ASHRAE Standard 15


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

Safety Standard for Refrigeration Systems

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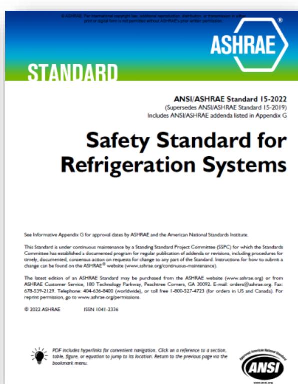
ASHRAE

ASHRAE Standard 15



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ASHRAE 15

- Purpose: *specify safe design, construction, installation, & operation of refrigeration systems*



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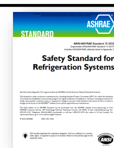

ASHRAE 15 scope

establishes safeguards for life, limb, health, and property and prescribes safety requirements – applies to

a) design, construction, test, installation, operation, and inspection of ***mechanical*** *and* ***absorption*** *refrigeration systems, including heat-pump systems used in* ***stationary applications****;*

b) modifications, including replacement of parts or components if they are not identical in function and capacity; and

c) refrigerant substitutions with a different designation

Ref: Section 2 of ASHRAE 15

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Changing refrigerant [§5.3]

- Changing refrigerant in a system to different refrigerant designation, triggers ASHRAE 15 application and requires
  - Notification of the owner
  - Compliance with instructions of OEM or evaluation of a registered design professional or nationally recognized testing lab to validate safety & suitability of new refrigerant or approval of AHJ
- If the refrigerant's safety group classification is the:
  - Same, original requirements applicable to the original installation continue to apply
  - Different, the current version of Std 15 applies and requires AHJ approval

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The 2022 edition of Std. 15 was released in November 2022

Many of the changes in the 2022 edition of Standard 15 were focused on establishing requirements for the use of 2L flammable refrigerants.

There will be a 2024 edition of ASHRAE 15 released this fall.

21 addenda to Std. 15 since 2019 were incorporated into the 2022 edition

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Note on the forthcoming 2024 edition of Std. 15

The 2024 edition will be published out of the normal 3-year publication cycle to better align as input to the model code publication cycle.

The 2024 edition will incorporate 14 addenda to Std. 15 since 2022.

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What's new in the 2022 edition?

Definitions

Pressure relief capacity factors

Clarification of requirements for product listings and listing standards

New requirements for A2L refrigerants: direct-systems, commercial refrigeration, machinery rooms

Revisions to piping design, materials, installation, and pressure testing

Small charge hydrocarbon systems in lobbies and corridors

Revised requirements for volume calculations to determine refrigerant quantity limits

Added Appendix with non-mandatory information on selected sections of the standard

Modified requirements for A2 & A3 refrigerants for machinery rooms

"Residential" now covered by Std. 15.2

Added mitigation methods to increase allowable refrigerant charge for direct systems

Ammonia refrigeration systems goes to IIAR 2

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New informative appendix[1] added to the 2022 edition

Content includes explanatory nonmandatory reference information for the purpose of improving ease of use of the standard. Normative reference information was also moved into the body of the standard.

INFORMATIVE APPENDIX A
EXPLANATORY MATERIAL

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

Section 3.1

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

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

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

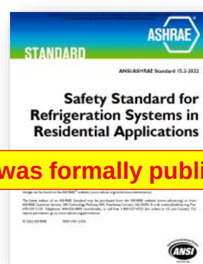
Section 5.3.1

The intent of notifying the owner or owner's agent is to ensure that the owner of the building is aware of the change and can address any consequences to the building or occupancy that might be tied to the change of

[1] The content was approved as part of Addendum to the **2019** addition of Std. 15.

Significant change to the 2022 edition of Std. 15

- Addendum d[1]
  - Revised the scope of Std. 15 to clarify it no longer applies to residential refrigeration systems. This change in scope coincided with the publication of the new ASHRAE Standard 15.2.



ASHRAE 15.2 was formally published in May 2022

[1] The addenda referenced here and in the slides that follow refer to addenda that were made to the **2019** addition of Std. 15.

ASHRAE 15.2

- Purpose: *specifies the minimum requirements for the safe design and installation of refrigeration systems used in residential applications*

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ASHRAE Standard 15.2

- Scope

  Applies to listed direct refrigeration systems in the following residential applications that are limited to serving only a single dwelling unit or sleeping unit:

  a. one- and two-family dwellings and townhouses;

  b. detached outbuildings associated with a one- or two-family dwelling or townhouse and located on the same property included in a) above, and

  c. individual dwelling units and sleeping units located in a multi-family occupancy.

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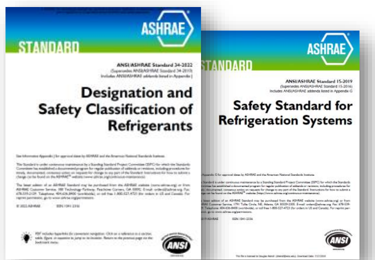
ASHRAE 15 and ASHRAE 34

- As a reminder, ASHRAE 15 relies on ASHRAE 34 for:
  - *Refrigerant safety classifications*
  - *Refrigerant concentration limits (RCLs)*
  - *Key refrigerant property information that must be submitted with an application for designation*



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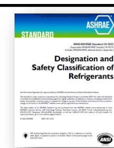
ASHRAE 34



- ***Safety group classification***
  - An alpha-numeric designation that considers both: toxicity and flammability

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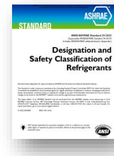
ASHRAE 34



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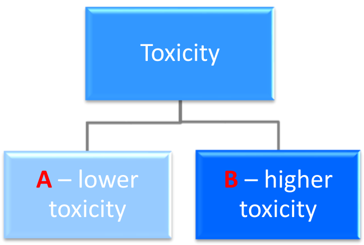
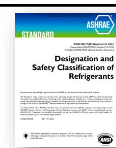
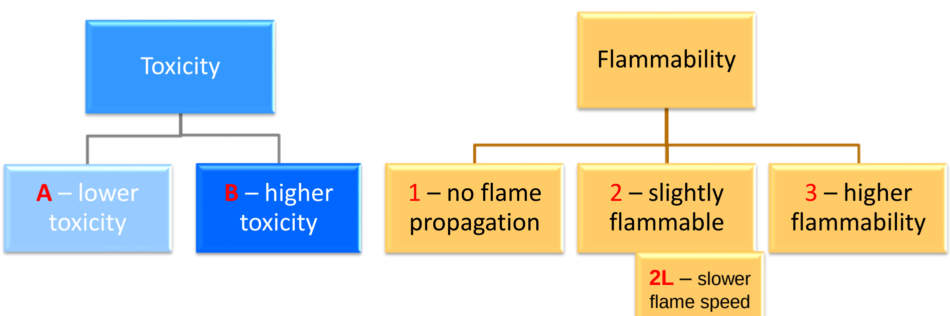


ASHRAE 34



- ***Safety group classification***
  - An alpha-numeric designation that considers both: toxicity and flammability



ASHRAE 34

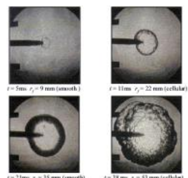
- ***Flammability classifications***

  1 – No flame propagation

  2 – Exhibits flame propagation, LFL > 0.10 kg/m^3, and heat of combustion < 19,000 kJ/kg

  2L – burning velocity not greater than 10 cm/s*

  3 – Exhibits flame propagation, LFL ≤ 0.10 kg/m^3, and heat of combustion ≥ 19,000 kJ/kg



* per ASTM E 681

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ASHRAE 34

26 lb per 1000 ft^3

TABLE 4-2 Data and Safety Classifications for Refrigerant Blends

Refrigerant Number	Composition (Mass %)	Composition Tolerances	OEL[h], ppm v/v	Safety Group	RCL[a] (ppm v/v)	RCL[a] (lb/Mcf)	RCL[a] (g/m^3)	Highly Toxic or Toxic[f] Under Code Classification
Zeotropes								
409B	R-22/124/142b (65.0/25.0/10.0)	(±2.0/±2.0/±1.0)	1000	A1	30,000	7.3	120	Neither
410A[i]	R-32/125 (50.0/50.0)	(+0.5, –1.5/+1.5, –0.5)	1000	A1	140,000	26	420	Neither
410B[i]	R-32/125 (45.0/55.0)	(±1.0/±1.0)		A1	140,000	27	430	Neither
Unsaturated Organic Compounds								
1234yf	2,3,3,3-tetrafluoro-1-propene	$CF_3CF=CH_2$	500	A2L	16,000	4.7	75	Neither
1234ze(E)	trans-1,3,3,3-tetrafluoro-1-propene	$CF_3CH=CFH$	800	A2L	16,000	4.7	75	Neither
1270	propene (propylene)	$CH_3CH=CH_2$	500	A3	1000	0.11	1.7	Neither

