PRODUCT APPLICATION

A technical bulletin for engineers, contractors and students in the air movement and control industry

The Safety of A2L Refrigerants in Direct Gas-Fired HVAC Equipment

The EPA Technology Transition Act has required the HVAC/R industry to transition to lower-GWP (global warming potential) refrigerants. Class A1 refrigerants, which have a higher GWP but no flame propagation, were widely used prior to the act. Class A2L refrigerants, which have a low GWP but can propagate flame, are the new standard beginning in 2025. The industry has worked diligently to address safety concerns for many of the most common air-conditioning and heat pump applications while maintaining similar performance, design, and efficiency. The use of direct gas-fired furnaces in HVAC equipment with new refrigerants, while a small portion of the industry, deserves close consideration. Greenheck has collaborated with industry organizations, experts, and nationally recognized testing laboratories to determine that its products joint-listed between UL 60335-2-40 and ANSI/CSA Z83.8 sufficiently address the risks presented with A2L refrigerants.

Direct gas furnaces are an effective source of heat in HVAC products where a significant amount of outdoor air needs to be heated, either to provide comfort to an occupied space directly or be used as a scavenger air source to regenerate desiccants. Natural gas or propane is delivered through redundant safety valves to a line burner placed in an open airstream without the need for a heat exchanger. The line burner and surrounding profile plates work together to inject air across the burner, where it mixes with the gaseous fuel to burn cleanly.

Figure 1. Make-up air unit with direct gas-fired furnace

Comparison of A1 and A2L Refrigerants

Previous generations of A1 refrigerants used in air-conditioners and heat pumps were combustible in open flames but would not sustain a flame on their own under normal conditions. Outside of the moderate increase in flammability risk, new A2L refrigerants are very similar to their A1 predecessors. R-410A was the predominate refrigerant used in air-conditioning and heat pump products since 2010, and the top two replacement refrigerants that will comply with hydrofluorocarbon (HFC) GWP phasedown requirements are R-32 and R-454B.

NOTE: This document addresses the use of direct gas-fired furnaces with A2L refrigerants in combined heating and cooling appliances. Direct gas-fired furnaces that are used as independent appliances, such as industrial ovens and process heaters, must be evaluated based on local building codes to address the risks of thermal degradation, combustion, and fire from refrigerant leaked into the presence of open flames.

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What's similar between R-410A, R-32, and R-454B?

1. R-32 is a major constituent in all three refrigerants.
2. All three refrigerants are combustible.
3. The products of combustion and thermal degradation are the same.

What's different?

Flammable concentrations of R-32 and R-454B in stagnant environments create a risk of fire when exposed to higher-energy ignition sources such as open flames, high-energy electrical arcing, or surface temperatures above 800°C (1472°F). Industry experience has determined that combustible A2L mixtures do not ignite when local mixture velocities exceed three times the refrigerant's burning velocity.[1] For A2L refrigerants, the risk of ignition is abated when in the presence of airflows of 30 cm/s (60 ft/min).

See Table 1 for a more detailed overview of differences and similarities.[2]

Concerns and Risks of Flame Exposure for A2L Refrigerants

Risk evaluation and mitigation require imagination of what risks exist, the severity of outcome if the risks aren't mitigated, the likelihood those risks exist, and the direct and social cost of requiring additional safety measures. Not all risks can be mitigated reasonably. One could require all HVAC units using A2L refrigerants to prevent a risk of fire when struck by space debris falling to Earth. But the structural design changes, additional testing needed, and of course the low likelihood would make this requirement a bit excessive.

Refrigerant Combustion/Thermal Decomposition Byproducts

The primary risk of refrigerant exposure to a flame is that the refrigerant will decompose or oxidize and create hydrogen chloride and hydrogen fluoride. While theoretically plausible but statistically unlikely, chlorinated and fluorinated refrigerants could create carbonyl halides if combustion happens in the absence of water vapor. Risks to exposure are most prevalent when torches are used for service and repair of refrigerating equipment. These risks are minimized through properly recovering refrigerant prior to service work and proper ventilation in the service area.

