ASHRAE Standard 15

ASHRAE

STANDARD

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

Safety Standard for Refrigeration Systems

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

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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Douglas Reindl, Ph.D., P.E.
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Professor, University of Wisconsin-Madison

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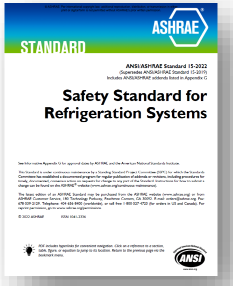
ASHRAE 15

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

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* <u>*heat-pump*</u> *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

Changing refrigerant [§5.3]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Safety Standard for Refrigeration Systems

- 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

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

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

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

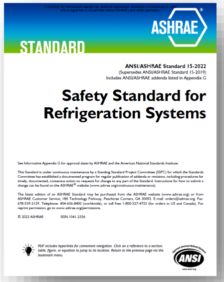
Summary of changes to Std. 15

Sections Affected	Description of Change*
3.1; 7.2.2; 7.4.2; 7.4.3; 7.5.1.8; 8.7; 8.8; 8.9; 8.10; 8.11; 8.12; 8.13; 8.14; 8.15; 9.9.1; 9.10; 9.11 (new); 9.12 (new); 9.13 (new); 9.14; 9.15; 9.16 (new); 9.17 (new); 10; 11; 12; 13; Informative Appendix A; Normative	Addendum *e* revises requirements related to the design, installation, location, and testing of refrigerant piping.

Summary of changes to Std. 15

Sections Affected	Description of Change*
3.1; 7.2; 7.3; 7.6; Informative Appendix A; Normative Appendix B	Addendum *m* to ANSI/ASHRAE Standard 15-2019 modifies allowances for the use of mechanical ventilation to expand this mitigation strategy for human comfort applications using A2L refrigerants.
7.6.3.3; Informative Appendix A	Addendum *n* to ANSI/ASHRAE Standard 15-2019 addresses a continuous maintenance proposal to clarify wording about face velocity.

Summary of changes to Std. 15

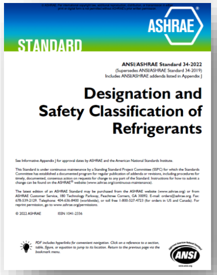


Sections Affected	Description of Change*
3.1; 7.6.2, 7.6.2.3, 7.6.2.4, 7.6.2.5 (new), 7.6.4, 7.6.5; Informative Appendix A	Addendum *s* addresses the use of refrigerant detection and mitigation requirements when a leak is detected in A2L systems for human comfort.

ASHRAE 15 and ASHRAE 34

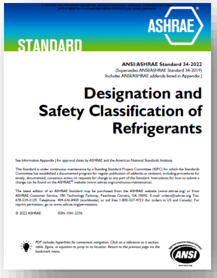
- As a reminder, ASHRAE 15 relies on ASHRAE 34 for:
  - *Refrigerant safety classifications*
  - *Refrigerant concentration limits (RCLs)*
  - *Key refrigerant property information that must be submitted with an application for designation*

ASHRAE 34

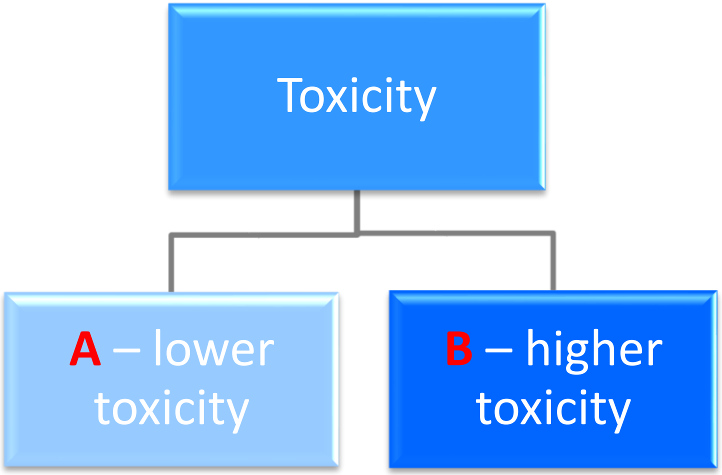


- ***Safety group classification***
  - An alpha-numeric designation that considers both: toxicity and flammability

