STANDARD

ASHRAE®

ANSI/ASHRAE Standard 15-2013

(Supersedes ANSI/ASHRAE Standard 15-2010)

Includes ANSI/ASHRAE addenda listed in Appendix F

Safety Standard for Refrigeration Systems

See Appendix F for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, 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. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE website (www.ashrae.org) or in paper form from the Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from the ASHRAE website (www.ashrae.org) or from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 678-539-2129. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

 ISSN 1041-2336

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 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.

DISCLAIMER

ASHRAE uses its best efforts to promulgate Standards and Guidelines for the benefit of the public in light of available information and accepted industry practices. However, ASHRAE does not guarantee, certify, or assure the safety or performance of any products, components, or systems tested, installed, or operated in accordance with ASHRAE's Standards or Guidelines or that any tests conducted under its Standards or Guidelines will be nonhazardous or free from risk.

ASHRAE INDUSTRIAL ADVERTISING POLICY ON STANDARDS

ASHRAE Standards and Guidelines are established to assist industry and the public by offering a uniform method of testing for rating purposes, by suggesting safe practices in designing and installing equipment, by providing proper definitions of this equipment, and by providing other information that may serve to guide the industry. The creation of ASHRAE Standards and Guidelines is determined by the need for them, and conformance to them is completely voluntary.

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 15-2013, Safety Standard for Refrigeration Systems

NOTE

Approved addenda, errata, or interpretations for this standard can be downloaded free of charge from the ASHRAE Web site 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 15-2013 is the most recent edition of one of ASHRAE's oldest standards. Standard 15 is under continuous maintenance, which means it is modified and updated based on feedback from users, changes in the science originating from ASHRAE and industry research, and industry changes that respond to the global interest in improved environmental responsibility. Interested parties can recommend changes to the standard by submitting a change proposal using the continuous maintenance form included in the back of the standard. Standard 15-2013 includes all of the published addenda to the 2010 version as shown in Informative Appendix F.

ASHRAE Standard 15 must be used with its sister standard, ANSI/ASHRAE Standard 34, Designation and Safety Classification of Refrigerants.[1] *Standard 34 prescribes the Refrigerant Classification System, as well as refrigerant concentration limits (RCL), that 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, it is the responsibility of the owner of a refrigerating system to make this judgment.

Users of ASHRAE Standard 15 may also find it useful to refer to the Standard 15-2001 User's Manual. *The user's manual was developed as a companion document to ASHRAE Standard 15. Though it does not reflect the addenda and changes incorporated into Standard 15 since its original publication, it still serves to clarify the intent of the standard and provides an explanation of the rationale behind its creation. Its purpose is to assist in use of the standard by including illustrations and examples of accepted industry practice, as well as explanations of and supporting references for formulas in the standard. The user's manual also covers building, system, and refrigerant classifications, restrictions on refrigerant use, installation restrictions, and equipment and system design and construction for commercial, residential, and industrial applications.*

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.[2]

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

- *rupture of a part with risk from flying debris;*
- *release of refrigerant from a fracture, due to a leaking seal or incorrect operation; or*
- *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

- *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; or*
- *freezing of tissue by contact with 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. Leaked refrigerant vapor will concentrate near the floor if undisturbed. Floor-level exhaust-air outlets are appropriate for heavier-than-air refrigerants. The user's manual may provide useful guidance for the design of ventilation systems and the location of supply air inlets and exhaust outlets.

The following short publishing history of this code traces the origins of these safety provisions. In 1919, the American Society of Refrigerating Engineers (ASRE) proposed a Tentative Code for the Regulation of Refrigerating Machines and Refrigerants. *Over the next 11 years, representatives from the American Gas Association, American Institute of Electrical Engineers, American Institute of Refrigeration, American Chemical Society, American Society of Heating and Ventilation Engineers, American Society of Mechanical Engineers, National Electrical Refrigerator Manufacturers Association, National Fire Protection Association, and ASRE met to expand the code to address all of the issues raised on the use of refrigeration equipment. The first Safety Code for Mechanical Refrigeration, recognized as American Standard B9 in October 1930, appeared in the first edition, 1932–1933, of the ASRE* Refrigerating Handbook and Catalog. *ASRE revisions designated ASA B9 appeared in 1933 and 1939. ASRE revisions designated ASA B9.1 appeared in 1950, 1953, and 1958. After the formation of ASHRAE, editions appeared as ASA B9.1-1964, ANSI B9.1-1971, ANSI/ASHRAE 15-1978, ANSI/ASHRAE 15-1989, ANSI/ASHRAE 15-1992, ANSI/ASHRAE 15-1994, ANSI/ASHRAE 15-2001, ANSI/ASHRAE 15-2004, ANSI/ASHRAE 15-2007, and ANSI/ASHRAE 15-2010.*

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 refrigerant having a different designation.

3. DEFINITIONS

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

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

approved, nationally recognized laboratory: a laboratory that is acceptable to the AHJ and provides uniform testing and examination procedures and standards for meeting design, manufacturing, and factory testing requirements of this code; is organized, equipped, and qualified for testing; and has a follow-up inspection service of the current production of the listed products.

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 temperatures above 1000°F (537°C) but less than the melting temperatures of the joined parts.

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* or *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, 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.

containers, 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.

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, not enclosed in a pressure vessel.

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

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

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

highside: those portions of the refrigerating system that are subject to approximate condensing pressure.

horsepower: 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.[1]

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.

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

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 or materials included in a list published by an approved, nationally recognized testing laboratory, inspection agency, or other organization concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets nationally recognized standards or has been tested and found suitable for use in a specified manner.

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): the minimum concentration of the refrigerant that propagates a flame through a homogeneous mixture of refrigerant and air.

lowside: the portion of a refrigerating system that is subjected to approximate evaporator pressure.

machinery: the 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 space, meeting the requirements of Sections 8.11 and 8.12, that is designed to house compressors and pressure vessels.

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.

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

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.

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

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

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 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): the refrigerant concentration limit in air, determined in accordance with ANSI/ASHRAE Standard 34[1]and intended to reduce the risks of acute toxicity, asphyxiation, and flammability hazards in normally occupied, enclosed spaces.

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.

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

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

sealed ammonia/water absorption system: an absorption system where ammonia (R-717) is the refrigerant and water (R-718) is the absorbent and all refrigerant-containing parts are made permanently tight by welding or brazing.

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 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 temperatures not exceeding 800°F (426.5°C) and above 400°F (204.5°C).

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

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

tenant: a person or organization having the legal right to occupy a premises.

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.

threshold limit value time-weighted average (TLV-TWA†): the refrigerant concentration in air for a normal eight-hour workday and a 40-hour workweek to which repeated exposure, day after day, will not cause an adverse effect in most persons.

ultimate strength: the stress at which rupture occurs.

unit system: see *self-contained system*.

unprotected tubing: tubing that is unenclosed and therefore exposed to crushing, abrasion, puncture, or similar damage after installation.

zeotropic: refers to blends comprising multiple components of different volatility 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).

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, multi-unit 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

† TLV® is a registered trademark of the American Conference of Governmental Industrial Hygienists (ACGIH®).

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		

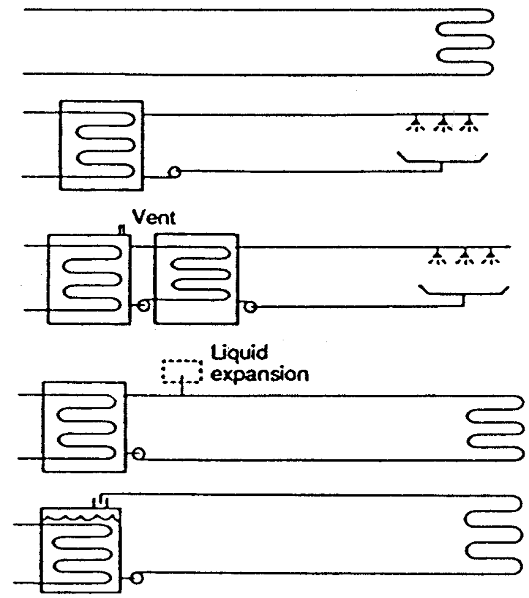


FIGURE 5.1 Refrigerating system designation.

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: 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.

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 Table 4-1 or 4-2 of ASHRAE Standard 34,[1] 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 location of the 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. A change in the type of refrigerant in a system shall not be made without the notification of the AHJ, the user, and due observance of safety requirements. The refrigerant being considered shall be evaluated for suitability.

6. REFRIGERANT SAFETY CLASSIFICATION

6.1 Single-Compound Refrigerants. Single-compound refrigerants shall be classified into safety groups in accordance with ASHRAE Standard 34.[1] The classifications indicated in the referenced edition of ASHRAE Standard 34 shall be used for refrigerants that have them assigned. Other refrigerants shall be classified in accordance with the criteria in ASHRAE Standard 34; such classifications shall be submitted for approval to the AHJ.

6.2 Blends. Refrigerant blends shall be classified following the worst-case of fractionation composition, determined in accordance with ASHRAE Standard 34.[1] For blends assigned only a single safety group in ASHRAE Standard 34, that classification shall be used.

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 Refrigerant Concentration Limits. The concentration of refrigerant in a complete discharge of each independent circuit of high-probability systems shall not exceed the amounts shown in Table 4-1 or 4-2 of ASHRAE Standard 34,[1] except as provided in Sections 7.2.1 and 7.2.2 of this standard. The volume of occupied space shall be determined in accordance with Section 7.3.

Exceptions:

1. Listed equipment containing not more than 6.6 lb (3 kg) of refrigerant, regardless of its refrigerant safety classification, is exempt from Section 7.2 provided the equipment is installed in accordance with the listing and with the manufacturer's installation instructions.
2. Listed equipment for use in laboratories with more than 100 ft^2 (9.3 m^2) of space per person, regardless of the refrigerant safety classification, is exempt from Section 7.2, provided that the equipment is installed in accordance with the listing and the manufacturer's installation instructions.

7.2.1 Institutional Occupancies. The amounts shown in Table 4-1 or 4-2 of ASHRAE Standard 34[1] shall be reduced by 50% for all areas of institutional occupancies. Also, the total of all Group A2, B2, A3, and B3 refrigerants shall not exceed 550 lb (250 kg) in the occupied areas and machinery rooms of institutional occupancies.

7.2.2 Industrial Occupancies and Refrigerated Rooms. Section 7.2 does not apply in industrial occupancies and refrigerated rooms where the following seven conditions are met:

a. The space(s) containing the machinery is (are) separated from other occupancies by tight construction with tight-fitting doors.
b. Access is restricted to authorized personnel.
c. The floor area per occupant is not less than 100 ft^2 (9.3 m^2).

Exception: The minimum floor area shall not apply where the space is provided with egress directly to the outdoors or into approved building exits.

d. Refrigerant detectors are installed with the sensing location and alarm level as required in refrigerating machinery rooms in accordance with Section 8.11.2.1.
e. Open flames and surfaces exceeding 800°F (426.7°C) are not permitted where any Group A2, B2, A3, or B3 refrigerant other than R-717 (ammonia) is used.
f. All electrical equipment conforms to Class 1, Division 2, of NFPA 70[5] where the quantity of any Group A2, B2, A3, or B3 refrigerant other than R-717 (ammonia) in an independent circuit would exceed 25% of the lower flammability limit (LFL) upon release to the space based on the volume determined by Section 7.3.
g. All 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, and connecting piping, are located either in a machinery room or outdoors.

7.3 Volume Calculations. The volume used to convert from refrigerant concentration limits to refrigerating system quantity limits for refrigerants in Section 7.2 shall be based on the volume of space to which refrigerant disperses in the event of a refrigerant leak.

7.3.1 Nonconnecting Spaces. Where a refrigerating system or a part thereof is located in one or more enclosed occupied spaces that do not connect through permanent openings or HVAC ducts, the volume of the smallest occupied space shall be used to determine the refrigerant quantity limit in the system. Where different stories and floor levels connect through an open atrium or mezzanine arrangement, the volume to be used in calculating the refrigerant quantity limit shall be determined by multiplying the floor area of the lowest space by 8.2 ft (2.5 m).

TABLE 7.4 Special Quantity Limits for Sealed Ammonia/Water Absorption and Self-Contained Systems

Type of Refrigeration System	Maximum lb (kg) for Various Occupancies			
	Institutional	Public/Large Mercantile	Residential	Commercial
Sealed Ammonia/Water Absorption System				
In public hallways or lobbies	0 (0)	0 (0)	3.3 (1.5)	3.3 (1.5)
In adjacent outdoor locations	0 (0)	0 (0)	22 (10)	22 (10)
In other than public hallways or lobbies	0 (0)	6.6 (3)	6.6 (3)	22 (10)
Unit Systems				
In other than public hallways or lobbies	0 (0)	0 (0)	6.6 (3)	22 (10)

7.3.2 Ventilated Spaces. Where a refrigerating system or a part thereof is located within an air handler, in an air distribution duct system, or in an occupied space served by a mechanical ventilation system, the entire air distribution system shall be analyzed to determine the worst-case distribution of leaked refrigerant. The worst case or the smallest volume in which the leaked refrigerant disperses shall be used to determine the refrigerant quantity limit in the system, subject to the following criteria.

7.3.2.1 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 volume(s) shall not be used in the calculation.

Exceptions: The following closure devices are not considered:

1. Smoke dampers, fire dampers, and combination smoke/fire dampers that close only in an emergency not associated with a refrigerant leak
2. Dampers, such as variable-air-volume (VAV) boxes, that provide limited closure where airflow is not reduced below 10% of its maximum (with the fan running)

7.3.2.2 Plenums. The space above a suspended ceiling shall not be included in calculating the refrigerant quantity limit in the system unless such space is part of the air supply or return system.

7.3.2.3 Supply and Return Ducts. The volume of the supply and return ducts and plenums shall be included when calculating the refrigerant quantity limit in the system.

7.4 Location in a Machinery Room or Outdoors. All components containing refrigerant shall be located either in a machinery room or outdoors, where

a. the quantity of refrigerant needed exceeds the limits defined by Section 7.2 and Section 7.3 or
b. direct-fired absorption equipment, other than sealed absorption systems not exceeding the refrigerant quantity limits indicated in Table 7.4, is used.

7.4.1 Nonflammable Refrigerants. Machinery rooms required by Section 7.4 shall be constructed and maintained in accordance with Section 8.11 for Group A1 and B1 refrigerants.

7.4.2 Flammable Refrigerants. Machinery rooms required by Section 7.4 shall be constructed and maintained in accordance with Sections 8.11 and 8.12 for Group A2, B2, A3, and B3 refrigerants.

7.5 Additional Restrictions

7.5.1 All Occupancies. Sections 7.5.1.1 through 7.5.1.8 apply to all occupancies.

7.5.1.1 Flammable Refrigerants. The total of all Group A2, B2, A3, and B3 refrigerants other than R-717 (ammonia) shall not exceed 1100 lb (500 kg) without approval by the AHJ.

7.5.1.2 Corridors and Lobbies. Refrigerating systems installed in a public corridor or lobby shall be limited to either

a. unit systems containing not more than the quantities of Group A1 or B1 refrigerant indicated in Table 4-1 or 4-2 of ASHRAE Standard 34[1] or
b. sealed absorption and unit systems having refrigerant quantities less than or equal to those indicated in Table 7.4.

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 ARI 700[3] 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: 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.[3] Contaminated refrigerants shall not be used unless reclaimed and found to meet the requirements of AHRI 700.

7.5.1.7 Mixing. Refrigerants, including refrigerant blends, with different designations in ASHRAE Standard 34[1] shall not be mixed in a system.

Exception: Addition of a second refrigerant is allowed where specified by the equipment manufacturer to improve oil return at low temperatures. The refrigerant and amount added shall follow the manufacturer's instructions.

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 11.2.3.

7.5.2 Applications for Human Comfort. Group A2, A3, B1, B2, and B3 refrigerants shall not be used in high-probability systems for human comfort.

Exceptions:

1. This restriction does not apply to sealed absorption and unit systems having refrigerant quantities less than or equal to those indicated in Table 7.4.
2. This restriction does 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:

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 portable-unit 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.

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 or compressor units.

8.2 Guards. Moving machinery shall be guarded in accordance with approved safety standards.[4]

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 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 Electrical Code*[5] 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 8.11.7.

8.8 Refrigerant Parts in Air Duct. Joints and all refrigerant-containing parts 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.

8.9 Refrigerant Pipe Joint Inspection. Refrigerant pipe joints erected on the premises shall be exposed to view for visual inspection prior to being covered or enclosed.

8.10 Location of Refrigerant Piping

8.10.1 Refrigerant piping crossing an open space that affords passageway in any building shall not be less than 7.25 ft (2.2 m) above the floor unless the piping is located against the ceiling of such space and is permitted by the AHJ.

8.10.2 Passages shall not be obstructed by refrigerant piping. Refrigerant piping shall not be placed in any elevator, dumbwaiter, or other shaft containing a moving object or in any shaft that has openings to living quarters or to means of egress. Refrigerant piping shall not be installed in an enclosed public stairway, stair landing, or means of egress.

8.10.3 Refrigerant piping shall not penetrate floors, ceilings, or roofs.

Exceptions:

1. Penetrations connecting the basement and the first floor.
2. Penetrations connecting the top floor and a machinery penthouse or roof installation.
3. Penetrations connecting adjacent floors served by the refrigeration system.
4. Penetrations of a direct system where the refrigerant concentration does not exceed that listed in Table 4-1 or Table 4-2 of ASHRAE Standard 34[1] for the smallest occupied space through which the refrigerant piping passes.
5. In other than industrial occupancies and where the refrigerant concentration exceeds that listed in Table 4-1 or 4-2 of ASHRAE Standard 34 for the smallest occupied space, penetrations that connect separate pieces of equipment that are
   a. enclosed by an approved gas-tight, fire-resistive duct or shaft with openings to those floors served by the refrigerating system or

b. located on the exterior wall of a building when vented to the outdoors or to the space served by the system and not used as an air shaft, closed court, or similar space.

