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# ASHRAE Standards 15 and 34 – Considerations for VRV/VRF Systems

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**Technical Article**
**May 2013**

# ASHRAE Standards 15 and 34 –
# Considerations for VRV/VRF Systems

## Executive Summary

The Variable Refrigerant Volume (*VRV*) technology was introduced by Daikin in the early 80's as an alternative method of cooling and heating in commercial buildings. Today over 25 million individual spaces are being served by this technology. *VRV* is a very energy efficient and flexible equivalent to a chiller system while it also offers superior comfort compared to traditional air handler terminal units.

The ASHRAE Standard 15 is significant to HVAC manufacturers, engineers and contractors because it specifies compliant design, construction, installation and operation of refrigeration systems. The standard was originally recognized in October 1930. Over time, the scope of the standard has been expanded but the features and technology of a *VRV* system have not been specifically addressed.

This document demonstrates that;

- *VRV* Systems can be properly selected and designed adhering to ASHRAE Safety Standard 15, and Standard 34.

- Since Standard 15 is an application based standard, not an equipment design guide, engineering judgment can be required when applying the standard.

- It is recommended to use the step-by-step approach, described in this document in order to ensure that the design of a system follows Standards 15 and 34.

Published by the Daikin Product Marketing Department

# Introduction

## *VRV* Technology

In the early 1980s, the Variable Refrigerant Volume (*VRV*) technology was introduced by Daikin as an alternative method of cooling and heating in commercial buildings. Although *VRV* has been commercially available globally for over 30 years, it remains a relatively new concept to the North American market.

*VRV* is an applied heating and cooling system that distributes refrigerant, rather than water, to multiple fan coil units serving the conditioned spaces. The natural attributes of a *VRV* system position it as a modular and scalable energy-saving equivalent to a chiller system while offering superior comfort when compared to traditional air handler terminal units. The compact, lightweight structure within the *VRV* modular concept ensures ease of installation in small or large buildings.

## ASHRAE Standard 15

The ASHRAE Standard 15-2010 provides safeguards for life, limb, health, property, and prescribes safety requirements.

The standard is recognized by equipment manufacturers, engineers, and contractors as the main guide for personal safety involving refrigeration systems. It strives to ensure a safe application of refrigerant systems by limiting the maximum charge so that a complete discharge due to a leak into a small, occupied, and enclosed room can never exceed the allowable limit.

As with most standards, ASHRAE Standard 15 is an application based standard, not an equipment design guide, so substantial engineering judgment can be required when designing a system. ASHRAE Standards are part of the "**National Voluntary Consensus Standard**". In order for a standard to become mandatory, it must first become model building code by an adoption process into the International Mechanical Code (IMC). Thereafter, the model code becomes mandatory when it is adopted at the state or local jurisdiction level. Since the conversion from ASHRAE Standard to state/local code can take time and parts of the original standard often changes, it is recommended to review the local code as well when designing a system.

> *"This standard specifies safe design, construction, installation, and operation of refrigeration systems."*
> *"This standard applies*
> *a. to the design, construction, test, installation, operation, and inspection of mechanical and absorption refrigeration systems, including heat pump systems used in stationary applications;…"*
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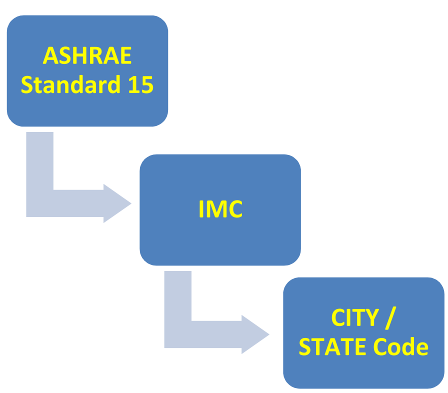
> 2010 ANSI/ASHRAE Standard 15



ASHRAE Standard 15 equivalent standards exist in Europe and Asia. Systems utilizing the Variable Refrigerant Volume technology are common in these regions and are applied successfully to meet these standards.

## ASHRAE Standards 15 and 34 applied on the *VRV* technology

The ASHRAE Standard 15 was written 1919. Initially, it was a Tentative Code and it was recognized as Standard B9 in October 1930.

Originally, the Standard was developed for safety following a catastrophic release of the content in a pressure vessel via a safety valve in a short time. Over time, the scope for the Standard has been expanded to cover most refrigerants and systems and 1978 it was issued by ASHRAE as Standard 15.

The current version of the Standard does not address the safety of any particular refrigerant. Instead, it refers to ASHRAE Standard 34-2010 which identifies safety classifications and Refrigerant Concentration Limit (RCL) for refrigerants.

> *"This standard provides an unambiguous system for numbering refrigerants and assigning composition-designating prefixes for refrigerants. Safety classifications based on toxicity and flammability data are included along with refrigerant concentration limits for the refrigerants."*
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Daikin *VRV* systems use refrigerant 410A with minimal potential safety risks compared to most other DX-type HVAC systems. The safety classification of R410A in Standard 34 is group 1 (meaning non-toxic and non-flammable), it has no ozone depletion potential and it meets the stringent mandates of both the Montreal Protocol and the U.S. Environmental Protection Agency. However, due to the ability to displace oxygen, **Addendum L to ASHRAE Standard 34-2010 has established the maximum RCL to 26 lbs/1000 $ft^3$ of room volume for occupied spaces.**
For Institutional Occupancies, the limit is reduced to 50% (13 lbs/1000 $ft^3$).