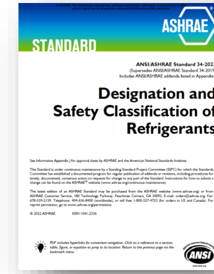
ASHRAE 34



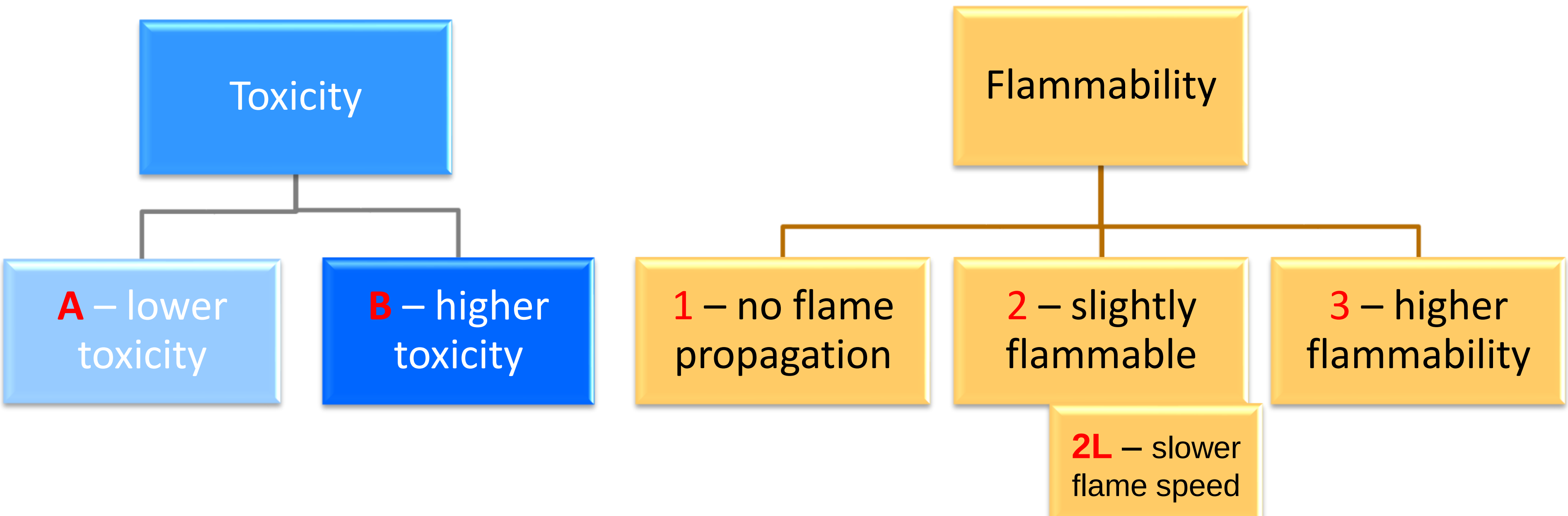
- ***Safety group classification***
  - An alpha-numeric designation that considers both: toxicity and flammability



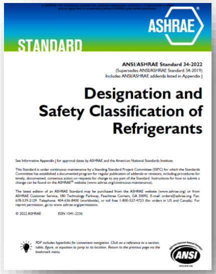
ASHRAE 34



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



ASHRAE 34



- ***Toxicity classifications***
  - **Class A** signifies refrigerants where toxicity has not been identified at concentrations ≥ 400 ppm_v based on OEL data or consistent indices
  - **Class B** signifies refrigerants where evidence of toxicity at concentrations < 400 ppm_v based on OEL or other consistent indices

ASHRAE 34

- ***Toxicity classifications***
  - Class A signifies refrigerants where toxicity has not been identified at concentrations ≥ 400 ppm_v based on OEL
  - Class B signifies refrigerants where evidence of toxicity at concentrations < 400 ppm_v based on OEL

Table 4-1 Refrigerant Data and Safety Classifications *(Continued)*

Refrigerant Number	Chemical Name [a,b]	Chemical Formula [a]	OEL [f], ppm v/v	Safety Group	RCL [c] ppm v/v	RCL [c] lb/1000 ft^3	RCL [c] g/m^3
Ethane Series (*continued*)							
116[e]	hexafluoroethane	CF_3CF_3	1000	A1	97,000	34	550
123	2,2-dichloro-1,1,1-trifluoroethane	$CHCl_2CF_3$	50	B1	9100	3.5	57
124	2-chloro-1,1,1,2-tetrafluoroethane	$CHClFCF_3$	1000	A1	10,000	3.5	56

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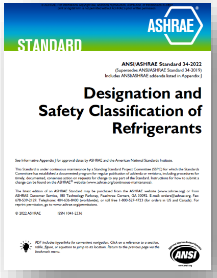


