The Impact of A2L Refrigerants on VRF System Design

White Paper

The change to refrigerants that are more friendly to the environment has been a long, ongoing journey. Right now, the HVAC industry is moving to next-generation refrigerants with less than 700 GWP, which can help to reduce GWP by 75%. This white paper discusses how next-generation A2L refrigerants impact VRF system design and installation, offering technical insights, regulatory updates, and best practices to assist engineers and contractors in navigating this transition.

Variable refrigerant flow (VRF) systems include both VRF equipment, consisting of outdoor units and terminal units, as well as a system to distribute conditioned outdoor air for ventilation, like a packaged direct expansion (DX) dedicated outdoor air system (DOAS) (see Figure 1). They have quickly gained popularity in the commercial sector due to their adaptability, effective heating and cooling performance, and energy efficiency. Recent regulations now mandate a shift from higher global warming potential (GWP) refrigerants like R-410A to lower GWP refrigerants alternatives such as R-32 and R-454B, which carry an A2L classification. A2L classification was created by ASHRAE® Standard 34 in 2010 and was designated for refrigerants that have some flammability characteristics but are difficult to ignite (see Figure 2). This transition necessitates updates to refrigerant safety standards and building codes, which affect both the VRF and DOAS equipment.

Figure 1: VRF Systems consist of VRF equipment, a dedicated outdoor air system and integrated building controls.

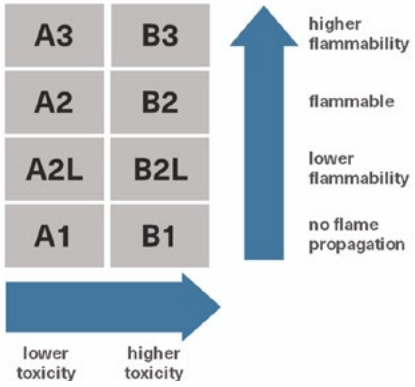

Figure 2. Refrigerant safety groups from ASHRAE Standard 34.

Timeline for A2L Refrigerant Transition

The transition to A2L refrigerants for VRF and DOAS equipment in the United States follows specific timelines.

Deadline	Action
End of 2024	Deadline for importing or manufacturing packaged DX DOAS equipment with R-410A.
End of 2025	Deadline for importing or manufacturing VRF equipment with R-410A.

Note: Installation deadlines pending based on EPA rule proposals.

By adhering to the AHRI 920 standard for DOAS equipment, engineers can ensure accurate specification, optimal performance, and efficient operation tailored to the unique dehumidification needs of their applications.

Understanding A2L Refrigerants

The HVAC industry has been proactively implementing essential precautions and standards for managing new refrigerants. Standards like ASHRAE® 15 prescribe comprehensive requirements for the design, handling, and installation of equipment utilizing these refrigerants. Over time, standards like ASHRAE® 15 are integrated into building codes like the International Mechanical Code (IMC). These model codes are updated every three years and governments can adopt these codes into law.

Both VRF system and packaged DX DOAS systems fall into the high-probability system category per ASHRAE® 15. A high-probability system is defined as a refrigeration system in which the basic design or location of components is such that leaked refrigerant from a failed connection, seal, or component has a high probability of entering an occupied space. When a high-probability system contains an A2L refrigerant, ASHRAE® Standard 15 details several requirements that must be met:

"Listed" Equipment: The refrigeration system must be listed by a Nationally Recognized Testing Laboratory (NRTL) in accordance with the UL 60335-2-40 product safety standard.

Refrigerant Quantity Limit: The releasable refrigerant charge (mrel) must not exceed the Effective Dispersal Volume Charge (EDVC) limit, which is based on the refrigerant's lower flammability limit (LFL) and whether the system has continuous or detector-initiated air circulation.

Required Mitigation Actions: If a refrigerant leak is detected, several actions must occur within 15 seconds, including energizing air circulation fans, opening zone dampers in the ductwork (if equipped), de-energizing electric resistance heaters in the ductwork and other ignition sources, activating safety shutoff valves (if equipped), and initiating mechanical ventilation (if required). These actions must continue for at least five minutes after the refrigerant concentration drops below the setpoint.

Ignition Source Restrictions: Open-flame-producing devices and electrical sources of ignition cannot be installed in ductwork. Hot surfaces exceeding 1290 F or 700 C are permitted during normal operation if an air velocity of 200 fpm and proof-of-airflow devices are in place.

These requirements ensure that the concentration of refrigerant remains below flammable levels, enhancing the safety of HVAC systems using A2L refrigerants in high-probability applications.

For a more in-depth explanation of ASHRAE® Standard 15, see the Trane application manual titled "Refrigeration Systems and Machinery Rooms: Application Considerations for Compliance with ASHRAE® Standard 15-2022 (APP-APM001G-EN)".