8.10.4 Refrigerant piping installed in concrete floors shall be encased in pipe duct. Refrigerant piping shall be properly isolated and supported to prevent damaging vibration, stress, or corrosion.

8.11 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.

8.11.1 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.

8.11.2 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 8.11.7, there shall be no openings that will permit passage of escaping refrigerant to other parts of the building.

8.11.2.1 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 8.11.4 at a value not greater than the corresponding TLV-TWA (or toxicity measure consistent therewith). 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.

Exceptions:

1. For ammonia, refer to Section 8.12(h).
2. Detectors are not required when only systems using R-718 (water) are located in the refrigerating machinery room.

8.11.3 Machinery rooms shall be vented to the outdoors, utilizing mechanical ventilation in accordance with Sections 8.11.4 and 8.11.5.

8.11.4 Mechanical ventilation referred to in Section 8.11.3 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 8.11.5. 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 as not to cause a nuisance or danger. The mechanical exhaust inlet(s) shall be located in an area where refrigerant from a leak is likely to concentrate, in consideration of the location of the replacement air path(s), refrigerating machine(s), and the density of the refrigerant relative to air.

8.11.5 The mechanical ventilation required to exhaust an accumulation of refrigerant due to leaks or a rupture of the system shall be capable of removing air from the machinery room in not less than the following quantity:

$$Q = 100 \times G^{0.5} \quad \text{(I-P)}$$

$$Q = 70 \times G^{0.5} \quad \text{(SI)}$$

where

Q = airflow, cfm (L/s)

G = mass of refrigerant in the largest system, 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 cfm/ft^2 (2.54 L/s/m^2) of machinery room area or 20 cfm (9.44 L/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).

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

$$F = G^{0.5} \quad \text{(I-P)}$$

$$F = 0.138 G^{0.5} \quad \text{(SI)}$$

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.

8.11.6 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 8.11.2.1, is employed to automatically shut down the combustion process in the event of refrigerant leakage.

Exceptions:

1. Machinery rooms where only carbon dioxide (R-744) or water (R-718) is the refrigerant.
2. Machinery rooms where only ammonia (R-717) is the refrigerant and internal combustion engines are used as the prime mover for the compressors.

8.11.7 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.

8.11.8 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.

8.12 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 8.11:

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. The refrigerating machinery room shall have a door that opens directly to the outdoors or through a vestibule equipped with self-closing, tight-fitting doors.
e. Exterior openings, if present, shall not be under any fire escape or any open stairway.
f. 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.
g. When refrigerants of Groups A2, A3, B2, and B3 are used, the machinery room shall conform to Class 1, Division 2, of the *National Electrical Code*.[5] When refrigerant Groups A1 and B1 are used, the machinery room is not required to meet Class 1, Division 2, of the *National Electrical Code*.

Exception: When ammonia is used, the requirements of Class 1, Division 2, of the *National Electrical Code* shall not apply, providing the requirements of Section 8.12(h) are met.

h. When ammonia (R-717) is used, the machinery room is not required to meet Class 1, Division 2, of the *National Electrical Code*,[5] provided (a) the mechanical ventilation system in the machinery room is run continuously and failure of the mechanical ventilation system actuates an alarm or (b) the machinery room is equipped with a detector, conforming to Section 8.11.2.1, except the detector shall alarm at 1000 ppm.
i. 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.

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

9. DESIGN AND CONSTRUCTION OF EQUIPMENT AND SYSTEMS

9.1 Materials

9.1.1 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.

9.1.2 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 Copper and its alloys shall not be used in contact with ammonia except as a component of bronze alloys for bearings or other nonrefrigerant-containing uses.

9.1.4 Aluminum and its alloys are suitable for use in ammonia systems.

9.1.5 Piping material used in the discharge line of a pressure-relief device or fusible plug shall be the same as required for refrigerants.

Exception: When discharging to atmosphere, Type F buttweld pipe is allowed.

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. The *ASME Boiler and Pressure Vessel Code*,[6] 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 (3.12 kPa). Design pressure for lithium bromide absorption systems shall not be less than 5 psig (34.7 kPa gage). Design pressure for mechanical refrigeration systems shall not be less than 15 psig (103.4 kPa gage) 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. Lowsides of all systems: 80°F (26.7°C)
b. Highsides 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 for which the equipment is designed or 104°F (40°C), whichever is greatest

c. Highsides of all air-cooled systems: 30°F (16.7°C) higher than the highest summer 1% design dry-bulb temperature for the location but not lower than 122°F (50°C)

Note: See Informative Reference 7 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 lowside components shall also consider pressure developed in the lowside 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 lowside and highside 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 highside or lowside 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 lowside.

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 When a refrigerating system utilizes carbon dioxide (R-744) as a heat transfer fluid, the minimum design pressure for system components shall comply with the following.

9.2.6.1 In a circuit without a compressor, the design pressure shall be at least 20% higher than the saturation pressure corresponding to the warmest location in the circuit.

9.2.6.2 In a cascade refrigerating system, the highside design pressure shall be at least 20% higher than the maximum pressure developed by a pressure-imposing element, and the lowside pressure shall be at least 20% higher than the saturation pressure corresponding to the warmest location in the circuit.

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 an approved, 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 Section VIII of the *ASME Boiler and Pressure Vessel Code*,[6] or
c. when requested by the AHJ, the manufacturer shall provide documentation to confirm that the vessel meets the design, fabrication, and testing requirements of Section VIII of the *ASME Boiler and Pressure Vessel Code*.

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

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.

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 Section VIII of the *ASME Boiler and Pressure Vessel Code*.[6]

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 Section VIII of the *ASME Boiler and Pressure Vessel Code*.[6]

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 control(s) shall be used that is (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 Evaporators located downstream, or upstream within 18 in. (460 mm), of a heating coil shall be fitted with a pressure-relief device discharging outside the building in accordance with the requirements of Section 9.7.8.

Exceptions:

1. Relief valves shall not be required on heating coils that are designed to produce a temperature that will result in the saturation pressure of the refrigerant being less than the design pressure.
2. A relief valve shall not be required on self-contained or unit systems if the volume of the lowside 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 by the following formula:

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

where

V_1 = lowside 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 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 9.7.8.4, 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 or
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: When fusible plugs are used on the highside, 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: See Section 9.7.8.1 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 paragraph UG-127 of Section VIII, Division 1, of the *ASME Boiler and Pressure Vessel Code.*[6] 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 Section VIII, Division 1, of the *ASME Boiler and Pressure Vessel Code.*[6] Each pressure-relief valve shall be marked by the manufacturer or assembler with the data required in Section VIII, Division 1, of the *ASME Boiler and Pressure Vessel Code.*

Exception: 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 paragraph UG-

129(e) of Section VIII, Division 1, of the *ASME Boiler and Pressure Vessel Code.*[6]

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 Section VIII, Division 1, of the *ASME Boiler and Pressure Vessel Code*.[6]

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 member(s) 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: 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 lowside 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 lowside 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 9.7.8.1.

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 of the pressure-relief device or fusible plug for each pressure vessel shall be determined by the following:

$$C = fDL$$

where

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

D = outside diameter of vessel, ft (m)

TABLE 9.7.5 Relief Devices Capacity Factor

Refrigerant	Value of *f*
When used on the lowside of a limited-charge cascade system:	
R-23, R-170, R-744, R-1150, R-508A, R-508B	1.0 (0.082)
R-13, R-13B1, R-503	2.0 (0.163)
R-14	2.5 (0.203)
Other applications:	
R-718	0.2 (0.016)
R-717	0.5 (0.041)
R-11, R-32, R-113, R-123, R-142b, R-152a, R-290, R-600, R-600a, R-764	1.0 (0.082)
R-12, R-22, R-114, R-124, R-134a, R-401A, R-401B, R-401C, R-405A, R-406A, R-407C, R-407D, R-407E, R-409A, R-409B, R-411A, R-411B, R-411C, R-412A, R-414A, R-414B, R-500, R-1270	1.6 (0.131)
R-143a, R-402B, R-403A, R-407A, R-408A, R-413A	2.0 (0.163)
R-115, R-402A, R-403B, R-404A, R-407B, R-410A, R-410B, R-502, R-507A, R-509A	2.5 (0.203)

f = factor dependent upon type of refrigerant (see Table 9.7.5)

Notes:

1. When combustible materials are used within 20 ft (6.1 m) of a pressure vessel, multiply the value of *f* by 2.5.
2. The formula is based on fire conditions. Other heat sources shall be calculated separately.

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.

9.7.6 The rated discharge capacity of a pressure-relief device expressed in pounds of air per minute (kilograms of air per second) shall be determined in accordance with paragraph UG-131, Section VIII, Division 1, of the *ASME Boiler and Pressure Vessel Code.*[6] 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 pounds of air per minute (kilograms of air per second) shall be determined by the following formulas:

$$C = 0.64 P_1 d^2 \qquad (C = 1.09 \times 10^{-6} P_1 d^2)$$

$$d = 1.25 (C/P_1)^{0.5} \qquad (d = 958.7 (C/P_1)^{0.5})$$

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,

$$P_1 = (\text{rated pressure psig}[\text{kPa gage}] \times 1.10) + 14.7(101.33)$$

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 For systems in which one or more of the following conditions apply, pressure-relief devices and fusible plugs shall discharge to the atmosphere at a location not less than 15 ft (4.57 m) above the adjoining ground level and not less than 20 ft (6.1 m) from any window, ventilation opening, or exit in any building:

a. Any system containing a Group A3 or B3 refrigerant
b. Any system containing more than 6.6 lb (3 kg) of a Group A2, B1, or B2 refrigerant
c. Any system containing more than 110 lb (50 kg) of a Group A1 refrigerant
d. Any system for which a machinery room is required by the provisions of Section 7.4

The discharge shall be terminated in a manner that will prevent both the discharged refrigerant from being sprayed directly on personnel in the vicinity and foreign material or debris from entering the discharge piping. Discharge piping connected to the discharge side of a fusible plug or rupture member shall have provisions to prevent plugging the pipe in the event the fusible plug or rupture member functions.

Exceptions: When R-718 (water) is the only refrigerant, discharge to a floor drain is also acceptable if all of the following three conditions are met:

1. The pressure relief device set pressure does not exceed 15 psig.
2. The floor drain is sized to handle no less than the flow rate from a single broken tube in any refrigerant-containing heat exchanger.
3. Either
   a. 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
   b. 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.

9.7.8.1 The application of pressure-relief valves that discharge from a higher-pressure vessel into a lower-pressure vessel of the system shall comply with (a) through (c) as follows:

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.

9.7.8.2 Ammonia Discharge. Ammonia from pressure-relief valves shall be discharged into one or more of the following:

a. The atmosphere, per Section 9.7.8
b. A tank containing one gallon of water for each pound of ammonia (8.3 litres of water for each kilogram of ammonia) that will be released in one hour from the largest relief device connected to the discharge pipe. The water shall be prevented from freezing. The discharge pipe from the pressure-relief device shall distribute ammonia in the bottom of the tank but no lower than 33 ft (10 m) below the maximum liquid level. The tank shall contain the volume of water and ammonia without overflowing.
c. Other treatment systems that meet the requirements of the AHJ

9.7.8.3 Optional Sulfur Dioxide Discharge. When sulfur dioxide is used, the discharge shall be into a tank of absorptive solution that shall be used for no other purpose except sulfur dioxide absorption. The absorptive solution shall be one gallon of standard dichromate solution (2.5 pounds of sodium dichromate per gallon of water [300 grams of sodium dichromate per litre of water]) for each pound of sulfur dioxide in the system (8.3 litres of standard dichromate solution for each kilogram of sulfur dioxide in the system). Solutions made with caustic soda or soda ash shall not be used in place of sodium dichromate unless the quantity and strength have the equivalent sulfur-dioxide-absorbing power. The tank shall be constructed of not less than 1/8 in. (3.2 mm) or No. 11 US gage iron or steel. The tank shall have a hinged cover or, if of the enclosed type, shall have a vent hole at the top. All pipe connections shall be through the top of the tank only. The discharge pipe from the pressure-relief valve shall discharge the sulfur dioxide in the center of the tank near the bottom.

9.7.8.4 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. Where outlets of two or more relief devices or fusible plugs are connected to a common line or header, the effect of back pressure that will be developed when more than one relief device or fusible plug operates shall be considered. The sizing of the common discharge header downstream from each of the two or more relief devices or fusible plugs that are expected to operate simultaneously shall be based on the sum of their outlet areas with due allowance for the pressure drop in all downstream sections.

9.7.8.5 The maximum length of the discharge piping installed on the outlets of pressure-relief devices and fusible plugs discharging to the atmosphere shall be determined by the method in Normative Appendix D. See Table 9.7.8.5 for the flow capacity of various equivalent lengths of discharge piping for conventional relief valves.

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 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.

Exception: 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)

The relief device(s) 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 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 stage(s) 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 lowside of the stage against overpressure.

Exceptions for (a), (b), and (c): The discharge capacity of the 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.

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 shall be provided on all systems operating above atmospheric pressure, except that a pressure-limiting device is not required on any factory-sealed system containing less than 22 lb (10 kg) of Group A1 refrigerant that has been listed by an approved, nationally recognized testing laboratory and is so identified.

9.9.2 Setting. When required by Section 9.9.1, the maximum setting to which a pressure-limiting device is capable of being readily set by use of the adjusting means provided shall not exceed the design pressure of the highside of a system that is not protected by a pressure-relief device or 90% of the setting of the pressure-relief device installed on the highside of a system. The pressure-limiting device shall stop the action of the pressure-imposing element at a pressure no higher than this maximum setting.

Exception: On systems using nonpositive displacement compressors, the maximum setting of the pressure-limiting device is not required to be less than the design pressure of the highside of the system, provided the pressure-relief device is (a) located in the lowside, (b) subject to lowside pressure, and (c) there is a permanent (unvalved) relief path between the highside and the lowside of the system.

9.9.3 Connection. Pressure-limiting devices shall be connected between the pressure-imposing element and any stop valve on the discharge side. There shall be no intervening stop valves in the line leading to the pressure-limiting device.

9.10 Refrigerant Piping, Valves, Fittings, and Related Parts

9.10.1 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 an approved, nationally recognized laboratory or shall comply with ASME B31.5[8] where applicable.

9.10.2 Refrigerant Parts in Air Duct. Joints and all refrigerant-containing parts 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 leaking into the airstream.

9.11 Components Other than Pressure Vessels and Piping

9.11.1 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 an approved, nationally recognized testing laboratory or shall be designed, constructed, and assembled to have an ultimate strength sufficient to withstand three times the design pressure for which it is rated.

Exception: Water-side components exempted from the rules of Section VIII of the *ASME Boiler and Pressure Vessel Code*[6] shall be designed, constructed, and assembled to have an ultimate strength sufficient to withstand 150 psig (1034 kPa) or two times the design pressure for which it is rated, whichever is greater.

9.11.2 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: Liquid-level-gage glasses of the bull's-eye type

TABLE 9.7.8.5 Pressure-Relief Valve Discharge Line Capacity (lb/min of air) of Various Discharge Line Lengths