4.7 lb per 1000 ft^3

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ASHRAE 34

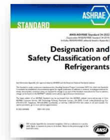

Table 4-2 Data and Safety Classifications for Refrigerant Blends *(Continued)*

Refrigerant Number	Composition (Mass%) (Composition Tolerances)	OEL[h], ppm v/v	Safety Group	RCL[a] ppm v/v	RCL[a] lb/1000 ft³	RCL[a] g/m³	LFL[j] ppm v/v	LFL[j] lb/1000 ft³	LFL[j] g/m³	BV[p] (cm/s)	Highly Toxic or Toxic[f] Under Code Classification
454A	R-32/1234yf (35.0/65.0) (+2.0/–2.0, +2.0/–2.0)	690	A2L	~~16,000~~ 21,000	~~3.2~~4.4	~~52~~70	~~63,000~~[m] 84,000	~~18.3~~[m] 17.5	~~293.9~~[m] 281.4	1.4	Neither
454B	R-32/1234yf (68.9/31.1) (+1.0/–1.0, +1.0/–1.0)	850	A2L	~~19,000~~ 29,000	~~3.1~~4.6	~~49~~74	~~77,000~~[m] 115,000	~~22.0~~[m] 18.5	~~352.6~~[m] 296.8	5.2	Neither

Addendum a to ASHRAE 34-2022 corrected RCL & LFL data for several refrigerants and added burning velocity data for flammable refrigerants.

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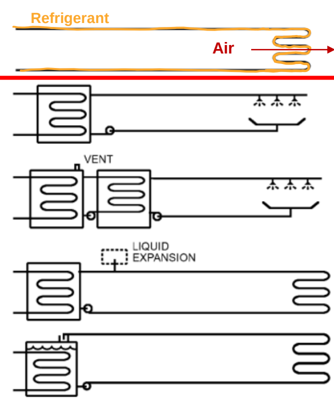
Refrig system classifications

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



[Std. 15: Section 5]

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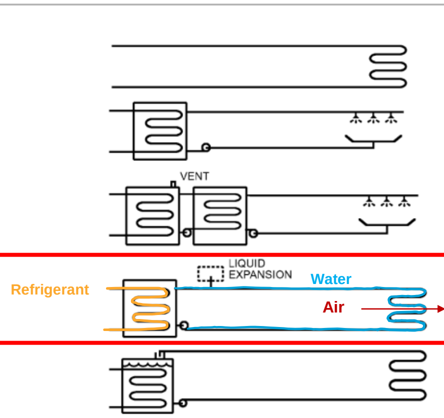
Refrig system classifications

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



[Std. 15: Section 5]

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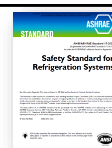
Refrig system classifications



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5.1.1	*Direct system*		
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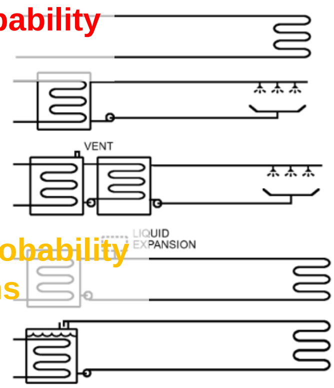
5.1.2.2	*Double indirect open spray system*		
5.1.2.3	*Indirect closed system*		
5.1.2.4	*Indirect vented closed system*		

High probability systems

Low probability systems



[Std. 15: Section 5]

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Standard 15 contents

- **Restrictions**
  - Section 7 – Refrigerant use restrictions
    - 7.1 – General
    - 7.2 – Volume calculations
    - 7.3 – Refrigerant system charge limits
    - 7.4 – Location in a machinery room or outdoors
    - 7.5 – Additional restrictions
    - 7.6 – Group A2L refrigerants for human comfort
    - 7.7 – Group A2L refrigerants for refrigeration systems other than human comfort
    - 7.8 – Group A2 refrigerants for refrigeration systems other than human comfort

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Let's get back to reviewing key changes incorporated into the 2022 edition


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STANDARD

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

Safety Standard for Refrigeration Systems

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

This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. Instructions for how to submit a change can be found on the ASHRAE® website (www.ashrae.org/continuous-maintenance).

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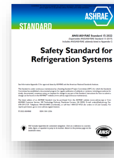
Definitions

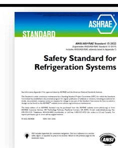
(§3.1)



- New definitions added for
  - connected spaces
  - effective dispersal volume
  - effective dispersal volume charge (*EDVC*)
  - Independent circuit
  - refrigerant detection system
  - refrigerant detector
  - releasable refrigerant charge (m_{rel})
  - System refrigerant charge (m_s), includes factory & field charge
- Existing definition for "listed" revised & new definition for "labeled" added

The new definitions were part of Addendum g and the revised definition of "listed" and added definition for "labeled" were part of Addendum b.to ASHRAE 15-2019.

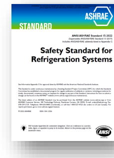
Significant modifications were made to Section 7

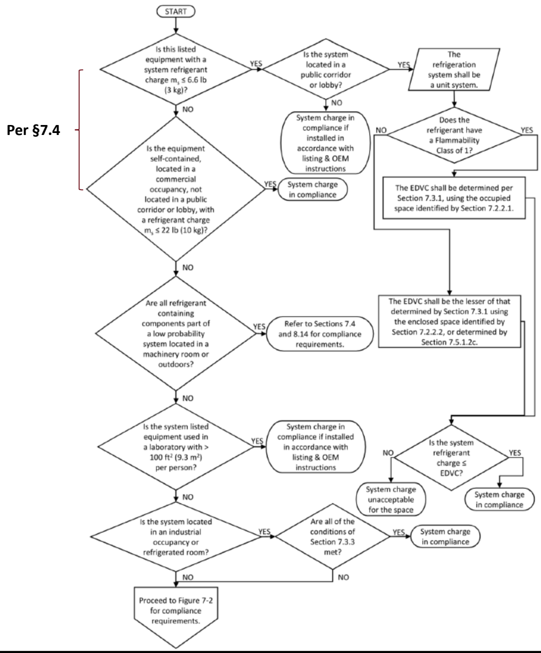


- Rewrites "Concentration Limits" (§7.2) and "Volume Calculations" (§7.2), by reversing the existing sections, first addressing the volume of spaces for consideration (new Section 7.2), then determining acceptable refrigerant charge quantity (new Section 7.3).
- Flowchart "Refrigerant system charge limit compliance" added to help navigate required evaluation for determining whether a machinery room is required or not

[1] These changes were part of Addendum g made to the **2019** addition of Std. 15.

Refrigerant charge limit compliance path





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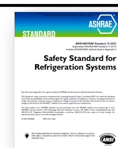
Concepts for room volume calculations applicable to high probability systems



- ***Volume calculations*** applicable to each space or connected space relevant to each refrigeration system is considered. The smallest volume into which refrigerant disperses shall be used to determine the refrigerant quantity limit in the system. [7.2.1]

- ***Effective dispersal volume*** represents the space(s) in which leaked refrigerant will disperse. It determined by the following physical enclosure elements: walls, floors, ceilings, windows or doors which can be closed, and partitions connecting to & extending from finished floor to more than 5.5 ft above the floor. [7.2.3.1]

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Concepts for room volume calculations applicable to high probability systems

- ***Effective dispersal volume charge (EDVC)*** is the maximum refrigerant charge permitted for an effective dispersal volume [3.1]
- ***Refrigerant charge, releasable refrigerant charge (m_{rel})*** is the quantity of refrigerant that can be discharged into an occupied space without or with mitigation controls
  - Single circuit – system charge [7.3.4.1]
  - Multiple independent circuit – each independent circuit released or a reduced quantity if equipped with mitigation controls [7.3.4.2 & 7.3.4.3]

  A2L-specific
  - Air circulation [7.6.1.1]
  - Largest independent circuit (without air circ) [7.6.1.2]

The refrigerant charge of a direct system (or releasable charge) cannot exceed the EDVC

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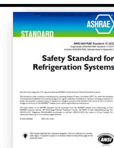
Releasable refrigerant charge
(comfort cooling)



- All refrigerants
  - Single circuit – system charge [7.3.4.1]
  - Multiple independent circuit – each independent circuit released or a reduced quantity if equipped with mitigation controls [7.3.4.2 & 7.3.4.3]

  A2L-specific
  - With air circulation, based on (EDVC * 0.5) [7.6.1.1]
  - Without air circulation, Table 7-1 values cannot be exceeded for largest independent circuit [7.6.1.2]

