Addendum a to
ASHRAE Guideline 41-2023

Public Review Draft

Proposed Addendum a to Guideline 41-2023, Design, Installation and Commissioning of Variable Refrigerant Flow (VRF) Systems

First Public Review (January 2025)
(Draft shows Proposed Changes to Current Guideline)

This draft has been recommended for public review by the responsible project committee. To submit a comment on this proposed standard, go to the ASHRAE website at www.ashrae.org/standards-research--technology/public-review-drafts and access the online comment database. The draft is subject to modification until it is approved for publication by the Board of Directors and ANSI. Until this time, the current edition of the standard (as modified by any published addenda on the ASHRAE website) remains in effect. The current edition of any standard may be purchased from the ASHRAE Online Store at www.ashrae.org/bookstore or by calling 404-636-8400 or 1-800-727-4723 (for orders in the U.S. or Canada).

This standard is under continuous maintenance. To propose a change to the current standard, use the change submittal form available on the ASHRAE website, www.ashrae.org.

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Insert foreword prior to publication

Note: In this addendum, changes to the current guideline are indicated in the text by underlining (for additions) and strikethrough (for deletions) unless the instructions specifically mention some other means of indicating the changes. Only these changes are open for review and comment at this time. Additional material is provided for context only and is not open for comment except as it relates to the proposed substantive changes.

3. DEFINITIONS AND SYMBOLS

3.1 Definitions

connected spaces: ~~with reference to ASHRAE Standard 15[2], the rooms or areas that are adjacent to each other with a common connected via permanent opening between them~~ two or more spaces connected by natural ventilation, a ducted air distribution system, or mechanical ventilation as defined by Standard 15.

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

~~***fault tree analysis***: a type of problem-solving technique used to determine the root causes of any failure of safety observance, accident, or undesirable loss event.~~

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

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

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

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

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

High-probability: as defined by ASHRAE Standard 15.

~~***inherently leak-tight system:*** in the absence of a manufacturer's more stringent guidelines, where the system is demonstrated and documented to hold a positive pressure of 600 psi (4137 kPa) or greater for 24 hours and a negative pressure to 500 µm (0.026 kPa abs) or less for an additional 24 hours. During the demonstration, the positive pressure does not fluctuate more than 40 psi (274.5 kPa). If the negative pressure fluctuates more than 1500 µm (0.0065 kPa abs), triple nitrogen purge and repeat the test.~~

~~***means of egress:*** **a continuous and unobstructed way of exit travel from any point in a building or structure to a public way that consists of three separate and distinct parts: the way of exit access, the exit, and the way of exit discharge.**~~

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

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

3.2 Abbreviations and Acronyms

EDVC	effective dispersal volume charge
LFL	lower flammability limit

5.1 Occupancy Classification. VRF systems can effectively serve the needs of the following occupancy classification types, as they offer zone-based distribution control, provide variable capacity, can be applied in low-sound applications, facilitate simultaneous heating and cooling, and are able to operate at low ambient conditions.

a. Institutional occupancies are premises, or those portions of premises, from which, because they are disabled, debilitated, or confined, occupants cannot readily leave without the assistance of others. Institutional occupancies include, among others, hospitals, nursing homes, asylums, and spaces containing locked cells. For these types of occupancies, the ~~refrigerant concentration limit (RCL) is~~ ASHRAE Standard 15 *Effective Dispersal Volume Charges (EDVC)* are reduced by 50%, causing the designer to look more carefully at the requirements of ASHRAE Standard 15[2].

b. Public assembly occupancies are premises, or those portions of premises, where large numbers of people congregate and from which occupants cannot quickly vacate the space. Public assembly occupancies include, among others, auditoriums, ballrooms, classrooms, passenger depots, restaurants, and theaters. ~~VRF systems are well suited for zoning application; however, for these larger spaces, that may not be required other systems may be more appropriate~~. ~~The large area is also generally less restrictive for refrigerant concentration issues.~~

c. Residential occupancies are premises, or those portions of premises, that provide the occupants with complete independent living facilities, including permanent provisions for living, sleeping, eating, cooking, and sanitation. Residential occupancies include, among others, dormitories, hotels, multiunit apartments, and private residences. For residential occupancies, designers should check sleeping areas or smaller rooms for ASHRAE Standard 15 compliance ~~RCL evaluations~~.

