAE Standard 15 by replacing the terms "flammable" and "nonflammable" with refrigerant class when referencing refrigerants classified by ANSI/ASHRAE Standard 34.	October 30, 2020 (ASHRAE Staff) October 30, 2020 (ANSI)
k	7.6.2; Normative Appendix B	Addendum *k* modifies the existing listing requirement in ANSI/ASHRAE Standard 15 by clarifying the acceptable product safety listing standards.	October 30, 2020 (ASHRAE Staff) October 30, 2020 (ANSI)
l	7.4; 7.5.1; 7.5.1.9 (new); 7.5.2, 7.5.2.1 (new), 7.5.2.2 (new); 7.5.3; 7.7 (new); 7.8 (new); Informative Appendix A; Normative Appendix B	Addendum *l* modifies portions of ASHRAE Standard 15 to incorporate requirements for commercial refrigeration applications with the use of A2L, A2, and A3 refrigerants.	August 31, 2022 (ASHRAE Staff) August 31, 2022 (ANSI)
m	3.1; 7.2; 7.3; 7.6; Informative Appendix A; Normative Appendix B	Addendum *m* to ANSI/ASHRAE Standard 15-2019 modifies allowances for the use of mechanical ventilation to expand this mitigation strategy for human comfort applications using A2L refrigerants.	June 30, 2022 (ASHRAE Staff) June 30, 2022 (ANSI)
n	7.6.3.3; Informative Appendix A	Addendum *n* to ANSI/ASHRAE Standard 15-2019 addresses a continuous maintenance proposal to clarify wording about face velocity.	May 31, 2022 (ASHRAE Staff) May 31, 2022 (ANSI)
o	5.3.1; Informative Appendix A	Addendum *o* clarifies the intent and requirement for notification.	April 29, 2022 (ASHRAE Staff) April 29, 2022 (ANSI)
p	3.1; 7.6.1, 7.6.1.1, 7.6.1.2; Informative Appendix A	Addendum *p* makes a modification to refrigerant charge quantity limits for A2L human comfort systems, which aligns Standard 15 with the outcome of the AHRTI-9015, *Assessment of Refrigerant Leakage Mitigation Effectiveness for Air-Conditioning and Refrigeration Equipment* research project. This modification will also make the requirements in Standard 15 more consistent with the requirements of the product safety standard.	August 31, 2022 (ASHRAE Staff) August 31, 2022 (ANSI)
q	7.4, 7.4.2, 7.4.3; 8.11.5, 8.11.8, 8.11.8.1, 8.13, Table 8-2, 8.13.11.4, Table 8-3, Figures 8-1 and 8-2; Informative Appendix A	Addendum *q* modifies requirements for mechanical ventilation in machinery rooms with equipment using one or more Class 2L flammable refrigerants but not containing any Class 2 or Class 3 flammable refrigerants.	May 31, 2022 (ASHRAE Staff) May 31, 2022 (ANSI)
r	3.1	Addendum *r* modifies the definition of "machinery room" in Section 3.	May 31, 2022 (ASHRAE Staff) May 31, 2022 (ANSI)

* These descriptions may not be complete and are provided for information only.

Table G-1 Addenda to ANSI/ASHRAE Standard 15-2019 [Continued]

Addendum	Sections Affected	Description of Change*	ASHRAE Standards Approval
s	3.1; 7.6.2, 7.6.2.3, 7.6.2.4, 7.6.2.5 (new), 7.6.4, 7.6.5; Informative Appendix A	Addendum *s* addresses the use of refrigerant detection and mitigation requirements when a leak is detected in A2L systems for human comfort.	August 31, 2022 (ASHRAE Staff) August 31, 2022 (ANSI)
u	3.1; 5.3.2; 9.3.3.1, 9.10.1, 9.11.1; 13; Informative Appendix A	Addendum *u* updates the definition of "approved, nationally recognized laboratory" to align Standard 15 with U.S. Occupational Safety and Health Administration's (OSHA) usage.	August 31, 2022 (ASHRAE Staff) August 31, 2022 (ANSI)
v	3.1	Addendum *v* updates the definitions of "brazed joint" and "soldered joint" by addressing a gap in the current definitions that exists between 800°F (426.5°C) and 1000°F (537.7°C). This change harmonizes Standard 15 usage with both ISO 4063:2009 and ANSI/AWS 3.0MM/A3.0:2020.	August 31, 2022 (ASHRAE Staff) August 31, 2022 (ANSI)
w	6.1, 6.2, 6.3	Addendum *j* to ANSI/ASHRAE Standard 15-2019 revised the definitions of "flammable" and "nonflammable" using the flammability classification class numbers from ANSI/ASHRAE Standard 34, *Designation and Safety Classification of Refrigerants*. That change creates an inconsistency in the standard, as all other content makes use of the safety group (a combination of both toxicity and flammability classifications) but does not make direct use of the toxicity classification alone nor the flammability classification alone. Section 6 currently explains how refrigerant safety classifications are used within Standard 15 but only describes the use of safety groups and not the individual classifications. Addendum *w* resolves this inconsistency.	August 31, 2022 (ASHRAE Staff) August 31, 2022 (ANSI)

* These descriptions may not be complete and are provided for information only.

NOTE

Approved addenda, errata, or interpretations for this standard can be downloaded free of charge from the ASHRAE website at www.ashrae.org/technology.

POLICY STATEMENT DEFINING ASHRAE'S CONCERN FOR THE ENVIRONMENTAL IMPACT OF ITS ACTIVITIES

ASHRAE is concerned with the impact of its members' activities on both the indoor and outdoor environment. ASHRAE's members will strive to minimize any possible deleterious effect on the indoor and outdoor environment of the systems and components in their responsibility while maximizing the beneficial effects these systems provide, consistent with accepted Standards and the practical state of the art.

ASHRAE's short-range goal is to ensure that the systems and components within its scope do not impact the indoor and outdoor environment to a greater extent than specified by the Standards and Guidelines as established by itself and other responsible bodies.

As an ongoing goal, ASHRAE will, through its Standards Committee and extensive Technical Committee structure, continue to generate up-to-date Standards and Guidelines where appropriate and adopt, recommend, and promote those new and revised Standards developed by other responsible organizations.

Through its *Handbook*, appropriate chapters will contain up-to-date Standards and design considerations as the material is systematically revised.

ASHRAE will take the lead with respect to dissemination of environmental information of its primary interest and will seek out and disseminate information from other responsible organizations that is pertinent, as guides to updating Standards and Guidelines.

The effects of the design and selection of equipment and systems will be considered within the scope of the system's intended use and expected misuse. The disposal of hazardous materials, if any, will also be considered.

ASHRAE's primary concern for environmental impact will be at the site where equipment within ASHRAE's scope operates. However, energy source selection and the possible environmental impact due to the energy source and energy transportation will be considered where possible. Recommendations concerning energy source selection should be made by its members.

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Founded in 1894, ASHRAE is a global professional society committed to serve humanity by advancing the arts and sciences of heating, ventilation, air conditioning, refrigeration, and their allied fields.

As an industry leader in research, standards writing, publishing, certification, and continuing education, ASHRAE and its members are dedicated to promoting a healthy and sustainable built environment for all, through strategic partnerships with organizations in the HVAC&R community and across related industries.

To stay current with this and other ASHRAE Standards and Guidelines, visit www.ashrae.org/standards, and connect on LinkedIn, Facebook, Twitter, and YouTube.

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IMPORTANT NOTICES ABOUT THIS STANDARD

To ensure that you have all of the approved addenda, errata, and interpretations for this Standard, visit www.ashrae.org/standards to download them free of charge.

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Product code: 86306 9/22

STANDARD

ANSI/ASHRAE Standard 34-2022

(Supersedes ANSI/ASHRAE Standard 34-2019)
Includes ANSI/ASHRAE addenda listed in Appendix J

Designation and Safety Classification of Refrigerants

See Informative Appendix J for approval dates by ASHRAE and the American National Standards Institute.

This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. Instructions for how to submit a change can be found on the ASHRAE® website (www.ashrae.org/continuous-maintenance).

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 ISSN 1041-2336

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Approved American National Standard
ANSI
www.ansi.org

SPECIAL NOTE

This American National Standard (ANS) is a national voluntary consensus Standard developed under the auspices of ASHRAE. *Consensus* is defined by the American National Standards Institute (ANSI), of which ASHRAE is a member and which has approved this Standard as an ANS, as "substantial agreement reached by directly and materially affected interest categories. This signifies the concurrence of more than a simple majority, but not necessarily unanimity. Consensus requires that all views and objections be considered, and that an effort be made toward their resolution." Compliance with this Standard is voluntary until and unless a legal jurisdiction makes compliance mandatory through legislation.

ASHRAE obtains consensus through participation of its national and international members, associated societies, and public review.

ASHRAE Standards are prepared by a Project Committee appointed specifically for the purpose of writing the Standard. The Project Committee Chair and Vice-Chair must be members of ASHRAE; while other committee members may or may not be ASHRAE members, all must be technically qualified in the subject area of the Standard. Every effort is made to balance the concerned interests on all Project Committees.

The Senior Manager of Standards of ASHRAE should be contacted for

a. interpretation of the contents of this Standard,
b. participation in the next review of the Standard,
c. offering constructive criticism for improving the Standard, or
d. permission to reprint portions of the Standard.

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In referring to this Standard or Guideline and in marking of equipment and in advertising, no claim shall be made, either stated or implied, that the product has been approved by ASHRAE.

CONTENTS

ANSI/ASHRAE Standard 34-2022
Designation and Safety Classification of Refrigerants

NOTE

Approved addenda, errata, or interpretations for this standard can be downloaded free of charge from the ASHRAE website at www.ashrae.org/technology.

(This foreword is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

FOREWORD

ASHRAE Standard 34 describes a shorthand way of naming refrigerants, and it assigns safety classifications and refrigerant concentration limits based on toxicity and flammability data.

The 2022 edition of the standard incorporates 31 approved and published addenda to the 2019 edition. Brief descriptions of the addenda and their dates of approval are included in Informative Appendix J.

First published in 1957, Standard 34 is updated on a regular basis using ASHRAE's continuous maintenance procedure. In accordance with this procedure, the standard is revised several times a year via addenda that are publicly reviewed, approved by ASHRAE and ANSI, and published on the ASHRAE website.

Users are encouraged to use the continuous maintenance procedure to propose changes for further improvements to the standard. Instructions can be found at www.ashrae.org/continuous-maintenance.

Also, because the standard changes as new addenda are published, ASHRAE recommends subscribing to the free Standards Actions listserv, which provides notice of all public reviews and approved and published addenda and errata. At the minimum, users should periodically review the ASHRAE website to ensure they have the latest published addenda.

Application guidance for designation, flammability, and toxicity is available at sspc34.ashraepcs.org.

The following are key changes included in the 2022 edition:

- *Twenty refrigerants were added to Table 4-2, and two were added to Table 4-1.*
- *LFL data were added to Tables 4-1 and 4-2 for flammable refrigerants.*
- *The standard was updated to remove the requirement for print format submissions of applications for designation and safety classification.*
- *The standard was revised to allow refrigerant designation alignment with ISO Standard 817.*
- *Language was added to clarify that blend toxicity data take precedent over calculated values for the components, where available.*

1. PURPOSE

This standard is intended to establish a simple means of referring to common refrigerants instead of using the chemical name, formula, or trade name. It establishes a uniform system for assigning reference numbers, safety classifications, and refrigerant concentration limits to refrigerants. The standard also identifies requirements to apply for designations and safety classifications for refrigerants and to determine refrigerant concentration limits.

2. SCOPE

This standard provides an unambiguous system for numbering refrigerants and assigning composition designating prefixes for refrigerants. Safety classifications based on toxicity and flammability data are included along with refrigerant concentration limits for the refrigerants.

This standard does not imply endorsement or concurrence that individual refrigerant blends are suitable for any particular application.

3. DEFINITIONS

3.1 Defined Terms

acute toxicity: the adverse health effects from a single, short-term exposure, as might occur during an accidental release of refrigerants.

acute toxicity exposure limit (ATEL): the refrigerant concentration limit determined in accordance with this standard and intended to reduce the risks of acute toxicity hazards in normally occupied, enclosed spaces. ATEL values are similar to the immediately dangerous to life or health (IDLH) concentrations set by the National Institute of Occupational Safety and Health (NIOSH). ATELs include explicit, additional components for cardiac sensitization and anesthetic effects, but they do not address flammability. The lowest ATEL, 50,000 ppm by volume, or 10% of the lower flammability limit, therefore provides a conservative approximation to IDLH concentrations when needed for refrigerants without adopted IDLH values.

approximate lethal concentration (ALC): the concentration of a substance, a refrigerant in this standard, that was lethal to even a single test animal when tested by the same conditions as for an LC_{50} test.

anesthetic effect: loss of the ability to perceive pain and other sensory stimulation.

azeotropic: an azeotropic blend is one containing two or more refrigerants whose equilibrium vapor and liquid-phase compositions are the same at a given pressure. At this pressure, the slope of the temperature-versus-composition curve equals zero, which mathematically is expressed as $(dt/dx)_p = 0$, which in turn implies the occurrence of a maximum, minimum, or saddle-point temperature. Azeotropic blends exhibit some segregation of components at other conditions. The extent of the segregation depends on the particular azeotrope and the application.

azeotropic temperature: the temperature at which the liquid and vapor phases of a blend have the same mole fraction of each component at equilibrium for a specified pressure.

blend: a refrigerant consisting of a mixture of two or more different chemical compounds, often used individually as refrigerants for other applications.

bubble point: the liquid saturation temperature of a refrigerant at the specified pressure; the temperature at which a liquid refrigerant first begins to boil. The bubble point of a zeotropic refrigerant blend, at constant pressure, is lower than the dew point.

burning velocity (S_u): the maximum velocity (in./s [cm/s]) at which a laminar flame propagates in a normal direction relative to the unburned gas ahead of it.

cardiac sensitization: an acute effect in which the heart is rendered more sensitive to the body's own catecholamine compounds or administered drugs, such as epinephrine, possibly resulting in irregular heart beat (cardiac arrhythmia), which could be fatal.

ceiling: an exposure level, permissible exposure level ceiling (PEL-C) or threshold limit value ceiling (TLV-C), that should not be exceeded during any part of the day.

central nervous system (CNS) effect: treatment-related depression, distraction, stimulation, or other behavioral modification suggesting temporary or permanent changes to control by the brain.

chronic toxicity: adverse health effects from long-term, repeated exposures. This information is used in part to establish TLV-TWA, PEL, or consistent indices.

committee: as used in this standard, *committee* refers to ASHRAE Standing Standards Project Committee (SSPC) 34.

compounds: substances formed by the chemical combination of two or more elements in definite proportions by mass.

critical point: the location on a plot of thermodynamic properties at which the liquid and vapor states of a substance meet and become indistinguishable. The temperature, density, and composition of the substance are the same for the liquid and vapor phases at this point. The density, pressure, specific volume, and temperature at the critical point are referred to as the *critical density*, *critical pressure*, *critical volume*, and *critical temperature*, respectively.

cyclic compound: an organic compound that contains three or more atoms arranged in a ring structure.

dew point: the vapor saturation temperature of a refrigerant at the specified pressure; the temperature at which the last drop of liquid refrigerant boils. The dew point of a zeotropic refrigerant blend, at constant pressure, is higher than the bubble point.

effective concentration 50% (EC_{50}): the concentration of a material, a refrigerant in this standard, that has caused a biological effect to 50% of test animals.

elevated temperature flame limit (ETFL): the minimum concentration of refrigerant that is capable of propagating a flame through a homogeneous mixture of the refrigerant and air using test equipment and procedures specified in Normative Appendix B, Section B1.1, at 14.7 psia (101.3 kPa) above 73°F (23°C). It is normally expressed as a refrigerant percentage by volume. When tested at 140°F (60°C), it is called the $ETFL_{60}$.

flame propagation: any combustion that moves upward and outward from the point of ignition as defined in Section B1.8 (for determining flammability according to Normative Appendix B).

flammable concentration limit (FCL): the refrigerant concentration limit, in air, determined in accordance with this standard and intended to reduce the risk of fire or explosion in normally occupied, enclosed spaces.

fractionation: a change in composition of a blend by preferential evaporation of the more volatile components or condensation of the less volatile components.

glide: the absolute value of the difference between the starting and ending temperatures of a phase change process by a refrigerant within a component of a refrigerating system, exclusive of any subcooling or superheating. This term usually describes condensation or evaporation of a zeotrope.

halocarbon: as used in this standard, a hydrocarbon derivative containing one or more of the halogens bromine, chlorine, fluorine, or iodine; hydrogen also may be present.

heat of combustion: the heat released when a substance is combusted, determined as the difference in the enthalpy between the reactants (refrigerants and air) and their products after combustion as defined in Section 6.1.3.6. The heat or enthalpy of combustion is often expressed as energy per mass (e.g., Btu/lb [kJ/kg]).

highly toxic: a material that produces a lethal dose or lethal concentration that falls within any of the following categories [1,2,3]:

a. A chemical that has a median lethal dose (LD_{50}) of 50 mg or less per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 g each.
b. A chemical that has a median lethal dose (LD_{50}) of 200 mg or less per kilogram of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between 2 and 3 kg each.
c. A chemical that has a median lethal concentration (LC_{50}) in air of 200 ppm by volume or less of gas or vapor, or 2 mg per litre or less of mist, fume, or dust, when administered by continuous inhalation for one (1) hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 g each.

hydrocarbon: a compound containing only the elements hydrogen and carbon.

isomer: one of a group of compounds having the same chemical composition with differing molecular structures. Examples include R-123 and R-123a, both of which contain one hydrogen atom and two carbon, three fluorine, and two chlorine atoms; both chlorine atoms are bonded to the same carbon atom in R-123 ($CHCl_2CF_3$), but one is bonded to each in R-123a ($CHClFCClF_2$). The methane series of refrigerants cannot form isomers because the single-carbon nucleus does not enable structural variations.

lethal concentration 50% (LC_{50}): a measure of acute inhalation toxicity representing a lethal concentration for 50% of exposed test animals for a specified time interval and species of animal.

lower flammability limit (LFL): the minimum concentration of a substance, a refrigerant in this standard, that is capable of propagating a flame through a homogeneous mixture of the substance and air under specified test conditions.

lowest observed effect level (LOEL): the concentration of a material, a refrigerant in this standard, that has caused any adverse effect to even one test animal.

maximum temperature glide: the difference between the saturated liquid temperature (bubble point) and the saturated vapor temperature (dew point) for the as-formulated blend composition at constant pressure. For a given pressure, the evaporator temperature glide in a direct expansion system will typically be 70% to 80% of the maximum temperature glide, as the refrigerant blend entering the evaporator is a mixture of liquid and vapor, and not at the saturated liquid temperature of the as-formulated blend composition.

near azeotropic: a zeotropic blend with a temperature glide sufficiently small that it may be disregarded without consequential error in analysis for a specific application.

nominal formulation: the bulk manufactured composition of the refrigerant, which includes the gas and liquid phases. For the purpose of this standard, when a container is 80% or more liquid filled, the liquid composition may be considered the nominal composition.

nonazeotropic: a synonym for *zeotropic*, the latter being the preferred descriptor. Both *non*- and *a*- are negation prefixes, the latter from Latin, and therefore cancel one another (i.e., not-not-zeotropic, hence zeotropic). The double negative results from antecedent interest in, and the need to make a distinction with, azeotropic mixtures.

no-observed-effect level (NOEL): the highest concentration of a material, a refrigerant in this standard, at which no adverse effect has been observed in even one test animal.

occupational exposure limit (OEL): the time-weighted average (TWA) concentration for a normal eight-hour workday and a 40-hour workweek to which nearly all workers can be repeatedly exposed without adverse effect, based on the OSHA PEL, ACGIH TLV-TWA, TERA OARS-WEEL, or consistent value.

olefin: an organic (carbon containing) compound characterized by the presence of one or more double bonds between carbon atoms in the molecule. Such a compound can also be described as being unsaturated.

oxygen deprivation limit (ODL): the concentration of a refrigerant or other gas that results in insufficient oxygen for normal breathing.

permissible exposure level (PEL): the TWA concentration (set by the U.S. Occupational Safety and Health Administration [OSHA]) for a normal eight-hour workday and a 40-hour workweek to which nearly all workers can be repeatedly exposed without adverse effect. Chemical manufacturers publish similar recommendations (e.g., acceptable exposure level [AEL], industrial exposure limit [IEL], or occupational exposure limit [OEL], depending on the company), generally for substances for which PEL has not been established.

ppm: parts per million.

propagation velocity of flame: the velocity at which the flame propagates in the test space.

refrigerant: the fluid used for heat transfer in a refrigerating system; the refrigerant absorbs heat and transfers it at a higher temperature and a higher pressure, usually with a phase change. Substances added to provide other functions, such as lubrication, leak detection, absorption, or drying, are not refrigerants.

refrigerant concentration limit (RCL): the refrigerant concentration limit, in air, determined in accordance with this standard and intended to reduce the risks of acute toxicity, asphyxiation, and flammability hazards in normally occupied, enclosed spaces.

relative molar mass: the ratio of the mass of a molecule to 1/12 of that of carbon-12. The relative molar mass is numerically equivalent to the molecular weight expressed in g/mol, but it is dimensionless.

saturated: an organic (carbon containing) compound in which each carbon atom is joined to four other atoms; all of the chemical bonds in a saturated compound are single.

short-term exposure limit (STEL): typically a 15-minute TWA exposure that should not be exceeded at any time during a workday.

temperature glide: see *glide*.

threshold limit value (TLV): TLVs refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse health effects. Because of the wide variation in individual susceptibility, however, a small percentage of workers may experience discomfort from some substances at concentrations at or below the threshold limit; a smaller percentage may be affected more seriously by aggravation of a preexisting condition or by development of an occupational illness. Smoking of tobacco is harmful for several reasons. Smoking may act to enhance the biological effects of chemicals encountered in the workplace and may reduce the body’s defense mechanisms against toxic substances.

Individuals may also be hypersusceptible or otherwise unusually responsive to some industrial chemicals because of genetic factors, age, personal habits (smoking, use of alcohol or other drugs), medication, or previous exposure. Such workers may not be adequately protected from adverse health effects from certain chemicals at concentrations at or below the threshold limits. An occupational physician should evaluate the extent to which such workers require additional protection.

TLVs are based on the best available information from industrial experience, from experimental human and animal studies, and, when possible, from a combination of the three. The basis on which the values are established may differ from substance to substance; protection against impairment of health may be a guiding factor for some, whereas reasonable freedom from irritation, narcosis, nuisance, or other forms of stress may form the basis for others [4]. (***Informative Note:*** This definition is reprinted by permission of the American Conference of Governmental Industrial Hygienists [ACGIH].)

threshold limit value time-weighted average (TLV-TWA): the time-weighted average concentration for a normal eight-hour workday and a 40-hour workweek to which nearly all workers may be repeatedly exposed, day after day, without adverse effect [4]. (***Informative Note:*** This definition is reprinted by permission of the American Conference of Governmental Industrial Hygienists [ACGIH].)

toxic: a chemical falling within any of the following categories [1,2,3]:

a. A chemical that has a median lethal dose (LD_{50}) of more than 50 mg/kg but not more than 500 mg/kg of body weight when administered orally to albino rats weighing between 200 and 300 g each.
b. A chemical that has a median lethal dose (LD_{50}) of more than 200 mg/kg but not more than 1000 mg/kg of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between 2 and 3 kg each.

c. A chemical that has a median lethal concentration (LC_{50}) in air of more than 200 ppm but not more than 2000 ppm by volume of gas or vapor, or more than 2 mg/L but not more than 20 mg/L of mist, fume, or dust, when administered by continuous inhalation for one (1) hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 g each.

toxicity: the ability of a refrigerant to be harmful or lethal due to acute or chronic exposure by contact, inhalation, or ingestion. The effects of concern include (but are not limited to) those of carcinogens, poisons, reproductive toxins, irritants, corrosives, sensitizers, hepatoxins, nephrotoxins, neurotoxins, agents that act on the hematopoietic system, and agents that damage the lungs, skin, eyes, or mucous membranes. For this standard, temporary discomfort at a level that is not impairing is excluded.

unsaturated: as used in this standard, an organic (carbon containing) compound in which one or more carbon atoms are joined to other carbon atoms by a carbon-carbon double bond. Such a compound can also be described as an *olefin*.

workplace environmental exposure level (WEEL): an OEL set by the Toxicology Excellence for Risk Assessment (TERA) Occupational Alliance for Risk Science (OARS) [5] (previously issued by American Industrial Hygiene Association [AIHA]); the TWA concentration, measured in the worker breathing zone, for a normal eight-hour workday and 40-hour workweek for which it is believed that nearly all workers can be repeatedly exposed without adverse health effects. OARS-WEEL values may be expressed as time-weighted average TWA concentrations, short-term exposure levels (STELs), or ceiling values.

worst case of formulation for flammability (WCF): the nominal formulation, including the composition tolerances, that results in the most flammable concentration of components.

worst case of fractionation for flammability (WCFF): the composition produced during fractionation of the worst case of formulation for flammability that results in the highest concentration of flammable components as identified in this standard in the vapor or liquid phase.

zeotropic: blends comprising multiple components of different volatilities that, when used in refrigeration cycles, change volumetric composition and saturation temperatures as they evaporate (boil) or condense at constant pressure. The word is derived from the Greek words *zein* (to boil) and *tropos* (to change).

3.2 Acronyms, Abbreviations, and Initialisms

ACGIH	American Conference of Governmental Industrial Hygienists
ALC	approximate lethal concentration
ATEL	acute toxicity exposure limit
CNS	central nervous system
EC	effective concentration
ETFL	elevated temperature flame limit
FCL	flammable concentration limit
IDLH	immediately dangerous to life or health
LC	lethal concentration
LFL	lower flammability limit
LOEL	lowest observed effect level
NIOSH	National Institute of Occupational Safety and Health
NOEL	no-observed-effect level
ODL	oxygen deprivation limit
OEL	occupational exposure limit
OSHA	U.S. Occupational Safety and Health Administration
PEL	permissible exposure level
RCL	refrigerant concentration limit
STEL	short-term exposure limit
TERA	Toxicology Excellence for Risk Assessment
TLV	threshold limit value
TLV-C	threshold limit value ceiling
TLV-TWA	threshold limit value time-weighted average
TWA	time-weighted average
WCF	worst case of formulation for flammability

WCFF	worst case of fractionation for flammability
WEEL	workplace environmental exposure level

4. NUMBERING OF REFRIGERANTS

An identifying number shall be assigned to each refrigerant. Assigned numbers are shown in Tables 4-1 and 4-2.

Informative Note: Atwood (1989) provides background on the need for a standard refrigerant nomenclature (see Informative Appendix C).

4.1 The identifying numbers assigned to the hydrocarbons and halocarbons of the methane, ethane, ethene, propane, propene, butane, butene, and cyclobutane series are such that the chemical composition of the compounds can be explicitly determined from the refrigerant numbers, and vice versa, without ambiguity. The molecular structure can be similarly determined for the methane, ethane, ethene, and most of the propane and propene, butane, butene, and cyclobutane series from only the identification number.

4.1.1 The first digit on the right is the number of fluorine (F) atoms in the compound.

4.1.2 The second digit from the right is one more than the number of hydrogen (H) atoms in the compound.

4.1.3 The third digit from the right is one less than the number of carbon (C) atoms in the compound. When this digit is zero, it is omitted from the number.

4.1.4 The fourth digit from the right is equal to the number of unsaturated carbon-carbon bonds in the compound. When this digit is zero, it is omitted from the number.

4.1.5 In those instances where bromine (Br) is present in place of part or all of the chlorine, the same rules apply, except that the uppercase letter "B" after the designation for the parent chlorofluoro compound shows the presence of bromine. The number following the letter "B" shows the number of bromine atoms present.

4.1.6 In those instances where iodine (I) is present in place of part or all of the chlorine, the same rules apply, except that the uppercase letter "I" after the designation for the parent chlorofluoro compound shows the presence of iodine. The number following the letter "I" shows the number of iodine atoms present.

4.1.7 The number of chlorine (Cl) atoms in the compound is found by subtracting the sum of fluorine (F), bromine (Br), iodine (I), and hydrogen (H) atoms from the total number of atoms that can be connected to the carbon (C) atoms. For saturated refrigerants, this number is $2n + 2$, where n is the number of carbon atoms. The number is $2n$ for monounsaturated and cyclic-saturated refrigerants.

4.1.8 The carbon atoms shall be numbered sequentially, in order of appearance, with the number "1" assigned to the end carbon with the greatest number of hydrogen substituents (i.e., number of halogenated atoms substituted for hydrogen on the alkane end carbon atoms). In the case where both end carbons of a saturated compound contain the same number of (but different) halogen atoms, the number "1" shall be assigned to the end carbon, defined as having the largest number of bromine, then chlorine, then fluorine, and then iodine atoms. If the compound is an olefin, then the end carbon nearest to the double bond will be assigned the number "1," as the presence of a double bond in the backbone of the molecule has priority over substituent groups on the molecule.

4.1.9 In the case of isomers in the ethane series, each has the same number, with the most symmetrical one indicated by the number alone. As the isomers become more and more asymmetrical, successive lowercase letters (e.g., "a," "b," or "c") are appended. Symmetry is determined by first summing the atomic mass of the halogen and hydrogen atoms attached to each carbon atom. One sum is subtracted from the other; the smaller the absolute value of the difference, the more symmetrical the isomer.

Informative Note: See Informative Appendix A, Table A-1, for an example of this system.

4.1.10 In the case of isomers in the propane series, each has the same number, with the isomers distinguished by two appended lowercase letters. The first appended letter indicates the substitution on the central carbon atom (C2):

$-CCl_2-$	a
$-CClF-$	b
$-CF_2-$	c
$-CClH-$	d
$-CFH-$	e
$-CH_2-$	f

For halogenated derivatives of cyclopropane, the carbon atom with the largest sum of attached atomic masses shall be considered the *central* carbon atom; for these compounds, the first appended letter is omitted.

The second appended letter indicates the relative symmetry of the substituents on the end carbon atoms (C1 and C3). Symmetry is determined by first summing the atomic masses of the halogen and hydrogen atoms attached to the C1 and C3 carbon atoms. One sum is subtracted from the other; the smaller the absolute value of this difference, the more symmetrical the isomer. In contrast to the ethane series, however, the most symmetrical isomer has a second appended letter of “a” (as opposed to no appended letter for ethane isomers); increasingly asymmetrical isomers are assigned successive letters. Appended letters are omitted when no isomers are possible, and the number alone represents the molecular structure unequivocally; for example, $CF_3CF_2CF_3$ is designated R-218, not R-218ca.

Informative Note: See Informative Appendix A, Table A-2, for an example of this system.

4.1.11 In the case of isomers of the propene series, each has the same number, with the isomers distinguished by two appended lowercase letters. The first appended letter indicates the substitution on the central carbon atom (C2):

—Cl	x
—F	y
—H	z

The second letter designates the substitution on the terminal methylene carbon as defined for the methylene carbon of the propane, consistent with the methodology described in Section 4.1.10:

$=CCl_2$	a
$=CClF$	b
$=CF_2$	c
$=CHCl$	d
$=CHF$	e
$=CH_2$	f

4.1.12 Extension to Compounds of Four Carbon Atoms. Compounds are coded according to the rules stated in Sections 4.1.1 through 4.1.11 above, with the designation number followed by a set of letters indicating structure. The number of unsaturated linkages is given in the fourth digit from the right. When the number for a digit place exceeds nine, it is set off by dashes. Linear compounds are lettered starting at one end, cyclic compounds from a side group, or, if none, from a carbon in the ring as described in Section 4.1.10. Carbon atoms with two hydrogens or halogens are lettered as in Section 4.1.10. Carbon atoms with three hydrogen or halogen atom substituents are lettered as shown below:

$–CCl_3$	j
$–CCl_2F$	k
$–CClF_2$	l
$–CF_3$	m
$–CHCl_2$	n
$–CH_2Cl$	o
$–CHF_2$	p
$–CH_2F$	q
$–CHClF$	r
$–CH_3$	s

Only as many letters are used as are required to completely define the compound when taken with the empirical structure given by the numerical designation. It is understood that no branching occurs in the remaining structure. After the starting point, side groups are given their letters before the backbone substituent (if any). When two or more lettering sequences may be applied, that with the fewest letters and first alphabetical sequence is used.