Key Terminology

Understanding the terminology associated with A2L refrigerants in ASHRAE® 15 is crucial for navigating the regulatory landscape and ensuring safe and effective system design and installation. Below are key terminology and their implications for VRF system design and installation:

- **EDVC (Effective Dispersal Volume Charge):** Represents "the maximum refrigerant charge permitted for an effective dispersal volume." This is used to prevent the concentration of refrigerant from reaching its lower flammability limit (LFL) in case of a leak. The standard includes specific formulas to ensure the concentration of refrigerant remains below the flammability limit. To comply with Standard 15, the releasable refrigerant charge (m_{rel}) cannot exceed the EDVC.
- **F_{occ} (Occupancy Factor):** A multiplier that adjusts the EDVC based on the type of occupancy. For most occupancies, this factor is 1, but for institutional occupancies (e.g., hospitals, nursing homes, prisons), it is 0.5.
- **m_s (System Refrigerant Charge):** Refers to "the total mass of refrigerant in an independent circuit of a system, including both factory and field refrigerant charge."
- **m_{rel} (Releasable Refrigerant Charge):** This is the "portion of the system refrigerant charge that can be released into a space as a result of a single point of failure." This is essential for assessing the potential impact of a refrigerant leak. The releasable charge may be equal to the system refrigerant charge (ms).
- **V_{eff} (Effective Dispersal Volume):** "The volume of a space or connected spaces in which leaked refrigerant will disperse," established using Sections 7.2.1 through 7.2.3 of ASHRAE 15.
- **LFL (Lower Flammability Limit):** The minimum concentration of a refrigerant in the air that is capable of propagating a flame. The LFL of R-454B is 18.5 lbs/1000 ft3 while that of R-32 is 19.1 lbs/1000 ft3.

ASHRAE® Standard 15-2022 also introduced several significant updates to address the safe use of A2L refrigerants in HVAC systems. These changes reflect the evolving landscape of refrigerant technology and the need for enhanced safety measures due to the lower flammability characteristics of A2L refrigerants.

- **Air Circulation:** Plays a vital role in maintaining safe refrigerant concentrations, with the updated standard specifying that air circulation must be initiated by a refrigerant detector or be continuous.
- **Mechanical Ventilation:** An option for managing refrigerant leaks, involving separate fans for exhaust and makeup air. Adding this will increase system complexity and cost as it requires the use of a separate fan to exhaust air from the space—or to transfer air to a separate indoor space—and provision to replace this exhaust air with makeup air from outdoors, or from other indoor spaces. In the context of Standard 15, the term "mechanical ventilation" refers to the process of removing air (along with leaked refrigerant) from a space to reduce

the concentration of refrigerant in that space. This is different than ASHRAE® Standard 62.1, in which ventilation refers to the process of introducing fresh outdoor air to a space for the purpose of controlling indoor air quality.

- **Connected Spaces via Natural Ventilation:** The standard defines the size of openings based on equations when two adjoining spaces are connected via permanent natural ventilation openings. When a permanent open meets the size requirements, it is possible to treat the spaces as one continuous space. Natural ventilation may be an effective strategy for spaces that are very close to the EDVC calculation.
- **Release Mitigation Controls:** Critical for limiting the amount of refrigerant that can be released into a space in the event of a leak. Examples include safety shut-off valves for lowering the releasable refrigerant charge and refrigerant detection systems.

Considerations to Prepare Facilities

New requirements outlined in ASHRAE ® Standard 15 and UL product safety standards are intended to maintain human safety during a refrigerant leak. These requirements present some key considerations to prepare facilities for VRF systems. Since the new lower GWP refrigerants are A2L, there are more stipulations on where refrigerant piping can and cannot be installed, refrigerant piping cannot be installed in:

- Exit passageways
- Interior exit ramps
- Elevator shafts

Guidelines on when fire-rated and ventilated pipe shafts are required have been established and are continually reviewed and updated to the standard. For example, a change with an addendum to Standard 15-2024 now states that a dedicated shaft enclosure is not required for continuous refrigerant piping that has been tested in accordance with Section 9.13. However, if a shaft is used, there are still ventilation requirements, and testing required. Testing involves a 10-minute strength test and a leakage test, including a 24-hour pressure test and a 24-hour vacuum test. The installing contractor or design professional of record must issue a certificate of test for systems with more than 55 pounds of refrigerant charge.

Exempted Spaces and Branch Controller Compliance

Exempted spaces are specific areas within a building where certain refrigerant safety requirements of Standard 15 do not apply. These exemptions simplify compliance for spaces that pose minimal risk due to their specific characteristics or usage. Per Section 7.2.3.1.1, areas that contain only continuous refrigerant pipe, or joints and connections that have been tested in accordance with Section 9.13, are exempt from the effective dispersal volume calculation, unless they are considered “connected spaces.”