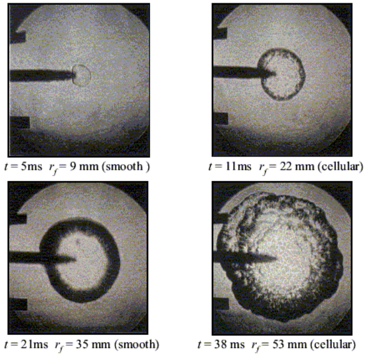
- ***Flammability classifications***

  1 – No flame propagation

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

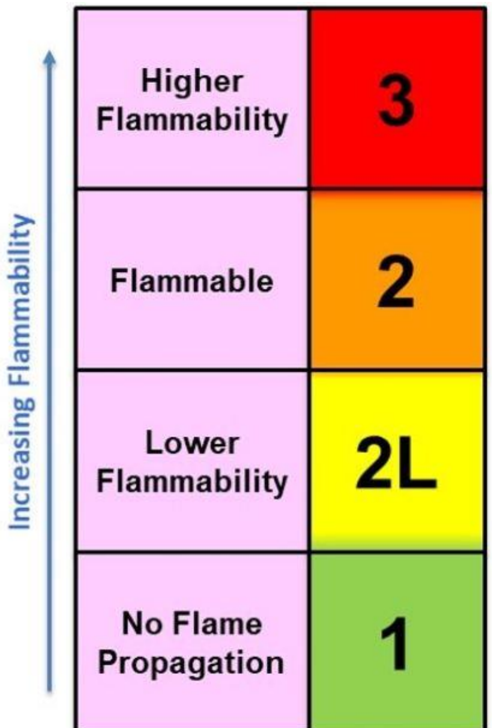
  2L – burning velocity not greater than 10 cm/s*

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



*** per ASTM E 681**

Refrigerant flammability classes



Examples

HCs (e.g., R-290, R-600a)

R-152a

Ammonia (R-717)

R-1234yf, R-32, R-454B

Most baseline HFCs

CO_2

R-449A, R-513A

Usage of these refrigerant groups are expected to expand

ASHRAE 34

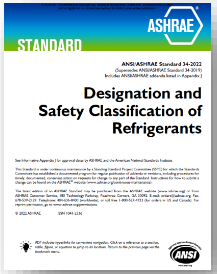
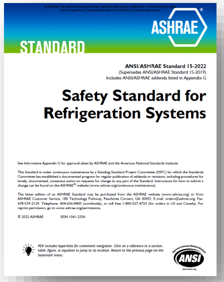


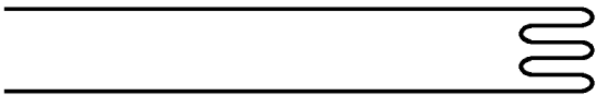
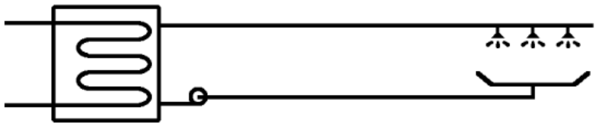
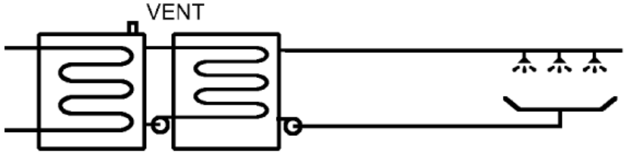
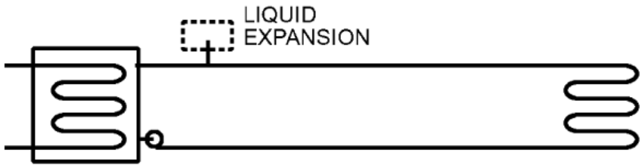
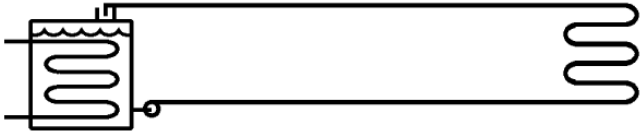
Table 4-2 Data and Safety Classifications for Refrigerant Blends *(Continued)*

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

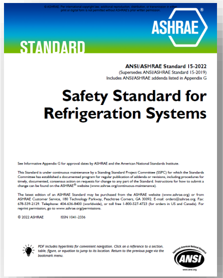
Addendum a to ASHRAE 34-2022 corrected RCL & LFL data for several refrigerants and added burning velocity data for flammable refrigerants.

