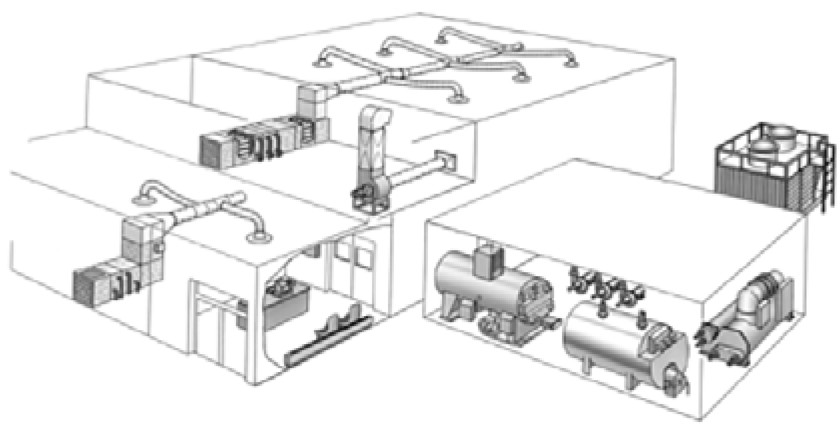
TRANE®

Applications Engineering Manual

Refrigerating Systems and Machinery Rooms

Application Considerations for Compliance with ASHRAE Standard 15



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Preface

As a leading HVAC manufacturer, we deem it our responsibility to serve the building industry by regularly disseminating information that promotes the effective application of commercial comfort systems. For that reason, we regularly publish educational materials, such as this one, to disseminate information gathered through laboratory research, testing programs, and practical experience.

This publication focuses on *design practices for machinery rooms that house refrigerating systems*. While such systems satisfy a wide range of cooling needs, they also contain potentially hazardous chemicals. To encourage safe and responsible handling of refrigerants, this guide outlines machinery-room design practices that are based on the refrigerant safety classifications in ANSI/ASHRAE Standard 34 and the refrigerant use restrictions in ANSI/ASHRAE Standard 15. Careful attention to these recommendations will help to provide a safe environment for personnel who operate and maintain refrigeration systems.

Note: A third standard — ASHRAE Standard 147, Reducing the Release of Halogenated Refrigerants from Refrigerating and Air-Conditioning Equipment and Systems *— recommends practices and procedures for curtailing leakage of CFC refrigerants from the operation and maintenance of HVAC equipment. Standard 147 contains valuable information for those who own or design refrigerating systems, but its subject matter is outside the scope of this guide.*

We encourage engineering professionals who design building comfort systems to become familiar with the contents of this guide and to use it as a reference. Architects, building owners, equipment operators, and technicians may also find this publication of interest because it addresses building layout and refrigerant-handling practices.

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Introduction

Building code requirements often originate from published standards (see inset below). Although the original wording and intent may be modified during the code-writing process, familiarity with the underlying standard can be useful in achieving compliance. With that in mind, we've written this application guide to help readers understand the refrigerant use restrictions outlined in ANSI/ASHRAE Standard 15–2004, *Safety Standard for Refrigeration Systems*. Although Standard 15 addresses mechanical cooling systems of all sizes and refrigerants of all types, **this guide focuses primarily on centrifugal and helical-rotary refrigerating systems that must be installed in specially designed *machinery rooms***.

ASHRAE reserves the term *machinery room* for a room that is specifically designed to house the compressors and pressure vessels of a refrigerating system. To comply with Standard 15, the design of the machinery room must:

- Limit access to authorized personnel
- Prevent escaped refrigerant from entering other parts of the building
- Provide adequate, unobstructed clearance for equipment operation and maintenance
- Assure proper ventilation
- Properly vent pressure-relief devices
- Enable continuous refrigerant detection

This guide examines specific requirements related to each of these design goals. Our intent in providing this information is to help engineering professionals design and specify refrigerating machinery rooms that comply with the current standard of care. (See Appendix A in this guide for an example specification.)

Enforceability: Industry standard versus building code

Industry standards, such as those authored by ASHRAE for the HVAC industry, serve as an important reference for code-writing agencies … but standards are *not* enforceable.

Model code agencies, such as the International Code Council (ICC), look to industry standards and other materials for "best practices." They then develop example codes that states and other governing bodies can legislate into enforceable minimum requirements, which are in turn used as criteria for approval by building inspectors.

The process that transforms an industry standard into enforceable requirements can take several years. Changes in wording, and sometimes intent, may occur along the way to arrive at language that is legally defensible (if not always readily understood).

At minimum, engineering professionals are responsible for specifying designs that satisfy code requirements; but they also may be held accountable for practicing the then-current "standard of care" represented by the relevant ASHRAE standards in their designs. For this reason, we strongly encourage practicing engineers to remain conversant with relevant industry standards and guidelines as well as the building code.

Note: Some refrigerating systems, particularly industrial applications, use ammonia as refrigerant. Significant differences exist between the design practices and relevant standards for ammonia versus those for the carbon-based refrigerants commonly used in comfort cooling applications. Rather than risk confusion by concurrently discussing both types of systems, this manual does not address ammonia-based refrigeration nor absorption refrigerating systems.

Conventions used in this manual

For the sake of simplicity, all references to “Standard 15” refer to the 2004 edition of ANSI/ASHRAE Standard 15 unless otherwise noted. Similarly, all references to “Standard 34” refer to the 2004 edition of ANSI/ASHRAE Standard 34 unless otherwise noted.

Excerpts (indented for easy identification) from these standards are accompanied by explanations, which suggest how to interpret and comply with Standard 15’s requirements for proper machinery-room design.

How ASHRAE Classifies Refrigerants

As its title implies, **ANSI/ASHRAE Standard 34, *Designation and Safety Classification of Refrigerants*,** provides a system for naming and classifying refrigerants. This system serves two important functions:

> … to establish a simple means of referring to common refrigerants instead of using the chemical name, formula, or trade name. It also establishes a uniform system for assigning reference numbers and safety classifications to refrigerants (Section 1).

The standard's statement of scope elaborates further:

> 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 (Section 2).

Familiarity with refrigerant safety classifications and naming conventions is fundamental to our discussion of design practices for refrigerating machinery rooms. For that reason, a brief review of Standard 34–2004 follows.

Naming conventions

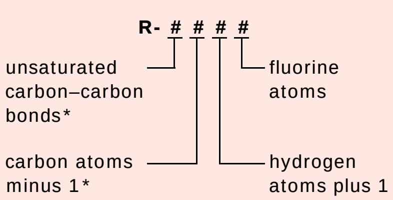
Standard 34 establishes a shorthand method of refrigerant numbering that provides a simple, unambiguous alternative to trade names and chemical formulas. The tables on the next page show the proper prefixes, identifying numbers, and chemical names for several common refrigerants (Table 1) and refrigerant blends (Table 2). As an alternative to the *R* prefix, the refrigerant's identifying number can be preceded by a more descriptive, composition-designating identifier that indicates whether the refrigerant contains, respectively, hydrogen (H), bromine (B), chlorine (Cl), fluorine (F), and carbon (C). So, Refrigerant 11 — which contains chlorine, fluorine, and carbon — can be designated as *CFC-11* or *R-11*, while Refrigerant 22 — which contains hydrogen, chlorine, fluorine, and carbon — becomes *HCFC-22* or *R-22*. Both shorthand designators are equally acceptable, as is using the word *Refrigerant* followed by the number.

Note: To avoid confusion and/or misunderstanding when referring to refrigerants, choose one of the permitted naming conventions (either R-123 or HCFC-123, for example) and use it consistently throughout the documentation for a project.

Refrigerant numbering

The scheme used to develop the numbers for identifying refrigerants is based on the number and specific types of components in the refrigerant. Numbering is partly based on the number of fluorine, hydrogen, carbon, bromine, and chlorine atoms, and on the number of carbon–carbon bonds.

The entire scheme is somewhat complicated, but the following example shows the basics:



*omitted if zero

See Section 4 of Standard 34 for a complete explanation of refrigerant numbering.

Table 1. Characteristics, safety classifications, and allowable amounts for several common refrigerants[a]

	Common names		Chemical name	Chemical formula	Normal boiling point	Safety group	Quantity per occupied space[b] lb per 1000 ft³[c]	ppm by vol	g/m³
Methane series	**R-11**	or CFC-11	trichlorofluoromethane	CCl_3F	24°C (75°F)	**A1**	1.6	4,000	25
Methane series	**R-12**	or CFC-12	dichlorodifluoromethane	CCl_2F_2	-30°C (-22°F)	**A1**	12	40,000	200
Methane series	**R-22**	or HCFC-22	chlorodifluoromethane	$CHClF_2$	-41°C (-41°F)	**A1**	9.4	42,000	150
Ethane series	**R-113**	or CFC-113	1,1,2–trichloro–1,2,2–trifluoroethane	CCl_2FCClF_2	48°C (118°F)	**A1**	1.9	4,000	31
Ethane series	**R-123**	or HCFC-123	2,2–dichloro–1,1,1–trifluoroethane	$CHCl_2CF_3$	27°C (81°F)	**B1**	0.40	1,000	6.3
Ethane series	**R-134a**	or HFC-134a	1,1,1,2–tetrafluoroethane	CH_2FCF_3	-26°C (-15°F)	**A1**	16	60,000	250
Ethane series	**R-152a**	or HFC-152a	1,1–difluoroethane	CH_3CHF_2	-25°C (-13°F)	**A2**	1.2	7,000	20

[a] Table 2 (below) provides similar data for two common refrigerant blends.

[b] Per ANSI/ASHRAE Standard 15–2004, only use these refrigerant quantities in conjunction with Section 7 of that standard. The basis for the refrigerant quantities shown above is a single event where a complete discharge of any refrigerating system into the occupied space occurs. The quantity for each refrigerant *listed above* is the most restrictive of a minimum oxygen concentration of 19.5% percent or as follows:
Group A1: 80% of the cardiac sensitization level.
Group A2: Approximately 20% of the lower flammability limit (LFL).
Group B1: 100% of the measure consistent with the *immediately-dangerous-to-life-or-health* (IDLH) value.
Refer to Table 1 of the standard for a complete list of refrigerants and refrigerant quantity limits.

[c] Per ANSI/ASHRAE Standard 15–2004: To correct for height above sea level, multiply these values either by $(1 - 2.42 \times 10^{-6}H)$, where H is measured in feet; *or* by $(1 - 7.94 \times 10^{-2}h)$, where h is measured in kilometers.

Table 2. Characteristics, safety classifications, and allowable amounts for two common azeotropic refrigerant blends[a, b]

Refrigerant number	Composition (mass %)	Normal boiling point	Safety group	Quantity per occupied space[c] lb per 1000 ft³[d]	ppm by vol	g/m³
R-500	R-12/R-152a (73.8/26.2)	-33°C (-27°F)	**A1**	12	47,000	200
R-502	R-22/R-115 (48.8/51.2)	-45°C (-49°F)	**A1**	19	65,000	300

[a] Table 1 (above) provides similar data for several common refrigerants.

[b] Per ANSI/ASHRAE Standard 34–2004, azeotropic refrigerant blends 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] Per ANSI/ASHRAE Standard 15–2004, only use the quantities here in conjunction with Section 7 of that standard. The basis for the refrigerant-blend quantities shown above is a single event where a complete discharge of any refrigerating system into the occupied space occurs. The quantity for each of the Group A1 refrigerant blends *listed above* is the most restrictive of a minimum oxygen concentration of 19.5% percent or 80% of the cardiac sensitization level. Refer to Table 1 of the standard for a complete list of refrigerants and refrigerant quantity limits.

[d] Per ANSI/ASHRAE Standard 15–2004: To correct for height above sea level, multiply these values either by $(1 - 2.42 \times 10^{-6}H)$, where H is measured in feet; *or* by $(1 - 7.94 \times 10^{-2}h)$, where h is measured in kilometers.

Safety group classifications

For more detailed information about the health hazards or recommended handling practices for a particular refrigerant, request a copy of the Material Safety Data Sheet (MSDS) from the refrigerant manufacturer.

In addition to establishing uniform naming conventions, Standard 34 classifies each refrigerant according to its *toxicity* (Class A or B) and its *flammability* (Class 1, 2, or 3).

Toxicity. Section 6.1.2 of the standard defines two toxicity categories based on allowable exposure:

> **Class A** signifies refrigerants for which toxicity has not been identified at concentrations less than or equal to 400 ppm by volume, based on data used to determine Threshold Limit Value–Time-Weighted Average (TLV–TWA) or consistent indices.
>
> **Class B** signifies refrigerants for which there is evidence of toxicity at concentrations below 400 ppm by volume, based on data used to determine TLV–TWA or consistent indices.

Standard 34 looks to the American Conference of Governmental Industrial Hygienists (ACGIH) for its definition of TLV–TWA:

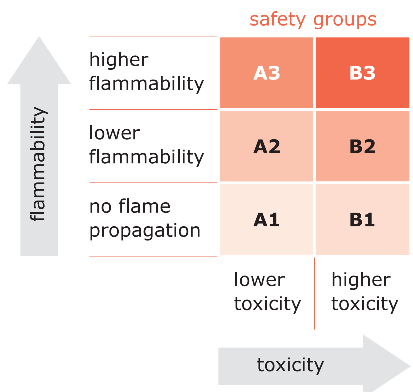
> … the time-weighted average concentration for a normal 8-hour workday and a 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect (Section 3).

Flammability. The letter designation for toxicity is followed by a number, which indicates how readily the refrigerant may ignite. Refrigerants with no potential for flame propagation are assigned to Class 1, while refrigerants deemed most likely to ignite are assigned to Class 3. Section 6.1.3 of Standard 34 defines the flame propagation and *lower flammability limits* (LFL) for each of three flammability categories:

> **Class 1** indicates refrigerants that do not show flame propagation when tested in air at 101 kPa (14.7 psia) and 21°C (70°F).
>
> **Class 2** signifies refrigerants having a lower flammability limit (LFL) of more than 0.10 kg/m^3 (0.00625 lb/ft^3) at 21°C and 101 kPa (70°F and 14.7 psia) *and* a heat of combustion of less than 19,000 kJ/kg (8,174 Btu/lb). The heat of combustion shall be calculated assuming that combustion products are in the gas phase and in their most stable state (for example: C, N, S give CO_2, N_2, SO_3; F and Cl give HF and HCl if there is enough H in the molecule, otherwise they give F_2 and Cl_2; excess H is converted to H_2O).
>
> **Class 3** indicates refrigerants that are highly flammable, as defined by an LFL of less than or equal to 0.10 kg/m^3 (0.00625 lb/ft^3) at 21°C and 101 kPa (70°F and 14.7 psia) *or* a heat of combustion greater than or equal to 19,000 kJ/kg (8,174 Btu/lb). The heat of combustion is calculated as explained above in the definition of a Class 2 category.

Together, the toxicity and flammability classifications define six safety groups — A1, A2, A3, B1, B2, and B3 — which are represented by the matrix in Figure 1. Standard 15 refers to these safety group designations in its specification of design criteria for refrigerating equipment located in or near a building.

Figure 1. Refrigerant safety groups from ANSI / ASHRAE Standard 34–2004



For a partial list of the refrigerants and refrigerant blends that are classified in this manner, see Table 1 and Table 2 on p. 4 of this guide.

Restrictions on Refrigerant Use

ANSI/ASHRAE Standard 15 is subject to *continuous maintenance* to help assure that its content remains relevant. This review process allows portions of the standard to be revised without republishing the entire document. Upon approval, each revision is issued as an electronic addendum. Addenda can be downloaded at no cost from the ASHRAE Web site (http://www.ashrae.org).

The design practices presented in this application guide are based on the **2004 edition** of Standard 15. Visit the ASHRAE Web site regularly to check for updates.

ANSI/ASHRAE Standard 15–2004, *Safety Standard for Refrigeration Systems*, defines the standard of care for specifying:

> … safe design, construction, installation, and operation of refrigeration systems (Section 1).

As for its scope:

> This standard establishes safeguards for life, limb, health, and property and prescribes safety requirements.
>
> This standard applies:
>
> (a) to the design, construction, test, installation, operation, and inspection of mechanical and absorption refrigeration systems, including heat pump systems used in stationary applications.
>
> (b) to modifications including replacement of parts or components if they are not identical in function and capacity, and
>
> (c) to substitutions of refrigerant having a different designation (Section 2).

Standard 15 details the design and installation requirements for a broad range of refrigerating systems. It applies not only to new construction, but also to replacements, conversions, and alterations that change the function of the system. Some of the requirements of the standard — like the safeguards mandated by Section 11.1 to minimize the risk of accidental damage or rupture of system components — are general and apply to all system types. Others are specific to the type and use of the refrigerating system: Sections 8.11 and 8.12, for example, pertain only to refrigerating systems that require machinery rooms.

Which safety requirements apply?

Performing the following four-step process (detailed in the next sections) can help you identify which safety requirements must be met to achieve compliance with Standard 15:

1. Identify the *safety group classification* of the refrigerating system.
2. Determine the *occupancy classification* of the room that houses the refrigerating system.
3. Determine the relevant *system probability* classification.
4. Identify the relevant application requirements using Section 7 of Standard 15 and the determinations made in the preceding steps.