d. Commercial occupancies are premises, or those portions of premises, where people ~~transact~~ conduct business, receive personal service, or purchase food and other goods. Commercial occupancies include, among others, office and professional buildings, markets (but not large mercantile occupancies), and work or storage areas that do not qualify as industrial occupancies. Generally, these are great applications for VRF systems.

e. Large mercantile occupancies are premises, or those portions of premises, where more than 100 people congregate on levels above or below street level to purchase personal merchandise. Designers should review ventilation requirements for below-street-level shops for sufficient air exchange and ASHRAE Standard 15 compliance ~~evaluation of RCL~~.

f. Industrial occupancies are premises, or those portions of premises, that are not open to the public; where access by authorized persons is controlled; and that are used to manufacture, process, or store goods such as chemicals, food, ice, meat, or petroleum. Generally, these are not the best applications for VRF systems. ~~The designer should review the plans for smaller or air-tight rooms for RCL evaluations.~~

g. Mixed occupancy occurs when two or more occupancy types are located within the same building. When each occupancy type is isolated from the rest of the building by tight walls, floors, and ceilings and by self-closing doors, the requirements for each occupancy type apply to its portion of the building. When the various occupancy types are not isolated, the occupancy type having the most stringent requirements governs. Generally, these are great applications for VRF systems. The designer should review the plans for <u>ASHRAE Standard 15 compliance</u> ~~smaller or air-tight rooms for RCL evaluations~~.

5.5 Life-Cycle Cost Analysis (LCCA). LCCA is a tool to determine the most cost-effective option among different competing alternatives to purchase, own, operate, maintain, and dispose of an object or process, when each is equally appropriate to be implemented on technical grounds. There are many aspects in con- ducting an LCCA, depending on the extent of the project. For VRF systems, the following items provide helpful factors to consider for these important and impactful aspects:

a. **Installed capital costs.** For a VRF system, costs include factory-supplied ODUs, indoor units (IDUs), controls, piping kits, and field-supplied standard parts such as refrigerant, copper piping, cables, and ducts, if needed.
   1. **Equipment costs.** Compared to a conventional system, a VRF system can be acquired from one supplier. For an air-source VRF system, the main operating components include compressors, fan motors, and electric expansion valves. Additional third-party pumps and regulating or control valves are typically not required. In many climates, air-source VRF systems can provide the complete building heating load with no need for a supplemental heating system.
   2. **Controls costs.** The primary control components of a VRF system are factory installed or packaged. This reduces the costs of installation, commissioning, and integration of different system components.

b. **Life-cycle operating costs.** Life-cycle operating costs depends on three factors:
   1. **Annual operating costs.** These costs are determined by many factors, including building load profile, occupancy profile, ventilation air requirements, heat recovery opportunities, energy costs (electricity for most VRF systems), etc. The designer should use the anticipated electric rate structure, including demand, ratchet, or other demand capacities.
   2. **Routine maintenance costs.** A VRF system requires proactive maintenance and routine inspections on both IDUs and ODUs. Maintenance costs are relatively low, as this can be conducted by in-house staff with training provided by manufacturers. Maintenance personnel should receive manufacturer training to be qualified to operate and maintain the equipment to include the VRF system controls, which may increase the cost of the maintenance. The following additional items should be considered:
      i. The maintenance cost of VRF systems may vary widely, depending on the number of ODUs and IDUs and their location and accessibility. As described in the 2019 *ASHRAE Handbook—HVAC Applications* [14], Chapter 38, "Owning and Operating Costs," a greater number of similar pieces of equipment installed may be more expensive to maintain than larger but fewer units.
      ii. The ability to maintain equipment in a repeatable and cost-effective manner may be significantly affected by the equipment's location and accessibility. Equipment maintenance requiring erection of ladders and scaffolding, hydraulic lifts, or moving of furniture below ceiling access panels increases maintenance costs while likely reducing the quantity and quality of maintenance performed. Equipment location may also dictate an unusual working condition that requires more service personnel than normal or after-hours work, because the equipment is located above occupied spaces.
      iii. VRF refrigeration piping leak detection, piping repairs, and ceiling repairs may increase repair costs and involve after-hours work to find the leaks and repair the piping and ceiling. Portions of the building may require shutdown or relocation due to the repair work. Best practices to reduce this risk include strategically locating refrigerant isolated valves with test ports and validating that the installing contractor has installed ~~an inherently leak-tight system.~~ <u>a system meeting the contractor and engineer declaration as defined in ASHRAE Standard 15.</u>
   3. **System replacement costs.** The average life expectancy range for most air-source VRF systems is 15 to 20 years, and the average range for water-source VRF systems is 20 to 25 years. The actual equipment life expectancy is affected by routine maintenance, operating hours, operating environment, and other factors. Include refrigeration piping demolition and replacement and