4.1.13 Bromine- or iodine-containing propane-series isomers cannot be uniquely designated by this system.

4.1.14 In the case where stereoisomers can exist, the opposed (Entgegen or trans) isomer will be identified by the suffix (E), and the same side (Zusamen or cis) isomer will be identified by the suffix (Z).

Informative Note: See Informative Appendix A, Table A-3, for an example of this system.

4.2 For cyclic derivatives, the letter “C” is used before the identifying refrigerant numbers.

4.3 Ether-based refrigerants shall be designated with the prefix “E” (for *ethers*) immediately preceding the number.

Except for the following differences, the root number designations for the hydrocarbon atoms shall be determined according to the current standard for hydrocarbon nomenclature (see Section 4.1).

Table 4-1 Refrigerant Data and Safety Classifications

Refrigerant Number	Chemical Name [a,b]	Chemical Formula[a]	OEL[f], ppm v/v	Safety Group	RCL [c] ppm v/v	RCL [c] lb/1000 ft^3	RCL [c] g/m^3	LFL ppm v/v	LFL lb/1000 ft^3	LFL g/m^3	Highly Toxic or Toxic [d] Under Code Classification
Methane Series											
11	trichlorofluoromethane	CCl_3F	1000	A1	1100	0.39	6.1				Neither
12	dichlorodifluoromethane	CCl_2F_2	1000	A1	18,000	5.6	90				Neither
12B1	bromochlorodifluoromethane	$CBrClF_2$									Neither
13	chlorotrifluoromethane	$CClF_3$	1000	Al							Neither
13B1	bromotrifluoromethane	$CBrF_3$	1000	Al							Neither
13I1	trifluoroiodomethane	CF_3I	500	A1	2000	1.0	16				Neither
14 [e]	tetrafluoromethane (carbon tetrafluoride)	CF_4	1000	Al	110,000	25	400				Neither
21	dichlorofluoromethane	$CHCl_2F$		B1							Toxic
22	chlorodifluoromethane	$CHClF_2$	1000	Al	59,000	13	210				Neither
23	trifluoromethane	CHF_3	1000	Al	41,000	7.3	120				Neither
30	dichloromethane (methylene chloride)	CH_2Cl_2		B1							Neither
31	chlorofluoromethane	CH_2ClF									Neither
32	difluoromethane (methylene fluoride)	CH_2F_2	1000	A2L	36,000	4.8	77	144,000	19.1	306	Neither
40	chloromethane (methyl chloride)	CH_3Cl		B2							Toxic
41	fluoromethane (methyl fluoride)	CH_3F									Neither
50	methane	CH_4	1000	A3				50,000			Neither
Ethane Series											
113	1,1,2-trichloro-1,2,2-trifluoroethane	CCl_2FCClF_2	1000	A1	2600	1.2	20				Neither
114	1,2-dichloro-1,1,2,2-tetrafluoroethane	$CClF_2CClF_2$	1000	A1	20,000	8.7	140				Neither
115[g]	chloropentafluoroethane	$CClF_2CF_3$	1000	A1	120,000	47	760				Neither

a. The chemical name and chemical formula are not part of this standard. Chemical names conform to IUPAC nomenclature[6,7] except where shortened, unambiguous names are used following ASHRAE Standard 34 convention.
b. The preferred chemical name is followed by the popular name in parentheses.
c. Data taken from Calm [8,9,10], Coombs[11,12], and Wilson and Richard [13] (see Section 10).
d. *Highly toxic*, *toxic*, or *neither*, where *highly toxic* and *toxic* are as defined in the *International Fire Code* [1], *Uniform Fire Code* [2], and OSHA regulations, and *neither* identifies those refrigerants having lesser toxicity than either of those groups[1,2,3].
e. At locations with altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
f. The OELs are eight-hour TWAs, as defined in Section 3, unless otherwise noted; a "C" designation denotes a ceiling limit.
g. At locations with altitudes higher than 3300 ft (1000 m) but below or equal to 4920 ft (1500 m), the ODL and RCL shall be 112,000 ppm, and at altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.

Table 4-1 Refrigerant Data and Safety Classifications *(Continued)*

Refrigerant Number	Chemical Name [a,b]	Chemical Formula [a]	OEL [f], ppm v/v	Safety Group	RCL [c] ppm v/v	RCL [c] lb/1000 ft^3	RCL [c] g/m^3	LFL ppm v/v	LFL lb/1000 ft^3	LFL g/m^3	Highly Toxic or Toxic [d] Under Code Classification
Ethane Series (*continued*)											
116[e]	hexafluoroethane	CF_3CF_3	1000	A1	97,000	34	550				Neither
123	2,2-dichloro-1,1,1-trifluoroethane	$CHCl_2CF_3$	50	B1	9100	3.5	57				Neither
124	2-chloro-1,1,1,2-tetrafluoroethane	$CHClFCF_3$	1000	A1	10,000	3.5	56				Neither
125[e]	pentafluoroethane	CHF_2CF_3	1000	A1	75,000	23	370				Neither
134a	1,1,1,2-tetrafluoroethane	CH_2FCF_3	1000	A1	50,000	13	210				Neither
141b	1,1-dichloro-1-fluoroethane	CH_3CCl_2F	500		2600	0.78	12	60,000	17.8	287	Neither
142b	1-chloro-1,1-difluoroethane	CH_3CClF_2	1000	A2	20,000	5.1	82	80,000	20.4	329	Neither
143a	1,1,1-trifluoroethane	CH_3CF_3	1000	A2L	21,000	4.4	70	82,000	17.5	282	Neither
152a	1,1-difluoroethane	CH_3CHF_2	1000	A2	12,000	2.0	32	48,000	8.1	130	Neither
170	ethane	CH_3CH_3	1000	A3	7000	0.54	8.6	31,000	2.4	38	Neither
Ethers											
E170	methoxymethane (dimethyl ether)	CH_3OCH_3	1000	A3	8500	1.0	16	34,000	4.0	64	Neither
Propane Series											
218[e]	octafluoropropane	$CF_3CF_2CF_3$	1000	A1	90,000	43	690				Neither
227ea[e]	1,1,1,2,3,3,3-heptafluoropropane	CF_3CHFCF_3	1000	A1	84,000	36	580				Neither
236fa	1,1,1,3,3,3-hexafluoropropane	$CF_3CH_2CF_3$	1000	A1	55,000	21	340				Neither
245fa	1,1,1,3,3-pentafluoropropane	$CHF_2CH_2CF_3$	300	B1	34,000	12	190				Neither
290	propane	$CH_3CH_2CH_3$	1000	A3	5300	0.59	9.5	21,000	2.4	38	Neither
Cyclic Organic Compounds											
C318	octafluorocyclobutane	$-(CF_2)_4-$	1000	A1	80,000	41	650				Neither

a. The chemical name and chemical formula are not part of this standard. Chemical names conform to IUPAC nomenclature[6,7] except where shortened, unambiguous names are used following ASHRAE Standard 34 convention.
b. The preferred chemical name is followed by the popular name in parentheses.
c. Data taken from Calm [8,9,10], Coombs[11,12], and Wilson and Richard [13] (see Section 10).
d. *Highly toxic*, *toxic*, or *neither*, where *highly toxic* and *toxic* are as defined in the *International Fire Code* [1], *Uniform Fire Code* [2], and OSHA regulations, and *neither* identifies those refrigerants having lesser toxicity than either of those groups[1,2,3].
e. At locations with altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
f. The OELs are eight-hour TWAs, as defined in Section 3, unless otherwise noted; a "C" designation denotes a ceiling limit.
g. At locations with altitudes higher than 3300 ft (1000 m) but below or equal to 4920 ft (1500 m), the ODL and RCL shall be 112,000 ppm, and at altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.

Table 4-1 Refrigerant Data and Safety Classifications *(Continued)*

Refrigerant Number	Chemical Name [a,b]	Chemical Formula [a]	OEL [f], ppm v/v	Safety Group	RCL [c] ppm v/v	RCL [c] lb/1000 ft^3	RCL [c] g/m^3	LFL ppm v/v	LFL lb/1000 ft^3	LFL g/m^3	Highly Toxic or Toxic [d] Under Code Classification
Miscellaneous Organic Compounds											
hydrocarbons											
600	butane	$CH_3CH_2CH_2CH_3$	1000	A3	1000	0.15	2.4	20,000	3.0	48	Neither
600a	2-methylpropane (isobutane)	$CH(CH_3)_2CH_3$	1000	A3	4000	0.59	9.5	16,000	2.4	38	Neither
601	pentane	$CH_3CH_2CH_2CH_2CH_3$	600	A3	1000	0.18	2.9	12,000	2.2	35	Neither
601a	2-methylbutane (isopentane)	$(CH_3)_2CHCH_2CH_3$	600	A3	1000	0.18	2.9	13,000	2.4	38	Neither
oxygen compounds											
610	ethoxyethane (ethyl ether)	$CH_3CH_2OCH_2CH_3$	400								Neither
611	methyl formate	$HCOOCH_3$	100	B2							Neither
sulfur compounds											
620	(Reserved for future assignment)										
Nitrogen Compounds											
630	methanamine (methyl amine)	CH_3NH_2									Toxic
631	ethanamine (ethyl amine)	$CH_3CH_2(NH_2)$									Neither
Inorganic Compounds											
702	hydrogen	H_2		A3							Neither
704	helium	He		A1							Neither
717	ammonia	NH_3	25	B2L	320	0.014	0.22	167,000	7.2	116	Neither
718	water	H_2O		A1							Neither
720	neon	Ne		A1							Neither

a. The chemical name and chemical formula are not part of this standard. Chemical names conform to IUPAC nomenclature[6,7] except where shortened, unambiguous names are used following ASHRAE Standard 34 convention.
b. The preferred chemical name is followed by the popular name in parentheses.
c. Data taken from Calm [8,9,10], Coombs[11,12], and Wilson and Richard [13] (see Section 10).
d. *Highly toxic*, *toxic*, or *neither*, where *highly toxic* and *toxic* are as defined in the *International Fire Code* [1], *Uniform Fire Code* [2], and OSHA regulations, and *neither* identifies those refrigerants having lesser toxicity than either of those groups[1,2,3].
e. At locations with altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
f. The OELs are eight-hour TWAs, as defined in Section 3, unless otherwise noted; a "C" designation denotes a ceiling limit.
g. At locations with altitudes higher than 3300 ft (1000 m) but below or equal to 4920 ft (1500 m), the ODL and RCL shall be 112,000 ppm, and at altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.

Table 4-1 Refrigerant Data and Safety Classifications *(Continued)*

Refrigerant Number	Chemical Name [a,b]	Chemical Formula[a]	OEL[f], ppm v/v	Safety Group	RCL [c] ppm v/v	RCL [c] lb/1000 ft^3	RCL [c] g/m^3	LFL ppm v/v	LFL lb/1000 ft^3	LFL g/m^3	Highly Toxic or Toxic [d] Under Code Classification
Inorganic Compounds (*continued*)											
728	nitrogen	N_2		A1							Neither
732	oxygen	O_2									Neither
740	argon	Ar		A1							Neither
744	carbon dioxide	CO_2	5000	A1	30,000	3.4	54				Neither
744A	nitrous oxide	N_2O									Neither
764	sulfur dioxide	SO_2		B1							Neither
Unsaturated Organic Compounds											
1130(E)	trans-1,2-dichloroethene	CHCl=CHCl	200	B2	1000	0.25	4	65,000	16	258	Neither
1132a	1,1-difluoroethene	CF_2=CH_2	500	A2	13,000	2.0	33	50,000	8.1	131	Neither
1132(E)	trans-1,2-difluoroethene	(E)-CFH=CFH	350	B2	11,000	1.8	28	43,000	7.0	113	Neither
1150	ethene (ethylene)	CH_2=CH_2	200	A3				31,000	2.2	36	Neither
1224yd(Z)	cis-1-chloro-2,3,3,3-tetrafluoro-1-propene	CF_3CF=CHCl	1000	A1	60,000	23	370				Neither
1233zd(E)	trans-1-chloro-3,3,3-trifluoro-1-propene	CF_3CH=CHCl	800	A1	16,000	5.3	85				Neither
1234yf	2,3,3,3-tetrafluoro-1-propene	CF_3CF=CH_2	500	A2L	16,000	4.5	75	62,000	18.0	289	Neither
1234ze(E)	trans-1,3,3,3-tetrafluoro-1-propene	CF_3CH=CFH	800	A2L	16,000	4.7	76	65,000	18.8	303	Neither
1270	propene (propylene)	CH_3CH=CH_2	500	A3	1000	0.11	1.7	27,000	2.9	46	Neither
1336mzz(E)	trans-1,1,1,4,4,4-hexafluoro-2-butene	CF_3CH=CHCF_3	400	A1	7200	3.0	48				Neither
1336mzz(Z)	cis-1,1,1,4,4,4-hexaflouro-2-butene	CF_3CH=CHCF_3	500	A1	13,000	5.2	84				Neither

a. The chemical name and chemical formula are not part of this standard. Chemical names conform to IUPAC nomenclature[6,7] except where shortened, unambiguous names are used following ASHRAE Standard 34 convention.
b. The preferred chemical name is followed by the popular name in parentheses.
c. Data taken from Calm [8,9,10], Coombs[11,12], and Wilson and Richard [13] (see Section 10).
d. *Highly toxic*, *toxic*, or *neither*, where *highly toxic* and *toxic* are as defined in the *International Fire Code* [1], *Uniform Fire Code* [2], and OSHA regulations, and *neither* identifies those refrigerants having lesser toxicity than either of those groups[1,2,3].
e. At locations with altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
f. The OELs are eight-hour TWAs, as defined in Section 3, unless otherwise noted; a "C" designation denotes a ceiling limit.
g. At locations with altitudes higher than 3300 ft (1000 m) but below or equal to 4920 ft (1500 m), the ODL and RCL shall be 112,000 ppm, and at altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.

Table 4-2 Data and Safety Classifications for Refrigerant Blends

Refrigerant Number	Composition (Mass%) (Composition Tolerances)	OEL[h], ppm v/v	Safety Group	RCL[a] ppm v/v	RCL[a] lb/1000 ft³	RCL[a] g/m³	LFL[j] ppm v/v	LFL[j] lb/1000 ft³	LFL[j] g/m³	Highly Toxic or Toxic[f] Under Code Classification
Zeotropes										
400	R-12/114 (must be specified)		A1							Neither
	(50.0/50.0)	1000	A1	28,000	10	160				
	(60.0/40.0)	1000	A1	30,000	11	170				
401A	R-22/152a/124 (53.0/13.0/34.0) (±2.0/+0.5, –1.5/±1.0)	1000	A1	27,000	6.6	110				Neither
401B	R-22/152a/124 (61.0/11.0/28.0) (±2.0/+0.5, –1.5/±1.0)	1000	A1	30,000	7.2	110				Neither
401C	R-22/152a/124 (33.0/15.0/52.0) (±2.0/+0.5, –1.5/±1.0)	1000	A1	20,000	5.2	84				Neither
402A	R-125/290/22 (60.0/2.0/38.0) (±2.0/+0.1, –1.0/±2.0)	1000	A1	66,000	17	270				Neither
402B	R-125/290/22 (38.0/2.0/60.0) (±2.0/+0.1, –1.0/±2.0)	1000	A1	63,000	15	240				Neither
403A	R-290/22/218 (5.0/75.0/20.0) (+0.2, –2.0/±2.0/±2.0)	1000	A2	33,000	7.6	120				Neither
403B[g]	R-290/22/218 (5.0/56.0/39.0) (+0.2, –2.0/±2.0/±2.0)	1000	A1	68,000	18	290				Neither
404A[i]	R-125/143a/134a (44.0/52.0/4.0) (±2.0/±1.0/±2.0)	1000	A1	130,000	31	500				Neither

Informative Note: LFL data values highlighted in gray in this table are based on conditions other than WCF @ 23°C (73.4°F). Refer to applicable table footnotes for details.

a. Data taken from Calm [8,9,10], Coombs[11,12], and Wilson and Richard [13] (see Section 10).
b. Azeotropic refrigerants exhibit some segregation of components at conditions of temperature and pressure other than those at which they were formulated. The extent of segregation depends on the particular azeotrope and hardware system configuration.
c. The exact composition of this azeotrope is in question, and additional experimental studies are needed.
d. R-507, R-508, and R-509 are allowed alternative designations for R-507A, R-508A, and R-509A due to a change in designations after assignment of R-500 through R-509. Corresponding changes were not made for R-500 through R-506.
e. The RCL values for these refrigerant blends are approximated in the absence of adequate data for a component comprising less than 4% m/m of the blend and expected to have only a small influence in an acute, accidental release.
f. *Highly toxic*, *toxic*, or *neither*, where *highly toxic* and *toxic* are as defined in the *International Fire Code* [1], *Uniform Fire Code*[2], and OSHA regulations, and *neither* identifies those refrigerants having lesser toxicity than either of those groups [1,2,3].
g. At locations with altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
h. The OELs are eight-hour TWAs as defined in Section 3 unless otherwise noted; a "C" designation denotes a ceiling limit.
i. At locations with altitudes higher than 3300 ft (1000 m) but below or equal to 4920 ft (1500 m), the ODL and RCL shall be 112, 000 ppm, and at altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
j. LFL is based on WCF @23°C (73.4°F) unless otherwise noted.
k. WCFF LFL @60°C (140°F)
l. Reserved for future assignment
m. WCFF LFL @23°C (73.4°F)
n. WCF LFL @100°C (212°F)

Table 4-2 Data and Safety Classifications for Refrigerant Blends *(Continued)*

Refrigerant Number	Composition (Mass%) (Composition Tolerances)	OEL[h], ppm v/v	Safety Group	RCL[a] ppm v/v	RCL[a] lb/1000 ft^3	RCL[a] g/m^3	LFL[j] ppm v/v	LFL[j] lb/1000 ft^3	LFL[j] g/m^3	Highly Toxic or Toxic[f] Under Code Classification
Zeotropes (*continued*)										
405A	R-22/152a/142b/C318 (45.0/7.0/5.5/42.5) (Individual components = [±2.0/±1.0/±1.0/±2.0]; sum of R-152a and R-142b = [+0.0, –2.0])	1000		57,000	16	260				Neither
406A	R-22/600a/142b (55.0/4.0/41.0) (±2.0/±1.0/±1.0)	1000	A2	21,000	4.7	75	82,000 [m]	18.8 [m]	301.9 [m]	Neither
407A [g]	R-32/125/134a (20.0/40.0/40.0) (±2.0/±2.0/±2.0)	1000	A1	83,000	19	300				Neither
407B [g]	R-32/125/134a (10.0/70.0/20.0) (±2.0/±2.0/±2.0)	1000	A1	79,000	21	330				Neither
407C [g]	R-32/125/134a (23.0/25.0/52.0) (±2.0/±2.0/±2.0)	1000	A1	81,000	18	290				Neither
407D	R-32/125/134a (15.0/15.0/70.0) (±2.0/±2.0/±2.0)	1000	A1	68,000	16	250				Neither
407E [g]	R-32/125/134a (25.0/15.0/60.0) (±2.0/±2.0/±2.0)	1000	A1	80,000	17	280				Neither
407F	R-32/125/134a (30.0/30.0/40.0) (±2.0/±2.0/±2.0)	1000	A1	95,000	20	320				Neither
407G	R-32/125/134a (2.5/2.5/95.0) (±0.5/±0.5/±1.0)	1000	A1	52,000	13	210				Neither
407H	R-32/125/134a (32.5/15.0/52.5) (±1.0/±1.0/±2.0)	1000	A1	92,000	19	300				Neither

Informative Note: LFL data values highlighted in gray in this table are based on conditions other than WCF @ 23°C (73.4°F). Refer to applicable table footnotes for details.

a. Data taken from Calm [8,9,10], Coombs[11,12], and Wilson and Richard [13] (see Section 10).
b. Azeotropic refrigerants exhibit some segregation of components at conditions of temperature and pressure other than those at which they were formulated. The extent of segregation depends on the particular azeotrope and hardware system configuration.
c. The exact composition of this azeotrope is in question, and additional experimental studies are needed.
d. R-507, R-508, and R-509 are allowed alternative designations for R-507A, R-508A, and R-509A due to a change in designations after assignment of R-500 through R-509. Corresponding changes were not made for R-500 through R-506.
e. The RCL values for these refrigerant blends are approximated in the absence of adequate data for a component comprising less than 4% m/m of the blend and expected to have only a small influence in an acute, accidental release.
f. *Highly toxic*, *toxic*, or *neither*, where *highly toxic* and *toxic* are as defined in the *International Fire Code* [1], *Uniform Fire Code*[2], and OSHA regulations, and *neither* identifies those refrigerants having lesser toxicity than either of those groups [1,2,3].
g. At locations with altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
h. The OELs are eight-hour TWAs as defined in Section 3 unless otherwise noted; a "C" designation denotes a ceiling limit.
i. At locations with altitudes higher than 3300 ft (1000 m) but below or equal to 4920 ft (1500 m), the ODL and RCL shall be 112, 000 ppm, and at altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
j. LFL is based on WCF @23°C (73.4°F) unless otherwise noted.
k. WCFF LFL @60°C (140°F)
l. Reserved for future assignment
m. WCFF LFL @23°C (73.4°F)
n. WCF LFL @100°C (212°F)

Table 4-2 Data and Safety Classifications for Refrigerant Blends *(Continued)*

Refrigerant Number	Composition (Mass%) (Composition Tolerances)	OEL[h], ppm v/v	Safety Group	RCL[a] ppm v/v	RCL[a] lb/1000 ft^3	RCL[a] g/m^3	LFL[j] ppm v/v	LFL[j] lb/1000 ft^3	LFL[j] g/m^3	Highly Toxic or Toxic[f] Under Code Classification
Zeotropes (*continued*)										
407I	R-32/125/134a (19.5/8.5/72.0) (+1.0, –2.0/+2.0, –1.0/±2.0)	1000	A1	71,100	16	250				Neither
408A[g]	R-125/143a/22 (7.0/46.0/47.0) (±2.0/±1.0/±2.0)	1000	A1	94,000	21	330				Neither
409A	R-22/124/142b (60.0/25.0/15.0) (±2.0/±2.0/±1.0)	1000	A1	29,000	7.1	110				Neither
409B	R-22/124/142b (65.0/25.0/10.0) (±2.0/±2.0/±1.0)	1000	A1	30,000	7.3	120				Neither
410A[i]	R-32/125 (50.0/50.0) (+0.5, –1.5/+1.5, –0.5)	1000	A1	140,000	26	420				Neither
410B[i]	R-32/125 (45.0/55.0) (±1.0/±1.0)	1000	A1	140,000	27	430				Neither
411A[e]	R-1270/22/152a (1.5/87.5/11.0) (+0.0, –1.0/+2.0, –0.0/+0.0, –1.0)	970	A2	14,000	2.9	46	55,000[k]	11.6[k]	185.6[k]	Neither
411B[e]	R-1270/22/152a (3.0/94.0/3.0) (+0.0, –1.0/+2.0, –0.0/+0.0, –1.0)	940	A2	13,000	2.8	45	70,000[k]	14.8[k]	238.3[k]	Neither
412A	R-22/218/142b (70.0/5.0/25.0) (±2.0/±2.0/±1.0)	1000	A2	22,000	5.1	82	87,000[k]	20.5[k]	328.6[k]	Neither
413A	R-218/134a/600a (9.0/88.0/3.0) (±1.0/±2.0/+0.0, –1.0)	1000	A2	22,000	5.8	93	88,000[k]	23.4[k]	374.9[k]	Neither

Informative Note: LFL data values highlighted in gray in this table are based on conditions other than WCF @ 23°C (73.4°F). Refer to applicable table footnotes for details.

a. Data taken from Calm [8,9,10], Coombs[11,12], and Wilson and Richard [13] (see Section 10).
b. Azeotropic refrigerants exhibit some segregation of components at conditions of temperature and pressure other than those at which they were formulated. The extent of segregation depends on the particular azeotrope and hardware system configuration.
c. The exact composition of this azeotrope is in question, and additional experimental studies are needed.
d. R-507, R-508, and R-509 are allowed alternative designations for R-507A, R-508A, and R-509A due to a change in designations after assignment of R-500 through R-509. Corresponding changes were not made for R-500 through R-506.
e. The RCL values for these refrigerant blends are approximated in the absence of adequate data for a component comprising less than 4% m/m of the blend and expected to have only a small influence in an acute, accidental release.
f. *Highly toxic*, *toxic*, or *neither*, where *highly toxic* and *toxic* are as defined in the *International Fire Code* [1], *Uniform Fire Code*[2], and OSHA regulations, and *neither* identifies those refrigerants having lesser toxicity than either of those groups [1,2,3].
g. At locations with altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
h. The OELs are eight-hour TWAs as defined in Section 3 unless otherwise noted; a "C" designation denotes a ceiling limit.
i. At locations with altitudes higher than 3300 ft (1000 m) but below or equal to 4920 ft (1500 m), the ODL and RCL shall be 112, 000 ppm, and at altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
j. LFL is based on WCF @23°C (73.4°F) unless otherwise noted.
k. WCFF LFL @60°C (140°F)
l. Reserved for future assignment
m. WCFF LFL @23°C (73.4°F)
n. WCF LFL @100°C (212°F)

Table 4-2 Data and Safety Classifications for Refrigerant Blends *(Continued)*

Refrigerant Number	Composition (Mass%) (Composition Tolerances)	OEL[h], ppm v/v	Safety Group	RCL[a]			LFL[j]			Highly Toxic or Toxic[f] Under Code Classification
				ppm v/v	lb/1000 ft^3	g/m^3	ppm v/v	lb/1000 ft^3	g/m^3	
Zeotropes (*continued*)										
414A	R-22/124/600a/142b (51.0/28.5/4.0/16.5) (±2.0/±2.0/±0.5/+0.5, –1.0)	1000	A1	26,000	6.4	100				Neither
414B	R-22/124/600a/142b (50.0/39.0/1.5/9.5) (±2.0/±2.0/±0.5/+0.5, –1.0)	1000	A1	23,000	6.0	96				Neither
415A	R-22/152a (82.0/18.0) (±1.0/±1.0)	1000	A2	14,000	2.9	47	56,000 [m]	11.7 [m]	187.9 [m]	Neither
415B	R-22/152a (25.0/75.0) (±1.0/±1.0)	1000	A2	12,000	2.1	34	47,000	8.4	135.1	Neither
416A [e]	R-134a/124/600 (59.0/39.5/1.5) (+0.5, –1.0/+1.0, –0.5/+1.0, –0.2)	1000	A1	14,000	3.9	62				Neither
417A [e]	R-125/134a/600 (46.6/50.0/3.4) (±1.1/±1.0/+0.1, –0.4)	1000	A1	13,000	3.5	55				Neither
417B	R-125/134a/600 (79.0/18.3/2.7) (±1.0/±1.0/+0.1, –0.5)	1000	A1	15,000	4.3	69				Neither
417C	R-125/134a/600 (19.5/78.8/1.7) (±1.0/±1.0/+0.1, –0.5)	1000	A1	21,000	5.4	87				Neither
418A	R-290/22/152a (1.5/96.0/2.5) (±0.5/±1.0/±0.5)	1000	A2	22,000	4.8	77	89,000 [m]	19.2 [m]	308.4 [m]	Neither
419A [g]	R-125/134a/E170 (77.0/19.0/4.0) (±1.0/±1.0/±1.0)	1000	A2	15,000	4.2	67	60,000 [m]	16.7 [m]	268.6 [m]	Neither

Informative Note: LFL data values highlighted in gray in this table are based on conditions other than WCF @ 23°C (73.4°F). Refer to applicable table footnotes for details.

a. Data taken from Calm [8,9,10], Coombs[11,12], and Wilson and Richard [13] (see Section 10).
b. Azeotropic refrigerants exhibit some segregation of components at conditions of temperature and pressure other than those at which they were formulated. The extent of segregation depends on the particular azeotrope and hardware system configuration.
c. The exact composition of this azeotrope is in question, and additional experimental studies are needed.
d. R-507, R-508, and R-509 are allowed alternative designations for R-507A, R-508A, and R-509A due to a change in designations after assignment of R-500 through R-509. Corresponding changes were not made for R-500 through R-506.
e. The RCL values for these refrigerant blends are approximated in the absence of adequate data for a component comprising less than 4% m/m of the blend and expected to have only a small influence in an acute, accidental release.
f. *Highly toxic*, *toxic*, or *neither*, where *highly toxic* and *toxic* are as defined in the *International Fire Code* [1], *Uniform Fire Code*[2], and OSHA regulations, and *neither* identifies those refrigerants having lesser toxicity than either of those groups [1,2,3].
g. At locations with altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
h. The OELs are eight-hour TWAs as defined in Section 3 unless otherwise noted; a “C” designation denotes a ceiling limit.
i. At locations with altitudes higher than 3300 ft (1000 m) but below or equal to 4920 ft (1500 m), the ODL and RCL shall be 112, 000 ppm, and at altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
j. LFL is based on WCF @23°C (73.4°F) unless otherwise noted.
k. WCFF LFL @60°C (140°F)
l. Reserved for future assignment
m. WCFF LFL @23°C (73.4°F)
n. WCF LFL @100°C (212°F)

Table 4-2 Data and Safety Classifications for Refrigerant Blends *(Continued)*

Refrigerant Number	Composition (Mass%) (Composition Tolerances)	OEL[h], ppm v/v	Safety Group	RCL[a]			LFL[j]			Highly Toxic or Toxic[f] Under Code Classification
				ppm v/v	lb/1000 ft^3	g/m^3	ppm v/v	lb/1000 ft^3	g/m^3	
Zeotropes (*continued*)										
419B	R-125/134a/E170 (48.5/48.0/3.5) (±1.0/±1.0/±0.5)	1000	A2	17,000	4.6	74	69,000[m]	18.5[m]	297.3[m]	Neither
420A	R-134a/142b (88.0/12.0) (+1.0, –0.0/+0.0, –1.0)	1000	A1	44,000	12	180				Neither
421A	R-125/134a (58.0/42.0) (±1.0/±1.0)	1000	A1	61,000	17	280				Neither
421B	R-125/134a (85.0/15.0) (±1.0/±1.0)	1000	A1	69,000	21	330				Neither
422A	R-125/134a/600a (85.1/11.5/3.4) (±1.0/±1.0/+0.1, –0.4)	1000	A1	63,000	18	290				Neither
422B	R-125/134a/600a (55.0/42.0/3.0) (±1.0/±1.0/+0.1, –0.5)	1000	A1	56,000	16	250				Neither
422C	R-125/134a/600a (82.0/15.0/3.0) (±1.0/±1.0/+0.1, –0.5)	1000	A1	62,000	18	290				Neither
422D	R-125/134a/600a (65.1/31.5/3.4) (+0.9, –1.1/±1.0/+0.1, –0.4)	1000	A1	58,000	16	260				Neither
422E	R-125/134a/600a (58.0/39.3/2.7) (±1.0/+1.7, –1.3/+0.3, –0.2)	1000	A1	57,000	16	260				Neither
423A	R-134a/227ea (52.5/47.5) (±1.0/±1.0)	1000	A1	59,000	19	300				Neither

Informative Note: LFL data values highlighted in gray in this table are based on conditions other than WCF @ 23°C (73.4°F). Refer to applicable table footnotes for details.