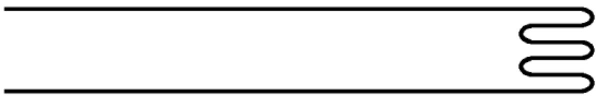
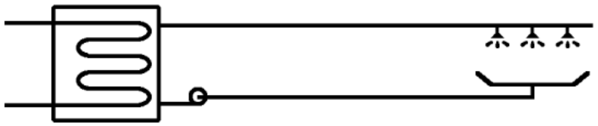
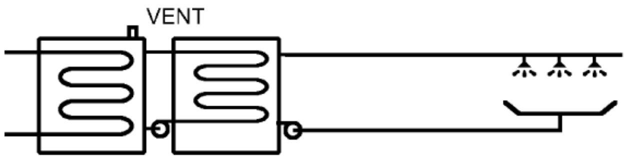
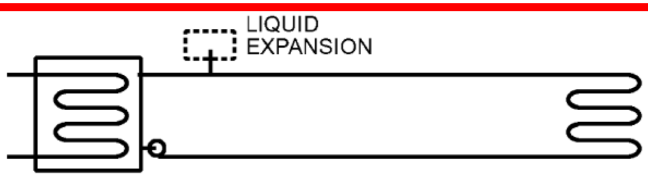
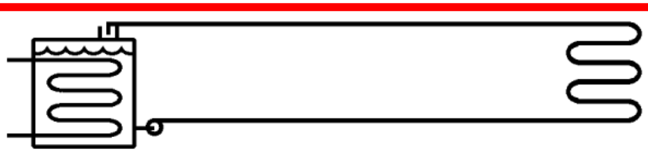
Refrig system classifications



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*		

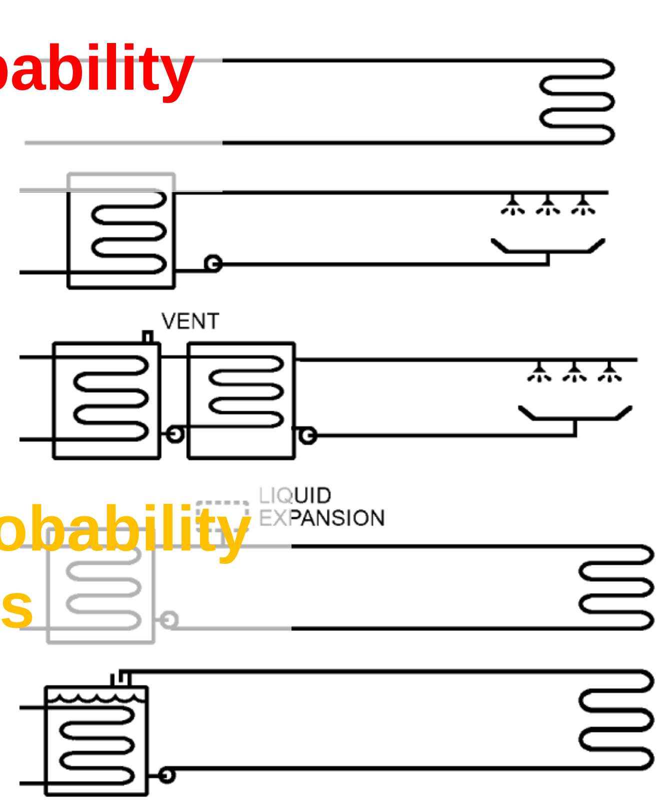
Refrig system classifications



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*		

Refrig system classifications

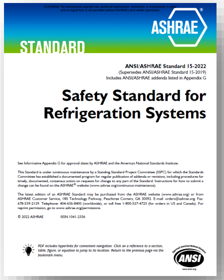
Paragraph	Designation	Cooling or Heating Source	Air or Substance to be Cooled or Heated
5.1.1	*Direct system*		
5.1.2.1	*Indirect open spray system*		
5.1.2.2	*Double indirect open spray system*		
5.1.2.3	*Indirect closed system*		
5.1.2.4	*Indirect vented closed system*		



High probability systems (5.1.1, 5.1.2.1)

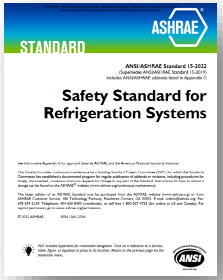
Low probability systems (5.1.2.2, 5.1.2.3, 5.1.2.4)

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]

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.

  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. [7.2.3.2]

Refrigerant charge limits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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 system charge is ≤ EDVC, high probability system can be used.

