Application Note 2001:

Application of ASHRAE Standards 15 and 34 to VRF Systems

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Reference Documents **ASHRAE Standard 15 - 2013**
ASHRAE Standard 34 - 2013

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Introduction

Variable Refrigerant Flow (VRF) Systems offer the North American market an innovative method of providing air conditioning and heating for commercial buildings. Since introduction, interest has been generated in regards to designing these systems to meet ASHRAE Standard 15 (Safety Standards for Refrigeration Systems) requirements.

Specific designs must focus on the refrigerant flow attributes of these systems. ASHRAE 15 instructs designers in many aspects of refrigerant safety.

VRF systems offer no more potential problems than most other DX-type HVAC systems. The uniqueness of these systems has led some traditional system manufacturers, however, to misinform the public as to the meaning and application of ASHRAE 15 requirements, which have created potential concerns that question the technology despite worldwide acceptance and use.

The information presented in this document is offered to clarify much of the misinformation, speculation, and rumor surrounding the issues and provide guidance to specifying and applying VRF systems. This publication is an application summary only and is not intended as a substitute for national, state or local code requirements.

ASHRAE Standard 15

ASHRAE Standard 15 is significant to all HVAC equipment manufacturers, engineers, and contractors because it "specifies safe design, construction, installation, and operation"[1] of all HVAC systems as a way of protecting building occupants and property. Originally written in 1919, Standard 15 was created to provide guidance for safety concerns in large refrigeration plants using ammonia and other early refrigerants. Over time, the scope of the Standard has been expanded to cover most refrigerants and systems, but the technology and features inherent in VRF systems have not been specifically addressed.

ASHRAE 15 is a "National Voluntary Consensus Standard"; but, equipment listed by a Nationally Recognized Testing Laboratory (NRTL) and identified as being in compliance with Standard 15 meets the applicable provisions of the Standard (ASHRAE Standard 15-2013, Section 13). Also, regulatory language was incorporated in the 2001 revision and, by adoption, the standard can be made part of local code requirements. This is specific to each jurisdiction, so it is important for the designer to be familiar with local codes and regulations.

[1] ASHRAE Standard 15-2013, Section 1

Applying ASHRAE Standards 15 and 34 to R410A

ASHRAE Standard 15-2013, does not specifically address the safety classification of any particular refrigerant, but instead through Section 6 specifies that single-compound refrigerants and refrigerant blends shall be classified into safety groups in accordance with ASHRAE Standard 34.

The overall purpose of ASHRAE Standard 34-2013 is

> "…*to establish a simple means of referring to common refrigerants… It also establishes a uniform system for assigning reference numbers, **safety classifications, and refrigerant concentration limits to refrigerants**. The standard also identifies requirements to apply for designations and safety classifications for refrigerants."* [2]

A main point of discussion under ASHRAE Standard 34 is the **Refrigerant Concentration Limit (RCL)** (ASHRAE Standard 34-2013, Section 7). RCL is defined as

> "…*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*".

RCL can be expressed in:

- ppm v/v
- g/m^3
- lb/Mcf (or lb/1,000 ft^3)

RCL can be converted between units by using the following excerpt from ASHRAE Standard 34-2013, Section 7.4.1:

7.4.1 Mass per Unit Volume. The following equation shall be used to convert the RCL from a volumetric ratio, ppm by volume, to mass per unit volume, lb/Mcf (g/m^3):

$$RCL_M = RCL \cdot a \cdot M$$

where

RCL_M	=	the RCL expressed as lb/Mcf (g/m^3)
RCL	=	the RCL expressed as ppm v/v
a	=	1.160×10^{-3} for lb/Mcf ($4.096 \cdot 10^{-5}$ for g/m^3)
M	=	the molecular mass of the refrigerant in lb/mol (g/mol)

Figure 1: Excerpt from ASHRAE Standard 34-2013

[2] "Designation and Safety Classification of Refrigerants" ASHRAE Standard 34-2013, Section 1

RCL values are the lowest of the following three factors:

- **Acute Toxicity Exposure Limit (ATEL):** Specifies that the ATEL shall be the lowest of four categories including mortality, cardiac sensitization, anesthetic or central nervous system effects and other escape-impairing effects and permanent injury.[3]

- **Oxygen Deprivation Limit (ODL):** Specifies an ODL of 140,000 ppm by volume down to 69,100 ppm depending on altitude.[4]

- **Flammable Concentration Limit (FCL):** Specifies the FCL be calculated as 25% of the Lower Flammability Limit (LFL).[5] The LFL is the minimum concentration of refrigerant that is capable of propagating a flame through a homogenous mixture of the refrigerant and air under specified conditions.