a. Data taken from Calm [8,9,10], Coombs[11,12], and Wilson and Richard [13] (see Section 10).
b. Azeotropic refrigerants exhibit some segregation of components at conditions of temperature and pressure other than those at which they were formulated. The extent of segregation depends on the particular azeotrope and hardware system configuration.
c. The exact composition of this azeotrope is in question, and additional experimental studies are needed.
d. R-507, R-508, and R-509 are allowed alternative designations for R-507A, R-508A, and R-509A due to a change in designations after assignment of R-500 through R-509. Corresponding changes were not made for R-500 through R-506.
e. The RCL values for these refrigerant blends are approximated in the absence of adequate data for a component comprising less than 4% m/m of the blend and expected to have only a small influence in an acute, accidental release.
f. *Highly toxic*, *toxic*, or *neither*, where *highly toxic* and *toxic* are as defined in the *International Fire Code* [1], *Uniform Fire Code*[2], and OSHA regulations, and *neither* identifies those refrigerants having lesser toxicity than either of those groups [1,2,3].
g. At locations with altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
h. The OELs are eight-hour TWAs as defined in Section 3 unless otherwise noted; a "C" designation denotes a ceiling limit.
i. At locations with altitudes higher than 3300 ft (1000 m) but below or equal to 4920 ft (1500 m), the ODL and RCL shall be 112, 000 ppm, and at altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
j. LFL is based on WCF @23°C (73.4°F) unless otherwise noted.
k. WCFF LFL @60°C (140°F)
l. Reserved for future assignment
m. WCFF LFL @23°C (73.4°F)
n. WCF LFL @100°C (212°F)

Table 4-2 Data and Safety Classifications for Refrigerant Blends *(Continued)*

Refrigerant Number	Composition (Mass%) (Composition Tolerances)	OEL[h], ppm v/v	Safety Group	RCL[a] ppm v/v	RCL[a] lb/1000 ft³	RCL[a] g/m³	LFL[j] ppm v/v	LFL[j] lb/1000 ft³	LFL[j] g/m³	Highly Toxic or Toxic[f] Under Code Classification
Zeotropes (*continued*)										
424A[e]	R-125/134a/600a/600/601a (50.5/47.0/0.9/1.0/0.6) (±1.0/±1.0/+0.1, –0.2/+0.1, +0.2/+0.1, –0.2)	990	A1	23,000	6.2	100				Neither
425A	R-32/134a/227ea (18.5/69.5/12.0) (±0.5/±0.5/±0.5)	1000	A1	72,000	16	260				Neither
426A[e]	R-125/134a/600/601a (5.1/93.0/1.3/0.6) (±1.0/±1.0/+0.1, –0.2/+0.1, –0.2)	990	A1	20,000	5.2	83				Neither
427A	R-32/125/143a/134a (15.0/25.0/10.0/50.0) (±2.0/±2.0/±2.0/±2.0)	1000	A1	79,000	18	290				Neither
427C	R-32/125/143a/134a (25.0/25.0/10.0/40.0) (±1.0/±2.0/±1.0/±2.0)	1000	A1	96,000	20.0	330				Neither
428A	R-125/143a/290/600a (77.5/20.0/0.6/1.9) (±1.0/±1.0/+0.1, –0.2/+0.1, –0.2)	1000	A1	84,000	23	370				Neither
429A	R-E170/152a/600a (60.0/10.0/30.0) (±1.0/±1.0/±1.0)	1000	A3	6300	0.81	13	25,000	3.2	83.8	Neither
430A	R-152a/600a (76.0/24.0) (±1.0/±1.0)	1000	A3	8000	1.3	21	32,000	5.2	44.0	Neither
431A	R-290/152a (71.0/29.0) (±1.0/±1.0)	1000	A3	5500	0.68	11	22,000	2.7	38.6	Neither
432A	R-1270/E170 (80.0/20.0) (±1.0/±1.0)	550	A3	1200	0.13	2.2	22,000	2.4	39.2	Neither

Informative Note: LFL data values highlighted in gray in this table are based on conditions other than WCF @ 23°C (73.4°F). Refer to applicable table footnotes for details.

a. Data taken from Calm [8,9,10], Coombs[11,12], and Wilson and Richard [13] (see Section 10).
b. Azeotropic refrigerants exhibit some segregation of components at conditions of temperature and pressure other than those at which they were formulated. The extent of segregation depends on the particular azeotrope and hardware system configuration.
c. The exact composition of this azeotrope is in question, and additional experimental studies are needed.
d. R-507, R-508, and R-509 are allowed alternative designations for R-507A, R-508A, and R-509A due to a change in designations after assignment of R-500 through R-509. Corresponding changes were not made for R-500 through R-506.
e. The RCL values for these refrigerant blends are approximated in the absence of adequate data for a component comprising less than 4% m/m of the blend and expected to have only a small influence in an acute, accidental release.
f. *Highly toxic*, *toxic*, or *neither*, where *highly toxic* and *toxic* are as defined in the *International Fire Code* [1], *Uniform Fire Code*[2], and OSHA regulations, and *neither* identifies those refrigerants having lesser toxicity than either of those groups [1,2,3].
g. At locations with altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
h. The OELs are eight-hour TWAs as defined in Section 3 unless otherwise noted; a "C" designation denotes a ceiling limit.
i. At locations with altitudes higher than 3300 ft (1000 m) but below or equal to 4920 ft (1500 m), the ODL and RCL shall be 112, 000 ppm, and at altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
j. LFL is based on WCF @23°C (73.4°F) unless otherwise noted.
k. WCFF LFL @60°C (140°F)
l. Reserved for future assignment
m. WCFF LFL @23°C (73.4°F)
n. WCF LFL @100°C (212°F)

Table 4-2 Data and Safety Classifications for Refrigerant Blends *(Continued)*

Refrigerant Number	Composition (Mass%) (Composition Tolerances)	OEL[h], ppm v/v	Safety Group	RCL [a]			LFL [j]			Highly Toxic or Toxic [f] Under Code Classification
				ppm v/v	lb/1000 ft^3	g/m^3	ppm v/v	lb/1000 ft^3	g/m^3	
Zeotropes (*continued*)										
433A	R-1270/290 (30.0/70.0) (±1.0/±1.0)	760	A3	3100	0.34	5.5	20,000	2.4	32.4	Neither
433B	R-1270/290 (5.0/95.0) (±1.0/±1.0)	950	A3	3500	0.39	6.3	18,000	2.0	32.1	Neither
433C	R-1270/290 (25.0/75.0) (±1.0/±1.0)	790	A3	3700	0.41	6.5	18,000	2.0	83.8	Neither
434A [g]	R-125/143a/134a/600a (63.2/18.0/16.0/2.8) (±1.0/±1.0/±1.0/+0.1, –0.2)	1000	A1	73,000	20	320				Neither
435A	R-E170/152a (80.0/20.0) (±1.0/±1.0)	1000	A3	8500	1.1	17	34,000	4.3	68.2	Neither
436A	R-290/600a (56.0/44.0) (±1.0/±1.0)	1000	A3	4000	0.50	8.1	16,000	2.0	32.3	Neither
436B	R-290/600a (52.0/48.0) (±1.0/±1.0)	1000	A3	4000	0.51	8.2	16,000	2.0	32.7	Neither
436C	R-290/600a (95.0/5.0) (±1.2/±1.2)	1000	A3	5000	0.57	9.1	20,000	2.3	36.5	Neither
437A	R-125/134a/600/601 (19.5/78.5/1.4/0.6) (+0.5, –1.8/+1.5, –0.7/+0.1,–0.2/+0.1, –0.2)	990	A1	19,000	5.1	82				Neither
438A	R-32/125/134a/600/601a (8.5/45.0/44.2/1.7/0.6) (+0.5, –1.5/±1.5/±1.5/+0.1, –0.2/+0.1, –0.2)	990	A1	20,000	4.9	79				Neither

Informative Note: LFL data values highlighted in gray in this table are based on conditions other than WCF @ 23°C (73.4°F). Refer to applicable table footnotes for details.

a. Data taken from Calm [8,9,10], Coombs[11,12], and Wilson and Richard [13] (see Section 10).
b. Azeotropic refrigerants exhibit some segregation of components at conditions of temperature and pressure other than those at which they were formulated. The extent of segregation depends on the particular azeotrope and hardware system configuration.
c. The exact composition of this azeotrope is in question, and additional experimental studies are needed.
d. R-507, R-508, and R-509 are allowed alternative designations for R-507A, R-508A, and R-509A due to a change in designations after assignment of R-500 through R-509. Corresponding changes were not made for R-500 through R-506.
e. The RCL values for these refrigerant blends are approximated in the absence of adequate data for a component comprising less than 4% m/m of the blend and expected to have only a small influence in an acute, accidental release.
f. *Highly toxic*, *toxic*, or *neither*, where *highly toxic* and *toxic* are as defined in the *International Fire Code* [1], *Uniform Fire Code*[2], and OSHA regulations, and *neither* identifies those refrigerants having lesser toxicity than either of those groups [1,2,3].
g. At locations with altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
h. The OELs are eight-hour TWAs as defined in Section 3 unless otherwise noted; a "C" designation denotes a ceiling limit.
i. At locations with altitudes higher than 3300 ft (1000 m) but below or equal to 4920 ft (1500 m), the ODL and RCL shall be 112, 000 ppm, and at altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
j. LFL is based on WCF @23°C (73.4°F) unless otherwise noted.
k. WCFF LFL @60°C (140°F)
l. Reserved for future assignment
m. WCFF LFL @23°C (73.4°F)
n. WCF LFL @100°C (212°F)

Table 4-2 Data and Safety Classifications for Refrigerant Blends *(Continued)*

Refrigerant Number	Composition (Mass%) (Composition Tolerances)	OEL[h], ppm v/v	Safety Group	RCL[a] ppm v/v	RCL[a] lb/1000 ft^3	RCL[a] g/m^3	LFL[j] ppm v/v	LFL[j] lb/1000 ft^3	LFL[j] g/m^3	Highly Toxic or Toxic[f] Under Code Classification
Zeotropes (*continued*)										
439A	R-32/125/600a (50.0/47.0/3.0) (±1.0/±1.0/±0.5)	1000	A2	26,000	4.7	76	104,000	18.9	303.3	Neither
440A	R-290/134a/152a (0.6/1.6/97.8) (±0.1/±0.6/±0.5)	1000	A2	12,000	1.9	31	46,000[n]	7.8[n]	124.7[n]	Neither
441A	R-170/290/600a/600 (3.1/54.8/6.0/36.1) (±0.3/±2.0/±0.6/±2.0)	1000	A3	3200	0.39	6.3	16,000	2.0	31.7	Neither
442A	R-32/125/134a/152a/227ea (31.0/31.0/30.0/3.0/5.0) (±1.0/±1.0±/1.0/±0.5/±1.0)	1000	A1	100,000	21	330				Neither
443A	R-1270/290/600a (55.0/40.0/5.0) (±2.0/±2.0/±1.2)	640	A3	1700	0.19	3.1	20,000	2.2	35.6	Neither
444A	R-32/152a/1234ze(E) (12.0/5.0/83.0) (±1.0/±1.0/±2.0)	850	A2L	21,000	5.1	81	82,000	19.9	324.8	Neither
444B	R-32/152a/1234ze(E) (41.5/10.0/48.5) (±1.0/±1.0/±1.0)	930	A2L	23,000	4.3	69	93,000	17.3	277.3	Neither
445A	R-744/134a/1234ze(E) (6.0/9.0/85.0) (±1.0/±1.0/±2.0)	930	A2L	16,000	4.2	67	63,000	2.7	347.4	Neither
446A	R-32/1234ze(E)/600 (68.0/29.0/3.0) (+0.5, –1.0/+2.0, –0.6/+0.1, –1.0)	960	A2L	16,000	2.5	39	62,000[m]	13.5[m]	217.4[m]	Neither
447A	R-32/125/1234ze(E) (68.0/3.5/28.5) (+1.5, –0.5/+1.5, –0.5/+1.0, –1.0)	960	A2L	16,000	2.6	42	65,000[m]	18.9[m]	303.5[m]	Neither

Informative Note: LFL data values highlighted in gray in this table are based on conditions other than WCF @ 23°C (73.4°F). Refer to applicable table footnotes for details.

a. Data taken from Calm[8,9,10], Coombs[11,12], and Wilson and Richard[13] (see Section 10).
b. Azeotropic refrigerants exhibit some segregation of components at conditions of temperature and pressure other than those at which they were formulated. The extent of segregation depends on the particular azeotrope and hardware system configuration.
c. The exact composition of this azeotrope is in question, and additional experimental studies are needed.
d. R-507, R-508, and R-509 are allowed alternative designations for R-507A, R-508A, and R-509A due to a change in designations after assignment of R-500 through R-509. Corresponding changes were not made for R-500 through R-506.
e. The RCL values for these refrigerant blends are approximated in the absence of adequate data for a component comprising less than 4% m/m of the blend and expected to have only a small influence in an acute, accidental release.
f. *Highly toxic*, *toxic*, or *neither*, where *highly toxic* and *toxic* are as defined in the *International Fire Code*[1], *Uniform Fire Code*[2], and OSHA regulations, and *neither* identifies those refrigerants having lesser toxicity than either of those groups[1,2,3].
g. At locations with altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
h. The OELs are eight-hour TWAs as defined in Section 3 unless otherwise noted; a "C" designation denotes a ceiling limit.
i. At locations with altitudes higher than 3300 ft (1000 m) but below or equal to 4920 ft (1500 m), the ODL and RCL shall be 112, 000 ppm, and at altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
j. LFL is based on WCF @23°C (73.4°F) unless otherwise noted.
k. WCFF LFL @60°C (140°F)
l. Reserved for future assignment
m. WCFF LFL @23°C (73.4°F)
n. WCF LFL @100°C (212°F)

Table 4-2 Data and Safety Classifications for Refrigerant Blends *(Continued)*

Refrigerant Number	Composition (Mass%) (Composition Tolerances)	OEL[h], ppm v/v	Safety Group	RCL[a] ppm v/v	RCL[a] lb/1000 ft^3	RCL[a] g/m^3	LFL[j] ppm v/v	LFL[j] lb/1000 ft^3	LFL[j] g/m^3	Highly Toxic or Toxic[f] Under Code Classification
Zeotropes (*continued*)										
447B	R-32/125/1234ze(E) (68.0/8.0/24.0) (+1.0, –2.0/+2.0, –1.0/+1.0, –2.0)	970	A2L	16,000	2.6	42	121,000	20.6	312.7	Neither
448A	R-32/125/1234yf/134a/1234ze(E) (26.0/26.0/20.0/21.0/7.0) (+0.5, –2.0/+2.0, –0.5/+0.5, –2.0/+2.0, –1.0/+0.5, –2.0)	860	A1	110,000	24	390				Neither
448B	R-32/125/1234yf/134a/1234ze(E) (21.0/21.0/20.0/31.0/7.0) (+0.5,–2.0/+2.0,–0.5/+0.5,–2.0/+2.0, –1.0/+0.5,–2.0)	850	A1	97,000	22.0	350				Neither
449A	R-32 /125 /1234yf /134a (24.3/24.7/25.3/25.7) (+0.2, –1.0/+1.0, –0.2/+0.2, –1.0/+1.0, –0.2)	840	A1	100,000	23	370				Neither
449B	R-32/125/1234yf/134a (25.2/24.3/23.2/27.3) (+0.3, –1.5/+1.5, –0.3/+0.3, –1.5/+1.5, –0.3)	850	A1	100,000	23	370				Neither
449C	R-32/125/1234yf/134a (20.0/20.0/31.0/29.0) (+0.5, –1.5/+1.5, –0.5/+0.5, –1.5/+1.5, –0.5)	800	A1	98,000	23	360				Neither
450A	R-134a/1234ze(E) (42.0/58.0) (±2.0/±2.0)	880	A1	72,000	20	320				Neither
451A	R-1234yf/134a (89.8/10.2) (±0.2/±0.2)	530	A2L	18,000	5.0	81	70,000[m]	20.3[m]	326.6[m]	Neither
451B	R-1234yf/134a (88.8/11.2) (±0.2/±0.2)	530	A2L	18,000	5.0	81	70,000[m]	20.3[m]	326.6[m]	Neither
452A	R-32/125/1234yf (11.0/59.0/30.0) (±1.7/±1.8/+0.1, –1.0)	790	A1	100,000	27	440				Neither

Informative Note: LFL data values highlighted in gray in this table are based on conditions other than WCF @ 23°C (73.4°F). Refer to applicable table footnotes for details.

a. Data taken from Calm [8,9,10], Coombs[11,12], and Wilson and Richard [13] (see Section 10).
b. Azeotropic refrigerants exhibit some segregation of components at conditions of temperature and pressure other than those at which they were formulated. The extent of segregation depends on the particular azeotrope and hardware system configuration.
c. The exact composition of this azeotrope is in question, and additional experimental studies are needed.
d. R-507, R-508, and R-509 are allowed alternative designations for R-507A, R-508A, and R-509A due to a change in designations after assignment of R-500 through R-509. Corresponding changes were not made for R-500 through R-506.
e. The RCL values for these refrigerant blends are approximated in the absence of adequate data for a component comprising less than 4% m/m of the blend and expected to have only a small influence in an acute, accidental release.
f. *Highly toxic*, *toxic*, or *neither*, where *highly toxic* and *toxic* are as defined in the *International Fire Code* [1], *Uniform Fire Code*[2], and OSHA regulations, and *neither* identifies those refrigerants having lesser toxicity than either of those groups [1,2,3].
g. At locations with altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
h. The OELs are eight-hour TWAs as defined in Section 3 unless otherwise noted; a “C” designation denotes a ceiling limit.
i. At locations with altitudes higher than 3300 ft (1000 m) but below or equal to 4920 ft (1500 m), the ODL and RCL shall be 112, 000 ppm, and at altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
j. LFL is based on WCF @23°C (73.4°F) unless otherwise noted.
k. WCFF LFL @60°C (140°F)
l. Reserved for future assignment
m. WCFF LFL @23°C (73.4°F)
n. WCF LFL @100°C (212°F)

Table 4-2 Data and Safety Classifications for Refrigerant Blends *(Continued)*

Refrigerant Number	Composition (Mass%) (Composition Tolerances)	OEL[h], ppm v/v	Safety Group	RCL [a] ppm v/v	RCL [a] lb/1000 ft³	RCL [a] g/m³	LFL [j] ppm v/v	LFL [j] lb/1000 ft³	LFL [j] g/m³	Highly Toxic or Toxic [f] Under Code Classification
Zeotropes (*continued*)										
452B	R-32/125/1234yf (67.0/7.0/26.0) (±2.0/±1.5/±2.0)	870	A2L	30,000	4.8	77	119,000	19.3	310.5	Neither
452C	R-32/125/1234yf (12.5/61.0/26.5) (+0.5, –1.5/±1.0/+0.5, –1.5)	810	A1	100,000	27	430				Neither
453A	R-32/125/134a/227ea/600/601a (20.0/20.0/53.8/5.0/0.6/0.6) (±1.0/±1.0/±1.0/±0.5/+0.1, –0.2/+0.1, –0.2)	1000	A1	34,000	7.8	120				Neither
454A	R-32/1234yf (35.0/65.0) (+2.0/–2.0, +2.0/–2.0)	690	A2L	16,000	3.2	52	63,000 [m]	18.3 [m]	293.9 [m]	Neither
454B	R-32/1234yf (68.9/31.1) (+1.0/–1.0, +1.0/–1.0)	850	A2L	19,000	3.1	49	77,000 [m]	22.0 [m]	352.6 [m]	Neither
454C	R-32/1234yf (21.5/78.5) (±2.0/±2.0)	620	A2L	19,000	4.4	71	62,000 [m]	18.0 [m]	289.5 [m]	Neither
455A	R-744/32/1234yf (3.0/21.5/75.5) (+2.0, –1.0/+1.0, –2.0/±2.0)	650	A2L	22,000	4.9	79	118,000	26.9	432.1	Neither
456A	R-32/134a/1234ze(E) (6.0/45.0/49.0) (±1.0/±1.0/±1.0)	900	A1	77,000	20	320				Neither
457A	R-32/1234yf/152a (18.0/70.0/12.0) (+0.5, –1.5/+0.5, –1.5/+0.1, –1.9)	650	A2L	15,000	3.4	54	60,000	13.5	216.3	Neither
457B	R-32/1234yf/152a (35.0/55.0/10.0) (+0.5, –1.5/+0.5, –1.5/+0.1, –1.9)	730	A2L	19,000	3.7	59	76,000	14.9	239	Neither

Informative Note: LFL data values highlighted in gray in this table are based on conditions other than WCF @ 23°C (73.4°F). Refer to applicable table footnotes for details.

a. Data taken from Calm [8,9,10], Coombs[11,12], and Wilson and Richard [13] (see Section 10).
b. Azeotropic refrigerants exhibit some segregation of components at conditions of temperature and pressure other than those at which they were formulated. The extent of segregation depends on the particular azeotrope and hardware system configuration.
c. The exact composition of this azeotrope is in question, and additional experimental studies are needed.
d. R-507, R-508, and R-509 are allowed alternative designations for R-507A, R-508A, and R-509A due to a change in designations after assignment of R-500 through R-509. Corresponding changes were not made for R-500 through R-506.
e. The RCL values for these refrigerant blends are approximated in the absence of adequate data for a component comprising less than 4% m/m of the blend and expected to have only a small influence in an acute, accidental release.
f. *Highly toxic*, *toxic*, or *neither*, where *highly toxic* and *toxic* are as defined in the *International Fire Code* [1], *Uniform Fire Code*[2], and OSHA regulations, and *neither* identifies those refrigerants having lesser toxicity than either of those groups [1,2,3].
g. At locations with altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
h. The OELs are eight-hour TWAs as defined in Section 3 unless otherwise noted; a "C" designation denotes a ceiling limit.
i. At locations with altitudes higher than 3300 ft (1000 m) but below or equal to 4920 ft (1500 m), the ODL and RCL shall be 112, 000 ppm, and at altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
j. LFL is based on WCF @23°C (73.4°F) unless otherwise noted.
k. WCFF LFL @60°C (140°F)
l. Reserved for future assignment
m. WCFF LFL @23°C (73.4°F)
n. WCF LFL @100°C (212°F)

Table 4-2 Data and Safety Classifications for Refrigerant Blends *(Continued)*

Refrigerant Number	Composition (Mass%) (Composition Tolerances)	OEL[h], ppm v/v	Safety Group	RCL[a] ppm v/v	RCL[a] lb/1000 ft^3	RCL[a] g/m^3	LFL[j] ppm v/v	LFL[j] lb/1000 ft^3	LFL[j] g/m^3	Highly Toxic or Toxic[f] Under Code Classification
Zeotropes (*continued*)										
457C	R-32/1234yf/152a (7.5/78.0/14.5) (+0.5, –1.5/+1.0, –1.0/+0.5, –1.5)	610	A2L	13,800	3.4	54	55,000	13.6	215	Neither
458A	R-32/125/134a/227ea/236fa (20.5/4.0/61.4/13.5/0.6) (±0.5/±0.5/±0.5/±0.5/±0.1)	1000	A1	76,000	18	280				Neither
459A	R-32/1234yf/1234ze(E) (68.0/26.0/6.0) (+0.5, –1.5/±2.0/+1.5, –0.5)	870	A2L	27,000	4.3	69	107,000	17.4	278.7	Neither
459B	R-32/1234yf/1234ze(E) (21.0/69.0/10.0) (+0.5, –1.0/±2.0/±1.0)	640	A2L	25,000	5.8	92	99,000	23.3	373.5	Neither
460A	R-32/125/134a/1234ze(E) (12.0/52.0/14.0/22.0) (±1.0/±1.0/±1.0/±1.0)	950	A1	92,000	24	380				Neither
460B	R-32/125/134a/1234ze(E) (28.0/25.0/20.0/27.0) (±1.0/±1.0/±1.0/±1.0)	950	A1	120,000	25	400				Neither
460C	R-32/125/134a/1234ze(E) (2.5/2.5/46.0/49.0) (±0.5/±0.5/±1.0/±1.0)	900	A1	73,000	20	310				Neither
461A	R-125/143a/134a/227ea/600a (55.0/5.0/32.0/5.0/3.0) (±1.0/ ±0.5/±1.0/±0.5/+0.1, –0.4)	1000	A1	61,000	17	270				Neither
462A	R-32/125/143a/134a/600 (9.0/42.0/2.0/44.0/3.0) (+1.5, –1.0/±2.0/±1.0/±2.0/±1.0)	1000	A2	16,000	3.9	62	105,000[k]	16.6[k]	265.8[k]	Neither
463A	R-744/32/125/1234yf/134a (6.0/36.0/30.0/14.0/14.0) (+2.0, –1.0/±2.0/±2.0/±2.0/±2.0)	990	A1	98,000	19	300				Neither

Informative Note: LFL data values highlighted in gray in this table are based on conditions other than WCF @ 23°C (73.4°F). Refer to applicable table footnotes for details.

a. Data taken from Calm[8,9,10], Coombs[11,12], and Wilson and Richard[13] (see Section 10).
b. Azeotropic refrigerants exhibit some segregation of components at conditions of temperature and pressure other than those at which they were formulated. The extent of segregation depends on the particular azeotrope and hardware system configuration.
c. The exact composition of this azeotrope is in question, and additional experimental studies are needed.
d. R-507, R-508, and R-509 are allowed alternative designations for R-507A, R-508A, and R-509A due to a change in designations after assignment of R-500 through R-509. Corresponding changes were not made for R-500 through R-506.
e. The RCL values for these refrigerant blends are approximated in the absence of adequate data for a component comprising less than 4% m/m of the blend and expected to have only a small influence in an acute, accidental release.
f. *Highly toxic*, *toxic*, or *neither*, where *highly toxic* and *toxic* are as defined in the *International Fire Code*[1], *Uniform Fire Code*[2], and OSHA regulations, and *neither* identifies those refrigerants having lesser toxicity than either of those groups[1,2,3].
g. At locations with altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
h. The OELs are eight-hour TWAs as defined in Section 3 unless otherwise noted; a “C” designation denotes a ceiling limit.
i. At locations with altitudes higher than 3300 ft (1000 m) but below or equal to 4920 ft (1500 m), the ODL and RCL shall be 112, 000 ppm, and at altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
j. LFL is based on WCF @23°C (73.4°F) unless otherwise noted.
k. WCFF LFL @60°C (140°F)
l. Reserved for future assignment
m. WCFF LFL @23°C (73.4°F)
n. WCF LFL @100°C (212°F)

Table 4-2 Data and Safety Classifications for Refrigerant Blends *(Continued)*

Refrigerant Number	Composition (Mass%) (Composition Tolerances)	OEL[h], ppm v/v	Safety Group	RCL [a] ppm v/v	RCL [a] lb/1000 ft^3	RCL [a] g/m^3	LFL [j] ppm v/v	LFL [j] lb/1000 ft^3	LFL [j] g/m^3	Highly Toxic or Toxic [f] Under Code Classification
Zeotropes (*continued*)										
464A	R-32/125/1234ze(E)/227ea (27.0/27.0/40.0/6.0) (±1.0/±1.0/±1.0/±0.5)	930	A1	120,000	27	430				Neither
465A	R-32/290/1234yf (21.0/7.9/71.1) (+0.5, –1.5/+0.1, –0.9/±1.0)	660	A2	12,000	2.5	40	98,000	10.0	160.9	Neither
466A	R-32/125/13I1 (49.0/11.5/39.5) (+0.5, –2.0/+2.0, –0.5/+2.0, –0.5)	860	A1	30,000	6.2	99				Neither
467A	R-32/125/134a/600a (22.0/5.0/72.4/0.6) (+0.1, –0.5/±0.5/+0.5, –1.5/±0.1)	1000	A2L	31,000	6.7	110				Neither
468A	R-1132a/32/1234yf (3.5/21.5/75.0) (+0.2, –1.5/±2.0/±2.0)	610	A2L	18,000	4.1	66				Neither
468B	R-1132a/32/1234yf (6.0/13.0/81.0) (+0.5,–1.0/+0.5,–1.0/–1.0,+2.0)	570	A2L	18,000	4.4	70				Neither
468C	R-1132a/32/1234yf (6.0/42.0/52.0) (+0.5,–1.0/+0.5,–1.5/–1.0,+2.0)	710	A2L	23,000	4.3	69				Neither
469A	R-744/R-32/R-125 (35.0/32.5/32.5) (±2.0/±2.0/±2.0)	1600	A1	53,000	8	130				Neither
470A	R-744/32/125/134a/1234ze(E)/227ea (10.0/17.0/19.0/7.0/44.0/3.0) (±1.0/±1.0/±1.0/±0.5/±2.0/±0.5)	1100	A1	77,000	17	270				Neither
470B	R-744/32/125/134a/1234ze(E)/227ea (10.0/11.5/11.5/3.0/57.0/7.0) (±1.0/±1.0/±1.0/±0.5/±2.0/±0.5)	1100	A1	72,000	16	260				Neither

Informative Note: LFL data values highlighted in gray in this table are based on conditions other than WCF @ 23°C (73.4°F). Refer to applicable table footnotes for details.

a. Data taken from Calm [8,9,10], Coombs[11,12], and Wilson and Richard [13] (see Section 10).
b. Azeotropic refrigerants exhibit some segregation of components at conditions of temperature and pressure other than those at which they were formulated. The extent of segregation depends on the particular azeotrope and hardware system configuration.
c. The exact composition of this azeotrope is in question, and additional experimental studies are needed.
d. R-507, R-508, and R-509 are allowed alternative designations for R-507A, R-508A, and R-509A due to a change in designations after assignment of R-500 through R-509. Corresponding changes were not made for R-500 through R-506.
e. The RCL values for these refrigerant blends are approximated in the absence of adequate data for a component comprising less than 4% m/m of the blend and expected to have only a small influence in an acute, accidental release.
f. *Highly toxic*, *toxic*, or *neither*, where *highly toxic* and *toxic* are as defined in the *International Fire Code* [1], *Uniform Fire Code*[2], and OSHA regulations, and *neither* identifies those refrigerants having lesser toxicity than either of those groups [1,2,3].
g. At locations with altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
h. The OELs are eight-hour TWAs as defined in Section 3 unless otherwise noted; a “C” designation denotes a ceiling limit.
i. At locations with altitudes higher than 3300 ft (1000 m) but below or equal to 4920 ft (1500 m), the ODL and RCL shall be 112, 000 ppm, and at altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
j. LFL is based on WCF @23°C (73.4°F) unless otherwise noted.
k. WCFF LFL @60°C (140°F)
l. Reserved for future assignment
m. WCFF LFL @23°C (73.4°F)
n. WCF LFL @100°C (212°F)

Table 4-2 Data and Safety Classifications for Refrigerant Blends *(Continued)*

Refrigerant Number	Composition (Mass%) (Composition Tolerances)	OEL[h], ppm v/v	Safety Group	RCL [a]			LFL [j]			Highly Toxic or Toxic [f] Under Code Classification
				ppm v/v	lb/1000 ft³	g/m³	ppm v/v	lb/1000 ft³	g/m³	
Zeotropes (*continued*)										
471A	R-1234ze(E)/227ea/1336mzz(E) (78.7/4.3/17.0) (+0.4, –1.5/+1.5, –0.4/+1.5, –0.4)	710	A1	31,000	9.7	160				Neither
472A	R-744/32/134a (69.0/12.0/19.0) (±1.0/±1.0/±1.0)	2700	A1	35,000	4.5	72				Neither
472B	R-744/32/134a (58.0/10.0/32.0) (±1.0/±1.0/±1.0)	2400	A1	36,000	5.0	80				Neither
473A	R-1132a/23/744/125 (20.0/10.0/60.0/10.0) (+0.5, –1.0/±1.0/±2.0/±1.0)	1700	A1	36,000	4.8	77				Neither
474A	R-1132(E)/1234yf (23.0/77.0) (±2.0/±2.0)	440	A2L	13,000	3.3	53	53,000	13	209	Neither
475A	R-1234yf/134a/1234ze(E) (45.0/43.0/12.0) (±1.0/±1.0/±1.0)	690	A1	73,000	20.0	320				Neither
476A	R-134a/1234ze(E)/1336mzz(E) (10.0/78.0/12.0) (+2.0, –0.5/+0.5, –2.0/+2.0, –0.5)	750	A1	38,000	11	180				Neither
Azeotropes [b]										
500	R-12/152a (73.8/26.2)	1000	A1	29,000	7.4	120				Neither
501	R-22/12 (75.0/25.0)[c]	1000	A1	54,000	13	210				Neither
502 [g]	R-22/115 (48.8/51.2)	1000	A1	73,000	21	330				Neither
503	R-23/13 (40.1/59.9)	1000								Neither