ceiling/wall demolition and repair costs in the system replacement costs. VRF equipment and piping located above the ceiling in the tenant space may require space shutdown costs and tenant relocation costs that must be included in the system replacement costs.

c. **Opportunity costs.** Designing VRF systems may also provide opportunity cost savings. Fewer space requirements reduce the needs and costs of building high floors. Equipment installed on the roof saves space for mechanical rooms.

5.6 Refrigerant Use Restrictions. VRF systems are classified as direct systems by ASHRAE Standard 15 [2], ~~meaning that the conditioned air passes directly over or through system components that contain refrigerant.~~ This means that in the event of a leak, there is a high probability that occupants will be exposed to the refrigerant.

5.7 Refrigerant Leak ~~Fault Tree~~ Risk Analysis. A ~~fault tree~~ risk analysis of the installed HVAC systems and component placement should be prepared in order to minimize the potential of refrigerant leaks into the conditioned space.

The following items serve as a starting point for ~~fault tree~~ risk analysis:

a. System components in conditioned space.
b. Refrigerant piping in conditioned space and whether the piping complies with ASHRAE Standard 15 instructions for:
   1. acceptable floor and wall penetrations,
   2. acceptable shaft ventilation requirements,
   3. compliance with prohibited pipe locations,
   4. piping system strength test and leakage test requirements,
   5. whether or not the pipe and associated connection qualify as exempted spaces for *EDVC* calculations,
   6. determining if a Contractor or Engineer Declaration is required.
c. ~~A comparison of all occupied spaces and/or zones, with the RCL of the refrigerant in use.~~ An analysis of all spaces to determine the *Effective Dispersal Volume* in order to calculate the *Effective Dispersal volume Charge (EDVC).*
d. ~~Connecting spaces, list the dimensions of~~ Identify the opening(s) between the spaces and the ~~air movement~~ connecting ductwork or mechanical ventilation that may be used ~~achieve compliance with the~~ ~~RCL~~ to calculate connected spaces as defined per ASHRAE Standard 15.
e. Identify~~worst-case refrigerant leak scenario~~ the largest independent charge per refrigerant circuit ~~or each system~~ to determine the *EDVC* for Standard 15 calculations.

6.7 Refrigerant Management. When assessing the management of refrigerants for VRF system design and layout, the following should be considered.

6.7.1 An important aspect of the design phase is to ensure that the VRF system layout complies with ~~the~~ ASHRAE Standard 15 [2] ~~sections that apply to VRF systems~~. The main purpose is to understand the amount of the refrigerant charge in relationship to the spaces, and the smallest occupied space ~~in particular,~~ where the refrigerant may leak. The concern would be if the concentration of the leaked refrigerant may exceed the *EDVC* ~~refrigerant concentration limit (RCL)~~. ~~Consider employing fault tree analysis to evaluate the refrigerant safety RCL criteria for the system layout.~~. If the resulting concentration of refrigerant in that space does not exceed the *EDVC*, the building occupants should not be exposed to a harmful level of refrigerant, provided that the refrigerant disperses equally throughout the space. This volume varies based on whether or not the occupancy is classified as institutional, and whether or not the fluid is an A1 or A2L refrigerant. It is not the purpose of this document to be a primer on ASHRAE Standard 15, and the user is encouraged to review ASHRAE Standard 15 thoroughly.

6.7.2 Identification of the Refrigerant Leak Risks ~~Fault Tree Analysis.~~ ~~A fault tree~~ Analyze the installed HVAC systems and component placement ~~is intended to minimize~~ and the impact of the potential of refrigerant leaks into the conditioned space. The following items serve as a starting point for ~~fault tree~~ leak risk analysis.

6.7.2.1 System components connections. Look at the types of IDUs that are being used and where the field joints are. Field joints are the most likely cause of a refrigerant leak. For indoor units directly in an occupied space, the field connections should be thoroughly inspected to ensure they are leak-free connections. Caution should be taken to review all applicable codes. An example of a more stringent municipal code is one that prohibits flare fittings.

