Odorant Integration for Enhanced Refrigerant Safety

OTS R&D, Inc. (OTS) successfully demonstrated the viability of odorant integration in flammable refrigerants for enhanced leak detection without compromising system performance. Through comprehensive research spanning over two years, multiple testing studies validated that an odorant can be safely incorporated into refrigerant systems, providing a robust 30-50X safety margin on the detectable limit with zero impact on equipment efficiency or delivered capacity.

Problem

The HVAC&R industry is transitioning to flammable refrigerants (R-290, R-32, R-454B) due to environmental regulations requiring low Global Warming Potential (GWP) working fluids. Flammable refrigerants pose obvious safety risks if they leak. While existing electronic leak detection systems can provide some protection, they also have significant limitations including their required calibration and maintenance, risk of false negatives, need for power/battery replacement, and expensive system integration costs. Additional methods for leak detection are of interest, particularly the potential for passive leak detection that works 24/7 without maintenance, alerts occupants immediately upon leak, requires no system modifications, and maintains full equipment performance while enabling safe adoption of environmentally friendly refrigerants.

Project Approach

OTS conducted a comprehensive testing program between 2023-2025 to validate safe odorant integration across multiple system configurations. The research encompassed both fundamental odorant behavior studies and real-world performance validation using six modified residential air conditioner systems (2.5-ton capacity), mini-split heat pump systems (9-12 kBtu/hr), and commercial two-door refrigerated merchandisers with multiple compressor types (pictured in Figure 1).

Figure 1: Refrigerator Test Setup

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The research encompassed two complementary testing phases. The first phase evaluated odorant distribution and stability across 12 unique refrigerant/odorant/oil combinations using R-290 (Propane), R-32, and R-454B refrigerants with dimethyl sulfide (DMS) and methyl ethyl sulfide (MES) odorants at 150-152 ppm-mass concentrations and POE, PAG, and PVE lubricants. This phase used six modified residential air conditioner systems with gas chromatography analysis at 0, 1, and 2-month intervals and sample collection from discharge, suction, and liquid line locations.

The second phase focused on performance validation using two systems: a mini-split heat pump (9-12 kBtu/hr) and a commercial two-door refrigerated merchandiser, both using R-290 with DMS odorant. This performance testing followed industry standards (AHRI 210/240, AHRI 1200, ASHRAE 37, ASHRAE 72) with continuous operation testing up to 6 months and analysis at 0, 1, 2, and 6-month intervals under controlled environmental chamber conditions.

Performance metrics included energy consumption and efficiency (COP), heating/cooling capacity and temperature control, odorant concentration stability over time, detection thresholds relative to lower flammability limits (LFL), and system reliability and component compatibility.

Key Observations

Based on comprehensive measurement and verification activities conducted across all test systems, OTS identified the following key observations for odorant integration:

1. **Zero Performance Impact**: No statistically significant difference between odorized and non-odorized systems. COP values and capacities remained unchanged throughout 6-month testing periods, as seen for energy consumption in Figure 2.