Informative Note: LFL data values highlighted in gray in this table are based on conditions other than WCF @ 23°C (73.4°F). Refer to applicable table footnotes for details.

a. Data taken from Calm [8,9,10], Coombs[11,12], and Wilson and Richard [13] (see Section 10).
b. Azeotropic refrigerants exhibit some segregation of components at conditions of temperature and pressure other than those at which they were formulated. The extent of segregation depends on the particular azeotrope and hardware system configuration.
c. The exact composition of this azeotrope is in question, and additional experimental studies are needed.
d. R-507, R-508, and R-509 are allowed alternative designations for R-507A, R-508A, and R-509A due to a change in designations after assignment of R-500 through R-509. Corresponding changes were not made for R-500 through R-506.
e. The RCL values for these refrigerant blends are approximated in the absence of adequate data for a component comprising less than 4% m/m of the blend and expected to have only a small influence in an acute, accidental release.
f. *Highly toxic*, *toxic*, or *neither*, where *highly toxic* and *toxic* are as defined in the *International Fire Code* [1], *Uniform Fire Code*[2], and OSHA regulations, and *neither* identifies those refrigerants having lesser toxicity than either of those groups [1,2,3].
g. At locations with altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
h. The OELs are eight-hour TWAs as defined in Section 3 unless otherwise noted; a "C" designation denotes a ceiling limit.
i. At locations with altitudes higher than 3300 ft (1000 m) but below or equal to 4920 ft (1500 m), the ODL and RCL shall be 112, 000 ppm, and at altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
j. LFL is based on WCF @23°C (73.4°F) unless otherwise noted.
k. WCFF LFL @60°C (140°F)
l. Reserved for future assignment
m. WCFF LFL @23°C (73.4°F)
n. WCF LFL @100°C (212°F)

Table 4-2 Data and Safety Classifications for Refrigerant Blends *(Continued)*

Refrigerant Number	Composition (Mass%) (Composition Tolerances)	OEL[h], ppm v/v	Safety Group	RCL[a] ppm v/v	RCL[a] lb/1000 ft^3	RCL[a] g/m^3	LFL[j] ppm v/v	LFL[j] lb/1000 ft^3	LFL[j] g/m^3	Highly Toxic or Toxic[f] Under Code Classification
Azeotropes[b] (*continued*)										
504[i]	R-32/115 (48.2/51.8)	1000		140,000	28	450				Neither
505	R-12/31 (78.0/22.0)[c]									Neither
506	R-31/114 (55.1/44.9)									Neither
507A[d,i]	R-125/143a (50.0/50.0)	1000	A1	130,000	32	510				Neither
508A[d]	R-23/116 (39.0/61.0)	1000	A1	55,000	14	220				Neither
508B	R-23/116 (46.0/54.0)	1000	A1	52,000	13	200				Neither
509A[d,g]	R-22/218 (44.0/56.0)	1000	A1	75,000	24	380				Neither
510A	R-E170/600a (88.0/12.0) (±0.5/±0.5)	1000	A3	7300	0.87	14	29,000	3.5	56.1	Neither
511A	R-290/E170 (95.0/5.0) (±1.0/±1.0)	1000	A3	5300	0.59	9.5	21,000	2.4	38.0	Neither
512A	R-134a/152a (5.0/95.0) (±1.0/±1.0)	1000	A2	11,000	1.9	31	45,000[m]	7.7[m]	123.9[m]	Neither
513A	R-1234yf/134a (56.0/44.0) (±1.0/±1.0)	650	A1	72,000	20	320				Neither
513B	R-1234yf/134a (58.5/41.5) (±0.5/±0.5)	640	A1	74,000	21	330				Neither
514A	R-1336mzz(Z)/1130 (E) (74.7/25.3) (+1.5, –0.5/+0.5, –1.5)	320	B1	2400	0.86	14				Neither

Informative Note: LFL data values highlighted in gray in this table are based on conditions other than WCF @ 23°C (73.4°F). Refer to applicable table footnotes for details.

a. Data taken from Calm [8,9,10], Coombs[11,12], and Wilson and Richard [13] (see Section 10).
b. Azeotropic refrigerants exhibit some segregation of components at conditions of temperature and pressure other than those at which they were formulated. The extent of segregation depends on the particular azeotrope and hardware system configuration.
c. The exact composition of this azeotrope is in question, and additional experimental studies are needed.
d. R-507, R-508, and R-509 are allowed alternative designations for R-507A, R-508A, and R-509A due to a change in designations after assignment of R-500 through R-509. Corresponding changes were not made for R-500 through R-506.
e. The RCL values for these refrigerant blends are approximated in the absence of adequate data for a component comprising less than 4% m/m of the blend and expected to have only a small influence in an acute, accidental release.
f. *Highly toxic*, *toxic*, or *neither*, where *highly toxic* and *toxic* are as defined in the *International Fire Code* [1], *Uniform Fire Code*[2], and OSHA regulations, and *neither* identifies those refrigerants having lesser toxicity than either of those groups [1,2,3].
g. At locations with altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
h. The OELs are eight-hour TWAs as defined in Section 3 unless otherwise noted; a "C" designation denotes a ceiling limit.
i. At locations with altitudes higher than 3300 ft (1000 m) but below or equal to 4920 ft (1500 m), the ODL and RCL shall be 112, 000 ppm, and at altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
j. LFL is based on WCF @23°C (73.4°F) unless otherwise noted.
k. WCFF LFL @60°C (140°F)
l. Reserved for future assignment
m. WCFF LFL @23°C (73.4°F)
n. WCF LFL @100°C (212°F)

Table 4-2 Data and Safety Classifications for Refrigerant Blends *(Continued)*

Refrigerant Number	Composition (Mass%) (Composition Tolerances)	OEL[h], ppm v/v	Safety Group	RCL [a]			LFL [j]			Highly Toxic or Toxic [f] Under Code Classification
				ppm v/v	lb/1000 ft^3	g/m^3	ppm v/v	lb/1000 ft^3	g/m^3	
Azeotropes [b] (*continued*)										
515A	R-1234ze(E)/227ea (88.0/12.0) (+1.0, –2.0/+2.0, –1.0)	810	A1	63,000	19	300				Neither
515B	R-1234ze(E)/227ea (91.1/8.9) (+0.1, –2.0/+2.0, –0.1)	810	A1	61,000	18	290				Neither
516A	R-1234yf/134a/152a (77.5/8.5/14.0) (±1.4/+0.5, –1.5/+0.1, –1.9)	590	A2L	13,000	3.2	52	50,000	13.1	210.1	Neither

Informative Note: LFL data values highlighted in gray in this table are based on conditions other than WCF @ 23°C (73.4°F). Refer to applicable table footnotes for details.

a. Data taken from Calm [8,9,10], Coombs[11,12], and Wilson and Richard [13] (see Section 10).
b. Azeotropic refrigerants exhibit some segregation of components at conditions of temperature and pressure other than those at which they were formulated. The extent of segregation depends on the particular azeotrope and hardware system configuration.
c. The exact composition of this azeotrope is in question, and additional experimental studies are needed.
d. R-507, R-508, and R-509 are allowed alternative designations for R-507A, R-508A, and R-509A due to a change in designations after assignment of R-500 through R-509. Corresponding changes were not made for R-500 through R-506.
e. The RCL values for these refrigerant blends are approximated in the absence of adequate data for a component comprising less than 4% m/m of the blend and expected to have only a small influence in an acute, accidental release.
f. *Highly toxic*, *toxic*, or *neither*, where *highly toxic* and *toxic* are as defined in the *International Fire Code* [1], *Uniform Fire Code*[2], and OSHA regulations, and *neither* identifies those refrigerants having lesser toxicity than either of those groups [1,2,3].
g. At locations with altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
h. The OELs are eight-hour TWAs as defined in Section 3 unless otherwise noted; a "C" designation denotes a ceiling limit.
i. At locations with altitudes higher than 3300 ft (1000 m) but below or equal to 4920 ft (1500 m), the ODL and RCL shall be 112, 000 ppm, and at altitudes higher than 4920 ft (1500 m), the ODL and RCL shall be 69,100 ppm.
j. LFL is based on WCF @23°C (73.4°F) unless otherwise noted.
k. WCFF LFL @60°C (140°F)
l. Reserved for future assignment
m. WCFF LFL @23°C (73.4°F)
n. WCF LFL @100°C (212°F)

4.3.1 Two-carbon, dimethyl ethers require no further suffixes, as the presence of the "E" prefix provides an unambiguous description.

4.3.2 Straight-chain, three-carbon ethers require the agreement of the hydrocarbon ordering in Section 4.1.8.

4.3.2.1 The positions of the ether oxygens shall be given by the carbons to which they are first encountered. An additional integer identifying the first carbon to which the ether oxygen is attached will be appended to the suffix letters.

4.3.2.2 In the case of otherwise symmetric hydrocarbon structures, the ether oxygen shall appear in the earliest sequential position.

4.3.2.3 Even in those cases where only a single propane isomer exists for the hydrocarbon portion of the ether structure, such as CF_3-O-CF_2-CF_3, the suffix letters described in Section 4.1.10 shall be retained. In this cited example, the correct designation shall be R-E218ca1.

4.3.2.4 Structures containing two interspersed oxygen atoms, di-ethers, shall be designated with two following integers to indicate the positions of the ether oxygens.

4.3.3 For cyclic ethers carrying both the "C-" and "E-" prefixes, the "C" shall precede the "E," as "CE," to designate *cyclic ethers*.

For four-membered cyclic ethers, including three carbon and one ether oxygen atom, the root number designations for the hydrocarbon atoms shall be constructed according to the current standard for hydrocarbon nomenclature (Section 4.1).

4.4 Blends shall be identified by the designations assigned in this standard. Blends without assigned designations shall be identified by their compositions, listing the components in order of increasing normal boiling points separated by slashes, for example, R-32/134a for a blend of R-32 and R-134a. Specific formulations shall be further identified by appending the corresponding mass fractions expressed as percentages to one decimal place and enclosing them in parentheses, for example, R-32/134a (30.0/70.0). No component shall be permitted at less than 0.6% m/m nominal. When formulation tolerances are relevant to the discussion, the corresponding tolerances shall be appended in a second set of parentheses, for example, R-32/125/134a (30.0/10.0/60.0) (+1.0, –2.0/±2.0/±2.0) for a blend of R-32, R-125, and R-134a with nominal mass fractions of 30.0%, 10.0%, and 60.0%, respectively, and mass fractions of 28.0% to 31.0%, 8.0% to 12.0%, and 58.0% to 62.0% with tolerances, respectively.

4.4.1 Designation. Zeotropic blends shall be assigned an identifying number in the 400 series. Azeotropes shall be assigned an identifying number in the 500 series. To differentiate among blends having the same components with different proportions (% m/m), an uppercase letter shall be added as a suffix. An example of a zeotrope would be R-401A, and an example of an azeotrope would be R-508A.

Informative Note: Refrigerant numbers and suffixes are preferably assigned in serial order. Refrigerant numbers and suffixes can be skipped to avoid confusion with other refrigerant designating standards.

4.4.2 Composition Tolerances. Blends shall have tolerances specified for individual components. Those tolerances shall be specified to the nearest 0.1% m/m. The maximum tolerance above or below the nominal shall not exceed 2.0% m/m. The tolerance above or below the nominal shall not be less than 0.1% m/m. The difference between the highest and the lowest tolerances shall not exceed one-half of the nominal component composition.

4.4.3 Composition Uniqueness. To ensure composition uniqueness, blends with the same components shall have at least one component range, including tolerances, that does not overlap and is separated by a minimum of 0.1% m/m.

Informative Note: See Informative Appendix H for examples.

4.5 Miscellaneous organic compounds shall be assigned numbers in the 600 series in decadal groups, as outlined in Table 4-1, in serial order of designation within the groups. For the saturated hydrocarbons with four to eight carbon atoms, the number assigned shall be 600 plus the number of carbon atoms minus four. For example, butane is R-600, pentane is R-601, hexane is R-602, heptane is R-603, and octane is R-604. The straight-chain or "normal" hydrocarbon has no suffix. For isomers of the hydrocarbons with four to eight carbon atoms, the lower-case letters "a," "b," "c," etc., are appended to isomers according to the groups attached to the longest carbon chain as indicated in Table 4-3. For example, R-601a is assigned for 2-methylbutane (isopentane), and R-601b would be assigned for 2,2-dimethylpropane (neopentane).

4.6 Inorganic compounds shall be assigned numbers in the 700 and 7000 series.

4.6.1 For compounds with relative molar masses less than 100, the number shall be the sum of 700 and the relative molar mass, rounded to the nearest integer.

Table 4-3 Attached Group Suffixes

Attached Groups	Suffix
none (straight chain)	No suffix
2-methyl-	a
2,2-dimethyl-	b
3-methyl-	c
2,3-dimethyl-	d
3,3-dimethyl-	e
2,4-dimethyl-	f
2,2,3-trimethyl-	g
3-ethyl-	h
4-methyl-	i
2,5-dimethyl-	j
3,4-dimethyl-	k
2,2,4-trimethyl-	l
2,3,3-trimethyl-	m
2,3,4-trimethyl-	n
2,2,3,3-tetramethyl	o
3-ethyl-2-methyl-	p
3-ethyl-3-methyl-	q

4.6.2 For compounds with relative molar masses equal to or greater than 100, the number shall be the sum of 7000 and the relative molar mass, rounded to the nearest integer.

4.6.3 When two or more inorganic refrigerants have the same relative molar masses, uppercase letters (i.e., "A," "B," "C," etc.) shall be added, in serial order of designation, to distinguish among them.

5. DESIGNATION

5.1 General. This section provides guidance on prefixes for refrigerants to improve uniformity in order to promote understanding. Both technical and nontechnical designations are provided to be selected based on the nature and audience of the use.

5.2 Identification. Refrigerants shall be identified in accordance with Section 5.2.1, 5.2.2, or 5.2.3. Section 5.2.1 shall be used in technical publications (for international uniformity and to preserve archival consistency), on equipment nameplates, and in specifications. Section 5.2.2 can be used for single-component halocarbon refrigerants, where distinction between the presence or absence of chlorine, bromine, or iodine is pertinent. Composition designation may be appropriate for nontechnical, public, and regulatory communications addressing compounds having environmental impact, such as ozone depletion or global warming potential. Section 5.2.3 can be used, under the same circumstances as Section 5.2.2, for blends (both azeotropic and zeotropic). Section 5.2.1 shall be used for miscellaneous organic and inorganic compounds.

5.2.1 Technical Prefixes. The identifying number, as determined by Section 4, shall be preceded by the letter "R," the word "Refrigerant" ("Refrigerants" if more than one), or the manufacturer's trademark or trade name. Examples include R 12, R-12, Refrigerant 12, <Trade Name> 12, <Trade Name> R 12, R-500, R-22/152a/114 (36.0/24.0/40.0), and R-717. Trademarks and trade names shall not be used to identify refrigerants on equipment nameplates or in specifications.

5.2.2 Composition Designating Prefixes. The identifying number, as determined by Section 4, shall be prefixed by the letter "C" for carbon and preceded by "B," "C," "F," or "I"—or a combination thereof in this sequence—to signify the presence of bromine, chlorine, fluorine, or iodine, respectively. Compounds that also contain hydrogen shall be further preceded by the letter "H" to signify the increased deterioration potential before reaching the stratosphere [14]. The compositional designating prefixes for ether shall substitute an "E" for "C," such that "HFE," "HCFE," and "CFE" refer to hydrofluoroethers, hydrochlorofluoroethers, and chlorofluoroethers, respectively. The composition designating prefixes for halogenated olefins shall be either "CFC," "HCFC," or "HFC" to refer to chlorofluorocarbon, hydrochlorofluorocarbon, or hydrofluorocarbon, respectively, or with substitution of an "O" for the carbon "C" as "CFO," "HCFO," or "HFO" to refer to chlorofluoro-olefin, hydrochlorofluoro-olefin, or hydrofluoro-olefin, respectively. Halogenated olefins are a subset of halogenated organic (or carbon-containing) compounds having significantly shorter atmospheric lifetimes than their saturated counterparts. Examples include CFC-11, CFC-12, BCFC-12B1, BFC-13B1, HCFC-22, HC-50, CFC-113, CFC-114, CFC-115, HCFC-123, HCFC-124, HFC-125, HFC-134a, HCFC-141b, HCFC-142b, HFC-143a, HFC-152a, HC-170, FC-C318, and HFC-1234yf or HFO-1234yf.

5.2.3 Recognized blends (whether azeotropic, near azeotropic, or zeotropic) with assigned numbers can be identified by linking the appropriate composition-designating prefixes of individual components (e.g., CFC/HFC-500). Blends without assigned numbers can be identified using appropriate composition designating prefixes for each component (e.g., HCFC-22/HFC-152a/CFC-114 [36.0/24.0/40.0]). Linked prefixes (e.g., HCFC/HFC/CFC-22/152a/114 [36.0/24.0/40.0]) and prefixes implying synthesized compositions (e.g., HCFC-500 or HCFC-22/152a/114 [36.0/24.0/40.0]) shall not be used.

5.2.4 Composition designating prefixes should be used only in nontechnical publications in which the potential for environmental impact is pertinent. The prefixes specified in Section 5.2.1, augmented if necessary as indicated in Section 5.4, are preferred in other communications. Section 5.2.1 also may be preferable for blends when the number of components makes composition designating prefixes awkward, such as for those containing more than three individual components (e.g., in tetrary and pentary blends).

5.3 Other prefixes, including "ACFC" and "HFA," for "alternative to chlorofluorocarbons" and "hydrofluorocarbon alternative," respectively, shall not be used. Similarly, neither "FC" nor "CFC" shall be used as universal prefixes to signify the fluorocarbon and chlorofluorocarbon families of refrigerants (i.e., other than as stipulated in Section 5.2.2).

5.4 The convention specified in Section 5.2.1 can be complemented with pertinent data, when appropriate, as a preferred alternative to composition designating prefixes in technical communications. For example, the first mention of R-12 in a discussion of the ozone-depletion issue might read, "R-12, a CFC" or "R-12 (ODP = 1.0)." Similarly, a document on the greenhouse effect could cite "R-22 (GWP = 0.34 relative to R-11)," and one on flammability might refer to "R-152a (LFL = 4.1%)."

6. SAFETY GROUP CLASSIFICATIONS

6.1 Refrigerants shall be classified into safety groups according to the following criteria.

6.1.1 Classification. The safety group classification shall consist of two or three alphanumeric characters (e.g., "B1" or "A2L"). The first character indicates the toxicity as determined by Section 6.1.2; the Arabic numeral with or without suffix letter denotes the flammability as determined by Section 6.1.3.

6.1.2 Toxicity Classification. Refrigerants shall be assigned to one of two classes, A or B, based on allowable exposure.

a. Class A refrigerants have an occupational exposure limit (OEL) of 400 ppm or greater.
b. Class B refrigerants have an OEL of less than 400 ppm.

6.1.3 Flammability Classification. Refrigerants shall be assigned to one of four classes (1, 2L, 2, or 3) based on lower flammability limit testing, heat of combustion, and the optional burning velocity measurement. Flammability tests shall be conducted in accordance with ASTM E681 [15] using a spark ignition source. Testing of all halocarbon refrigerants shall be in accordance with the annex of ASTM E681. Single-compound refrigerants shall be assigned a single flammability classification. Refrigerant blends shall be 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 (see Normative Appendix B, Section B2). A fractionation analysis for flammability is not required if the components of the blend are all in one class; the blend shall be assigned the same class (see Table 6-1).

Burning velocity measurements shall be conducted according to a credible method. The method shall be in agreement with established methods of determining burning velocity by demonstrating measurement results of 6.7 ± 0.7 cm/s burning velocity for R-32. When the burning velocity of the proposed refrigerant is above 6.7 cm/s, an additional test shall be required demonstrating the burning velocity for R-152a of 23.0 ± 2.3 cm/s to validate the method, or by presenting other evidence supporting the accuracy of the method. One acceptable method is the vertical-tube method as detailed by Jabbour and summarized by Jabbour and

Table 6-1 Flammability Classifications

Class	Single-Component Refrigerant	WCF of a Refrigerant Blend	WCFF of a Refrigerant Blend
1	No flame propagation when tested at 140°F (60°C) and 14.7 psia (101.3 kPa)	No flame propagation when tested at 140°F (60°C) and 14.7 psia (101.3 kPa)	No flame propagation when tested at 140°F (60°C) and 14.7 psia (101.3 kPa)
2L	Flame propagation when tested at 140°F (60°C) and 14.7 psia (101.3 kPa) *and* LFL[a] > 0.0062 lb/ft^3 (0.10 kg/m^3) *and* heat of combustion < 8169 Btu/lb (19,000 kJ/kg) *and* burning velocity ≤ 3.9 in./s (10 cm/s) when tested at 73.4°F (23°C), 14.7 psia (101.3 kPa) in dry air	Flame propagation when tested at 140°F (60°C) and 14.7 psia (101.3 kPa) *and* LFL[a] > 0.0062 lb/ft^3 (0.10 kg/m^3) *and* heat of combustion <8169 Btu/lb (19,000 kJ/kg) *and* burning velocity ≤ 3.9 in./s (10 cm/s) when tested at 73.4°F (23°C) and 14.7 psia (101.3 kPa) in dry air	Flame propagation when tested at 140°F (60°C) and 14.7 psia (101.3 kPa) *and* LFL[a] > 0.0062 lb/ft^3 (0.10 kg/m^3) *and* heat of combustion <8169 Btu/lb (19,000 kJ/kg) *and* burning velocity ≤ 3.9 in./s (10 cm/s) when tested at 73.4°F (23°C) and 14.7 psia (101.3 kPa) in dry air
2	Flame propagation when tested at 140°F (60°C) and 14.7 psia (101.3 kPa) *and* LFL[a] > 0.0062 lb/ft^3 (0.10 kg/m^3) *and* heat of combustion < 8169 Btu/lb (19,000 kJ/kg)	Flame propagation when tested at 140°F (60°C) and 14.7 psia (101.3 kPa) *and* LFL[a] > 0.0062 lb/ft^3 (0.10 kg/m^3) *and* heat of combustion < 8169 Btu/lb (19,000 kJ/kg)	Flame propagation when tested at 140°F (60°C) and 14.7 psia (101.3 kPa) *and* *LFL[a] > 0.0062 lb/ft^3 (0.10 kg/m^3)* *and* heat of combustion < 8169 Btu/lb (19,000 kJ/kg)
3	Flame propagation when tested at 140°F (60°C) and 14.7 psia (101.3 kPa) *and* LFL[a] ≤ 0.0062 lb/ft^3 (0.10 kg/m^3) *or* heat of combustion ≥ 8169 Btu/lb (19,000 kJ/kg)	Flame propagation when tested at 140°F (60°C) and 14.7 psia (101.3 kPa) *and* LFL[a] ≤ 0.0062 lb/ft^3 (0.10 kg/m^3) *or* heat of combustion ≥ 8169 Btu/lb (19,000 kJ/kg)	Flame propagation when tested at 140°F (60°C) and 14.7 psia (101.3 kPa) *and* LFL[a] ≤ 0.0062 lb/ft^3 (0.10 kg/m^3) *or* heat of combustion ≥ 8169 Btu/lb (19,000 kJ/kg)

a. Lower flammability limit (LFL) is determined at ambient temperature and pressure. If an LFL does not exist at 73.4°F (23.0°C) and 14.7 psia (101.3 kPa), refer to Section 6.1.3.5.

Clodic [16,17]. Measurements shall be conducted starting from the LFL to at least 125% of the stoichiometric concentration. Measurements shall be conducted with increments of, at most, 10% of the stoichiometric concentration, and each measurement shall be repeated at least two times. The burning velocity is the maximum value obtained from a least-squares fit to the measured data. The gas mixture shall be made by any method that produces a blend of air/refrigerant that is accurate to ±0.1% in the test chamber. Dry air (less than 0.00015 g of water vapor per gram of dry air) containing 21.0% ± 0.1% O_2 shall be used as the oxidant. The flammable gas shall have a minimum purity of 99.5% by weight.

Informative Note: Methods that have been used include (a) a pressurized mixture made by using partial pressure and (b) quantitative flow methods like volumetric flowmeters and mass flow controllers fixing the ratio of air and refrigerant.

6.1.3.1 Class 1 (No Flame Propagation)

a. A single-compound refrigerant shall be classified as Class 1 if the refrigerant does not show flame propagation when tested in air at 140°F (60°C) and 14.7 psia (101.3 kPa).
b. The WCF of a refrigerant blend shall be classified as Class 1 if the WCF of the blend does not show flame propagation when tested in air at 140°F (60°C) and 14.7 psia (101.3 kPa).
c. The WCFF of a refrigerant blend shall be classified as Class 1 if the WCFF of the blend, as determined from a fractionation analysis specified by Normative Appendix B, Section B2, does not show flame propagation when tested at 140°F(60.0°C) and 14.7 psia (101.3 kPa).

6.1.3.2 Class 2L (Lower Flammability)

a. A single-compound refrigerant shall be classified as Class 2L if the refrigerant meets all four of the following conditions:
   1. Exhibits flame propagation when tested at 140°F (60°C) and 14.7 psia (101.3 kPa)

2. Has an LFL >0.0062 lb/ft^3 (0.10 kg/m^3) (See Section 6.1.3.5 if the refrigerant has no LFL at 73.4°F [23.0°C] and 14.7 psia [101.3 kPa].)
3. Has a heat of combustion <8169 Btu/lb (19,000 kJ/kg) (see Section 6.1.3.6)
4. Has a maximum burning velocity of ≤3.9 in./s (10 cm/s) when tested at 73.4°F (23.0°C) and 14.7 psia (101.3 kPa) in dry air

b. The WCF of a refrigerant blend shall be classified as Class 2L if it meets all four of the following conditions:
   1. Exhibits flame propagation when tested at 140°F (60°C) and 14.7 psia (101.3 kPa)
   2. Has an LFL >0.0062 lb/ft^3 (0.10 kg/m^3) (See Section 6.1.3.5 if the WCF of the blend has no LFL at 73.4°F [23.0°C] and 14.7 psia [101.3 kPa].)
   3. Has a heat of combustion <8169 Btu/lb (19,000 kJ/kg) (See Section 6.1.3.6.)
   4. Has a maximum burning velocity of ≤3.9 in./s (10 cm/s) when tested at 73.4°F (23.0°C) and 14.7 psia (101.3 kPa) in dry air
c. The WCFF of a refrigerant blend shall be classified as Class 2L if it meets all four of the following conditions:
   1. Exhibits flame propagation when tested at 140°F (60.0°C) and 14.7 psia (101.3 kPa)
   2. Has an LFL >0.0062 lb/ft^3 (0.10 kg/m^3) (See Section 6.1.3.5 if the WCFF of the blend has no LFL at 73.4°F [23.0°C] and 14.7 psia [101.3 kPa].)
   3. Has a heat of combustion <8169 Btu/lb (19,000 kJ/kg) (See Section 6.1.3.6.)
   4. Has a maximum burning velocity of ≤3.9 in./s (10 cm/s) when tested at 73.4°F (23.0°C) and 14.7 psia (101.3 kPa) in dry air

6.1.3.3 Class 2 (Flammable)

a. A single-compound refrigerant shall be classified as Class 2 if the refrigerant meets all three of the following conditions:
   1. Exhibits flame propagation when tested at 140°F (60°C) and 14.7 psia (101.3 kPa)
   2. Has an LFL >0.0062 lb/ft^3 (0.10 kg/m^3) (See Section 6.1.3.5 if the refrigerant has no LFL at 73.4°F [23.0°C] and 14.7 psia [101.3 kPa].)
   3. Has a heat of combustion <8169 Btu/lb (19,000 kJ/kg) (See Section 6.1.3.6.)
b. The WCF of a refrigerant blend shall be classified as Class 2 if it meets all three of the following conditions:
   1. Exhibits flame propagation when tested at 140°F (60°C) and 14.7 psia (101.3 kPa)
   2. Has an LFL >0.0062 lb/ft^3 (0.10 kg/m^3) (See Section 6.1.3.5 if the WCF of the blend has no LFL at 73.4°F [23.0°C] and 14.7 psia [101.3 kPa].)
   3. Has a heat of combustion <8169 Btu/lb (19,000 kJ/kg) (See Section 6.1.3.6.)
c. The WCFF of a refrigerant blend shall be classified as Class 2 if it meets all three of the following conditions:
   1. Exhibits flame propagation when tested at 140°F (60.0°C) and 14.7 psia (101.3 kPa)
   2. Has an LFL >0.0062 lb/ft^3 (0.10 kg/m^3) (See Section 6.1.3.5 if the WCFF of the blend has no LFL at 73.4°F [23.0°C] and 14.7 psia [101.3 kPa].)
   3. Has a heat of combustion <8169 Btu/lb (19,000 kJ/kg) (See Section 6.1.3.6.)

6.1.3.4 Class 3 (Higher Flammability)

a. A single-compound refrigerant shall be classified as Class 3 if the refrigerant meets both of the following conditions:
   1. Exhibits flame propagation when tested at 140°F (60°C) and 101.3 kPa (14.7 psia)
   2. Has an LFL ≤0.0062 lb/ft^3 (0.10 kg/m^3) (See Section 6.1.3.5 if the refrigerant has no LFL at 73.4°F [23.0°C] and 14.7 psia [101.3 kPa]) or it has a heat of combustion that is ≥8169 Btu/lb [19,000 kJ/kg].)
b. The WCF of a refrigerant blend shall be classified as Class 3 if it meets both of the following conditions:
   1. Exhibits flame propagation when tested at 140°F (60°C) and 101.3 kPa (14.7 psia)
   2. Has an LFL ≤0.0062 lb/ft^3 (0.10 kg/m^3) (See Section 6.1.3.5 if the refrigerant has no LFL at 73.4°F [23.0°C] and 14.7 psia [101.3 kPa]) or it has a heat of combustion that is ≥8169 Btu/lb [19,000 kJ/kg].)
c. The WCFF of a refrigerant blend shall be classified as Class 3 if it meets both of the following conditions:
   1. Exhibits flame propagation when tested at 60.0°C (140°F) and 101.3 kPa (14.7 psia)

INCREASING FLAMMABILITY

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

INCREASING TOXICITY

Figure 6-1 Refrigerant safety group classification.

2. Has an LFL ≤0.0062 lb/ft^3 (0.10 kg/m^3) (See Section 6.1.3.5 if the refrigerant has no LFL at 73.4°F [23.0°C] and 14.7 psia [101.3 kPa]) or it has a heat of combustion that is ≥8169 Btu/lb [19,000 kJ/kg].)

6.1.3.5 For Class 2L, Class 2, or Class 3 refrigerants or refrigerant blends, the LFL shall be determined. For those Class 2L, Class 2, or Class 3 refrigerants or refrigerant blends that show no flame propagation when tested at 73.4°F (23.0°C) and 14.7 psia (101.3 kPa) (i.e., no LFL), an elevated temperature flame limit at 140°F (60°C) ($ETFL_{60}$) shall be used in lieu of the LFL for determining their flammability classifications.

