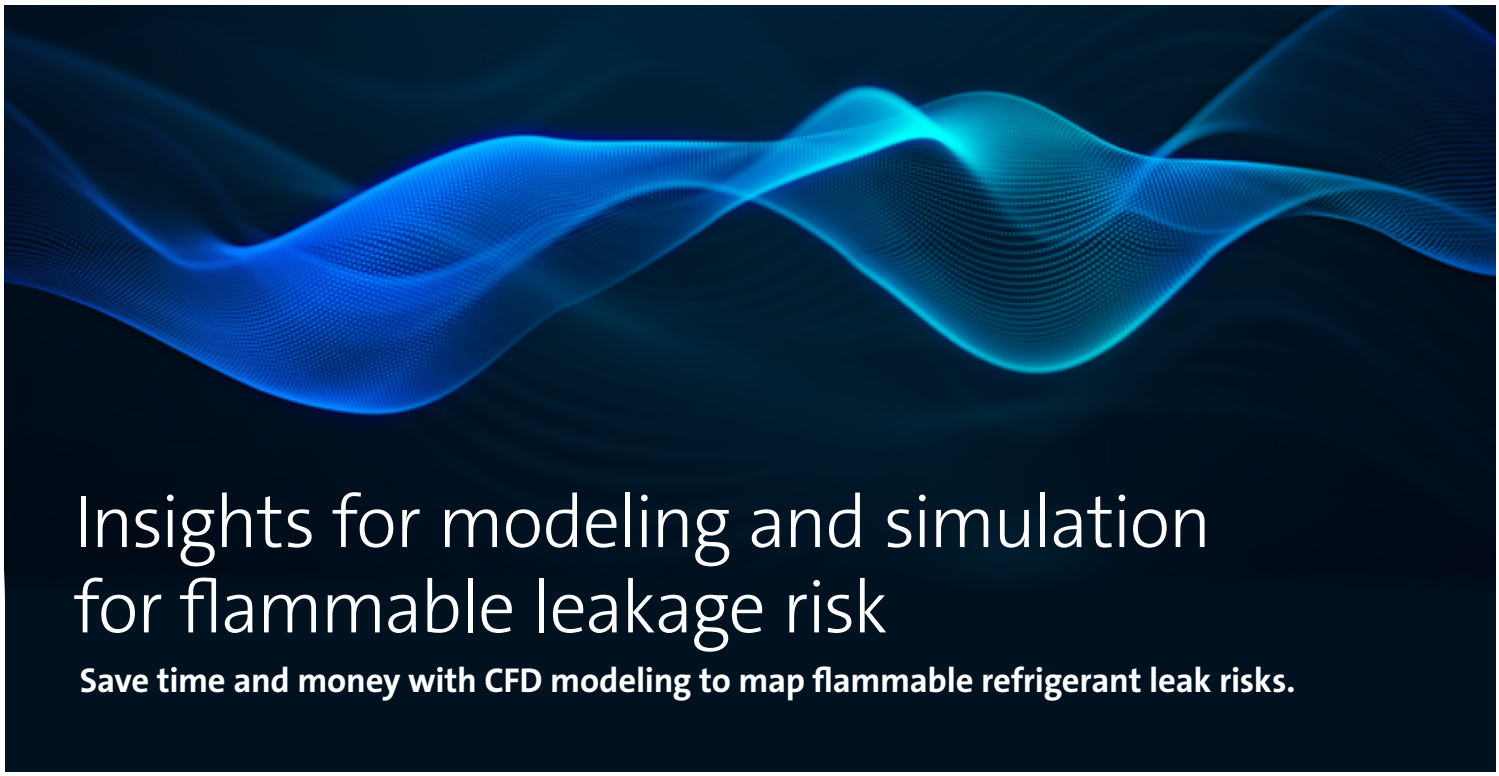

Insights for modeling and simulation for flammable leakage risk

Save time and money with CFD modeling to map flammable refrigerant leak risks.

Modeling and simulation for flammable refrigerants used in HVAC/R

Hydrocarbon-based refrigerants have favorable environmental characteristics. However, they represent an additional layer of risk to be managed by HVAC/R equipment designers due to their flammability if a leak in the refrigeration system should occur.