Set, psig	Length, ft	Nominal Pipe Size, NPS/DN											Set, psig	Length, ft	Nominal Pipe Size, NPS/DN										
		0.5	0.75	1	1.25	1.5	2	2.5	3	4	5	6			0.5	0.75	1	1.25	1.5	2	2.5	3	4	5	6
		15	20	25	32	40	50	65	80	100	125	150			15	20	25	32	40	50	65	80	100	125	150
5	2	2.8	5.8	10.7	21.3	31.4	57.8	88.8	148.0	278.9	469	704	50	2	7.6	14.7	25.4	46.5	65.3	111.7	162.8	256	451	718	1045
5	3	2.3	4.8	9.0	18.1	26.8	49.9	77.3	130.4	249.8	426	647	50	3	6.8	13.2	23.2	43.4	61.4	106.3	156.1	248	439	704	1027
5	4	2.0	4.2	7.9	16.0	23.7	44.5	69.4	117.8	228.2	393	601	50	4	6.1	12.2	21.6	40.8	58.1	101.6	150.2	240	429	691	1011
5	5	1.8	3.8	7.1	14.4	21.5	40.6	63.5	108.3	211.4	367	564	50	5	5.7	11.3	20.2	38.6	55.2	97.4	144.9	233	419	678	996
5	6	1.7	3.5	6.6	13.3	19.8	37.5	58.9	100.8	197.8	346	533	50	6	5.3	10.6	19.1	36.7	52.8	93.8	140.1	226	410	666	981
5	8	1.5	3.0	5.7	11.6	17.4	33.1	52.0	89.5	177.0	312	484	50	8	4.7	9.5	17.3	33.6	48.7	87.5	131.8	215	393	644	953
5	10	1.3	2.7	5.1	10.5	15.7	29.9	47.1	81.3	161.7	286	446	50	10	4.3	8.7	15.9	31.2	45.5	82.4	124.8	205	378	624	927
5	15	1.1	2.2	4.2	8.6	12.9	24.7	39.2	67.9	135.9	243	380	50	15	3.6	7.4	13.6	26.9	39.6	72.7	113.3	185	347	582	872
5	20	0.9	1.9	3.7	7.5	11.3	21.6	34.2	59.4	119.5	214	337	50	20	3.1	6.5	12.0	24.0	35.5	65.8	101.4	170	323	547	825
5	25	0.8	1.7	3.3	6.7	10.1	19.4	30.8	53.5	107.9	194	306	50	25	2.8	5.9	10.9	21.9	32.4	60.5	93.8	158	303	517	785
5	30	0.8	1.6	3.0	6.2	9.3	17.8	28.2	49.1	99.1	179	282	50	30	2.6	5.4	10.0	20.3	30.1	56.3	87.6	148	286	492	750
5	40	0.7	1.4	2.6	5.3	8.0	15.4	24.5	42.8	86.5	156	247	50	40	2.3	4.7	8.8	17.8	26.6	50.1	78.3	133	260	451	692
5	60	0.5	1.1	2.1	4.4	6.6	12.6	20.1	35.1	71.2	129	205	50	60	1.9	3.9	7.3	14.8	22.1	42.0	66.0	113	224	393	608
5	100	0.4	0.9	1.7	3.4	5.1	9.8	15.6	27.3	55.6	101	160	50	100	1.4	3.0	5.7	11.6	17.4	33.3	52.6	91	182	323	504
5	160	0.3	0.7	1.3	2.7	4.0	7.8	12.4	21.7	44.1	80	127	50	160	1.1	2.4	4.5	9.3	13.9	26.7	42.3	73	148	265	416
5	250	0.3	0.6	1.0	2.1	3.2	6.2	9.9	17.4	35.3	64	102	50	250	0.9	1.9	3.6	7.5	11.2	21.5	34.2	59	120	217	342
15	2	4.6	9.3	16.7	32.0	46.0	81.6	121.8	196.5	355.2	577	849	75	2	9.1	17.2	29.4	53.3	74.3	126.0	182.7	286	501	795	1154
15	3	3.9	8.0	15.5	28.3	41.0	74.0	111.6	182.3	334.5	550	815	75	3	8.2	15.8	27.3	50.4	70.7	121.2	176.9	279	491	783	1140
15	4	3.5	7.1	13.0	25.6	37.4	68.1	103.6	170.8	317.1	526	784	75	4	7.5	14.6	25.7	47.8	67.6	116.9	171.6	272	482	772	1127
15	5	3.1	6.5	11.9	23.6	34.6	63.5	97.1	161.2	302.2	506	757	75	5	7.0	13.7	24.3	45.7	64.8	113.1	166.8	266	474	762	1114
15	6	2.9	6.0	11.0	22.0	32.3	59.7	91.7	153.1	289.2	487	732	75	6	6.5	13.0	23.1	43.7	62.4	109.6	162.3	260	466	751	1101
15	8	2.5	5.2	9.7	19.5	28.9	53.8	83.2	140.0	267.5	455	689	75	8	5.9	11.8	21.1	40.6	58.3	103.4	154.4	249	450	732	1077
15	10	2.3	4.7	8.8	17.8	26.3	49.3	76.7	129.7	250.1	429	683	75	10	5.4	10.8	19.6	38.0	54.9	98.2	147.5	240	437	714	1054
15	15	1.9	3.9	7.3	14.8	22.1	41.7	65.3	111.6	218.0	379	583	75	15	4.5	9.2	16.9	33.2	48.4	88.0	133.7	220	407	675	1004

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

TABLE 9.7.8.5 Pressure-Relief Valve Discharge Line Capacity (lb/min of air) of Various Discharge Line Lengths *(Continued)*

Set, psig	Length, ft	Nominal Pipe Size, NPS/DN										
		0.5	0.75	1	1.25	1.5	2	2.5	3	4	5	6
		15	20	25	32	40	50	65	80	100	125	150
15	20	1.6	3.4	6.4	13.0	19.4	36.8	57.9	99.4	195.8	344	532
15	25	1.5	3.1	5.7	11.7	17.5	33.3	52.5	90.5	179.3	316	492
15	30	1.3	2.8	5.3	10.7	16.1	30.7	48.4	83.6	166.3	295	460
15	40	1.2	2.4	4.6	9.4	14.0	26.8	42.4	73.5	147.1	262	411
15	60	1.0	2.0	3.8	7.7	11.6	22.1	35.1	61.0	122.7	220	347
15	100	0.7	1.5	2.9	6.0	9.0	17.3	27.5	47.9	96.8	175	276
15	160	0.6	1.2	2.3	4.7	7.1	13.7	21.8	38.1	77.3	140	222
15	250	0.5	1.0	1.9	3.8	5.7	11.0	17.5	30.6	62.3	113	179
25	2	5.7	11.3	20.0	37.6	53.5	93.2	137.5	219.2	390.5	628	918
25	3	4.9	9.9	17.8	34.0	48.8	86.5	128.8	207.5	374.4	608	893
25	4	4.4	8.9	16.2	31.3	45.3	81.0	121.6	197.6	360.1	589	869
25	5	4.0	8.2	14.9	29.1	42.3	76.4	115.5	188.9	347.3	572	848
25	6	3.7	7.6	13.9	27.4	39.9	72.6	110.2	181.3	335.8	556	828
25	8	3.3	6.7	12.4	24.6	36.1	66.4	101.5	168.5	315.9	529	791
25	10	3.0	6.1	11.3	22.6	33.3	61.5	94.6	158.1	299.1	505	759
25	15	2.5	5.1	9.5	19.1	28.3	52.9	82.1	138.7	266.6	457	694
25	20	2.1	4.5	8.3	16.8	25.0	47.1	73.5	125.0	242.9	420	643
25	25	1.9	4.0	7.5	15.2	22.7	42.9	67.1	114.7	224.5	391	602
25	30	1.8	3.7	6.9	14.0	20.9	39.6	62.2	106.6	209.8	367	568
25	40	1.5	3.2	6.0	12.2	18.3	34.8	54.9	94.5	187.3	331	514
25	60	1.3	2.6	4.9	10.1	15.1	28.9	45.7	79.1	158.0	281	440
25	100	1.0	2.0	3.8	7.9	11.8	22.7	36.0	62.5	125.8	226	356
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

Set, psig	Length, ft	Nominal Pipe Size, NPS/DN										
		0.5	0.75	1	1.25	1.5	2	2.5	3	4	5	6
		15	20	25	32	40	50	65	80	100	125	150
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

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

TABLE 9.7.8.5 Pressure-Relief Valve Discharge Line Capacity (lb/min of air) of Various Discharge Line Lengths *(Continued)*

Set, psig	Length, ft	Nominal Pipe Size, NPS/DN											Set, psig	Length, ft	Nominal Pipe Size, NPS/DN										
		0.5	0.75	1	1.25	1.5	2	2.5	3	4	5	6			0.5	0.75	1	1.25	1.5	2	2.5	3	4	5	6
		15	20	25	32	40	50	65	80	100	125	150			15	20	25	32	40	50	65	80	100	125	150
150	2	12.5	23.3	39.2	70.1	96.8	162.7	234.5	366	636	1006	1457	300	2	18.4	33.7	56.1	99.4	136.7	228.3	328	510	884	1395	2019
150	3	11.6	21.8	37.2	67.4	93.7	158.5	229.6	360	628	996	1446	300	3	17.3	32.1	54.0	96.0	133.5	224.2	323	504	877	1386	2009
150	4	10.8	20.6	35.5	64.9	90.8	154.7	225.1	354	621	987	1435	300	4	16.4	30.8	52.2	94.1	130.6	220.4	319	498	869	1378	1998
150	5	10.2	19.6	34.0	62.8	88.1	151.2	220.7	348	613	979	1425	300	5	15.6	29.6	50.5	91.7	127.8	216.8	314	493	862	1369	1988
150	6	9.6	18.7	32.7	60.8	85.7	147.8	216.6	343	606	970	1414	300	6	14.9	28.5	49.0	89.6	125.2	213.4	310	488	856	1361	1978
150	8	8.8	17.3	30.5	57.3	81.4	141.8	209.1	333	593	954	1394	300	8	13.8	26.6	46.3	85.6	120.4	206.9	302	478	843	1345	1959
150	10	8.1	16.1	28.7	54.4	77.7	136.5	202.3	324	581	938	1375	300	10	12.8	25.1	44.1	82.2	116.2	201.0	295	468	830	1330	1940
150	15	6.9	14.0	25.2	48.7	70.3	125.4	187.8	304	553	902	1330	300	15	11.2	22.2	39.6	75.1	107.2	188.3	279	447	801	1293	1895
150	20	6.2	12.5	22.8	44.5	64.6	116.6	176.0	288	529	870	1289	300	20	10.0	20.1	36.2	69.6	100.1	177.7	265	428	775	1260	1853
150	25	5.6	11.4	21.0	41.2	60.2	109.4	166.2	274	507	841	1251	300	25	9.2	18.6	33.6	65.2	94.2	168.7	253	412	751	1229	1814
150	30	5.2	10.6	19.5	38.6	56.5	103.4	157.9	261	488	815	1217	300	30	8.5	17.3	31.5	61.5	89.2	160.9	243	397	729	1200	1777
150	40	4.5	9.4	17.3	34.5	50.8	93.9	144.5	241	456	769	1156	300	40	7.5	15.4	28.2	55.6	81.3	148.2	225	372	691	1148	1710
150	60	3.8	7.8	14.5	29.2	43.3	80.8	125.4	212	407	696	1058	300	60	6.3	12.9	23.9	47.7	70.2	129.7	199	333	639	1061	1595
150	100	2.9	6.1	11.5	23.3	34.7	65.6	102.7	175	343	597	918	300	100	4.9	10.3	19.1	38.5	57.2	107.1	167	282	544	934	1422
150	160	2.3	4.9	9.2	18.7	28.0	53.3	84.0	145	286	505	785	300	160	3.9	8.2	15.4	31.3	46.6	88.1	138	236	463	807	1243
150	250	1.9	3.9	7.4	15.2	22.7	43.4	68.6	119	238	423	662	300	250	3.2	6.6	12.5	25.4	38.0	72.3	114	196	389	687	1068
200	2	14.6	26.9	45.0	80.2	110.6	185.2	266.6	415	721	1139	1649	350	2	20.3	37.0	61.4	108.6	149	249	358	556	963	1519	2199
200	3	13.6	25.4	43.1	77.5	107.4	181.2	261.9	409	713	1130	1638	350	3	19.1	35.3	59.3	105.8	146	245	353	550	956	1510	2189
200	4	12.7	24.2	41.3	75.1	104.6	177.4	257.4	404	706	1121	1628	350	4	18.1	33.9	57.4	103.3	143	241	348	544	949	1502	2178
200	5	12.0	23.1	39.8	72.8	101.9	173.9	253.1	398	699	1113	1618	350	5	17.3	32.7	55.7	100.9	140	237	344	539	941	1493	2168
200	6	11.5	22.1	38.4	70.8	99.4	170.6	249.1	393	692	1105	1608	350	6	16.6	31.5	54.1	98.6	137	234	340	534	935	1484	2158
200	8	10.5	20.5	36.0	67.2	95.0	164.5	241.5	383	679	1089	1588	350	8	15.3	29.6	51.3	94.5	132	227	331	523	921	1468	2139
200	10	9.7	19.2	34.0	64.1	91.1	159.0	234.6	374	667	1073	1570	350	10	14.4	28.0	48.9	90.9	128	221	324	514	908	1452	2120
200	15	8.4	16.8	30.2	57.9	83.2	147.3	219.6	354	639	1038	1525	350	15	12.5	24.8	44.1	83.5	119	208	307	492	879	1414	2075

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

TABLE 9.7.8.5 Pressure-Relief Valve Discharge Line Capacity (lb/min of air) of Various Discharge Line Lengths *(Continued)*

Set, psig	Length, ft	Nominal Pipe Size, NPS/DN											Set, psig	Length, ft	Nominal Pipe Size, NPS/DN										
		0.5	0.75	1	1.25	1.5	2	2.5	3	4	5	6			0.5	0.75	1	1.25	1.5	2	2.5	3	4	5	6
		15	20	25	32	40	50	65	80	100	125	150			15	20	25	32	40	50	65	80	100	125	150
200	20	7.5	15.2	27.5	53.2	77.0	137.9	207.2	337	614	1005	1485	350	20	11.3	22.6	40.5	77.6	111	196	293	473	852	1379	2032
200	25	6.8	13.9	24.3	49.5	72.0	130.1	196.6	322	592	967	1447	350	25	10.3	20.8	37.6	72.8	105	187	280	455	827	1347	1992
200	30	6.3	12.9	23.6	46.5	67.9	123.4	187.6	309	572	949	1412	350	30	9.6	19.4	35.3	68.8	99	178	269	440	804	1317	1954
200	40	5.6	11.4	21.1	41.8	61.4	112.8	172.6	287	538	901	1349	350	40	8.5	17.3	31.7	62.4	91	163	250	413	764	1262	1885
200	60	4.6	9.6	17.7	35.5	52.5	97.7	151.1	254	484	823	1245	350	60	7.1	14.6	26.9	53.7	79	145	222	372	699	1170	1765
200	100	3.6	7.5	14.1	28.5	42.4	79.9	124.7	212	413	714	1094	350	100	5.6	11.6	21.6	43.5	64	120	186	316	607	1034	1582
200	160	2.9	6.0	11.3	23.0	34.4	65.2	102.5	176	347	610	944	350	160	4.5	9.3	17.4	35.4	52	99	155	266	519	897	1390
200	250	2.3	4.9	9.1	18.6	27.9	53.3	84.1	145	290	514	802	350	250	3.6	7.5	14.1	28.8	43	81	128	222	438	766	1200
250	2	16.5	30.4	50.7	89.9	123.8	207.0	297.7	463	803	1268	1836	400	2	22.0	40.2	66.6	117.7	161.7	269.6	387	601	1041	1642	2376
250	3	15.5	28.8	48.6	87.2	120.7	203.0	293.0	457	796	1260	1826	400	3	20.9	38.5	64.5	114.8	158.4	265.5	382	595	1034	1633	2366
250	4	14.6	27.5	46.9	84.7	117.8	199.3	288.5	452	789	1251	1815	400	4	19.8	37.0	62.5	112.2	155.3	261.5	378	589	1026	1625	2355
250	5	13.8	26.4	45.2	82.4	115.1	195.7	284.2	446	782	1243	1805	400	5	18.9	35.7	60.7	109.7	152.4	257.7	373	584	1019	1616	2345
250	6	13.2	25.4	43.8	80.3	112.5	192.3	280.2	441	775	1234	1795	400	6	18.2	34.5	59.1	107.4	149.6	254.1	369	578	1012	1608	2335
250	8	12.2	23.6	41.3	76.6	107.9	186.1	272.5	431	762	1219	1776	400	8	16.9	32.5	56.1	103.1	144.5	247.3	360	568	999	1591	2315
250	10	11.3	22.2	39.1	73.3	103.9	180.4	265.4	422	750	1203	1757	400	10	15.8	30.7	53.6	99.3	139.9	241.0	353	558	986	1575	2295
250	15	9.8	19.6	35.0	66.7	95.4	168.2	249.8	401	721	1167	1713	400	15	13.9	27.4	48.5	91.5	130.1	227.1	335	535	955	1537	2249
250	20	8.8	17.7	31.9	61.5	88.7	158.1	236.7	383	696	1135	1672	400	20	12.5	24.9	44.6	85.2	122.0	215.4	320	515	927	1502	2205
250	25	8.0	16.3	29.5	57.5	83.3	149.7	225.5	368	673	1104	1634	400	25	11.4	23.0	41.6	80.1	115.3	205.4	307	497	902	1469	2164
250	30	7.4	15.1	27.6	54.1	78.7	142.5	215.7	354	652	1076	1598	400	30	10.6	21.5	39.0	75.8	109.6	196.6	296	481	878	1438	2125
250	40	6.5	13.4	24.7	48.8	71.5	130.7	199.5	330	616	1026	1533	400	40	9.4	19.2	35.1	68.9	100.4	182.0	276	453	836	1382	2052
250	60	5.4	11.3	20.9	41.7	61.5	114.0	175.6	294	558	944	1423	400	60	7.9	16.2	26.9	59.4	87.2	160.4	246	409	767	1286	1927
250	100	4.3	8.9	16.6	33.6	49.9	93.7	145.9	248	479	826	1261	400	100	6.2	12.9	24.0	48.3	71.5	133.4	207	349	669	1143	1734
250	160	3.4	7.1	13.4	27.2	40.6	76.8	120.5	207	406	710	1096	400	160	5.0	10.4	19.4	39.3	58.5	110.3	173	294	574	996	1529
250	250	2.7	5.8	10.8	22.1	33.0	62.9	99.2	171	340	602	937	400	250	4.0	8.4	15.7	32.0	47.9	90.9	143	246	468	854	1324

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

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

9.11.4 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).

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.

9.12 Service Provisions

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

9.12.2 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.

9.12.3 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.

9.12.4 Systems containing more than 6.6 lb (3 kg) of refrigerant shall have stop valves installed at

a. the suction inlet of each compressor, compressor unit, or condensing unit;
b. the discharge of each compressor, compressor unit, or condensing unit; and
c. the outlet of each liquid receiver.

Exception: Systems that have a refrigerant pumpout function capable of storing the entire refrigerant charge, or are equipped with the provisions for pumpout of the refrigerant, or self-contained systems

9.12.5 Systems containing more than 110 lb (50 kg) of refrigerant shall have stop valves installed at

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 inlet of each liquid receiver, except for self-contained systems or where the receiver is an integral part of the condenser or condensing unit;
d. the outlet of each liquid receiver; and
e. the inlets and outlets of condensers when more than one condenser is used in parallel in the system.

Exception: Systems that have a refrigerant pumpout function capable of storing the entire refrigerant charge, or are equipped with the provisions for pumpout of the refrigerant, or self-contained systems

9.12.6 Stop valves shall be suitably labeled if the components to and from which the valve regulates flow are not in view at the valve location. Valves or piping adjacent to the valves shall be identified in accordance with ANSI A13.1.[9] When numbers are used to label the valves, there shall be a key to the numbers located within sight of the valves with letters at least 0.5 in. (12.7 mm) high.