*"refrigerant concentration limit (RCL): the refrigerant concentration limit, in air, determined in accordance with this standard and intended to reduce the risks of acute toxicity, asphyxiation, and flammability hazards in normally occupied, enclosed spaces."*
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For smaller systems with less than 6.6 lbs of total refrigerant charge, the 26 lbs/1000 $ft^3$ limit described above does not apply, regardless of refrigerant safety classification, if the system is installed according to the listing and manufacturer's instructions.

*"Listed equipment containing not more than 6.6 lb(3 kg) of refrigerant, regardless of its refrigerant safety classification, is exempt from Section 7.2 provided the equipment is installed in accordance with the listing and with the manufacturer's installation instructions."*
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Since the indoor unit fan coils are in direct contact with the air being distributed, a *VRV* system is classified as a Direct System according to Standard 15.
By definition, a Direct System is also classified as a High Probability system, meaning that a leak of refrigerant can potentially enter into occupied space.

*"A high-probability system is any system in which the basic design, or the location of components, is such that a leakage of refrigerant from a failed connection, seal, or component will enter the occupied space…"*
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The information in this document is intended to provide guidance to specifying and designing a *VRV* system while applying ASHRAE safety Standard 15. However, since many of the attributes of a modern cooling/heating technology, such as *VRV*, are not specifically addressed in Standard 15, there might be variations in how the "authority having jurisdiction" (AHJ) interprets compliance requirements to Standard 15 between jurisdictions.
Therefore, it is good practice to review the local code and work with the local AHJ when designing a system.

*"The terms "authority having jurisdiction (AHJ)" and "jurisdictional authority" used herein refer to the organization or individual responsible for enforcing the requirements of this standard."*
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## Applying Standard 15 when designing a *VRV* system

If refrigerant system piping, components and units are located in occupied spaces, the spaces must be evaluated regarding safety for the occupants. Occupied space is not necessarily just one room or an area but can also be several rooms/areas that are "connected" by corridors, ductwork or other means.

> *"occupied space: that portion of the premises accessible to or occupied by people, excluding machinery rooms."*
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It is recommended to apply the Standard 15 requirements on the design of a *VRV* system in 4 basic steps as listed below. The checklist at the end of this document can be used to facilitate the steps.

**First Step**
**Preliminary layout of the system**

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**Second Step**
**Determine the amount of refrigerant**

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**Third Step**
**Verify that the *VRV* system layout complies with Standard 15 requirements**

↓

**Fourth Step**
**Actions if a room is too small**

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### First Step
**Preliminary layout of the system**

The first step in applying Standard 15 in the design process of the *VRV* system is to develop a preliminary layout of the complete system (piping, indoor unit fan coil units, and outdoor units) to meet the heating/cooling requirements in the rooms/zones of the project.
Even though the *VRV* technology allows very long piping distances, due to cost and refrigerant charge limitations in ASHRAE Standard 15, the equipment layout should strive to minimize the piping lengths where possible.

## Second Step

**Determine the amount of refrigerant**

The second step is to determine the total amount of refrigerant 410A for the system. This calculation can either be done manually according to guidelines in Daikin *VRV* Installation Manual or by using Daikin *VRV* Xpress selection software. In addition to quickly providing the refrigerant charge, the output from *VRV* Xpress also automatically generates piping and wiring diagrams. If piping or indoor unit fan coil locations need to be revised, the *VRV* Xpress will recalculate pipe sizes and refrigerant charge automatically.
If a room has more than one *VRV* system serving it thus more than one refrigerant circuit installed, it is recommended to check with the AHJ regarding how to determine the "Quantity of Refrigerant per Occupied Space". It is not necessarily the sum of the refrigerant charges in all of the circuits in the room. It might be allowed to use the quantity of refrigerant in the largest circuit in the calculations.

## Third Step

**Verify that the *VRV* system layout complies with Standard 15 requirements**

The third step is to verify that the initial layout of the *VRV* system complies with the Standard 15 requirements by:

- ***Determine the occupancy classification for the room(s)***
- ***Determine room volume(s)***
- ***Verify that no room is too small***
- ***Review refrigerant piping requirements***

The checklist at the end of this document can be used to facilitate the steps.

**Determine the occupancy classification for the room(s).**

The classifications are: Institutional occupancy, Public assembly occupancy, Residential occupancy, Commercial occupancy, Large mercantile occupancy, Industrial occupancy, and Mixed occupancy.

For Institutional occupancies (a premise where the occupants cannot readily leave without assistance of others), the maximum refrigerant concentration limit (RCL) is reduced by 50% compared to the other occupancy classifications.
For Industrial occupancies and Refrigerated rooms, several special conditions applies, see section 7.2.2 in Standard 15.