6.1.3.6 The heat of combustion shall be calculated for conditions of 77°F (25°C) and 14.7 psia (101.3 kPa).

a. For single-component refrigerants, the heat of combustion shall be calculated. The heat of combustion is the enthalpy of formation of the reactants (refrigerant and oxygen) minus the enthalpy of formation of the products of reaction. Values for heats of formation are tabulated in several chemical and physical property handbooks and databases. In this standard, the heat of combustion is positive for exothermic reactions. Calculated values shall be based on the complete combustion of one mole of refrigerant with enough oxygen for a stoichiometric reaction. The reactants and the combustion products shall be assumed to be in the gas phase. The combustion products shall be HF(g), CO_2(g), N_2(g), SO_2(g), HCl(g), and H_2O(g). (***Informative Note:*** Gaseous [g], not aqueous solution [aq].)

   If there is insufficient hydrogen (H) available for the formation of HF(g), HCl(g), and H_2O(g), then the formation of HF(g) takes preference over the formation of HCl(g), which takes preference over the formation of H_2O. If there is insufficient hydrogen available for all of the fluorine (F) to form HF(g), then the remaining fluorine produces COF_2(g) in preference of carbon (C) forming CO_2. Any remaining chloride (Cl) produces Cl_2(g) (chlorine).

b. For refrigerant blends, the heat of combustion shall be calculated from a balanced stoichiometric equation of all component refrigerants. This can be thought of conceptually as breaking the refrigerant molecules into their constituent atoms and creating a hypothetical molecule with the same molar ratio of total carbons, hydrogens, fluorines, etc. as is in the original blend. The hypothetical molecule would then be treated as a pure refrigerant as in Section 6.1.3.6(a). The heat of formation for this hypothetical molecule is the molar average of the heats of formation for the original blend of molecules. (***Informative Note:*** The molar percent or mass percent weighted average of the heat of combustion of the pure component of a blend produces incorrect results. For an example, see Informative Appendix F.)

c. Heats of formation and heats of combustion are normally expressed as energy per mole (kJ/mol or Btu/mol). For purposes of flammability classification under this standard, convert the heat of combustion for a refrigerant from an energy per mole value to an energy per mass value (Btu/lb [kJ/kg]).

6.1.4 Matrix Diagram of Safety Group Classification System. The toxicity and flammability classifications described in Sections 6.1.1, 6.1.2, and 6.1.3 yield eight separate safety group classifications (A1, A2L, A2, A3, B1, B2L, B2, and B3) for refrigerants. These safety group classifications are represented by the matrix shown in Figure 6-1.

6.1.5 Safety Classification of Refrigerant Blends. Blends, whether zeotropic or azeotropic, shall be assigned a safety group classification based on composition requirements of Sections 6.1.2 and 6.1.3 of this standard. This safety classification shall be determined according to the same criteria as that for a single-compound refrigerant.

6.1.5.1 Toxicity Classification. The chronic toxicity classification of a refrigerant blend is based on the nominal formulation. The OEL of mixtures upon which the safety classification is based shall be calculated from the threshold limit values (TLVs) or workplace environmental exposure level (WEELs) of the individual components following American Conference of Governmental Industrial Hygienists guidelines [4].

6.1.5.2 Flammability Classification. Blends shall be assigned a flammability classification based on the requirements in Section 6.1.3.

6.2 Other Standards. The safety group classification, in accordance with Section 6.1, is to be used in conjunction with other relevant safety standards, such as ASHRAE Standard 15 [18].

7. REFRIGERANT CONCENTRATION LIMIT

7.1 Single-Compound Refrigerants. The refrigerant concentration limit (RCL) for each refrigerant shall be the lowest of the quantities calculated in accordance with Sections 7.1.1, 7.1.2, and 7.1.3, using data as indicated in Section 7.3 and adjusted in accordance with Section 7.4. Determination shall assume full vaporization with no removal by ventilation, dissolution, reaction, or decomposition and complete mixing of the refrigerant in the space to which it is released.

7.1.1 Acute Toxicity Exposure Limit. The acute toxicity exposure limit (ATEL) shall be the lowest of items (a) through (d) as follows:

a. Mortality: 28.3% of the four-hour LC_{50} for rats. If not determined, 28.3% of the four-hour approximate lethal concentration (ALC) for rats. If neither has been determined, 0 ppm. The following equations shall be used to adjust LC_{50} or ALC values that were determined with 15-minute to eight-hour tests for refrigerants for which four-hour test data are not available:

$$LC_{50\ \mathrm{for}\ T} = LC_{50\ \mathrm{for}\ t} \times (t/T)^{1/2} \tag{7-1}$$

or

$$ALC_T = ALC_t \times (t/T)^{1/2} \tag{7-2}$$

where

T = four hours

t = test duration expressed in hours, 0.25 to 8

b. Cardiac Sensitization: 100% of the no-observed-effect level (NOEL) for cardiac sensitization in unanesthetized dogs. If not determined, 80% of the lowest observed effect level (LOEL) for cardiac sensitization in dogs. If neither has been determined, 1000 ppm. The cardiac sensitization term is omitted from ATEL determination if the LC_{50} or ALC in Section 7.1.1(a) is less than 10,000 ppm by volume or if the refrigerant is found, by toxicological review, not to cause cardiac sensitization.

c. Anesthetic or Central Nervous System Effects: 50% of the ten-minute EC_{50} in mice or rats for loss of righting ability in a rotating apparatus, or 80% of NOEL in mice or rats for loss of righting ability in a rotating apparatus, whichever is higher. If not determined, 50% of the LOEL for signs of any anesthetic or central nervous system (CNS) effect in rats during acute toxicity studies. If neither has been determined, 80% of the NOEL for signs of any anesthetic or CNS effect in rats during an acute, subchronic, or chronic toxicity study in which clinical signs are documented.

d. Other Escape Impairing Effects and Permanent Injury: 80% of the lowest concentration, for human exposures of 30 minutes, that is likely to impair ability to escape or to cause irreversible health effects.

7.1.2 Oxygen Deprivation Limit. The oxygen deprivation limit (ODL) shall be 140,000 ppm by volume for locations with altitudes at and below 3300 ft (1000 m) above sea level. At locations higher than 3300 ft (1000 m) but below or equal to 4920 ft (1500 m), the ODL shall be 112,000 ppm, and at altitudes higher than 4920 ft (1500 m), the ODL shall be 69,100 ppm (19.5% oxygen by volume).

7.1.3 Flammable Concentration Limit. The flammable concentration limit (FCL) shall be calculated as 25% of the lower flammability limit (LFL) determined in accordance with Section 6.1.3.

7.2 Blends. The RCL for refrigerants comprising multiple compounds shall be determined by the method in Section 7.1. Where available, the blend toxicity data shall be used for individual parameter values in Section 7.1.1(a) through 7.1.1(d), and when toxicity data for the blend are not available they shall be calculated as the mole-weighted average, by composition of the nominal formulation, of the values for the components.

The calculation used to determine the ATEL and RCL of a refrigerant blend is summarized in Informative Appendix G. The calculation can also be conducted using a computer program or spreadsheet.

7.3 Data for Calculations. The data used to calculate the RCL shall be taken from scientific and engineering studies or published safety assessments by governmental agencies or expert panels. The applications submitted under Section 9, or therein referenced source studies for toxicity data, must indicate the extent of compliance with good laboratory practices regulations in accordance with Reference [17], [18], [19], or [20] or earlier editions of these references in effect at the time when the studies were conducted. Data from peer-reviewed publications, including journal articles and reports, also are allowed.

7.3.1 Alternative Data. Data from studies that have not been published, from studies that have not been peer reviewed, or from studies involving species other than those indicated in Section 7.1.1(a) through 7.1.1(d) shall be submitted to SSPC 34 for approval. For RCL values to be published in addenda or revisions to this standard, SSPC 34 shall be the approving committee. Submissions shall include an evaluation of the experimental and analytical methods used, data from alternative sources, and the extent of the data search. Submissions shall summarize the qualifications of the person or persons providing the evaluation.

7.3.2 Conservative Data. Where multiple data values have been published, the values used shall be those resulting in the lowest RCL.

Exceptions to 7.3.2:

1. Where subsequent peer-reviewed studies explicitly document flaws in or refinements to previously published data, the newer values shall be used.
2. For the cardiac sensitization and anesthetic effect NOELs in Section 7.1.1(b) through 7.1.1(c), respectively, the highest-published NOEL not exceeding a published LOEL, for any fraction of tested animals, shall be used. Both the NOEL and LOEL must conform to Section 7.3 or 7.3.1 for this exception.

7.3.3 No-Effect Data. Where no treatment-related effect was observed in animal tests for Section 7.1.1(a) through 7.1.1(d), the ATEL calculation required by Section 7.1.1 shall use the highest concentration tested in lieu of the specified effect or no-effect level.

7.3.4 ALC and LOEL Qualification. No ALC or LOEL shall be used for Section 7.1.1(a) through 7.1.1(c) if it resulted in the effect measured (mortality, cardiac sensitization, or anesthetic effect) in more that half the animals exposed at that concentration or if there is a lower ALC or LOEL for any fraction of tested animals.

7.3.5 Consistent Measures. Use of data that are determined in consistent manner, or by methods that consistently yield a lower RCL for the same effects, is allowed for the parameters identified in Section 7.1.

7.4 Unit Conversion

7.4.1 Mass per Unit Volume. The following equation shall be used to convert the RCL from a volumetric ratio, ppm by volume, to mass per unit volume, lb/1000 ft^3 (g/m^3):

$$\mathrm{RCL}_M = \mathrm{RCL} \times a \times M \tag{7-3}$$

where

RCL_M	=	RCL expressed as lb/1000 ft^3 (g/m^3)
RCL	=	RCL expressed as ppm v/v
a	=	1.160×10^{-3} for lb/1000 ft^3 (4.096×10^{-5} for g/m^3)
M	=	relative molar mass of the refrigerant, lb/mol (g/mol)

7.4.2 Adjustment for Altitude. The RCL shall be adjusted for altitude, when expressed as mass per unit volume, lb/1000 ft^3 (g/m^3), for locations above sea level. The RCL shall not be adjusted when expressed as a volumetric ratio, ppm.

$$\mathrm{RCL}_a = \mathrm{RCL}_M \times [1 - (b \times h)] \tag{7-4}$$

where

RCL_a	=	the adjusted RCL_M
b	=	2.42×10^{-5} for ft (7.94×10^{-5} for m)
h	=	altitude above sea level in ft (m)

7.5 RCL Values. Refrigerants are assigned the RCLs indicated in Tables 4-1 and 4-2.

7.5.1 Influence of Contaminants. The RCLs indicated in Tables 4-1 and 4-2 are based on data for pure chemicals; RCLs shall be determined in accordance with Section 7.5.2 for refrigerants containing contaminants or other impurities that alter the flammability or toxicity.

7.5.2 RCLs for Other Refrigerants. RCLs for other refrigerants shall be determined in accordance with this standard and submitted to SSPC 34 for approval. Submissions shall include an evaluation of the experimental and analytical methods used, data from alternative sources, and an indication of the extent of the data search. The submission shall summarize the qualifications of the person or persons that prepared the recommended RCLs.

8. REFRIGERANT CLASSIFICATIONS

Refrigerants are assigned the safety group classifications indicated in Tables 4-1 and 4-2.

Informative Note: Toxicity and flammability data used to determine RCL values are summarized in Informative Appendix E.

9. APPLICATION INSTRUCTIONS

This section identifies requirements to apply for designations and safety group classifications for refrigerants, including blends, in addenda or revisions to the standard.

9.1 Eligibility

9.1.1 Applicants. Any interested party may request designations and safety group classifications for refrigerants. Applicants may be individuals, organizations, businesses, or government agencies. A primary contact shall be identified for groups of individuals, organizations, businesses, or agencies. Neither the individuals nor primary contacts need be members of ASHRAE.

9.1.2 Fee. The applicant is required to pay for the cost of distributing copies of the application to members of SSPC 34. Please contact the ASHRAE Senior Manager of Standards for more information.

9.1.3 Timing. Applications may be submitted at any time. Committee consideration will be deferred if received by committee members fewer than 30 calendar days before a scheduled meeting. Applicants may communicate with the Senior Manager of Standards (see Section 9.9.5) to determine when the next meeting is scheduled and the additional lead time required. Consideration also may be deferred, by vote of the majority of voting members present, if inadequate opportunity was afforded for review based on the number or complexity of applications received for a specific meeting.

9.1.4 Precedence. Applications normally will be taken up in the order received. Early submission will be beneficial in the event that too many applications are received for consideration at a specific meeting.

9.1.5 Amendments. Pending applications may be amended to revise or add information, whether initiated by the applicant or in response to a committee request for further information. Amended applications will be resequenced to the date of receipt of the last amendment to determine the order of consideration. Amendments shall be separated into the parts indicated in Section 9.2, with the information for each part beginning on a new page to facilitate its insertion into the original or previously amended application. Amendments must repeat the data certification specified in Section 9.4.2. Rejected applications may not be amended, but they may be resubmitted in their entirety as new applications based on new information that may become available.

9.1.6 Blends

9.1.6.1 Components. The components of refrigerant blends must be individually classified before safety group classifications will be assigned to blends containing them. Applications for designation and classification of blends, therefore, shall be accompanied or preceded by applications for all components not yet classified in this standard.

9.1.6.2 Single Application. Designations, formulation tolerances, and safety group classifications (both as formulated and for the worst case of fractionation) shall be requested in a single application for blends. None of these will be assigned separately. Revisions of these items may be requested separately.

9.1.7 Confidentiality. Confidential information shall not be included in applications. All information contained in applications and amendments thereto shall be deemed to be public information, even if marked as confidential or proprietary. Restricted handling of data would unduly impede committee deliberations and assignment of designations and classifications through a consensus review process.

9.2 Organization and Content. Separate applications shall be submitted for each refrigerant. Applications shall be organized into the following parts as further identified in Section 9.3 through Section 9.8:

a. Cover
b. Administrative information
c. Designation information
d. Toxicity information

e. Flammability information
f. Other safety information (if applicable)
g. Appendices (if applicable)

9.3 Cover. The cover shall identify the applicant and primary contact, the refrigerant in accordance with Section 9.5.1, and the requested action. Requested actions may include assignment or revision of a designation, safety group classification, or—for blends—formulation tolerance. Commercial and trade names for refrigerants shall not be used on the cover.

9.4 Administrative Information

9.4.1 Applicant Identification. The applicant, primary contact, and/or other persons authorized to represent the applicant shall be identified. Names, titles, addresses, and phone numbers shall be provided for the primary contact and other representatives. Fax numbers and e-mail addresses also may be provided to facilitate communications. The applicant's interest in the subject refrigerant shall be stated.

9.4.2 Data Certification. An application shall include the following statements signed by the individual(s) or—for organizations and businesses—both a corporate officer and the primary contact:

> I/We certify that the information provided in this application (including its appendices) is true and accurate to the best of my/our knowledge and that no information that would affect classification of toxicity or flammability safety is being withheld. I/We further certify that I/we have reviewed ANSI/ASHRAE Standard 34 (including all published addenda thereto) and that the information provided in this application is consistent with the requirements of that standard.

9.4.3 Designation and Classification Certification. Applications shall include the following statement signed by the individual(s) or—for organizations and businesses—both a corporate officer and the primary contact:

> I/We understand that designations and safety classifications recommended for public review approval or publication are not assigned and may be revised or disapproved until actually published in an addendum or revision to ANSI/ASHRAE Standard 34.

9.5 Designation Information. Applications for refrigerant designations shall contain the information identified in Sections 9.5.1 through Section 9.5.2.

9.5.1 Refrigerant Identification

9.5.1.1 Single-compound refrigerants shall be identified in accordance with Section 4 with the exception of Section 4.4, which applies to blends.

9.5.1.2 Blends shall be identified in accordance with Section 4.4 but not Section 4.4.1. Applicants shall indicate whether the blend is azeotropic or zeotropic (including near azeotropic) as defined in Section 3.

9.5.2 Refrigerant Data

Informative Note: **Recommended Precision and Specification of Source.** The numerical data required in Section 9.5.2 are recommended to conform to the levels of precision stated in Informative Appendix I.

9.5.2.1 Individual Compounds. The following information shall be provided for single-compound refrigerants or for each component of blends:

a. Chemical name
b. Chemical formula
c. Chemical Abstract Service registry number
d. Relative molar mass
e. Normal boiling-point temperature at 14.7 psia (101 kPa)
f. Saturation vapor pressure at 68°F and 140°F (20°C and 60°C)
g. Temperature at the critical point
h. Pressure at the critical point
i. Specific volume at the critical point
j. Uses and typical application temperatures (i.e., evaporating and condensing ranges)

9.5.2.2 Azeotropic Blends. Applications for an azeotropic (R-500 series) blend shall provide evidence proving that an azeotrope exists at the nominal blend composition within the intended application range, typically the temperature range $T_{NBP} < T < (0.95T_{crit})$, where T_{NBP} is the bubble-point temperature at a pressure of 0.101 MPa and T_{crit} is the critical temperature (in Kelvin) of the blend. The existence of the azeotrope shall be proven by one or more of the following methods:

a. Measurement of the vapor-liquid equilibrium at the azeotropic temperature at multiple compositions and with sufficient accuracy to (1) show the existence of a maximum or a minimum in the vapor pressure of the mixture and (2) to define the composition of the maximum or minimum
b. Measurement of the vapor-liquid equilibrium at the azeotropic pressure at multiple compositions and with sufficient accuracy to (1) show the existence of a maximum or a minimum in the boiling point of the mixture and (2) to define the composition of the maximum or minimum
c. Experimental data showing that the azeotropic composition under consideration (x wt%) is achieved at the overhead of a high-efficiency distillation column (theoretical plates >20) when the two compositions x/2 wt% and (100 – x)/2 wt% are distilled separately

Azeotropic blends exhibit some segregation of components at other conditions. The blend must not deviate substantially from azeotropic behavior at conditions away from the azeotropic temperature and pressure as evidenced by a temperature glide less than 0.9°F (0.5°C) over the temperature range $T_{NBP} < T < (0.95T_{crit})$. This requirement shall be met by either experimental evidence or a computer simulation of phase equilibrium behavior, provided that the computer model has been verified by experimental data.

The following additional information shall be provided for azeotropes:

a. Azeotropic temperature
b. Formulation at the azeotropic temperature
c. Relative molar mass as formulated
d. Relative molar mass of the saturated vapor at 140°F (60°C)
e. Normal boiling-point temperature (bubble-point temperature) at 14.7 psia (101 kPa) as formulated
f. Normal dew-point temperature at 14.7 psia (101 kPa) as formulated
g. Maximum temperature glide at the normal boiling point and at 68°F (20°C)
h. Saturation vapor pressure at 68°F and 140°F (20°C and 60°C) as formulated
i. A vapor-liquid equilibrium diagram plotting either temperature versus composition at constant pressure or pressure versus composition at constant temperature
j. Latent heat of vaporization at 140°F (60°C)
k. Specific heat ratio of the vapor at 140°F (60°C)
l. Temperature at the critical point
m. Pressure at the critical point
n. Specific volume at the critical point
o. Uses and typical application temperatures (i.e., evaporating and condensing ranges)
p. Proposed composition tolerances for classification
q. Worst case of formulation for flammability (WCF) of the blend
r. Worst case of fractionation for flammability (WCFF) of the blend

9.5.2.3 Zeotropic Blends. The following additional information shall be provided for zeotropes (including near azeotropes):

a. Formulation
b. Relative molar mass as formulated
c. Relative molar mass of the vapor at 140°F (60°C)
d. Bubble-point temperature at 14.7 psia (101 kPa)
e. Dew-point temperature at 14.7 psia (101 kPa)
f. Maximum temperature glide at the normal boiling point and at 68°F (20°C)
g. Latent heat of vaporization at 140°F (60°C)
h. Specific heat ratio of the vapor at 140°F (60°C)
i. Temperature at the critical point
j. Pressure at the critical point
k. Specific volume at the critical point
l. Uses and typical application temperatures (i.e., evaporating and condensing ranges)
m. Proposed composition tolerances for classification
n. Worst case of formulation for flammability (WCF) of the blend
o. Worst case of fractionation for flammability (WCFF) of the blend

9.5.2.4 Refrigerants with Low Critical Temperatures. If the critical temperature is less than a temperature at which data are required in Sections 9.5.2.1, 9.5.2.2, and 9.5.2.3, substitute as follows:

a. For data requirements at 68°F (20°C), provide the required data at the normal boiling point or 32°F (0°C), whichever is higher. For pressure data, also provide the superheated vapor pressure at 68°F (20°C) and the critical density.
b. For data requirements at 140°F (60°C), provide the required data at a temperature calculated as the normal boiling point plus 80% of the difference between the critical temperature and the normal boiling point. For pressure data, also provide the superheated vapor pressure at 140°F (60°C) and the critical density.
c. Indicate the applicable temperature, or temperature and critical density, at which the substitute data are provided.

9.5.2.5 Critical Point for Blends. For refrigerant blends, in the absence of experimental data, the critical temperature, pressure, and specific volume shall be calculated as the weighted average by mole fractions of the critical temperatures, pressures, and specific volumes, respectively, of the blend components in the as-formulated composition.

9.6 Toxicity Information. Applications shall include the data identified in Sections 9.6.1 and 9.6.2. The sources for these data shall be identified, and the applicant shall provide copies if requested by the committee. The identified sources shall describe the test methods, specimens, and materials used and also document clinical observations and the test results. The documentation must indicate the extent of compliance with good laboratory practices regulations in accordance with Reference 19, 20, 21, or 22 or earlier editions of these references in effect at the time when the studies were conducted. Data from peer-reviewed publications, including journal articles, reports, and assessments, also are allowed. Safety data sheets (SDSs), hygiene standard sheets, manufacturers' product literature, and databases are not acceptable as sources for toxicity information for this section.

9.6.1 Acute Toxicity. Applications shall include the following short-term toxicity data, with identified sources, for single-compound refrigerants or for each component of blends, and, if available, the blend:

a. ACGIH TLV-C if assigned
b. ACGIH TLV-STEL if assigned
c. NIOSH IDLH if assigned
d. LC_{50} for four hours for rats
e. LD_{50} if available
f. Cardiac sensitization response level
g. Anesthetic and central nervous system effects
h. Other escape impairing effects and permanent injury

9.6.2 Chronic Toxicity. For single-compound refrigerants, or for each component of blends and for the blend itself, applications shall include the following with identified sources:

a. Repeat exposure toxicity data if available
b. ACGIH TLV-TWA or TLV-C if assigned
c. TERA OARS-WEEL if assigned
d. OSHA PEL if assigned; otherwise, a recommended exposure value, determined on a consistent basis, with an explanation of how it was determined

9.7 Flammability Information. Applications for single-compound refrigerants and refrigerant blends shall include flammability test data and information identified in Normative Appendix B, Section B1.9. Applications for refrigerant blends shall also include tabulated fractionation data and information identified in Normative Appendix B, Section B2.6. See Section 9.1.6 regarding blend components.

9.7.1 Fractionation Analysis. Applications shall include an analysis of fractionation and shall include test results determined in accordance with Normative Appendix B, Section B2.

9.7.2 Burning Velocity Information (optional). Applications seeking an assignment of Class 2L shall include the following:

a. A full description of the test method employed
b. Results of standards testing with the specified test approach to ensure agreement with accepted values:
    1. Burning velocity for R-32 (acceptable range is 6.7 ± 0.7 cm/s) and burning velocity for R-152a (acceptable range is 23.0 ± 2.3 cm/s)
    2. Other evidence supporting the accuracy of the method against accepted burning velocity values for other Class 2L and Class 2 refrigerants above and below 10 cm/s
c. Duplicate test results from the LFL to at least 125% of the stoichiometric concentration

9.8 Contaminants and Impurities. Identify contaminants and impurities, including isomeric and decomposition impurities, from manufacturing, transport, and storage known to increase the flammability or toxicity within the precision of the RCL. Also identify limits for those impurities.

9.9 Submission

9.9.1 Language. Applications shall be submitted in English.

9.9.2 Units. Applications shall be submitted either in SI (metric) units or in dual units (SI and inch-pound [I-P]). Refrigerant designation data for Section 9.5.2 shall be submitted in both SI and I-P units.

9.9.3 Electronic Formats. Required information and evidence shall be submitted in PDF or word-searchable electronic format.

9.9.4 Quantity. A PDF or word-searchable electronic file shall be provided to the ASHRAE Senior Manager of Standards. A scanned PDF file is acceptable for figures and other inserts.

9.9.5 Recipient. Submit applications by email to standards.section@ashrae.org with attention to the ASHRAE Senior Manager of Standards.

9.9.6 Elaborate Applications. Elaborate proposals containing brochures on the applicant, performance data, and other material not needed for committee deliberations are discouraged.

9.9.7 Substantiation. Copies of data sources referenced in applications shall be submitted for committee use upon request by the Senior Manager of Standards. These copies shall include the complete documents or pertinent chapters to enable verification of methods and limitations.

10. NORMATIVE REFERENCES

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14. J.M. Calm. 1989. Composition designations for refrigerants. *ASHRAE Journal* 31(11):48–51.
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22. *GLP for Industrial Chemicals*, Kikyoku [Basic Industries Bureau] Dispatch 85, Ministry of International Trade and Industry (MITI), and Kanpogyo [Planning and Coordination Bureau] Dispatch 39, Environmental Agency, Tokyo, Japan, 31 March 1984.

This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

INFORMATIVE APPENDIX A
ISOMER DESIGNATION EXAMPLES

Table A-1 illustrates the designation of isomers for the ethane series with three isomers of dichlorotrifluoroethane. Table A-2 illustrates the designation of isomers for the propane series with nine isomers of dichloropentafluoropropane. Table A-3 illustrates the designation of isomers for the propene series with seven isomers for tetrafluoropropene.

The configuration of atoms around the double bond is specified by using “E” or “Z” organic nomenclature rules. The letters “E” or “Z” are appended at the end of the refrigerant number to show the precedence of the atoms or groups that are attached to the carbon atoms at either end of the double bond. “E,” for *Entgegen*, is similar to *trans*, where priority atoms or groups are across the double bond from each other. “Z,” for *Zusammen*, is similar to *cis*, signifying that priority atoms or groups are on the same side of a double bond. Priority order of atoms connected to either of the unsaturated carbons is determined by standard Cahn-Ingold-Prelog (CIP) rules of organic nomenclature. In essence, attached atoms of higher atomic number have higher priority. Therefore, in order of priority, I > Br > Cl > F > O > C > H. In case of a priority tie, the next attached atoms or substituents on the next attached carbon atom are considered until a priority is determined. In the case of refrigerants, it is more exact and less cumbersome to use atomic mass rather than atomic numbers of the atoms. This is because the sum of the atomic numbers of substituents on CHF_2 and CHCl are the same, while the summed atomic masses do differentiate. These nomenclature rules can be reviewed in many organic chemistry textbooks, at the website of the International Union of Pure and Applied Chemistry (IUPAC) [7], or at the following Wikipedia pages:

en.wikipedia.org/wiki/Sequence_rule
en.wikipedia.org/wiki/Cahn-Ingold-Prelog_priority_rule

Also, the software that IUPAC recommends for naming is described at the IUPAC-approved ACD/ChemSketch website www.acdlabs.com/resources/freeware/chemsketch, as noted at the IUPAC website old.iupac.org/nomenclature.

Table A-1 Ethane Series Isomers

Isomer	Chemical Formula	Attached Mass		
		W_1	W_2	$\|W_1 - W_2\|$
R-123	$CHCl_2CF_3$	71.9	57.0	14.9
R-123a	$CHClFCClF_2$	55.5	73.4	17.9
R-123b	CCl_2FCHF_2	89.9	39.0	50.9g

where
W_i = the sum of the atomic mass of halogens and hydrogens attached to carbon atom *i*

Table A-2 Propane Series Isomers

Isomer	Chemical Formula	C2 Group	Attached Mass		
			W_1	W_3	$\|W_1 - W_3\|$
R-225aa	$CF_3CCl_2CHF_2$	CCl_2	57.0	39.0	18.0
R-225ba	$CHClFCClFCF_3$	CClF	55.5	57.0	1.5
R-225bb	$CClF_2CClFCHF_2$	CClF	73.4	39.0	34.4
R-225ca	$CHCl_2CF_2CF_3$	CF_2	71.9	57.0	14.9
R-225cb	$CHClFCF_2CClF_2$	CF_2	55.5	73.4	17.9
R-225cc	$CCl_2FCF_2CHF_2$	CF_2	89.9	39.0	50.9

Table A-2 Propane Series Isomers *(Continued)*

Isomer	Chemical Formula	C2 Group	Attached Mass		
			W_1	W_3	$\lvert W_1 - W_3 \rvert$
R-225da	$CClF_2CHClCF_3$	CHCl	73.4	57.0	16.4
R-225ea	$CClF_2CHFCClF_2$	CHF	73.4	73.4	0.0
R-225eb	$CCl_2FCHFCF_3$	CHF	89.9	57.0	32.9

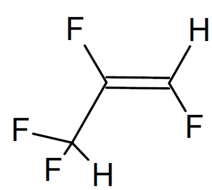
where
C2 = the central (second) carbon atom and
W_i = the sum of the atomic mass of halogens and hydrogens attached to carbon atom *i*

Table A-3 Propene Series Isomers

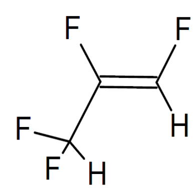
Isomer	Chemical Formula	Stereoisomer	
		IUPAC*	ACS*
R-1234yc	$CH_2F\text{-}CF{=}CF_2$		
R-1234zc	$CHF_2\text{-}CH{=}CF_2$		
R-1234ye(E)	$CHF_2\text{-}CF{=}CHF$	Entgegen	Trans
R-1234ye(Z)	$CHF_2\text{-}CF{=}CHF$	Zusammen	Cis
R-1234ze(E)	$CF_3\text{-}CH{=}CHF$	Entgegen	Trans
R-1234ze(Z)	$CF_3\text{-}CH{=}CHF$	Zusammen	Cis
R-1234yf	$CF_3\text{-}CF{=}CH_2$		

* IUPAC = International Union of Pure and Applied Chemistry; ACS = American Chemical Society

Examples of Stereoisomers:



1(E)-1,2,3,3-tetrafluoro-1-propene, or HFO-1234ye(E)



1(Z)-1,2,3,3-tetrafluoro-1-propene or HFO-1234ye(Z)

A1. FOUR-CARBON EXAMPLE: HFC-365mfc $CF_3\text{-}CH_2\text{-}CF_2\text{-}CH_3$

The CF_3 end has priority—it has the greatest summed mole weight of substituted atoms. Per Section 4.1.12, this terminal CF_3 indicates the first suffix shall be *m*. The next carbon is CH_2, so per Section 4.1.10, the second suffix is *f*. The third carbon is CF_2, so again per Section 4.1.10, the third suffix is *c*. At this point all of the substituted atoms have been accounted for, so no other letters are necessary.

(This appendix is a normative appendix and is part of this standard.)

NORMATIVE APPENDIX B
DETAILS OF TESTING—FLAMMABILITY

B1. FLAMMABILITY TESTING

Flammability tests shall be conducted in accordance with ASTM E681 [15]. For classification of Class 2L, Class 2, or Class 1 materials, testing shall be in a nominal 0.424 ft^3 (12 L) spherical glass flask (see Figure B-1). The ignition source shall be a spark from a transformer secondary rated at 15 kV and 30 mA alternating current (A/C) as described in ASTM E681, with a 0.4 second spark duration. The electrodes shall be 0.04 in. (1 mm) diameter L-shaped tungsten wire electrodes that are spaced 0.25 in. (6.4 mm) apart and that extend out of the plane of the electrode holder (see spark assembly diagram in Figure B-2 for more details). The ignition source shall be placed at a height from the bottom of the test vessel that is one-third the diameter of the vessel. Tests shall be conducted at the temperatures specified in Section B1.1 and at 1% by volume (refrigerant/air) increments. The absolute humidity of the air used for mixing shall be 0.0088 g of water vapor per gram of dry air (which equates to 50% rh at 73.4°F [23.0°C] and 14.7 psia [101.3 kPa]).