The refrigerant charge of a direct system (or releasable charge) cannot exceed the EDVC

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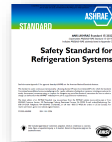
Releasable charge, no mitigation controls



- For systems with multiple independent circuits, the releasable refrigerant charges shall be the refrigerant charges in each independent circuit, unless release mitigation controls are provided in accordance with Section 7.3.4.4. [7.3.4.1]

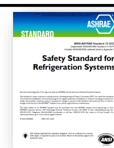
Mitigation controls function to reduce the releasable charge

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

Concepts for room volume calculations applicable to high probability systems

- ***Connected spaces*** are two or more spaces connected by natural ventilation, a ducted air distribution system or mechanical ventilation. [3.1]

For natural ventilation, permanent opening(s) sized in accordance with this section shall be based on net free area. The lower edge of the opening between rooms shall be located a maximum of 12" (30.5 cm) AFF. The area of any openings above 12 in. (305 mm) from the floor shall not be considered. The required size of opening(s) shall be based on the net free area. [7.2.3.2]



Refrigerant charge limits (**Class 1 refrigerant**)

The maximum refrigerant charge permitted for an *effective dispersal volume* shall be calculated as follows:

$$EDVC = RCL \times V_{eff} \times F_{occ}$$

EDVC = effective dispersal volume charge, lb (kg)

RCL = refrigerant concentration limit, lb/ft^3 (g/m^3)

V_{eff} = effective dispersal volume, ft^3 (m^3), established using Sections 7.2.1-7.2.3

F_{occ} = occupancy adjustment factor (For occupancies other than institutional, F_{occ} = 1, institutional occupancies, F_{occ} = 0.5.)

If the releasable charge is ≤ EDVC, a high probability system can be used.

Per [7.3.1]

Refrigerant charge limits (**Class A2L**) in human comfort cooling applications

For any refrigeration system <u>without</u> air circulation, the refrigerant charge of the largest independent circuit of the system (m_s) shall not exceed the value from Eq 7-9:

$$EDVC = M_{def} \times F_{LFL} \times F_{occ} \qquad \text{Eq 7-9}$$

where

EDVC = effective dispersal volume charge, ft3 (m3)

M_{def} = *refrigerant* charge limit from Table 7-1 (lb) or Table 7-2 (kg)

F_{LFL} = *LFL* conversion factor from Table 7-3

Table 7-3 LFL Conversion Factor

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

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

	Height, ft							
Floor Area, ft²	≤2.0	3.3	4.6	5.9	6.6	7.2	8.0	≥9.0
50	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.3
100	4.0	4.0	4.4	5.6	6.3	6.9	7.7	8.6
125	4.0	4.0	5.5	7.0	7.8	8.6	9.6	10.7

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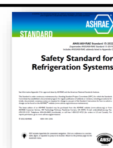
Added restrictions in §7.6 (Class **A2Ls**) in human comfort applications



- The maximum refrigerant charge of any independent circuit of each refrigeration system shall be as specified in Section 7.6.1.1 and 7.6.1.2. [per 7.6.1]
- For high-probability systems used for human comfort **<u>with</u>** either **air circulation** (continuous or initiated by a refrigerant detector complying with 7.6.2.4), the refrigerant charge quantity per circuit shall be limited to Eq 7-8

$$EDVC = V_{eff} \times LFL \times CF \times F_{occ} \qquad \text{Eq 7-8}$$

CF is a concentration factor = 0.5

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Strategies for dealing with systems having a refrigerant charge in excess of the *EDVC*

- Decrease releasable refrigerant charge
  - Specify a unit with lower refrigerant charge
  - Specify two smaller units
  - Determine if a multi-circuit unit can be used
  - Specify a unit equipped with release mitigation controls
- Increase the effective dispersal volume
  - Connected two or more spaces
    - Natural ventilation opening(s) [7.2.3.2.2]
    - Mechanical ventilation [7.2.3.4 & 7.6.4]
  - Utilize a ducted air distribution system [7.2.3.3]
- Use a low probability system with refrigerant-containing parts of the system located in machinery room/outdoors

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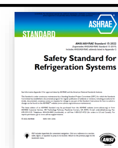
Releasable charge, mitigation controls



Per equation 7-4a,

$$m_{rel} = (t_{r1} \times 0.0062) + m_{r2} + m_{r3}$$

where

t_{r1} = time before the leak is detected per Section 7.6.2.4

0.0062 = leakage rate in lb/s

m_{r2} = leakage between the detection of the leak and the closing of the *safety shutoff valve*, lb

m_{r3} = leakage in the *piping* downstream of the *safety shutoff valve* after the valve is closed, lb

Per equation 7-5a,

$$m_{r2} = t_{close} \times 0.0062$$

where

t_{close} = time from when a leak is detected until the *safety shutoff valve* closes

0.0062 = leakage rate in lb/s

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Releasable charge, mitigation controls

Per equation 7-6,

$$m_{r3} = \sum V_{pipe} \times \rho_{ref}$$

where

V_{pipe} = internal volume of each section of the *piping* and *heat exchanger coil* downstream of the *safety shutoff valve*, ft^3

ρ_{ref} = density of the *refrigerant* in each pipe section downstream of *safety shutoff valve*, lb/ft^3

Requires details from equipment manufacturer and specifics of a given installation

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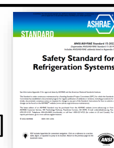

Natural ventilation opening for connected spaces with A2L, A2, or A3 refrigerants [7.2.3.2.2]

- The minimum size of the opening for a Group A2L, A2, or A3 refrigerant (A_{vent}) shall be calculated using the following formula

$$A_{vent} = \frac{\overbrace{m_{rel} - m_{room}}^{\text{Refrigerant quantity over the limit}}}{LFL \times 0.417} \times \sqrt{\frac{A}{g \times m_{room}} \times \frac{M}{M-29}}$$

A_{vent} = minimum area of a permanent opening, ft^2 (m^2)
m_{rel} = releasable refrigerant charge, lb (kg)
m_{room} = allowable refrigerant charge of an individual room, lb (kg); V_{eff}, used to calculate *EDVC*, is the volume of an individual room
LFL = lower flammability limit, lb per 1000 ft^3 (kg/m3)
A = actual area of the individual room, ft2 (m2)
M = relative molar mass of the refrigerant, dimensionless
g = acceleration due to gravity, 32.2 ft/s2 (9.81 m/s2)
0.417 = I-P conversion factor
104 = SI conversion factor
29 = relative molar mass of air, dimensionless

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Determining the refrigerant charge from Table 7-1

The floor area shall be the floor area of the volume of space established in accordance with §7.2 in cu ft. The height shall be the lowest point of any opening in the supply air duct, the return air duct, or the equipment providing air circulation. Heights below 2.0 ft shall use the first height column. Heights greater than 9.0 ft shall use the last height column. For floor areas or heights in between the values listed, linear interpolation or the next lower value shall be used. [7.6.1.2]

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Additional requirements for **A2L** in human comfort applications

- Refrigerant detection system requirements [7.6.2.4]
- Mitigation action requirements [7.6.2.5]
- Limitations on ignition sources in ductwork [7.6.3]
- Mechanical ventilation requirements [7.6.4]
  - Either outside air or transfer air to another space to dilute leaked refrigerant
  - Ventilation rate requirements & actuation
  - Monitoring/verification of ventilation function
  - Makeup air requirements to replace exhausted & transfer air
  - Non-sparking fans
  - Discharge air openings must be arranged to prevent recirculation of exhaust air back into the space

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Mandatory refrigerant detection requirement (**A2L**s in human comfort)

- The following refrigeration systems require an integral refrigerant detection system [7.6.2.3]
  - Ducted HVAC systems with a releasable refrigerant charge (m_{rel}) more than 4.0 lb (1.8 kg) and with any duct openings less than 5.9 ft (1.8 m) above the finished floor
  - Ducted HVAC systems where spaces connected to the same supply air duct are used as the dispersal floor area to calculate volume per Section 7.2
  - Refrigeration systems installed in institutional occupancies

These revisions were part of Addendum s to ASHRAE 15-2019.

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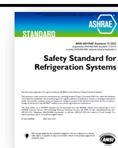
Refrigerant detection system requirements (**A2L**s in human comfort)



- The refrigerant detection system shall comply with the following [7.6.2.4]:
  - Utilize a set point, nonadjustable in the field, to generate an output signal to initiate mitigation actions
  - Field recalibration of detection system is not permitted
  - Capable of detecting presence of the refrigerant corresponding to the system’s refrigerant designation
  - Have access for replacement of refrigerant detection system components

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Refrigerant detection system requirements (A2Ls in human comfort)

- The refrigerant detection system shall comply with the following [7.6.2.4]: cont.
  - Have self-diagnostics to determine operational status of the sensing element
  - Energize air circulation fans of the equipment upon failure of a self-diagnostic check
  - Generate an output signal in <30 seconds when exposed to a refrigerant concentration of 25% LFL (+0%, –1%)

These revisions were part of Addendum s to ASHRAE 15-2019.