To understand and address the risks, safety standards such as EN 378, UL/IEC-60335-2-40, the Standard for Household And Similar Electrical Appliances - Safety: Particular Requirements for Electrical Heat Pumps, Air-Conditioners and Dehumidifiers; UL/IEC-60335-2-89, the Standard for Household and Similar Electrical Appliances - Safety: Particular Requirements for Commercial Refrigerating Appliances with an Incorporated or Remote Refrigerant Unit or Compressor; ISO 5149; and ASHRAE 15 prescribe physical test methods. But, a challenge and a limit exist when using physical testing to thoroughly understand the potential risks associated with leakage of a combustible refrigerant in confined spaces. That is why computational modeling tools are a valuable and insightful complement to physical testing.

Physical testing challenges

Physical testing can be time consuming and expensive, especially when using flammable refrigerants, due to the destructive nature of the testing. Each test, in practical terms, is a single data point. Given that many tests must be run to produce the necessary insights for potential risks, this can become an expensive endeavor.
Yet, another limit of physical testing is even more problematic: capturing data is only possible at discrete points in a physical test setup. These discrete points are usually selected to address the specific question the test was designed to answer and so the data collected may not provide sufficient insight into the testing conditions or allow for generalization.

And if this were not enough, another challenge exists for refrigeration systems that operate at high charge levels. The physical testing of such systems for safety can itself require substantial infrastructure that is not commonly available.

UL modeling and simulation services:

- Risk evaluation and mitigation modeling
- Independent model verification and validation
- Virtual testing for certification

The power of modeling and simulation

Computational modeling tools come in many different flavors. From finite element-based to meshless methods, these tools help predict the physical phenomenon in many different disciplines including mechanical, thermal/fluid and electromagnetic.

Over the years, these tools have been used to help understand the risks associated with leakage of combustible refrigerants. For modeling, the key challenge is to validate the simulation, that is, to demonstrate via experimental evidence and rigorous modeling process review that the model predictions are accurate.

To validate our simulations, using computational fluid dynamics (CFD) analysis, we built a model of a testing room and recreated the same leakage scenarios as those conducted using physical tests. In each scenario, we calculated the refrigerant concentrations at specific sensor locations available from the test over the time frame of the test.

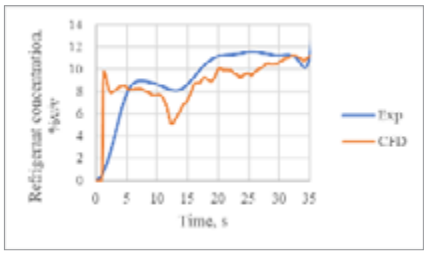

Figure 1: Refrigerant concentration over time

The true power of modeling is that we can go beyond simply looking at the concentration levels within one location or even a handful of locations. The model provides results throughout the test room. Figure 2 shows a visualization of the concentration in a room for one scenario at a point in time.

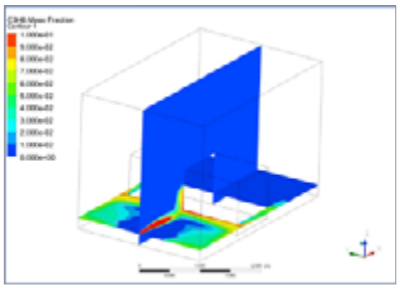

Figure 2: Refrigerant concentration at a specific time on cut planes.

The flammable volume can be quantified over any time frame using data generated by a high confidence CFD model. The use of modeling and simulation coupled with targeted physical testing can provide the insights needed to help ensure safety in equipment design.

Unlocking the value of UL's model verification and validation program

We offer a model verification and validation (MV&V) assessment that helps manufacturers incorporate the predictions from a model to support a certification or safety risk activity. The MV&V assessment is built on standards and best practices gathered from a variety of industry groups and professional associations such as the American Society of Mechanical Engineers (ASME), the International Association for the Engineering Modeling, Analysis and Simulation Community (NAFEMS) and NASA.

As for the specific area of refrigerant fire safety due to gaseous phase leakage, we have shown that modeling and simulation can provide accurate predictions when built correctly. Physical testing is still important and required, but more than generating insights directly to understand a risk, its true value can be found in how it helps advance the use of computer-based engineering modeling and simulation tools. The use of modeling and simulation can certainly reduce your need for physical testing, resulting in reduced development time, effort and cost.

To learn more, visit us at UL.com/LowGWP or contact us today by emailing: HVACInfo@ul.com.

Empowering Trust®