*"Institutional occupancy is a premise or that portion of a premise from which, because they are disabled, debilitated, or confined, occupants cannot readily leave without the assistance of others. Institutional occupancies include, among others, hospitals, nursing homes, asylums, and spaces containing locked cells."*
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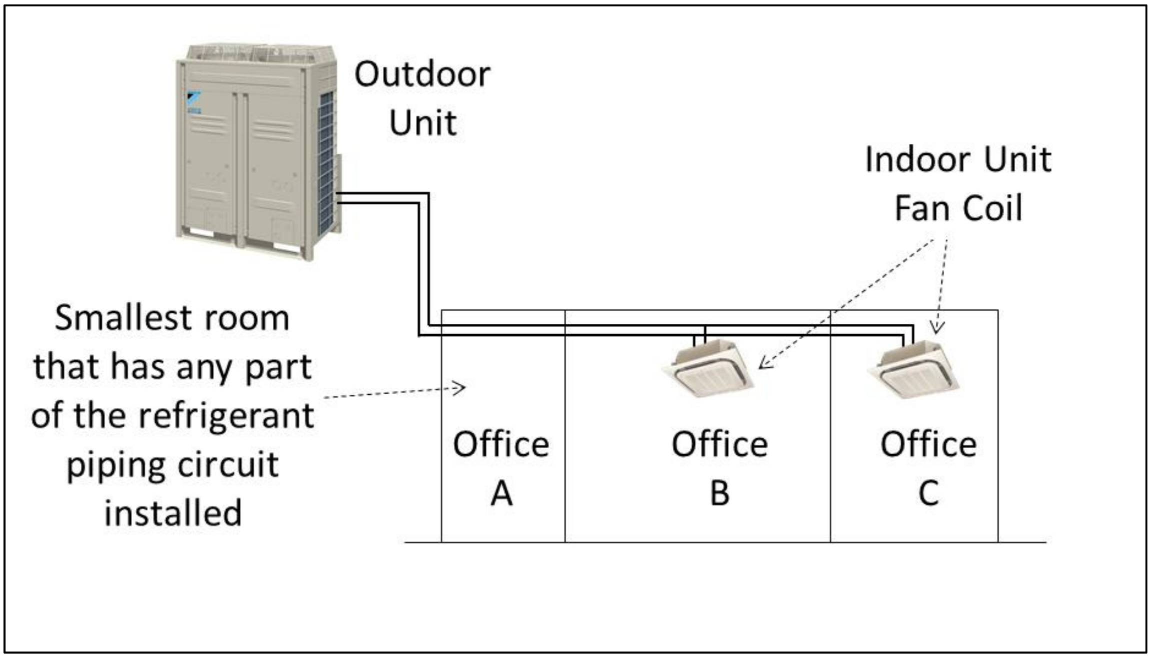
## Determine Room volume(s)

Calculate the room volume of the smallest occupied room(s).

In addition to the rooms where each indoor unit fan coil is located, all rooms that have any part of the refrigerant piping circuit installed should be examined, as shown in the following figure.




According to Standard 15, ***volume calculation shall be based on the volume of space to which the refrigerant disperses in case of a leak.*** This is an important section in Standard 15 and it should be considered if other parts of the Standard do not give clear enough directions when applying the Standard.

The plenum space above a suspended ceiling can be considered a part of the room if it is a part of the air supply or return system.

When calculating the room volume, it is permissible to include the air volume of the supply/return ducts connected to fan coil if the airflow cannot be shut-off (excludes fire and smoke dampers, and VAV units if the units cannot shut down to less than 10 % of design airflow, with the fan running).