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Refrigerant mitigation actions (A2Ls in human comfort) [7.6.2.5]

The following mitigation actions, if utilized, shall be within 15 seconds after initiation of output signal and shall be sustained for at least 5 minutes after the output signal has reset:

Mitigation Actions
Energize air circulation fans
Open / set zone dampers full airflow in air duct system
Activate mechanical ventilation required by Section 7.6.4
De-energize electric heat installed in air duct system
Activate safety shutoff valves to reduce releasable charge
De-energize potential ignition sources

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Mechanical ventilation requirements (A2Ls in human comfort) [7.6.4]

- Mechanical ventilation for refrigerant safety mitigation shall be provided that will remove leaked refrigerant from the space where refrigerant leaking from the refrigeration system is expected to accumulate using either an exhaust or transfer fan.
- The minimum mechanical ventilation rate shall comply with Eq. 7-10

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

Q_{min} = minimum mechanical ventilation airflow rate, ft^3/min

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

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

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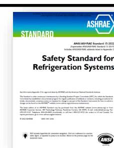
Mechanical ventilation requirements (A2Ls in human comfort) [7.6.4]



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

$$Q_{req} = \frac{m_s - EDVC}{4 \times LFL} \times SF_{vent} \qquad \text{Eq. 7-11a}$$

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

m_s = largest system refrigerant charge from independent circuit, lb

EDVC = effective dispersal volume charge, lb

LFL = lower flammability limit, lb/ft^3

4 = assumed leak duration, min

SF_{vent} = safety factor, value See Section 7.6.4 for additional requirements!

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Group A2L refrigerants for refrigeration in other than human comfort [7.7]

- High-probability systems using A2L refrigerants for other than human comfort applications shall comply with Sections 7.7.1 through 7.7.5.
  - 7.7.1 covers refrigerant charge limits
  - 7.7.2 covers refrigerant concentration limits
  - 7.7.3 covers listing and installation requirements
  - 7.7.4 covers ignition sources in ductwork
  - 7.7.5 covers compressors and pressure vessels located indoors

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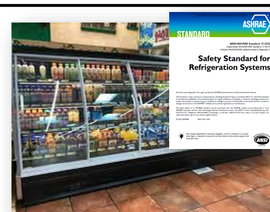
New requirements[1] for commercial refrigeration systems using A2L, A2, and A3



- Permits addition of doors to refrigerated display cases:
  - When owner is notified and does not object
  - When applying refrigerant charge limits of UL/CSA 60335-2-89
    - 8*LFL for closed cases vs. 13*LFL for open cases
    - Construction, testing, and marking requirements for new install apply
  - Validation of safety / suitability with one of the following:
    - OEM written instructions and AHJ approval, or
    - Registered design professional evaluation and AHJ approval, or
    - Evaluation by an NRTL

[1] These requirements were established by Addendum I to the **2019** addition of Std. 15.

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Other changes to the 2022 edition of Standard 15

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Relief device capacity factors

- Capacity factors for overpressure protection are now a function design pressure and values are provided for each specific refrigerant

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

Design Pressure (psi, gage)								
Refrigerant	**50**	**100**	**150**	**200**	**300**	**400**	**500**	**600**
R436B	0.79	0.88	0.97	1.05	1.24	1.49	—	—
R437A	1.06	1.19	1.31	1.43	1.68	2.1	—	—
R438A	1.04	1.17	1.28	1.38	1.62	1.93	—	—
R439A	0.90	0.99	1.08	1.15	1.31	1.50	1.77	—
R440A	0.84	0.94	1.02	1.10	1.27	1.47	1.80	—
R441A	0.73	0.82	0.89	0.96	1.12	1.33	1.71	—
R442A	0.93	1.03	1.12	1.20	1.38	1.58	1.90	—
R443A	0.76	0.85	0.92	1.00	1.15	1.34	1.67	—

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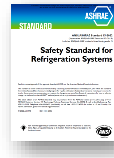
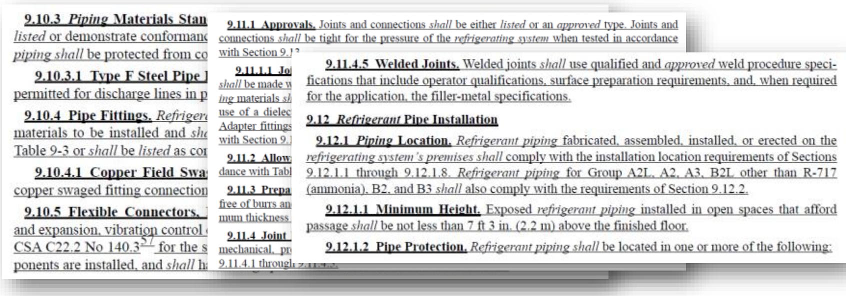
Refrigerant piping, valves, fittings, and related parts [9.10]



- Adds definitions: *building code, building element, exit passageway, etc.*
- **Extensive** revisions/additions for requirements in design, installation, location, and testing of *refrigerant piping*



9.10.3 *Piping* Materials Stan…
listed or demonstrate conformanc…
piping shall be protected from co…

9.10.3.1 Type F Steel Pipe…
permitted for discharge lines in p…

9.10.4 Pipe Fittings. *Refriger*…
materials to be installed and *sh*…
Table 9-3 or *shall* be *listed* as co…

9.10.4.1 Copper Field Swa…
copper swaged fitting connection…

9.10.5 Flexible Connectors…
and expansion, vibration control…
CSA C22.2 No 140.3 for the s…
ponents are installed, and *shall* h…

9.11.1 Approvals. Joints and connections *shall* be either *listed* or an *approved* type. Joints and connections *shall* be tight for the pressure of the *refrigerating system* when tested in accordance with Section 9.1…

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

9.12 *Refrigerant* Pipe Installation

9.12.1 *Piping* Location. *Refrigerant piping* fabricated, assembled, installed, or erected on the *refrigerating system's premises shall* comply with the installation location requirements of Sections 9.12.1.1 through 9.12.1.8. *Refrigerant piping* for Group A2L, A2, A3, B2L other than R-717 (ammonia), B2, and B3 *shall* also comply with the requirements of Section 9.12.2.

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

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

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ASHRAE 15 - 2022

- Addenda to the 2022 edition are being published as part of the continuous maintenance process of Std. 15

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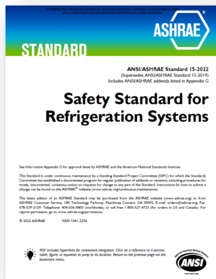
This is just a quick overview

to Standard 15 – lots of changes were incorporated into the 2022 edition and more changes/refinements are in process!



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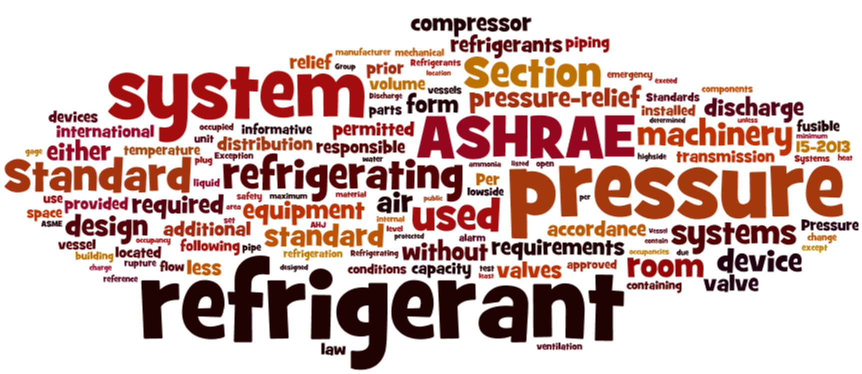
Questions on Standard 15?



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Examples

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Which would you rather do?