Refrigerant Comparisons			
Refrigerant Number	**R-410A**	**R-32**	**R-454B**
Safety Classification	A1	A2L	A2L
Refrigerant Composition	50% R-32 (HFC) 50% R-125 (HFC)	100% R-32 (HFC)	68.9% R-32 (HFC) 31.1% R-1234yf (hydrofluoroolefin, or HFO)
Lower Flammability Limit (LFL)	–	14%	11%
Upper Flammability Limit (UFL)	–	29%	22%
Auto-Ignition Temperature	–	648°C	496°C
Hot Surface Ignition Temperature	–	> 800°C	> 800°C
Minimum Ignition Energy	–	30–100 MJ	100–300 MJ
Heat of Combustion	5.91 MJ/kg	9.5 MJ/kg	9.9 MJ/kg
Burning Velocity	–	6.7 cm/s	5.2 cm/s
Products of Thermal Decomposition	Hydrogen fluoride	Hydrogen fluoride	Hydrogen fluoride
Products of Combustion	Hydrogen fluoride, Carbonyl fluoride	Hydrogen fluoride, Carbonyl fluoride	Hydrogen fluoride, Carbonyl fluoride

Table 1

Outside of direct service operations, there have been no known hydrogen fluoride (HF) exposure incidents in normal operation between the mobile and stationary HVAC/R industries.[3] With proper design and safety measures incorporated into direct gas-fired equipment to avoid flammable concentrations of A2L refrigerants, the exposure risk to HF chemicals hasn't significantly changed with the industry's transition to low-GWP refrigerants.

Flame Expansion and Heat Release

Industry testing documented in AHRI Test Report 8028 sprayed high leak rates of refrigerants at an open 120 kW sand burner in a large open space to observe the flame and the heat release rate.[4] The release rate of refrigerants was close to 50 g/s, which approaches a theoretical heat release rate of 475 kW for complete combustion of R-32 refrigerant. The results of the testing showed that the maximum heat release measured was 80 kW, indicating a 17% effective combustion scenario. The same 80 kW heat release was also observed during testing with R-410A refrigerant. Significant flame expansion wasn't observed for either classification of refrigerant, and the difference in flammability level did not create additional risks. Combustion effectiveness was low because when sprayed out, the refrigerant was not well-mixed with air. Also, the cooled refrigerant chilled the flame through the expansion process, and the local velocity of refrigerant prevented some flammable concentration levels from igniting.

Risk of Fire

The increased risk of fire with A2L refrigerants played out mainly in confined-room testing where leaked refrigerant was stagnant and exposed to high-energy electrical arc devices and open burners.[5] In these scenarios, A2L refrigerants can ignite and propagate. These tests helped solidify the refrigerant charge and room size limits used in product safety standards and building codes to prevent refrigerant from reaching flammable thresholds in confined spaces. Additionally, new mitigation strategies such as air circulation and ventilation can be used to help keep leaked refrigerant well-mixed at low flammability levels and avoid localized high concentrations of A2L refrigerants.

Product Design Safety Features

As part of the direct gas-fired design process for A2L refrigerants, Greenheck has implemented mandatory requirements from the relevant product safety standards and designed additional safety features to address risks. These safety features include limited charge requirements, strategically compartmentalizing components and mounting coils downstream of the burner, and adding refrigerant leak detection systems in key locations.

Table 2 on the next page gives information on specific safety measures and whether they are required by any code or product standard.