*"Volume Calculations. The volume ... shall be based on the volume of space to which refrigerant disperses in the event of a refrigerant leak."*
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*"Plenums. The space above a suspended ceiling shall not be included in calculating the refrigerant quantity limit in the system unless such space is part of the air supply or return system."*
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*"Supply and Return Ducts. The volume of the supply and return ducts and plenums shall be included when calculating the refrigerant quantity limit in the system."*
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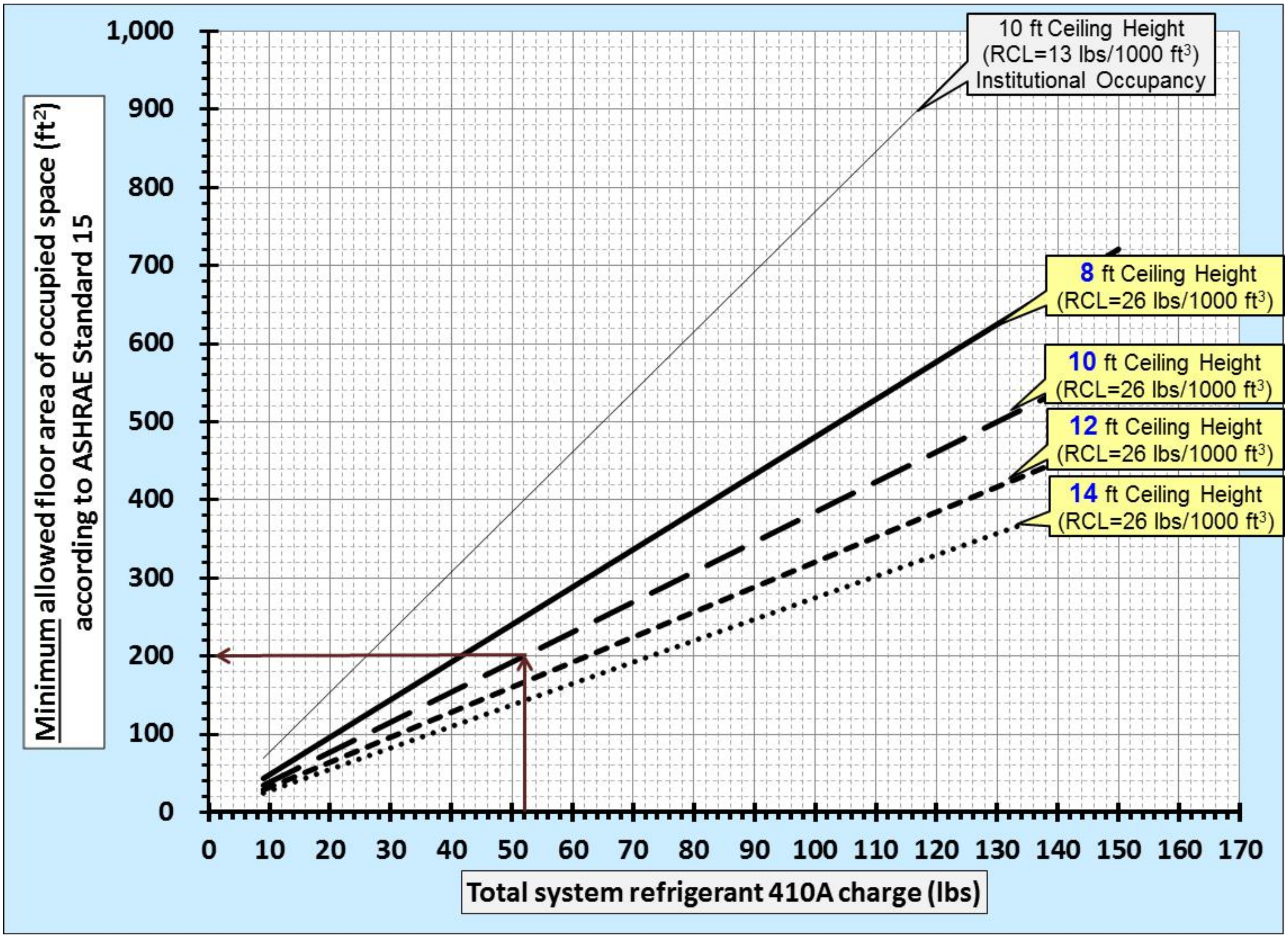
## Verify that no room is too small

Using the calculated total refrigerant charge, verify that there are no rooms that have a part of the refrigeration circuit installed, that has a smaller calculated room size than shown in the following Diagram.
If a room is verified to be too small according to the Diagram, review the section "***Fourth Step – Actions if a room is too small***" in this document.




*Example:*
*According to Standard 15, minimum allowed floor area is 200 ft² if the ceiling height is 10 ft for a non-institutional occupancy space that has part of a 52 lbs R410A charge piping circuit installed.*

*Formula used for the Diagram*

$$\text{Minimum Allowed Floor Area (ft}^2\text{)} = \frac{\text{Total System Refrigerant Charge (lbs)}}{\text{RCL (lbs/1000 ft}^3\text{) x Ceiling Height (ft)}} \text{ x } 1000$$

## Review refrigerant piping requirements

### Refrigerant piping location

According to Standard 15, Refrigerant Piping must not be less than 7.25ft (2.2m) above the floor unless the piping is located against the ceiling and is permitted by the AHJ.

Refrigerant piping cannot be placed in a shaft containing a moving object and must not be installed in an enclosed public means of egress.
The wording of the paragraph in Standard 15 says that piping cannot be installed in enclosed stairway/landing or means of egress. However, it also implies that the AHJ could approve installation of the piping above the ceiling as the statement is to protect the piping from being damaged or cause obstruction to an occupant trying to exit the building.

Standard 15 also states that field installed refrigerant pipe joints must remain exposed for visual inspection before they are covered or enclosed.

In addition, refrigerant piping must be properly supported and if it is installed in concrete floors the piping must be encased in pipe duct.

> *"Refrigerant piping crossing an open space that affords passageway in any building shall not be less than 7.25ft (2.2m) above the floor unless piping is located against the ceiling of such space and is permitted by the AHJ".*
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> *"Passages shall not be obstructed by refrigerant piping. Refrigerant piping shall not be placed in any elevator, dumbwaiter, or other shaft containing a moving object or in any shaft that has openings to living quarters or to means of egress. Refrigerant piping shall not be installed in an enclosed public stairway, stair landing, or means of egress."*
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> *"Refrigerant Pipe Joint Inspection. Refrigerant pipe joints erected on the premises shall be exposed to view for visual inspection prior to being covered or enclosed."*
> *"Refrigerant piping installed in concrete floors shall be encased in pipe duct. Refrigerant piping shall be properly isolated and supported to prevent damaging vibration, stress, or corrosion."*
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### Refrigerant monitoring

Standard 15 only mentions refrigerant monitoring and alarm functions in case of a leak for refrigerating machinery rooms. For occupied spaces, refrigerant monitoring should be discussed with the local AHJ.