9.13 Fabrication

9.13.1 The following are requirements for unprotected refrigerant-containing copper pipe or tubing:

a. Copper tubing used for refrigerant piping shall conform to one of the following ASTM specifications: B88[10] types K or L or B280.[11] Where ASTM B68[12] and B75[13] tubing is used, the tube wall thickness shall meet or exceed the requirements of ASTM B280[11] for the given outside diameter.
b. Copper tube shall be connected by brazed joints, soldered joints, or compression fittings.
c. For Group A2, A3, B1, B2, and B3 refrigerants, protective metal enclosures shall be provided for annealed copper tube erected on the premises.

Exception: No enclosures shall be required for connections between a condensing unit and the nearest protected riser if such connections are not longer than 6.6 ft (2 m) in length.

9.13.2 Joints on refrigerant-containing copper tube that are made by the addition of filler metal shall be brazed.

Exception: A1 refrigerants

9.14 Factory Tests

9.14.1 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.

9.14.1.1 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:

1. Mixtures of dry nitrogen, inert gases, nonflammable refrigerants allowed for factory tests.
2. Mixtures of dry nitrogen, inert gases, or a combination of them with flammable refrigerants in concentrations not exceeding the lesser of a refrigerant weight fraction (mass fraction) of 5% or 25% of the 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.

9.14.2 The test pressure applied to the highside of each factory-assembled refrigerating system shall be at least equal to the design pressure of the highside. The test pressure applied to the lowside of each factory-assembled refrigerating system shall be at least equal to the design pressure of the lowside.

The pressure test on the complete unit shall not be conducted at the lowside design pressure per Section 9.2 unless the final assembly connections are made per ASME B31.5.[8] In this case, parts shall be individually tested by either the unit manufacturer or the manufacturer of the part at not less than the highside design pressure.

9.14.3 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 lowside design pressure.

9.15 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 Table 4-1 or 4-2 of ASHRAE Standard 34.[1]

10. OPERATION AND TESTING

10.1 Field Tests

10.1.1 Every refrigerant-containing part of every system that is erected on the premises, except compressors, condensers, evaporators, safety devices, pressure gages, control mechanisms, and systems that are factory-tested, shall be tested and proved tight after complete installation and before operation. The highside and lowside of each system shall be tested and proved tight at not less than the lower of the design pressure or the setting of the pressure-relief device protecting the highside or lowside of the system, respectively.

10.1.2 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:

1. Mixtures of dry nitrogen, inert gases, or a combination of them with nonflammable refrigerants in concentrations of a refrigerant weight fraction (mass fraction) not exceeding 5% are allowed for tests.
2. Mixtures of dry nitrogen, inert gases, or a combination of them with flammable refrigerants in concentrations not exceeding the lesser of a refrigerant weight fraction (mass fraction) of 5% or 25% of the LFL are allowed for tests.
3. Compressed air without added refrigerant is allowed for 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.
4. Systems erected on the premises using Group A1 refrigerant and with copper tubing not exceeding 0.62 in. (16 mm) outside diameter shall be tested by means of the refrigerant charged into the system at the saturated vapor pressure of the refrigerant at 68°F (20°C) minimum.

10.2 Declaration. A dated declaration of test shall be provided for all systems containing 55 lb (25 kg) or more of refrigerant. The declaration shall give the name of the refrigerant and the field test pressure applied to the highside and the lowside of the system. The declaration of test shall be signed by the installer and, if an inspector is present at the tests, the inspector shall also sign the declaration. When requested, copies of this declaration shall be furnished to the AHJ.

11. GENERAL REQUIREMENTS

11.1 General Restrictions—Safeguards. Means shall be taken to adequately safeguard piping, controls, and other refrigerating equipment to minimize possible accidental damage or rupture by external sources.

11.2 Signs and Identification

11.2.1 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.

11.2.2 Controls and Piping Identification. Systems containing more than 110 lb (50 kg) of refrigerant shall be provided with durable signs having letters not less than 0.5 in. (12.7 mm) in height designating

a. valves or switches for controlling the refrigerant flow, the ventilation, and the refrigeration compressor(s); and
b. the kind of refrigerant or secondary coolant contained in exposed piping outside the machinery room. Valves or piping adjacent to valves shall be identified[14] in accordance with *ANSI A13.1, Scheme for Identification of Piping Systems*.[9]

11.2.3 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 11.2.1 and 11.2.2 shall be replaced, or added if not present, to identify the refrigerant and lubricant used.

11.2.4 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 11.7 when the refrigerant alarm, required by Section 8.11.2.1, has been activated.

11.3 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.

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

11.4 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.

11.5 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 9.7 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.

11.6 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.

11.6.1 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.

11.6.2 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.

11.6.3 Periodic Tests. Detector(s), alarm(s), and mechanical ventilating systems shall be tested in accordance with manufacturers' specifications and the requirements of the jurisdiction having authority.

11.7 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 8.11.2.1 has been activated except by persons provided with the appropriate respiratory and other protective equipment and trained in accordance with jurisdictional requirements.

12. 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.

13. LISTED EQUIPMENT

Equipment listed by an approved, 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.

(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 INFORMATIVE REFERENCES

This appendix contains full citations for informative references only. Full citations for normative references are listed in Normative Appendix B. 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. Not an informative reference.
2. ANSI/ASHRAE Standard 147-2013*, Reducing the Release of Halogenated Refrigerants from Refrigerating and Air-Conditioning Equipment and Systems.* Atlanta: ASHRAE.
3. Not an informative reference.
4. Not an informative reference.
5. Not an informative reference.
6. Not an informative reference.
7. 2013 *ASHRAE Handbook—Fundamentals*. Atlanta: ASHRAE.
8. Not an informative reference.
9. Not an informative reference.
10. Not an informative reference.
11. Not an informative reference.
12. Not an informative reference.
13. Not an informative reference.
14. IIAR Bulletin 114*, Guidelines for Identification of Ammonia Refrigeration Piping and System Components*. Arlington, VA: International Institute of Ammonia Refrigeration.
15. *NIST REFPROP, Standard Reference Database 23*, Version 9.1, (2013), National Institute of Standards and Technology, Gaithersburg, MD.
16. *IUPAC Atomic Weights of the Elements 2011*, International Union of Pure and Applied Chemistry, Research Triangle Park, NC.

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

NORMATIVE APPENDIX B NORMATIVE REFERENCES

This appendix contains full citations for normative references. Full citations for references that are solely informative are included in Informative Appendix A. Note that in some locations within the standard, normative references are also used as informative references. 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. *ANSI/ASHRAE Standard 34-2001, Designation and Safety Classification of Refrigerants*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA 30329.
2. Not a normative reference.
3. *ARI 700-1999, Specifications for Flourocarbon Refrigerants* and *ARI Standard 700c-1999, Appendix C to ARI Standard 700—Analytical Procedures for ARI Standard 700-99*, Air-Conditioning and Refrigeration Institute, 4100 North Fairfax Drive, Arlington, VA 22203.
4. *UL 1995-1995 Heating and Cooling Equipment*, Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.
5. *NFPA 70-2002, National Electrical Code®*, National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02269-9101.
6. *ANSI/ASME Boiler and Pressure Vessel Code*, Section VIII, Rules for Construction of Pressure Vessels, Division 1, 2001, American Society of Mechanical Engineers (ASME), 3 Park Avenue, New York, NY 10016-5990.

Note: Reference 6 is mandatory for designers, manufacturers, and producers of refrigeration equipment. For all other users, this reference is informative.

7. Not a normative reference.
8. *ANSI//ASME B31.5-2001, Refrigeration Piping and Heat Transfer Components*, American Society of Mechanical Engineers (ASME), 3 Park Avenue, New York, NY 10016.

Note: Reference 8 is mandatory for designers, manufacturers, and producers of refrigeration equipment. For all other users, this reference is informative.

9. *ANSI/ASME A13.1-1996, Scheme for the Identification of Piping Systems*, American Society of Mechanical Engineers (ASME), 3 Park Avenue, New York, NY 10016-5990.
10. *ANSI/ASTM B88-99e1, Standard Specification for Seamless Copper Water Tube*, American Society for Testing and Materials (ASTM), 100 Barr Harbor Drive, West Conshohocken, PA 19428.
11. *ANSI/ASTM B280-99e1, Standard Specification for Seamless Copper Tube for Air Conditioning and Refrigeration Field Service*, American Society for Testing and Materials (ASTM),100 Barr Harbor Drive, West Conshohocken, PA 19428.
12. *ANSI/ASTM B68-99, Standard Specification for Seamless Copper Tube, Bright Annealed*, American Society for Testing and Materials (ASTM), 100 Barr Harbor Drive, West Conshohocken, PA 19428.
13. *ANSI/ASTM B75-99, Standard Specification for Seamless Copper Tube*, American Society for Testing and Materials (ASTM), 100 Barr Harbor Drive, West Conshohocken, PA 19428.
14. Not a normative reference.
15. Not a normative reference.
16. Not a normative reference.

(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 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:††

$$W_r = \frac{Q \cdot PL \cdot \eta_v}{v_g} \qquad \text{(C-1)}$$

where

W_r = mass flow of refrigerant, lb_m/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 (m^3/kg)

Next, find the relieving capacity in mass flow of air, W_a, for an ASME-rated (Reference 6 in Normative Appendix B) pressure-relief device:

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

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

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

†† Section 9.8 permits the discharge capacity of the 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.

TABLE C-1 Constants for Calculating Discharge Capacity

Refrigerant	k*	Molar Mass†	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-717	1.422	17.0	358.0	1.28
R-718	1.328	18.0	349.6	1.28
R-744	2.690	44.0	437.0	0.65

* Source: *NIST Refprop, Standard Reference Database 23*, Version 7, 2002.[15]
† Source: *IUPAC Atomic Weights*, 2003.[16]

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

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 relief device for an ammonia (R-717) screw compressor with a swept volume, Q, of 1665 ft^3/min (0.7858 m^3/s). The compressor is equipped with capacity control that is actuated at 90% of the pressure relief device set pressure to its minimum regulated flow of 10%.

$$Q = 1665 \text{ ft}^3\text{/min} \quad \text{(I-P)}$$

$$Q = 0.7858 \text{ m}^3\text{/s} \quad \text{(SI)}$$

$$\eta_v = 0.90\text{, assumed}$$

$$PL = 0.1$$

$$v_g = 3.2997 \text{ ft}^3\text{/lb}_\text{m} \quad \text{(I-P)}$$

$$v_g = 0.206 \text{ m}^3\text{/kg} \quad \text{(SI)}$$

$$W_r = \frac{1665\dfrac{\text{ft}^3}{\text{min}} \cdot 0.1 \cdot 0.9}{3.2997\dfrac{\text{ft}^3}{\text{lb}_\text{m}}} = 45.4\frac{\text{lb}_\text{m}}{\text{min}} \quad \text{(I-P [see C-1])}$$

$$W_r = \frac{0.7858\dfrac{\text{m}^3}{\text{s}} \cdot 0.1 \cdot 0.9}{0.206\dfrac{\text{m}^3}{\text{kg}}} = 0.343\frac{\text{kg}}{\text{s}} \quad \text{(SI)}$$

$$W_a = W_r \cdot r_w = 45.4 \cdot 1.28 = 58.1\frac{\text{lb}_\text{m}}{\text{min}} \text{ of air} \quad \text{(I-P [see C-2])}$$

$$W_a = W_r \cdot r_w = 0.343 \cdot 1.28 = 0.439\frac{\text{kg}}{\text{s}} \text{ of air} \quad \text{(SI)}$$

Converting to standard cubic feet per minute (SCFM), where V_a = specific volume of air = 13.1 ft^3/lb$_\text{m}$ (0.818 m^3/kg) for dry air at 60°F (15.6°C):

$$\text{SCFM} = 13.1(58.1) = 761 \text{ ft}^3\text{/min} \quad \text{(I-P)}$$

$$\text{SCFM} = 0.818(0.439) = 0.359 \text{ m}^3\text{/s} \quad \text{(SI)}$$

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

NORMATIVE APPENDIX D ALLOWABLE EQUIVALENT LENGTH OF DISCHARGE PIPING

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 by Equation D-1 (I-P or SI). See Table 9.7.8.5 for the flow capacity of various equivalent lengths of discharge piping for conventional relief valves.

$$L = \frac{0.2146 d^5 (P_0^2 - P_2^2)}{f C_r^2} - \frac{d^* \ln(P_0/P_2)}{6f} \quad \text{(D-1 [I-P])}$$

$$L = \frac{7.4381 \times 10^{-15} d^5 (P_0^2 - P_2^2)}{f C_r^2} - \frac{d^* \ln(P_0/P_2)}{500f} \quad \text{(D-1 [SI])}$$

where

L = equivalent length of discharge piping, ft (m)

C_r = rated capacity as stamped on the relief device in lb/min (kg/s), or in SCFM 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 (see typical values in Table D-1)

d = inside diameter of pipe or tube, in. (mm)

ln = natural logarithm

P_2 = absolute pressure at outlet of discharge piping, psi (kPa)

P_0 = allowed back pressure (absolute) at the outlet of pressure relief device, psi (kPa)

For the allowed back pressure (P_0), use the percent of set pressure specified by the manufacturer, or, when the allowed back pressure is not specified, use the following values, where P is the set pressure:

- for conventional relief valves, 15% of set pressure, $P_0 = (0.15\ P)$ + atmospheric pressure
- for balanced relief valves, 25% of set pressure, $P_0 = (0.25\ P)$ + atmospheric pressure
- for rupture members, fusible plugs, and pilot operated relief valves, 50% of set pressure, $P_0 = (0.50\ P)$ + atmospheric pressure

Note: For fusible plugs, P is 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, psi (kPa), and atmospheric pressure is at the elevation of the installation above sea level. A default value is the atmospheric pressure at sea level, 14.7 psi (101.325 kPa).

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	**DN**	**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 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 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 8.11.2.1 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.

E1. ALARM LEVELS

A refrigerant level above the TLV-TWA activates the alarms required by Section 8.11.2.1. 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 TLV-TWA 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 TLV-TWA.

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 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 8.11.2.1 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.)

E2. ALTERNATE REFRIGERANT LEVEL MEASUREMENTS

The required alarms signal only that refrigerant was detected at concentrations above the TLV-TWA. Some facilities may find it useful to have multiple levels of alarms 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 8.11.2.1. 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.

E3. 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 pre-positioned 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.

E4. 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 8.11.2.1, along with signage warning "Authorized Personnel Only. Stay Out When Refrigerant Alarm Sounds; Call Facilities Management Immediately"; This alarm triggers at the TLV-TWA.

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 8.11.2.1.

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 F
ADDENDA DESCRIPTION INFORMATION

TABLE F-1 Addenda Description Information

Addendum	Section(s) Affected	Description of Change(s)*	ASHRAE Standards Committee Approval	ASHRAE BOD Approval	ANSI Approval
b	Section 8.11.4	This addendum clarifies the location requirements for machinery room mechanical ventilation.	January 21, 2012	January 25, 2012	January 26, 2012
c	Section 3	This addendum clarifies that design pressure is expressed in terms of relative pressure or gauge pressure (not absolute pressure).	January 21, 2012	January 25, 2012	January 26, 2012
d	Section 11.3	This addendum is intended to more closely harmonize Standard 15 with the 2012 International Mechanical Code (IMC) section 1101.10.	January 21, 2012	January 25, 2012	January 26, 2012
e	Appendix A	This addendum removes an obsolete Appendix from Standard 15, pertaining to calculating allowable concentration for refrigerant blends.	January 21, 2012	January 25, 2012	January 26, 2012
f	Section 8.13	This addendum removes obsolete information from Standard 15-2010, as follow-up to the removal of Standard 15-2007 Appendix B ("Guidelines For Emergency Discharge of Refrigerants when Required by Local Codes").	January 21, 2012	January 25, 2012	January 26, 2012

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

NOTE

When addenda, interpretations, or errata to this standard have been approved, they can be downloaded free of charge from the ASHRAE Web site at http://www.ashrae.org.

NOTICE

INSTRUCTIONS FOR SUBMITTING A PROPOSED CHANGE TO THIS STANDARD UNDER CONTINUOUS MAINTENANCE

This standard is maintained under continuous maintenance procedures 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. SSPC consideration will be given to proposed changes within 13 months of receipt by the manager of standards (MOS).

Proposed changes must be submitted to the MOS in the latest published format available from the MOS. However, the MOS may accept proposed changes in an earlier published format if the MOS concludes that the differences are immaterial to the proposed change submittal. If the MOS concludes that a current form must be utilized, the proposer may be given up to 20 additional days to resubmit the proposed changes in the current format.

ELECTRONIC PREPARATION/SUBMISSION OF FORM FOR PROPOSING CHANGES

An electronic version of each change, which must comply with the instructions in the Notice and the Form, is the preferred form of submittal to ASHRAE Headquarters at the address shown below. The electronic format facilitates both paper-based and computer-based processing. Submittal in paper form is acceptable. The following instructions apply to change proposals submitted in electronic form.

Use the appropriate file format for your word processor and save the file in either a recent version of Microsoft Word (preferred) or another commonly used word-processing program. Please save each change proposal file with a different name (for example, "prop01.doc," "prop02.doc," etc.). If supplemental background documents to support changes submitted are included, it is preferred that they also be in electronic form as word-processed or scanned documents.

For files submitted attached to an e-mail, ASHRAE will accept an electronic signature (as a picture; *.tif, or *.wpg) on the change submittal form as equivalent to the signature required on the change submittal form to convey non-exclusive copyright.

Submit an e-mail containing the change proposal files to:
change.proposal@ashrae.org

Alternatively, mail paper versions to:
ASHRAE
Manager of Standards
1791 Tullie Circle, NE
Atlanta, GA 30329-2305

Or fax them to:
Attn: Manager of Standards
404-321-5478

The form and instructions for electronic submittal may be obtained from the Standards section of ASHRAE's Home Page, www.ashrae.org, or by contacting a Standards Secretary via phone (404-636-8400), fax (404-321-5478), e-mail (standards.section@ashrae.org), or mail (1791 Tullie Circle, NE, Atlanta, GA 30329-2305).