RCL for R-410A is based on the ODL (140,000 ppm) because it is lower than the ATEL (170,000 ppm). Toxicologists considered the elderly and children when determining the RCL values for refrigerants. There is no discussion on this in the Standard; however, it should be note that the toxicology subcommittee of SSPC 34 includes toxicologists from a broad range of interests (manufacturers, consultants and testing laboratories).

Limits for RCL have been developed as indicated in Table 1.

Table 1. Refrigerant Safety Data from ASHRAE Standard 34-2013

Refrigerant	Safety Group	RCL lb./Mcf	Highly Toxic or Toxic Under Code Classification
R-22 ($CHClF_2$)	A1	13	Neither
R-134A (CH_2FCF_3)	A1	13	Neither
R-407C (Blend)	A1	19	Neither
R-410A (Blend)	A1	26	Neither

R410A Quantity per Occupied Space = RCL =140,000 ppm v/v = 420 g/m^3 **= 26 lb/Mcf** (detailed information provided in Standard 34-2013, Appendix G)**.**

[3] ASHRAE Standard 34-2013, Section 7.1.1
[4] ASHRAE Standard 34-2013, Section 7.1.2
[5] ASHRAE Standard 34-2013, Section 7.1.3

Designing VRF Systems with ASHRAE 15 and 34

Occupied Spaces

Standard 15 guides designers on how to apply a refrigeration system in a safe manner, and details information on the type and amount of refrigerant allowed in an *occupied space*, defined as

> "…*that portion of the premises accessible to or occupied by people, excluding machinery rooms"* .[6]

Section 4 of ASHRAE Standard 15 defines the occupancy classifications:

- Institutional Occupancy[7]
- Public Assembly Occupancy
- Residential Occupancy
- Commercial Occupancy
- Large Mercantile Occupancy
- Industrial Occupancy
- Mixed Occupancy

Section 5 of ASHRAE Standard 15 defines refrigerating system classifications:

- Direct Systems[8]
- Indirect Open Spray Systems
- Double Indirect Open Spray Systems
- Indirect Closed Systems
- Indirect Vented Closed Systems

In reviewing specific applications, the designer must look at the space any HVAC system serves, as well as the refrigerant line paths. If system components are located in normally occupied spaces, then they must be evaluated for safety and suitability. Corridors and lobbies – especially points of egress - should be evaluated as well since their volume is, by definition, part of the *connected spaces* volume and the restrictions in the Standard limit refrigeration concentrations in these areas to specified amounts.

In most cases such system components – including refrigerant piping – do not pose a safety or suitability issue. ASHRAE Standard 15 requires factory testing on all refrigerant containing components; as a result, the likelihood of subsequent failure is remote. Field fabricated connections also require inspection and evaluation. CITY MULTI® VRF Systems require evacuation of the complete system and all piping, including field fabricated connections, and

[6] ASHRAE Standard 15-2013, Section 3

[7] ASHRAE Standard 15-2013, Section 7.2.1 indicates that all values should be reduced by 50% for institutional occupancies.

[8] All CITY MULTI® systems are direct systems, which are systems having evaporator, condenser, or refrigerant lines in direct contact with the material [air] to be cooled or heated.

vacuum must be held with no leaks as a part of the commissioning process for every system installed

Refrigerant Leaks in Occupied Spaces

The term “leak” is not defined in ASHRAE Standard 15, but it generally addresses a catastrophic event where full circuit refrigerant volume is to be considered as available for discharge into the occupied space. Standard 15 also does not address any time period over which a leak might occur. Even in the unlikely event of a line rupture, the full amount of refrigerant in a circuit would not release instantaneously but would require a significant period to escape from the system.

The design professional should keep in mind that ASHRAE Standard 15 was primarily developed and written for the catastrophic release of the entire contents of a pressure vessel thru a safety valve of large diameter in a short period of time. No such device exists on any interior portion of a CITY MULTI® VRF system.