**Roof and floor piping penetration**

A *VRV* system is classified as a direct system and it must always be designed according to the leakage concentration limits in ASHRAE Standard 34. Therefore, the penetration restriction in Section 8.10.3 in Standard 15 does not apply for *VRV* if the system is designed correctly and the RCL is within the stated limits.

Also, if the RCL is above the stated limits in a non-industrial occupancy application, the penetration restriction does not apply if:

- piping is enclosed by an approved duct/shaft with openings to the floors served by the system
  or
- piping is located on the exterior wall of a building when vented to the outdoors or to the space served by the system and not used as an air shaft, or similar space.

> *"Refrigerant piping shall not penetrate floors, ceiling, or roofs." "Exceptions…*
> *d. Penetrations of a direct system where refrigerant concentration does not exceed that listed in Table 1 or 2 of ASHRAE Standard 34 for the smallest occupied space through which the refrigerant piping passes."*
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## Fourth Step

### Actions if a room is too small

If the calculated room volume is too small in relation to the actual refrigerant charge in the system, there are generally three different ways to remedy this situation:

- **Increase the room volume used in calculations**
- **Relocate/remove piping or indoor unit fan coil**
- **Reduce the refrigerant charge by dividing the refrigerant circuit into multiple smaller systems**

The checklist at the end of this document can be used to facilitate the possible actions.

**<u>Increase the room volume used in calculations</u>**

**Permanent openings**

If a room is too small for the amount of refrigerant, it might be possible to increase the room volume used in the calculations by "connecting" it to other rooms by using louvers, transfer grilles, door undercuts, or similar.

A permanent opening made to increase the room volume allows any leak of refrigerant to disperse into the adjacent area(s). However, since Standard 15 does not address how to calculate a permanent opening, this should be determined by the Engineer of record and/or the AHJ.

The Japanese standard JRA GL-13:2012 could serve as a guideline regarding the opening. It defines a permanent opening as one that has an area of 0.15% or more of the total floor area of the smaller enclosed occupied space in which refrigerant-containing parts are located.

> *"Nonconnecting Spaces. Where a refrigerating system or a part thereof is located in one or more enclosed occupied spaces that do not connect through permanent openings or HVAC ducts, the volume of the smallest occupied space shall be used to determine the refrigerant quantity limit in the system..."*
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**Ventilation**

When occupied space is served by a mechanical ventilation system, the entire air distribution system must be analyzed to determine the worst-case distribution of leaked refrigerant.

According to the formal interpretation IC 15-2007, never consider increasing the allowable refrigerant limits due to dilution by supply and/or exhaust air ventilation.

> *"Ventilated Spaces. Where a refrigerating system or a part thereof is located within an air handler, in an air distribution duct system, or in an occupied space served by a mechanical ventilation system, the entire air distribution system shall be analyzed to determine the worst-case distribution of leaked refrigerant."*
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**Doors**

A regular door that cannot be closed between two rooms should satisfy the requirement of enabling connected spaces. Removing the door completely is the safest way to make sure that the rooms always are connected.

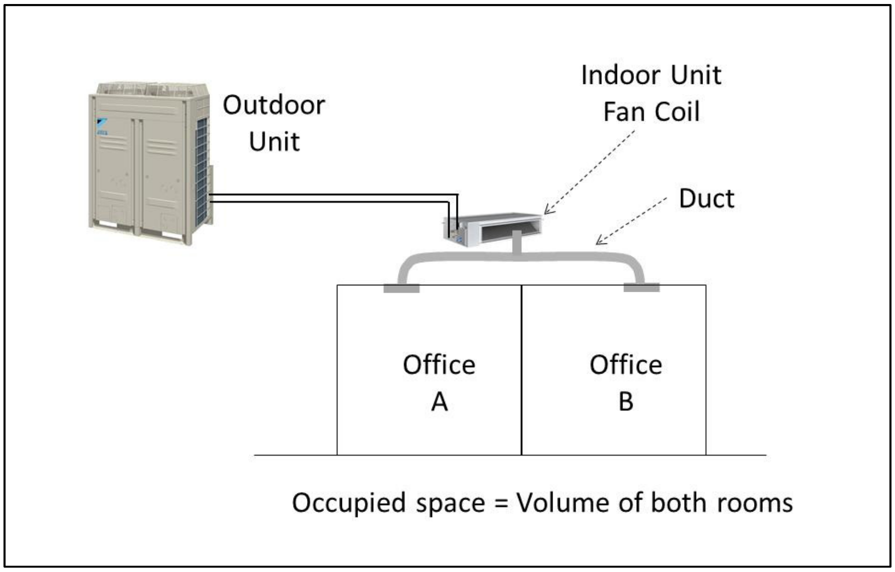
**Remove, or raise, suspended ceiling**

Since Standard 15 does allow the space above a suspended ceiling to be used in calculating the room volume if it is a part of the air supply or return system, one option could be to remove the ceiling completely. Alternatively, the suspended ceiling could possibly be raised to a height that provides the required room volume. This can be accommodated by using Daikin's indoor unit fan coils that are low profile. The height of some of the ceiling units is less than 10" and the height of a slim duct concealed unit is less than 8".