- Example of VRF system with A1 refrigerant
- Example of VRF system with A2L refrigerant

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Example of VRF system with A1 refrigerant

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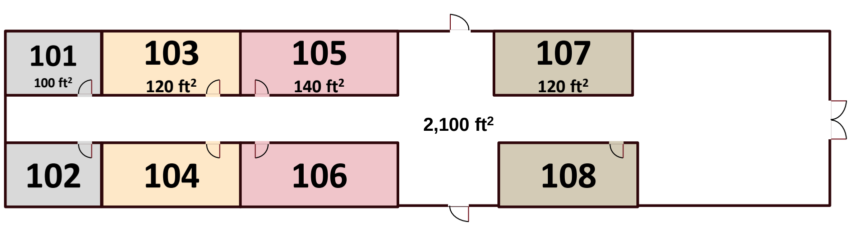
Evaluation of refrigerant quantity limit

A single **R-410A (A1)** ductless **VRF**[1] unit is proposed to serve a small single-story 3,060 ft^2 building with 9’ ceiling height in the occupied space with in-ceiling supply/return & indoor unit locations. To serve the estimated 7.5 ton peak cooling load for the building, an 8 ton unit is being considered and its rated refrigerant charge is 26.5 lb. Determine if the refrigerant quantity limit in Std. 15 is met for the single VRF unit.



[1] A VRF system is considered a “high probability” system.

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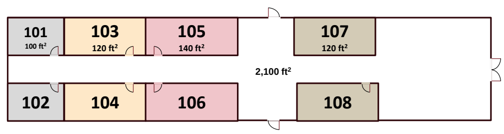
Evaluation of refrigerant quantity limit

- For R410A, the RCL is 26 lb/mcf

Table 4-2 Data and Safety Classifications for Refrigerant Blends *(Continued)*

Refrigerant Number	Composition (Mass%) (Composition Tolerances)	OEL[h], ppm v/v	Safety Group	RCL[a] ppm v/v	RCL[a] lb/1000 ft³	RCL[a] g/m³	LFL[j] ppm v/v	LFL[j] lb/1000 ft³	LFL[j] g/m³	BV[p] (cm/s)	Highly Toxic or Toxic[f] Under Code Classification
410A[i]	R-32/125 (50.0/50.0) (+0.5, –1.5/+1.5, –0.5)	1000	A1	140,000	26	420					Neither

Room	V_{eff} (ft³)	Total Vol (ft³)
101, 102	900	1,800
103, 104	1,080	2,160
105, 106	1,260	2,520
107, 108	1,080	2,160
Common	9,450	18,900
	Total	27,540



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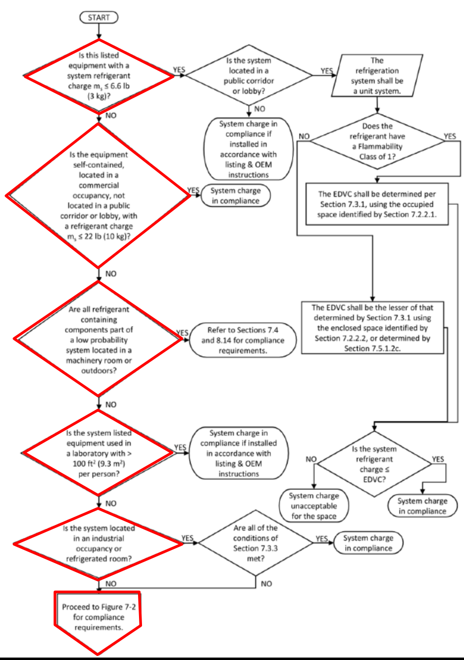
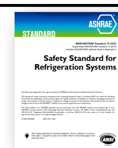
Refrigerant charge limit compliance path





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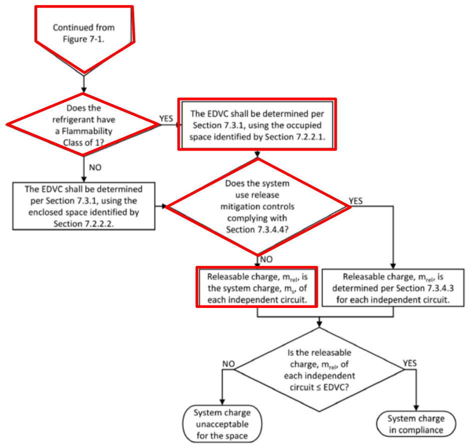
Refrigerant charge limit compliance path, cont.



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Occupied space criteria

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

- Per ASHRAE 15 definitions:
  - *effective dispersal volume*: the volume of a space or *connected spaces* in which leaked *refrigerant* will disperse.
  - *effective dispersal volume charge* (EDVC): the maximum *refrigerant* charge permitted for an *effective dispersal volume*.
  - *occupied space*: that portion of the *premises* accessible to or occupied by people, excluding *machinery rooms*.

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Evaluation of refrigerant quantity limit per §7.3.1

For Room 101 & 102:

$$EDVC = RCL \times V_{eff} \times F_{occ} = \frac{26 \text{ lb}}{1000 \text{ cf}} \times 900 \text{ cf} \times 1 = 23.4 \text{ lb}$$

The other rooms are calculated similarly with their respective effective room volumes.

Room	V_{eff} (ft³)	*EDVC* (lb)
101, 102	900	23.4
103, 104	1,080	28.1
105, 106	1,260	32.8
107, 108	1,080	28.1
Common	18,900	491

Now check to see if these effective dispersal volume charge values exceed the releasable refrigerant charge, m_{rel}

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Releasable charge, m_{rel}, with no mitigation controls

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

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Releasable charge, m_{rel}, with no mitigation controls

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

- Because the system is a single circuit, $m_{rel} = 26.5\ \mathrm{lb}$

Room	V_{eff} (ft^3)	*EDVC* (lb)
101, 102	900	23.4
103, 104	1,080	28.1
105, 106	1,260	32.8
107, 108	1,080	28.1
Common	18,900	491

Fail

In this case, any space with an EDVC less than the releasable charge, $m_{rel} = 26.5\ \mathrm{lb}$ fails.

Pass

A space with EDVC greater than the releasable charge passes.

Options to address fails (1) smaller system charge, (2) multiple systems with smaller charge, (3) ducted system, (4) mitigation controls, (5) interconnect rooms to the common area to increase the *EDV*.

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Connected spaces

7.2.3.2 Connected Spaces via Natural Ventilation.

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

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Natural ventilation opening for connected spaces

7.2.3.2.1 Natural Ventilation Opening for Group A1 Refrigerants. The minimum size of the opening for a Group A1 refrigerant (A_{vent}) shall be calculated as (IP units)

$$A_{vent} = \frac{m_{rel} - m_{room}}{RCL \times 0.833} \times \sqrt{\frac{A}{g \times m_{room}} \times \frac{M}{M - 29}}$$

A_{vent} = minimum area of a permanent opening, ft^2
m_{rel} = releasable refrigerant charge, lb
m_{room} = allowable refrigerant charge of an individual room, lb; V_{eff}, used to calculate *EDVC*, is the volume of an individual room
LRCL = refrigerant concentration limit, lb per 1,000 ft^3
A = actual area of the individual room, ft^2
M = relative molar mass of the refrigerant, dimensionless
g = acceleration due to gravity, 32.2 ft/s^2
0.833 = I-P conversion factor
29 = relative molar mass of air, dimensionless

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Open area required for Rooms 101 & 102 with no mitigation controls

$$A_{vent} = \frac{m_{rel} - m_{room}}{RCL \times 0.833} \times \sqrt{\frac{A}{g \times m_{room}} \times \frac{M}{M - 29}}$$

$$A_{vent} = \frac{26.5 - 23.4}{26 \times 0.833} \times \sqrt{\frac{100}{32.2 \times 23.4} \times \frac{72.6}{72.6 - 29}}$$

$$A_{vent} = 0.07\ ft^2\ (10.1\ in^2)$$

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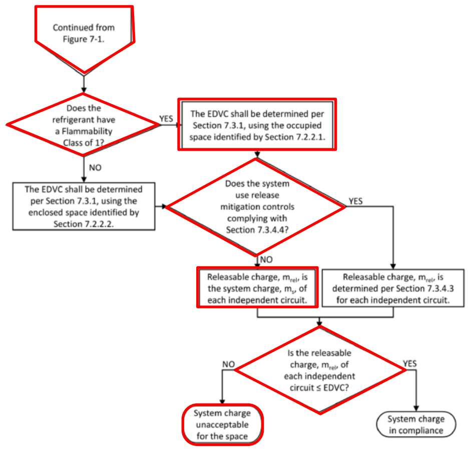
Refrigerant charge limit compliance path, cont.