FORM FOR SUBMITTAL OF PROPOSED CHANGE TO AN ASHRAE STANDARD UNDER CONTINUOUS MAINTENANCE

NOTE: Use a separate form for each comment. Submittals (Microsoft Word preferred) may be attached to e-mail (preferred), or submitted in paper by mail or fax to ASHRAE, Manager of Standards, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: change.proposal@ashrae.org. Fax: +1-404/321-5478.

1. Submitter:

Affiliation:

Address: City: State: Zip: Country:

Telephone: Fax: E-Mail:

I hereby grant ASHRAE the non-exclusive royalty rights, including non-exclusive rights in copyright, in my proposals. I understand that I acquire no rights in publication of the standard in which my proposals in this or other analogous form is used. I hereby attest that I have the authority and am empowered to grant this copyright release.

Submitter's signature: ____ Date: ____________________________

All electronic submittals must have the following statement completed:

I *(insert name)*____, through this electronic signature, hereby grant ASHRAE the non-exclusive royalty rights, including non-exclusive rights in copyright, in my proposals. I understand that I acquire no rights in publication of the standard in which my proposals in this or other analogous form is used. I hereby attest that I have the authority and am empowered to grant this copyright release.

2. Number and year of standard:

3. Page number and clause (section), subclause, or paragraph number:

4. I propose to: [ ] Change to read as follows [ ] Delete and substitute as follows
(check one) [ ] Add new text as follows [ ] Delete without substitution

Use underscores to show material to be added (added) and strike through material to be deleted (~~deleted~~). Use additional pages if needed.

5. Proposed change:

6. Reason and substantiation:

7. Will the proposed change increase the cost of engineering or construction? If yes, provide a brief explanation as to why the increase is justified.

[ ] Check if additional pages are attached. Number of additional pages: _______

[ ] Check if attachments or referenced materials cited in this proposal accompany this proposed change. Please verify that all attachments and references are relevant, current, and clearly labeled to avoid processing and review delays. *Please list your attachments here:*

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.

ASHRAE · 1791 Tullie Circle NE · Atlanta, GA 30329 · www.ashrae.org

About ASHRAE

ASHRAE, founded in 1894, is an international building technology society with more than 50,000 members worldwide. The Society and its members focus on building systems, energy efficiency, indoor air quality, refrigeration, and sustainability. Through research, standards writing, publishing, certification and continuing education, ASHRAE shapes tomorrow's built environment today.

For more information or to become a member of ASHRAE, visit www.ashrae.org.

To stay current with this and other ASHRAE standards and guidelines, visit www.ashrae.org/standards.

Visit the ASHRAE Bookstore

ASHRAE offers its standards and guidelines in print, as immediately downloadable PDFs, on CD-ROM, and via ASHRAE Digital Collections, which provides online access with automatic updates as well as historical versions of publications. Selected standards are also offered in redline versions that indicate the changes made between the active standard and its previous version. For more information, visit the Standards and Guidelines section of the ASHRAE Bookstore at www.ashrae.org/bookstore.

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.

Addenda, errata, and interpretations for ASHRAE standards and guidelines are no longer distributed with copies of the standards and guidelines. ASHRAE provides these addenda, errata, and interpretations only in electronic form to promote more sustainable use of resources.

Product code: 86021 11/13

STANDARD

ANSI/ASHRAE Standard 34-2013
(Supersedes ANSI/ASHRAE Standard 34-2010)
Includes ANSI/ASHRAE addenda listed in Appendix H

Designation and Safety Classification of Refrigerants

See Appendix H for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, 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. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE website (www.ashrae.org) or in paper form from the Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from the ASHRAE website (www.ashrae.org) or from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 678-539-2129. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

 ISSN 1041-2336

Approved American National Standard

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 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.

DISCLAIMER

ASHRAE uses its best efforts to promulgate Standards and Guidelines for the benefit of the public in light of available information and accepted industry practices. However, ASHRAE does not guarantee, certify, or assure the safety or performance of any products, components, or systems tested, installed, or operated in accordance with ASHRAE's Standards or Guidelines or that any tests conducted under its Standards or Guidelines will be nonhazardous or free from risk.

ASHRAE INDUSTRIAL ADVERTISING POLICY ON STANDARDS

ASHRAE Standards and Guidelines are established to assist industry and the public by offering a uniform method of testing for rating purposes, by suggesting safe practices in designing and installing equipment, by providing proper definitions of this equipment, and by providing other information that may serve to guide the industry. The creation of ASHRAE Standards and Guidelines is determined by the need for them, and conformance to them is completely voluntary.

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 34-2013, Designation and Safety Classification of Refrigerants

SECTION **PAGE**

NOTE

Approved addenda, errata, or interpretations for this standard can be downloaded free of charge from the ASHRAE Web site 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

ANSI/ASHRAE Standard 34-2013, Designation and Safety Classification of Refrigerants*, is the latest edition of Standard 34, which describes a shorthand way of naming refrigerants and assigns safety classifications and refrigerant concentration limits based on toxicity and flammability data.*

The 2013 edition combines Standard 34-2010 and the 36 approved and published addenda to the 2010 edition. More specific information on the content of each addendum and its approval date is included in Informative Appendix H of this standard.

First published in 1957 as an ASRE standard, ASHRAE Standard 34 is now updated on a regular basis using ASHRAE's continuous maintenance procedures. According to these procedures, Standard 34 is continuously revised—often several times a year—by addenda that are publicly reviewed, approved by ASHRAE and ANSI, and published on the ASHRAE website. Because the standard changes as new addenda are published, users are encouraged to sign up for the free Internet listserve for the ASHRAE Standards Actions publication, 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 all of the published addenda.

Application guidance for designation, flammability, and toxicity is available on the ASHRAE website at http://sspc34.ashraepcs.org.

Among the key changes incorporated into the 2013 edition are the following:

- *Fourteen refrigerants added to Table 4-2 and one to Table 4-1.*
- *Changed the RCL values of five refrigerants in Table 4-2 and one refrigerant in Table 4-1 that did not comply with the flammability test methodology of the standard.*
- *Added missing RCL data for one refrigerant in Table 4-1 and corrected significant figures for RCL data for four refrigerants in Tables 4-1 and 4-2.*
- *Changed the flammability safety classifications of four refrigerants in Table 4-1 from Class 2 to Subclass 2L, based on optional burning velocity measurement data.*
- *Changed the cardiac sensitization NOEL and LOEL values for R-32 in Table E-1 based on more recent acceptable GLP methodology; subsequently, the RCL values for thirteen refrigerant blends containing R-32 were changed in Table 4-2.*
- *Added Toxicity Code Classification assignments for two refrigerants in Table 4-1 and sixteen refrigerants in Table 4-2 that had been unassigned in Standard 34-2010.*
- *Modified the language in Section 6.1.2, Toxicity Class A and B, to clarify the intent based on OEL.The OEL of one refrigerant was changed.*
- *Modified the definitions of LOEL and NOEL for consistency as applied in this standard.*
- *Modified the definition of WEEL to allow the possibility of a ceiling value and provided a reference citation.*
- *Deleted the provisional status of RCL values for eleven refrigerants in Tables 4-1 and 4-2; subsequently, deleted footnote (d) in Table 4-1 and footnote (e) in Table 4-2 of Standard 34-2010.*
- *Defined acceptable methodology for experimental verification of computer or mathematical models used to identify the WCFF fractionated compositions for flammability testing and also clarified flammability test apparatus to be used for Class 1 or Class 2 refrigerants.*
- *Changed the methodology by which the heat of combustion shall be calculated under various reaction stoichiometry conditions for refrigerant blends. Heat of combustion calculation example for refrigerant blends and component input data table are provided in Informative Appendix F.*
- *Defined requirements applicants shall provide as evidence of the existence of an azeotropic blend within the intended application range if requesting an R-500 series designation.*
- *Modified sections of the standard to add bubble-point and dew-point definitions and test conditions, clarified applicant documentation requirements related to GLP compliance, and added critical pressure data and specific volume calculation methodology for applicant submissions.*

Users of the standard are encouraged and invited to use the continuous maintenance procedure to suggest changes for further improvements. A form for submitting proposed changes to the standard is included at the back of this edition. The project committee for Standard 34 will take formal action on all proposals received.

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 OF TERMS

acute toxicity: the adverse health effect(s) 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 of the 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 effect(s) 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.

EC_{50} (effective concentration 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 Section B1.1 (in Normative Appendix B) 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 (for determining flammability according to Normative Appendix B): any combustion that moves upward and outward from the point of ignition as defined in Section B1.8 in 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 component(s) or condensation of the less volatile component(s).

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, or fluorine; hydrogen also may be present.

heat of combustion (HOC): the heat released when a substance is combusted, determined as the difference in the enthalpy between the reactants (refrigerant[s] and air) and their products after combustion as defined in Section 6.1.3.5. 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 hour (or less if death occurs within 1 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.

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.

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.

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.

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, AIHA 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.

ppm: parts per million.

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.

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 molecular mass: the ratio of the mass of a molecule to 1/12 of that of carbon-12. The relative molecular 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 pre-existing 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] (This definition 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] (This definition reprinted by permission of 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 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 atom(s) is/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 occupational exposure limit set by the American Industrial Hygiene Association (AIHA).[5] 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. 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 component(s) 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).

4. NUMBERING OF REFRIGERANTS

An identifying number shall be assigned to each refrigerant. Reference C1 in Informative Appendix C provides background on the need for a standard refrigerant nomenclature. Assigned numbers are shown in Tables 4-1 and 4-2.

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 The number of chlorine (Cl) atoms in the compound is found by subtracting the sum of fluorine (F), bromine (Br), 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 mono-unsaturated and cyclic-saturated refrigerants.

4.1.7 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.

4.1.8 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 unsymmetrical, 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. For an example of this system, see Informative Appendix A.

4.1.9 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. An example of this system is given in Informative Appendix A.

4.1.10 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 4.1.9:

$=CCl_2$	a
$=CClF$	b
$=CF_2$	c
$=CHCl$	d
$=CHF$	e
$=CH_2$	f

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). An example of this system is given in Table A-3 of Informative Appendix A.

4.1.11 Extension to Compounds of Four Carbon Atoms. Compounds are coded according to the above-stated rules 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 4.1.9. Carbon atoms with two hydrogens or halogens are lettered as in Section 4.1.9. 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, a side group(s) is/are given its/their letter(s) 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.

4.1.12 Bromine-containing, propane-series isomers cannot be uniquely designated by 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).

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 4.1.7.

4.3.2.1 The position(s) of the ether oxygen(s) 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 4.1.9 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 designate 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 in serial order of assignment. An example of a zeotrope would be R-401A and an example of an azeotrope would be R-508A.

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.

4.5 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 group(s) attached to the longest carbon chain as indicated below. For example, R-601a is assigned for 2-methylbutane (isopentane) and R-601b would be assigned for 2,2-dimethylpropane (neopentane).

Attached Group(s)	Suffix
none (straight chain)	No suffix
2-methyl-	a
2,2-dimethyl-	b
3-methyl-	c
2,3-dimethyl-	d
3,3-dimethyl-	e

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/Mcf)	RCL[c] (g/m³)	Highly Toxic or Toxic[d] Under Code Classification
Methane Series								
11	trichlorofluoromethane	CCl_3F	C1000	A1	1100	0.39	6.2	Neither
12	dichlorodifluoromethane	CCl_2F_2	1000	A1	18,000	5.6	90	Neither
12B1	bromochlorodifluoromethane	$CBrClF_2$						Neither
13	chlorotrifluoromethane	$CClF_3$	1000	A1				Neither
13B1	bromotrifluoromethane	$CBrF_3$	1000	A1				Neither
14[e]	tetrafluoromethane (carbon tetrafluoride)	CF_4	1000	A1	110,000	25	400	Neither
21	dichlorofluoromethane	$CHCl_2F$		B1				Toxic
22	chlorodifluoromethane	$CHClF_2$	1000	A1	59,000	13	210	Neither
23	trifluoromethane	CHF_3	1000	A1	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	Neither
40	chloromethane (methyl chloride)	CH_3Cl		B2				Toxic
41	fluoromethane (methyl fluoride)	CH_3F						Neither
50	methane	CH_4	1000	A3				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
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	Neither
142b	1-chloro-1,1-difluoroethane	CH_3CClF_2	1000	A2	20,000	5.1	83	Neither
143a	1,1,1-trifluoroethane	CH_3CF_3	1000	A2L	21,000	4.5	70	Neither
152a	1,1-difluoroethane	CH_3CHF_2	1000	A2	12,000	2.0	32	Neither
170	ethane	CH_3CH_3	1000	A3	7000	0.54	8.7	Neither
Ethers								
E170	methoxymethane (dimethyl ether)	CH_3OCH_3	1000	A3	8500	1.0	16	Neither
Propane								
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

a. The chemical name and chemical formula are not part of this standard. Chemical names conform to IUPAC nomenclature[14,15] 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 J.M. Calm, "ARTI Refrigerant Database," Air- Conditioning and Refrigeration Technology Institute (ARTI), Arlington, VA, July 2001; J.M. Calm, "Toxicity Data to Determine Refrigerant Concentration Limits," Report DE/CE 23810-110, Air- Conditioning and Refrigeration Technology Institute (ARTI), Arlington, VA, September 2000; J.M. Calm, "The Toxicity of Refrigerants," *Proceedings of the 1996 International Refrigeration Conference*, Purdue University, West Lafayette, IN, pp. 157–62, 1996; D.P. Wilson and R.G. Richard, "Determination of Refrigerant Lower Flammability Limits (LFLs) in Compliance with Proposed Addendum p to ANSI/ASHRAE Standard 34-1992 (1073-RP)," *ASHRAE Transactions* 2002, 108(2); D.W. Coombs, "HFC-32 Assessment of Anesthetic Potency in Mice by Inhalation," Huntingdon Life Sciences Ltd., Huntingdon, Cambridgeshire, England, February 2004 and amendment February 2006; D.W. Coombs, "HFC-22 An Inhalation Study to Investigate the Cardiac Sensitization Potential in the Beagle Dog," Huntingdon Life Sciences Ltd., Huntingdon, Cambridgeshire, England, August 2005; and other toxicity studies.

d. *Highly toxic*, *toxic*, or *neither*, where *highly toxic* and *toxic* are as defined in the *International Fire Code*, *Uniform Fire Code*, 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/Mcf)	RCL[c] (g/m^3)	Highly Toxic or Toxic[d] Under Code Classification
Propane *(continued)*								
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	0.56	9.5	Neither
Cyclic Organic Compounds								
C318	octafluorocyclobutane	$-(CF_2)_4-$	1000	A1	80,000	41	660	Neither
Miscellaneous Organic Compounds								
hydrocarbons								
600	butane	$CH_3CH_2CH_2CH_3$	1000	A3	1000	0.15	2.4	Neither
600a	2-methylpropane (isobutane)	$CH(CH_3)_2CH_3$	1000	A3	4000	0.59	9.6	Neither
601	pentane	$CH_3CH_2CH_2CH_2CH_3$	600	A3	1000	0.18	2.9	Neither
601a	2-methylbutane (isopentane)	$(CH_3)_2CHCH_2CH_3$	600	A3	1000	0.18	2.9	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	Neither
718	water	H_2O		A1				Neither
720	neon	Ne		A1				Neither
728	nitrogen	N_2		A1				Neither
732	oxygen	O_2						Neither
740	argon	Ar		A1				Neither
744	carbon dioxide	CO_2	5000	A1	40,000	4.5	72	Neither
744A	nitrous oxide	N_2O						Neither
764	sulfur dioxide	SO_2		B1				Neither
Unsaturated Organic Compounds								
1150	ethene (ethylene)	$CH_2=CH_2$	200	A3				Neither
1234yf	2,3,3,3-tetrafluoro-1-propene	$CF_3CF=CH_2$	500	A2L	16,000	4.7	75	Neither
1234ze(E)	trans-1,3,3,3-tetrafluoro-1-propene	$CF_3CH=CFH$	800	A2L	16,000	4.7	75	Neither
1270	propene (propylene)	$CH_3CH=CH_2$	500	A3	1000	0.11	1.7	Neither

a. The chemical name and chemical formula are not part of this standard. Chemical names conform to IUPAC nomenclature[14,15] 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 J.M. Calm, "ARTI Refrigerant Database," Air- Conditioning and Refrigeration Technology Institute (ARTI), Arlington, VA, July 2001; J.M. Calm, "Toxicity Data to Determine Refrigerant Concentration Limits," Report DE/CE 23810-110, Air- Conditioning and Refrigeration Technology Institute (ARTI), Arlington, VA, September 2000; J.M. Calm, "The Toxicity of Refrigerants," *Proceedings of the 1996 International Refrigeration Conference*, Purdue University, West Lafayette, IN, pp. 157–62, 1996; D.P. Wilson and R.G. Richard, "Determination of Refrigerant Lower Flammability Limits (LFLs) in Compliance with Proposed Addendum p to ANSI/ASHRAE Standard 34-1992 (1073-RP)," *ASHRAE Transactions* 2002, 108(2); D.W. Coombs, "HFC-32 Assessment of Anesthetic Potency in Mice by Inhalation," Huntingdon Life Sciences Ltd., Huntingdon, Cambridgeshire, England, February 2004 and amendment February 2006; D.W. Coombs, "HFC-22 An Inhalation Study to Investigate the Cardiac Sensitization Potential in the Beagle Dog," Huntingdon Life Sciences Ltd., Huntingdon, Cambridgeshire, England, August 2005; and other toxicity studies.

d. *Highly toxic*, *toxic*, or *neither*, where *highly toxic* and *toxic* are as defined in the *International Fire Code*, *Uniform Fire Code*, 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/Mcf)	RCL[a] (g/m^3)	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	120	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	70,000	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
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	25	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
408A[g]	R-125/143a/22 (7.0/46.0/47.0)	(±2.0/±1.0/±2.0)	1000	A1	95,000	21	340	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)		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)	990	A2	14,000	2.9	46	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)	980	A2	13,000	2.8	45	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	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	94	Neither

a. Data taken from J.M. Calm, "ARTI Refrigerant Database," Air- Conditioning and Refrigeration Technology Institute (ARTI), Arlington, VA, July 2001; J.M. Calm, "Toxicity Data to Determine Refrigerant Concentration Limits," Report DE/CE 23810-110, Air- Conditioning and Refrigeration Technology Institute (ARTI), Arlington, VA, September 2000; J.M. Calm, "The Toxicity of Refrigerants," *Proceedings of the 1996 International Refrigeration Conference*, Purdue University, West Lafayette, IN, pp. 157–62, 1996; D.P. Wilson and R.G. Richard, "Determination of Refrigerant Lower Flammability Limits (LFLs) in Compliance with Proposed Addendum p to ANSI/ASHRAE Standard 34-1992 (1073-RP)," *ASHRAE Transactions* 2002, 108(2); D.W. Coombs, "HFC-32 Assessment of Anesthetic Potency in Mice by Inhalation," Huntingdon Life Sciences Ltd., Huntingdon, Cambridgeshire, England, February 2004 and amendment February 2006; D.W. Coombs, "HFC-22 An Inhalation Study to Investigate the Cardiac Sensitization Potential in the Beagle Dog," Huntingdon Life Sciences Ltd., Huntingdon, Cambridgeshire, England, August 2005; and other toxicity studies.