Step 1: Identify the safety group classification

The safety group classification is covered by Section 6 of Standard 15. As discussed earlier, refrigerants are classified into one of six groups according to their *flammability* and *toxicity*. These safety classification criteria are thoroughly defined in ANSI/ASHRAE Standard 34–2004. Table 1 and Table 2 (p. 4 of this guide) indicate the safety classifications for several commonly used single-compound refrigerants and refrigerant blends.

Note: The safety group classification for any blend corresponds to the "worst-case fractionation," which is the change in the blend's composition over time due to evaporation of the more volatile components or condensation of the less volatile components.

Step 2: Determine the occupancy classification

ASHRAE defined seven occupancy classes to reflect the various uses of a building and the ability of the people inside to respond in case of emergency. Key to proper use of these classifications is an understanding of what is meant by the terms *occupied space* and *machinery room*. Standard 15 offers these definitions:

> *occupied space:* that portion of the premises accessible to or occupied by people, excluding machinery rooms.
>
> *machinery room:* a space, meeting the requirements of [Section] 8.11 or 8.12, that is designed to house compressors and pressure vessels (Section 3).

In other words, the room that contains the refrigerating equipment is *initially* considered part of the occupied space. It is only excluded if the "Restrictions on Refrigerant Use" in Section 7 require that the equipment room satisfies the specific criteria in either Section 8.11 or Section 8.12, which in turn qualify it as a *machinery room*.

Other than piping and certain types of listed equipment, all refrigerating equipment *inside* the building — or located less than 20 ft (6.1 m) from any building opening *other* than an opening to a machinery room — is governed by one of the seven occupancy classifications described in Table 3 (facing page).

Table 3. Occupancy classifications from ANSI / ASHRAE Standard 15–2004

Occupancy class	Characteristics	Examples
Institutional	Occupants cannot readily leave without assistance	Hospitals, nursing homes, prisons
Public assembly	Occupants cannot quickly vacate due to large numbers	Auditoriums, ballrooms, classrooms, restaurants
Residential	Occupants are provided with complete, independent living facilities	Hotels, dormitories, apartments
Commercial	Occupants transact business, receive personal services, or purchase food/goods	Office and professional buildings and markets (but excluding large mercantile)
Large mercantile	More than 100 occupants congregate either above or below street level to purchase merchandise	Shopping malls
Industrial	Occupancy by the general public is prohibited; access by authorized personnel is controlled	Manufacturing plants, processing plants, storage facilities
Mixed	Two or more occupancy types (classes) share the same building[a]	Hotels

[a] Per Section 4.1.7 of the standard, 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 apply to that portion of the building. (For example, a cold-storage space in a hotel might be classified as an industrial occupancy, while the rest of the building is considered residential.) When the occupancy areas are not isolated in this manner, the occupancy with the most stringent requirements governs the entire area.

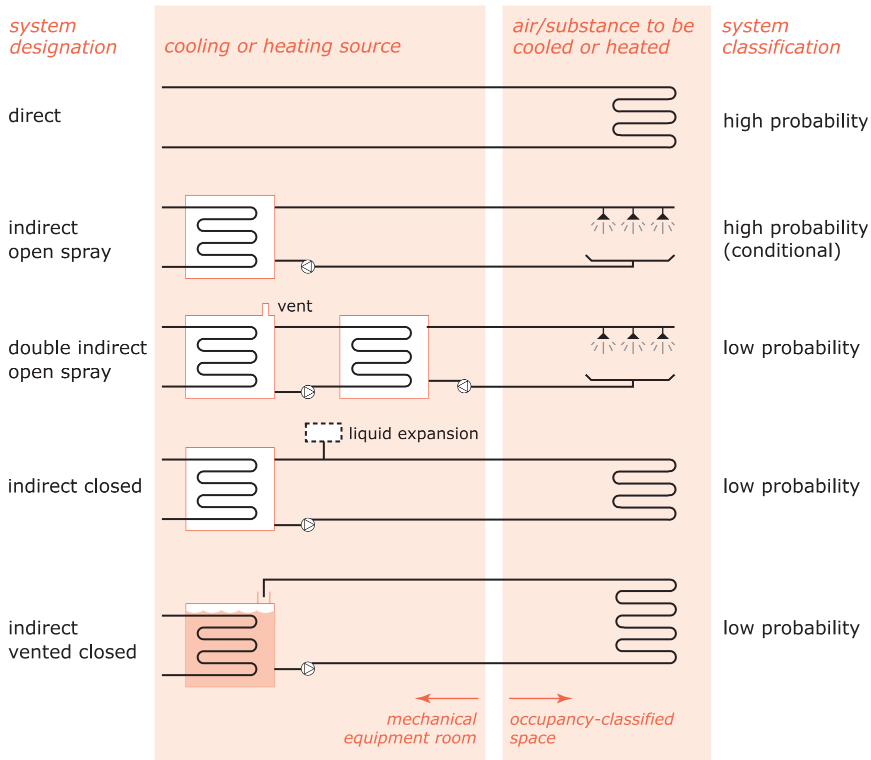
Step 3: Determine system probability

The "Refrigerating System Classification" section of Standard 15 divides refrigerating systems into five categories (Figure 2, p. 10), based on the method used to extract or deliver heat. This categorization indicates *system probability*—that is, the likelihood of refrigerant leaking from a refrigerating system into an occupancy-classified area. As defined below, refrigerating systems are categorized as either *high probability* or *low probability:*

- *High-probability systems* are those in which the basic design or location of components is such that refrigerant leakage from a failed connection, seal, or component will enter the occupied space. Examples include direct-expansion, split-system, and packaged rooftop applications.
- *Low-probability systems* are any systems in which the basic design or location of components is such that refrigerant leakage from a failed connection, seal, or component cannot enter the occupied space. A typical example is a water chiller that serves a remote air handler.

  Indirect open-spray systems, also known as "air washers," are considered to be low probability when the secondary coolant pressure remains higher than the refrigerant pressure during all operating and standby conditions. (See Appendix C of this guide for information about the design of low-probability air-washer systems.)

Figure 2. Refrigerating system classifications (ANSI / ASHRAE Standard 15 – 2004)



Step 4: Identify safety requirements based on refrigerant quantity and system application

After the safety group, occupancy, and system-probability classifications of a refrigerating system have been determined, Section 7 of Standard 15 can be used to ascertain which of the standard's refrigerant-quantity rules apply. The rules define how much refrigerant can be used in each situation and detail any restrictions that apply.

When an applicable "rule" refers to a refrigerant quantity in Table 1 (of the standard), you must determine the amount of refrigerant per 1,000 ft^3 (28.3 m^3) of occupied space for the proposed system. And to do *that,* you must determine how much refrigerant the largest single chiller — or the largest refrigeration circuit — contains, and then calculate the volume of the occupied space. Different calculations must be used for nonconnecting and ventilated spaces.

Allowable refrigerant quantity

The basis for the "Refrigerant and Amounts" values in Table 1 of Standard 15 is a single event in which the refrigerant in a refrigerating system completely discharges into an occupied space. If the quantity of refrigerant in the system does not exceed the amount defined by the rules, the building occupants will not be exposed to a harmful level of refrigerant, provided that the refrigerant disperses equally throughout the occupied space. (Table 1 and Table 2, both on p. 4 of this guide, show allowable refrigerant amounts for several common refrigerants and refrigerant blends.)

The proper quantity of refrigerant to use when determining the "Quantity of Refrigerant per Occupied Space" is *not* the sum of the refrigerant charges in all of the refrigerating systems, but rather, *it is the quantity of refrigerant in the largest chiller or circuit.* When the machinery room houses multiple refrigerating systems that use different refrigerants, it's necessary to determine which refrigerant results in the most restrictive requirements.

Location of the refrigerating system

Any indoor space that contains components of the refrigerating system must be identified as one of three space types: *ventilated* (and occupied), *nonconnecting* (and occupied), or *machinery room*. This designation helps determine the allowable amount of refrigerant for a particular application based on the refrigerant use restrictions outlined in Section 7 of the standard.

If all or part of a refrigerating system is housed indoors, then that space initially can be considered as an "occupied space" (that is, a space that's accessible to or occupied by people). To comply with Standard 15, the amount of refrigerant in the largest circuit or unit of the refrigerating system must not exceed the limit shown for that refrigerant type in Table 1 of the standard; otherwise, the refrigerant-containing components must be installed outdoors or in a machinery room that is specifically designed to safely house refrigerating compressors and pressure vessels.

Calculating the allowable refrigerant quantity for an occupied-space volume

The refrigerant quantity limits defined in Standard 15 are based on the volume of the occupied space and the ventilation method, which together describe two types of occupied spaces — *nonconnecting* and *ventilated*.

"Nonconnecting" and "ventilated" spaces are defined in Sections 7.3.1 and 7.3.2, respectively, of Standard 15.

Nonconnecting spaces

A nonconnecting space is an occupied space that contains a refrigerating system (or part of one) but is not connected to other spaces by permanent openings or HVAC ducts. Refrigerant released into a nonconnecting space generally stays in that space and does not disperse into other occupied portions of the building. Examples include a hotel room that houses a packaged terminal air conditioner (PTAC) or an equipment room that houses a chiller. In each case, the "occupied-space volume" equals the volume of the room, which then determines how much refrigerant is permitted.

If the refrigerant quantity within the refrigerating system exceeds the pounds-per-1,000 ft^3 (g/m^3) limit set in Table 1 of Standard 15 — which it typically does for chillers — then the room is no longer considered an occupied space. In that case, the room must conform to the requirements for a *machinery room*, as defined in Section 8.11 (and Section 8.12, if applicable) of the standard.

Note: When several stories of unpartitioned space are connected by an open atrium or mezzanine, use the volume calculated by multiplying the floor area of the lowest space by 8.2 ft (2.5 m).

Example. A 600-ton (2106 kW) centrifugal chiller that contains 1,800 lb (816.5 kg) of R-134a will be located in a room that is 30 ft (9.1 m) wide, 60 ft (18.3 m) long, and 18 ft (5.5 m) high. The quantity of refrigerant per occupied space in this case is:

$$1800\ \text{lb}/(30 \times 60 \times 18)\text{ft}^3 = 0.056\ \text{lb}/\text{ft}^3 \text{or } 56\ \text{lb}/1000\ \text{ft}^3$$
$$(816.5\ \text{kg}/(9.1 \times 18.3 \times 5.5)\text{m}^3 = 0.89\ \text{kg}/\text{m}^3 \text{or } 890\ \text{g}/\text{m}^3)$$

Section 7.2.1 of Standard 15–2001 reduces the "quantity of refrigerant" values in Table 1 by 50% for all areas of institutional occupancies.

For occupancies *other than institutional*, the Table 1 limit for this refrigerant is 16 lb/1000 ft^3 (250 g/m^3) … significantly less than the 56 lb/ft^3 (890 g/m^3) of refrigerant in our example chiller. To comply with Standard 15, the chiller must be placed in a machinery room rather than an occupied space.

Ventilated spaces

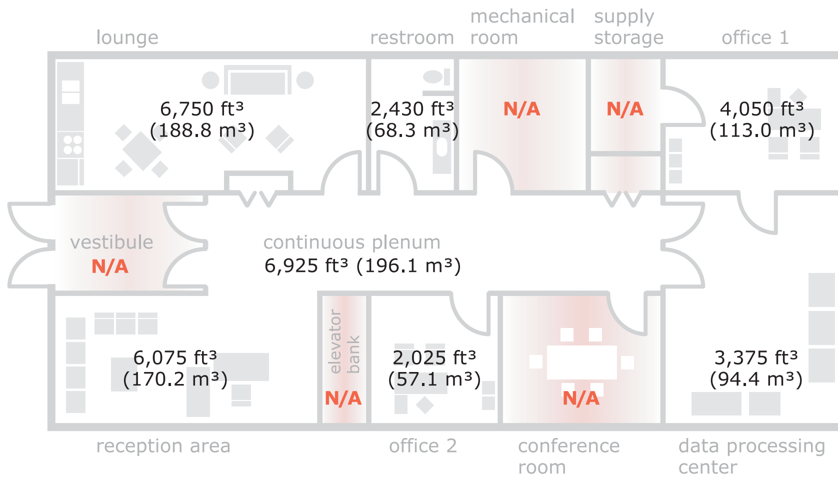
Ventilated spaces are the areas in the building that will be affected by a refrigerant leak due to dispersal by the ventilation system. All or part of the refrigerating system that serves these spaces is located in an air handler, a distribution duct, or in an occupied space with a mechanical ventilation system. A typical example is a direct-expansion (DX) refrigerating system, where the evaporator coil is located in the air stream that supplies other occupied areas of the building. For such systems, the "occupied space" is the worst-case (smallest) volume into which the leaked refrigerant could disperse, which requires review of the entire duct system.

Parallel spaces that are connected to the duct system may be excluded *if they can be isolated from the source of the refrigerant leak by something other than smoke and/or fire dampers*. (Smoke/fire dampers are excluded as "isolators" because they close only in an emergency and not in response to a refrigerant leak.) For example, the occupied-space volume for the PTAC in a hotel room excludes the volume of the bathroom because the bathroom door isolates that part of the room from the part that contains the refrigerating system.

When calculating the occupied-space volume for a ventilated space, **include** the volumes of:

- parallel spaces served by VAV boxes, but only if the VAV dampers or air valves do not reduce airflow to less than 10% of the maximum design flow (with the fan running);
- plenums, but only if they are part of the supply- or return-air system; and,
- supply and return ductwork.

Figure 3. Calculating "occupied-space volume" for ventilated spaces in a small office building



total occupied space volume = 31,630 ft³ (887.9 m³)

Note: Total excludes the mechanical room, supply storage, vestibule, and elevator bank, which are unventilated; and the conference room because its airflow can be less than 10% of design.

Example. A 20-ton (5.7 kW), packaged, cooling-only rooftop air conditioner with VAV control serves the small office building shown in Figure 3. Each of the occupied spaces in the building has a 9-ft (2.7 m) ceiling with an 18-in. (0.5 m) plenum above it. The continuous plenum is interrupted over the mechanical room, where the walls extend from the floor slab to the roof.

The rooftop unit contains two 10-ton (2.8 kW) refrigerating circuits, each of which holds 20 lb (9.072 kg) of R-22. VAV boxes with a minimum flow setting of 25% deliver supply air to all rooms except the conference room, which is served by a VAV box with a minimum flow setting of 0%. An open plenum provides the return-air path to the unit.

Based on this information, we can deduce that the relevant safety group classification of the refrigerant is *A1*, that the occupancy is *commercial*, and that the refrigerating system classification is *high probability*. According to Standard 15–Section 7.2, the allowable refrigerant quantity for this scenario is limited to the value shown in Table 1 of the standard: 9.4 lb/1,000 ft³ (150 g/m³) of occupied space.

To find the office building's total volume of occupied space, calculate the volume of each occupied room and add the resulting values. In this case, we will omit the mechanical room, supply storage, vestibule, and elevator bank because these spaces are not served by the rooftop unit nor the return-air plenum. We will also exclude the conference room because its minimum airflow setting is less than 10% of design. With these exceptions, the total occupied-space volume is 31,630 ft³ (887.9 m³).

Having determined the volume of the occupied space, we now can calculate the quantity of refrigerant in our rooftop unit for every 1,000 ft³ (1 m³) of occupied space and find that the resulting value is well below the 9.4 lb/1,000 ft³ (150 g/m³) limit set by Standard 15–Table 1:

$$20\ \text{lb} \div 31{,}630\ \text{ft}^3/1{,}000\ \text{ft}^3 = 0.6\ \text{lb}/1{,}000\ \text{ft}^3$$

$$(9{,}072 \div 887.9\ \text{m}^3/1\ \text{m}^3 = 10.2\ \text{g}/\text{m}^3)$$

You can also use the refrigerant limits in Table 1 to determine the minimum volume of occupied space that a particular refrigerating system will require. For example, inverting the 9.4 lb/1,000 ft³ (150 g/m³) limit indicates that each pound (gram) of R-22 in the system will require 106.4 ft³ (0.0067 m³) of occupied space:

$$1{,}000\ \text{ft}^3 \div 9.4\ \text{lb} = 106.4\ \text{ft}^3/1\ \text{lb}$$

$$(1\ \text{m}^3 \div 150\ \text{g} = 0.0067\ \text{m}^3/1\ \text{g})$$

Because the "largest" circuit in our example rooftop unit contains 20 lb (9,072 g) of refrigerant, the occupied space it serves must be at least 2,128 ft³ (60.78 m³):

$$20\ \text{lb} \times 106.4\ \text{ft}^3/1\ \text{lb} = 2{,}128\ \text{ft}^3$$

$$(9{,}072\ \text{g} \times 0.0067\ \text{m}^3/1\ \text{g} = 60.78\ \text{m}^3)$$

Application requirements for A1 or B1 refrigerating systems

Standard 15 includes "general requirements" (Section 11), which are relevant to a wide variety of refrigerating systems, as well as "installation restrictions" (Section 8), which apply to specific combinations of refrigerant, occupancy, and refrigerating system. Recall that our focus in this guide is much narrower; **here, we discuss the restrictions that apply to low-probability systems containing either A1 or B1 refrigerants.** This subset includes most of the refrigerating systems — typically chillers — that require machinery rooms in commercial comfort-cooling applications.