There is a clearly defined relationship between the amount of refrigerant in a system and the volume of the occupied space into which the refrigerant could flow. According to ASHRAE Standard 15,

> “…*the volume used to convert from refrigerant concentration limits to refrigerating system quantity limits for refrigerants in 7.2 shall be based on the volume of space to which the refrigerant disperses in the event of a refrigerant leak*”. [9]

Occupied space is not necessarily a single room or area. If a group of rooms or spaces (offices, corridors, other spaces off the corridor, etc.) are connected by ductwork or other means, then all of their connected volumes are counted in calculating the affected volume. These “connected spaces” could also include louvers or “permanent” openings to adjacent spaces or to the outside, as in a ventilation source or exhaust, and even undercuts on connecting doors, provided there is forced movement of air.

ASHRAE Standard 15-2013 specifically lists ventilated spaces as a means to establish the critical volume of an occupied space, but does not quantify the amount or type of ventilation required to count a space as ventilated. The Standard only states that,

> *“…Where a refrigerating system or a part thereof is located within an air handler, 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. The worst case or the smallest volume in which the leaked refrigerant disperses shall be used to determine the refrigerant quantity limit in the system, …”* [10]

VRF System Volume Example

[9] ASHRAE Standard 15-2013, Section 7.3
[10] ASHRAE Standard 15-2013, Section 7.3.2

To further illustrate the design options, a CITY MULTI® system is shown in Figure 2. The space is a single-bay tenant upfit within a strip mall located in a mild climate. The space is 30 feet by 70 feet, with 14 feet from the floor to the underside of the roof deck. The interior walls extend 18 inches above the dropped ceiling.