**<u>Relocate/remove piping or indoor unit fan coil</u>**

**Relocate the indoor unit fan coil and duct it to several rooms**

If none of the actions above are possible for increasing room volume, an alternative could be to install the indoor unit fan coil outside the room that is too small. By ducting the supply air to several rooms, the rooms would be considered connected according to Standard 15. If a leak occurs in the indoor unit fan coil, the refrigerant would be dispersed to both rooms, as shown in the following figure.



**Locate the indoor unit fan coil to the plenum above the suspended ceiling**

One way to be able to include the plenum space above the suspended ceiling in the room volume calculation is to install an indoor unit fan coil above the suspended ceiling and duct it to one or several smaller rooms, while drawing un-ducted return air through the plenum space above the suspended ceiling. See the following figure.

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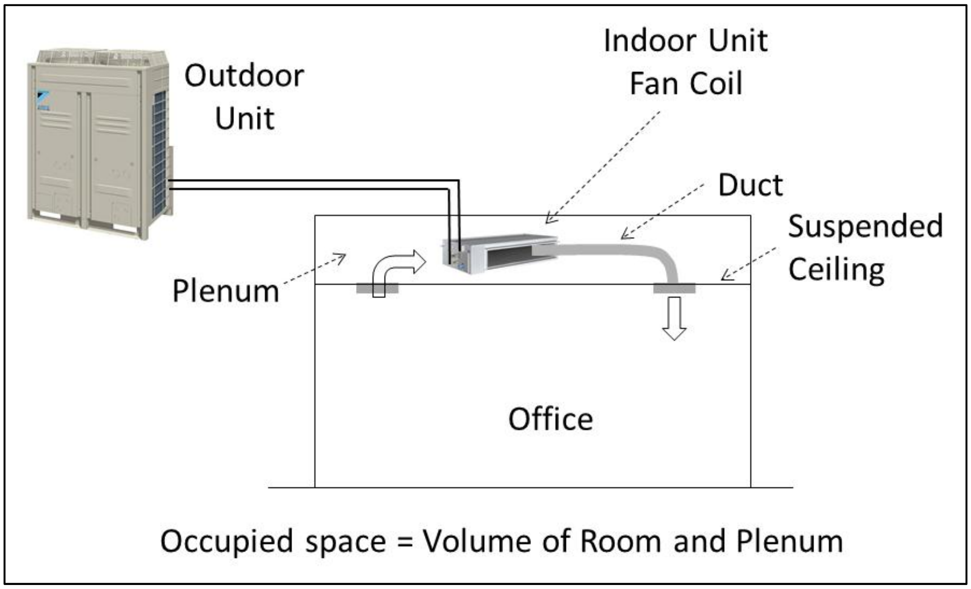