6.7.2.2 Refrigerant piping. The standard provides a provision that if the field installed refrigerant lines are strength and vacuum tested per the procedures described in the standard, that the piping shall be treated as continuous. This would exempt the piping that is merely transiting a space from EDVC calculations. There are exceptions to this rule, such as pipe shaft. As pipe shafts tend to be tightly sealed to prevent fire migration, there is risk of leaked refrigerant being contained in the bottom of the shaft and creating a flammable condition. To prevent this, the standard details several mitigation paths, including ventilation and refrigerant detector activated circulation fans. In addition to any strength and vacuum testing Any joints should be readily available for inspection until the system is commissioned. Caution should be taken to review all applicable codes. An example of a more stringent municipal code includes code that prohibits flare fittings.

6.7.2.3 Contractor or Engineer Declaration: whenever a system contains 55 lb (25 kg) or more of refrigerant, ASHRAE Standard 15 requires certifying the field erected piping has passed the prescribed strength and vacuum. This is referred to as the Contractor or Engineer Declaration. This information is then entered into the public record. Regardless of the charge size it is recommended to perform this test as it will help the contractor to identify potential installation errors that would allow the system to leak refrigerant. Further, all piping that is certified is considered continuous and exempt from *EDVC* calculations. This declaration provides evidence that the contractor or engineer performed their due diligence.

6.7.2.4 Smallest occupied space and/or zone. To show compliance with the ASHRAE Standard 15 calculation for the refrigerant in use, it is recommended to identify the smallest occupied space for each VRF system in the project and evaluate the potential for leaked refrigerant to enter that space. ASHRAE Standard 15 provides several paths to mitigate this space, including natural ventilation, ducted connected spaces, safety shut off valves, and mechanical ventilation.

6.7.2.5 Natural ventilation Spaces that are connected by two or more natural ventilation openings may be treated as one space provided the opening meets the requirements as specified in ASHRAE Standard 15. Additionally, the standard prescribes limitations on the maximum height and placement of these openings. Finally, the opening must allow the refrigerant to also disperse into the supply and return of the air distribution system. When properly applied, the *EDVC* is large enough that the risk is reduced for the building occupant. When a natural ventilation opening is too small by itself to allow compliance with the *EDVC*, it still may be useful as part of a multistep mitigation using other strategies.

6.7.2.6 Ducted Connected Space: When two or more spaces are connected by an air distribution system as detailed in ASHRAE Standard 15, refrigerant released can disperse into all the connected spaces, as well as any transfer ductwork that is part of the ventilation system. These spaces are considered one large, connected space. When using ductwork for connected spaces it is critical that the refrigerant can be introduced into the air stream. For example, a dedicated outdoor air system (DOAS) would be allowed to use the ductwork to calculate connected spaces, as any refrigerant that leaked in the DOAS would be distributed to the connected spaces. However, a VRF indoor unit served by the DOAS system would not be allowed to use the DOAS ductwork to calculate the connected space unless it could be reasonably shown that the DOAS distributed the leaked refrigerant from the VRF system to other spaces. It should also be noted that it is common for ductwork to have fire and smoke dampers. These are specifically excluded by the standard as an isolation barrier within the ductwork as they only close in the event of an emergency. Lastly, VAV dampers are also not considered a barrier so long as they do not close to less than 10% of their air volume.

6.7.2.7 Mechanical Ventilation Mechanical ventilation is different from ventilation used for indoor air quality. Mechanical ventilation is the process of providing uncontaminated makeup air as defined by ASHRAE Standard 15 and exhausting that air to a location that does not exceed the EDVC. The makeup air may be continuous or triggered by a refrigerant detector. This exhaust location need not be outdoors, and it may be in the occupied space provided the air is not recirculated back for make-up. This process allows the designer to increase the EDVC of a space that would otherwise not comply and does not contain a circulating fan. This approach may be useful for a mechanical space containing water source VRF.