Per [7.3.1] with no air circulation

Strategies for dealing with releasable charge in excess of the *EDVC*

- Decrease releasable 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
  - Incorporate mechanical or natural ventilation openings between two or more spaces
  - Incorporate mechanical ventilation to move air between spaces
- Use a low probability system with refrigerant-containing parts of the system located in machinery room/outdoors

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]

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

$$A_{vent} = \frac{m_{rel} - m_{room}}{LFL \times 0.417} \times \sqrt{\frac{A}{g \times m_{room}} \times \frac{M}{M - 29}}$$

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

Added restrictions in §7.6 for **A2L** 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 has either air circulation (continuous or initiated by a refrigerant detector in compliance with Section 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

NEW

Refrigerant charge limit per circuit for **A2L** in human comfort applications

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 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)

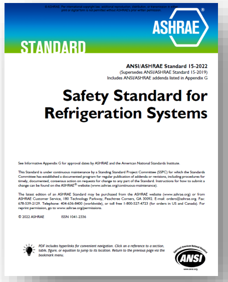
M_{def} = *refrigerant* charge from Table 7-1 (lb) or Table 7-2 (kg)

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

Table 7-3 LFL Conversion Factor

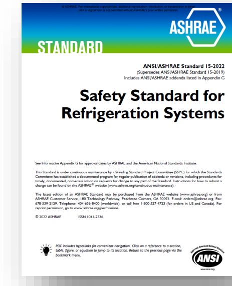
Refrigerant	F_{LFL}
R-32	1.00
R-452B	1.02
R-454A	0.92
R-454B	0.97
R-454C	0.95
R-457A	0.71

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



- Refrigerant detection system requirements [7.6.2.4]
- Mitigation action requirements found in [7.6.2.5]
- Limitations on ignition sources in ductwork [7.6.3]
- Mechanical ventilation requirements [7.6.4]
  - Not outside air but air movement circulation & transfer
  - Ventilation rate requirements & actuation
  - Monitoring/verification of ventilation function
  - Makeup air requirements to replace exhausted & transfer air
  - Non-sparking fans
  - Separation to avoid recirculation of exhaust air back into the space

Mandatory refrigerant detection requirements (**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.

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

The following mitigation actions 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

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

- 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
- 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

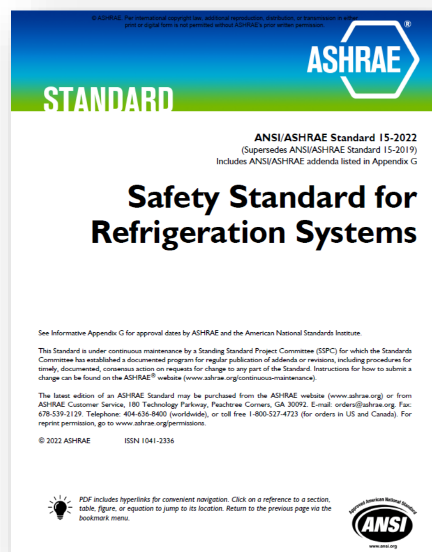
C_{LFL} = *lower flammability limit* conversion factor from Table 7-5