For a large system, such as a chiller, Section 7.4 and its subsections establish the maximum quantity of refrigerant based on the mass of refrigerant in the chiller.[1] When evaluated in this manner (see the example for nonconnecting spaces on p. 12), the refrigerant charge in most chillers will require installation in a machinery room or outdoors:

> 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 in [Section] 7.2, or

[1] More specifically, the maximum quantity of refrigerant is based on the mass of refrigerant in the largest refrigerating system (any part of which is located in the machinery room). If the system consists of distinct, independent refrigeration circuits, then the maximum refrigerant quantity is based on the mass of refrigerant in the largest circuit.

(b) direct-fired absorption equipment, other than sealed absorption systems not exceeding the refrigerant quantity limits indicated in Table 2 [of ANSI/ASHRAE Standard 15–2004], 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.

Refrigerating systems in large spaces

Occasionally, chillers or other large refrigerating equipment are placed in a room that is so expansive (a manufacturing facility, for example) that the actual amount of "refrigerant per occupied space" does not exceed the limit set by Standard 15. These cases require special attention. Why? Even if the combination of a large amount of refrigerant in an exceptionally large space satisfies Standard 15's installation restrictions, it may not meet the *purpose* of the standard, which is to ensure the *safe use* of refrigerating systems. If the refrigerant vessel ruptured in a way that released the charge rapidly, the result could be a high, localized concentration of refrigerant. As a precaution, it may be appropriate to provide monitoring and ventilation.

General Requirements for Machinery Rooms

Section 11 of Standard 15, "General Requirements," addresses several important issues; for easy reference, it is reprinted in the inset on the facing page. Most of these requirements are self-explanatory, so this discussion simply highlights the implications of five particularly important subsections.

Note: The requirements in Section 11 apply to all *refrigerating systems, regardless of whether the system is installed in an "equipment room" or a "machinery room." (Recall that Standard 15 defines a "machinery room" as a space that complies with the requirements of Section 8.11 or 8.12 of the standard, and that is designed specifically to house compressors and pressure vessels.)*

11.1 General restrictions — Safeguards. Standard 15's broad requirement to "adequately safeguard" refrigerating equipment, piping, and controls gives the presiding jurisdictional authority far-reaching power. Basically, *anything* that the presiding authority cites as "unsafe" must be remedied. Although the purpose of Standard 15 is to provide for the *safe* use of refrigerating equipment, following the standard to the letter may not afford an acceptable level of safety in certain situations.

11.2 Signs and identification. This subsection details the signage requirements inside, and at the entrances to, the machinery room. The 2004 standard requires *at each entrance* the placement of a sign, which states "Machinery Room — Authorized Personnel Only." The sign also must prohibit entering the machinery room without proper protective gear during a refrigerant-alarm condition.

11.5 Storing refrigerant. Refrigerant can be stored in a machinery room, provided that it's kept in approved storage containers and that the amount does not exceed 330 lb (150 kg). To store larger quantities of refrigerant in the machinery room and still comply with Standard 15, the containers must be provided with relief valves and piping in accordance with Section 9.7.

Standard 15 does not *explicitly* allow storage of the refrigerant charge from a chiller during servicing. However, it seems reasonable to make that inference *provided that the charge is stored in approved and properly filled containers*. The rationale for this interpretation is that a machinery room, as defined by ASHRAE, is specifically designed to handle the amount of refrigerant in use. Storing the charge in separate containers, rather than in one large chiller, does not change the type or quantity of refrigerant in the room.

11.6 Maintenance. Among the safety-focused requirements in this subsection is periodic testing of the detectors, alarms, and mechanical ventilation systems in accordance with the respective equipment manufacturers and the presiding code authority.

11.7 Responsibility for operation and emergency shutdown. The 2001 edition of Standard 15 changed the requirements related to self-contained breathing apparatus (SCBA). Notably missing from that edition of the

(continued on p. 18)

General requirements for refrigerating systems

[The following excerpt presents Section 11, in its entirety, from ANSI/ASHRAE Standard 15–2004.]

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* in accordance with ANSI A13.1, *Scheme for Identification of Piping Systems*.

11.2.3 Changes in refrigerant or lubricant. When the kind of refrigerant or lubricant is changed as provided in 7.5.1.8, the signs required by 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 11.7 when the refrigerant alarm, required by 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 noncondensibles, 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.

11.4 Containers. Containers used for refrigerants withdrawn from a refrigerating system shall be as prescribed in the pertinent regulations of the 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 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 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.

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* *IIAR Bulletin 114, 9/91, Guidelines for Identification of Ammonia Refrigeration Piping and System Components,* International Institute of Ammonia Refrigeration, 1101 Connecticut Ave, N.W., Washington, DC 20036.

(continued from p. 16)

standard is the prescriptive requirement to provide self-contained breathing apparatus *outside the machinery room*. However, the new wording in Section 11.7 underscores the ongoing necessity for SCBA:

> 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.

In essence, this proviso still requires the availability of SCBA, but it gives owners more flexibility for determining *where* the protective gear is housed. For more information, see the "Handling Machinery-Room Emergencies" chapter in this guide. Also consult "Appendix I: Emergencies in Refrigerating Machinery Rooms," in ANSI/ASHRAE Standard 15–2004.

Open-flame devices

When exposed to high temperatures, refrigerants often break down into harmful products that can injure humans and damage machinery. To avoid both hazards, Standard 15 strictly prohibits the use of open-flame devices in machinery rooms that house refrigerating equipment:

> 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, or
>
> (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 (Section 8.11.6).

When combustion equipment, such as a boiler or direct-fired absorption machine, is designed to accept intake ductwork, condition (a) — ducting combustion air from outside the room directly into the open-flame device — offers the best solution. This strategy separates combustion-air requirements from ventilation needs, and avoids shutting down the combustion equipment if a refrigerant leak or nuisance alarm occurs.

Condition (b) describes a simple, cost-effective method for compliance that is especially useful in retrofit and replacement installations. If properly located, a high-quality, compound-specific monitor (see pp. 31–32) can avoid nuisance shutdowns that otherwise might be triggered by paints, cleaning agents, and other chemicals.

Considerations for Machinery-Room Layout

Equipment clearances

Equipment manufacturers typically include minimum clearance requirements in their submittals. This information is useful for assuring that the size and layout of the machinery room provides sufficient space to operate, maintain, and service the chiller(s) and any other equipment housed there. With respect to equipment clearance, Standard 15 specifically requires at least 7.25 ft (2.2 m) of clear headroom beneath equipment mounted above a passageway (Section 8.11.1).

The standard also mandates "*safe* access" to the chiller and any other components of the refrigerating system:

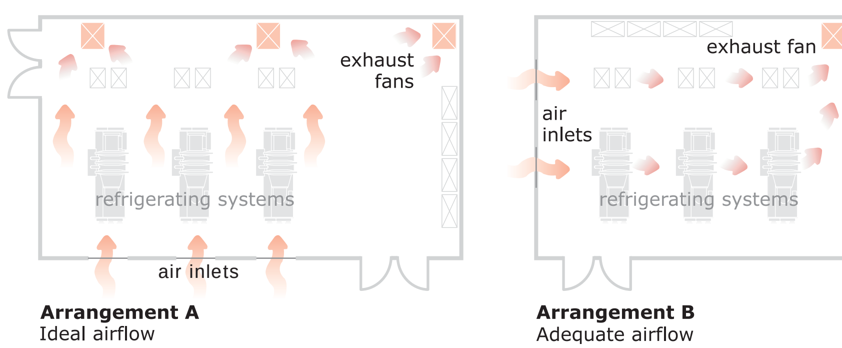
> A clear and unobstructed approach and space shall be provided for inspection, service, and emergency shutdown of condensing units, compressor units, condensers, stop valves, and other serviceable components of refrigerating machinery. Permanent ladders, platforms or portable access equipment shall be provided in accordance with the requirements of the authority having jurisdiction (Section 8.11.3).

Note: Standard 15 provides for minimum *protection to help prevent injury from accidents in refrigerating machinery rooms. The presiding code authority may impose additional requirements related to equipment access.*

Equipment placement for proper airflow

Another important consideration is the airflow pattern that results from interaction of the ventilation system with equipment in the room. Place the chillers between the ventilation inlet and exhaust, and orient them to avoid creating stagnant areas. Figure 4 compares two configurations for a machinery room that houses multiple chillers. Positioning the units as shown in Arrangement A provides good air movement, while Arrangement B inhibits airflow between the chillers.

Figure 4. Ventilation airflow in machinery rooms that house multiple chillers



The next chapter, “Ventilation for Machinery Rooms,” provides additional information on how to achieve proper ventilation in refrigerating machinery rooms.

Doors and passageways

Standard 15 requires that:

> 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 (Section 8.11.2).

In other words:

- There must be enough doors to permit rapid evacuation in case of an emergency.
- Machinery doors must fit tightly, open outward, and close automatically if they open into a building.
- There can be no openings, such as pipe tunnels and conduit raceways, that would permit leaked refrigerant from escaping to other parts of the building.
- Air handlers and ductwork that serve other parts of the building can be installed in the machinery room; however, openings must be gasketed and covered by tight-fitting panels.

This portion of the standard focuses on keeping escaped refrigerant within the machinery room, which would seemingly preclude the use of louvered doors. However, an exception *may* be granted if the louvered doors do not open into a walkway and if they are used only as inlets for ventilation air and to provide service clearance. (See inset on p. 25 for an example.) Be sure to consult the local code authority to verify compliance.

Access

Sections 8.11.8 and 11.2.4 of Standard 15 limit machinery-room access to authorized personnel:

> 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 (Section 8.11.5).
>
> 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 (Section 11.2.4).

Although Standard 15 no longer prescribes two self-contained breathing apparatus (SCBAs) outside the machinery-room entrance, Section 11.2.4 now forbids entry without appropriate protection — typically an SCBA used by *trained* personnel. For further discussion of this requirement, see “Handling Machinery-Room Emergencies” (pp. 39–41) in this guide and to Appendix I of ANSI/ASHRAE Standard 15–2004.

Ventilation for Machinery Rooms

How much ventilation airflow?

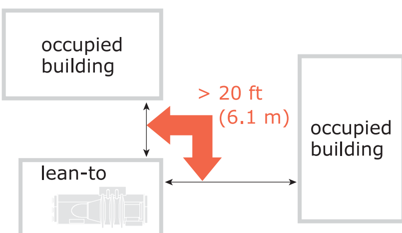
Standard 15 specifies the required volume of ventilation air based on the location of the equipment and whether the air is delivered via natural or mechanical means.

Natural ventilation airflow

Standard 15 states that:

> ... 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 (Section 8.11.5) ...

Figure 5. Remote, naturally ventilated machinery room



Site a naturally ventilated, remote machinery room more than 20 ft (6.1 m) from openings in adjacent occupied buildings

To use natural ventilation, the structure must not be connected to any occupied building by any means, including: doorways, pipe tunnels, open electrical conduit raceways, ventilation shafts, or ductwork. When these conditions are met, the requirements for natural ventilation are:

(c) The free-aperture cross section for the ventilation of a machinery room shall be at least:

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

where,

F = the free opening area in square feet (square meters),

G = the mass of refrigerant in pounds (kilograms) in the largest system, any part of which is located in the machinery room.

(d) Locations of the gravity ventilation openings shall be based on the relative density of the refrigerant to air (Section 8.11.5).

Mechanical ventilation airflow

Most machinery-room designs do not permit the use of natural ventilation. When the refrigerating system does not meet the previously described requirements for a natural ventilation system, mechanical ventilation must be provided. According to Standard 15:

> 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:

$Q = 100 \times G^{0.5}$ ($Q = 70 \times G^{0.5}$)

where,

Q = the airflow in cubic feet per minute (liters per second),

G = the mass of refrigerant in pounds (kilograms) in the largest system, any part of which is located in the machinery room (Section 8.11.5).

Denser than air

Many of the commonly used refrigerants in comfort-cooling HVAC applications have vapor densities that are three to five times denser than air. It's important to compensate for this difference when sizing the ventilation system to deliver alarm-rate airflow—especially for refrigerants that boil below the ambient temperature. A liquid spill or a rupture of a vessel containing such a refrigerant will quickly release a large quantity of vapor in the machinery room.

Q represents the minimum airflow that the ventilation system must deliver to effectively exhaust "spilled" refrigerant from the room. For chillers with more than one isolated refrigeration circuit, *G* represents the amount of refrigerant in the largest circuit. According to Standard 15, it's not necessary to run the ventilation system at this volume continuously, provided that:

> A part of the refrigerating machinery room mechanical ventilation shall be:
>
> (a) operated, when occupied, to supply at least at 0.5 cfm per square foot (2.54 L/s per square meter) 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) (Section 8.11.5).

In effect, Standard 15 defines two distinct mechanical ventilation rates for a refrigerating machinery room:

- ***Normal ventilation** at 0.5 cfm/ft² (2.54 L/s per m²) whenever the equipment room is occupied*. In most cases, this rate is sufficient to meet the secondary requirement that room temperature not exceed the inlet air temperature by more than 18°F (10°C) nor reach a temperature greater than 122°F (50°C). However, if the machinery room contains a number of heat sources, such as large air-cooled motors, it may be necessary to increase the normal ventilation rate in order to comply with the standard.

  Although Standard 15 states that the machinery room must be ventilated at the normal rate whenever the room is occupied, it does not specify how. Options include running the fan continuously, starting the fan automatically with a motion detector, or providing a fan switch near the machinery room entrance(s).

  If you provide a switch, accompany it with a sign or other prompt to indicate the need for ventilation during occupancy.

- ***Alarm ventilation**, at a rate based on the mass of refrigerant in the chiller,*[2] *whenever the refrigerant monitor detects a refrigerant concentration that exceeds the TLV–TWA of the refrigerant*. Use the alarm contacts of the monitor to automatically initiate ventilation at this volume. (See "Monitor input and output signals," p. 33.)

  As a further safeguard, provide a manually operated fan switch outside the main entrance to the machinery room.

One way to comply with Standard 15 is to provide a single ventilation system that operates at the higher of the two rates, and is triggered by both occupancy and an alarm condition. If alarm ventilation is significantly higher than normal ventilation, consider using multiple fans or fans with multi- or variable-speed drives.

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[2] More accurately, alarm-rate ventilation must be based on the mass of refrigerant in the largest refrigerating system (any part of which is located in the machinery room). If the system consists of distinct, independent refrigeration circuits, then base alarm-rate ventilation on the mass of refrigerant in the largest circuit.

Vent locations

Locations for the ventilation system intake and discharge must be properly positioned to provide efficient machinery-room ventilation. Standard 15 addresses this requirement in a general manner, stating:

> … 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 (Section 8.11.4).

Do not overlook the two fundamental requirements in this excerpt:

First, **the machinery-room ventilation system must be separate from the systems that ventilate other parts of the building**. In other words, the fans and ductwork that ventilate the machinery room must not supply or use air from any other part of the building, and the discharge must not interfere with any fresh air intakes. Some fans may not run continuously, so it's important to locate the inlet and discharge for each fan where it will not be inadvertently blocked when the fan is off. Also, outdoor air used for ventilation must be properly conditioned to avoid potential equipment damage from wide, abrupt temperature swings or freezing temperatures.

Second, **the exhaust fan must remove refrigerant from the machinery room**. To remove heavier-than-air refrigerants, locate the exhaust fan inlet near the equipment (if possible) and close to the floor rather than at ceiling height. Why? Refrigerant released in a machinery room sinks to the floor and fills the room from the bottom up unless disturbed by air turbulence. Maximum protection for machinery-room occupants is provided when the exhaust-fan inlet is situated:

- below the normal breathing zone, typically less than 4 ft (1.2 m) above the floor (Figure 6);
- near the potential source(s) of a refrigerant leak; and,
- away from the outdoor air intake to create a "sweeping" airflow pattern that draws outdoor air across the refrigerating equipment to the exhaust fan.

Figure 6. Position exhaust inlets near the floor

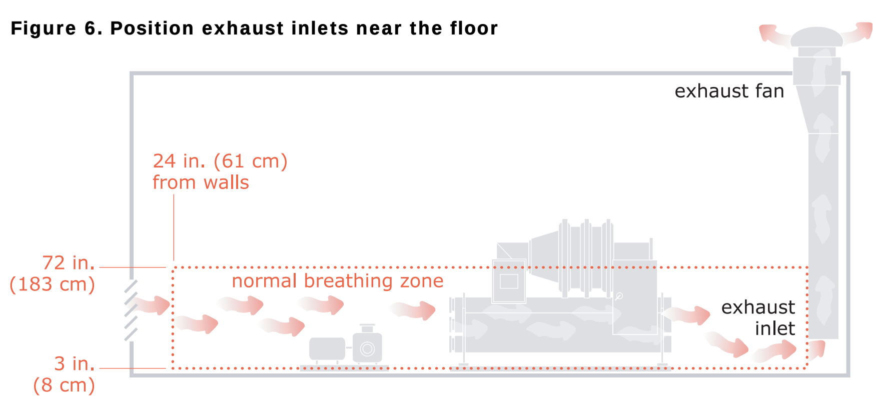
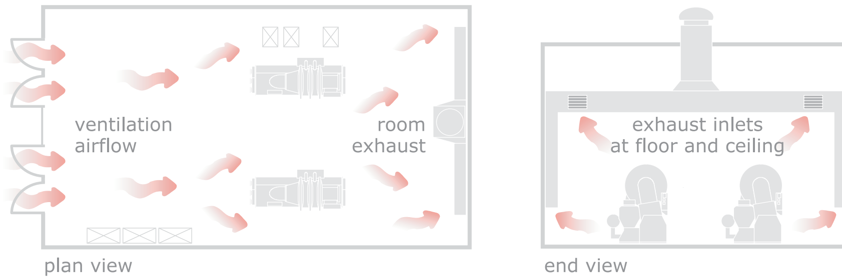


Figure 7. Arrange the ventilation system for adequate airflow throughout the room



When machinery-room exhaust fans serve a cooling or smoke-removal function, they usually are installed in the ceiling because both heat and smoke rise. However, if the ventilation system also exhausts “spilled” refrigerant, make provisions for inlets at both floor and ceiling levels.