A VRF branch controller (BC) is a device to manage the distribution of refrigerant to different zones. It is typically located above a ceiling, in a small mechanical closet, or in a plenum. Although, ASHRAE® Standard 15 does not specifically mention terms like “Branch Controller”, recent updates clarify that a BC is different from continuous refrigerant piping because it contains valves. Therefore, a BC is not exempt from the EDVC calculation.

In addition, non-connected spaces (such as closets) that are not served by the ducted air distribution system and do not contain any part of a refrigeration system do not need to be included in the effective dispersal volume calculation.

Trane® / Mitsubishi Electric VRF System Solutions

VRF Systems offer innovative solutions to make the transition to A2L refrigerants smoother and more efficient. Innovative solutions have been developed, such as the hybrid branch controller and advanced refrigerant leak mitigation controls, to facilitate a more seamless transition. These solutions are designed to help systems comply with the new safety standards while maintaining optimal performance and efficiency.

The **hybrid branch controller** is a groundbreaking solution that utilizes water instead of refrigerant in conditioned spaces (Figure 3). This design significantly reduces the amount of refrigerant within occupied spaces, enhancing safety and simplifying compliance with ASHRAE® 15-2022. Using a hybrid branch controller in a VRF system, refrigerant is confined to the outdoor unit and a heat exchanger, while water is circulated through indoor units to provide heating and cooling. Hybrid VRF systems use up to 30% less refrigerant in the overall system, while still maintaining zoned comfort and energy efficiency.

Figure 3. The hybrid branch controller exchanges heat between refrigerant and water in order to reduce the use of refrigerant in VRF systems.

Release mitigation controls are critical for limiting the amount of refrigerant that can be released into a space in the event of a leak. The release mitigation system must be "listed" by a NRTL with proper labelling (Figure 4). The release mitigation includes:

Figure 4. Proper labelling with leak detection systems is required on equipment. Image from: Understanding A2L Refrigerants and Changes to Governance in Air Handling Equipment CSAA/PSCA/UCCA & Refrigerant coils – Trane Commercial HVAC Help Center

- Safety Shut-Off Valves: Installed in the refrigerant piping system to automatically close and isolate sections of the system when a leak is detected. When a leak is detected, these valves isolate the refrigerant, limiting the leaked quantity to the volume passing through the valve during detection and closing, plus any downstream charge. This approach significantly reduces the releasable refrigerant charge (mrel) compared to the entire system charge. Valves must close within 15 seconds of detection.
- Refrigerant Detection Systems: Designed to continuously monitor the concentration of refrigerant in the air. When a leak is detected, these systems trigger alarms and activate safety shut-off valves. The time required for the detector to identify the leak is essential for calculating the releasable charge. ASHRAE 15 stipulates that the refrigerant leak must be detected within 30 seconds.

Trane Horizon® DOAS Refrigerant Detection System

The Refrigerant Leak Detection System on the Horizon® DOAS is a standard safety design feature designed to detect refrigerant leaks and initiate immediate mitigation actions, ensuring compliance with ASHRAE® Standard 15. According to UL 60335-2-40, ducted systems that have more than 3.91 pounds of A2L refrigerant are required to include refrigerant detection sensors.

Figure 5. Horizon DOAS units provide conditioned 100% outdoor air to the building.

Industry Innovations and Future Outlook

The HVAC industry is inventive and resourceful, and this is yet another opportunity for the industry to showcase its ability to drive progress. HVAC equipment that has already transitioned to A2L refrigerants comes with integral refrigerant detectors and unit-level controls to activate mitigation actions, including safety shutoff valves and air circulation. Advanced product features are emerging to address the challenges of A2L refrigerants, such as the Hybrid Branch Controller, reducing the need for leak detection or mitigation control. Trane has also incorporated A2L mitigation sequences into building automation systems, simplifying the setup and configuration process.

Resources

Variable Refrigerant Flow Systems by Trane

VRF: Staying Cool through the Refrigerant Change | Trane Commercial HVAC

Quick Reference ANSI/ASHRAE Standard 15-2022 (REFR-SLB017-EN)

Refrigeration Systems and Machinery Rooms: Application Considerations for Compliance with ASHRAE® Standard 15-2022 (Trane application manual APP-APM001G-EN)

Trane Engineers Newsletter LIVE: ASHRAE Standard 15 2022

A2L Refrigerants and ASHRAE Standard 15 Engineers Newsletter

What Engineers Need to Know: The Impact of A2L Refrigerants on VRF System Design and Installation | Trane Commercial HVAC

What Contractors Need to Know: The Impact A2L Refrigerants Will Have on the Design, Installation, and Maintenance of VRF Systems | Trane Commercial HVAC

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