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*, *Uniform Fire Code*, 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.

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]			Highly Toxic or Toxic[f] Under Code Classification
					(ppm v/v)	(lb/Mcf)	(g/m³)	
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	95	Neither
415A	R-22/152a (82.0/18.0)	(±1.0/±1.0)	1000	A2	14,000	2.9	47	Neither
415B	R-22/152a (25.0/75.0)	(±1.0/±1.0)	1000	A2	12,000	2.1	34	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	56	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	70	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	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	Neither
419B	R-125/134a/E170 (48.5/48.0/3.5)	(±1.0/±1.0/±0.5)	1000	A2	17,000	4.6	74	Neither
420A	R-134a/142b (88.0/12.0)	(+1.0,–0.0/+0.0,–1.0)	1000	A1	45,000	12	190	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	310	Neither
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)	970	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
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	83,000	23	370	Neither

a. Data taken from J.M. Calm, "ARTI Refrigerant Database," Air- Conditioning and Refrigeration Technology Institute (ARTI), Arlington, VA, July 2001; J.M. Calm, "Toxicity Data to Determine Refrigerant Concentration Limits," Report DE/CE 23810-110, Air- Conditioning and Refrigeration Technology Institute (ARTI), Arlington, VA, September 2000; J.M. Calm, "The Toxicity of Refrigerants," *Proceedings of the 1996 International Refrigeration Conference*, Purdue University, West Lafayette, IN, pp. 157–62, 1996; D.P. Wilson and R.G. Richard, "Determination of Refrigerant Lower Flammability Limits (LFLs) in Compliance with Proposed Addendum p to ANSI/ASHRAE Standard 34-1992 (1073-RP)," *ASHRAE Transactions* 2002, 108(2); D.W. Coombs, "HFC-32 Assessment of Anesthetic Potency in Mice by Inhalation," Huntingdon Life Sciences Ltd., Huntingdon, Cambridgeshire, England, February 2004 and amendment February 2006; D.W. Coombs, "HFC-22 An Inhalation Study to Investigate the Cardiac Sensitization Potential in the Beagle Dog," Huntingdon Life Sciences Ltd., Huntingdon, Cambridgeshire, England, August 2005; and other toxicity studies.

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*, *Uniform Fire Code*, 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.

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]			Highly Toxic or Toxic[f] Under Code Classification
					(ppm v/v)	(lb/Mcf)	(g/m³)	
Zeotropes (*continued*)								
429A	R-E170/152a/600a (60.0/10.0/30.0)	(±1.0/±1.0/±1.0)	1000	A3	6300	0.81	13	Neither
430A	R-152a/600a (76.0/24.0)	(±1.0/±1.0)	1000	A3	8000	1.3	21	Neither
431A	R-290/152a (71.0/29.0)	(±1.0/±1.0)	1000	A3	5500	0.69	11	Neither
432A	R-1270/E170 (80.0/20.0)	(±1.0/±1.0)	700	A3	1200	0.13	2.1	Neither
433A	R-1270/290 (30.0/70.0)	(±1.0/±1.0)	880	A3	3100	0.34	5.5	Neither
433B	R-1270/290 (5.0/95.0)	(±1.0/±1.0)	950	A3	4500	0.51	8.1	Neither
433C	R-1270/290 (25.0/75.0)	(±1.0/±1.0)	790	A3	3600	0.41	6.6	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	Neither
436A	R-290/600a (56.0/44.0)	(±1.0/±1.0)	1000	A3	4000	0.50	8.1	Neither
436B	R-290/600a (52.0/48.0)	(±1.0/±1.0)	1000	A3	4000	0.51	8.2	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	5.0	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
439A	R-32/125/600a (50.0/47.0/3.0)	(±1.0/±1.0/±0.5)	990	A2	26,000	4.7	76	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	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	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)	580	A3	1700	0.19	3.1	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	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	Neither
Azeotropes[b]								
500	R-12/152a (73.8/26.2)		1000	A1	30,000	7.6	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
504[i]	R-32/115 (48.2/51.8)		1000		140,000	28	450	Neither

a. Data taken from J.M. Calm, "ARTI Refrigerant Database," Air- Conditioning and Refrigeration Technology Institute (ARTI), Arlington, VA, July 2001; J.M. Calm, "Toxicity Data to Determine Refrigerant Concentration Limits," Report DE/CE 23810-110, Air- Conditioning and Refrigeration Technology Institute (ARTI), Arlington, VA, September 2000; J.M. Calm, "The Toxicity of Refrigerants," *Proceedings of the 1996 International Refrigeration Conference*, Purdue University, West Lafayette, IN, pp. 157–62, 1996; D.P. Wilson and R.G. Richard, "Determination of Refrigerant Lower Flammability Limits (LFLs) in Compliance with Proposed Addendum p to ANSI/ASHRAE Standard 34-1992 (1073-RP)," *ASHRAE Transactions* 2002, 108(2); D.W. Coombs, "HFC-32 Assessment of Anesthetic Potency in Mice by Inhalation," Huntingdon Life Sciences Ltd., Huntingdon, Cambridgeshire, England, February 2004 and amendment February 2006; D.W. Coombs, "HFC-22 An Inhalation Study to Investigate the Cardiac Sensitization Potential in the Beagle Dog," Huntingdon Life Sciences Ltd., Huntingdon, Cambridgeshire, England, August 2005; and other toxicity studies.

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*, *Uniform Fire Code*, 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.

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/Mcf)	RCL[a] (g/m^3)	Highly Toxic or Toxic[f] Under Code Classification
Azeotropes (*continued*)[b]								
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	520	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	390	Neither
510A	R-E170/600a (88.0/12.0)	(±0.5/±0.5)	1000	A3	7300	0.87	14	Neither
511A	R-290/E170 (95.0/5.0)	(±1.0/±1.0)	1000	A3	5300	0.59	9.5	Neither
512A	R-134a/152a (5.0/95.0)	(±1.0/±1.0)	1000	A2	11,000	1.9	31	Neither

a. Data taken from J.M. Calm, "ARTI Refrigerant Database," Air- Conditioning and Refrigeration Technology Institute (ARTI), Arlington, VA, July 2001; J.M. Calm, "Toxicity Data to Determine Refrigerant Concentration Limits," Report DE/CE 23810-110, Air- Conditioning and Refrigeration Technology Institute (ARTI), Arlington, VA, September 2000; J.M. Calm, "The Toxicity of Refrigerants," *Proceedings of the 1996 International Refrigeration Conference*, Purdue University, West Lafayette, IN, pp. 157–62, 1996; D.P. Wilson and R.G. Richard, "Determination of Refrigerant Lower Flammability Limits (LFLs) in Compliance with Proposed Addendum p to ANSI/ASHRAE Standard 34-1992 (1073-RP)," *ASHRAE Transactions* 2002, 108(2); D.W. Coombs, "HFC-32 Assessment of Anesthetic Potency in Mice by Inhalation," Huntingdon Life Sciences Ltd., Huntingdon, Cambridgeshire, England, February 2004 and amendment February 2006; D.W. Coombs, "HFC-22 An Inhalation Study to Investigate the Cardiac Sensitization Potential in the Beagle Dog," Huntingdon Life Sciences Ltd., Huntingdon, Cambridgeshire, England, August 2005; and other toxicity studies.

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*, *Uniform Fire Code*, 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.

Attached Group(s)	Suffix (*continued*)
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 Inorganic compounds shall be assigned numbers in the 700 and 7000 series.

4.6.1 For compounds with relative molecular masses less than 100, the number shall be the sum of 700 and the relative molecular mass, rounded to the nearest integer.

4.6.2 For compounds with relative molecular masses equal to or greater than 100, the number shall be the sum of 7000 and the relative molecular mass, rounded to the nearest integer.

4.6.3 When two or more inorganic refrigerants have the same relative molecular 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 or bromine 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," or "F"—or a combination thereof in this sequence—to signify the presence of bromine, chlorine, or fluorine, respectively. Compounds that also contain hydrogen shall be further preceded by the letter "H" to signify the increased deterioration potential before reaching the stratosphere.[6] 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 classification shall consist of two alphanumeric characters (e.g., "A2" or "B1"). The capital letter indicates the toxicity as determined by Section 6.1.2; the arabic numeral 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:

Class A refrigerants have an OEL of 400 ppm or greater.

Class B refrigerants have an OEL of less than 400 ppm.

6.1.3 Flammability Classification. Refrigerants shall be assigned to one of three classes (1, 2, or 3) and one optional subclass (2L) 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, *Standard Test Method for Concentration Limits of Flammability of Chemicals (Vapors and Gases)*[7] 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 flammability classifications as specified in Section 6.1.5. Blends shall be assigned a flammability classification based on their WCF and WCFF, as determined from a fractionation analysis (see Section B2 in Normative Appendix B). 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 6.1.3).

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 and 23.0 ± 2.3 cm/s for R-152a, 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 Clodic.[8,9] Measurements shall be conducted starting from the LFL to at least 125% of the stoichiometric concentration. Measurements shall be done 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

TABLE 6.1.3 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)
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 6.1.3.4.

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.

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

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 Section B2 in Normative Appendix B, 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 2

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 6.1.3.4 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 6.1.3.5).
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 6.1.3.4 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 6.1.3.5).
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 6.1.3.4 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 6.1.3.5).

6.1.3.2.1 Subclass 2L (Optional). Refrigerants that meet the following additional condition: have 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).

6.1.3.3 Class 3

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 6.1.3.4 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 6.1.3.4 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)

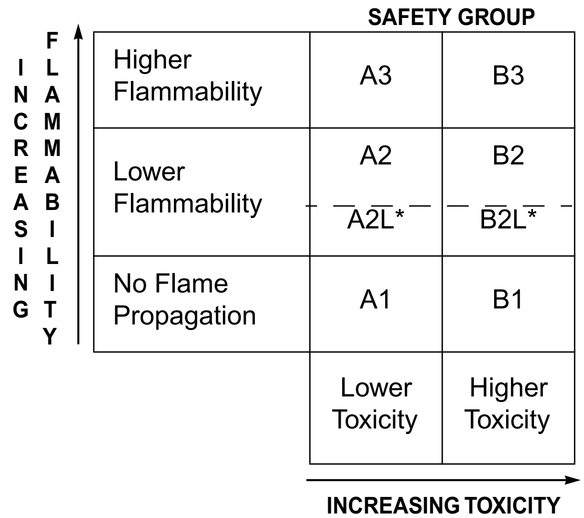
c. The WCFF of a refrigerant blend shall be classified as Class 3 if it meets both of the following conditions:
   1. Exhibits flame propagation when tested at 60.0°C (140°F) and 101.3 kPa (14.7 psia) and
   2. Has an LFL ≤0.0062 lb/ft^3 (0.10 kg/m^3) (see Section 6.1.3.4 if the refrigerant has no LFL 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)

6.1.3.4 For Class 2 or Class 3 refrigerants or refrigerant blends, the LFL shall be determined. For those 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.

6.1.3.5 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) (***Note:*** not aqueous solution (aq)], CO_2(g), [N_2(g) or SO_2(g) if nitrogen or sulfur are part of the refrigerant's molecular structure], HCl(g), and H_2O(g).

   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).



* A2L and B2L are lower flammability refrigerants with a maximum burning velocity of ≤3.9 in./s (10 cm/s).

FIGURE 6.1.4 Refrigerant safety group classification.

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 6.1.3.5(a). The heat of formation for this hypothetical molecule is the molar average of the heats of formation for the original blend of molecules.

   Note: The molar percent or mass percent weighted average of the HOC 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 six separate safety group classifications (A1, A2, A3, B1, B2, and B3) and two subclasses (A2L and B2L) for refrigerants. These classifications are represented by the matrix shown in Figure 6.1.4.

6.1.5 Safety Classification of Refrigerant Blends. Blends, whether zeotropic or azeotropic, whose flammability and/or toxicity characteristics may change as the composition changes during fractionation, shall be assigned a safety group classification based on the worst case of fractionation. This classification shall be determined according to the same criteria as that for a single-compound refrigerant.

For flammability, *worst case of fractionation* is defined as the composition during fractionation that results in the highest concentration of the flammable component(s) in the vapor or liquid phase. For toxicity, *worst case of fractionation* is defined as the composition during fractionation that results in the highest concentration of the component(s) in the vapor or liquid phase for which the TLV-TWA is less than 400 ppm by volume. The TLV-TWA for a specific blend composition shall be calculated from the TLV-TWA of the individual components (see Reference C-4 of Informative Appendix C).

6.2 Other Standards. This classification is to be used in conjunction with other relevant safety standards, such as ANSI/ASHRAE Standard 15*, Safety Standard for Refrigeration Systems*.[10]

7. REFRIGERANT CONCENTRATION LIMIT (RCL)

7.1 Single-Compound Refrigerants. The 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 (ATEL). The 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 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:

$$LC_{50\text{ for }T} = LC_{50\text{ for }t} \cdot (t/T)^{1/2}$$

or

$$ALC_T = ALC_t \cdot (t/T)^{1/2}$$

where

T = four hours

t = test duration expressed in hours, 0.25 to 8

b. *Cardiac Sensitization:* One-hundred percent of the NOEL for cardiac sensitization in unanesthetized dogs. If not determined, 80% of the 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 (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:* Fifty percent 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 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:* Eighty percent 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 (ODL). The 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 (FCL). The FCL shall be calculated as 25% of the 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 except that individual parameter values in Section 7.1.1 (a) through (d) 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 performed 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 (GLP) regulations in accordance with References 11, 12, 13, or 14 or earlier editions of these references in effect at the time when the studies were performed. 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 (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:

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 Sections 7.1.1(b) and 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 (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 (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 Units 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/Mcf (g/m^3):

$$\mathrm{RCL}_M = \mathrm{RCL} \cdot a \cdot M$$

where

RCL_M = the RCL expressed as lb/Mcf (g/m^3)

RCL = the RCL expressed as ppm v/v

a = 1.160×10^{-3} for lb/Mcf ($4.096 \cdot 10^{-5}$ for g/m^3)

M = the molecular mass of the refrigerant in 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/Mcf (g/m^3), for locations above sea level. The RCL shall not be adjusted when expressed as a volumetric ratio, ppm.

$$rcl_a = \mathrm{RCL}_M \cdot (1 - [b \cdot h])$$

where

rcl_a = the adjusted RCL_M

b = $2.42 \cdot 10^{-5}$ for ft ($7.94 \cdot 10^{-5}$ 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 classifications indicated in Tables 4-1 and 4-2. 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 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 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. There is an application fee. In addition, the applicant is required to pay for the cost of distributing copies of the application to members of SSPC 34. Please contact the ASHRAE 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 Manager of Standards (see Section 9.9.6) 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 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 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 Sections 9.3 through 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 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 34-2013 (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 9.5.3.

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

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. Molecular 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. Molecular mass as formulated
d. Molecular 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. Molecular mass as formulated
c. Molecular 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, 9.6.2, and 9.6.3. 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 GLP regulations in accordance with Reference 11, 12, 13, or 14 or earlier editions of these references in effect at the time when the studies were performed. Data from peer-reviewed publications, including journal articles, reports, and assessments, also are allowed. Material Safety Data Sheets (MSDSs), 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:

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. AIHA 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

9.6.3 Material Safety Data Sheet (MSDS). Applications for single-compound refrigerants shall include an MSDS, or information consistent therewith, as an appendix. Applications for blends shall include MSDSs for the blend as formulated and for each component of the blend as appendices.

9.7 Flammability Information. Applications for single-compound refrigerants and refrigerant blends shall include flammability test data and information identified in Section B1.9 in Normative Appendix B. Applications for refrigerant blends shall also include tabulated fractionation data and information identified in Section B2.6 in Normative Appendix B. 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 Section B2 in Normative Appendix B.

9.7.2 Burning Velocity Information (optional). Applications seeking an assignment of 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 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]).

9.9.3 Printed and Electronic Formats. Required information and evidence must be submitted in both printed and electronic formats.