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

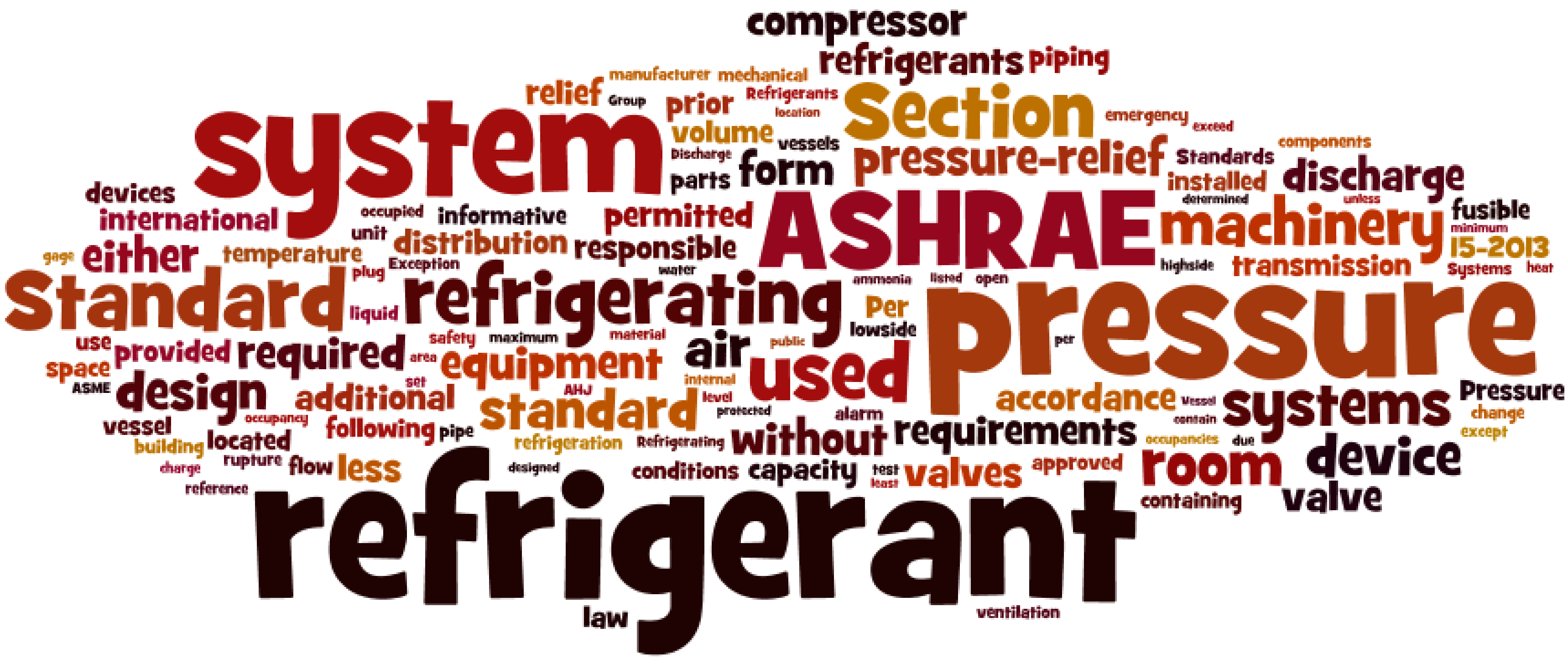
- High-probability systems using A2L refrigerants for other than human comfort applications shall comply with Sections 7.7.1 through 7.7.5.
  - 7.7.1 covers refrigerant charge limits
  - 7.7.2 covers refrigerant concentration limits
  - 7.7.3 covers listing and installation requirements
  - 7.7.4 covers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

This is just a quick overview

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



Questions on Standard 15?



Examples

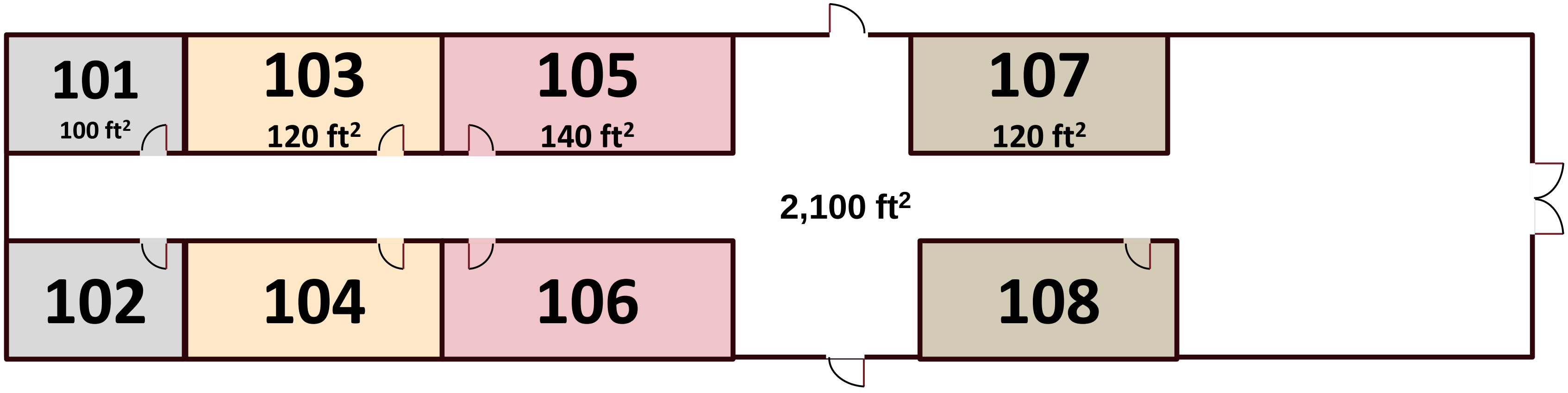
Which would you rather do?

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

Example of VRF system with A2L refrigerant

Evaluation of refrigerant quantity limit

A single R454B (A2L) VRF unit is proposed to serve a small single-story 3,060 ft^2 building with 10' 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.