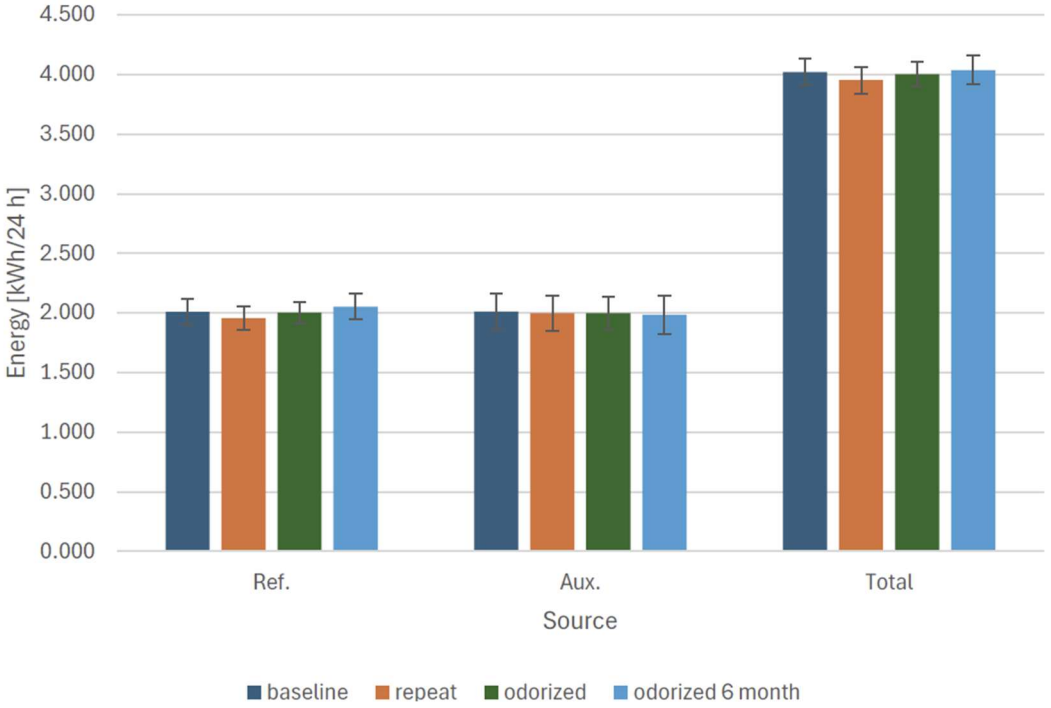
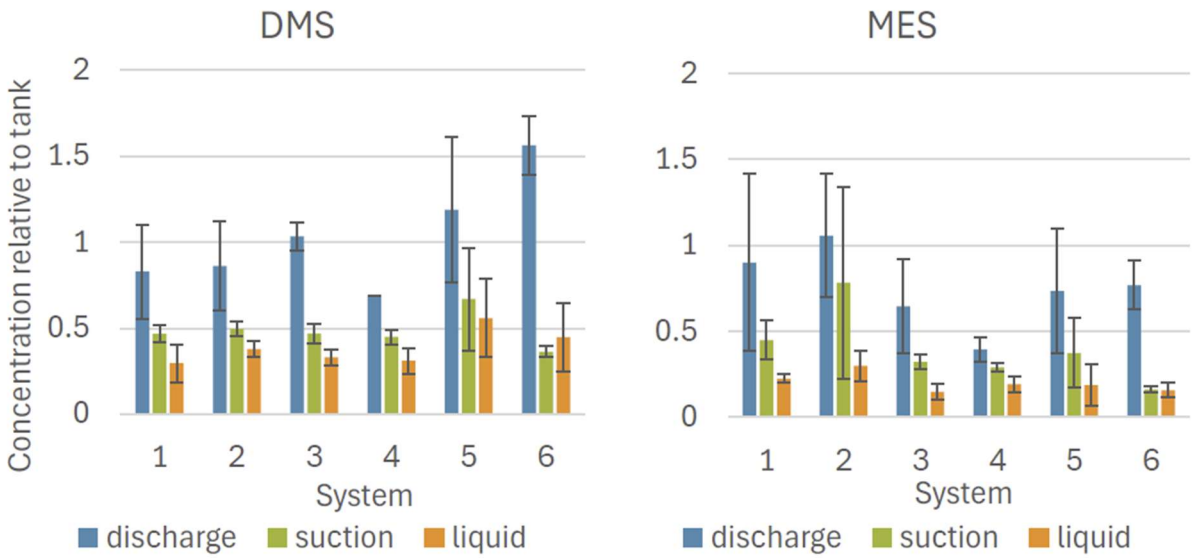


Figure 2: Energy Consumption

2. **50X Safety Margin**: Odorants remain detectable at concentrations 30-50 times higher than human detection limits, even after 6 months of operation, per Figure 3.



3. Figure 3: Average Odorant Concentrations Relative to Initial Tank Concentration by System and Measurement Location (Error Bars Indicate Standard Deviation of Samples)**Long-Term Effectiveness**: Extended operation testing showed no significant decline in odorant effectiveness across R-290, R-32, and R-454B refrigerants with various lubricant types.
4. **Concentration Stability**: Initial system concentrations drop 50-70% from original tank levels due to liquid-vapor partitioning but stabilize and remain effective throughout operation.
5. **System Compatibility**: No adverse effects observed on system components, materials, or refrigerant purity over extended (6-month) operation periods.

Conclusions

OTS demonstrated that odorant integration for flammable refrigerants is feasible with robust durability in detection and no negative performance impacts. While further research is needed to understand longer-term impacts, the research conducted to date is a promising first step to enabling safe adoption of flammable refrigerant use.