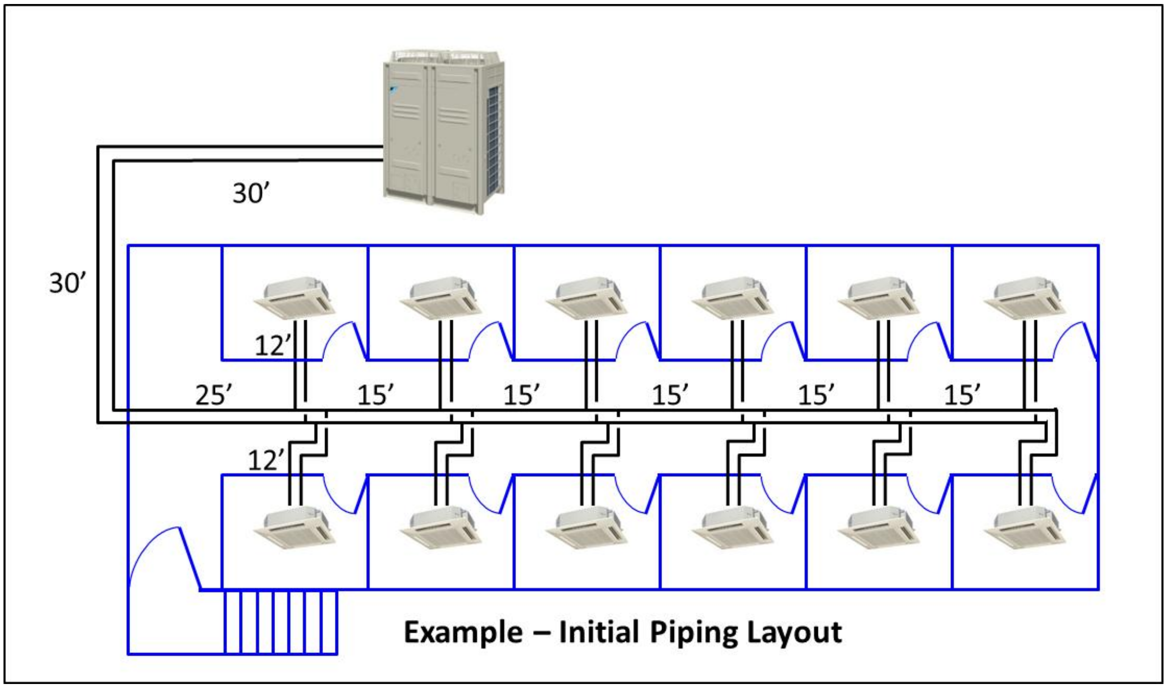

**Remove indoor unit fan coil from system**

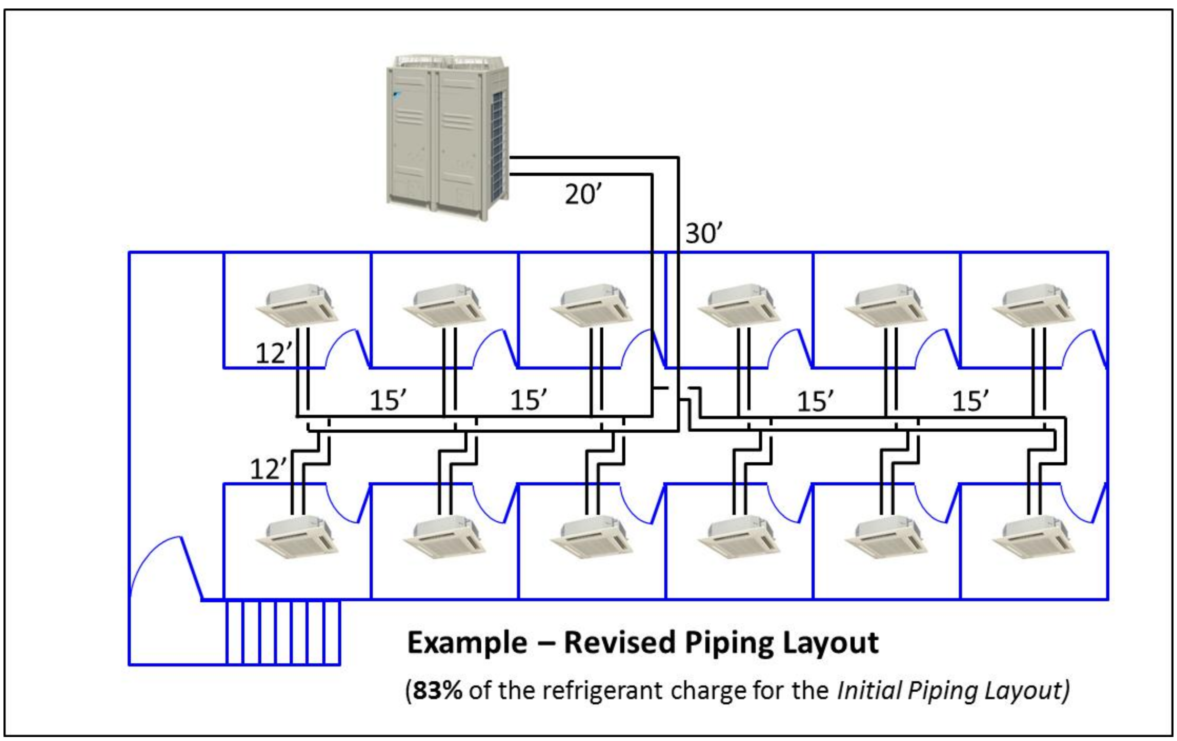
If none of the prescribed actions to increase the room volume can be accomplished, one option could be to remove the indoor unit fan coil from the system and install a separate split unit to handle the load in the room. Removing the unit from the system would also lower the total refrigerant charge in the *VRV* system.

**Optimize the piping layout**

An alternative or additional remedy is to review the piping layout to see if it can be altered to reduce refrigerant and piping.

Reduced lengths of the main distribution piping can decrease the refrigerant charge in the circuit considerably. In the following figures, the ***Revised Piping Layout*** lowers the total refrigerant charge in the circuit to 83% of the charge for the ***Initial Piping Layout***.