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Mitigation controls function to reduce the releasable charge

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

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Releasable charge, mitigation controls

Per equation 7-4a,

$$m_{rel} = (t_{r1} \times 0.0062) + m_{r2} + m_{r3}$$

where

t_{r1} = time before the leak is detected per Section 7.6.2.4

0.0062 = leakage rate in lb/s

m_{r2} = leakage between the detection of the leak and the closing of the *safety shutoff valve*, lb

m_{r3} = leakage in the *piping* downstream of the *safety shutoff valve* after the valve is closed, lb

Per equation 7-5a,

$$m_{r2} = t_{close} \times 0.0062$$

where

t_{close} = time from when a leak is detected until the *safety shutoff valve* closes

0.0062 = leakage rate in lb/s

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Release mitigation controls

7.3.4.4 Release Mitigation Controls. Release mitigation controls used to limit the releasable refrigerant charge shall comply with the following:

a. Release mitigation systems shall be components of a refrigeration system that is listed [UL2/40 or UL 2/89].

b. No indoor unit can have a cooling capacity greater than 5 tons.

c. Release mitigation controls shall be activated by a refrigerant detection system. Refrigerant detector shall be located either in all refrigeration equipment serving the spaces or in all spaces served by the release-mitigation-controlled circuit. The refrigerant detector shall activate the release mitigation controls and isolate all possible paths of refrigerant that can leak into the space(s).

d. If release mitigation controls or refrigerant detector fails, the release mitigation controls shall isolate all possible paths of refrigerant that can leak into the space(s).

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Release mitigation controls

7.3.4.4 Release Mitigation Controls. Release mitigation controls used to limit the releasable refrigerant charge shall comply with the following: (cont)

e. Refrigerant detectors shall comply with Section 7.6.2.4 and shall activate the mitigation controls per Section 7.6.2.5. For Group A1 refrigerants, 100% of RCL shall be substituted in place of 25% of LFL.

f. The location of refrigerant mitigation controls shall be marked in accordance with the requirements of ASME A13.1 9.

g. Release mitigation controls shall be tested in accordance with Section 9.13

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In this example case*,

- Time for closing valve when refrigerant is detected, 15 s
- Downstream of safety shutoff valve for Rooms 101/102 includes:
  - 25 ft of 1/4” copper piping (0. 305” id) → V=0.01268 ft^3
  - 25 ft of 1/2” of copper piping (0.527” id) → V=0.03787 ft^3
  - Internal volume of VRF cassette serving 101 & 102 is 0.03 ft^3
- At room temperature of 72°F, the liquid and vapor density of R410A is 67 lb/ft^3 and 3.8 lb/ft^3, respectively

$$m_{rel} = (t_{r1} \times 0.0062) + t_{close} \times 0.0062 + m_{r3}$$

$$= \cancel{(t_{r1} \times 0.0062)} + 15 \times 0.0062 + (0.01268 \cdot 67 + 0.03787 \cdot 3.8 + 0.03 \cdot 67)$$

m_{rel} =3.0 lb

* Use the specific actuation times, equipment & piping sizes, lengths, etc. for your specific installation

101

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Releasable charge, with mitigation controls

- $m_{rel} = 3.0\ \mathrm{lb}$

Room	V_{eff} (ft^3)	*EDVC* (lb)
101, 102	900	23.4
103, 104	1,080	28.1
105, 106	1,260	32.8
107, 108	1,080	28.1
Common	18,900	491

Passes with safety shutoff valves

These spaces passed previously without the use of safety shutoff valves to decrease the releasable charge.

- Keep in mind the releasable charge with mitigation controls will be system and installation specific!

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Questions?

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Example of VRF system with A2L refrigerant

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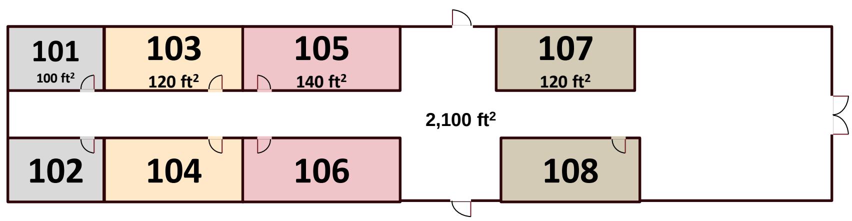
Evaluation of refrigerant quantity limits

A single R-454B (A2L) ductless VRF system is proposed to serve a small single-story 3,060 ft^2 building with 9' ceiling height with indoor units located at an 8' height in the occupied space. To serve the estimated 7.5 ton peak cooling load for the building, an 8 ton unit is being considered and its rated refrigerant charge is 26.5 lb. Determine if the refrigerant quantity limit in Std. 15 is met for the single VRF unit.



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Direct-refrigerant (high probability) systems for human comfort

- EDVC & room volume determination:
  - Effective room dispersal volume for class 2, 2L, 3 [per 7.2.2.2]
  - Room volume [per 7.2.3.1]
  - Connected spaces via. natural ventilation [per 7.2.3.2.2]
  - Connected spaces via. mechanical ventilation [per 7.2.3.4 & 7.6.4]
  - Mitigation controls (if equipped) [per 7.2.6.5 and 7.3.4.3 (for m_{rel})]
- For A2L refrigerants, Section 7.6 also applies
  - Charge limitations based on LFL when a system is equipped with air circulation [7.6.1.1] or without [7.6.1.2]
  - Listing requirements [per 7.6.2]
  - Refrigerant detection [per 7.6.2.3-7.6.2.4]
  - Ignition sources for ducted systems [per 7.6.3] (present system is not ducted)

[1] RCL will be exceed if the releasable charge, m_s, exceeds the effective dispersal volume charge, *EDVC*.

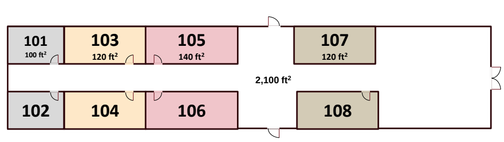
Evaluation of refrigerant quantity limits

- For R454B, the RCL is 4.6 lb/mcf* and the LFL is 18.5 lb/mcf*

Table 4-2 Data and Safety Classifications for Refrigerant Blends *(Continued)*

Refrigerant Number	Composition (Mass%) (Composition Tolerances)	OEL[h], ppm v/v	Safety Group	RCL[a] ppm v/v	RCL[a] lb/1000 ft³	RCL[a] g/m³	LFL[j] ppm v/v	LFL[j] lb/1000 ft³	LFL[j] g/m³	BV[p] (cm/s)	Highly Toxic or Toxic[f] Under Code Classification
454A	R-32/1234yf (35.0/65.0) (+2.0/–2.0, +2.0/–2.0)	690	A2L	~~16,000~~ 21,000	~~3.2~~4.4	~~52~~70	~~63,000[m]~~ 84,000	~~18.3[m]~~ 17.5	~~293.9[m]~~ 281.4	1.4	Neither
454B	R-32/1234yf (68.9/31.1) (+1.0/–1.0, +1.0/–1.0)	850	A2L	~~19,000~~ 29,000	~~3.1~~4.6	~~49~~74	~~77,000[m]~~ 115,000	~~22.0[m]~~ 18.5	~~352.6[m]~~ 296.8	5.2	Neither

Room	V_{eff} (ft³)	Total Vol (ft³)
101, 102	900	1,800
103, 104	1,080	2,160
105, 106	1,260	2,520
107, 108	1,080	2,160
Common	9,450	18,900
	Total	27,540



* These revised values were published as corrections in Addendum a to ASHRAE 34-2022.

Requirements for A2L refrigerant systems

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

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

With air circulation

Without air circulation

Requirements for A2L refrigerant systems (without continuous or detector-initiated air circulation)

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

$$EDVC = M_{def} \times F_{LFL} \times F_{occ} \qquad \text{Eq 7-9}$$

where:

EDVC = effective dispersal volume charge, lb

M_{def} = refrigerant charge from Table 7-1 (based on floor area and height refrigerant is released into the space

F_{LFL} = LFL conversion factor from Table 7-3

F_{occ} = occupancy adjustment factor; (For all occupancies other than institutional occupancies, F_{occ} = 1. For institutional occupancies, F_{occ} = 0.5)

Requirements for A2L refrigerant systems

(for systems without air circulation within the space)

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

	Height, ft							
Floor Area, ft^2	≤2.0	3.3	4.6	5.9	6.6	7.2	8.0	≥9.0
50	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.3
100	4.0	4.0	4.4	5.6	6.3	6.9	7.7	8.6
125	4.0	4.0	5.5	7.0	7.8	8.6	9.6	10.7
150	4.0	4.7	6.5	8.4	9.3	10.3	11.4	12.8
175	4.0	5.0	7.1	9.1	10.1	11.1	12.4	13.8
200	4.0	5.4	7.6	9.7	10.8	11.9	13.2	14.8
225	4.0	5.7	8.0	10.3	11.4	12.6	14.0	15.7
250	4.0	6.0	8.4	10.9	12.1	13.3	14.8	16.5
300	4.0	6.6	9.3	11.9	13.2	14.5	16.2	18.1
350	4.3	7.1	10.0	12.8	14.3	15.7	17.5	19.6
400	4.6	7.6	10.7	13.7	15.3	16.8	18.7	20.9
450	4.9	8.1	11.3	14.6	16.2	17.8	19.8	22.2
500	5.1	8.5	11.9	15.4	17.1	18.8	20.9	23.4
600	5.6	9.3	13.1	16.8	18.7	20.6	22.9	25.6
700	6.1	10.1	14.1	18.2	20.2	22.2	24.7	27.7
800	6.5	10.8	15.1	19.4	21.6	23.7	26.4	29.6
900	6.9	11.4	16.0	20.6	22.9	25.2	28.0	31.4
1000	7.2	12.1	16.9	21.7	24.1	26.5	29.6	33.1
1200	7.9	13.2	18.5	23.8	26.4	29.1	32.4	36.3

The 8' height is based on the lowest point of (a) any opening in the supply air duct, (b) the return air duct, or (c) the equipment providing air circulation per 7.6.1.2.