Direct-refrigerant (high probability) systems for human comfort

- EDVC & room volume determination[2]:
  - Effective room dispersal volume per 7.2.2.2
  - Room volume per 7.2.3.1
  - Connected spaces per 7.2.3.2.2 for natural ventilation
  - Connected spaces via mechanical ventilation per 7.2.3.4
  - Mitigation controls (if equipped) per 7.3.4.3
- Apply 7.6 for A2L refrigerants
  - Charge limitations based on LFL when a system is equipped with air circulation or without
  - Listing requirements
  - Refrigerant detection
  - Ignition sources

[1] RCL will be exceed if the releasable charge, m_s, exceeds the effective dispersal volume charge, *EDVC*.
[2] Although not clear, this requirement applies to all but A2L refrigerants.

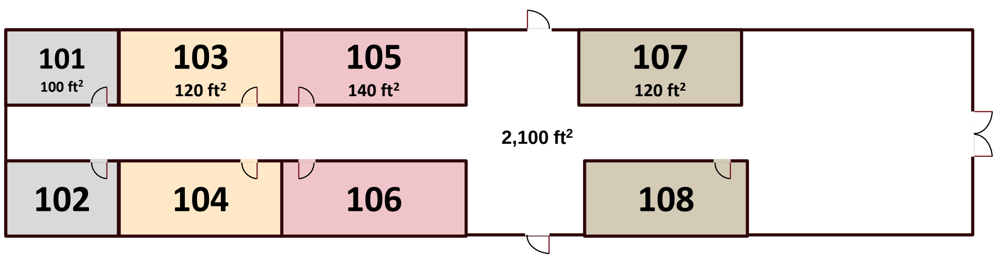
Evaluation of refrigerant quantity limit

- 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.

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 (without air circulation)

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

Floor Area, ft²	Height, ft							
	≤2.0	3.3	4.6	5.9	6.6	7.2	8.0	≥9.0
50	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.3
100	4.0	4.0	4.4	5.6	6.3	6.9	7.7	8.6
125	4.0	4.0	5.5	7.0	7.8	8.6	9.6	10.7
150	4.0	4.7	6.5	8.4	9.3	10.3	11.4	12.8
175	4.0	5.0	7.1	9.1	10.1	11.1	12.4	13.8
200	4.0	5.4	7.6	9.7	10.8	11.9	13.2	14.8
225	4.0	5.7	8.0	10.3	11.4	12.6	14.0	15.7
250	4.0	6.0	8.4	10.9	12.1	13.3	14.8	16.5
300	4.0	6.6	9.3	11.9	13.2	14.5	16.2	18.1
350	4.3	7.1	10.0	12.8	14.3	15.7	17.5	19.6
400	4.6	7.6	10.7	13.7	15.3	16.8	18.7	20.9
450	4.9	8.1	11.3	14.6	16.2	17.8	19.8	22.2
500	5.1	8.5	11.9	15.4	17.1	18.8	20.9	23.4
600	5.6	9.3	13.1	16.8	18.7	20.6	22.9	25.6
700	6.1	10.1	14.1	18.2	20.2	22.2	24.7	27.7
800	6.5	10.8	15.1	19.4	21.6	23.7	26.4	29.6
900	6.9	11.4	16.0	20.6	22.9	25.2	28.0	31.4
1000	7.2	12.1	16.9	21.7	24.1	26.5	29.6	33.1
1200	7.9	13.2	18.5	23.8	26.4	29.1	32.4	36.3

Determining the refrigerant charge from Table 7-1

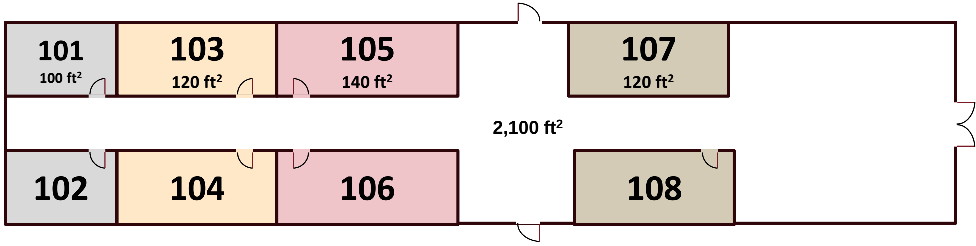
- The floor area shall be the floor area of the volume of space established in accordance with Section 7.2 in cubic ft. The height shall be the lowest point of any opening in the supply air duct, the return air duct, or the equipment providing air circulation. Heights below 2.0 ft shall use the first 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]

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]	[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



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

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

$$for\ R414B,$$

$$F_{LFL}\frac{18.5}{19.1} = 0.97$$

Refrigerant charge limit per circuit for A2L in human comfort applications

- 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 this case, none of the individual office spaces would have their EDVC below the releasable charge of 26.5 lb.