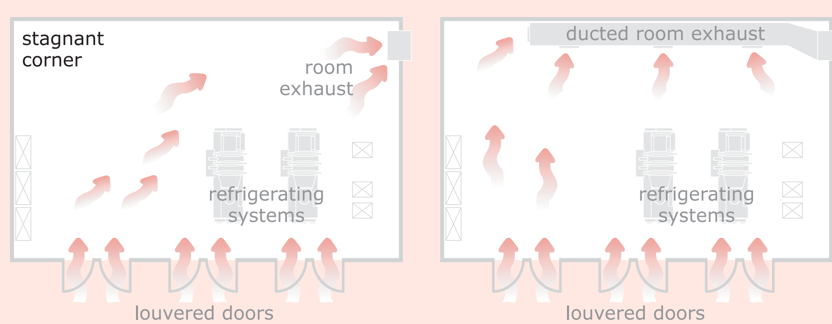
Dedicated fans. Separate ceiling- and floor-level fans can be operated together to provide the total ventilation volume needed for refrigerant removal. For greatest removal efficiency, make sure that the floor-level fan can deliver the calculated alarm rate of ventilation airflow.

Dual-purpose fan. When using a single fan both for cooling or smoke removal and for removing “spilled” refrigerant, provide ducted inlets at the floor *and* the ceiling (Figure 7). If this arrangement is used, it’s important to account for the density of the refrigerant vapor. In some cases, it may be necessary to add properly designed and controlled flow dampers to maximize ventilation effectiveness if an alarm condition occurs.

Case study: Opportunity for improvement

Arrangement A shows the layout of an actual machinery room, which is situated in the corner of a building. Six louvered service doors bring outdoor air into the machinery room, while a dual-purpose exhaust fan operates continuously to provide ventilation airflow at the alarm rate. The fan is mounted 4 ft (1.2 m) above the floor in an adjacent wall.

Although Arrangement A provides adequate air movement across the chillers, notice that it also creates a stagnant area in one corner of the room. Ducting the exhaust fan inlet across the wall that lies opposite of the service doors, as shown in Arrangement B, provides better airflow throughout the room.



Arrangement A
Adequate ventilation airflow

Arrangement B
Better ventilation airflow

Pressure-Relief Piping

With respect to refrigeration, ANSI/ ASHRAE Standard 15–2004 defines a *pressure vessel* as:

> Any refrigerant-containing receptacle in a refrigerating system … *[excluding]* evaporators where each separate evaporator section does not exceed 0.5 ft³ (0.014 m³) of refrigerant-containing volume regardless of the maximum inside dimension. This also … *[excludes]* evaporator coils, compressors, condenser coils, controls, headers, pumps, and piping (Section 3).

Under this definition, the direct-expansion evaporator of a split system is not a "pressure vessel" but the flooded evaporator of a chiller is.

The "pressure-relief protection" portion of Standard 15 opens with this general requirement:

> 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 (Section 9.4.1).

The rest of Section 9.4 specifically describes when pressure-relief devices are needed and how to size them. Manufacturers of packaged refrigerating systems and of the major components for "built-up" systems usually engineer pressure-relief devices into their equipment designs. Despite this convenience, it is still important to use the current edition of Standard 15 to verify that all pressure vessels are adequately protected against rupture.

Vent-line termination

After the refrigerating equipment is installed, each rupture device must be piped to a safe location in accordance with these requirements, regardless of whether the installation requires a machinery room:

> Pressure-relief devices and fusible plugs on any system containing a Group A3 or B3 refrigerant; on any system containing more than 6.6 lb (3 kg) of a Group A2, B1, or B2 refrigerant; and on any system containing more than 110 lb (50 kg) of a Group A1 refrigerant 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. The discharge shall be terminated in a manner that will prevent 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 (Section 9.7.8).

In other words:

- Route the vent-line piping so that it discharges outdoors in an area that will not spray refrigerant on anyone.
- Position the vent-line discharge at least 15 ft (4.57 m) above grade level and at least 20 ft (6.1 m) from any building opening.
- Provide a vent-line termination that cannot be blocked by debris.

Do not underestimate the importance of these requirements—nor the potential consequences of noncompliance. For example, improperly terminating a refrigerant vent line could allow rain to enter the line. Accumulated rainwater can cause the relief device to malfunction; or, in the case of a rupture disc, the rainwater pressure may cause the disc to rupture, allowing water to enter the chiller. Remember, too, that when a pressure-relief device operates, it may discharge a large amount of fluid and/or vapor. An improper vent-line termination could allow the discharge to injure bystanders and/or damage property.

Vent-line materials

All materials in the rupture-device vent system must be compatible with the refrigerant in use. Commonly used and accepted piping materials include steel and DWV (drain/waste/vent) copper. Consult local codes for restrictions on materials.

Note: PVC piping is compatible with most refrigerants, but the glue that joins the sections of plastic pipe may not be. When considering a vent system constructed of plastic piping, such as PVC, make sure that both the pipe material and the adhesive have been tested for refrigerant compatibility. Also, verify that the local code permits PVC for refrigerant vent lines; even though Standard 15 doesn't prohibit its use, some local codes do.

Flexible connection devices for vibration isolation must be compatible with the vented refrigerant, too. Trane recommends a flexible stainless-steel pump connector (or equivalent).

Vent-line sizing

The *vent line*—also called "relief line" or "discharge piping"— refers to the length of pipe that carries refrigerant from the relief device (or fusible plug) to the point where it is released to the atmosphere for dispersal. Refrigerant only passes through the vent line if an overpressure condition causes the relief device or fusible plug to operate.

Standard 15 provides specific requirements for the discharge piping that allows pressure-relief devices to safely vent refrigerant to the atmosphere if overpressurization occurs. In part, the standard mandates that:

> 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 (Section 9.7.8.4).

In other words, Standard 15 makes these stipulations for compliance:

- The *minimum* pipe size of the vent line must equal the size of the discharge connection on the pressure-relief device. A larger vent-line size may be necessary, depending on the length of the run.
- Two or more relief devices can be piped together — but only if the vent line is sized to handle all devices that could relieve at the same time.
- When two or more relief devices share a common vent line, the shared line must *equal or exceed* the sum of the outlet areas of all upstream relief devices, depending on the resulting back pressure.

Section 9.7.8.5 provides guidance for determining the maximum vent-line length. Appendix H of the standard (see p. 48 in this guide) provides the equation and data necessary to properly size the vent line at the outlet of a pressure-relief device or fusible plug. The equation accounts for the relationship between pipe diameter, equivalent pipe length, and the pressure difference between the vent-line inlet and outlet to help assure that the vent-line system provides sufficient flow capacity. As a further aid, Table 3 in the standard lists the capacities of various vent-line sizes and lengths; however, that data only applies to conventional pressure-relief valves and NOT to balanced relief valves, rupture members, fusible plugs, or pilot-operated valves

Note: Using Table 3 in Standard 15 to size the vent line for any non-conventional pressure-relief device will result in a maximum equivalent length that is significantly less than that calculated with the equation in Appendix H.

Manufacturers may use several pressure-relief devices on the same unit, either to vent distinct areas of the machine or to provide more discharge capacity than a single valve. System designers sometimes use a common header to combine the vent lines of multiple machines.

Appendix B in this guide provides several examples of how to use the information in Standard 15 to properly size refrigerant vent lines. These examples demonstrate an analytical method for sizing the common line when a single unit has more than one relief device and when multiple units share the same header.

Be sure to consult local codes and product installation information to determine whether other restrictions on refrigerant vent-line piping apply. (For example, it may not be permissible to manifold the pressure-relief devices of certain types of chillers.)

Vent-line drip leg

Although Standard 15 does not require it, it's prudent to equip each refrigerant vent line with a drip leg that's capable of holding up to 1 gal, or 231 in.^{3} (3800 cm^3), of liquid. Use the following equation to find the required length *L*, in inches (cm), of pipe for the drip leg …

$$L = 294/d^2$$
$$(L = 4840/d^2)$$

Recall that the volume, *V*, of a length of pipe is calculated as:

$$V = L \times \frac{\pi d^2}{4}$$

… where *d* is the inside diameter, in inches (cm), of the pipe. Figure 8 illustrates one example of a properly piped refrigerant vent. The standard, capped, 1/4 in. FL × 1/4 in. NPT refrigerant service valve in that arrangement simplifies draining. As part of the regular chiller maintenance program and using appropriate refrigerant-handling procedures, remove any accumulated liquid from the drip leg at least once every six months.

Purge discharge

To comply with Standard 15, the discharge piping from purge units that remove noncondensible gas from refrigerating systems must conform to the standard's requirements for relief piping:

> 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 (Section 8.14).

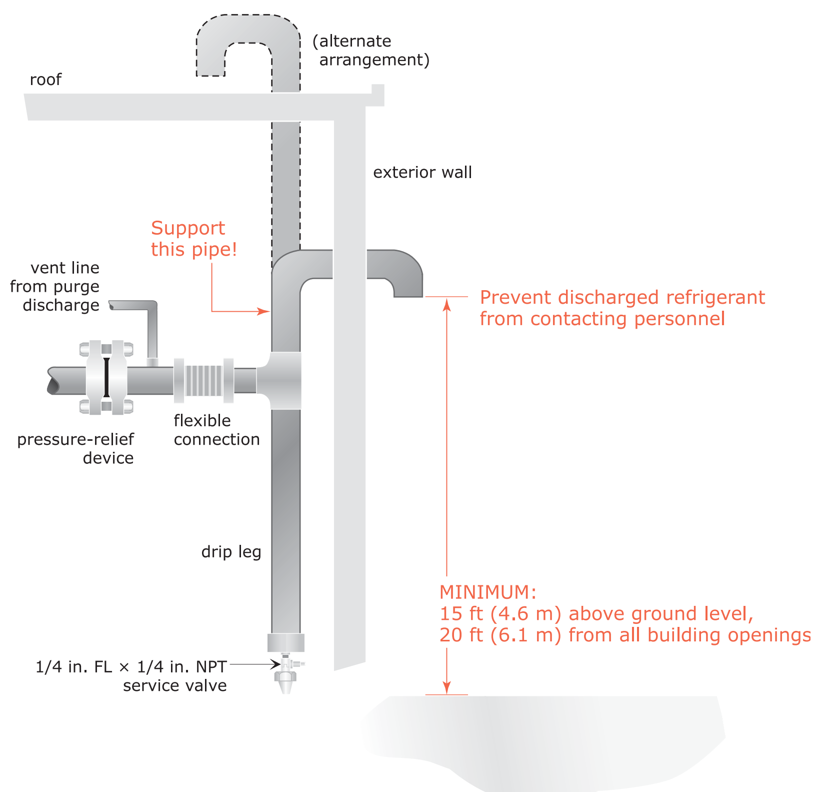
Generally, the most convenient way to properly exhaust the purge discharge to the atmosphere is to route it into the vent line for the pressure-relief device, upstream of any vibration isolation (Figure 8). Make sure that the purge discharge line does not contain any liquid traps, and that it slopes away from the purge unit to prevent liquid from collecting there. Consult the purge manufacturer for proper discharge-line sizing.

To minimize purge-related refrigerant loss and refrigerant replacement expense, choose a purge unit with these characteristics:

- A low refrigerant-to-noncondensible-gas discharge ratio
- Ability to operate while the chiller is off
- An integral safety system that prevents excessive purging that results from a large leak or an equipment malfunction

In addition, routinely monitor the refrigerating system for leaks and promptly repair any that are found. Regular logging of purge operation and chiller run-time provides an excellent indicator of system integrity.

Figure 8. Example of a refrigerant vent-line arrangement



Refrigerant Detection

Various monitors are available for refrigerant detection applications. Differences in their designs and operating characteristics determine which applications best suit each monitor. This chapter describes what types of monitors are available and summarizes how they can be used to help provide a safe machinery-room environment.

What Standard 15 requires

According to Standard 15, *every* machinery room that houses refrigerating equipment (regardless of the refrigerant's safety classification) must be equipped with a refrigerant detection system — one that will activate alarms and start the ventilation system if a refrigerant release occurs:

> 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)[3] 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 (Section 8.11.2.1).

This passage contains several key provisos, some of which represent marked changes from the 1994 version of the standard. To comply with Standard 15:

- Choose a detector that actuates at or below the TLV–TWA of the refrigerant in use. Other alarm levels are permitted as long as the actions required at the TLV–TWA are provided.
- Install the sensor in a location where refrigerant is likely to concentrate.
- Assure that the detector not only signals both *audible and visual* alarms when it actuates but also starts alarm-rate ventilation (defined in Section 8.11.5).
- Situate the alarms inside the machinery room *and* outside each entry.
- Provide appropriate signage outside each machinery-room entrance. The signs must forbid entry to the machinery room during an alarm condition, *except* by trained personnel who are equipped with protective gear (including respiratory devices).

[3] Recall that IDLH represents “immediately dangerous to life or health,” which is further defined in the glossary at the end of this manual.

Alarms

In acknowledgement of the Americans with Disabilities Act (1990), which mandates horn–strobe alarms, Standard 15 now explicitly requires audible *and* visual alarms, both inside the machinery room and outside each entrance. Furthermore, the standard now requires a manual-type alarm reset, and that reset must be located inside the machinery room. To help assure that these devices remain in good working order, the "general requirements" section of the standard specifies 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 (Section 11.6.3).

Continuous monitoring

Implicit in the standard's requirement of a refrigerant detection system is the need for its *continuous operation*. In other words, the detector must be permanently mounted in the machinery room, which often is unoccupied for extended periods, and it must never shut off. That's because most refrigerants give no warning of their presence: They are odorless, colorless, and tasteless. Continuously monitoring the machinery room for refrigerant — and alarming a buildup, if it occurs — assures personnel that the room is free from this hazard. Early detection of a refrigerant leak also assures less refrigerant loss.

Notice that Section 8.11.2.1 stipulates a *detector* that "actuates an alarm and mechanical ventilation … at a value not greater than the corresponding TLV–TWA" rather than a *refrigerant vapor monitor*. This phrasing deliberately specifies the required function of the detector and not the technology that's used to accomplish it. Note, too, that the requirement to alarm at the TLV–TWA means that the detector must be able to discern relatively small amounts of refrigerant.

The 2004 standard clearly defines the need for machinery-room monitoring, but it leaves a number of important issues to the designer's discretion, including what type of monitor to use, how many monitors to provide, and where to install them.

Types of monitors

Various monitors are available for refrigerant detection applications. Differences in their designs, sensing technologies, and operating characteristics determine which applications best suit each monitor. Table 4 (p. 32) identifies three types of refrigerant monitors based on existing technology. Of these, *compound-specific monitors are best suited for detecting refrigerant in machinery rooms.*

To comply with Standard 15, any machinery room that contains more than one type of refrigerating equipment must satisfy the individual requirements

> **"Short-term" monitors** are used briefly, at regular intervals, to check a refrigerating system for leaks during preventive maintenance or troubleshooting. Consequently, a monitor that serves this purpose must:
>
> - withstand large doses of refrigerant;
> - respond and clear rapidly;
> - be portable; and
> - be sensitive (but not necessarily specific) to the refrigerant in use.

of each system. For example, if the room houses an R-11 chiller and an R-123 chiller, the room also must contain either:

- one refrigerant detector that can sense *both* types of refrigerant, or …
- two compound-specific monitors — one for R-11 and one for R-123.

Choosing the right monitor

Refrigerant monitors can be divided into two categories based on duration of use: those used periodically for short-term detection of refrigerant leaks, and those that operate continuously. Both kinds of monitors are appropriate in a machinery-room environment, but compliance with the intent of Standard 15, which is to safeguard machinery-room occupants, requires installation of a *continuous-duty refrigerant monitor*.

When selecting a continuous-duty monitor for a refrigerating machinery room, be sure to consider these important operating characteristics:

- *Refrigerant-specific sensitivity*. Less-discriminating monitors can alarm if nonrefrigerant compounds, such as cleaning agents or paints, are detected.
- *Stability over the expected operating range* of temperatures, voltages, humidities, and barometric pressures. Calibration stability is a critical aspect of monitors used for continuous surveillance, and is provided by the electronic component that reads the sensor output. In general, monitor accuracy must be unaffected under all machinery-room conditions.
- *Low zero-drift or "auto-zeroing" capability*. To be suitable for continuous machinery-room duty, the monitor must provide a means of setting the "zero" reference point — that is, either a very small zero-drift (parts per million, ppm, between inspections) or an "auto-zero" feature.