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Determining the refrigerant charge from Table 7-1

- The floor area shall be the floor area of the volume of space established in accordance with Section 7.2 in cubic ft. The height shall be the lowest point of any opening in the supply air duct, the return air duct, or the equipment providing air circulation. Heights below 2.0 ft shall use the first height column. Heights greater than 9.0 ft shall use the last height column. For floor areas or heights in between the values listed, linear interpolation or the next lower value shall be used. [7.6.1.2]

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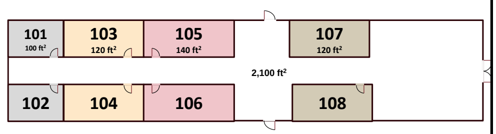
M_{def} using Table 7-1

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

Floor Area, ft²	Height, ft ≤2.0	3.3	4.6	5.9	6.6	7.2	8.0	≥9.0
50	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.3
100	4.0	4.0	4.4	5.6	6.3	6.9	7.7	8.6
125	4.0	4.0	5.5	7.0	7.8	8.6	9.6	10.7
150	4.0	4.7	6.5	8.4	9.3	10.3	11.4	12.8
175	4.0	5.0	7.1	9.1	10.1	11.1	12.4	13.8
200	4.0	5.4	7.6	9.7	10.8	11.9	13.2	14.8
225	4.0	5.7	8.0	10.3	11.4	12.6	14.0	15.7
[illegible]	[illegible]	[illegible]	[illegible]	10.9	12.1	13.3	14.8	16.5

Room	A (ft²)	M_{def} (lb)
101, 102	100	7.7
103, 104	120	9.3
105, 106	140	10.7
107, 108	120	9.3
Common	2,100	42.8



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Requirements for A2L refrigerant systems (without air circulation)

Table 7-3 LFL Conversion Factor

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

$$F_{LFL} = \frac{LFL_{refr}}{LFL_{R32}}$$

$$for\ R454B, F_{LFL}\ \frac{18.5}{19.1} = 0.97$$

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Refrigerant charge limit per circuit for A2L in human comfort applications without air circulation

- For rooms 101, 102:

$$EDVC = M_{def} \times F_{LFL} \times F_{occ} = 7.7 \times 0.97 \times 1.0 = 7.5\ lb$$

- For rooms 103, 104, 107, 108:

$$EDVC = M_{def} \times F_{LFL} \times F_{occ} = 9.3 \times 0.97 \times 1.0 = 9.0\ lb$$

- For rooms 105, 106:

$$EDVC = M_{def} \times F_{LFL} \times F_{occ} = 10.7 \times 0.97 \times 1.0 = 10.4\ lb$$

Room	*A* (ft^2)	M_{def} (lb)	EDVC (lb)
101, 102	100	7.7	7.5
103, 104	120	9.3	9.0
105, 106	140	10.7	10.4
107, 108	120	9.3	9.0
Common	2,100	42.8	41.5

In a ductless VRF case, none of the individual office spaces would have their EDVC below the releasable charge of 26.5 lb.

If a ducted VRF system were used, the volume associated with groups of the smaller offices could be combined.

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Refrigerant charge limit compliance path options

1. *Would natural ventilation via. the connected spaces provision of 7.2.3.2.2 bring the system into compliance?*
2. *Would the addition of air circulation within the space per 7.6.1.1 bring the system into compliance?*
3. *Air circulation plus natural ventilation via. connected spaces?*
4. *Would the release mitigation controls in 7.3.4.3 bring the system into compliance (see also 7.6.2.5 for details on control action)?*

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Natural ventilation opening for connected spaces

7.2.3.2.2 The minimum size of the opening for a Group A2L, A2, or A3 refrigerant (A_{vent}) shall be calculated using the following formula

$$A_{vent} = \frac{\overbrace{m_{rel} - m_{room}}^{\text{Refrigerant quantity over the limit}}}{LFL \times 0.417} \times \sqrt{\frac{A}{g \times m_{room}} \times \frac{M}{M - 29}}$$

A_{vent} = minimum area of a permanent opening, ft^2
m_{rel} = releasable refrigerant charge, lb
m_{room} = allowable refrigerant charge of an individual room, lb;
LFL = lower flammability limit, lb per 1000 ft^3
A = actual area of the individual room, ft^2
M = relative molar mass of the refrigerant, dimensionless
g = acceleration due to gravity, 32.2 ft/s^2
0.417 = I-P conversion factor
29 = relative molar mass of air, dimensionless

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Natural ventilation openings for connected spaces for systems without mitigation controls or air circulation

The minimum size of the opening (A_{vent}) for rooms 101/102

$$A_{vent} = \frac{26.5 - 7.5}{18.5 \times 0.417} \times \sqrt{\frac{100}{7.5 \times 32.2} \times \frac{62.6}{62.6 - 29}} = 1.82\ ft^2\ (\sim 262\ in^2)$$

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Natural ventilation openings for connected spaces for systems without mitigation controls or air circulation

The minimum size of the opening (A_{vent}) for rooms 101/102

$$A_{vent} = \frac{26.5 - 7.5}{18.5 \times 0.417} \times \sqrt{\frac{100}{7.5 \times 32.2} \times \frac{62.6}{62.6 - 29}} = 1.82\ ft^2\ (\sim 262\ in^2)$$

The minimum size of the opening (A_{vent}) for rooms 105/106

$$A_{vent} = \frac{26.5 - 10.4}{18.5 \times 0.417} \times \sqrt{\frac{140}{10.4 \times 32.2} \times \frac{62.6}{62.6 - 29}} = 1.55\ ft^2\ (\sim 223\ in^2)$$

If the permanent openings can be provided, all rooms could be brought into compliance. Intermediate size openings would be required for rooms 103/104.

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Refrigerant charge limit compliance path options

1. *Would natural ventilation via. the connected spaces provision of 7.2.3.2.2 bring the system into compliance?*
2. *Would the addition of air circulation within the space per 7.6.1.1 bring the system into compliance?*
3. *Air circulation plus natural ventilation via. connected spaces?*
4. *Would the release mitigation controls in 7.3.4.3 bring the system into compliance (see also 7.6.2.5 for details on control action)?*

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Requirements for A2L refrigerant systems
(with air circulation within the space)

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

a. air circulation initiated by a refrigerant detector in compliance with Section 7.6.2.4 or

b. continuous air circulation,

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

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Requirements for A2L refrigerant systems
(with air circulation within the space meeting specs in 7.6.1.1)

$$EDVC = V_{eff} \times LFL \times CF \times F_{occ} \qquad \text{Eq 7-8}$$

where:

$EDVC$ = effective dispersal volume charge, lb

V_{eff} = effective dispersal volume, ft^3

LFL = lower flammability limit, lb/ft^3

CF = concentration factor, value of 0.5

F_{occ} = occupancy adjustment factor; (For all occupancies other than institutional occupancies, F_{occ} = 1. For institutional occupancies, F_{occ} = 0.5)

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Evaluation of refrigerant limit per §7.6

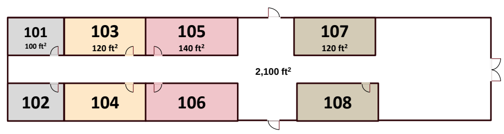
(with air circulation within the space meeting specs in 7.6.1.1)

- For R454B, the LFL is 18.5 lb/mcf

Table 4-2 Data and Safety Classifications for Refrigerant Blends *(Continued)*

Refrigerant Number	Composition (Mass%) (Composition Tolerances)	OEL[h], ppm v/v	Safety Group	RCL[a] ppm v/v	RCL[a] lb/1000 ft³	RCL[a] g/m³	LFL[j] ppm v/v	LFL[j] lb/1000 ft³	LFL[j] g/m³	~~BV~~[p] (cm/s)	Highly Toxic or Toxic[f] Under Code Classification
454A	R-32/1234yf (35.0/65.0) (+2.0/–2.0, +2.0/–2.0)	690	A2L	~~16,000~~ 21,000	~~3.2~~4.4	~~52~~70	~~63,000~~[m] 84,000	~~18.3~~[m] 17.5	~~293.9~~[m] 281.4	1.4	Neither
454B	R-32/1234yf (68.9/31.1) (+1.0/–1.0, +1.0/–1.0)	850	A2L	~~19,000~~ 29,000	~~3.1~~4.6	~~49~~74	~~77,000~~[m] 115,000	~~22.0~~[m] 18.5	~~352.6~~[m] 296.8	5.2	Neither

Room	V_{eff} (ft³)	Total Vol (ft³)
101, 102	900	1,800
103, 104	1,080	2,160
105, 106	1,260	2,520
107, 108	1,080	2,160
Common	9,450	18,900
	Total	27,540



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Evaluation of refrigerant quantity limit per §7.6.1.1

(with air circulation within the space meeting specs in 7.6.1.1)

For rooms 101/102:

$$EDVC = V_{eff} \times LFL \times CF \times F_{occ} = 900\ ft^3 \times \frac{18.5\ lb}{1000 ft^3} \times 0.5 \times 1 = 8.3\ lb$$

The remaining rooms/spaces are similarly calculated.