CAUTION: Flammability test procedures specified in this standard are modified procedures of an ASTM test that uses a glass flask as a test vessel. Extreme caution should be employed by test facilities to safeguard against personal injury and equipment damage. Vessels are subject to explosion during test. Combustion of refrigerants may produce highly toxic or corrosive byproducts. Testing facilities should consult safety precautions cited in the ASTM test standard along with state and federal regulations.

B1.1 Test Conditions

a. For single-compound refrigerants, flammability tests shall be conducted at 140°F (60°C) and 14.7 psia (101.3 kPa). Testing shall be conducted up to and including the point at which flame propagation is demonstrated. If no flame propagation is apparent, testing shall be conducted until at least three consecutive concentration increments have been made beyond the stoichiometric composition and beyond the point that combustion around the spark has diminished.

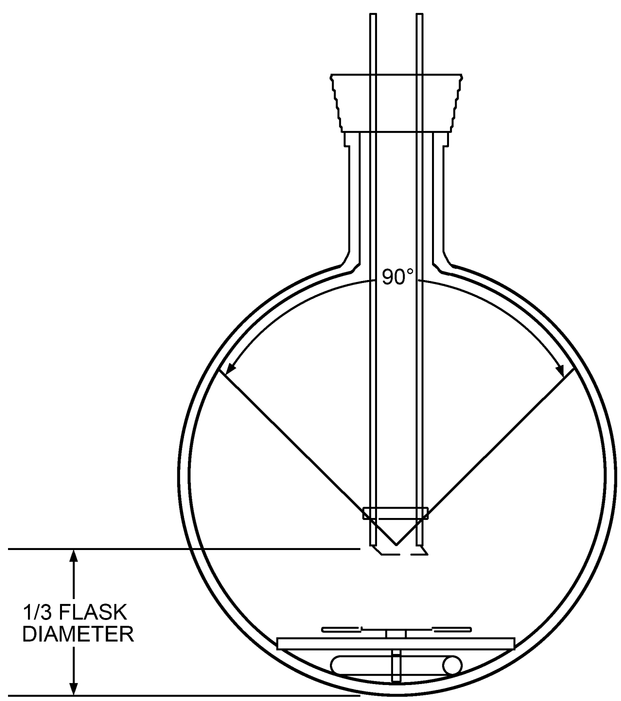


Figure B-1 Test apparatus.

a. Test vessel is a 0.424 ft^3 (12 L) spherical glass flask.
b. Ignition source electrodes are positioned at a height from the bottom of the vessel that is equal to 1/3 of the diameter of the vessel.
c. The substended arc represents $\pi/2$ (90 degrees) fan for determining flame propagation.
d. A stirrer shall be installed in the flask to ensure mixing of vapors prior to ignition.

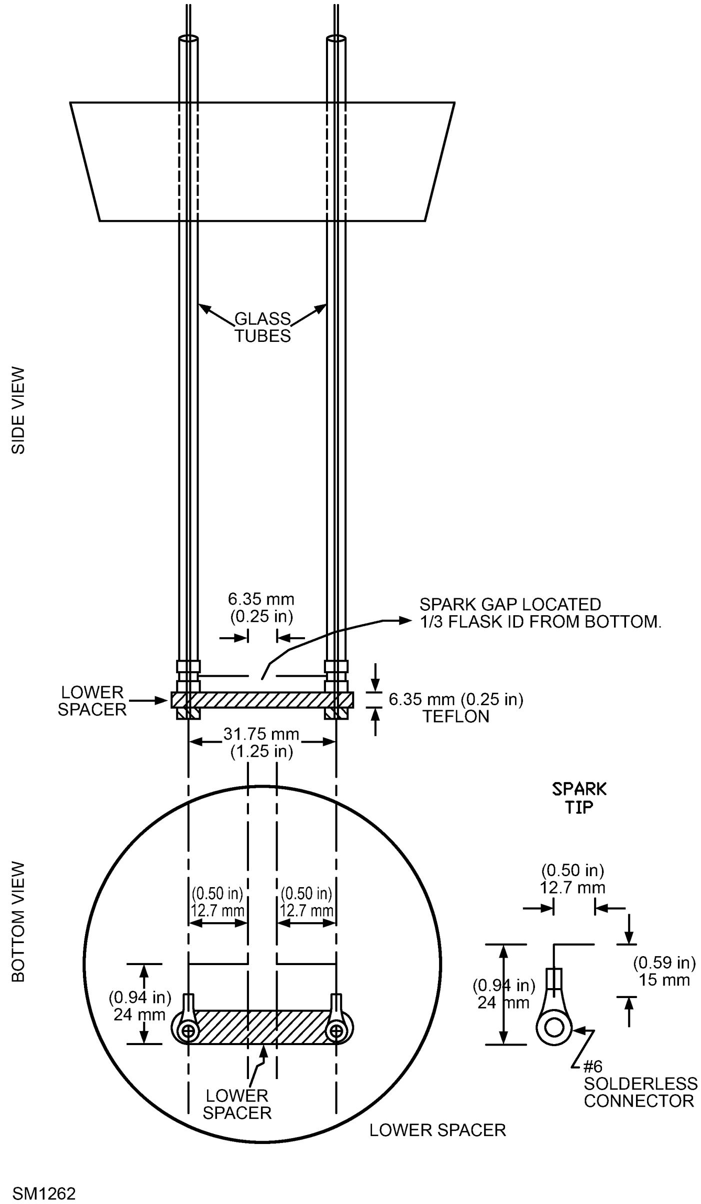


Figure B-2 Spark electrodes.

b. For refrigerant blends, flammability tests shall be conducted on the worst case of formulation for flammability (WCF) at 140°F (60°C) and 14.7 psia (101.3 kPa) and also shall be conducted on the worst case of fractionation for flammability (WCFF) at 140°F (60.0°C) and 14.7 psia (101.3 kPa). The WCFF shall be determined by the method specified in Section B2. When application of the composition tolerances to the nominal formulation produces several possible WCFF formulations, the applicant shall conduct flammability testing on all possible WCFF formulations or provide sufficient justification for eliminating one or more of the possible WCFF formulations.

c. For those refrigerants that show flame propagation in accordance with step (a) or (b), flammability testing shall also be conducted at 73.4°F (23.0°C) and 14.7 psia (101.3 kPa) to determine the lower flammability limit (LFL). The LFL normally is expressed as refrigerant percentage by volume percent; multiply this by 0.00041 × relative molar mass (g·mol) to obtain kg/m^3, or by 0.000026 × relative molar mass (g·mol) to obtain lb/ft^3. For refrigerant blends, these tests shall be conducted on the WCF and the WCFF.

B1.2 When a refrigerant blend containing one or more flammable components is being examined, testing shall be conducted up to and including the point at which flame propagation is demonstrated. If no flame propagation is apparent, testing shall be conducted until at least three consecutive concentration increments have been made beyond the stoichiometric composition and beyond the point that combustion around the spark has diminished.

B1.3 When the $ETFL_{60}$ of the flammable components is known, testing for the $ETFL_{60}$ or the LFL shall begin at 1%, by volume, lower than the lowest $ETFL_{60}$. When the $ETFL_{60}$ is not known, testing shall begin at 1% refrigerant by volume. If the test of the initial concentration results in a flame propagation, then subsequent testing concentrations shall be reduced in 1% volume increments until the appropriate flame limit is determined.

B1.4 The mass percent formulation of the tested blend shall be verified through gas chromatography to a tolerance of ±0.5 mass percent or one-fourth of the composition tolerance range, whichever is smaller.

B1.5 Samples shall be introduced into the flammability test apparatus in the vapor phase in accordance with ASTM E681. Liquid samples of the refrigerant or blend composition to be tested shall be expanded into a suitable evacuated container such that only vapor under pressure is present. The vapors shall be introduced into the flammability test apparatus. Air shall then be added to the test apparatus. Measurement of the refrigerant-to-air concentration shall be by partial pressures. The refrigerant and air shall be mixed in the chamber for at least two minutes. Activation of the ignition source shall commence within 30 to 60 seconds of stirrer deactivation.

B1.6 If flame propagation is observed while the spark is still active (i.e., the spark is overdriving the test vessel), then the test shall be repeated using a spark duration of less than 0.4 seconds but at least 0.2 seconds.

B1.7 All flammability tests shall be recorded using a video recorder. A playback device capable of freeze frame and single-frame advance shall be available during testing. A copy of the video recordings shall be submitted upon request of the committee.

B1.8 Criterion for Determining Flame Propagation. A refrigerant-air concentration shall be considered flammable for flammability classification under this standard only if a flame propagation occurs in at least two of three flammability tests on that refrigerant-air concentration. A flame propagation is any combustion that, having moved upward and outward from the point of ignition to the walls of the flask, is continuous along an arc that is greater than that subtended by an angle equal to 90 degrees, as measured from the point of ignition to the walls of the flask (see Figure B-1).

B1.9 Flammability Test Data Required. Applications shall include test results determined in accordance with Section B1. Test conditions shall be controlled to the tolerances cited below. Applications shall include tabulated flammability test data for each refrigerant or refrigerant blend composition tested. These data shall include but are not limited to the following:

a. Refrigerant blend composition tested: ±0.1 mass percent
b. Flammability test temperature: ±5°F (3°C)
c. Fractionation or leak test temperature: ±0.2°F (0.1°C)
d. Test pressure: ±0.1 psi (0.7 kPa)
e. Humidity: ±0.0005 g of water vapor per gram of dry air
f. Refrigerant/air concentration: ±0.2% by volume
g. Spark duration: ±0.05 seconds
h. Flame propagation determination as measured from the point of ignition to the walls of the flask: ±5.0 degrees

B2. FRACTIONATION ANALYSIS

Applications shall include an analysis of fractionation.

B2.1 The applicant shall report results of a fractionation analysis made to determine vapor-phase and liquid-phase compositions of refrigerant blends under conditions of leakage (see Section B2.3) and successive charge/recharge conditions (see Section B2.4). The analysis shall be validated through experimentation. A computer or mathematical model may be used to identify the WCFF. If a computer or mathematical model is used, then the applicant shall identify the model used and shall submit experimental data that verify the accuracy of the model at the conditions that predict the WCFF.

B2.1.1 Experimental Verification. Experimental verification of the model shall take the form of leakage experiments (carried out in accordance with Section B2.3) that result in the WCFF. For blends of three or fewer components where the initial composition of the vapor or liquid phase results in the WCFF, this verification may instead be experimental vapor liquid equilibrium data at the temperature of the WCFF or over a range of temperatures that includes the temperature of the WCFF; such experiments may be carried out by the applicant or be taken from the peer-reviewed literature.

B2.2 All fractionation analysis shall begin using the WCF. When application of the composition tolerances to the nominal formulation produces several possible WCF formulations, the applicant shall investigate all possible WCF formulations or provide sufficient justification for eliminating one or more of the possible WCF formulations.

B2.3 The mass percent formulation of the tested blend shall be verified through gas chromatography to a tolerance of ±0.5 mass percent or one-fourth of the composition tolerance, whichever is smaller.

B2.4 Leakage Testing. Refrigerant blends containing flammable components shall be evaluated to determine their WCFF formulations during storage/shipping or use. Experimental tests or computer/mathematical modeling shall be conducted to simulate leaks from

a. a container under storage/shipping conditions and
b. a container representing air-conditioning and refrigeration equipment during normal operation, standby, and shipping conditions.

Informative Note: The container used for these tests shall be rated to handle the vapor pressure of the formulation at the highest temperature encountered.

B2.4.1 Leaks Under Storage/Shipping Conditions. To simulate leaks under storage/shipping conditions, the container shall be filled with the WCF to 90%, by mass, of the maximum fill. The maximum fill for fluids having a critical temperature greater than 130°F (54.4°C) is the calculated mass that gives a 100% liquid fill at 130°F (54.4°C). The maximum fill for fluids whose critical temperature is lower than 130°F (54.4°C) is the calculated mass that gives 100% liquid fill at temperature $T = T_b + 0.8(T_c - T_b)$, where T_b is the bubble-point temperature at atmospheric pressure (101.3 kPa) and T_c is the fluid critical temperature. The charged blend shall be vapor leaked, 2% by mass of the initial charge per hour, at the following temperatures:

a. 130°F (54.4°C)
b. –40.0°F (–40.0°C) or the bubble point at 14.7 psia (101.3 kPa) plus 18.0°F (10.0°C), whichever is warmer
c. The temperature that results in the WCFF between (a) and (b) if the WCFF does not exist at either (a) or (b). If no temperature between (a) and (b) results in the WCFF, then the fractionation test shall instead be conducted at 73.4°F (23.0°C). The applicant shall justify and document what constitutes the temperature at which the WCFF formulation occurs.

In the fractionation experiment, the composition of the head space gas and remaining liquid shall be determined by analysis. Analyses shall be made initially after 2% of the total charge has leaked (vapor leak), next at 10% loss of the initial mass, then at 10% mass loss intervals of the initial mass until atmospheric pressure is reached in the cylinder or no liquid remains. If liquid remains after 90% of the initial mass is lost, and atmospheric pressure has not been reached, then the next and last analysis of head space gas and remaining liquid shall be made at 95% mass loss.

B2.4.2 Leaks from Equipment. To simulate leaks from equipment, the container shall be filled with the WCF to 15% of the maximum fill (as defined in Section B2.4.1) and then shall be vapor leaked at the following temperatures:

a. 140°F (60.0°C)
b. –40.0°F (–40.0°C) or the bubble point at 14.7 psia (101.3 kPa) plus 18.0°F (10.0°C), whichever is warmer
c. The temperature that results in the WCFF between (a) and (b) if the WCFF does not exist at either (a) or (b). If no temperature between (a) and (b) results in the WCFF, then the fractionation test shall instead be conducted at 73.4°F (23.0°C). The applicant shall justify and document what constitutes the temperature at which the WCFF formulation occurs.

In the fractionation experiment, the composition of the head space gas and remaining liquid shall be determined by analysis. Analyses shall be made initially after 2% of the total charge has leaked, next at 10% loss of the initial mass, then at 10% mass loss intervals of the initial mass until atmospheric pressure is reached in the cylinder or no liquid remains. If liquid remains after 90% of the initial mass is lost, and atmospheric pressure has not been reached, then the next and last analysis of head space gas and remaining liquid shall be made at 95% mass loss.

B2.5 Leak/Recharge Testing. Refrigerant blends containing flammable components shall be evaluated to determine the fractionation effects of successive leakage and recharging on the composition of the blend. A container shall be charged to 15% of the maximum fill (as defined in Section B2.4.1) with the WCF formulation of the refrigerant blend. A vapor leak at a rate of 2% by mass of the starting charge per hour shall be created and maintained at 73.4°F ± 5.4°F (23.0°C ± 3.0°C) until 20% of the starting charge has been leaked. When 20% leak is reached, the composition of the head space gas shall be determined by analysis. The container shall again be charged with the WCF to 15% of the maximum fill (as defined in Section B2.4.1), leaked, and measured in the above defined manner. The charge/leak cycle shall be conducted a total of five times. At the conclusion of the fifth leakage, the composition of the head space gas and liquid shall again be determined by gas chromatography.

B2.6 Fractionation Analysis Data Required. The applicant shall submit the following for each fractionation scenario:

a. Fractionation or leak test temperature (±0.2°F [±0.1°C])
b. Tabulated liquid and vapor compositions at each leaked increment (±0.1 mass percent)
c. For modeled analysis, model accuracy at conditions that predict the WCFF formulation

The applicant shall also provide a description of test apparatus and procedures used. If the applicant uses a computer or mathematical model for determining the WCFF, the applicant shall identify the model used and submit supporting data verifying the accuracy of the model against experimental measurements at conditions that predict the WCFF.

(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

INFORMATIVE APPENDIX C
INFORMATIVE REFERENCES AND BIBLIOGRAPHY

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(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

INFORMATIVE APPENDIX D
REFRIGERANT DATA

This appendix provides refrigerant data such as relative molar mass and normal boiling point for the refrigerants listed. It also provides bubble points and dew points for zeotropic blends.

Table D-1 Refrigerant Data

Refrigerant Number	Chemical Name[a]	Chemical Formula	Relative Molar Mass	Normal Boiling Point °F	Normal Boiling Point °C
Methane Series					
11	trichlorofluoromethane	CCl_3F	137.4	75	24
12	dichlorodifluoromethane	CCl_2F_2	120.9	–22	–30
12B1	bromochlorodifluoromethane	$CBrClF_2$	165.4	25	–4
13	chlorotrifluoromethane	$CClF_3$	104.5	–115	–81
13B1	bromotrifluoromethane	$CBrF_3$	148.9	–72	–58
13I1	trifluoroiodomethane	CF_3I	195.9	–7.4	–21.9
14	tetrafluoromethane (carbon tetrafluoride)	CF_4	88.0	–198	–128
21	dichlorofluoromethane	$CHCl_2F$	102.9	48	9
22	chlorodifluoromethane	$CHClF_2$	86.5	–41	–41
23	trifluoromethane	CHF_3	70.0	–116	–82
30	dichloromethane (methylene chloride)	CH_2Cl_2	84.9	104	40
31	chlorofluoromethane	CH_2ClF	68.5	16	–9
32	difluoromethane (methylene fluoride)	CH_2F_2	52.0	–62	–52
40	chloromethane (methyl chloride)	CH_3Cl	50.5	–12	–24
41	fluoromethane (methyl fluoride)	CH_3F	34.0	–108	–78
50	methane	CH_4	16.0	–259	–161
Ethane Series					
113	1,1,2-trichloro-1,2,2-trifluoroethane	$CC1_2FCC1F_2$	187.4	118	48

a. The preferred chemical name is followed by the popular name in parentheses.

Table D-1 Refrigerant Data *(Continued)*

Refrigerant Number	Chemical Name[a]	Chemical Formula	Relative Molar Mass	Normal Boiling Point	
				°F	°C
Ethane Series (*continued*)					
114	1,2-dichloro-1,1,2,2-tetrafluoroethane	$CC1F_2CC1F_2$	170.9	38	4
115	chloropentafluoroethane	$CC1F_2CF_3$	154.5	–38	–39
116	hexafluoroethane	CF_3CF_3	138.0	–109	–78
123	2,2-dichloro-1,1,1-trifluoroethane	$CHC1_2CF_3$	153.0	81	27
124	2-chloro-1,1,1,2-tetrafluoroethane	$CHC1FCF_3$	136.5	10	–12
125	pentafluoroethane	CHF_2CF_3	120.0	–56	–49
134a	1,1,1,2-tetrafluoroethane	CH_2FCF_3	102.0	–15	–26
141b	1,1-dichloro-1-fluoroethane	CH_3CC1_2F	117.0	90	32
142b	1-chloro-1,1-difluoroethane	CH_3CC1F_2	100.5	14	–10
143a	1,1,1-trifluoroethane	CH_3CF_3	84.0	–53	–47
152a	1,1-difluoroethane	CH_3CHF_2	66.0	–11	–24
170	ethane	CH_3CH_3	30.0	–128	–89
Ethers					
E170	dimethyl ether	CH_3OCH_3	46.1	–13	–25
Propane Series					
218	octafluoropropane	$CF_3CF_2CF_3$	188.0	–35	–37
227ea	1,1,1,2,3,3,3-heptafluoropropane	CF_3CHFCF_3	170.0	3.9	–15.6
236fa	1,1,1,3,3,3-hexafluoropropane	$CF_3CH_2CF_3$	152.0	29	–1
245fa	1,1,1-3,3-pentafluoropropane	$CF_3CH_2CHF_2$	134.0	59	15
290	propane	$CH_3CH_2CH_3$	44.0	–44	–42
Cyclic Organic Compounds					
C318	octafluorocyclobutane	$\text{-}(CF_2)_4\text{-}$	200.0	21	–6
Miscellaneous Organic Compounds					
hydrocarbons					
600	butane	$CH_3CH_2CH_2CH_3$	58.1	31	0

a. The preferred chemical name is followed by the popular name in parentheses.

Table D-1 Refrigerant Data *(Continued)*

Refrigerant Number	Chemical Name[a]	Chemical Formula	Relative Molar Mass	Normal Boiling Point °F	Normal Boiling Point °C
Miscellaneous Organic Compounds (*continued*)					
600a	isobutane	$CH(CH_3)_2CH_3$	58.1	11	–12
601	pentane	$CH_3CH_2CH_2CH_2CH_3$	72.1	97.0	36.1
oxygen compounds					
610	ethyl ether	$CH_3CH_2OCH_2CH_3$	74.1	94	35
611	methyl formate	$HCOOCH_3$	60.0	89	32
sulfur compounds					
620	(Reserved for future assignment)				
Nitrogen Compounds					
630	methylamine	CH_3NH_2	31.1	20	–7
631	ethyl amine	$CH_3CH_2(NH_2)$	45.1	62	17
Inorganic Compounds					
702	hydrogen	H_2	2.0	–423	–253
704	helium	He	4.0	–452	–269
717	ammonia	NH_3	17.0	–28	–33
718	water	H_2O	18.0	212	100
720	neon	Ne	20.2	–411	–246
728	nitrogen	N_2	28.1	–320	–196
732	oxygen	O_2	32.0	–297	–183
740	argon	Ar	39.9	–303	–186
744	carbon dioxide	CO_2	44.0	–109	–78
744A	nitrous oxide	N_2O	44.0	–129	–90
764	sulfur dioxide	SO_2	64.1	14	–10
Unsaturated Organic Compounds					
1130(E)	trans-1,2-dichloroethene	CHCl=CHCl	96.9	117.9	47.7
1132a	1,1-difluoroethene	$CF_2 = CH_2$	64.0	–117	–83

a. The preferred chemical name is followed by the popular name in parentheses.

Table D-1 Refrigerant Data *(Continued)*

Refrigerant Number	Chemical Name[a]	Chemical Formula	Relative Molar Mass	Normal Boiling Point °F	Normal Boiling Point °C
Unsaturated Organic Compounds (*continued*)					
1132(E)	trans-1,2-difluoroethene	(E)-CFH=CFH	64.0	–62.5	–52.5
1150	ethene (ethylene)	CH_2=CH_2	28.1	–155	–104
1224yd(Z)	cis-1-chloro-2,3,3,3-tetrafluoro-1-propene	CF_3CF=CHCl	148.5	58.1	14.5
1233zd(E)	trans-1-chloro-3,3,3-trifluoro-1-propene	CF_3CH=CHCl	130.5	64.6	18.1
1234yf	2,3,3,3-tetrafluoro-1-propene	CF_3CF=CH_2	114.0	–20.9	–29.4
1234ze(E)	trans-1,3,3,3-tetrafluoro-1-propene	CF_3CH=CFH	114.0	–2.2	–19.0
1270	propene (propylene)	CH_3CH=CH_2	42.1	–54	–48
1336mzz(E)	trans-1,1,1,4,4,4-hexafluoro-2-butene	CF_3CH=CHCF_3	164.1	45.3	7.4
1336mzz(Z)	cis-1,1,1,4,4,4-hexaflouro-2-butene	CF_3CHCHCF_3	164.1	91.4	33.4

a. The preferred chemical name is followed by the popular name in parentheses.

Table D-2 Data for Refrigerant Blends

Refrigerant Numbers	Composition (mass %) [a]	Average Relative Molar Mass	Bubble Point, °F	Dew Point, °F	Bubble Point, °C	Dew Point, °C
Zeotropes						
400	R-12/114 (must be specified)					
	(50.0/50.0)					
	(60.0/40.0)					
401A	R-22/152a/124 (53/13/34)	94.4	–29.9	–19.8	–34.4	–28.8
401B	R-22/152a/124 (61/11/28)	92.8	–32.3	–23.4	–35.7	–30.8
401C	R-22/152a/124 (33/15/52)	101.0	–22.9	–10.8	–30.5	–23.8
402A	R-125/290/22 (60/2/38)	101.6	–56.6	–52.6	–49.2	–47.0
402B	R-125/290/22 (38/2/60)	94.7	–53.0	–48.8	–47.2	–44.9
403A	R-290/22/218 (5/75/20)	92.0	–47.2	–44.1	–44.0	–42.3
403B	R-290/22/218 (5/56/39)	103.3	–46.8	–44.1	–43.8	–42.3
404A	R-125/143a/134a (44/52/4)	97.6	–51.9	–50.4	–46.6	–45.8
405A	R-22/152a/142b/C318 (45/7/5.5/42.5)	111.9	–27.2	–12.1	–32.9	–24.5
406A	R-22/600a/142b (55/4/41)	89.9	–26.9	–10.3	–32.7	–23.5
407A	R-32/125/134a (20/40/40)	90.1	–49.4	–37.7	–45.2	–38.7
407B	R-32/125/134a (10/70/20)	102.9	–52.2	–44.3	–46.8	–42.4
407C	R-32/125/134a (23/25/52)	86.2	–46.8	–34.1	–43.8	–36.7
407D	R-32/125/134a (15/15/70)	91.0	–38.9	–26.9	–39.4	–32.7
407E	R-32/125/134a (25/15/60)	83.8	–45.0	–32.1	–42.8	–35.6
407F	R-32/125/134a (30.0/30.0/40.0)	82.1	–51.0	–39.5	–46.1	–39.7
407G	R-32/125/134a (2.5/2.5/95.0)	100.7	–20.6	–17.0	–29.2	–27.2
407H	R-32/125/134a (32.5/15.0/52.5)	79.1	–48.5	–35.7	–44.7	–37.6
407I	R-32/125/134a (19.5/8.5/72.0)	86.9	–39.6	–27.4	–39.8	–33.0
408A	R-125/143a/22 (7/46/47)	87.0	–49.9	–49.0	–45.5	–45.0

a. Composition tolerances can be found in Table 4-2.
b. Azeotropic refrigerants exhibit some segregation of components at conditions of temperature and pressure other than those at which they were formulated. The extent of segregation depends on the particular azeotrope and hardware system configuration.
c. The exact composition of this azeotrope is in question and additional experimental studies are needed.
d. R-507, R-508, and R-509 are allowed alternative designations for R-507A, R-508A, and R-509A due to a change in designations after assignment of R-500 through R-509. Corresponding changes were not made for R-500 through R-506.

Table D-2 Data for Refrigerant Blends *(Continued)*

Refrigerant Numbers	Composition (mass %) [a]	Average Relative Molar Mass	Bubble Point, °F	Dew Point, °F	Bubble Point, °C	Dew Point, °C
Zeotropes (*continued*)						
409A	R-22/124/142b (60/25/15)	97.4	–31.7	–17.5	–35.4	–27.5
409B	R-22/124/142b (65/25/10)	96.7	–33.7	–21.5	–36.5	–29.7
410A	R-32/125 (50/50)	72.6	–60.9	–60.7	–51.6	–51.5
410B	R-32/125 (45/55)	75.6	–60.7	–60.5	–51.5	–51.4
411A	R-1270/22/152a (1.5/87.5/11.0)	82.4	–39.5	–35.0	–39.7	–37.2
411B	R-1270/22/152a (3.0/94.0/3.0)	83.1	–42.9	–42.3	–41.6	–41.3
412A	R-22/218/143b (70/5/25)	92.2	–33.5	–19.8	–36.4	–28.8
413A	R-218/134a/600a (9/88/3)	104.0	–20.7	–17.7	–29.3	–27.6
414A	R-22/124/600a/142b (51/28.5/4/16.5)	96.9	–29.2	–14.4	–34.0	–25.8
414B	R-22/124/600a/142b (50/39/1.5/9.5)	101.6	–29.9	–15.0	–34.4	–26.1
415A	R-22/152a (82.0/18.0)	81.9	–35.5	–30.5	–37.5	–34.7
415B	R-22/152a (25.0/75.0)	70.2	–17.8	–15.2	–27.7	–26.2
416A	R-134a/124/600 (59.0/39.5/1.5)	111.9	–10.1	–7.2	–23.4	–21.8
417A	R-125/134a/600 (46.6/50.0/3.4)	106.7	–36.4	–27.2	–38.0	–32.9
417B	R-125/134a/600 (79.0/18.3/2.7)	113.1	–48.8	–42.7	–44.9	–41.5
417C	R-125/134a/600 (19.5/78.8/1.7)	103.7	–26.9	–20.6	–32.7	–29.2
418A	R-290/22/152a (1.5/96.0/2.5)	84.6	–42.2	–40.2	–41.2	–40.1
419A	R-125/134a/E170 (77.0/19.0/4.0)	109.3	–44.7	–32.8	–42.6	–36.0
419B	R-125/134a/E170 (48.5/48.0/3.5)	105.2	–35.3	–24.7	–37.4	–31.5
420A	R-134a/142b (88.0/12.0)	101.8	–13.0	–11.6	–25.0	–24.2
421A	R-125/134a (58.0/45.0)	111.8	–41.5	–31.9	–40.8	–35.5
421B	R-125/134a (85.0/15.0)	116.9	–50.2	–44.6	–45.7	–42.6
422A	R-125/134a/600a (85.1/11.5/3.4)	113.6	–51.7	–47.4	–46.5	–44.1

a. Composition tolerances can be found in Table 4-2.
b. Azeotropic refrigerants exhibit some segregation of components at conditions of temperature and pressure other than those at which they were formulated. The extent of segregation depends on the particular azeotrope and hardware system configuration.
c. The exact composition of this azeotrope is in question and additional experimental studies are needed.
d. R-507, R-508, and R-509 are allowed alternative designations for R-507A, R-508A, and R-509A due to a change in designations after assignment of R-500 through R-509. Corresponding changes were not made for R-500 through R-506.

Table D-2 Data for Refrigerant Blends *(Continued)*

Refrigerant Numbers	Composition (mass %) [a]	Average Relative Molar Mass	Bubble Point, °F	Dew Point, °F	Bubble Point, °C	Dew Point, °C
Zeotropes (*continued*)						
422B	R-125/134a/600a (55.0/42.0/3.0)	108.5	–40.9	–32.2	–40.5	–35.6
422C	R-125/134a/600a (82.0/15.0/3.0))	116.3	–49.5	–44.2	–45.3	–42.3
422D	R-125/134a/600a (65.1/31.5/3.4)	109.9	–45.8	–37.1	–43.2	–38.4
422E	R-125/134a/600a (58.0/39.3/2.7)	109.3	–43.2	–33.5	–41.8	–36.4
423A	R-134a/227ea (52.5/47.5)	126.0	–11.6	–10.3	–24.2	–23.5
424A	R-125/134a/600a/600/601a (50.5/47.0/0.9/1.0/0.6)	108.4	–38.4	–27.9	–39.1	–33.3
425A	R-32/134a/227ea (18.5/69.5/12.0)	90.3	–36.6	–24.3	–38.1	31.3
426A	R-125/134a/600/601a (5.1/93.0/1.3/0.6)	101.6	–19.3	–16.1	–28.5	–26.7
427A	R-32/125/143a/134a (15.0/25.0/10.0/50.0)	90.4	–45.4	–33.3	–43.0	–36.3
427C	R-32/125/143a/134a (25.0/25.0/10.0/40.0)	83.3	–50.6	–38.9	–45.9	–39.4
428A	R-125/143a/290/600a (77.5/20.0/0.6/1.9)	107.5	–54.9	–53.5	–48.3	–47.5
429A	R-E170/152a/600a (60.0/10.0/30.0)	50.8	–14.8	–14.1	–26.0	–25.6
430A	R-152a/600a (76.0/24.0)	64.0	–17.7	–17.3	–27.6	–27.4
431A	R-290/152a (71.0/29.0)	48.8	–45.6	–45.6	–43.1	–43.1
432A	R-1270/E170 (80.0/20.0)	42.8	–51.9	–50.1	–46.6	–45.6
433A	R-1270/290 (30.0/70.0)	43.5	–48.3	–47.6	–44.6	–44.2
433B	R-1270/290 (5.0/95.0)	44.0	–44.9	–44.5	–42.7	–42.5
433C	R-1270/290 (25.0/75.0)	43.6	–47.7	–47.0	–44.3	–43.9
434A	R-125/143a/134a/600a (63.2/18.0/16.0/2.8)	105.7	–49.0	–44.1	–45.0	–42.3
435A	R-E170/152a (80.0/20.0)	49.04	–15.0	–14.6	–26.1	–25.9
436A	R-290/600a (56.0/44.0)	49.33	–29.7	–15.2	–34.3	–26.2
436B	R-290/600a (52.0/48.0)	49.87	–28.1	–13.0	–33.4	–25.0
436C	R-290/600a (95.0/5.0)	44.60	–42.7	–39.1	–41.5	–39.5

a. Composition tolerances can be found in Table 4-2.
b. Azeotropic refrigerants exhibit some segregation of components at conditions of temperature and pressure other than those at which they were formulated. The extent of segregation depends on the particular azeotrope and hardware system configuration.
c. The exact composition of this azeotrope is in question and additional experimental studies are needed.
d. R-507, R-508, and R-509 are allowed alternative designations for R-507A, R-508A, and R-509A due to a change in designations after assignment of R-500 through R-509. Corresponding changes were not made for R-500 through R-506.