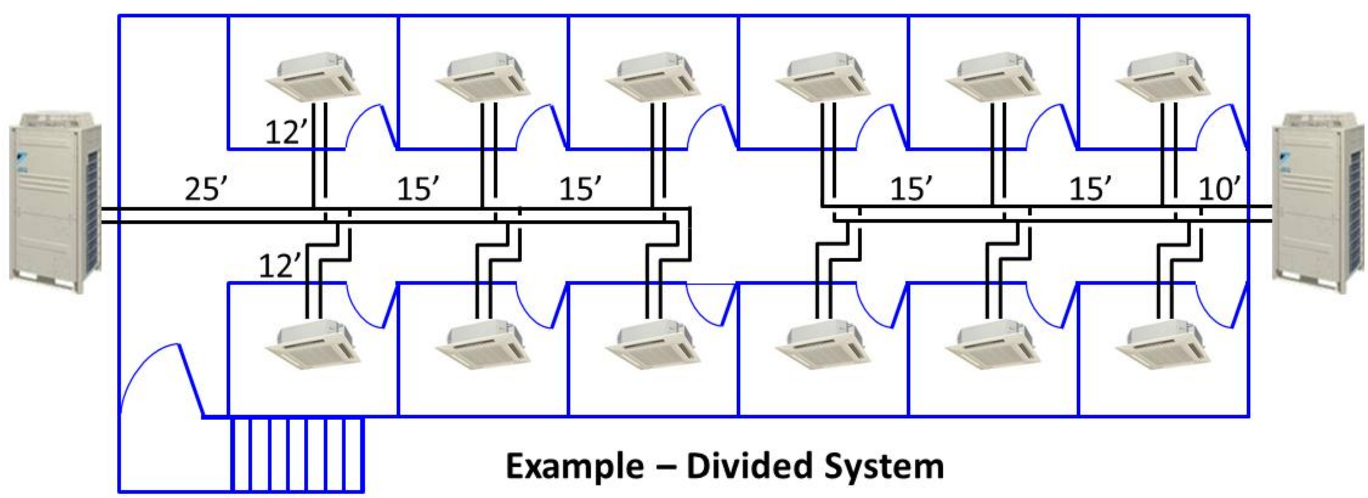


**Reduce the refrigerant charge by dividing the refrigerant circuit into multiple smaller systems**

Depending on system layout, size, and other factors, another option could be to divide the system into multiple smaller and completely separate *VRV* systems. This would dramatically decrease the refrigerant charge in a single circuit and due to the modularity of the *VRV* technology, the cost per Ton of cooling/heating is very similar for several smaller systems or one larger system.

In the following figure, ***Divided System***, the larger of the two refrigerant circuits contain 40% of the total refrigerant charge compared to the previous figures ***Initial Piping Layout*** and 48% compared to the ***Revised Piping Layout*.**




**Example – Divided System**

(**40%** of the refrigerant charge for the *Initial Piping Layout)*
(**48%** of the refrigerant charge for the *Revised Piping Layout)*

## Additional Information

ASHRAE has published a Standard 15-2001 Users Manual (ISBN 1931862168) that "*was developed as a companion document to ASHRAE Standard 15-2001. It does not reflect the addenda and changes incorporated into Standard 15-2004. The User's Manual clarifies the intent of the Standard and provides an explanation of the rationale behind it. It eases use of the standard by including illustrations and examples of accepted industry practice, as well as explanations of and supporting references for formulas in the Standard. This guide also covers building, system, and refrigerant classifications, restrictions on refrigerant use, installation restrictions, and equipment and system design and construction. The User's Manual includes information on mechanical and absorption refrigeration systems for commercial, residential, and industrial applications."*

## Conclusion

A *VRV* System can be properly selected and designed adhering to ASHRAE Safety Standards 15 and 34. However, it is important to keep the following considerations in mind:

- Standard 15 is an application based standard, not an equipment design guide, so substantial engineering judgment can be required when applying the standard.
- Since the indoor unit fan coils are in direct contact with the air being distributed, a *VRV* system is classified as a Direct System according to Standard 15. By definition, a Direct System is also classified as a High Probability system, meaning that a leak of refrigerant can potentially enter into occupied space.
- ASHRAE Standard 34-2010 has established the maximum Refrigerant Concentration Limit (RCL) for R410A to 26 lbs/1000 $ft^3$ of room volume for occupied spaces. For Institutional Occupancies, the limit is 13 lbs.1000/$ft^3$.
- According to Standard 15, room volume calculation "shall be based on the volume of space to which the refrigerant disperses in case of a leak."
- Many of the attributes of a modern cooling/heating technology, such as *VRV*, are not addressed in Standard 15. Therefore, it is recommended to follow a step-by-step approach and also work with the local "authority having jurisdiction" (AHJ) when designing a system.

## Checklist

| Step | Action | √ |
|---|---|---|
| **First Step** | **Preliminary layout of the system** | |
| | | |
| **Second Step** | **Determine the amount of refrigerant** | |
| | | |
| **Third Step** | **Verify that the *VRV* system layout complies with Standard 15 requirements** | |
| | Determine the occupancy classification for the room(s) | |
| | Determine room volume(s) | |
| | Verify that no room is too small | |
| | Review refrigerant piping requirements | |
| | - Refrigerant piping location | |
| | - Refrigerant monitoring | |
| | - Roof and floor piping penetration | |
| | | |
| **Fourth Step** | **Actions if a room is too small** | |
| | Increase the room volume used in calculations | |
| | - Permanent openings | |
| | - Ventilation | |
| | - Doors | |
| | - Remove, or raise, suspended ceiling | |
| | | |
| | Relocate/remove piping or indoor unit fan coil | |
| | - Relocate the indoor unit fan coil and duct it to several rooms | |
| | - Locate the indoor unit fan coil to the plenum above the suspended ceiling | |
| | - Remove indoor unit fan coil from system | |
| | - Optimize the piping layout | |
| | | |
| | Reduce the refrigerant charge by dividing the refrigerant circuit into multiple smaller systems | |

*Disclaimer*
*The information contained herein is provided for general guidance and informational purposes only and is not a substitute for complying with all national, state and local codes as may be required. Every HVAC installation varies in its individual circumstances and the local, authorized engineer and/or installer will have to use their professional judgment in each installation for code compliance.*

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