Table 4. Comparison of refrigerant-monitor types

Monitor type	Sensing technology	Accuracy	Advantages	Disadvantages
Nonselective	• Metal-oxide semiconductors • Thermal ionization	20 to 30 ppm (minimum)	• Least expensive • Long used in "pinpointing" leak detectors	• Unable to differentiate between chemicals • More susceptible to false alarms than other monitor types, which severely limits use as an area monitor
Halogen-specific	Element-type ionization	10 ppm (maximum)	• Can distinguish refrigerants from other chemicals: responds only to chlorine, fluorine, and bromine • Allows calibration • Typical operating life is 1 year	• Unable to differentiate one refrigerant from another
Compound-specific	• Infrared spectroscopy • Gas chromatography • Photoacoustic spectroscopy	1 ppm (maximum)	• Least susceptible to false alarms • Requires less recalibration than other monitor types • Less susceptible to interference than other monitor types • **Best choice** for refrigerating machinery-room applications	• More expensive than other monitor types

- *Long service life with minimal maintenance.*
- *Alarm limits that correspond to the TLV–TWA (or an equivalent toxicity measurement) of the monitored refrigerant.*
- *Output signal*. To enable compliance with Standard 15, the monitor must provide an output signal that performs two functions: actuates an alarm, which will alert machinery-room occupants that the refrigerant concentration exceeds the TLV or AEL (acceptable exposure limit); and dilutes the leaked refrigerant by starting mechanical ventilation.

Some chiller manufacturers offer unit-mounted refrigerant monitors as a factory-installed option. In such cases, the monitor is an integral part of the unit control system and is prepiped to an appropriate sampling point on the chiller. Other areas of the machinery room can be sampled if the monitor supports "multichannel scanning." Aside from the obvious advantage of reduced installation costs, the data gathered by the monitor can be passed to a building automation system as part of the chiller data, eliminating the need for separate, hard-wired points.

Multichannel scanners

To adequately monitor a large refrigerating system, a machinery room with several chillers, or a machinery room with two or more levels, it may be necessary to sense the refrigerant concentration at various locations. Either a *multichannel scanner* that's connected to a single monitor, or a monitor with a multichannel option, provides an alternative to mounting several individual monitors in the equipment room.

Typically, two or more sampling tubes are routed from the scanner to other parts of the room, as shown in Figure 9 (p. 34). Equipment design determines the length of each sensing-tube run and the number of "pickup" points that can be monitored.

Multichannel scanning enables the monitor to check the air sampled at each location by individually "connecting" each sampling tube to the monitor on a rotating basis.

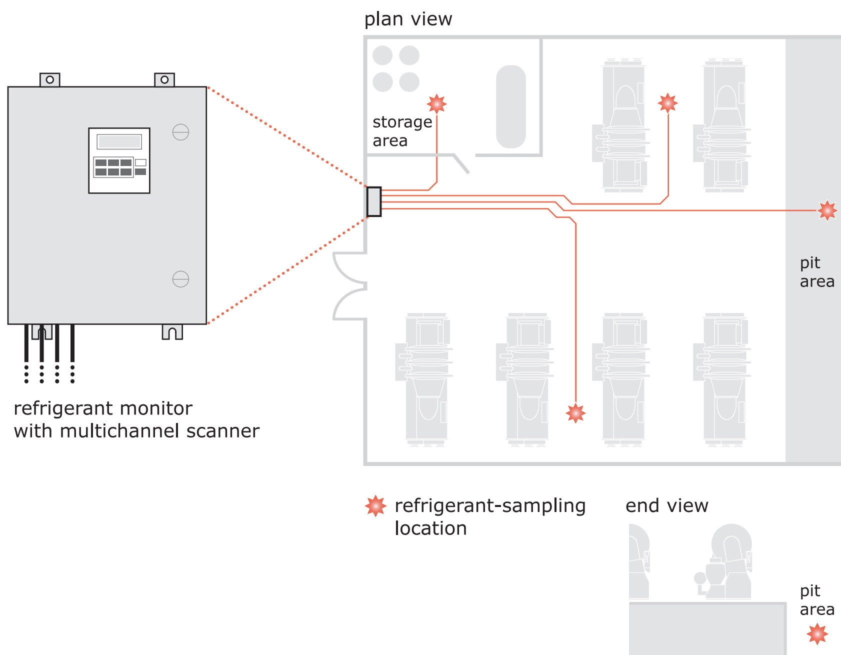
Monitor input and output signals

Remote reset input

Typically, the alarm state initiated by refrigerant monitor triggers a latching alarm that requires manual reset. Some monitors contain a remote reset input, which can be used to cancel the alarm from a distance when the refrigerant buildup disperses sufficiently.

The 2001 and 2004 editions of Standard 15 require placement of the refrigerant monitor's alarm reset *inside the machinery room*. This requirement also applies to any reset switch that is connected to the remote reset input.

Figure 9. Typical application of a multichannel scanner for multiple chillers and/or floor levels



Alarm output(s)

Regardless of how many alarm-level outputs the monitor employs or the refrigerant concentration used to trigger the alarm(s), at least one alarm output must activate alarm-rate ventilation *and* signal audible and visual alarms (both inside the machinery room and outside each entry) at or below the TLV–TWA of the refrigerant in use. This particular level of alarm requires manual reset from inside the machinery room.

Note: Follow local regulatory requirements and equipment manufacturers' recommendations when establishing alarm settings and actions. The following suggestions are based on ANSI/ASHRAE Standard 15–2004 and Trane publication APP-SVG02A-EN, Low-Pressure Refrigerant Emergency Spill Procedures*. The TLV–TWA (or equivalent toxicity measurement) can be found in the material safety data sheet (MSDS) supplied by the refrigerant manufacturer.*

One stage of alarm. The alarm-relay output energizes when the refrigerant concentration exceeds the preset alarm limit. To satisfy Standard 15, the alarm must energize at or below the TLV–TWA (or equivalent toxicity measurement) for the refrigerant in use. It also must activate an alarm (both visual and audible, in the room and outside each entrance) *and* start mechanical ventilation at the alarm rate.

When only one level of alarm is available, consider setting the alarm limit at 50 ppm or at the TLV–TWA, whichever is lower. This meets the alarm requirement for all commonly used refrigerants, and provides early warning of refrigerant loss for most refrigerants. Remote alarm indication also can be provided by connecting this relay to the building automation system (BAS).

Note: With only one level of alarm, personnel always must don appropriate protective gear (SCBA) before entering the room to reset the alarm. With multiple alarm levels, it is possible to signal detection of a refrigerant concentration that is low enough to permit safe entry and check for leaks without protective gear.

Two stages of alarm. If the monitor provides two levels of alarm:

- Set the trip point of the *first-stage alarm* low enough to provide early leak detection (generally at 10 ppm). Use this output to activate alarm-rate ventilation and to notify personnel of the leak by (for example) illuminating an indicator light.
- Set the trip point for the *second-stage alarm* to the TLV–TWA (or equivalent toxicity measurement) for the refrigerant in use. Use this output to notify the remote area supervisor and to energize an alarm indication (both visual and audible, inside the room and outside each entrance), alerting personnel that the room is not safe to enter without proper personal protective equipment.

Three stages of alarm. Monitors with three levels of alarm provide greater notification flexibility. As described for monitors with two alarm-relay outputs (above), the trip point for the *first-stage alarm* can be set low enough to provide early leak detection; in this case, it is used to start alarm-rate ventilation and to energize an indicator notifying personnel of the leak.

Alternatively, alarm-rate ventilation and indicator activation can be performed by the *second-stage alarm*. This approach allows a lower first-stage trip point and provides even earlier notice of a refrigerant leak. Of course, the second-stage alarm could, instead, be used to indicate the need for an intermediate type of personal protective equipment.

In either case, set the trip point for the third-stage alarm to the concentration at which personal protective equipment is required for personnel in the room. Use this level to notify the remote area supervisor, and to energize an alarm indication (both visual and audible, inside the room and outside each entrance) alerting personnel that the room is not safe to enter without proper personal protective gear.

Failure output

This relay energizes if the monitor malfunctions due to low airflow, circuit failure, or a saturated (or absent) sensor signal. It also can indicate loss of power if these contacts are normally powered open. Use the failure output to visually or audibly signal the building operator that the monitor must be checked and returned to operation.

Note: As part of monitor checkout, the operator should bring a portable detector to the machinery room to determine the refrigerant concentration.

Refrigerant monitor output

Some monitors provide a 0-to-10 Vdc, 4-to-20 mA (or serial) signal that is proportional to the detected level of refrigerant. Use this output to provide a remote indication of the refrigerant level in the machinery room, for example on a meter installed outside the machinery-room entrance. The meter can help operating personnel assess the need for breathing apparatus or verify that the ventilation system successfully cleared leaked refrigerant from the room.

When connected to a building automation system, this output can alert operating personnel of a leak, initiate alarm-rate ventilation, and automatically log the refrigerant concentration detected in the room.

BAS interface

A building automation system (BAS) provides a means for efficient system-level control and documented performance. Using the BAS to monitor the machinery room for refrigerant offers several benefits:

- *Automatic logging and documentation of refrigerant monitor readings.* Automatic trend-logging of refrigerant concentrations in the equipment room:
  - assures employees that they are working in a safe environment.
  - confirms, in writing, that refrigerant concentrations are maintained below the applicable TLV–TWA (or equivalent toxicity measurement).
  - satisfies EPA-imposed regulations requiring verification of the operating procedures used to control CFC and HCFC equipment-room emissions. Automated reports offer unquestionable proof that even minute concentration levels of refrigerant have been measured and recorded.
- *Automatic dial-out on alarm detection.* The BAS not only monitors refrigerant level and initiates necessary alarms from a remote central location, but also can automatically dial the service contractor when an alarm occurs. In this way, a trained expert — one who can take quick and appropriate corrective action — can constantly oversee machinery-room operation.
- *Purge-rate surveillance for early leak detection*. Leaks are the primary cause of refrigerant loss from refrigerating systems. A refrigerant monitor can detect a leak before a significant amount of refrigerant is lost, but in low-pressure chiller applications, a BAS can provide an even earlier indication by monitoring, logging, and plotting operation of the chiller purge unit(s). It also can display a diagnostic message for the operator if the purge rate exceeds a preset limit.

How many monitors?

Section 8.11.2.1 of Standard 15 explicitly states that a refrigerating machinery room "shall contain a detector." One refrigerant monitor usually can provide sufficient detection coverage for applications with three or fewer chillers if the chillers are aligned for good airflow (Figure 10, Arrangement A). But a single monitor may not adequately ensure occupant safety in all machinery-room settings.

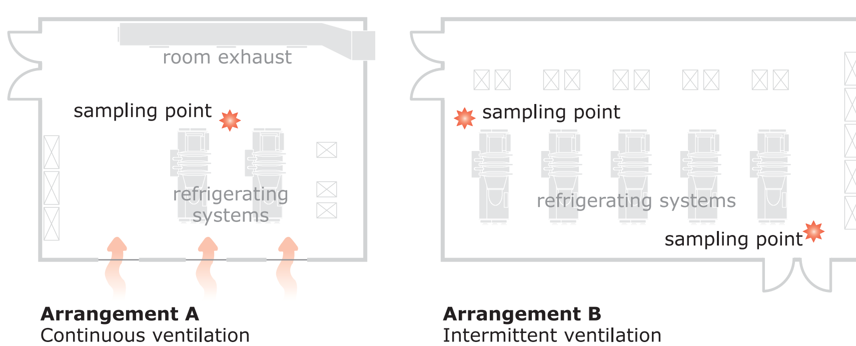
Sampling point refers to the location where the air sample is collected; it coincides with the location of the monitor unless a sampling line is added. A "sampling line" is the length of tubing (usually copper) that connects the monitor to the sampling point.

For example, a system consisting of four to six chillers typically requires two *sampling points* if it is housed in a machinery room with either intermittent ventilation or an indeterminate direction of airflow. The sampling points in such cases are positioned at opposite corners of the chiller group (Figure 10, Arrangement B). As a general rule, the distance between any refrigerating "system" (chiller) and a refrigerant sampling point should not exceed 50 ft (15.2 m).

Multiple sampling points also are recommended for large machinery rooms and for machinery rooms with multiple levels; see "Where to site sampling points."

Note: If a machinery-room layout requires several sampling points for adequate refrigerant monitoring, it may be more cost-effective to use a single monitor that's capable of checking refrigerant concentrations at multiple sampling points rather than several "single-channel" monitors. See "Multichannel scanners," p. 33, for more information.

Figure 10. Suggested placement for refrigerant sampling points

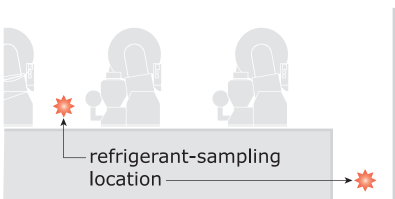


Where to site sampling points

The only instruction that Standard 15 provides for determining where to locate the refrigerant monitor is "… in an area where refrigerant from a leak will concentrate" (Section 8.11.2.1). That guidance is unavoidably vague, given the countless machinery-room layouts. When selecting a mounting location for the monitor or a remote sensor, remember that the monitor's purpose is to help assure occupant safety. The most likely exposure to refrigerant is through inhalation, so proper placement will account for the *airflow pattern in the room* and the *density of the refrigerant vapor*.

Elevation. All commonly used halocarbon refrigerants are three to five times heavier than air, so sampling points typically are positioned *near* the floor — but not at floor level to avoid causing nuisance alarms. Typical placement is 12 to 18 in. (30 to 46 cm) above the floor. Checking for refrigerant at a height that is well below the normal breathing zone provides occupants with an added margin of safety.

Figure 11. Sample at each level in the machinery room



Low areas that could be occupied — such as stairwells, pits, or trenches (Figure 11) — demand dedicated sampling points because heavier-than-air sampling points will quickly sink to the floor and spread if released. Pits and other low areas are likely to fill with refrigerant before the released refrigerant is detected at a conventionally mounted sampling point.

Plan location. If the machinery room is continuously ventilated, the pattern of the ventilation airflow will carry refrigerant away from its source. In this case, position the sampling point between the refrigerating equipment and the room exhaust (Figure 10–Arrangement A, p. 37).

For machinery rooms with intermittent ventilation or where the direction of airflow isn't obvious, position the sampling point so that it's near the refrigerating system or the machinery-room entry but no more than 50 ft (15.2 m) from each refrigerating equipment (Figure 10–Arrangement B). As examples, place the sampling point next to the chiller in a single-chiller plant, between the chillers in a two-chiller plant, or at the center chiller in a three-chiller plant.

Handling Machinery-Room Emergencies

The protection that compliance with the minimum requirements in Standard 15 provides should help prevent injuries resulting from accidents in a refrigerating machinery room. But minimal conformance to the standard's requirements may not allow *expeditious* handling of machinery-room incidents. Appendix I of the standard provides guidance on how to integrate the standard's minimum requirements for emergency warning and training into a comprehensive health and safety program.[4] The recommendations in the appendix address alarm levels, alternate refrigerant-level measurements, and room reentry during an emergency.

The appendix also outlines a six-step emergency procedure, which illustrates one of many approaches for handling minor maintenance problems in a Standard 15-compliant refrigerating machinery room.

Although we've summarized Appendix I here for your convenience, we urge you to obtain and read the standard in its entirety, including the appendixes.

Note: Coordinating with local and national regulations and providing proper training for anyone authorized to enter the machinery room are two key elements of any emergency response plan. It's also important to implement an intuitive warning system that will be explicitly understood by untrained personnel in the area. (As an example, when the alarm sounds/flashes, it should be obvious to bystanders that they must leave the machinery room.)

Alarm levels

As a minimum requirement, Standard 15 prescribes both an alarm signal and the start of alarm-rate ventilation if the refrigerant concentration detected in the room reaches the TLV–TWA. A *minimum-response plan* would call for evacuation of the machinery room when the alarm sounds, even if the presence of refrigerant results from a routine service operation rather than a genuine emergency. Personnel may not reenter the room to silence the alarm and complete the service operation (or repair any damage, if the incident was an emergency) without the services of emergency responders.

Providing two or more stages of alarm enables a more sophisticated response plan by providing more information about the alarm condition (see "Alarm output(s)," p. 34). Based on the level of alarm, machinery-room occupants can determine whether evacuation is necessary. If the concentration isn't high enough to warrant evacuation, the "low-level" alarm could alert them to put on appropriate protective gear while warning bystanders not to enter the room.

[4] Appendix I, "Emergencies in Refrigerating Machinery Rooms," is not prescriptive; it is included in the standard solely for informational purposes.

Alternate refrigerant-level measurements

Standard 15 only requires an alarm that signals when the detected refrigerant concentration exceeds the TLV–TWA, but it may be helpful to provide additional monitoring equipment. For example, a portable monitor could be used to back up the primary detector when it's necessary to open the refrigerating system for service.

Similarly, the primary detector could be augmented by a permanently mounted, secondary detection device that collects and displays more information about the refrigerant concentration in the air—but with two caveats:

- Any secondary detectors or additional alarms must be clearly distinguished from the main alarm to avoid confusing bystanders.
- Automatic-reset devices can be used for secondary alarms, but the main alarm must be manually reset to comply with the standard.