Safety Measure	Element of Refrigerant Safety	Required by Code	Required by Product Standard
Air Proving by Pressure Switches	Low- and high-air differential pressure switches guarantee that sufficient airflow is present for the direct gas-fired furnace to operate. Airflow velocities in direct gas-fired equipment need to be around 1,525 cm/s (3,000 ft/min) at the entrance to the burner and transition to typical air-handler velocities of 152 cm/s (300 ft/min) or greater, well above the ignition threshold for A2L refrigerants.	–	ANSI Z83.8
Fan Proving by Variable Frequency Drive	Products will use direct-drive fans with variable frequency drives that verify motor rotation before allowing heat to operate. This is a redundant verification that airflow is sufficiently high and above the ignition threshold for A2L refrigerants.	–	UL 60335-2-40
Heat Exchanger Location/Isolation	Greenheck products place refrigerant heat exchangers downstream of the direct gas-fired furnace to prevent leaked refrigerant from being drawn into the flame during operation. Only the refrigerant heat exchanger tubes are exposed to the burner. All potential leak points such as brazed joints and return bends are compartmentalized to force refrigerant leaks downstream of the furnace or are isolated from the air handling cabinet.	–	ANSI Z83.8
Airstream Refrigerant Detection System	An airstream leak detection sensor mounted by the refrigerant heat exchanger will detect leaks at 12% of refrigerant lower flammability limit (LFL). At this level, the system will disable furnace operation and force the fan to operate to address refrigerant mitigation requirements for the occupied space.	ASHRAE 15 for Ducted Equipment	UL 60335-2-40
Refrigerant Cabinet Leak Detection System	The refrigerant cabinet leak detection sensor will detect leaks at 12% of refrigerant LFL for non-airstream-mounted refrigerant components, and also disable furnace operation and initiate fan operation.	–	UL 60335-2-40
Pre-purge Timing for Furnace Operation	The pre-purge timing of the direct gas-fired furnace provides an additional safety element. It requires several fresh air changes of the air-handling cabinet prior to allowing the furnace to operate. This will force any leaked refrigerant that may have accumulated during off-cycle operation below the LFL threshold of the refrigerant detection sensors. It also acts as a redundant measure to airstream leak detection sensors, coil placement, airflow proving, and fan proving to prevent refrigerant from reaching the burner during furnace operation.	–	ANSI Z83.8
Limited Charge Equipment	The use of microchannel outdoor coils, short piping runs, and relative cooling capacity creates low refrigerant charges. Even in catastrophic leak rate scenarios, the average refrigerant concentrations will be below the refrigerant's LFL due to the dilution from supply airflow.	–	–

Table 2

References

1) Goetzler, Bill, and Matt Guernsey, Sean Faltermeier, and Michael Droesch. ***AHRI Project No. 8016: Risk Assessment of Class 2L Refrigerants in Commercial Rooftop Units.*** Air-Conditioning, Heating, and Refrigeration Institute. 2016. https://www.ahrinet.org/system/files/2023-08/AHRI_8016_Final_Report.pdf

2) Data for Table 1 was derived from multiple sources, including refrigerant manufacturer technical documents as well as reports by the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) and its research division, the Air-Conditioning, Heating, and Refrigeration Technology Institute (AHRTI).

3) "AHRI Refrigerant Webinar Series – Webinar 5: Refrigerant Ignition in Open Flame/Hot Surfaces: Has Anything Fundamentally Changed?" Webinar from Air-Conditioning, Heating, and Refrigeration Institute. October 21, 2020. https://www.ahrinet.org/news-events/events/webinars/ahri-refrigerant-webinar-series

4) Hunter, George. ***AHRI Report No. 8028: A2L Refrigerants and Firefighter Tactical Considerations.*** Air-Conditioning, Heating, and Refrigeration Institute. 2021. https://www.ahrinet.org/system/files/2023-08/AHRI-8028_Final_Report.pdf

5) Gandhi, Pravinray, and George Hunter, Randall Haseman, and Brian Rodgers. ***AHRTI Report No. 9007-01: Benchmarking Risk by Whole Room Scale Leaks and Ignitions Testing of A2L Refrigerants.*** Air-Conditioning, Heating, and Refrigeration Technology Institute, Inc. 2017. https://www.ahrinet.org/system/files/2023-07/AHRI_9007-01_Final_Report_1.pdf

P.O. Box 410 • Schofield, WI 54476
Phone: 715.359.6171 • greenheck.com
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