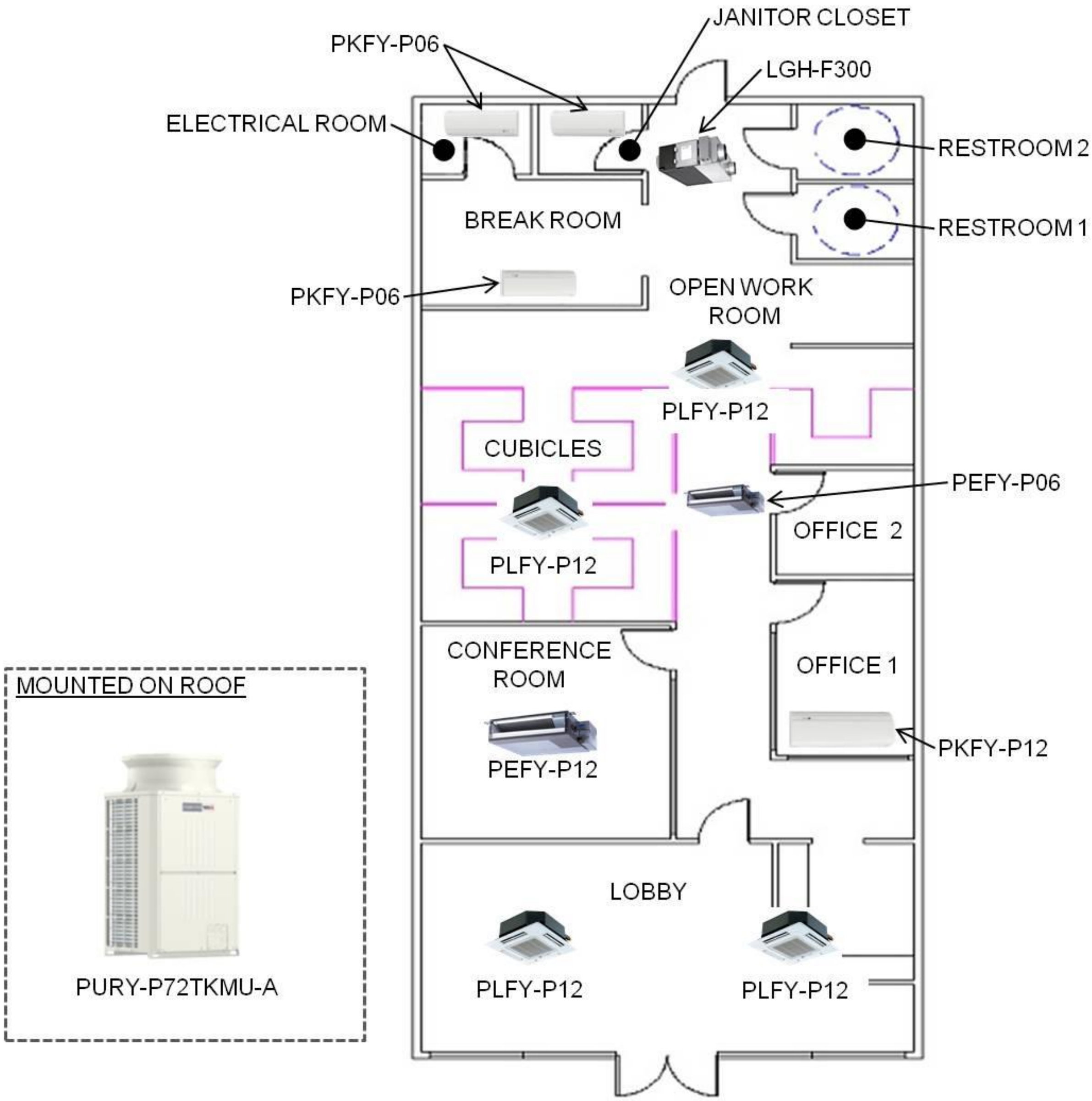

Figure 2: Example Layout of a VRF System

Table 2. Tenant Upfit Example Spaces

Room Name	Room Area (sq ft)	Ceiling Height (ft)	Room Volume (cu ft)
LOBBY	450	10	4,500
CONFERENCE ROOM	235	12	2,820
OFFICE 1	115	10	1,150
OFFICE 2	70	10	700
OPEN WORK AREA	944	12	11,328
BREAK ROOM	127	10	1,270
RESTROOM 1	42	9	378
RESTROOM 2	42	9	378
ELECTRICAL ROOM	39	14	546
JANITOR CLOSET	36	14	504
TOTAL CONNECTED VOLUME			**23,574**

The outdoor unit contains 26 lb 1 oz. of R410A refrigerant. With the additional charge for the piping[11], the total refrigerant charge in the system is 33 lb 4 oz. The RCL limit for this project is in accordance with ASHRAE Standard 34, which is 26 lb/Mcf for R410A. As shown below, the minimum applied volume needed to handle the full refrigerant charge of the system can be easily calculated.

$$\text{RCL} = \text{Refrigerant Concentration Limit in lbs/Mcf}$$
$$\text{R}_\text{C} = \text{Refrigerant Charge of System in lbs}$$
$$\text{MAV} = \text{Minimum Applied Volume in ft}^3$$

$$\text{RCL}_{\text{R410A}} = 26\ \text{lbs/Mcf}$$
$$\text{R}_{\text{C, Example System}} = 33\ \text{lb}\ 4\ \text{oz.} = 33.25\ \text{lb}$$

$$\text{MAV} = {}^{\text{R}_\text{C}}/_{\text{RCL}}$$

$$= {}^{33.25\ [\text{lbs}]}\Big/_{26\ [{}^{\text{lbs}}/_{1000\text{ft}^3}]}$$

$$= 1279\ \text{ft}^3$$

The MAV is the smallest space in which the total refrigerant charge of the system could be safely dispersed in the event of a total leak. To summarize the above equation, the smallest **unconnected** space in which any of the CITY MULTI® indoor units could be located is1279 ft^3.

[11] Additional refrigerant charge is typically, but not always, required for VRF systems. Additional charge can be calculated automatically by using Diamond System Builder software, or manually by using calculation located in Technical Service manual or design section of Engineering Manual for outdoor unit.

However, if all areas were connected via door undercuts or transfer ducts (permanent opening as referenced in ASHRAE Standard 15-2013, 7.3.1) the applied volume is 23,574 ft^3 and the Applied Refrigerant Concentration Level can be calculated as shown below.

R_C = Refrigerant Charge of System in lbs
AV = Applied Volume in ft^3
ARC = Applied Refrigerant Concentration Level in lbs/Mcf

$R_{C,\ Example\ System}$ = 33 lb 4 oz. = 33.25 lb
$AV_{Example\ System}$ = 23,574 ft^3 = 23.574 Mcf

$$ARC = R_C / AV$$

$$= 33.25\ [lbs] / 23.574\ [1000\ ft^3]$$

$$= 1.41\ [lbs/Mcf]$$

Should the design professional be challenged on the interpretation of connected spaces, the project team has several options available to deal with smaller spaces.