Reentering a refrigerating machinery room

Previous versions of Standard 15 prescribed the installation of self-contained breathing apparatus (SCBA) outside the machinery room. However, the 2001 edition of the standard omitted that requirement because of the risk that the SCBA could be used by untrained personnel or vandalized, either of which would result in an unsafe situation.

Standard 15 still requires the *availability* of SCBA (and other protective gear), but it permits flexibility in *how* to provide that equipment. For example, a facility that already provides protective gear outside the machinery room could choose to leave it there, to relocate it to an area that is only accessible to trained personnel, or to remove the gear and contract with an outside firm for emergency response services.

Example emergency procedures

Ideally, Standard 15's minimum requirements for warning of emergencies and training should be integrated into the facility's occupational health and safety program. The objective is to enable the facility to safely handle minor maintenance problems. There are countless ways to accomplish this objective; Appendix I offers one example (paraphrased here):

- Provide an alarm that triggers at the TLV–TWA, per Section 8.11.2.1.
- Post signage at machinery-room entrances, which warns: "Authorized personnel only. Stay out when refrigerant alarm sounds; call facilities management immediately."
- Provide a digital readout, outside the machinery room, that displays the current reading on the refrigerant detector in the room. Provide a sign adjacent to the readout, which differentiates it from the alarm indicator required by the standard.

- Provide machinery-room technicians with respiratory protection that's appropriate for use when the refrigerant concentration is less than the IDLH and that complies with all applicable national and local regulations.
- Define an "incidental" (non-emergency) refrigerant release — that is, one that does not produce refrigerant levels above the IDLH in a properly ventilated machinery room.
- Train technicians how to respond to a refrigerant alarm. As an example:
  - Leave the room when the alarm sounds.
  - If the current refrigerant level is below the IDLH, put on appropriate respiratory protection (if necessary) and reenter the room to close valves, fix leaks, shut off alarms, etc.
  - If the refrigerant level exceeds the IDLH or the problem seems uncontrolled in any way, leave the room and call for emergency responders.

As Appendix I notes, implementing additional safety procedures (such as the ones in this example) can "significantly aid the facility's efforts to handle minor maintenance problems safely" without contradicting the requirements of the standard.

Appendix A
Example Guide Specification

Contact your local Trane representative for an electronic version of this example specification.

Note: This chapter demonstrates phrasing to help engineering professionals specify the design and control of chilled water systems and machinery rooms that comply with ANSI/ASHRAE Standard 15–2004 and ANSI/ASHRAE Standard 34–2004. This example applies only to low-probability refrigerating systems that use Group A1 or B1 refrigerants and that require a machinery room. If used as a guide for specifying and designing a refrigerating machinery room, check local codes to avoid any conflicts or deficiencies.

Machinery-Room Design and Control

PART 1 GENERAL

1.01 References

A. ANSI/ASHRAE Standard 15–2004, *Safety Standard for Refrigeration Systems*

B. ANSI/ASHRAE Standard 34–2004, *Designation and Safety Classification of Refrigerants*

C. ASHRAE Standard 147–2002, *Reducing the Release of Halogenated Refrigerants from Refrigerating and Air-Conditioning Equipment and Systems*

1.02 Summary

A. The design, installation, and operation of the machinery room containing the refrigeration system shall meet ANSI/ASHRAE Standard 15–2004 as the minimum design criteria. Additional equipment and controls shall be added as required to protect the occupants of the machinery room from hazardous exposure to refrigerants. Access to the machinery room shall be restricted to authorized personnel.

PART 2 PRODUCTS

2.01 Machinery-Room Ventilation

A. General: Ventilation systems that serve the machinery room must be entirely separate from other portions of the building. Air discharged from the machinery room shall be to the outdoors, and shall not cause inconvenience or danger. Sufficient inlet air shall be provided to replace the air being exhausted. Openings for air inlets shall be positioned to avoid intake of discharged air. Inlet air shall be treated as required to avoid equipment damage caused by freezing temperatures and/or large, rapid temperature swings.

B. Ventilation inlets and outlets for the machinery room shall be placed to provide an air sweep across refrigeration equipment. Unit spacing and positioning shall be coordinated with ventilation inlets and outlets to avoid areas of stagnation around the refrigeration equipment.

C. All exhaust fans used to meet the maximum ventilation rate shall have inlets located no more than 4 feet above floor level. In addition, at least 50 percent of the air used for normal ventilation shall be exhausted from less than 4 feet above floor level.

D. The ventilation system shall be capable of exhausting a buildup of refrigerant from the machinery room at a rate that is the greater of the refrigerant evacuation rate or the occupied ventilation rate as defined by Standard 15, Section 8.11.5. The required exhaust air volume shall be ___ cfm at ___ inch SP.

••••• **OR** •••••

D. The ventilation system shall have two exhaust rates. It shall be capable of ventilating the machinery room at the occupied ventilation rate and the refrigerant evacuation rate as defined by Standard 15, Section 8.11.5. The occupied ventilation rate shall be ___ cfm at ___ inch SP. The refrigerant evacuation rate shall be ___ cfm at ___ inch SP.

E. The ventilation system shall be operated as follows:

1. When the machinery room is occupied:

a. The ventilation system shall operate at the occupied ventilation rate as a minimum.

b. The ventilation system shall increase the ventilation volume so as not to exceed the higher of a temperature rise of 18°F above the inlet air temperature or a maximum room temperature of 122°F.

2. The exhaust ventilation must be automatically triggered to run at the refrigerant evacuation rate, as a minimum, by the refrigerant monitor whenever a refrigerant concentration above the TLV–TWA (or toxicity measurement consistent therewith) is detected in the machinery room.

Include Section 2.02 in the appropriate specification, based on who is supplying the refrigerant detector, that is:

- in the machinery-room specification if the mechanical contractor is the supplier; or,
- in the chiller specification if the chiller manufacturer is the supplier.

2.02 Refrigerant Detector(s)

A. A minimum of one permanently mounted, continuously operating refrigerant monitor *[as supplied by the installing contractor] [as supplied by the chiller manufacturer]* shall be mounted in the machinery room to detect leakage of refrigerant from locations where the refrigerant is either stored or used.

B. Multiple monitors or monitor pickup points shall be used to limit the distance between the sensor and the refrigerant source to not more than 50 feet. Pits, tunnels, or trenches in the machinery room that are accessible to personnel shall also be monitored. Monitor sampling point(s) shall normally be located 18 inches above the floor in a location near the refrigerant source, and shall be situated between the refrigerant source and the exhaust fan inlet.

C. Refrigerant Monitor Performance

1. The refrigerant monitor shall be capable of detecting concentrations of 1 ppm for low-level leak detection and for insuring the safety of operators. It shall be supplied factory-calibrated for the appropriate refrigerant.

2. All monitors shall be capable of continuously monitoring the machinery room for the refrigerant used in the system. Monitor design and construction shall be compatible with temperature, humidity, barometric pressure, and voltage fluctuations of the machinery-room operating environment.

3. The refrigerant monitor shall provide an alarm-relay output that energizes when the monitor detects a refrigerant level at or below the TLV–TWA (or toxicity measurement consistent therewith). This relay shall be latching and require a manual reset from inside the machinery room. The relay shall be used to initiate the following events:

a. Energize visual and audible alarms inside the machinery room that are consistent with other alarms used in the building to signify evacuation, and outside the machinery room, adjacent to each entry door, to signify that entry to the machinery room is only permitted by authorized personnel equipped with appropriate safety gear.

b. Energize all exhaust fans required to achieve the refrigerant evacuation rate of exhaust. Exhaust fans shall remain energized until manually deactivated by an operator.

c. Shut down any open-flame devices that draw combustion air from the machinery room.

••••• or •••••

3. The refrigerant monitor shall provide two levels of alarm with a relay output for each level. These relays shall be used to initiate the following events:

a. The first level of alarm shall be set at ___ ppm (10 ppm or bottom of monitor range, whichever is higher) and shall energize an alarm to notify operating personnel of a potential leak; and shall energize ventilation at the refrigerant evacuation rate.

b. The second level of alarm shall be set at ___ ppm (TLV–TWA of the refrigerant in use) and shall energize visual and audible alarms inside the machinery room that are consistent with other alarms used in the building to signify evacuation; energize visual and audible alarms outside the machinery room, adjacent to each entry door, to signify that entry to the machinery room is only permitted by authorized personnel equipped with appropriate safety gear; and shut down any open-flame devices that draw combustion air directly from the machinery room. This relay shall be latching and requires manual reset from inside the machinery room.

4. The refrigerant monitor shall provide a failure relay output, separate from those described above, that energizes when the monitor detects a fault in its operation. Examples of faults include low airflow through the monitor, circuit failure, and a saturated or absent sensor signal. This output shall signal an alarm condition to the building operator so that the monitor can be checked and returned to operation.

5. Operating instructions that detail the calibration and maintenance requirements of the refrigerant monitor in use shall be accessible to machinery-room maintenance personnel. Calibration and maintenance of the refrigerant monitor shall be included in the general maintenance procedures for the machinery room.

2.03 Machinery-Room Entry Requirements

A. All machinery-room entry doors shall be tight-fitting and open outward. Doors leading to the building shall be self-closing. There shall be no openings to permit passage of escaping refrigerant to other parts of the building.

B. Each entry shall have audible and visual alarms as follows:

1. An audible alarm and warning light energized by the refrigerant monitor at or below the TLV–TWA of the refrigerant in use.

••••• or •••••

1. An audible alarm and visual alarm as follows:

   a. A blue light that energizes to indicate that refrigerant is not detected in the machinery room

   b. A yellow light that energizes to indicate that refrigerant has been detected in the machinery room, but the level has not reached the TLV–TWA of the refrigerant in use

   c. A red light that energizes to indicate that the refrigerant level in the machinery room has exceeded the TLV–TWA of the refrigerant in use

2.04 Machinery-Room Signs and Identification

A. Each entrance to a refrigerating machinery room shall be provided with a legible permanent sign, securely attached and easily readable, reading "Machinery Room—Authorized Personnel Only."

B. Operation and Emergency Shutdown

1. The emergency procedures shall forbid entry into the refrigerating machinery room when the refrigerant monitor has detected a machinery-room refrigerant level at or above the TLV–TWA, except by persons provided with appropriate respiratory and other protective equipment and trained in accordance with jurisdictional requirements. These emergency procedures shall be posted outside the room, immediately adjacent to each door.

2. 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.

C. Each refrigerating system erected on the premises shall be provided with an easily legible, permanent sign that is securely attached, easily accessible, and that indicates the following:

1. Name and address of the installer
2. Proper name and amount of refrigerant
3. Lubricant identity and amount
4. Field test pressure applied

D. Systems that contain more than 110 lb of refrigerant shall be provided with durable signs that have letters not less than 0.5 inch in height and that identify the following:

1. Valves or switches that control refrigerant flow
2. Switches that control ventilation
3. Switches that control operation of the refrigeration compressor(s)
4. The kind of refrigerant or secondary coolant contained in the exposed piping outside the machinery room
5. Valves or piping adjacent to valves shall be identified in accord with ANSI A13.1, "Scheme for Identification of Piping Systems."

Include Section 2.05 in the appropriate specification, based on who is supplying the self-contained breathing apparatus, that is:

- in the machinery-room specification if the mechanical contractor is the supplier; or,
- in the chiller specification if the chiller manufacturer is the supplier.

2.05 Self-Contained Breathing Apparatus

A. Two approved self-contained breathing apparatus (SCBA) *[as supplied by the installing contractor] [as supplied by the chiller manufacturer]* shall be mounted outside of, but adjacent to, the machinery room entry.

••••• or •••••

A. Two approved self-contained breathing apparatus (SCBA) *[as supplied by the installing contractor] [as supplied by the chiller manufacturer]* shall be located where they are accessible only to authorized and approved personnel.

2.06 Open-Flame Devices

A. No open flames nor apparatus to produce an open flame installed in the machinery room shall use combustion air from the machinery room except as permitted below.

B. Open-flame devices (e.g., boilers or direct-fired chillers) shall be permitted when:

1. The device is tied to a refrigerant monitor, such that the device is shut down when the monitor alarms.

Include Section 2.07 in the appropriate specification, based on who is providing chiller plant management, that is:

- in the machinery-room specification if the mechanical contractor is responsible; or,
- in the chiller specification if the chiller manufacturer is responsible.

2.07 Chiller Plant Management

A. General: The chiller plant management system (CPMS) shall provide for machinery-room control and refrigerant management.

B. Refrigerant Concentration Monitoring

1. The CPMS shall track the level of refrigerant sensed by the refrigerant monitor. This signal shall be used to generate an electronic log of the refrigerant level in the machinery room. Any increase in that level shall trigger an informational diagnostic indicating that the refrigeration system should be checked for leaks.

2. The CPMS shall monitor the alarm status of the refrigerant monitor and provide an alarm condition for each of the following:

a. Monitor malfunction.

b. Refrigerant alarm triggers at the TLV–TWA (or equivalent toxicity measurement) for the refrigerant in use.

c. Refrigerant alarm triggers at three times the TLV–TWA (or equivalent toxicity measurement) for the refrigerant in use.

3. The CPMS shall be tied to the machinery-room ventilation system to provide control of both normal- and maximum-rate ventilation of the machinery room. This control shall parallel the primary control of the fans provided by the refrigerant monitor.

C. Purge Monitoring

1. The machinery-room CPMS shall monitor the operation of each chiller purge unit and log the following information:

a. Purge alarm/failure contacts to provide operator notification of any malfunction of unit operation.

b. Purge pump-out compressor 24-hour run-time.

c. Initiate an alarm when the 24-hour purge pump-out compressor run-time exceeds 5 minutes on any chiller. The time limit at which an alarm occurs shall be operator-editable for each chiller.

2. The machinery-room CPMS shall monitor the operation of each chiller purge unit and notify the operator of required run-time/ maintenance, including:

a. Semiannual air-cooled condenser cleaning

b. Annual purge tank service, filter-drier core replacement, and controls calibration

Appendix B
Vent-Line Sizing

The *vent line*—also called “relief line” or “discharge piping”—refers to the length of pipe that carries refrigerant from the relief device (or fusible plug) to the point where it is released to the atmosphere for dispersal. Refrigerant only passes through the vent line if an overpressure condition causes the relief device or fusible plug to operate.

Appendix H, “Allowable Equivalent Length of Discharge Piping (Normative),” of ANSI/ASHRAE Standard 15–2004 provides the equation and data necessary to properly size the vent line at the outlet of a pressure-relief device or fusible plug. The equation (see inset below) accounts for the relationship between pipe diameter, equivalent pipe length, and the pressure difference between the vent-line inlet and outlet to help assure that the vent-line system provides sufficient flow capacity.

Although the information in Appendix H is the basis for Table 3 of the standard, which provides discharge-line capacities for various line lengths, *the values in Table 3 only pertain to conventional relief valves.* The Table 3 values are *NOT* appropriate for balanced relief valves, rupture members, fusible plugs, and pilot-operated relief valves. Using Table 3 to size the vent line for any of these non-conventional pressure-relief devices will result in a

Appendix H: Allowable equivalent length of discharge piping (normative)

[The following excerpt is from Appendix H of ANSI/ASHRAE Standard 15–2004.]

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 Equations (1) or (2). See Table 3 *[in the standard]* for the flow capacity of various equivalent lengths of discharge piping for conventional relief valves.

$$L = \frac{0.2146 d^5 (P_0^2 - P_2^2)}{f C_r^2} - \frac{d \times \ln(P_0/P_2)}{6f} \qquad (1)$$

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

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 at right]*;

d = inside diameter [ID] 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).

Typical Moody friction factors *(f)* for fully turbulent flow

Tubing OD (in.)	DN *[mm]*	ID (in.)	*f*
3/8	8	0.315	0.0136
1/2	10	0.430	0.0128
5/8	13	0.545	0.0122
3/4	16	0.666	0.0117
7/8	20	0.785	0.0114
1 1/8	25	1.025	0.0108
1 3/8	32	1.265	0.0104
1 5/8	40	1.505	0.0101
Piping NPS *[in.]*	**DN *[mm]***	**ID (in.)**	***f***
1/2	15	0.622	0.0259
3/4	20	0.824	0.0240
1	25	1.049	0.0225
1 1/4	32	1.380	0.0209
1 1/2	40	1.610	0.0202
2	50	2.067	0.0190
2 1/2	65	2.469	0.0182
3	80	3.068	0.0173
4	100	4.026	0.0163
5	125	5.047	0.0155
6	150	6.065	0.0149

[“DN” represents “Diametre Nominel,” which approximates the metric equivalent of NPS (nominal pipe size).]

maximum equivalent length that is significantly less than that calculated with the equation in Appendix H.

One of the equation factors for determining the allowable vent-line length is the "allowed back pressure," represented as P_0. The method by which P_0 is calculated varies with the type of relief device. Refrigerating equipment with helical-rotary or scroll compressors often use conventional relief valves, while rupture members are the norm for equipment with centrifugal compressors. Check with the equipment manufacturer to verify the relief-device type.