6.7.2.8 Release Mitigation Controls: Release Mitigation controls, also known as safety shut off valves, may be an important strategy to mitigate refrigerant releases in small spaces. In the event of a leak, the valves are commanded shut by a refrigerant detection system. This isolates the remaining refrigerant circuit from the leak and limits the *EDVC*. Standard 15 allows the designer great freedom in the location of the safety shut off valves but does require that the valves be listed for use with the system being installed. The standard also states that the detection system must meet the requirements as prescribed by the standard and must detect and respond in a defined time period. These valves are a newer technology and are not available for all systems. They are expected to be more common for systems containing A2L refrigerants.

6.7.2.9 Refrigerant Detection System: A refrigerant detection system in itself has no value for refrigerant safety. However, if the system is integrated and listed as prescribed in ASHRAE Standard 15 and initiates a set of mitigation measures also as prescribed by ASHRAE Standard 15, then it becomes an essential risk reduction component for any VRF system. These refrigerant detection systems are most likely found as a component for systems that contain A2L refrigerants. The standard requires that they be located in the unit. The standard requires the detection system to detect the specified refrigerant within 30 seconds of a leak exceeding 25 % of the *lower flammable limit (LFL)* for a flammable refrigerant. The detection system must then initiate the required mitigations within 15 seconds of detection.

~~6.7.3 The following items serve as a starting point for fault tree analysis:~~

~~a) **System components in conditioned space.** Look at the types of IDUs that are being used and where the field joints are. Field joints are the most likely cause of a refrigerant leak. For wall-mounted units and ceiling-suspended units, the field joints are likely in the occupied space, and extra care should be taken to ensure they are leak-free connections. Caution should be taken to review all applicable codes. An exam- ple of a more stringent interpretation is a municipal code that prohibits flare fittings.~~

~~b) **Refrigerant piping in conditioned space.** The best plan to consider is to route the refrigerant piping so that it is not physically in any occupied space. Additionally, any joints should be readily available for inspection until the system is commissioned. Caution should be taken to review all applicable codes. An example of a more stringent interpretation is a municipal code that requires that any refrigerant piping located in a public corridor be behind a fire-rated barrier. Another example is a municipal code that pro- hibits flare fittings.~~

~~c) **Smallest occupied space and/or zone.** Show compliance with the RCL of the refrigerant in use. It is recommended to identify the smallest occupied space for each VRF system in the project, evaluate the potential for leaked refrigerant to enter that space, then come up with a plan to mitigate.~~

~~d) **Connecting spaces.** There is not specific guidance on the dimensions of the opening needed. Computa- tional fluid dynamic analysis has shown that as little as 25 cfm (11.8 L/s) exhaust will move air under a 1/4 in. (0.635 cm) undercut door. For these spaces,~~

   ~~a. list the dimensions of the opening(s) between the spaces, and~~

   ~~b. define the devices that create air movement which will achieve compliance with the RCL.~~

~~e) Identify the worst-case refrigerant leak scenario for each system/zone. The first point of consideration is where leaks are likely to occur.~~

~~f) Demonstrate and document an inherently leak-tight system.~~

~~6.7.4 **Ventilated Spaces.** Aspects of ventilated spaces should be considered for refrigerant management, including~~

~~the following~~:

a. ~~Know the RCL~~EDVC ~~of the refrigerant in the system and how it applies to each occupied space.~~

b. ~~Evaluate connected spaces beyond each zone and contribution of connected ductwork.~~

1. ~~Supply and return duct: Per Standard 15, Section 7.3.2.3, the supply and return ductwork volume is counted with the space.~~
2. ~~Plenums: Per Standard 15, Section 7.3.2.2, the volume of the plenum area above ceiling is counted if it is part of the supply or return system.~~
3. ~~Closures: Per Standard 15, Section 7.3.2.1, Exceptions 1 and 2, any dampers with minimum position of 10% or emergency dampers are not considered closures.~~
4. ~~Transfer openings: Determine if there is a transfer duct, transfer grill, undercut door, or other permanent opening to an adjoining space~~ ~~meets the requirements as specified in ASHRAE Standard 15~~. ~~ISO 5149-3~~ [27].

c. ~~Know how much refrigerant is available in the system if a leak were to occur~~ ~~per individual circuit. Then compare this value versus the EDVC. It should be noted that~~

1. ~~ISO 5149-3~~[27]~~, Section 6.3.3, includes guidelines for mechanical ventilation to maintain RCL, and maximum leak rate of 22 lb/h (9.9 kg/h).~~

~~6.7.5~~ ~~Appendix A of this document discusses the concept of *refrigerant management* and is based on ISO 5149-3~~ [27] ~~concepts. Twelve conditions are described in Appendix A that should be in place for a VRF system to be considered acceptable under the concept of refrigerant management~~.