Refrigerant charge limit compliance path

Would the addition of air circulation bring the system into compliance?

Requirements for A2L refrigerant systems (with air circulation)

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:

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

Requirements for A2L refrigerant systems (with air circulation)

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

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} = 1)

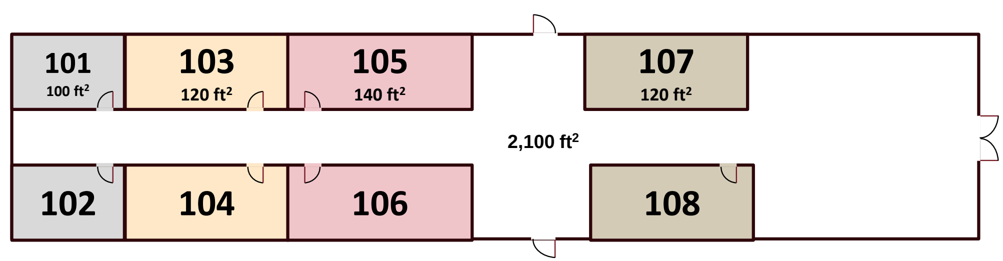
Evaluation of refrigerant limit per §7.6 (with air circulation)

- 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 ft^3	RCL[a] g/m^3	LFL[j] ppm v/v	LFL[j] lb/1000 ft^3	LFL[j] g/m^3	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} (ft^3)	Total Vol (ft^3)
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



Evaluation of refrigerant quantity limit per §7.6.1.1 (with air circulation)

For rooms 101/102:

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

The remaining rooms/spaces are similarly calculated.

Room	V_{eff} (ft^3)	*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

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

$$m_{rel} = 26.5\ \text{lb}$$

Refrigerant charge limit compliance path

Would a system with release mitigation controls bring the system into compliance?

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]

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,

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

where

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

0.0062 = leakage rate in lb/s

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

For this example case,

- Time for closing valve when refrigerant is detected, 15 s
- Downstream of safety shutoff valve includes:
  - 70 ft of 1/2” copper piping (0.430” id) → V=0.071 ft^3
  - 70 ft of 5/8” of copper piping (0.545” id) → V=0.113 ft^3
  - Internal volume of VRF cassette serving 101 & 102 is 0.10 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

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

$$= \cancel{(t_{r1} \times 0.0062)} + 15 \times 0.0062 + (0.071 \cdot 62.5 + 0.113 \cdot 2.8 + 0.10 \cdot 62.5)$$

m_{rel} =11.1 lb

Releasable charge, with mitigation controls

- $m_{rel} = 11.1 \text{ lb}$

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	10.0
105, 106	1,260	10.4	11.7
107, 108	1,080	9.0	10.0
Common	18,900	41.5	175

Fail
Pass

- Rooms 101 & 102 do not pass
- Keep in mind the releasable charge with mitigation controls will be system and installation specific!

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

$$A_{vent} = \frac{m_{rel} - m_{room}}{LFL \times 0.417} \times \sqrt{\frac{A}{g \times m_{room}} \times \frac{M}{M - 29}}$$

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; V_{eff}, used to calculate *EDVC*, is the volume of an individual room

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

Natural ventilation opening for connected spaces

The minimum size of the opening (A_{vent}) for rooms 101/102 with mitigation controls and no air circulation

$$A_{vent} = \frac{11.1 - 7.5}{18.5 \times 0.417} \times \sqrt{\frac{100}{32.2 \times 7.5} \times \frac{62.6}{62.6 - 29}} = 0.41\ ft^2\ (\sim 59\ sq\ in)$$

With mitigation controls and this permanent opening is provided, rooms 101/102 would be compliant. Smaller openings would be required for rooms 103/104 and rooms 107/108.

Alternatively, mechanical ventilation could be used for refrigerant safety mitigation (for transfer air, not for "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:

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

Q_{req}: From Table 7-4

C_{LFL}: From Table 7-5

Q_{min}: Minimum transfer air rate, CFM

Mechanical ventilation for release mitigation without air circulation

- For rooms 101/102, the EDVC = 7.5 lb (no air circulation)

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

$$= 529\ cfm$$

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	-

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.

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.

Questions?