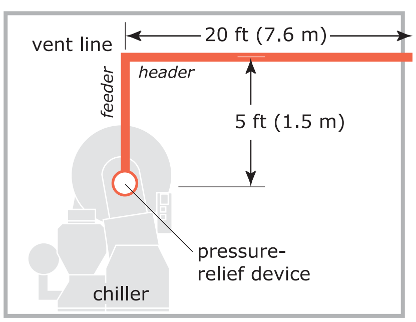
The rated discharge capacity, C_r, of a conventional relief device typically is stamped on the exterior of the device. However, for rupture members or fusible plugs, it is common to use either a C value (calculated in accordance with Section 9.7.7 of Standard 15) or an equipment-specific value provided by the manufacturer.

Note: For simplicity, the "equivalent length" calculations in the following examples pertain only to the vent line; they do not account for the pressure drop through fittings. Refer to the ASHRAE Handbooks for more information about "equivalent length" and how to calculate it for various fitting types.

Non-manifolded relief devices

For a chiller application in which each relief device is piped separately, the equation from Appendix H of Standard 15 (p. 48) can be used to determine the proper vent-line size for the required length of run. The following example demonstrates how.

Figure 12. Example of a dedicated pressure-relief vent line



Example. Consider a low-pressure chiller with a single, rupture-member relief device. The device has an outlet connection of 3 in. NPS (80 mm DN), a calculated discharge rating, C, of 64 lb/minute (0.48 kg/s), and a pressure setting of 15 psi (103 kPa). The vent line must run an equivalent length of 25 ft (7.6 m) to exit the building; see Figure 12.

1 Find the inside diameter, d, and Moody friction factor, f, that corresponds to the vent-line size using the table in Appendix H of Standard 15. To comply with Section 9.7.8.4 of the standard, the vent-line size cannot be smaller than the outlet connection of the relief device.

According to the Appendix H table, the minimum vent-line size of 3 in. NPS (80 mm DN) for our example chiller corresponds to $d = 3.068$ in. (77.93 mm) and $f = 0.0173$.

2 Determine the absolute pressure at the vent-line outlet, P_2. At sea level, $P_2 = 14.7$ psi (101 kPa).

3 Calculate the allowed back pressure (absolute), P_0, based on the type of relief device. For a rupture member, $P_0 = (0.50\ P)$ + atmospheric pressure. So:

$$P_0 = (0.5 \times 15) + 14.7 = 22.2 \text{ psi}$$
$$(P_0 = (0.5 \times 103) + 101 = 153 \text{ kPa})$$

Appendix H divides pressure-relief devices into three types: conventional relief valves; balanced relief valves; and rupture members, fusible plugs, and pilot-operated relief valves.

4 Solve the Appendix H equation to find the allowable equivalent length for the vent line:

$$L = \frac{0.2146 \times 3.068^5 \text{in.}(22.2^2 - 14.7^2 \text{psi})}{0.0173 \times 64^2 \text{lb/min}} - \frac{3.068 \text{in.} \times \ln(22.2/14.7 \text{psi})}{6 \times 0.0173} = 215 \text{ ft}$$

$$\left(L = \frac{(7.4381 \times 10^{-15})(77.93^5 \text{mm})(153^2 - 101^2 \text{kPa})}{0.0173 \times 0.48^2 \text{kg/s}} - \frac{77.93 \text{mm} \times \ln(153/101)}{500 \times 0.0173} = 67.1 \text{ m}\right)$$

5 Finally, compare the *allowable* equivalent length, *L*, to the total equivalent length of the vent-line run (that is, straight piping/tubing *plus* elbows). In this example, *L* = 215 ft (67.1 m), far exceeding the 25 ft (7.6 m) needed to transport released refrigerant outside the building.

Although a smaller pipe would satisfy the pressure requirements, using a pipe size that's smaller than the outlet of the relief device would violate Section 9.7.8.4 of the standard.

Note: The convenience of Table 3 in Standard 15 may tempt its use to size vent lines for non-conventional relief devices … but doing so significantly lessens the safety factor. To illustrate, if the vent line in the preceding example was sized according to Table 3, the allowable equivalent length would be only 54 ft (16 m) versus the 215 ft (67.1 m) that was calculated using Appendix H.

Manifolded relief devices with identical capacity ratings

For more information about how to size a vent line that's shared by multiple relief devices, refer to *User's Manual for ANSI/ASHRAE Standard 15–2001, Safety Standard for Refrigeration Systems*. Visit ASHRAE's online bookstore at www.ashrae.org to order or download a copy.

When a header connects more than one pressure-relief device, the size of the common line must account for the back pressure that would occur if two or more of the devices operate at the same time. The *User's Manual for ANSI/ASHRAE Standard 15–2001* demonstrates different methods for sizing the common header, depending on the rated capacities of the relief devices and whether the devices can be expected to operate at the same time.

The following equation (Equation 20 from the *User's Manual*) is part of an analytical method for sizing a header that connects identically rated pressure-relief devices that are expected to operate simultaneously.

"resource" used by one vent-line feeder or header

$$\frac{LC^2}{d^5} = \frac{0.2146\,(P_0^2 - P_2^2)}{f} - \frac{C^2 \ln(P_0/P_2)}{6fd^4}$$

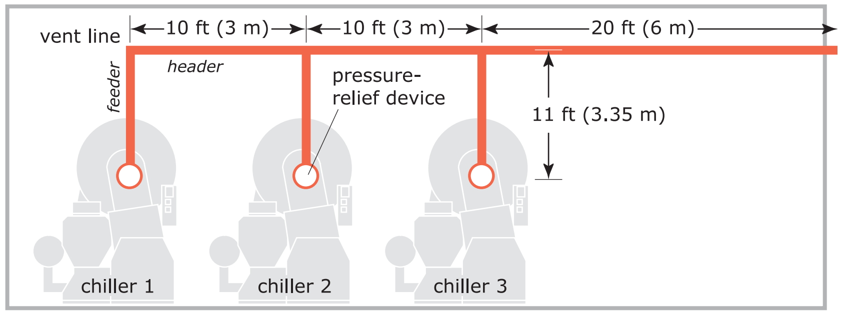
$$\left(\frac{LC^2}{d^5} = \frac{7.4381 \times 10^{-15}(P_0^2 - P_2^2)}{f} - \frac{C^2 \ln(P_0/P_2)}{500fd^4}\right)$$

"resource" available at the pressure-relief device

The right-hand side of the equation represents the "resource," K_x, available at the pressure-relief device, while the left-hand side calculates how much of the available "resource" a particular header or feeder will use.

Example. Consider the three low-pressure chillers shown in Figure 13. The rupture member of each chiller has a 3-in. NPS (80 mm DN) outlet connection and a calculated *C* of 64 lb/minute (0.48 kg/s). The equivalent length of the

Figure 13. Example of manifolded pressure-relief devices (identical device ratings)



feeder from each chiller to the common header is 11 ft (3.35 m), while the equivalent length of the header is 40 ft (12.0 m).

1 Determine the "resource," K_x, available at the pressure-relief device by solving the right-hand side of the equation. In this case, K_x = 3,249 (16.78):

$$\frac{0.2146\ (22.2^2 - 14.7^2\text{psi})}{0.0173} - \frac{(64^2\text{lb/min})\ln(22.2/14.7\text{psi})}{6 \times 0.0173 \times 3.068^4\text{in.}} = 3,249$$

$$\left(\frac{7.4381 \times 10^{-15}(153^2 - 101^2\text{kPa})}{0.0173} - \frac{(0.48^2\text{kg/s})\ln(153/101\text{kPa})}{500 \times 0.0173 \times 76^4\text{mm}} = 16.78\right)$$

Per Section 9.7.8.4 of Standard 15, the size of the vent line can be no smaller than the outlet connection of the pressure-relief device.

2 Solve the left-hand side of the equation to calculate how much of the available "resource" the feeder will use if it is sized to match the pressure-relief device. In this case, an equivalent length of 11 ft (3.35 m) of 3-in. NPS (80 mm DN) pipe will use 166 (0.857):

$$\frac{11\text{ft} \times 64^2\text{lb/min}}{3.068^5\text{in.}} = 166$$

$$\left(\frac{3.35\text{m} \times 0.48^2\text{kg/s}}{77.93^5\text{mm}} = 0.857\right)$$

3 Compare the "resource" values to verify that the feeder will provide sufficient flow capacity, given the pipe diameter and equivalent length—that is, whether the "resource" used is less than the total available "resource." In this case, a 3-in. NPS (80 mm DN) pipe is large enough because 166 < 3,249 (0.857 < 16.78). That leaves an available "resource" of 3249 – 166 = 3,083 (16.78 – 0.857 = 15.923) for the header.

Note: It would be necessary to repeat this step using a larger pipe size if the "resource" used exceeded the available "resource."

4 Verify that the area of the header equals or exceeds the sum of the cross-sectional areas of the *relief devices* discharging into it, per Section 9.7.8.4 of Standard 15. The area, *A*, of a single disk is:

$$A = \pi R^2 = 3.14 \times 1.5^2 = 7.07\text{in.}^2$$

$$(A = \pi R^2 = 3.14 \times 38^2 = 4534\text{mm}^2)$$

The three identically sized relief devices in this example have a total area of 21.2 in.^{2} (13,600 mm^2), but the area of the 5-in. NPS (125 mm DN) pipe is only 19.6 in.^{2} (12,600 mm^2) — too small to comply with Standard 15. Using a 6-in. NPS (150 mm DN) pipe increases the header area to 28.3 in.^{2} (18,300 mm^2), which is more than large enough.

5 Solve the left-hand side of the equation to determine how much of the remaining available "resource" a 6-in. NPS (150 mm DN) header will use, accounting for the combined *C* of the pressure-relief devices:

$$\frac{40\,\text{ft} \times (64 \times 3)^2\,\text{lb/min}}{6.065^5\,\text{in.}} = 180$$

$$\left(\frac{12\,\text{m} \times (0.48 \times 3)^2\,\text{kg/s}}{77.93^5\,\text{mm}} = 0.93\right)$$

6 Finally, sum the "resources" used by the feeder and header, and compare the resulting total to the available "resource" of the vent-line system. If the total "resource" used does not exceed K_x … 3,249 (16.78) in this case … then the header size provides the required discharge capacity to comply with Standard 15. In this example, the total "resource" used by this combination of vent-line sizes and equivalent lengths is well within the available "resource":

$$166 + 180 = 346 < 3249$$
$$0.857 + 0.93 = 1.787 < 16.78$$

Manifolded relief devices with unlike capacity ratings

Not all chillers use identically rated pressure-relief devices, so it's not uncommon for a vent-line system to serve multiple relief devices with *different* rated capacities. The calculation method that was just described for like-rated relief devices works in this situation, too, but it's also necessary to:

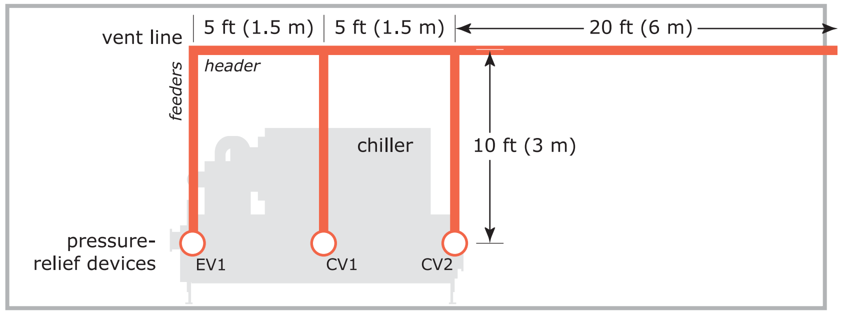
- calculate the available "resource," K_x, for *each* of the feeder lines, which connects each pressure-relief device to the common header; and then,
- choose a header size that's based on the *smallest remaining* K_x value after accounting for the "resource" required for each feeder.

Example. Consider a single, medium-pressure chiller equipped with three conventional pressure-relief valves, one for the evaporator (EV1) and two for the condenser (CV1, CV2):

Relief-device characteristics	*EV1*		*CV1, CV2*	
Connection size, NPS (DN)	1.25 in.	(32 mm)	1.25 in.	(32 mm)
Rated discharge capacity, C_r	78 lb/min	(0.59 kg/s)	48 lb/min	(0.36 kg/s)
Pressure setting, P	200 psi	(1379 kPa)	200 psi	(1379 kPa)
Absolute pressure at discharge, P_2	14.7 psi	(101 kPa)	14.7 psi	(101 kPa)
Allowed back pressure, P_0	44.7 psi	(308 kPa)	44.7 psi	(308 kPa)

The equivalent length of the feeder from each pressure-relief device to the common header is 10 ft (3 m), while the header extends an equivalent length of 30 ft (9 m) to exit the building; see Figure 14.

Figure 14. Example of manifolded pressure-relief devices (unlike device ratings)



1 Calculate the allowed back pressure (absolute), P_0, based on the relief-device type. For conventional relief valves, $P_0 = (0.15) +$ atmospheric pressure. So:

$$P_0 = (0.15 \times 200) + 14.7 = 44.7 \text{ psi}$$
$$(P_0 = (0.15 \times 1379) + 101 = 398 \text{ kPa})$$

2 Calculate the available "resource," K_x, for *each* of the pressure-relief valves. To do so, use the values provided on p. 52 to solve the right-hand side of this equation for each C_r value — once for valve EV1 and once for valves CV1 and CV2:

"resource" used by one vent-line feeder or header

$$\frac{LC^2}{d^5} = \frac{0.2146\,(P_0^2 - P_2^2)}{f} - \frac{C^2 \ln(P_0/P_2)}{6fd^4}$$

$$\left(\frac{LC^2}{d^5} = \frac{7.4381 \times 10^{-15}(P_0^2 - P_2^2)}{f} - \frac{C^2 \ln(P_0/P_2)}{500fd^4}\right)$$

"resource" available at the pressure-relief device

Per Section 9.7.8.4 of Standard 15, the size of the vent line can be no smaller than the outlet connection of the pressure-relief device.

3 Solve the left-hand side of the equation to calculate how much of the available "resource" each feeder will use if it's sized to match the pressure-relief device.

4 Compare each pair of "resource" values for each feeder to verify that the equivalent length and minimum diameter will provide sufficient flow capacity. If the "resource" used exceeds the "available" resource, increase the pipe size.

Device	*Feeder size*		*"Resource" Used*		*"Resource" Available*	*Sufficient flow capacity?*	*"Resource" remaining*
EV1	1.25 in.	(31.75 mm)	12,156	<	3,420	No	–8,736
	1.5 in.	(38.1 mm)	5,624	<	10,623	Yes	4,999
CV1	1.25 in.	(31.75 mm)	4,603	<	12,663	Yes	8,060
CV2	1.25 in.	(31.75 mm)	4,603	<	12,663	Yes	8,060

5 Find the sum of the cross-sectional areas, ΣA, of the relief devices, which is 1.25 in. (31.75 mm) in this case ...

$$\Sigma A = 3 \times \Pi(1.25^2 / 4) = 3.68 \text{in.}^2$$
$$(\Sigma A = 3 \times \Pi(31.75^2 / 4) = 2375.19 \text{mm}^2)$$

Then choose a header size with a cross-sectional area that equals or exceeds ΣA. A 2-in. (50 mm) header is too small: 3.14 < 3.68 in.^{2} (1963.49 < 2375.19 mm^2). Increasing the header size to 3 in. (80 mm) will provide the necessary cross-sectional area: 7.07 > 3.68 in.^{2} (5026.54 > 2375.19 mm^2).

6 Determine how much of the remaining available “resource” the 3-in. (80 mm) header will use by solving the left-hand side of the equation on p. 53. Remember that for the header, *C* is the *combined* capacity of all of the pressure-relief devices that are connected to it.

$$\frac{30 \text{ft} \times (78 + 48 + 48)^2 \text{lb/min}}{3^5 \text{in.}} = 3{,}738$$
$$\left(\frac{9 \text{m} \times (0.59 + 0.36 + 0.36)^2 \text{kg/s}}{80^5 \text{mm}} = \sim 0\right)$$

7 Verify that the “resource” used by the header is less than the remaining available “resource” for each relief device; see Step 4 (p. 53). In this case, the smallest remaining “resource” from the feeders is 4,999 from EV1, so this combination of vent-line sizes and equivalent lengths provides sufficient discharge capacity to comply with Standard 15.

Note: If the header size will use more than the available “resource,” you can either:

- *Increase the size of the header to reduce the amount of “resource” it will use. Or ...*
- *Increase the size of the critical feeder to make more “resource” available for the header. (The critical feeder is the run with the least available “resource” remaining.)*

Appendix C
Indirect Open-Spray Systems

An *air washer* is a device that sprays or atomizes clean water into the supply air path. If heated or chilled, the water can heat, cool, humidify, or dehumidify the passing air, as well as remove some of the entrained liquids or solids.

Indirect open-spray systems — more commonly known as "air washers" — are occasionally used in industrial processes, particularly those associated with textile manufacturing. Air washers are classified as "low-probability" systems, provided that the water pressure in the chiller evaporator *always* exceeds the refrigerant pressure in that same vessel. Under this condition, it is almost impossible for refrigerant to enter the process air stream.

This appendix reviews the design characteristics of an indirect open-spray system that uses an R-123 centrifugal chiller and that complies with the criteria established for low-probability systems in ANSI/ASHRAE Standard 15–2004 and ANSI/ASHRAE Standard 34–2004.