9.9.4 Format. Applications shall be provided on 8.5 × 11 in. or A4 (21 × 29.7 cm) paper. Reproduction may be either single- or double-sided (on one or both sides of the paper). Pages shall be bound using a cover that facilitates disassembly, insertion of supplementary pages, and reassembly without staples or binding machines, such as three-ring binders or covers with three bend-over tabs (standard two- or four-ring binders or covers with two bend-over tabs for A4 paper). Tabbed dividers shall be inserted before each part identified in Section 9.2 except the cover.

9.9.5 Quantity. Thirty-five compact discs with the application in electronic format shall be provided. In addition, a maximum of 35 bound copies may be required for committee and administrative use (contact the ASHRAE Manager of Standards for the exact number of hard copies required). The electronic format shall be an electronically searchable PDF file of minimal size. A scanned PDF file is acceptable for figures and other inserts. Committee members may request only the compact discs, thereby reducing the number of bound paper copies required.

9.9.6 Recipient. Submit applications to the following address:

Manager of Standards
ASHRAE
1791 Tullie Circle NE
Atlanta, GA 30329-2305 USA

9.9.7 Elaborate Applications. Elaborate proposals containing brochures on the applicant, performance data, and other material not needed for committee deliberations are discouraged.

9.9.8 Substantiation. Copies of data sources referenced in applications shall be submitted for committee use upon request by the Manager of Standards. These copies shall include the complete documents or pertinent chapters to enable verification of methods and limitations. The quantity shall be as indicated in Section 9.9.5.

Exception: The quantity shall be reduced to four copies for copyrighted journal articles, conference papers, reports, or other publications for which royalties are charged for reproduction.

10. REFERENCES

1. *International Fire Code* (IFC), International Code Council, Fairfax, VA, section 3702, 2003.
2. *Uniform Fire Code* (UFC), Western Fire Chiefs Association, Walnut Creek, CA, sections 209 and 221, 2000.
3. *Health Hazard Definitions (Mandatory)*, Occupational Safety And Health Administration (OSHA), US Department of Labor, 29 Code of Federal Regulations (CFR) 1910.1200 Subpart Z Appendix A, US Government Printing Office, Washington, DC, 2009.
4. *2010 Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices*, American Conference of Governmental Industrial Hygienists, Cincinnati, OH, 2010.
5. *AIHA 2011 Emergency Response Planning Guidelines and Workplace Environmental Exposure Level Handbook*, document AEAH11-559, American Industrial Hygiene Association (AIHA), Fairfax, VA, USA, 2011.
6. J.M. Calm, "Composition Designations for Refrigerants," *ASHRAE Journal*, Vol. 31, No. 11, pp. 48-51, November 1989.
7. ASTM E681-2009, *Standard Test Method for Concentration Limits of Flammability of Chemicals (Vapors*

and Gases), American Society of Testing and Materials, West Conshohocken, PA, 2009.

8. Jabbour, T., Flammable refrigerant classification based on the burning velocity. PhD Thesis, Ecole des Mines: Paris, France, 2004.

9. Jabbour, T. and Clodic, D.F., Burning velocity and refrigerant flammability classification. *ASHRAE Transactions* 110(2), 2004.

10. *ANSI/ASHRAE Standard 15-2010, Safety Standard for Refrigeration Systems.* American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta.

11. *OECD Principles of Good Laboratory Practice, Annex 2 of Decision C(81)30(Final),* Organization for Economic Co-operation and Development (OECD), Paris, France, 13 May, 1981 as revised through 1999.

12. *Good Laboratory Practice for Nonclinical Laboratory Studies, Food and Drug Administration (FDA), 21 CFR Chapter 1 Part 58, Subparts A-K,* Government Printing Office, Washington, DC, 1 April 2009.

13. *Good Laboratory Practice Standards,* Environmental Protection Agency, 40 CFR Part 792, Subparts A-J, Government Printing Office, Washington, DC, 1 July 2007.

14. *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.

15. *A Guide to IUPAC Nomenclature of Organic Compounds (Recommendations 1993)*. R. Panico, W.H. Powell, and J.-C. Richer. Blackwell Scientific Publications, 1993. www.acdlabs.com/iupac/nomenclature/.

16. IUPAC. www.iupac.org. Research Triangle Park, NC: International Union of Pure and Applied Chemistry.

(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), www.iupac.org; or at the following Wikipedia pages:

http://en.wikipedia.org/wiki/Sequence_rule

http://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 Web site www.acdlabs. com/resources/freeware/chemsketch/, as noted at the IUPAC Web site http://old.iupac.org/nomenclature/.

TABLE A-1 Ethane Series Isomers

Isomer	Chemical Formula	Attached Mass		
		W_1	W_2	$\lvert W_1 - W_2 \rvert$
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	50.9

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	$\lvert W_1 - W_3 \rvert$
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
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

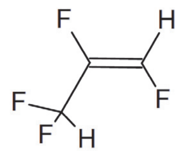
W_i = the sum of the atomic mass of halogens and hydrogens attached to carbon atom *i*

TABLE A-3 Propene Series Isomers

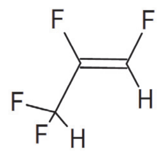
Isomer	Chemical Formula	Stereoisomer	
		IUPAC*	ACS*
R-1234yc	$CH_2F\text{-}CF{=}CF_2$		
R-1234zc	$CHF_2\text{-}CH{=}CF_2$		
R-1234ye(E)	$CHF_2\text{-}CF{=}CHF$	Entgegen	Trans
R-1234ye(Z)	$CHF_2\text{-}CF{=}CHF$	Zusammen	Cis
R-1234ze(E)	$CF_3\text{-}CH{=}CHF$	Entgegen	Trans
R-1234ze(Z)	$CF_3\text{-}CH{=}CHF$	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)

FOUR-CARBON EXAMPLE: HFC-365mfc

CF_3-CH_2-CF_2-CH_3

The CF_3 end has priority—it has the greatest summed mole weight of substituted atoms. Per Section 4.1.11, this terminal CF_3 indicates the first suffix shall be *m*. The next carbon is CH_2, so per Section 4.1.9, the second suffix is *f*. The third carbon is CF_2, so again per Section 4.1.9, 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.[6] For classification of Class 2 or Class 1 materials, testing shall be in a nominal 0.424 ft^3 (12 L) spherical glass flask (see Figure B1-1). 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 s 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 B1-2 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 done 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.
b. For refrigerant blends, flammability tests shall be conducted on the WCF at 140°F (60°C) and 14.7 psia (101.3 kPa) and also shall be conducted on the 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 LFL. The LFL normally is expressed as refrigerant percentage by volume percent; multiply this by 0.00041 × molecular mass (g·mol) to obtain kg/m^3 or by 0.000026 × molecular 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 component(s) 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 done 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 component(s) 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 B1-1).

B1.9 Flammability Test Data Required. Applications shall include test results determined in accordance with Section B1.

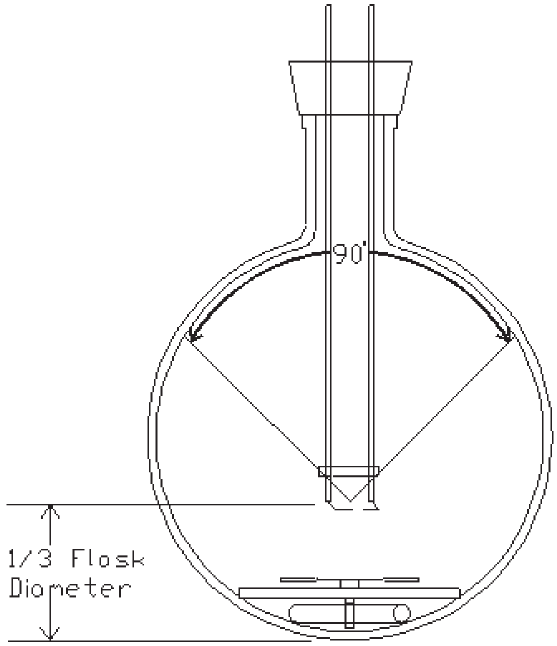


FIGURE B1-1 Test apparatus.

- **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 π/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.**

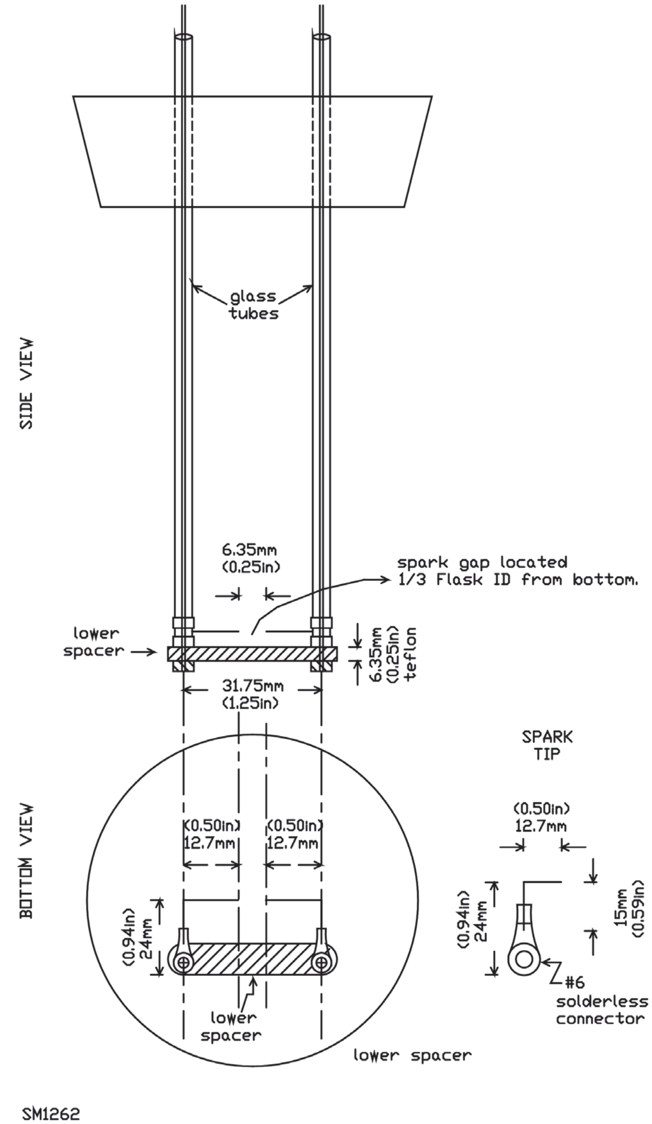


FIGURE B1-2 Spark electrodes.

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

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; and
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 conducted to determine vapor- and liquid-phase compositions of refrigerant blends under conditions of leakage (see Section B2.4) and successive charge/recharge conditions (see Section B2.5). 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 verifies 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 B2.4) 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 (VLE) 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 component(s) shall be evaluated to determine their WCFF formulation(s) 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.

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 is the calculated mass that gives a 100% liquid fill at 130°F (54.4°C). 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 done 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 done at 95% mass loss.

B2.5 Leak/Recharge Testing. Refrigerant blends containing flammable component(s) 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 performed 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 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), and
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 BIBLIOGRAPHY

C1. Atwood, T. 1989. The need for standard nomenclature for refrigerants. *ASHRAE Journal* 31(11):44–47.

C2. NFPA. 2007. NFPA 704, *Identification of the Fire Hazards of Materials*. Quincy, MA: National Fire Protection Association.

C3. Underwriters Laboratories. 2006. UL Standard 2182, *Standard for Safety—Refrigerants*. Northbrook, IL: Underwriters Laboratories, Inc.

C4. Richard, R. Refrigerant flammability testing in large volume vessels. ARTI MCLR Final Report DOE/CE/23810-87, Air-Conditioning and Refrigeration Technology Institute, Arlington, VA, 1998.

(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 molecular 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	Molecular Mass	Normal Boiling Point	
				°F	°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
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
114	1,2-dichloro-1,1,2,2-tetrafluoromethane	$CC1F_2CC1F_2$	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

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	Molecular Mass	Normal Boiling Point	
				°F	°C
Propane Series					
218	octafluoropropane	$CF_3CF_2CF_3$	188.0	–35	–37
227ea	1,1,1,2,3,3,3-heptafluoropropane	CF3CHFCF3	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	-$(CF_2)_4$-	200.0	21	–6
Miscellaneous Organic Compounds					
hydrocarbons					
600	butane	$CH_3CH_2CH_2CH_3$	58.1	31	0
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					
1150	ethene (ethylene)	$CH_2=CH_2$	28.1	–155	–104
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

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 Molecular 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
408A	R-125/143a/22 (7/46/47)	87.0	–49.9	–49.0	–45.5	–45.0
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

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 Molecular Mass	Bubble Point (°F)	Dew Point (°F)	Bubble Point (°C)	Dew Point (°C)
Zeotropes (*continued*)						
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
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
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
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
445A	R-744/134a/1234ze(E) (6.0/9.0/85.0)	103.1	–58.5	–10.3	–50.3	–23.5

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 Number	Composition (Mass %)[a]	Azeotropic Temperature		Azeotropic Molecular Mass	Normal BPt.	
		°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
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

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 R-[b]	Chemical Name	LC_{50}[c,d]	Cardiac Sensitization		Anesthesia			Other[i]	ATEL	ODL	FCL	RCL	LFL	ATEL Source	RCL Source
			LOEL[e]	NOEL[e]	EC_{50}[f]	LOEL[g]	NOEL[h]								
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
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	50,000	59,300[k]	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 fluroride)	>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
114	1,2-dichloro-1,1,2,2-tetrafluoroethane	255,000[j]	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[l]	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[d]	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[d]	150,000	50,000	ND	ND	100,000	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
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[d,m]	400,000	300,000	ND	ND	113,000	ND	90,000	140,000	NA	90,000	—	80% Anesthesia NOEL	ATEL

TABLE E-1 Toxicity Table for Standard 34—ATEL, ODL, FCL, and RCL Values for Single-Compound Refrigerants[a] (ppm v/v) *(Continued)*

Refrigerant R-[b]	Chemical Name	LC_{50}[c,d]	Cardiac Sensitization		Anesthesia			Other[i]	ATEL	ODL	FCL	RCL	LFL	ATEL Source	RCL Source
			LOEL[e]	NOEL[e]	EC_{50}[f]	LOEL[g]	NOEL[h]								
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[n]	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[o]	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[u]	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[q]	ND	-p-	ND	-p-	38,900	400	320	140,000	42,000	320	167,000	Other	ATEL
744	carbon dioxide	-s-	ND	-p-	ND	-p-	ND	50,000[r]	40,000	140,000	NA	40,000	—	NIOSH IDLH	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[t]	ND	ND	ND	ND	10,000	7200	1000	140,000	6700	1000	27,000	Sect 7.1.1 (b)	ATEL

ND: None determined or not adequately defined according to criteria of this standard.
NA: Not applicable
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 J.M. Calm, "ARTI Refrigerant Database," Air- Conditioning and Refrigeration Technology Institute (ARTI), Arlington, VA, July 2001; J.M. Calm, "Toxicity Data to Determine Refrigerant Concentration Limits," Report DE/CE 23810-110, Air- Conditioning and Refrigeration Technology Institute (ARTI), Arlington, VA, September 2000; J.M. Calm, "The Toxicity of Refrigerants," *Proceedings of the 1996 International Refrigeration Conference*, Purdue University, West Lafayette, IN, pp. 157–62, 1996; D.P. Wilson and R.G. Richard, "Determination of Refrigerant Lower Flammability Limits (LFLs) in Compliance with Proposed Addendum p to ANSI/ASHRAE Standard 34-1992 (1073-RP)," *ASHRAE Transactions* 2002, 108(2); D.W. Coombs, "HFC-32 Assessment of Anesthetic Potency in Mice by Inhalation," Huntingdon Life Sciences Ltd., Huntingdon, Cambridgeshire, England, February 2004 and amendment February 2006; D.W. Coombs, "HFC-22 An Inhalation Study to Investigate the Cardiac Sensitization Potential in the Beagle Dog," Huntingdon Life Sciences Ltd., Huntingdon, Cambridgeshire, England, August 2005; and other toxicity studies
b. From ANSI/ASHRAE Standard 34-2007 and subsequent published addenda.
c. 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.
d. Four-hour approximate lethal concentration (ALC) rat used for mortality indicator; LC_{50} not determined
e. Dog with epinephrine injection
f. Ten-minute EC_{50} mouse or rat.
g. Lowest anesthetic/CNS LOEL rat during ALC, LC_{50}, or other acute toxicity study
h. Highest anesthetic/CNS NOEL rat in any toxicity study not exceeding an acute LOEL
i. Other escape-impairing or permanently injuring effects, including severe sensory irritation, for short exposures
j. R-114 30-minute LC_{50} rat—720,000 ppm v/v, two-hour LC_{50} rat >600,000 ppm v/v.
k. Not used
l. R-134a LC_0 substituted for ALC; >50% of animals died at ALC of 566,700 ppm v/v.
m. R-218 one-hour ALC rat >800,000 ppm v/v
n. R-290 15-min LC_{50} rat > 800,000 ppm v/v
o. R-600a 15-min LC_{50} rat = 570,000 ppm v/v; anesthetic/CNS value is a 17-min EC_{50} mouse.
p. No data, but believed to exceed LC_{50} and ALC
q. Published LC_{50} values—6,586–19,671 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.
r. See NIOSH IDLH documentation for other effect.
s. R-744 treated as simple asphyxiant; five-minute LC_{Lo} human = 90,000 ppm v/v.
t. 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.
u. The value shown is the LC_{50} for isopentane. The value for pentane is expected to be similar.