Table D-2 Data for Refrigerant Blends *(Continued)*

Refrigerant Numbers	Composition (mass %) [a]	Average Relative Molar Mass	Bubble Point, °F	Dew Point, °F	Bubble Point, °C	Dew Point, °C
Zeotropes (*continued*)						
437A	R-125/134a/600/601 (19.5/78.5/1.4/0.6)	103.7	–27.2	–20.6	–32.9	–29.2
438A	R-32/125/134a/600/601a (8.5/45.0/44.2/1.7/0.6)	99.1	–45.4	–33.5	–43.0	–36.4
439A	R-32/125/600a (50.0/47.0/3.0)	71.2	–61.6	–61.2	–52.0	–51.8
440A	R-290/134a/152a (0.6/1.6/97.8)	66.2	–13.9	–11.7	–25.5	–24.3
441A	R-170/290/600a/600 (3.1/54.8/6.0/36.1)	48.2	–43.4	–4.7	–41.9	–20.4
442A	R-32/125/134a/152a/227ea (31.0/31.0/30.0/3.0/5.0)	81.77	–51.7	–39.8	–46.5	–39.9
443A	R-1270/290/600a (55.0/40.0/5.0)	43.48	–48.6	–42.2	–44.8	–41.2
444A	R-32/152a/1234ze(E) (12.0/5.0/83.0)	96.7	–29.7	–11.7	–34.3	–24.3
444B	R-32/152a/1234ze(E) (41.5/10.0/48.5)	72.8	–48.3	–30.8	–44.6	–34.9
445A	R-744/134a/1234ze(E) (6.0/9.0/85.0)	103.1	–58.5	–10.3	–50.3	–23.5
446A	R-32/1234ze(E)/600 (68.0/29.0/3.0)	62.0	–56.9	–47.2	–49.4	–44.0
447A	R-32/125/1234ze(E) (68.0/3.5/28.5)	63.0	–56.7	–47.6	–49.3	–44.2
447B	R-32/125/1234ze(E) (68.0/8.0/24.0)	63.0	–58.2	–50.8	–50.1	–46.0
448A	R-32/125/1234yf/134a/1234ze(E) (26.0/26.0/20.0/21.0/7.0)	86.3	–50.6	–39.6	–45.9	–39.8
448B	R-32/125/1234yf/134a/1234ze(E) (21.0/21.0/20.0/31.0/7.0)	89.3	–47.3	–35.1	–44.1	–37.4
449A	R-32/125/1234yf/134a (24.3/24.7/25.3/25.7)	87.2	–50.8	–39.8	–46.0	–39.9
449B	R-32/125/1234yf/134a (25.2/24.3/23.2/27.3)	86.4	–51.0	–40.4	–46.1	–40.2
449C	R-32/125/1234yf/134a (20.0/20.0/31.0/29.0)	90.3	–48.3	–36.6	–44.6	–38.1
450A	R-134a/1234ze(E) (42.0/58.0)	108.7	–10.1	–9.0	–23.4	–22.8
451A	R-1234yf/134a (89.8/10.2)	112.7	–23.4	–22.9	–30.8	–30.5
451B	R-1234yf/134a (88.8/11.2)	112.6	–23.8	–23.1	–31.0	–30.6
452A	R-32/125/1234yf (11.0/59.0/30.0)	103.5	–52.6	–45.8	–47.0	–43.2
452B	R-32/125/1234yf (67.0/7.0/26.0)	63.5	–59.8	–58.5	–51.0	–50.3

a. Composition tolerances can be found in Table 4-2.
b. Azeotropic refrigerants exhibit some segregation of components at conditions of temperature and pressure other than those at which they were formulated. The extent of segregation depends on the particular azeotrope and hardware system configuration.
c. The exact composition of this azeotrope is in question and additional experimental studies are needed.
d. R-507, R-508, and R-509 are allowed alternative designations for R-507A, R-508A, and R-509A due to a change in designations after assignment of R-500 through R-509. Corresponding changes were not made for R-500 through R-506.

Table D-2 Data for Refrigerant Blends *(Continued)*

Refrigerant Numbers	Composition (mass %) [a]	Average Relative Molar Mass	Bubble Point, °F	Dew Point, °F	Bubble Point, °C	Dew Point, °C
Zeotropes (*continued*)						
452C	R-32/125/1234yf (12.5/61.0/26.5)	101.9	–53.5	–47.6	–47.5	–44.2
453A	R-32/125/134a/227ea/600/601a (20.0/20.0/53.8/5.0/0.6/0.6)	88.8	–44.0	–31.0	–42.2	–35.0
454A	R-32/1234yf (35.0/65.0)	80.5	–55.1	–42.9	–48.4	–41.6
454B	R-32/1234yf (68.9/31.1)	62.6	–59.6	–58.0	–50.9	–50.0
454C	R-32/1234yf (21.5/78.5)	90.8	–50.8	–36.0	–46.0	–37.8
455A	R-744/32/1234yf (3.0/21.5/75.5)	87.5	–60.9	–38.4	–51.6	–39.1
456A	R-32/134a/1234ze(E) (6.0/45.0/49.0)	101.4	–22.7	–14.1	–30.4	–25.6
457A	R-32/1234yf/152a (18.0/70.0/12.0)	87.6	–44.9	–31.9	–42.7	–35.5
457B	R-32/1234yf/152a (35.0/55.0/10.0)	76.5	–51.5	–40.7	–46.4	–40.4
457C	R-32/1234yf/152a (7.5/78.0/14.5)	95.4	–35.1	–25.7	–37.3	–32.1
458A	R-32/125/134a/227ea/236fa (20.5/4.0/61.4/13.5/0.6)	89.9	–39.6	–26.3	–39.8	–32.4
459A	R-32/1234yf/1234ze(E) (68.0/26.0/6.0)	63.0	–58.6	–55.5	–50.3	–48.6
459B	R-32/1234yf/1234ze(E) (21.0/69.0/10.0)	91.2	–47.2	–33.0	–44.0	–36.1
460A	R-32/125/134a/1234ze(E) (12.0/52.0/14.0/22.0)	100.6	–48.3	–35.0	–44.6	–37.2
460B	R-32/125/134a/1234ze(E) (28.0/25.0/20.0/27.0)	84.8	–49.4	–34.8	–45.2	–37.1
460C	R-32/125/134a/1234ze(E) (2.5/2.5/46.0/49.0)	105.3	–20.6	–14.8	–29.2	–26.0
461A	R-125/143a/134a/227ea/600a (55.0/5.0/32.0/5.0/3.0)	109.6	–44.0	–38.0	–42.0	–37.0
462A	R-32/125/143a/134a/600 (9.0/42.0/2.0/44.0/3.0)	97.1	–44.7	–33.9	–42.6	–36.6
463A	R-744/32/125/1234yf/134a (6.0/36.0/30.0/14.0/14.0)	74.7	–73.1	–52.4	–58.4	–46.9
464A	R-32/125/1234ze(E)/227ea (27.0/27.0/40.0/6.0)	88.5	–51.7	–34.4	–46.5	–36.9
465A	R-32/290/1234yf (21.0/7.9/71.1)	83.0	–61.2	–40.0	–51.8	–40.0
466A	R-32/125/13I1 (49.0/11.5/39.5)	80.7	–61.1	–59.8	–51.7	–51.0
467A	R-32/125/134a/600a (22.0/5.0/72.4/0.6)	84.4	–40.9	–27.9	–40.5	–33.3

a. Composition tolerances can be found in Table 4-2.
b. Azeotropic refrigerants exhibit some segregation of components at conditions of temperature and pressure other than those at which they were formulated. The extent of segregation depends on the particular azeotrope and hardware system configuration.
c. The exact composition of this azeotrope is in question and additional experimental studies are needed.
d. R-507, R-508, and R-509 are allowed alternative designations for R-507A, R-508A, and R-509A due to a change in designations after assignment of R-500 through R-509. Corresponding changes were not made for R-500 through R-506.

Table D-2 Data for Refrigerant Blends *(Continued)*

Refrigerant Numbers	Composition (mass %) [a]	Average Relative Molar Mass	Bubble Point, °F	Dew Point, °F	Bubble Point, °C	Dew Point, °C
Zeotropes (*continued*)						
468A	R-1132a/32/1234yf (3.5/21.5/75.0)	88.8	–60.3	–38.2	–51.3	–39.0
468B	R-1132a/32/1234yf (6.0/13.0/81.0)	94.9	–62.3	–34.2	–52.4	–36.8
468C	R-1132a/32/1234yf (6.0/42.0/52.0)	73.7	–69.9	–51.2	–56.6	–46.2
469A	R-744/R-32/R-125 (35.0/32.5/32.5)	59.1	–109.3	–78.7	–78.5	–61.5
470A	R-744/32/125/134a/1234ze(E)/227ea (10.0/17.0/19.0/7.0/44.0/3.0)	84.4	–80.7	–32.1	–62.7	–35.6
470B	R-744/32/125/134a/1234ze(E)/227ea (10.0/11.5/11.5/3.0/57.0/7.0)	89.7	–79.1	–24.5	–61.7	–31.4
471A	R-1234ze(E)/227ea/1336mzz(E) (78.7/4.3/17.0)	122.1	1.5	7.2	–16.9	–13.8
472A	R-744/32/134a (69.0/12.0/19.0)	50.39	–119.7	–78.7	–84.3	–61.5
472B	R-744/32/134a (58.0/10.0/32.0)	54.8	–117.2	–66.6	–82.9	–54.8
473A	R-1132a/23/744/125 (20.0/10.0/60.0/10.0)	52.58	–126.0	–117.0	–87.6	–83.0
474A	R-1132(E)/1234yf (23.0/77.0)	96.7	–45.5	–33.6	–43.1	–36.4
475A	R-1234yf/134a/1234ze(E) (45.0/43.0/12.0)	108.54	–19.8	–19.0	–28.8	–28.3
476A	R-134a/1234ze(E)/1336mzz(E) (10.0/78.0/12.0)	116.9	–2.4	2.9	–19.1	–16.1

Refrigerant Number	Composition (mass %)[a]	Azeotropic Temperature		Azeotropic Relative Molar Mass	Normal Bubble Point	
		°C	°F		°C	°F
Azeotropes [b]						
500	R-12/152a (73.8/26.2)	0	32	99.3	–33	–27
501	R-22/12 (75.0/25.0)[c]	–41	–42	93.1	–41	–42
502	R-22/115 (48.8/51.2)	19	66	112.0	–45	–49
503	R-23/13 (40.1/59.9)	88	126	87.5	–88	–126
504	R-32/115 (48.2/51.8)	17	63	79.2	–57	–71
505	R-12/31 (78.0/22.0)[c]	115	239	103.5	–30	–22

a. Composition tolerances can be found in Table 4-2.
b. Azeotropic refrigerants exhibit some segregation of components at conditions of temperature and pressure other than those at which they were formulated. The extent of segregation depends on the particular azeotrope and hardware system configuration.
c. The exact composition of this azeotrope is in question and additional experimental studies are needed.
d. R-507, R-508, and R-509 are allowed alternative designations for R-507A, R-508A, and R-509A due to a change in designations after assignment of R-500 through R-509. Corresponding changes were not made for R-500 through R-506.

Table D-2 Data for Refrigerant Blends *(Continued)*

Refrigerant Number	Composition (mass %)[a]	Azeotropic Temperature °C	Azeotropic Temperature °F	Azeotropic Relative Molar Mass	Normal Bubble Point °C	Normal Bubble Point °F
Azeotropes [b] (*continued*)						
506	R-31/114 (55.1/44.9)	18	64	93.7	–12	10
507A[d]	R-125/143a (50/50)	–40	–40	98.9	–46.7	–52.1
508A[d]	R-23/116 (39/61)	–86	–122	100.1	–86	–122
508B	R-23/116 (46/54)	–45.6	–50.1	95.4	–88.3	–126.9
509A[d]	R-22/218 (44/56)	0	32	124.0	–47	–53
510A	R-E170/600a (88.0/12.0)	–25.2	–13.4	47.24	–25.2	4–13.4
511A	R-290/E170 (95.0/5.0)	–20 to 40	–4 to 104	44.19	–42.1	–43.7
512A	R-134a/152a (5.0/95.0)	–20 to 40	–4 to 104	67.24	–24.0	–11.2
513A	R-1234yf/134a (56.0/44.0)	27.0	80.6	108.4	–29.2	–20.6
513B	R-1234yf/134a (58.5/41.5)	27.2	81.0	108.7	–29.2	–20.6
514A	R-1336mzz(Z)/1130 (E) (74.7/25.3)	50.0	122	139.6	29.0	84.2
515A	R-1234ze(E)/227ea (88.0/12.0)	60.0	140	118.7	–18.9	–2.0
515B	R-1234ze(E)/227ea (91.1/8.9)	30	86	117.9	–19.0	–2.3
516A	R-1234yf/134a/152a (77.5/8.5/14.0)	5 to 90	41 to 194	102.6	–29.4	–20.9

a. Composition tolerances can be found in Table 4-2.
b. Azeotropic refrigerants exhibit some segregation of components at conditions of temperature and pressure other than those at which they were formulated. The extent of segregation depends on the particular azeotrope and hardware system configuration.
c. The exact composition of this azeotrope is in question and additional experimental studies are needed.
d. R-507, R-508, and R-509 are allowed alternative designations for R-507A, R-508A, and R-509A due to a change in designations after assignment of R-500 through R-509. Corresponding changes were not made for R-500 through R-506.

(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

INFORMATIVE APPENDIX E
TOXICITY AND FLAMMABILITY DATA FOR SINGLE-COMPOUND REFRIGERANTS

Table E-1 Toxicity Table for Standard 34—ATEL, ODL, FCL, and RCL Values for Single-Compound Refrigerants[a] (ppm v/v)

Refrigerant Number	Chemical Name	Cardiac Sensitization			Anesthesia										
		LC_{50} [b,c]	LOEL [d]	NOEL [d]	EC_{50} [e]	LOEL [f]	NOEL [g]	Other [h]	ATEL	ODL	FCL	RCL	LFL	ATEL Source	RCL Source
11	trichlorofluoromethane	26,200	4800	1100	35,000	ND	12,500	ND	1100	140,000	NA	1100	—	100% Cardiac NOEL	ATEL
12	dichlorodifluoromethane	>800,000	50,000	40,000	250,000	ND	200,000	22,700	18,000	140,000	NA	18,000	—	Other	ATEL
13I1	trifluoroiodomethane	128,000	ND	2000	ND	ND	10,000	ND	2000	140,000	ND	2000	ND	Cardiac Sensitization	ATEL
14	tetrafluoromethane	>390,000	ND	200,000	ND	ND	226,000	ND	110,000	140,000	NA	110,000	—	28.3% LC_{50}	ATEL
22	chlorodifluoromethane	220,000	ND	59,300	140,000	ND	ND	ND	59,000	140,000	NA	59,000	—	100% Cardiac NOEL	ATEL
23	trifluoromethane	>663,000	ND	800,000	ND	ND	51,000	ND	41,000	140,000	NA	41,000	—	80% Anesthesia NOEL	ATEL
32	difluoromethane (methylene fluoride)	>760,000	ND	350,000	ND	ND	250,000	ND	200,000	140,000	36,000	36,000	144,000	80% Anesthesia NOEL	25% LFL
113	1,1,2-trichloro-1,2,2-trifluoroethane	52,500	4850	2600	28,000	ND	25,000	ND	2600	140,000	NA	2600	—	100% Cardiac NOEL	ATEL

ND: None determined or not adequately defined according to criteria of this standard.
NA: Not applicable
Informative Note: The data shown in this table are rounded to three significant digits to avoid suggestion of artificial precision, but actual calculations used the data as published or converted to avoid propagation of errors in calculations, especially for blends. The ATEL and RCL concentrations are rounded to two significant figures.

a. Data taken from Calm [8,9,10], Coombs[11,12], and Wilson and Richard [13] (see Section 10).
b. Four-hour LC_{50} rat used for mortality indicator; some federal and fire code toxicity classifications are based on a one-hour LC_{50} rat.
c. Four-hour approximate lethal concentration (ALC) rat used for mortality indicator; LC_{50} not determined.
d. Dog with epinephrine injection.
e. Ten-minute EC_{50} mouse or rat.
f. Lowest anesthetic/CNS LOEL rat during ALC, LC_{50}, or other acute toxicity study.
g. Highest anesthetic/CNS NOEL rat in any toxicity study not exceeding an acute LOEL.
h. Other escape-impairing or permanently injuring effects, including severe sensory irritation, for short exposures.
i. R-114 30-minute LC_{50} rat—720,000 ppm v/v, two-hour LC_{50} rat >600,000 ppm v/v.
j. R-134a LC_0 substituted for ALC; >50% of animals died at ALC of 566,700 ppm v/v.
k. R-218 one-hour ALC rat >800,000 ppm v/v.
l. Reserved for future assignment
m. R-290 15-min LC_{50} rat > 800,000 ppm v/v.
n. R-600a 15-min LC_{50} rat = 570,000 ppm v/v; anesthetic/CNS value is a 17-min EC_{50} mouse.
o. No data, but believed to exceed LC_{50} and ALC.
p. Published LC_{50} values—6586 to 19,671 ppm v/v for one hour and 2000 to 4067 for four hour; conversion of the lowest one-hour LC_{50} rat to four-hour yields 3300, approximately the midpoint of the four-hour values.
q. See NIOSH IDLH documentation for other effect.
r. R-744 treated as simple asphyxiant; five-minute LC_{Lo} human = 90,000 ppm v/v.
s. R-1270 six-hour ALC > 400,000 ppm v/v; cardiac sensitization in 2 of 2 dogs at 100,000 ppm; respiratory rate decrease in half of tested animals at 7200 ppm v/v.
t. The value shown is the LC_{50} for isopentane. The value for pentane is expected to be similar.

Table E-1 Toxicity Table for Standard 34—ATEL, ODL, FCL, and RCL Values for Single-Compound Refrigerants[a] (ppm v/v) ***(Continued)***

Refrigerant Number	Chemical Name	Cardiac Sensitization			Anesthesia										
		LC_{50} [b,c]	LOEL [d]	NOEL [d]	EC_{50} [e]	LOEL [f]	NOEL [g]	Other [h]	ATEL	ODL	FCL	RCL	LFL	ATEL Source	RCL Source
114	1,2-dichloro-1,1,2,2-tetrafluoroethane	255,000 [i]	25,000	ND	250,000	ND	100,000	ND	20,000	140,000	NA	20,000	—	80% Cardiac LOEL	ATEL
115	chloropentafluoroethane	>800,000	150,000	ND	ND	ND	800,000	ND	120,000	140,000	NA	120,000	—	80% Cardiac LOEL	ATEL
116	hexafluoroethane	>800,000	ND	200,000	ND	ND	121,000	ND	97,000	140,000	NA	97,000	—	80% Anesthesia NOEL	ATEL
123	2,2-dichloro-1,1,1-trifluoroethane	32,000	ND	10,300	27,000	ND	2500	ND	9100	140,000	NA	9100	—	28.3% LC_{50}	ATEL
124	2-chloro-1,1,1,2-tetrafluoroethane	263,000	25,000	10,100	150,000	ND	48,000	ND	10,000	140,000	NA	10,000	—	100% Cardiac NOEL	ATEL
125	pentafluoroethane	>769,000	100,000	75,000	ND	ND	709,000	ND	75,000	140,000	NA	75,000	—	100% Cardiac NOEL	ATEL
134a	1,1,1,2-tetrafluoroethane	>359,000 [j]	75,200	49,800	270,000	ND	81,000	ND	50,000	140,000	NA	50,000	—	100% Cardiac NOEL	ATEL
141b	1,1-dichloro-1-fluoroethane	61,600	5200	2600	25,000	29,000	20,000	ND	2600	140,000	15,000	2600	60,000	100% Cardiac NOEL	ATEL
142b	1-chloro-1,1-difluoroethane	106,000 [c]	50,000	25,000	250,000	ND	591,000	ND	25,000	140,000	20,000	20,000	80,000	100% Cardiac NOEL	25% LFL
143a	1,1,1-trifluoroethane	>591,000	300,000	250,000	500,000	ND	24,800	ND	170,000	140,000	21,000	21,000	82,000	28.3% LC_{50}	25% LFL
152a	1,1-difluoroethane	400,000 [c]	150,000	50,000	ND	ND	66,400	500,000	50,000	140,000	12,000	12,000	48,000	100% Cardiac NOEL	25% LFL
170	ethane	>24,800	100,000	ND	ND	ND	ND	ND	7000	140,000	7700	7000	31,000	28.3% LC_{50}	ATEL

ND: None determined or not adequately defined according to criteria of this standard.
NA: Not applicable
Informative Note: The data shown in this table are rounded to three significant digits to avoid suggestion of artificial precision, but actual calculations used the data as published or converted to avoid propagation of errors in calculations, especially for blends. The ATEL and RCL concentrations are rounded to two significant figures.

a. Data taken from Calm [8,9,10], Coombs[11,12], and Wilson and Richard [13] (see Section 10).
b. Four-hour LC_{50} rat used for mortality indicator; some federal and fire code toxicity classifications are based on a one-hour LC_{50} rat.
c. Four-hour approximate lethal concentration (ALC) rat used for mortality indicator; LC_{50} not determined.
d. Dog with epinephrine injection.
e. Ten-minute EC_{50} mouse or rat.
f. Lowest anesthetic/CNS LOEL rat during ALC, LC_{50}, or other acute toxicity study.
g. Highest anesthetic/CNS NOEL rat in any toxicity study not exceeding an acute LOEL.
h. Other escape-impairing or permanently injuring effects, including severe sensory irritation, for short exposures.
i. R-114 30-minute LC_{50} rat—720,000 ppm v/v, two-hour LC_{50} rat >600,000 ppm v/v.
j. R-134a LC_0 substituted for ALC; >50% of animals died at ALC of 566,700 ppm v/v.
k. R-218 one-hour ALC rat >800,000 ppm v/v.
l. Reserved for future assignment
m. R-290 15-min LC_{50} rat > 800,000 ppm v/v.
n. R-600a 15-min LC_{50} rat = 570,000 ppm v/v; anesthetic/CNS value is a 17-min EC_{50} mouse.
o. No data, but believed to exceed LC_{50} and ALC.
p. Published LC_{50} values—6586 to 19,671 ppm v/v for one hour and 2000 to 4067 for four hour; conversion of the lowest one-hour LC_{50} rat to four-hour yields 3300, approximately the midpoint of the four-hour values.
q. See NIOSH IDLH documentation for other effect.
r. R-744 treated as simple asphyxiant; five-minute LC_{Lo} human = 90,000 ppm v/v.
s. R-1270 six-hour ALC > 400,000 ppm v/v; cardiac sensitization in 2 of 2 dogs at 100,000 ppm; respiratory rate decrease in half of tested animals at 7200 ppm v/v.
t. The value shown is the LC_{50} for isopentane. The value for pentane is expected to be similar.

Table E-1 Toxicity Table for Standard 34—ATEL, ODL, FCL, and RCL Values for Single-Compound Refrigerants[a] (ppm v/v) *(Continued)*

Refrigerant Number	Chemical Name	Cardiac Sensitization			Anesthesia										
		LC_{50} [b,c]	LOEL [d]	NOEL [d]	EC_{50} [e]	LOEL [f]	NOEL [g]	Other [h]	ATEL	ODL	FCL	RCL	LFL	ATEL Source	RCL Source
E170	Dimethyl ether	164,000	200,000	100,000	ND	84,000	ND	ND	42,000	140,000	8500	8500	34,000	50% Anesthesia LOEL	25% LFL
218	octafluoropropane	>400,000 [c,k]	400,000	300,000	ND	ND	113,000	ND	90,000	140,000	NA	90,000	—	80% Anesthesia NOEL	ATEL
227ea	1,1,1,2,3,3,3-heptafluoropropane	>788,696	105,000	90,000	ND	ND	105,000	ND	84,000	140,000	NA	84,000	—	80% Anesthesia NOEL	ATEL
236fa	1,1,1,3,3,3-hexafluoropropane	>457,000	150,000	100,000	110,000	ND	20,000	ND	55,000	140,000	NA	55,000	—	80% Anesthesia EC_{50}	ATEL
245fa	1,1,1,3,3-pentafluoropropane	>203,000	44,000	34,100	ND	ND	50,600	ND	34,000	140,000	NA	34,000	—	100% Cardiac NOEL	ATEL
290	propane	>200,000 [m]	100,000	50,000	280,000	ND	ND	ND	50,000	140,000	5300	5300	21,000	100% Cardiac NOEL	25% LFL
C318	octafluorocyclobutane	>800,000	100,000	ND	>800,000	ND	800,000	ND	80,000	140,000	NA	80,000	—	80% Cardiac LOEL	ATEL
600	butane	272,000	ND	ND	ND	ND	130,000	10,000	1000	140,000	5000	1000	20,000	Sect 7.1.1(b)	ATEL
600a	isobutane	143,000 [n]	50,000	25,000	200,000	10,000	ND	ND	25,000	140,000	4000	4000	16,000	100% Cardiac NOEL	25% LFL
601	pentane	434,000 [t]	ND	ND	ND	32,000	16,000	ND	1000	140,000	3000	1000	12,000	Sect 7.1.1(b)	ATEL
601a	isopentane	434,000	ND	ND	ND	120,000	ND	ND	1000	140,000	3300	1000	13,000	Sect 7.1.1(b)	ATEL
717	ammonia	3300 [p]	ND	-p-	ND	-p-	38,900	400	320	140,000	42,000	320	167,000	Other	ATEL

ND: None determined or not adequately defined according to criteria of this standard.
NA: Not applicable
Informative Note: The data shown in this table are rounded to three significant digits to avoid suggestion of artificial precision, but actual calculations used the data as published or converted to avoid propagation of errors in calculations, especially for blends. The ATEL and RCL concentrations are rounded to two significant figures.

a. Data taken from Calm [8,9,10], Coombs[11,12], and Wilson and Richard [13] (see Section 10).
b. Four-hour LC_{50} rat used for mortality indicator; some federal and fire code toxicity classifications are based on a one-hour LC_{50} rat.
c. Four-hour approximate lethal concentration (ALC) rat used for mortality indicator; LC_{50} not determined.
d. Dog with epinephrine injection.
e. Ten-minute EC_{50} mouse or rat.
f. Lowest anesthetic/CNS LOEL rat during ALC, LC_{50}, or other acute toxicity study.
g. Highest anesthetic/CNS NOEL rat in any toxicity study not exceeding an acute LOEL.
h. Other escape-impairing or permanently injuring effects, including severe sensory irritation, for short exposures.
i. R-114 30-minute LC_{50} rat—720,000 ppm v/v, two-hour LC_{50} rat >600,000 ppm v/v.
j. R-134a LC_0 substituted for ALC; >50% of animals died at ALC of 566,700 ppm v/v.
k. R-218 one-hour ALC rat >800,000 ppm v/v.
l. Reserved for future assignment
m. R-290 15-min LC_{50} rat > 800,000 ppm v/v.
n. R-600a 15-min LC_{50} rat = 570,000 ppm v/v; anesthetic/CNS value is a 17-min EC_{50} mouse.
o. No data, but believed to exceed LC_{50} and ALC.
p. Published LC_{50} values—6586 to 19,671 ppm v/v for one hour and 2000 to 4067 for four hour; conversion of the lowest one-hour LC_{50} rat to four-hour yields 3300, approximately the midpoint of the four-hour values.
q. See NIOSH IDLH documentation for other effect.
r. R-744 treated as simple asphyxiant; five-minute LC_{Lo} human = 90,000 ppm v/v.
s. R-1270 six-hour ALC > 400,000 ppm v/v; cardiac sensitization in 2 of 2 dogs at 100,000 ppm; respiratory rate decrease in half of tested animals at 7200 ppm v/v.
t. The value shown is the LC_{50} for isopentane. The value for pentane is expected to be similar.

Table E-1 Toxicity Table for Standard 34—ATEL, ODL, FCL, and RCL Values for Single-Compound Refrigerants[a] (ppm v/v) ***(Continued)***

Refrigerant Number	Chemical Name	Cardiac Sensitization			Anesthesia									ATEL Source	RCL Source
		LC_{50} [b,c]	LOEL [d]	NOEL [d]	EC_{50} [e]	LOEL [f]	NOEL [g]	Other [h]	ATEL	ODL	FCL	RCL	LFL		
744	carbon dioxide	159,000	ND	30,000	ND	-p-	50,000	50,000 [q]	30,000	140,000	NA	30,000	—	100% Cardiac NOEL	ATEL
1132a	1,1-difluoroethene	100,000	ND	50,000	ND	ND	200,000	ND	28,000	ND	13,000	13,000	50,000	28.3% LC_{50}	25% LFL
1132(E)	trans-1,2-difluoroethene	106,000	ND	116,000	ND	ND	106,250	ND	30,000	140,000	11,000	11,000	43,000	Mortality	FCL
1224yd(Z)	cis-1-chloro-2,3,3,3-tetrafluoro-1-propene	213,000	ND	75,000	ND	152,000	ND	ND	60,000	140,000	NA	60,000	ND	28.3% LC_{50}	ATEL
1234yf	2,3,3,3-tetrafluoro-1-propene	>406,000	ND	>120,000	ND	201,000	ND	ND	100,000	140,000	16,000	16,000	62,000	50% CNS/ Anesthesia LOEL	25% LFL
1234ze(E)	trans-1,3,3,3-tetrafluoro-1-propene	>207,000	ND	>120,000	ND	ND	>207,000	ND	59,000	140,000	16,000	16,000	65,000	28.3% LC_{50}	25% LFL
1270	propene (propylene)	>490,000 [s]	ND	ND	ND	ND	10,000	7200	1000	140,000	6700	1000	27,000	Sect 7.1.1(b)	ATEL
1336mzz(E)	trans-1,1,1,4,4,4-hexafluoro-2-butene	25,400	ND	70,000	ND	ND	14,600	ND	7190	140,000	ND	7200	ND	Mortality	ATEL
1336mzz(Z)	cis-1,1,1,4,4,4-hexaflouro-2-butene	102,900	25,000	12,500	ND	ND	102,900	ND	13,000	140,000	—	13,000	—	100% cardiac NOEL	ATEL

ND: None determined or not adequately defined according to criteria of this standard.
NA: Not applicable
Informative Note: The data shown in this table are rounded to three significant digits to avoid suggestion of artificial precision, but actual calculations used the data as published or converted to avoid propagation of errors in calculations, especially for blends. The ATEL and RCL concentrations are rounded to two significant figures.

a. Data taken from Calm [8,9,10], Coombs[11,12], and Wilson and Richard [13] (see Section 10).
b. Four-hour LC_{50} rat used for mortality indicator; some federal and fire code toxicity classifications are based on a one-hour LC_{50} rat.
c. Four-hour approximate lethal concentration (ALC) rat used for mortality indicator; LC_{50} not determined.
d. Dog with epinephrine injection.
e. Ten-minute EC_{50} mouse or rat.
f. Lowest anesthetic/CNS LOEL rat during ALC, LC_{50}, or other acute toxicity study.
g. Highest anesthetic/CNS NOEL rat in any toxicity study not exceeding an acute LOEL.
h. Other escape-impairing or permanently injuring effects, including severe sensory irritation, for short exposures.
i. R-114 30-minute LC_{50} rat—720,000 ppm v/v, two-hour LC_{50} rat >600,000 ppm v/v.
j. R-134a LC_0 substituted for ALC; >50% of animals died at ALC of 566,700 ppm v/v.
k. R-218 one-hour ALC rat >800,000 ppm v/v.
l. Reserved for future assignment
m. R-290 15-min LC_{50} rat > 800,000 ppm v/v.
n. R-600a 15-min LC_{50} rat = 570,000 ppm v/v; anesthetic/CNS value is a 17-min EC_{50} mouse.
o. No data, but believed to exceed LC_{50} and ALC.
p. Published LC_{50} values—6586 to 19,671 ppm v/v for one hour and 2000 to 4067 for four hour; conversion of the lowest one-hour LC_{50} rat to four-hour yields 3300, approximately the midpoint of the four-hour values.
q. See NIOSH IDLH documentation for other effect.
r. R-744 treated as simple asphyxiant; five-minute LC_{Lo} human = 90,000 ppm v/v.
s. R-1270 six-hour ALC > 400,000 ppm v/v; cardiac sensitization in 2 of 2 dogs at 100,000 ppm; respiratory rate decrease in half of tested animals at 7200 ppm v/v.
t. The value shown is the LC_{50} for isopentane. The value for pentane is expected to be similar.