- In cases such as the restrooms, the code-required ventilation will likely be all that is required to maintain space conditions. If extra cooling is required, a ducted unit located in the workroom corridor would solve the problem.
- The electrical room/janitor closet area provides another opportunity for the architect to help the mechanical design team. An opening located low along the common wall between the two spaces would increase the available volume from 504 ft^3 minimum to over 1000 ft^3. Should the electrical closet require a rated enclosure as required by NFPA-70, a fire damper could be installed.
- Office 2 was provided with a ducted unit located in the corridor to meet the requirements of the Standard. Another option for Office 2 would be to omit the ceiling entirely or install it at a level which provides the needed volume. It shall be noted that ASHRAE 15 Section 7.3.2 clearly states:

> *"…the space above a suspended ceiling shall not be included in calculating the refrigerant quantity limit in the system…"*

As illustrated by the example, the only requirement to meet the standard was an understanding of the language and not major accommodations or changes. With the application of sound engineering practice, any design professional can easily integrate VRF technology into his or her design.

Adjustment for Altitude

The RCL for R-410A is based on the Oxygen Deprivation Limit (ODL), the gas concentration resulting in insufficient oxygen for normal breathing. For refrigerant gas, the ODL is 140,000 ppm (26 lb/Mcf for R-410A) at altitudes up to 3,300 ft, 112,000 ppm ((20.8 lb/Mcf for R-410A) at altitudes above 3,300 ft to 4,920 ft, and 69,100 ppm (12.8 lb/Mcf for R-410A) at altitudes higher than 4,920 ft.

Location of Refrigerant Piping

ASHRAE 15-2013 does address the location of refrigerant piping in buildings.

Sections 8.10.1 States:

> *"Refrigerant piping crossing an open space that affords passageway in any building shall not be less than 7.25 ft above the floor unless piping is located above the ceiling of such space and is permitted by the AHJ (authority having jurisdiction)".*

Section 8.10.2 also states that passages shall not be obstructed and that:

> *"Refrigerant piping shall not be installed in an enclosed public stairway, stair landing, or means of egress".*

These statements often give rise to questions regarding refrigerant piping in main building corridors. Analyzing this wording closely, it states only that refrigerant piping not be located "IN" the egress. Therefore, installation of piping above a ceiling in a corridor above the occupied space should be permissible. If a local jurisdiction takes a more extreme interpretation, then an additional enclosure could be provided up above the ceiling space where the piping passes.

Section 8.10.3 also states that:

> *"Refrigerant piping shall not penetrate floors, ceiling, or roofs."*

However, exceptions to this exist in the standard, the most significant being "Exception 4." which states that:

> *"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"*

Since VRF systems are direct systems, and must always be designed to not exceed the leakage concentration limits set forth by ASHRAE Standard 34 this restriction is not applicable.

Conclusion

Engineers and designers have great flexibility in applying CITY MULTI® VRF systems to ensure the design is "ASHRAE 15 compliant". Examining the project spaces and determining the occupied and connected spaces needs to be a primary consideration, and care must be taken in the location and layout of refrigerant lines and indoor units. The energy effectiveness and design and layout efficiencies of CITY MULTI® systems combined with the ability to use building diversities allow the designer to achieve high levels of comfort while keeping operating costs under control.

Additional References:

Table 3. Summary of Refrigerants (excerpt from ASHRAE Standard 34-2013)

Refrigerant	Blend	Composition	Contains Chlorine	Safety Group
R-22	Single Compound	HCFC Methane-based	Y	A1 (Table 4-1)
R-32	Single Compound	HFC	N	A2L (Table 4-1)
R-125	Single Compound	HFC	N	A1 (Table 4-1)
R-134A	Single Compound	HFC Ethane-based	N	A1 (Table 4-1)
R-407C	Zeotropic Blend (23.0% R-32, 25.0% R-125, 52.0% R-134A)	HFC	N	A1 (Table 4-2)
R-410A	Zeotropic Blend (50% R-32, 50% R-125)	HFC	N	A1 (Table 4-2)

Safety Group Classifications (from ASHRAE Standard 34)

Classification consists of two alphanumeric characters. The capital letter indicates toxicity and the numeral indicates flammability (S34-6.1.1).

Class A signifies refrigerants for which toxicity has not been identified at concentrations less than 400 ppm (S34-6.1.2).

Class 1 indicates refrigerants that do not show flame propagation, Class 2 indicates refrigerants that have a low flammability limit (S34-6.1.3).