(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 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:

$$\text{R-125: } C_2HF_5 + O_2 \rightarrow 2COF_2 + HF \qquad \text{(F1-1)}$$

and

$$\text{R-290: } C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_20 \qquad \text{(F1-2)}$$

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:

$$xC_2HF_5 + yC_3H_8 + (x + 5y)O_2 \rightarrow (3y)CO_2 + 2xCOF_2 + xHF + 4yH_2O \qquad \text{(F1-3)}$$

But Equation F1-3 would be incorrect. Instead, combine the atoms of the R-125 and R-290 into a hypothetical molecule:

$$xC_2HF_5 + yC_3H_8 \rightarrow C_{2x+3y}H_{x+8y}F_{5x} \qquad \text{(F1-4)}$$

This hypothetical molecule is then reacted with oxygen:

$$C_{2x+3y}H_{x+8y}F_{5x} + (x + 5y)O_2 \rightarrow (2x + 3y)CO_2 + 5xHF + [(x + 8y - 5x) / 2]H_2O \qquad \text{(F1-5)}$$

In comparing Equations F1-3 and F1-5, note that the products of combustion are different. There is no COF_2 formed in Equation F1-5; 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:

$$\Delta h_f(\text{blend}) = x\Delta h_f(\text{R125}) + y\Delta h_f(\text{R290}) = 0.2311\ (-1104.58\ \text{kJ/mol}) + 0.7689\ (-104.70\ \text{kJ/mol}) = -335.77\ \text{kJ/mol} \qquad \text{(F1-6)}$$

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:

$$\begin{aligned}
\Delta h_{combustion} &= \\
\sum\Delta h_f(\text{reactants}) - \sum\Delta h_f(\text{products}) &= \\
\{\Delta h_f(C_{2x+3y}H_{x+8y}F_{5x}) + (x+5y)\Delta h_f(O_2)\} & \\
-\{(2x+3y)\Delta h_f(CO_2) + (5x)\Delta h_f(HF) & \\
+ [(x+8y-5x)/2]\Delta h_f(H_2O)\} &= \\
-335.77 + [0.2311 + 5(0.7689)][O] & \\
- \{[2(0.2311) + 3(0.7689)][-393.51] & \\
+ [5(0.2311)][-273.30] & \\
+ [0.5]\ [0.2311 + 8(0.7689) & \\
- 5(0.2311)[-241.83]\} & \\
&= 1701.6\ \text{kJ/mol}
\end{aligned} \qquad \text{(F1-7)}$$

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 F2. 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:

$$\begin{aligned}
\Delta h_{combustion} &= 1701.6\ \text{kJ/mol} \\
&= 1701.6/\{(0.2311)(120.021) + (0.7689)(44.096)\} \\
&= 27.604\ \text{kJ/g} = 27604\ \text{kJ/kg}
\end{aligned} \qquad \text{(F-8)}$$

TABLE F2 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

(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
CALCULATION OF RCL AND ATEL FOR BLENDS

The ATEL for a refrigerant blend shall be set as the lowest concentration based on Section 7.1.1 (a) through (d), where the ATEL of the blend is calculated from the individual components, following the Additivity Method for Mixtures (reference Appendix C of the 2010 American Conference of Governmental Industrial Hygienists [ACGIH], *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:

$$\text{Blend Mortality Indicator } (a)_{blend} = \frac{1}{\frac{mf_1}{a_1} + \frac{mf_2}{a_2} + \ldots + \frac{mf_n}{a_n}}$$

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 Section 7.1.1 (a) through (d).

Each acute toxicity endpoint (Section 7.1.1 [a] through [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).

Mortality Indicator (a) of R-410A

$$= \frac{1}{\frac{0.698}{215,000 \text{ ppm}} + \frac{0.302}{218,000 \text{ ppm}}}$$

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**.

Cardiac Sensitization Indicator (b) of R-410A

$$= \frac{1}{\frac{0.698}{350,000 \text{ ppm}} + \frac{0.302}{75,000 \text{ ppm}}}$$

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 (NOEL).

$(b)_{R\text{-}410A}$ = **166,000 ppm as the R-410A cardiac sensitization indicator**.

Anesthetic Effect Indicator (c) or R-410A

$$= \frac{1}{\frac{0.698}{200,000 \text{ ppm}} + \frac{0.302}{567,000 \text{ ppm}}}$$

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 (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.

F1. 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. Since 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.

(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 H
ADDENDA DESCRIPTION INFORMATION

ANSI/ASHRAE Standard 34-2013 incorporates ANSI/ASHRAE Standard 34-2010 and Addenda a, b, c, d, e, f, g, h, i, j, k, l, n, o, p, q, r, s, t, u, v, w, x, y, z, aa, ab, ac, ad, ae, af, ag, ah, ai, aj, and ak to ANSI/ASHRAE Standard 34-2010. Table H1 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 the addenda.

TABLE H-1 Addenda to ANSI/ASHRAE Standard 34-2010

Addendum	Section(s) Affected	Description of Changes[a]	ASHRAE Standards Approval	ASHRAE Board of Directors Approval	ANSI Approval
a	Tables 4-2 and D-2	Adds 407F, a new zeotropic refrigerant blend, to Table 4-2 and Table D-2.	6/26/10	6/30/10	7/1/10
b	Tables 4-2 and D-2	Adds 417B, a new zeotropic refrigerant blend, to Table 4-2 and Table D-2	6/26/10	6/30/10	7/1/10
c	Table 4-1	Changes the occupational exposure limit (OEL), expressed as ppm (v/v), for R-1234yf from 400 to 500 to be consistent with the 2009 Workplace Environmental Exposure Limit (WEEL) established by the American Industrial Hygiene Association (AIHA).	6/25/11	6/29/11	7/27/11
d	Section 6.1.2	Modifies the language in 6.1.2, Toxicity Classification, to clarify the intent.	6/26/10	6/30/10	7/1/10
e	Tables 4-2 and D-2	Adds 439A, a new zeotropic refrigerant blend, to Table 4-2 and Table D-2.	1/29/11	2/2/11	2/3/11
f	Tables 4-2 and D-2	Adds 440A, a new zeotropic refrigerant blend, to Table 4-2 and Table D-2.	1/29/11	2/2/11	2/3/11
g	Tables 4-2 and D-2	Adds 441A, a new zeotropic refrigerant blend, to Table 4-2 and Table D-2.	1/29/11	2/2/11	2/3/11
h	Table 4-1	Changes the flammability safety classifications of refrigerants 32, 143a, 717, and 1234yf in Table 4-1 from Class 2 to its Subclass 2L based on the optional burning velocity measurement.	1/29/11	2/2/11	2/3/11
i	Tables 4-1 and D-1	Adds 1234ze(E), a new single-compound refrigerant, to Table 4-1 and Table D-1.	6/25/11	6/29/11	6/30/11
j	Tables 4-2 and D-2	Adds 511A, a new azeotropic refrigerant blend, to Table 4-2 and Table D-2.	6/25/11	6/29/11	6/30/11
k	Tables 4-1 and 4-2	Deletes the provisional status of RCL values for refrigerants 14, 115, 170, C318, 1270, 405A, 416A, 417A, 424A, 426A, and 504 and deletes footnote d in Table 4-1 and footnote e in Table 4-2.	6/25/11	6/29/11	6/30/11
l	Tables 4-2 and E-1	Changes for R-32 the cardiac sensitization NOEL from 200,000 ppm to 350,000 ppm and deletes the LOEL value of 250,000 ppm in Table E-1. RCL values for refrigerants containing R-32 are subsequently changed in Table 4-2.	6/25/11	6/29/11	6/30/11
n	Section 9.5.2	Adds “pressure at the critical point” to subclauses 9.5.2.1, 9.5.2.2, and 9.5.2.3 and modifies subclause 9.5.2.5.	6/25/11	6/29/11	6/30/11
o	Clause B1	Clarifies the requirements of clause B1, Flammability Testing.	6/25/11	6/29/11	6/30/11
p	Tables 4-2 and D-2	Adds 512A, a new azeotropic refrigerant blend, to Table 4-2 and Table D-2.	1/21/12	1/25/12	1/26/12
q	Tables 4-2 and D-2	Adds 442A, a new zeotropic refrigerant blend, to Tables 4-2 and D-2.	1/21/12	1/25/12	1/26/12
r	Tables 4-1 and 4-2	Adds toxicity Code Classification assignments for refrigerants 421B to 433A (inclusive), 601a, and 227ea to Tables 4-1 and 4-2.	1/21/12	1/25/12	1/26/12
s	Tables 4-1 and 4-2	Adds missing RCL data for 600 in Table 4-1 and corrects significant figures for RCL data for 1270, 436B, and 437A in Tables 4-1 and 4-2.	1/21/12	1/25/12	1/26/12

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

TABLE H-1 Addenda to ANSI/ASHRAE Standard 34-2010

Addendum	Section(s) Affected	Description of Changes[a]	ASHRAE Standards Approval	ASHRAE Board of Directors Approval	ANSI Approval
t	Section 3	Clarifies the definitions of lowest observed effect level (LOEL) and no- observed-effect level (NOEL) to be consistent as applied in this Standard.	1/21/12	1/25/12	1/26/12
u	Sections 7.3 and 9.6	Clarifies *7.3 Requirements for Data Calculations* and *9.6 Toxicity Information* for consistency.	1/21/12	1/25/12	1/26/12
v	Appendix G	Removes the term *toxic concentration factors (TCFs)* from Informative Appendix G, *Calculation of RCL and ATEL for Blends*, as the term is not defined or used in Standard 34 or Standard 15, and more suitable toxicity terms are provided.	1/21/12	1/25/12	1/26/12
w	Section 3	Modifies the definition of Workplace Environmental Exposure Level (WEEL) and adds a reference for AIHA WEEL.	6/22/13	6/26/13	6/27/13
x	Appendix B2	Clarifies the conditions for bubble point in Sections B2.4.1 and B2.4.2 of Normative Appendix B.2, *Fractionation Analysis*.	6/22/13	6/26/13	6/27/13
y	Section B2.1.1	Better defines the experimental verification of models used to identify the WCFF fractionated compositions, and allows vapor-liquid equilibrium (VLE) data only to be used for experimental verification.	1/21/12	1/25/12	1/26/12
z	Section 3	Adds definitions of “bubble point” and “dew point” to Section 3 of this standard.	6/23/12	6/27/12	6/28/12
aa	Section 9.5.2.2	Modifies Section 9.5.2.2, Azeotropic Blends, to define the requirements applicants shall provide as evidence of the existence of an azeotropic blend within the intended application range in requesting a 500 Series Designation.	6/23/12	6/27/12	6/28/12
ab	Tables 4-2 and D-2	Adds 443A, a new zeotropic refrigerant, to Table 4-2 and Table D-2.	6/23/12	6/27/12	6/28/12
ac	Tables 4-2 and D-2	Adds 444A, a new zeotropic refrigerant, to Table 4-2 and Table D-2.	1/26/13	1/29/13	1/30/13
ad	Section 6.1.3.5(a) and Appendix F	Deletes the use of the potential formation of CF_4 in Section 6.1.3.5(a) for Heat of Combustion calculations, as this is not possible when working at stoichiometric concentrations in air. SO_3 is deleted from the sample calculation table in Appendix F. The units in Appendix F example calculations and table are changed from kcal/mol to kJ/mol or kJ/kg, to be consistent with the definition of Heat of Combustion in this standard.	1/26/13	1/29/13	1/30/13
ae	Appendix B	Changes the flammability safety classification from Class 2 to Class 1 for R-30 in Table 4-1, as published data show that R-30 is nonflammable at 60°C and 1 atm. pressure.	1/26/13	1/29/13	1/30/13
af	Table 4-2	Changes the RCL values for 402A, 415A, 415B, 418A, and 419A in Table 4-2 due to prior errors in the flammability properties for these refrigerants.	1/26/13	1/29/13	1/30/13
ag	Tables 4-2 and D-2	Adds 417C, a new zeotropic refrigerant, to Table 4-2 and Table D-2.	6/22/13	6/26/13	6/27/13
ah	Tables 4-2 and D-2	Adds 445A, a new zeotropic refrigerant, to Table 4-2 and Table D-2.	6/22/13	6/26/13	6/27/13
ai	Tables 4-2 and D-2	Adds 419B, a new zeotropic refrigerant, to Table 4-2 and Table D-2.	6/22/13	6/26/13	6/27/13
aj	Tables 4-2 and D-2	Adds 422E, a new zeotropic refrigerant, to Table 4-2 and Table D-2.	6/22/13	6/26/13	6/27/13
ak	Section 9.5.2.5	This addendum adds “specific volume at the critical point” calculation requirements for blends to Section 9.5.2.5.	6/22/13	6/26/13	7/24/13

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

NOTE

When addenda, interpretations, or errata to this standard have been approved, they can be downloaded free of charge from the ASHRAE Web site at http://www.ashrae.org.

NOTICE

INSTRUCTIONS FOR SUBMITTING A PROPOSED CHANGE TO THIS STANDARD UNDER CONTINUOUS MAINTENANCE

This standard is maintained under continuous maintenance procedures 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. SSPC consideration will be given to proposed changes within 13 months of receipt by the manager of standards (MOS).

Proposed changes must be submitted to the MOS in the latest published format available from the MOS. However, the MOS may accept proposed changes in an earlier published format if the MOS concludes that the differences are immaterial to the proposed change submittal. If the MOS concludes that a current form must be utilized, the proposer may be given up to 20 additional days to resubmit the proposed changes in the current format.

ELECTRONIC PREPARATION/SUBMISSION OF FORM FOR PROPOSING CHANGES

An electronic version of each change, which must comply with the instructions in the Notice and the Form, is the preferred form of submittal to ASHRAE Headquarters at the address shown below. The electronic format facilitates both paper-based and computer-based processing. Submittal in paper form is acceptable. The following instructions apply to change proposals submitted in electronic form.

Use the appropriate file format for your word processor and save the file in either a recent version of Microsoft Word (preferred) or another commonly used word-processing program. Please save each change proposal file with a different name (for example, “prop01.doc,” “prop02.doc,” etc.). If supplemental background documents to support changes submitted are included, it is preferred that they also be in electronic form as word-processed or scanned documents.

For files submitted attached to an e-mail, ASHRAE will accept an electronic signature (as a picture; *.tif, or *.wpg) on the change submittal form as equivalent to the signature required on the change submittal form to convey non-exclusive copyright.

Submit an e-mail containing the change proposal files to:
change.proposal@ashrae.org

Alternatively, mail paper versions to:
ASHRAE
Manager of Standards
1791 Tullie Circle, NE
Atlanta, GA 30329-2305

Or fax them to:
Attn: Manager of Standards
404-321-5478

The form and instructions for electronic submittal may be obtained from the Standards section of ASHRAE’s Home Page, www.ashrae.org, or by contacting a Standards Secretary via phone (404-636-8400), fax (404-321-5478), e-mail (standards.section@ashrae.org), or mail (1791 Tullie Circle, NE, Atlanta, GA 30329-2305).

FORM FOR SUBMITTAL OF PROPOSED CHANGE TO AN ASHRAE STANDARD UNDER CONTINUOUS MAINTENANCE

NOTE: Use a separate form for each comment. Submittals (Microsoft Word preferred) may be attached to e-mail (preferred), or submitted in paper by mail or fax to ASHRAE, Manager of Standards, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: change.proposal@ashrae.org. Fax: +1-404/321-5478.

1. Submitter:

Affiliation:

Address: City: State: Zip: Country:

Telephone: Fax: E-Mail:

I hereby grant ASHRAE the non-exclusive royalty rights, including non-exclusive rights in copyright, in my proposals. I understand that I acquire no rights in publication of the standard in which my proposals in this or other analogous form is used. I hereby attest that I have the authority and am empowered to grant this copyright release.

Submitter's signature: ____ Date: ____________________________

All electronic submittals must have the following statement completed:

I *(insert name)* ____, through this electronic signature, hereby grant ASHRAE the non-exclusive royalty rights, including non-exclusive rights in copyright, in my proposals. I understand that I acquire no rights in publication of the standard in which my proposals in this or other analogous form is used. I hereby attest that I have the authority and am empowered to grant this copyright release.

2. Number and year of standard:

3. Page number and clause (section), subclause, or paragraph number:

4. I propose to: [ ] Change to read as follows [ ] Delete and substitute as follows
(check one) [ ] Add new text as follows [ ] Delete without substitution

Use underscores to show material to be added (<u>added</u>) and strike through material to be deleted (~~deleted~~). Use additional pages if needed.

5. Proposed change:

6. Reason and substantiation:

7. Will the proposed change increase the cost of engineering or construction? If yes, provide a brief explanation as to why the increase is justified.

[ ] Check if additional pages are attached. Number of additional pages: _______

[ ] Check if attachments or referenced materials cited in this proposal accompany this proposed change. Please verify that all attachments and references are relevant, current, and clearly labeled to avoid processing and review delays. *Please list your attachments here:*

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.

ASHRAE · 1791 Tullie Circle NE · Atlanta, GA 30329 · www.ashrae.org

About ASHRAE

ASHRAE, founded in 1894, is an international building technology society with more than 50,000 members worldwide. The Society and its members focus on building systems, energy efficiency, indoor air quality, refrigeration, and sustainability. Through research, standards writing, publishing, certification and continuing education, ASHRAE shapes tomorrow's built environment today.

For more information or to become a member of ASHRAE, visit www.ashrae.org.

To stay current with this and other ASHRAE standards and guidelines, visit www.ashrae.org/standards.

Visit the ASHRAE Bookstore

ASHRAE offers its standards and guidelines in print, as immediately downloadable PDFs, on CD-ROM, and via ASHRAE Digital Collections, which provides online access with automatic updates as well as historical versions of publications. Selected standards are also offered in redline versions that indicate the changes made between the active standard and its previous version. For more information, visit the Standards and Guidelines section of the ASHRAE Bookstore at www.ashrae.org/bookstore.

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.

Addenda, errata, and interpretations for ASHRAE standards and guidelines are no longer distributed with copies of the standards and guidelines. ASHRAE provides these addenda, errata, and interpretations only in electronic form to promote more sustainable use of resources.

Product code: 86021 11/13