6.7.3 The Commissioning (Cx) Process should include the design details and ensure that installation techniques used have been consistent throughout the project. The importance of redline/as-built accuracy cannot be overstated, as all connections have the potential to be a source of leaks. Review of the documents should verify that these points of failure (leaks) have sufficient clearances for future testing and repairs and are clearly marked on the redline/as-built drawings. If field installed, detectors shall be inspected for proper installation and connection.

6.9 Piping Design and Layout

6.9.1 Special Considerations for VRF Systems. The following piping issues should be considered when designing VRF systems:

d. Piping serviceability

1. When installing VRF refrigerant piping and/or equipment above hard ceilings, a minimum access should be provided to enable maintenance of controls, electrical, and piping connections. Access may be provided via ceiling access panels, access to interstitial spaces, and/or other means. Locate refrigerant piping joints in accessible locations to allow for maintenance, leak detection, and repair.
2. The design professional should account for future replacement of the equipment. This may require access panels, access to interstitial spaces, and or other considerations.
3. VRF systems are generally low-maintenance. (See Section 5.5[b][2]) However, access is still required for basic services such as filter replacement and coil cleaning. Consult the manufacturer for guidance on basic clearances for routine maintenance. In addition to the standard clearances, consult local codes to ensure all required electrical clearances are maintained.
4. VRF refrigeration piping leak detection, piping repairs, and ceiling repairs may increase repair costs and involve after-hours work to find the leaks and repair the piping and ceiling. Portions of the building may require shutdown or relocation due to the repair work.

Demonstrating and documenting the Contractor or Engineer Declaration as defined by ASHRAE Standard 15 reduces this risk.

7. INSTALLATION PHASE

This section provides a general overview of considerations for variable refrigerant flow (VRF) system installation. Refer to the system manufacturer's guidelines for detailed installation instructions, and review all applicable codes for additional installation requirements.

7.1 Submittal Review. Perform reviews of coordination drawings, shop drawings, and equipment/system submittal data sheets to check the systems for consistency with construction documents. Factors to review include the following:

a. System capacity for both heating and cooling operation at design conditions
b. Sequence of operations:
1. Cooling operations
2. Heating operation
3. Defrost operation
4. Mode changeover
5. Fault detection
6. Operational integration with base building systems, controls, and other equipment
c. Review applicable refrigerant <u>safety requirements</u> ~~concentration limits (RCLs~~)
d. Consistency with on-site piping system materials matches the data sheets
e. Consistency with the dimensions, weight, and service clearances of the construction documents
f. Consistency with the electrical and communication requirements
g. Coordination with other construction trades

7.4.2 General Considerations. There are many considerations to take into account when determining what piping and components are acceptable and how to properly apply them. Some general considerations include, but are not limited to, the following:

a. **Compatibility.** All piping and piping system components should be designed for the appropriate pressure, refrigerant, and oil used in the system.
b. **Cleanliness.** It is important that all components used, including the piping, are clean and free of debris or corrosion. Debris can clog critical system components such as electronic expansion valves (EEVs), which are integral to maintaining proper control of the system. Corrosion can come off as debris, but it can also degrade the integrity of the piping, component, or joints. Other contaminants should also be avoided, as they may have an unwanted effect on the system, causing performance degradation or failure.
c. **Support/hanging.** Proper support of refrigerant piping, branches, and all other piping system components is critical to prevent stress on joints, piping, or other components that can cause failure.
d. **Expansion loops.** Regardless of the piping material or components chosen, it is critical that expansion loops are properly designed and applied to the piping system to avoid tensile or compressive stress on piping, piping system components, and their joints that can cause failure.
e. **Insulation.** All pipes and piping system components should be properly insulated to prevent condensation that could promote corrosion and degradation of the pipe or piping system component and related failure. Insulation is also required to ensure proper system operation by maintaining refrigerant quality in the system to deliver proper heating or cooling and prevent condensation. Review applicable codes for insulation requirements for personnel protection. All field-installed insulation should comply with applicable codes.
f. **Pressure drop.** Pressure drop is considered as equivalent units length of standard copper refrigerant pipe. Any refrigerant system component or joint used, including valves or elbows, should be considered in equivalent units length and added to the actual refrigerant piping length to

be considered against the piping limitations defined by the manufacturer for the equipment being installed.