Room	V_{eff} (ft³)	*EDVC* (lb)
101, 102	900	8.3
103, 104	1,080	10.0
105, 106	1,260	11.7
107, 108	1,080	10.0
Common	18,900	175

$m_{rel} = 26.5$ lb

The *EDVC* with air circulation increased slightly but still only the common area has sufficient volume to accommodate the releasable charge (m_{rel} < *EDVC*).

Alternatively, a ducted VRF could be considered which would allow room volumes to be combined. To stay below the EDVC, the aggregate room volumes for the ducted portions would need to be at least 2,865 ft³.

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Refrigerant charge limit compliance path options

1. *Would natural ventilation via. the connected spaces provision of 7.2.3.2.2 bring the system into compliance?*
2. *Would the addition of air circulation within the space per 7.6.1.1 bring the system into compliance?*
3. *Air circulation plus natural ventilation via. connected spaces?*
4. *Would the release mitigation controls in 7.3.4.3 bring the system into compliance (see also 7.6.2.5 for details on control action)?*

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Natural ventilation openings for connected spaces for systems with air circulation but no mitigation controls

The minimum size of the opening (A_{vent}) for rooms 101/102

$$A_{vent} = \frac{26.5-8.3}{18.5\times0.417} \times \sqrt{\frac{100}{8.3\times32.2} \times \frac{62.6}{62.6-29}} = 1.66\ ft^2\ (\sim 239\ in^2)$$

[A_{vent} decreases by 9% compared to no air circulation case]

The minimum size of the opening (A_{vent}) for rooms 105/106

$$A_{vent} = \frac{26.5-11.7}{18.5\times0.417} \times \sqrt{\frac{140}{111.7\times32.2} \times \frac{62.6}{62.6-29}} = 1.34\ ft^2\ (\sim 193\ in^2)$$

[A_{vent} decreases by 14% compared to no air circulation case]

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Refrigerant charge limit compliance path options

1. *Would natural ventilation via. the connected spaces provision of 7.2.3.2.2 bring the system into compliance?*
2. *Would the addition of air circulation within the space per 7.6.1.1 bring the system into compliance?*
3. *Air circulation plus natural ventilation via. connected spaces?*
4. ***Would the release mitigation controls in 7.3.4.3 bring the system into compliance** (see also 7.6.2.5 for details on control action)?*

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Mitigation controls function to reduce the releasable charge

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

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Releasable charge, mitigation controls

Per equation 7-4a,

$$m_{rel} = \underbrace{(t_{r1} \times 0.0062)}_{\text{small}} + m_{r2} + m_{r3}$$

where

t_{r1} = time before the leak is detected per Section 7.6.2.4

0.0062 = leakage rate in lb/s

m_{r2} = leakage between the detection of the leak and the closing of the *safety shutoff valve*, lb

m_{r3} = leakage in the *piping* downstream of the *safety shutoff valve* after the valve is closed, lb

Per equation 7-5a,

$$m_{r2} = \underbrace{t_{close} \times 0.0062}_{\text{small}}$$

where

t_{close} = time from when a leak is detected until the *safety shutoff valve* closes

0.0062 = leakage rate in lb/s

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Releasable charge, mitigation controls

Per equation 7-6,

$$m_{r3} = \sum V_{pipe} \times \rho_{ref}$$

where

V_{pipe} = internal volume of each section of the *piping* and *heat exchanger coil* downstream of the *safety shutoff valve*, ft^3

ρ_{ref} = density of *refrigerant* in each pipe section downstream of *safety shutoff valve*, lb/ft^3

This calculation requires obtaining relevant details about the indoor unit volume, size of liquid and suction lines serving the indoor unit, location of safety shutoff valves (SSVs) relative to the indoor unit (length of lines). Several calculations will likely be required where the indoor unit size varies and/or line lengths vary.

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For this example case*,

- Time for closing valve when refrigerant is detected, 15 s
- Downstream of safety shutoff valve for Rooms 101/102 includes:
  - 25 ft of 1/4” copper piping (0. 305” id) → V=0.01268 ft^3
  - 25 ft of 1/2” of copper piping (0.527” id) → V=0.03787 ft^3
  - Internal volume of VRF cassette serving 101 & 102 is 0.03 ft^3
- At room temperature of 72°F, the liquid and vapor density of R454B is 62.5 lb/ft^3 and 2.8 lb/ft^3, respectively

$$m_{rel} = (t_{r1} \times 0.0062) + t_{close} \times 0.0062 + m_{r3}$$

$$= \cancel{(t_{r1} \times 0.0062)} + 15 \times 0.0062 + (0.01268 \cdot 62.5 + 0.03787 \cdot 2.8 + 0.03 \cdot 62.5) \rightarrow m_{rel} = 2.87 \text{ lb}$$

* Use the specific actuation times, equipment & piping sizes, lengths, etc. for your specific installation

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Releasable charge, with mitigation controls

- $m_{rel} = 2.87 \text{ lb}$

Room	V_{eff} (ft^3)	EDVC (lb) No air circulation	*EDVC* (lb) With air circulation
101, 102	900	**7.5**	8.3
103, 104	1,080	9.0	-
105, 106	1,260	10.4	-
107, 108	1,080	9.0	-
Common	18,900	41.5	-

Pass

These values need to be updated to reflect the pipe sizes, lengths, and indoor unit volume for each space.

- Keep in mind the releasable charge with mitigation controls will be system and installation specific!

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Refrigerant charge limit compliance path

Can we comply by incorporating room-to-room air exchange via mechanical ventilation?

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Mechanical ventilation for refrigerant safety mitigation (transfer air, not "fresh" air)

7.6.4 Mechanical Ventilation. Mechanical ventilation for *refrigerant* safety mitigation *shall* comply with this section.

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

$$Q_{min} = \frac{Q_{req}}{C_{LFL}}$$

From Table 7-4

From Table 7-5

Minimum transfer air rate, CFM

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Mechanical ventilation for release mitigation

The minimum required ventilation rate is given by the following when Eq. 7-10 & 7-11 are combined :

$$Q_{min} = \frac{m_s - EDVC}{4 \times LFL \times C_{LFL}} \times SF_{vent}$$

Where

Q_{min} = minimum mechanical ventilation air flow rate, ft^3/min

m_s = largest *system refrigerant charge* from an *independent circuit*, lb

$EDVC$ = *effective dispersal volume charge,* lb

LFL = *lower flammability limit,* lb/ft^3

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

SF_{vent} = safety factor, 2

Table 7-5 Lower Flammability Limit Conversion Factor

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

[Section 7.6.4]

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Mechanical ventilation for release mitigation without in-room air circulation

- For rooms 101/102, the EDVC = 7.5 lb (assuming no mitigation controls)

$$Q_{min} = \frac{m_s - EDVC}{4 \times LFL \times C_{LFL}} \times SF_{vent} = \frac{26.5\ lb - 7.5\ lb}{4\ min \times 18.5 \frac{lb}{1000\ ft^3} \times 0.97} \times 2 = 529\ cfm$$

Room	*A* (ft^2)	EDVC (lb)	Q_{min}
101, 102	100	7.5	529
103, 104	120	9.0	488
105, 106	140	10.4	449
107, 108	120	9.0	488
Common	2,100	41.5	-

Air flow rate between each individual room and the common area.

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If VRF includes a ducted air distribution system,

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

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If VRF includes a ducted air distribution system,

7.2.3.3.2 Plenums. Volume ceiling plenum or floor plenum shall be included when calculating the effective dispersal volume if plenum part of air distribution system.

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

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

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

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Questions?

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