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INFORMATIVE APPENDIX F
EXAMPLE CALCULATIONS FOR HEATS OF COMBUSTION

F1. REACTION STOICHIOMETRY FOR A REFRIGERANT BLEND

Consider the combustion of the mixture R-125/290 (45/55), which corresponds to a mole fraction ratio of (0.2311/0.7689). If the R-125 and R-290 were to burn individually, they would undergo the following reactions:

$$\textbf{R-125: } C_2HF_5 + O_2 \rightarrow 2COF_2 + HF \tag{F-1}$$

and

$$\textbf{R-290: } C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O \tag{F-2}$$

Taking $x = 0.2311$ (the mole fraction of R-125) and $y = 0.7689$ (the mole fraction of R-290), the mixture might be thought to undergo the following combustion reaction:

$$xC_2HF_5 + yC_3H_8 + (x + 5y)O_2 \rightarrow (3y)CO_2 + 2xCOF_2 + xHF + 4yH_2O \tag{F-3}$$

But Equation F-3 would be incorrect. Instead, combine the atoms of the R-125 and R-290 into a hypothetical molecule:

$$xC_2HF_5 + yC_3H_8 \rightarrow C_{2x+3y}H_{x+8y}F_{5x} \tag{F-4}$$

This hypothetical molecule is then reacted with oxygen:

$$C_{2x+3y}H_{x+8y}F_{5x} + (x + 5y)O_2 \rightarrow (2x + 3y)CO_2 + 5xHF + [(x + 8y - 5x)/2]H_2O \tag{F-5}$$

In comparing Equations F-3 and F-5, note that the products of combustion are different. There is no COF_2 formed in Equations F-5; instead, the hydrogen (H) from the R-290 combines with the fluorine (F) from the R-125 to form additional HF.

F2. HEAT OF COMBUSTION FOR A REFRIGERANT BLEND

The enthalpy of formation of the hypothetical blend molecule is the mole-fraction weighted average of the components:

$$\begin{gathered}\Delta h_f(\text{blend}) = x\Delta h_f(\text{R125}) + y\Delta h_f(\text{R290}) \\ = 0.2311\ (-1104.58\ \text{kJ/mol}) + 0.7689\ (-104.70\ \text{kJ/mol}) = -335.77\ \text{kJ/mol}\end{gathered} \tag{F-6}$$

The heat of combustion is the enthalpy of formation of the reactants (refrigerant and oxygen) minus the enthalpy of formation of the products of reaction:

$$\begin{gathered}\Delta h_{combustion} = \sum \Delta h_f(\text{reactants}) - \sum \Delta h_f(\text{products}) = \\ \{\Delta h_f(C_{2x+3y}H_{x+8y}F_{5x}) + (x+5y)\Delta h_f(\text{O}_2)\} - \{(2x+3y)\Delta h_f(\text{CO}_2) + (5x)\Delta h_f(\text{HF}) \\ + [(x+8y-5x)/2]\Delta h_f(\text{H}_2\text{O})\} = -335.77 + [0.2311 + 5(0.7689)][\text{O}] \\ - \{[2(0.2311) + 3(0.7689)][-393.51] + [5(0.2311)][-273.30] \\ + [0.5]\ [0.2311 + 8(0.7689) - 5(0.2311)[-241.83]\} = 1701.6\ \text{kJ/mol}\end{gathered} \tag{F-7}$$

Note that the enthalpy of formation of any element (e.g., O_2) in its normal state at 77°F (25°C) is zero by definition. Sample enthalpies of formation are shown in Table F-1. To convert this result to a mass basis (e.g., for use in Section 6.1.3), divide by the average molar mass of the blend:

$$\begin{gathered}\Delta h_{combustion} = 1701.6\ \text{kJ/mol} = \\ 1701.6/[(0.2311)(120.021) + (0.7689)(44.096)] = 27.604\ \text{kJ/g} = 27604\ \text{kJ/kg}\end{gathered} \tag{F-8}$$

Table F-1 Sample Enthalpies of Formation

Refrigerant	Enthalpy of Formation, kJ/mol
CO_2(g)	–393.51
H_2O(g)	–241.83
HF(g)	–273.30
HCl(g)	–92.31
HI(g)	26.50
HBr(g)	–36.29
SO_2(g)	–296.81
CF_4(g)	–930.00
COF_2	–638.90
$COCl_2$(g)	–220.08
R-290(g)	–104.70
R-125(g)	–1104.58

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INFORMATIVE APPENDIX G
CALCULATION OF RCL AND ATEL FOR BLENDS

The acute toxicity exposure limit (ATEL) for a refrigerant blend shall be set as the lowest concentration based on Sections 7.1.1(a) through 7.1.1(d), where the ATEL of the blend is calculated from the individual components, following the Additivity Method for Mixtures (reference Appendix C of *Threshold Limit Values for Chemical Substances and Physical Agents* [4]). The additivity method is especially applicable to materials of similar chemical properties—for example, hydrocarbons or halogenated hydrocarbons.

The blend acute toxicity calculation shall be done as follows:

$$\text{Blend Mortality Indicator } (a)_{blend} = \frac{1}{\dfrac{mf_1}{a_1} + \dfrac{mf_2}{a_2} + \ldots + \dfrac{mf_n}{a_n}} \tag{G-1}$$

where a_n is the mortality indicator for component n in the blend (i.e., the four-hour LC_{50}) and mf_n is the mole fraction of component n.

In a similar fashion, Blend Cardiac Sensitization Indicator $(b)_{blend}$ can be calculated from $1/(\sum mf_n/b_n)$, where b_n is the cardiac sensitization indicator for component n in the blend (i.e., 100% of the NOEL or, if not determined, 80% of the LOEL), and from the mole fraction mf_n of component n, and so forth, as described in Sections 7.1.1(a) through 7.1.1(d).

Each acute toxicity endpoint (Sections 7.1.1[a] through 7.1.1[d]) for a blend can be expressed in ppm (parts per million of substance in air by volume) if the acute toxicity values for each component n are expressed in ppm and mf_n is expressed as the mole fraction of component n in the blend. The toxicity of each component shall be determined according to the endpoints indicated in Section 7. Thus, the determining method for each component may not be consistent, such as 100% of NOEL of component A and 80% of LOEL of component B.

Example: ATEL Calculation for R-410A (50/50 wt% R-32/R-125)

R-410A composition expressed in mole fraction is (0.698 mole fraction R-32/0.302 mole fraction R-125).

$$\text{Mortality Indicator } (a) \text{ of R-410A} = \frac{1}{\dfrac{0.698}{215,000 \text{ ppm}} + \dfrac{0.302}{218,000 \text{ ppm}}} \tag{G-2}$$

where $(a)_{R\text{-}32}$ = the LC_{50} of R-32, or 760,000 ppm × 0.283 = 215,000 ppm, and $(a)_{R\text{-}125}$ = the LC_{50} of R-125, or 769,000 ppm × 0.283 = 218,000 ppm.

$(a)_{R\text{-}410A}$ = **216,000 ppm as the R-410A mortality indicator**.

$$\text{Cardiac Sensitization Indicator } (b) \text{ of R-410A} = \frac{1}{\dfrac{0.698}{350,000 \text{ ppm}} + \dfrac{0.302}{75,000 \text{ ppm}}} \tag{G-3}$$

where $(b)_{R\text{-}32}$ = Cardiac Sensitization Indicator NOEL for R-32, or 350,000 ppm, and $(b)_{R\text{-}125}$ = Cardiac Sensitization Indicator NOEL for R-125, or 75,000 ppm.

$(b)_{R\text{-}410A}$ = **166,000 ppm as the R-410A cardiac sensitization indicator**.

$$\text{Anesthetic Effect Indicator } (c) \text{ of R-410A} = \frac{1}{\dfrac{0.698}{200,000 \text{ ppm}} + \dfrac{0.302}{567,000 \text{ ppm}}} \tag{G-4}$$

where $(c)_{R\text{-}32}$ = Anesthetic Effect Indicator NOEL for R-32, or 250,000 ppm × 0.8 = 200,000 ppm, and $(c)_{R\text{-}125}$ = Anesthetic Effect Indicator NOEL for R-125, or 709,000 ppm × 0.8 = 567,000 ppm.

$(c)_{R\text{-}410A}$ = **249,000 ppm as the R-410A anesthetic indicator**.

Note: EC_{50} was not used because there was no value for R-32 or R-125, and LOEL was not used because the values for R-32 and R-125 affected more than half (10/10 and >5/10) of the animals. Had legitimate EC_{50}, LOEL, or NOEL values been available, it would have been possible to use a EC_{50} for one blend component, a LOEL for a second, and a NOEL for a third, etc.

There are no pertinent escape-impairing or permanent injury effect indicators (d) known for R-410A. The lowest toxicity endpoint in Section 7.1.1(a) through 7.1.1(c) for the blend is set on the Cardiac Sensitization Effect (b), 166,000 ppm. Rounding to two significant figures gives 170,000 ppm as the ATEL of R-410A.

G1. RCL FOR R-410A

The RCL shall be the lowest of the quantities calculated in accordance with Section 7.1.1, 7.1.2, or 7.1.3. Because the R-410A blend is nonflammable and the ATEL is 170,000 ppm, which is greater than the ODL of 140,000 ppm, the RCL is 140,000 ppm.

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INFORMATIVE APPENDIX H
EXAMPLES OF COMPOSITION UNIQUENESS

Section 4.4.3 requires that blends comprising the same components shall have at least one component with composition range, including tolerances, that does not overlap. This requirement ensures that blends have unique compositions. That is, the composition resulting from a blend analysis can be assigned unambiguously to only a single refrigerant designation. This informative appendix provides examples to help visualize and clarify this requirement.

H1. EXAMPLE—BINARY BLENDS

Table H-1 lists example compositions for two binary blends comprising Component A and Component B that are not unique. Note that the concentration of Component A can be 45.0 mass % and that of Component B can be 55.0 mass % in both Refrigerant 1 and Refrigerant 2. This is shown visually in Figure H-1 where the edge of the lower range of Component A in Refrigerant 2 is coincident with the edge of the upper range of Refrigerant 1 and vice versa for Component B.

Presuming that Refrigerant 1 received its designation first, the tolerances on Refrigerant 2 would need to be made smaller to make its composition unique. An example is listed in Table H-2. Here, the lower tolerance on Component A in Refrigerant 2 has been decreased by 0.1 mass % (the smallest increment allowed in Section 4.4.2 for reporting compositions). As seen in Figure H-2, the ranges for Refrigerant 1 and Refrigerant 2 no longer share coincident edges.

Alternatively, the tolerances for Refrigerant 2 could have been kept the same as those in Table H-1 and the nominal composition adjusted upward by a minimum of 0.1 mass % in Component A to create a blend unique from Refrigerant 1.

Table H-1 Two Binary Blends That Are Not Unique

Component	Concentration (mass %)	
	A	B
Refrigerant 1	44.0	56.0
Tolerances	–2.0/+1.0	–1.0/+2.0
Range	42.0 to 45.0	55.0 to 58.0
Refrigerant 2	46.0	54.0
Tolerances	±1.0	±1.0
Range	45.0 to 47.0	53.0 to 55.0

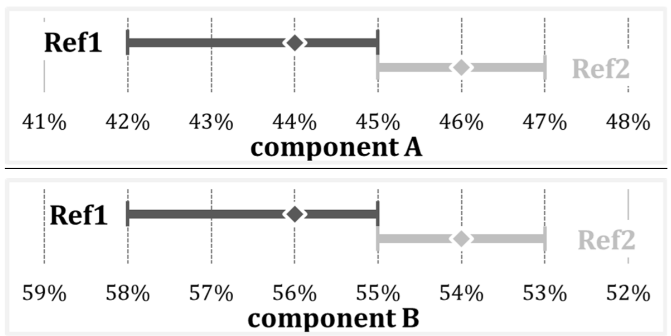

Figure H-1 Two binary blends that are not unique.

Table H-2 Two Binary Blends That Are Unique

Component	Concentration (mass %)	
	A	B
Refrigerant 1	44.0	56.0
Tolerances	–2.0/+1.0	–1.0/+2.0
Range	42.0 to 45.0	55.0 to 58.0
Refrigerant 2	46.0	54.0
Tolerances	–0.9/+1.0	–1.0/+0.9
Range	45.1 to 47.0	53.0 to 54.9

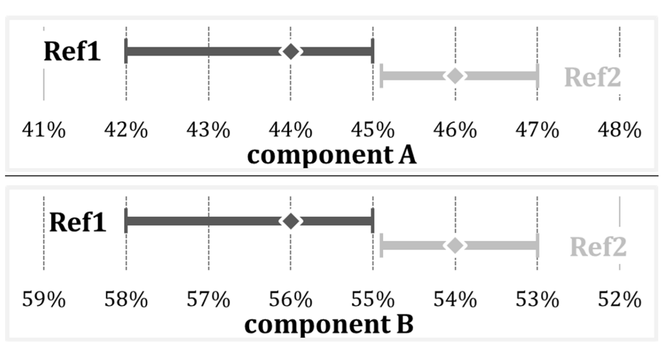

Figure H-2 Two binary blends that are unique.

H2. EXAMPLE—TERNARY BLENDS

Table H-3 lists example compositions for two ternary blends comprising Component A, B, and C that are not unique. The concentrations of Components B and C are allowed to overlap if the concentrations of Component A does not. However, in this case, the upper boundary of Component A concentration in Refrigerant 2 (19.0) coincides with lower boundary of Refrigerant 1 (19.0). This is shown visually in Figure H-3. The hexagonal cells, created by the intersections of the tolerance ranges on each of the components, represent the range of compositions associated with each of the blends Refrigerant 1 and Refrigerant 2. Note that they share a common boundary along the Component A concentration line of 19.0 mass %.

Presuming that Refrigerant 1 received its designation first, the tolerance on Component A in Refrigerant 2 would need to be made smaller to make its composition unique. An example is listed in Table H-4. Here, the upper tolerance on Component A in Refrigerant 2 has been decreased by 0.1 mass %. As seen in Figure H-4, the ranges for Refrigerant 1 and Refrigerant 2 no longer share coincident boundaries.

As with the binary blends, an alternative is to simply move the nominal composition so that the blend range of Refrigerant 2 is not coincident with the range of Refrigerant 1.

Table H-3 Two Ternary Blends That Are not Unique

Component	Concentration (mass %)		
	A	B	C
Refrigerant 1	20.0	40.0	40.0
Tolerances	±1.0	±1.0	±1.0
Range	19.0 to 21.0	39.0 to 41.0	39.0 to 41.0
Refrigerant 2	18.0	41.0	41.0
Tolerances	±1.0	±1.0	±1.0
Range	17.0 to 19.0	40.0 to 42.0	40.0 to 42.0

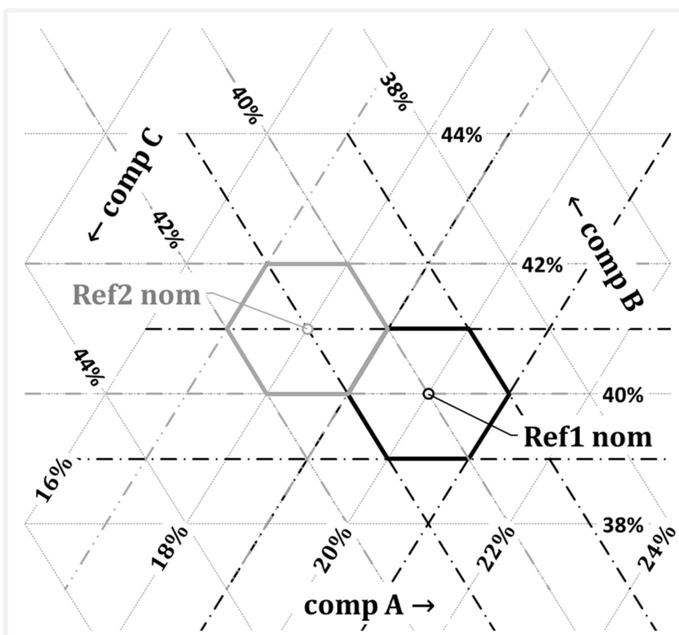

Figure H-3 Two ternary blends that are not unique.

Table H-4 Two Ternary Blends That Are Unique

Component	Concentration (mass %)		
	A	B	C
Refrigerant 1	20.0	40.0	40.0
Tolerances	±1.0	±1.0	±1.0
Range	19.0 to 21.0	39.0 to 41.0	39.0 to 41.0
Refrigerant 2	18.0	41.0	41.0
Tolerances	–1.0/+0.9	±1.0	±1.0
Range	17.0 to 18.9	40.0 to 42.0	40.0 to 42.0

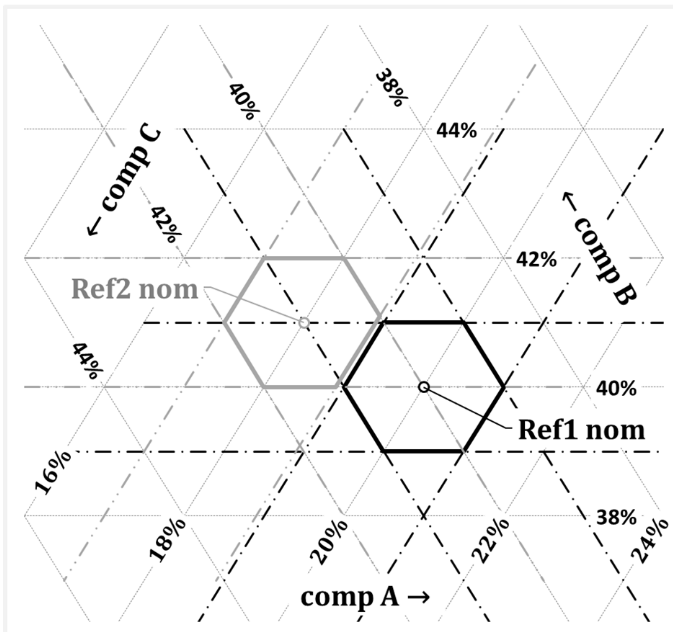

Figure H-4 Two ternary blends that are unique.

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INFORMATIVE APPENDIX I
RECOMMENDED SIGNIFICANT FIGURES REPORTING OF QUANTITIES IN APPLICATIONS TO ASHRAE SSPC 34

This appendix provides guidance on the recommended number of significant figures for refrigerant data in applications for designation and safety group classifications for refrigerants, including blends, in addenda or revisions to the standard on new compounds or blends to be added to the standard.

I1. RECOMMENDED SIGNIFICANT FIGURES

Table I-1 gives the recommended significant figures.

I2. SPECIFICATION OF SOURCES

The source of all of the quantities required in Section 9.5.2 are recommended to be stated and documented. Examples include the following:

a. Direct experimental measurement: state method used and experimental uncertainty.
b. Calculation by an equation of state model: state the program used (e.g., NIST REFPROP, version 10.0).
c. Literature references for the underlying equations of state for each of the components (e.g., for R-134a: Tillner-Roth, R., and H.D. Baehr. 1994. An international standard formulation of the thermodynamic properties of 1,1,1,2-tetrafluoroethane (HFC-134a) for temperatures from 170K to 455K at pressures up to 70 MPa. *J. Phys. Chem. Ref. Data* 23:657–729.) and, in the case of mixtures, the mixing rule and associated parameter values.
d. Calculation by an approximate method, such as the calculation of critical properties given by Section 9.5.2.5 or the calculation of the heat of combustion given by the method in Informative Appendix F.

Table I-1 Recommended Significant Figures

Property	Recommended Data Reporting	Examples
Temperatures (normal boiling point, critical point, azeotropic, bubble point, dew point, and temperature glide)	0.1	23.0°C (73.4°F)
Application temperatures	1	–40 to + 10°C
Pressures	Three (3) significant figures	5.78 MPa
Specific volume	Three (3) significant figures	0.00195 m^3/kg
Density	Three (3) significant figures	472 kg/m^3
Latent heat of vaporization	Three (3) significant figures	125 kJ/kg
Specific heat ratio	Three (3) significant figures	1.53
Compositions (nominal, WCF, WCFF, tolerances)	0.1	(23.0/25.0/52.0)
Molecular weights	0.01	102.03 g/mole

(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

INFORMATIVE APPENDIX J
ADDENDA DESCRIPTION

ANSI/ASHRAE Standard 34-2022 incorporates ANSI/ASHRAE Standard 34-2019 and Addenda a, b, c, d, e, f, g, h, i, j, k, l, m, n, p, q, r, s, t, u, v, w, x, y, z, aa, ab, ad, ae, af, and ag to ANSI/ASHRAE Standard 34-2019. Table J-1 lists each addendum and describes the way in which the standard is affected by the change. It also lists the ASHRAE and ANSI approval dates for each addendum.

Table J-1 Addenda to ANSI/ASHRAE Standard 34-2019

Addendum	Sections Affected	Description of Changes*	Approval Dates
a	7.2	Addendum *a* provides clarification for determining the RCL values of refrigerant blends by revising Section 7.2, "Blends."	October 16, 2019 (ASHRAE Std. Comm.) November 1, 2019 (ASHRAE BOD) November 5, 2019 (ANSI)
b	9.6.1	Addendum *b* provides clarification for producing short-term toxicity data of blends in refrigerant applications.	October 16, 2019 (ASHRAE Std. Comm.) November 1, 2019 (ASHRAE BOD) November 5, 2019 (ANSI)
c	Tables 4-1 and 4-2	Addendum *c* corrects errors in several RCL values found in Tables 4-1 and 4-2.	October 16, 2019 (ASHRAE Std. Comm.) November 1, 2019 (ASHRAE BOD) November 5, 2019 (ANSI)
d	Table 4-2; Table D-2	Addendum *d* adds the zeotropic refrigerant blend R-469A to Tables 4-2 and D-2.	October 16, 2019 (ASHRAE Std. Comm.) November 1, 2019 (ASHRAE BOD) November 5, 2019 (ANSI)
e	Table 4-2; Table D-2	Addendum *e* adds the zeotropic refrigerant blend R-470A to Tables 4-2 and D-2.	October 16, 2019 (ASHRAE Std. Comm.) November 1, 2019 (ASHRAE BOD) November 5, 2019 (ANSI)
f	Tables 4-1 and 4-2	Addendum *f* adds LFL data to Tables 4-1 and 4-2.	October 16, 2019 (ASHRAE Std. Comm.) November 15, 2019 (ASHRAE BOD) December 12, 2019 (ANSI)
g	Table 4-2; Table D-2	Addendum *g* adds the zeotropic refrigerant blend R-470B to Tables 4-2 and D-2.	February 1, 2020 (ASHRAE Std. Comm.) February 5, 2020 (ASHRAE BOD) February 6, 2020 (ANSI)

* These descriptions may not be complete and are provided for information only.

Table J-1 Addenda to ANSI/ASHRAE Standard 34-2019 *(Continued)*

Addendum	Sections Affected	Description of Changes*	Approval Dates
h	Table 4-2; Table D-2	Addendum *g* adds the zeotropic refrigerant blend R-471A to Tables 4-2 and D-2.	September 30, 2020 (ANSI/ASHRAE Staff)
i	3.2; 9.6, 9.6.3	Addendum *i* removes the requirement for refrigerant applications to include material data safety sheets.	September 1, 2020 (ANSI/ASHRAE Staff)
j	4.4.1	Addendum *j* provides additional flexibility in designating refrigerants in order to avoid potential confusion with other refrigerant designating bodies.	September 30, 2020 (ANSI/ASHRAE Staff)
k	4.4.3 (new); Informative Appendix H (new)	Addendum *k* ensures blends with the same components cannot have an identical composition, including the allowance for the component composition tolerances.	September 30, 2020 (ANSI/ASHRAE Staff)
l	Table 4-2; Table D-2	Addendum *l* adds the zeotropic refrigerant blend R-457B to Tables 4-2 and D-2.	September 30, 2020 (ANSI/ASHRAE Staff)
m	Table 4-2; Table D-2	Addendum *m* adds the zeotropic refrigerant blend R-472A to Tables 4-2 and D-2.	September 30, 2020 (ANSI/ASHRAE Staff)
n	9.5.2; Informative Appendix I (new)	Addendum *n* adds an informative note to Section 9.5.2 that references the new Informative Appendix I.	September 30, 2020 (ANSI/ASHRAE Staff)
p	Table 4-2; Table D-2	Addendum *p* adds azeotropic refrigerant blend R-515B to Tables 4-2 and D-2.	June 26, 2019 (ASHRAE Std. Comm.) August 1, 2019 (ASHRAE BOD) August 26, 2019 (ANSI)
q	Table 4-2; Table D-2	Addendum *q* adds the zeotropic refrigerant blend R-473A to Tables 4-2 and D-2.	June 30, 2021 (ANSI/ASHRAE Staff)
r	Table 4-2; Table D-2	Addendum *r* adds the zeotropic refrigerant blend R-427C to Tables 4-2 and D-2.	June 30, 2021 (ASHRAE Staff) June 30, 2021 (ANSI)
s	Table 4-2; Table D-2	Addendum *s* adds the zeotropic refrigerant blend R-448B to Tables 4-2 and D-2.	June 30, 2021 (ASHRAE Staff) June 30, 2021 (ANSI)
t	Table 4-1; Table D-1; Table E-1	Addendum *t* adds single-component refrigerant R-13I1 to Tables 4-1, D-1, and E-1.	June 22, 2019 (ASHRAE Std. Comm.) June 26, 2019 (ASHRAE BOD) July 24, 2019 (ANSI)
u	Table 4-2; Table D-2	Addendum *u* adds the zeotropic refrigerant blend R-466A to Tables 4-2 and D-2.	October 16, 2019 (ASHRAE Std. Comm.) November 1, 2019 (ASHRAE BOD) November 5, 2019 (ANSI)
v	Table 4-2; Table D-2	Addendum *v* adds the zeotropic refrigerant blend R-475A to Tables 4-2 and D-2.	September 30, 2021 (ANSI/ASHRAE Staff)
w	Table 4-2; Table D-2	Addendum *v* adds the zeotropic refrigerant blend R-472B to Tables 4-2 and D-2.	September 30, 2021 (ANSI/ASHRAE Staff)
x	Table 4-2; Table D-2	Addendum *x* adds the zeotropic refrigerant blend R-467A to Tables 4-2 and D-2.	June 22, 2019 (ASHRAE Std. Comm.) June 26, 2019 (ASHRAE Tech. Council) June 27, 2019 (ANSI)

* These descriptions may not be complete and are provided for information only.

Table J-1 Addenda to ANSI/ASHRAE Standard 34-2019 *(Continued)*

Addendum	Sections Affected	Description of Changes*	Approval Dates
y	Table 4-2; Table D-2	Addendum *y* adds the zeotropic refrigerant blend R-468A to Tables 4-2 and D-2.	June 22, 2019 (ASHRAE Std. Comm.) June 26, 2019 (ASHRAE Tech. Council) June 27, 2019 (ANSI)
z	Table 4-2; Table D-2	Addendum *z* adds the zeotropic refrigerant blend R-468B to Tables 4-2 and D-2.	September 30, 2021(ANSI/ASHRAE Staff)
aa	Table 4-2; Table D-2	Addendum *aa* adds the zeotropic refrigerant blend R-468C to Tables 4-2 and D-2.	September 30, 2021 (ANSI/ASHRAE Staff)
ab	Table 4-2; Table D-2	Addendum *ab* adds the zeotropic refrigerant blend R-476A to Tables 4-2 and D-2.	June 30, 2022 (ANSI/ASHRAE Staff)
ad	Table 4-1; Table D-1; Table E-1	Addendum *ad* adds single-component refrigerant R-1132(E) to Tables 4-1, D-1, and E-1.	July 29, 2022 (ANSI/ASHRAE Staff)
ae	Table 4-2; Table D-2	Addendum *ae* adds the zeotropic refrigerant blend R-474A to Tables 4-2 and D-2.	July 29, 2022 (ANSI/ASHRAE Staff)
af	Table 4-2; Table D-2	Addendum *af* adds the zeotropic refrigerant blend R-457C to Tables 4-2 and D-2.	July 29, 2022 (ANSI/ASHRAE Staff)
ag	9.9	Addendum *ag* revises the submission instructions to remove the requirement for applications for designation and safety classification of refrigerants to be submitted in print format, and clarifies that applications are to be submitted in electronic format only.	August 31, 2022 (ANSI/ASHRAE Staff)

* These descriptions may not be complete and are provided for information only.

NOTE

Approved addenda, errata, or interpretations for this standard can be downloaded free of charge from the ASHRAE website at www.ashrae.org/technology.

POLICY STATEMENT DEFINING ASHRAE'S CONCERN FOR THE ENVIRONMENTAL IMPACT OF ITS ACTIVITIES

ASHRAE is concerned with the impact of its members' activities on both the indoor and outdoor environment. ASHRAE's members will strive to minimize any possible deleterious effect on the indoor and outdoor environment of the systems and components in their responsibility while maximizing the beneficial effects these systems provide, consistent with accepted Standards and the practical state of the art.

ASHRAE's short-range goal is to ensure that the systems and components within its scope do not impact the indoor and outdoor environment to a greater extent than specified by the Standards and Guidelines as established by itself and other responsible bodies.

As an ongoing goal, ASHRAE will, through its Standards Committee and extensive Technical Committee structure, continue to generate up-to-date Standards and Guidelines where appropriate and adopt, recommend, and promote those new and revised Standards developed by other responsible organizations.

Through its *Handbook*, appropriate chapters will contain up-to-date Standards and design considerations as the material is systematically revised.

ASHRAE will take the lead with respect to dissemination of environmental information of its primary interest and will seek out and disseminate information from other responsible organizations that is pertinent, as guides to updating Standards and Guidelines.

The effects of the design and selection of equipment and systems will be considered within the scope of the system's intended use and expected misuse. The disposal of hazardous materials, if any, will also be considered.

ASHRAE's primary concern for environmental impact will be at the site where equipment within ASHRAE's scope operates. However, energy source selection and the possible environmental impact due to the energy source and energy transportation will be considered where possible. Recommendations concerning energy source selection should be made by its members.

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About ASHRAE

Founded in 1894, ASHRAE is a global professional society committed to serve humanity by advancing the arts and sciences of heating, ventilation, air conditioning, refrigeration, and their allied fields.

As an industry leader in research, standards writing, publishing, certification, and continuing education, ASHRAE and its members are dedicated to promoting a healthy and sustainable built environment for all, through strategic partnerships with organizations in the HVAC&R community and across related industries.

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Product code: 86306 9/22