g. **Pressure and vacuum testing.** Proper pressure and vacuum testing is required prior to charging the system with refrigerant and prior to start up. In the absence of more stringent guidelines from the equipment manufacturer, the testing should meet the requirements for ~~an inherently leak-tight system~~ the Contractors and Engineers Declaration as defined in ASHRAE Standard 15. A successful pressure test can be one indication that the system is free of leaks. A proper pressure test should be per- formed to ensure the pressure is held. A vacuum test serves two purposes. First, a proper vacuum test can be a second indication that the system is free of leaks. Second, a proper vacuum test evaporates and removes moisture from the piping system. A proper vacuum test should be performed, ensuring the vacuum is held. If the vacuum is not held, it could be that there is a leak or that there is still moisture in the system.

h. **Code and best practice.** Always follow applicable national, state, or local codes and industry best prac- tice for refrigerant piping installation in addition to all requirements set forth by the manufacturer.

i. **Warranty.** Unless specified as not allowed, piping type or other piping system components may not void the manufacturer's limited warranty by themselves. Equipment problems that stem from improper compatibility, cleanliness, support, expansion loops, insulation, pressure-drop consideration, leaks, moisture, installation, application, etc., are not under the manufacturer's control and therefore may not be covered by the limited warranty. Failure to follow requirements may cause significant performance degradation for any and all manufacturers. A manufacturer's limited warranty may be voided in whole or in part should any field-supplied accessory fail in any way that causes product failure.

7.4.4 Installation Methodology

a. **Location of refrigerant piping.** The manufacturer's design tools should be used for designing refrigerant piping layout. During refrigerant pipe installation, the installer is encouraged to follow the designed layout. Ensure that all piping is clearly marked and installed in the appropriate location.

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

1. Exposed within a fire-resistance-rated exit access corridor
2. Exposed within an interior exit stairway
3. Interior exit ramp
4. Exit passageway
5. Elevator, dumbwaiter, or other shaft containing a moving object

Informative Note: *Exposed* means that the piping can be seen in the finished corridor without removal of building components, such as ceiling tiles.

c. Depending on the size of the system, the refrigerant pipe network may be exhaustive; the installer is encouraged to prepare detailed refrigerant piping layout diagrams after installation that clearly indicate the following:

1. Main refrigerant lines and all lines connecting to IDUs
2. Isolation valves
3. Location of refrigerant line connections
4. Location of elbows
5. Exposed refrigerant lines in conditioned space

6. Other pertinent information

Informative Notes: For egress areas:
• ~~The refrigerant piping should in the conditioned space~~.
• The ~~RCL~~ ASHRAE Standard 15 calculations should be verified to ensure that the limits are not exceeded.
• ~~Some municipality codes require that the refrigerant piping be enclosed with or located behind gastight, fire-resistive material.~~

d.~~c.~~ A detailed piping layout serves to assist the maintenance personnel and service contractors in locating and identifying piping to determine the location of a leak, should one occur. This helps to reduce down- time and damage to equipment or the environment. As a general practice, installers are encouraged to adequately protect piping from any external damage that may occur during installation and regular use of equipment.

e.~~d.~~ Most VRF systems allow for flexibility of installation in phases, e.g., tenant build. Where applicable, the installer should size the equipment per the manufacturer's guidelines prior to completion of the piping network. This ensures that pipes of appropriate diameter and with required support are installed to reduce pipe stress during the final assembly phases.

f.~~e~~. Protect the refrigerant piping.

1. Exposed piping must comply with ASHRAE Standard 15 [2], Section 8.10.
   i. Section 8.10.1 allows exposed refrigerant piping that is at least 7.25 ft (2.22 m) above the floor or against the ceiling.
   ii. Section 8.10.3, Exception 5(a), allows enclosing piping with a gas-tight, fire-resistive material to isolate from such areas.
2. ASHRAE Standard 15, Section 8.10.2, disallows exposed refrigerant piping that is installed in an enclosed public stairway, stair landing, or a *fire-resistance rated access corridor* ~~means of egress~~; inside any elevator, dumbwaiter, or other shaft containing moving objects; or inside a shaft open to living quarters ~~or means of egress~~.