Note: The concepts in this section are presented solely to demonstrate how refrigerant properties can affect the design of an "air-washing" system. However, the prerogative and responsibility for designing HVAC systems, and the refrigerating machinery rooms housing them, rests solely with the engineering professional.

Temperature–pressure relationships

Table 5 shows the temperature–pressure characteristics of saturated R-123. Notice that the refrigerant boils at 82.1°F (27.8°C) at atmospheric pressure. At any temperature below 82.1°F (27.8°C), the saturation pressure is less than atmospheric pressure. As long as the evaporator water is cooler than 82.1°F (27.8°C), there is no chance of violating the "low probability" criterion: that is, refrigerant pressure will not exceed water pressure at the evaporator.

Table 6 shows the conversion between gauge pressure (psi) and head (ft of water). The pressure-relief device on all standard Trane centrifugal HCFC-123 chillers is designed to relieve at 15 psi (103 kPa). Any system water pressure greater than 15 psi (103 kPa) is almost certain to exceed the evaporator

Table 5. Temperature–pressure traits of saturated R-123 vapor

	Temperature, °F	(°C)	Pressure, psia	(kPa)
Meets low probability criterion	40	(4.4)	5.8	(40.0)
	50	(10.0)	7.3	(50.3)
	60	(15.6)	9.2	(63.4)
	70	(21.0)	11.4	(78.6)
	80	(26.7)	14.1	(97.2)
P$_{atm}$	**82.1**	(27.8)	**14.7**	(101.0)
Violates low probability criterion	90	(32.2)	17.2	(119.0)
	100	(37.8)	20.8	(143.0)
	110	(43.3)	25.0	(172.0)
	199.9	(48.83)	29.7	(205.0)

Table 6. Pressure-to-head conversion

Gauge pressure, psi	(kPa)	Head ft of water	(m of water)
0	(0.0)	0.00	(0.00)
2	(13.8)	4.61	(1.41)
4	(27.6)	9.23	(2.81)
6	(41.4)	13.8	(4.21)
8	(55.2)	18.5	(5.64)
10	(68.9)	23.1	(7.04)
12	(82.7)	27.7	(8.44)
14	(96.5)	32.3	(9.85)
15	(103.0)	34.6	(10.50)

refrigerant pressure. Therefore, any system with a static hydraulic head of at least 34.6 ft (10.5 m) at the evaporator guarantees a system classification of “low probability.”

Maintaining the system’s “low probability” status

Figure 15 illustrates a typical air-washer system, which in this case includes an electric centrifugal chiller. To help assure a “low probability” classification for such a system, base its design on *one* of the following premises:

- **Static (at rest) hydraulic head equals or exceeds 34.6 ft (10.5 m).** The physical location of the chilled-water-system components enables many “air washers” to meet this criterion. Such cases do not require a special configuration.
- **When the “natural” static head is less than 34.6 ft (10.5 m), add a standpipe or expansion tank to the chilled water supply riser.** This arrangement does not require external controls. However, be sure to add a check valve at the discharge of the chilled water pump to prevent reverse drain-down when the system is at rest; see Figure 16. If an expansion tank is used, set the automatic pressurizing valve to maintain 15 psi (103 kPa) at the chiller evaporator.
- **Use a special low-pressure relief valve (disc) to reduce the minimum required system water pressure.** For example, a 10-psi (68.9 kPa) relief valve can be used to lower the required static head from 34.6 ft to 23.1 ft (10.5 m to 7.04 m). Lowering the static head also lowers the maximum evaporator equilibrium temperature at which refrigerant venting will occur. For this example, the new equilibrium temperature of 108.8°F (42.7°C) remains well above the ambient that one would expect to find in a typical refrigerating machinery room.

Figure 15. Typical air-washer system with chilled water cooling

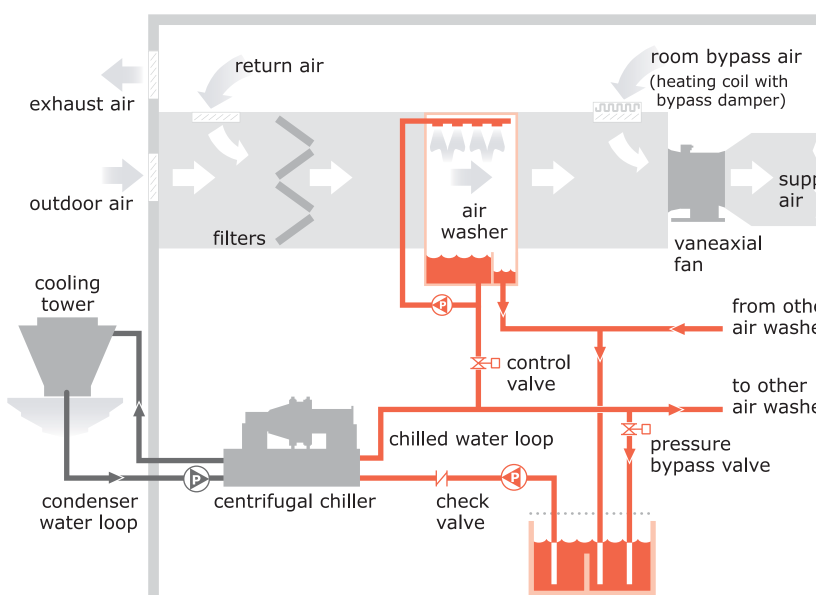
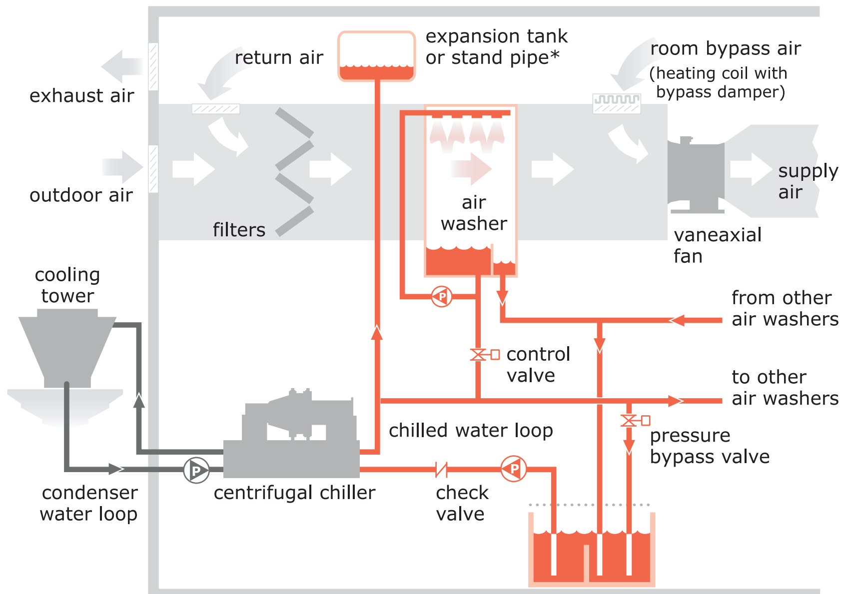


Figure 16. Typical air-washer system with expansion tank: Chilled water application, "natural" static hydraulic head < 34.7 ft [11.4 m])



*OPTIONAL: Add an expansion tank or a standpipe. Size it to maintain 15 psi (103 kPa) at the chiller evaporator and a static, "at rest" head of no less than 34.6 ft (10.5 m).

- **Operate the chilled water pump to produce a dynamic head that's greater than 15 psi (103 kPa) at the evaporator.** To maintain the "low probability" classification of the system, start the chilled water pump whenever the water temperature leaving the evaporator exceeds the refrigerant saturation temperature associated with the *static* hydraulic head. For example:

  a If the air washer has a static head of zero when at rest, control the chilled water pump to start whenever the leaving-evaporator water temperature exceeds 82°F (27.8°C). At this saturation temperature, HCFC-123 develops a vapor pressure of 0.0 psig (0.0 kPa gauge).

  b If the piping configuration for the air washer results in a static head of 18 ft (5.5 m) when the system is at rest, control the chilled water pump to start whenever the leaving-evaporator water temperature exceeds 103.6°F (39.8°C). This control point is determined by converting the static head of 18 ft (5.5 m) to 7.79 psi (53.7 kPa) [1.0 psi = 2.31 ft of water], and then calculating the equivalent saturation temperature — 103.6°F (39.8°C) for HCFC-123 in this case — at 7.79 psi (53.7 kPa).

Pump-induced pressurization is easy to implement: It depends solely on the action of a two-position thermostat that monitors chilled water temperature. When closed, the thermostat starts the chilled water pump and notifies operators of the event by energizing an alarm light or message.

Note: As a control medium, water temperature is preferred over refrigerant pressure because it allows the use of a more robust, less expensive controller.

Why are indirect open-spray systems “low probability”?

In practice, it’s unlikely that refrigerant could ever leak through the chilled water loop into the process air stream. For this to happen, several improbable events would have to occur simultaneously:

- *An evaporator tube develops a significant leak.* Evaporator tube leaks are not only rare but also easily detected: The presence of water in the refrigerant triggers immediate operation of the chiller’s purge-monitoring station.
- *Refrigerant pressure significantly exceeds evaporator pressure.* This condition can only occur when the evaporator-water temperature is highly elevated — usually well above the normal ambient, especially when the plant is occupied and in operation.
- *Refrigerant vapor escapes into the process air stream.* This can only occur while the air washer is operating, when the chilled water contacts air. Because the air washer always functions as a cooler, the chilled water in the washer rarely exceeds 55°F (13°C) — well below the 82°F (27.8°C) boiling point of HCFC-123.

Refrigerant containment

Of greater safety and economic concern is the entire issue of refrigerant containment. The “low probability” classification of a refrigerating system does not address this issue; that classification refers only to the likelihood and consequences of a refrigerant leak.

Refrigerant containment can only be achieved through proper equipment design, manufacture, installation, and maintenance. Therefore, effective leak *prevention* requires that members of the HVAC community:

- design for minimum leak opportunities (for example, use hermetic construction, avoid flare fittings wherever possible, construct welds correctly, and use proper materials);
- design for manufacturability;
- ensure manufacturing quality;
- use low-pressure refrigerants to permit application of near-zero-emission purge-monitoring systems; and,
- practice maintenance procedures for leak prevention and refrigerant containment. For example, use an automation system (such as a Tracer™ or Tracer Summit™ building management system) to monitor purge-system operation; fix leaks if and when they occur; and follow the maintenance procedures suggested by the chiller manufacturer.

For additional information on refrigerant containment, refer to ASHRAE Standard 147–2002, *Reducing the Release of Halogenated Refrigerants from Refrigerating and Air-Conditioning Equipment and Systems*.

Glossary

accessible. Easy to approach for service or use. *See also* readily accessible.

ACGIH. American Conference of Governmental Industrial Hygienists.

AEL. Acceptable exposure limit.

air washer. Device that sprays or atomizes clean water into the supply air path. If heated or chilled, the water can heat, cool, humidify, or dehumidify the passing air, as well as remove some of the entrained liquids or solids. Occasionally used in industrial processes, particularly those associated with textile manufacturing.

ANSI. American National Standards Institute.

ASHRAE. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

azeotropic refrigerant. Blend of two or more component refrigerants (with different volatilities) whose equilibrium vapor-phase and liquid-phase compositions remain the same at a given pressure. *See also* zeotropic refrigerant.

back pressure. Static pressure existing at the outlet of an operating pressure-relief device due to pressure in the discharge (refrigerant vent) line.

building automation system (BAS). Combination of controllers and software that communicates with and controls various mechanical systems, enabling centralized building management.

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

BOCA. Building Officials and Code Administrators.

CFC. Chlorofluorocarbon.

corridor. Enclosed passageway that limits travel to a single path.

discharge piping. *See* vent line.

EEL. Emergency exposure limit.

EPA. Environmental Protection Agency.

equipment room. Room that houses mechanical equipment, such as refrigerating systems, but which may not conform to the special requirements for a machinery room, as detailed in ANSI/ASHRAE Standard 15–2004. *See also* machinery room *and* mechanical equipment room.

Glossary

equivalent length. Flow resistance of fittings or appurtenances in a conduit through which fluid passes, expressed as the length of straight conduit of the same diameter or shape that would have the same resistance; also expressed in length/diameter units.

fractionation. Change in composition of a blend by preferential evaporation of the more volatile component(s) or condensation of the less volatile component(s). *See also* zeotropic refrigerant.

fusible plug. Plug containing an alloy, which melts at a specified temperature to relieve pressure.

halocarbon. Hydrocarbon derivative containing one or more of the halogens bromine, chlorine, or fluorine; hydrogen also may be present.

header. Pipe or tube to which other pipes or tubes (from pressure-relief devices, in the context of this manual) are connected.

hydrocarbon. Compound containing only hydrogen and carbon.

HVAC&R. Heating, ventilation, air conditioning, and refrigeration.

IBC. International Building Code.

ICBO. International Conference of Building Officials.

ICC. International Code Council.

IDLH. "Immediately dangerous to life or health"; that is, the maximum concentration from which unprotected persons are able to escape within 30 minutes without escape-impairing symptoms or irreversible health effects.

informative appendix. Addendum that is not part of the standard but is included for information only. Appendix I, "Emergencies in Refrigerating Machinery Rooms," is one of several informative appendixes in ANSI/ASHRAE Standard 15–2004. *See also* normative appendix.

lower flammability limit (LFL). Minimum concentration of refrigerant that can propagate a flame through a homogeneous mixture of that refrigerant and air under test conditions; normally expressed as refrigerant percentage by volume.

machinery room. Space that is designed to house compressors and pressure vessels, and that meets the requirements of Section 8.11 or 8.12 of ANSI/ASHRAE Standard 15–2004. *See also* equipment room *and* mechanical equipment room.

manifolded relief devices. *See* header.

material safety data sheet (MSDS). Document that provides the following information about a substance: chemical name, hazardous ingredients, physical characteristics, fire and/or explosion data, reactivity, health hazards, usage, handling and/or storage, and special protection and precautions.

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

MER. Mechanical equipment room; room that houses mechanical equipment, such as refrigerating systems, but which may not conform to the special requirements for a machinery room, as detailed in ANSI/ASHRAE Standard 15–2004. *See also* equipment room *and* machinery room.

NFPA. National Fire Protection Association.

NIOSH. National Institute for Occupational Safety and Health.

normative appendix. Addendum that is integral to the mandatory requirements of the standard but which, for convenience, is placed after all other normative elements. Appendix H, "Allowable Equivalent Length of Discharge Piping," is a normative appendix in ANSI/ASHRAE Standard 15–2004. *See also* informative appendix.

occupied space. Portion of the premises that are accessible to or occupied by people, but which excludes machinery rooms.

OSHA. Occupational Safety and Health Administration.

PEL. Permissible exposure limit.

pressure-relief device. Pressure-actuated valve or rupture member that is designed to automatically relieve pressure in excess of the current setting.

pressure vessel. Any refrigerant-containing receptacle in a refrigerating system, excluding: evaporators, provided that the refrigerant-containing volume of each separate evaporator section does not exceed 0.5 ft^3 (0.014 m^3); evaporator coils; compressors; condenser coils; controls; headers; pumps; and piping.

readily accessible. Capable of being reached safely and quickly for operation, repair, and inspection, without climbing over or removing obstacles or using portable access equipment. *See also* accessible.

refrigerant. Fluid used for heat transfer in a refrigerating system. Refrigerant absorbs heat and transfers it at a higher temperature and a higher pressure, usually with a phase change.

refrigerant detector. Device that can sense the presence of refrigerant vapor.

refrigerating system. Combination of interconnected parts forming a closed circuit in which refrigerant is circulated for the purpose of extracting, then rejecting, heat.

refrigerating system classification. Categorization — based on basic design or component location — that groups refrigerating systems according to the probability (low or high) that leaked refrigerant from a failed connection, seal, or component could enter an occupied area.

relief line. *See* vent line.

rupture member. Device that is designed to break open in order to relieve excessive pressure.

sampling point. Location where an air sample is collected to determine (in this case) the presence and concentration of refrigerant; the sample "collector" may be at the refrigerant detector or at a remote location that is connected to the detector with tubing.

SBC. Southern Building Code.

SCBA. Self-contained breathing apparatus.

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.

STEL. Short-term exposure limit.

threshold limit value (TLV). A registered trademark of the American Conference of Governmental Industrial Hygienists. It refers to the airborne concentrations of substances, and represents conditions under which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse health effects.

threshold limit value–time-weighted average (TLV–TWA). Time-weighted average concentration for a normal 8-hour workday and a 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse health effects.

toxicity. Characteristic of a refrigerant to be harmful or lethal due to acute or chronic exposure by contact, inhalation, or ingestion. Effects of concern include (but are not limited to) those of carcinogens, poisons, reproductive toxins, irritants, corrosives, sensitizers, hepatoxins, nephrotoxins, agents that act on the hematopoietic system, and agents that damage the lungs, skin, eyes, or mucous membranes.

vent line. Length of pipe that carries refrigerant from the pressure-relief device (or fusible plug) to the point where it is released to the atmosphere for dispersal. Refrigerant only passes through the vent line if an overpressure condition causes the relief device or fusible plug to operate.

zeotropic refrigerant. Blend of two or more component refrigerants (with different volatilities) whose equilibrium vapor-phase and liquid-phase compositions differ at a given temperature. *See also* azeotropic refrigerant.

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