   (***Informative Note***: ASHRAE Standard 15 has significantly revised this requirement from previous editions of the standard. Please reference the latest edition of the standard and applicable addenda. ~~The 2012 Seattle Mechanical Code allows an exception for piping installed above the ceiling in an exit access corridor if the piping has no joints in that corridor~~.)

3. Precautions for shafts and penetrations:
   i. Prevent stress on piping joints by properly supporting piping in riser shafts between floors and installing expansion loops.
   ii. Prevent expansion/contraction from causing wear on the insulation or pipe by using protective sleeves to protect piping from abrasions where it passes through walls, obstructions, or other materials.
   iii. Run proper pressure and vacuum tests after installation to verify no damage occurred during installation.
4. Follow the piping.
   i. Know what piping may affect the space if a leak should occur and how much refrigerant its system contains.
5. Protect the piping (Figure 13).

i. Locate piping in places where it is away from risk of accidental damage.
ii. A robust piping network is a supported network. Ensure pipes are supported appropriately. The installer should ensure that pipe suspensions are installed per applicable codes.
iii. Supports should be in direct contact with pipe insulation; however, they should not compress the insulation excessively. Under no circumstances should the pipe supporting systems be attached directly to the pipe.
iv. Vertical refrigerant pipes should be supported by anchoring them to rigid structures. Supports for vertical pipes should allow for thermal expansion of pipes due to high-temperature refrigerant flowing through them. As a general practice, installers are encouraged to install piping with a mix of fixed and flexible support to allow for expansion in both directions.
v. Figure 14 provides general guidelines for distance between supports for vertical and horizontal refrigerant piping.

Informative Note: Unsupported piping will cause pipe failure and lead to refrigerant leaks.

g.~~f.~~ Expansion loop (Figure 15):

1. Where possible, expansion loops should be designed and installed.
2. Refrigerant piping is exposed to varying temperature ranges, depending on the modes of operation; this leads to thermal expansion and contraction of copper pipes.
3. If thermal expansion loops have not been considered for design of refrigerant pipe network, the chart in *Copper Tube Handbook* [37] can be referenced for determining expansion of copper at various temperatures to design the expansion loops.
4. Pay close attention to providing expansion loops in situations where copper tubing is installed with fixed supports.
1. For detailed expansion loop design, types of expansion loops, etc., refer to the appropriate section of the *Copper Tube Handbook*.

h.~~g.~~ Underground piping:

~~1. Refrigerant lines should be installed below the frost line. The depth required past the frost line depends on the amount of foot or vehicle traffic that may pass over the refrigerant line path.~~

1. Buried piping should be avoided. The challenge with buried piping is that it is extremely cost prohibitive to excavate and inspect. This makes it very challenging to detect defects in the installations.
2. Possible concerns with underground piping include, but are not limited to:
   a. corrosion due to ground water migration,
   b. damage due to expansion and contraction,
   c. damage due to nesting and burrowing animals and their wastes
   d. suction lines ground coupling resulting in condensed liquid refrigerant flooding back to the compressor.
   e. long runs of piping that are extremely susceptible to damage from expansion and contraction.
3. When underground piping cannot be avoided, contact the manufacturer to determine if there is any impact on the compressor warranty, as some manufacturers will regard underground piping as an installation error not covered by the manufacturer's defect warranty.
4. ~~1~~. Refrigerant lines should be installed below the frost line. The depth required past the frost line

depends on the amount of foot or vehicle traffic that may pass over the refrigerant line path.

5. ~~2.~~ Use 45-degree elbows to simplify covering the refrigerant lines with casing. For refrigerant piping with outside diameters of up to 3/4 in. (19 mm), soft tubing can be used, and large sweeping curves can be bent by hand.
6. ~~3.~~ Refrigerant piping should be pressure tested before being insulated and covered with casing.
7. Hard casing should be used in an attempt to waterproof the pipe against possible underground water migration.
8. It may be beneficial to install a safety set of lines and charge them with nitrogen. These lines will be useful if the initial lines fail.
9. Closed cell insulation should be used to mitigate the damage from surface and ground water infiltration.

1. NORMATIVE REFERENCES

~~23. ISO. 2014. ISO 5149-3, *Refrigerating systems and heat pumps—Safety and environmental requirements—Part 3: Installation site*. Geneva, Switzerland: International Organization for Standardization.~~