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Sandia National Laboratories

Risk-Informed LNG/CNG Vehicle Codes and Standards

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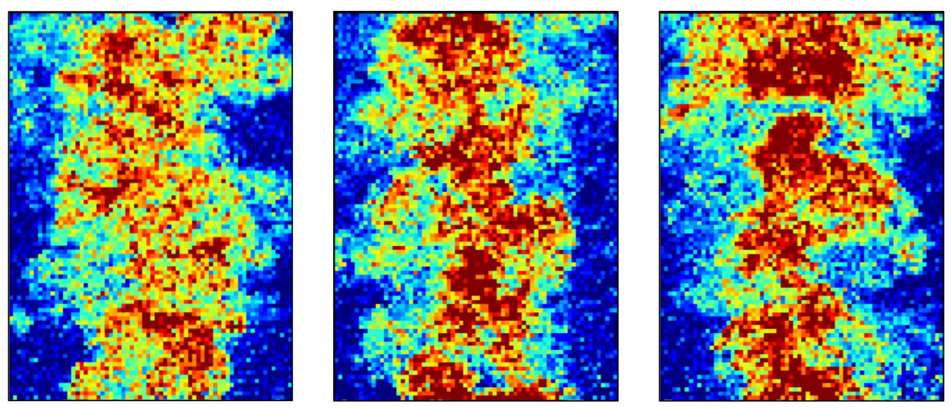
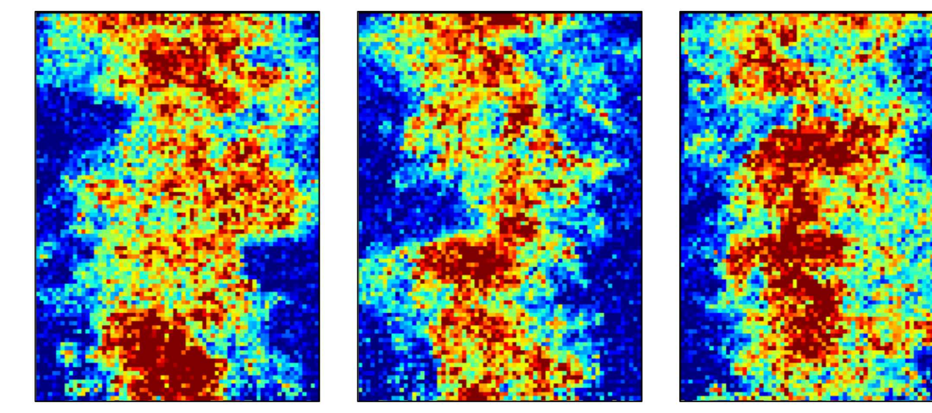
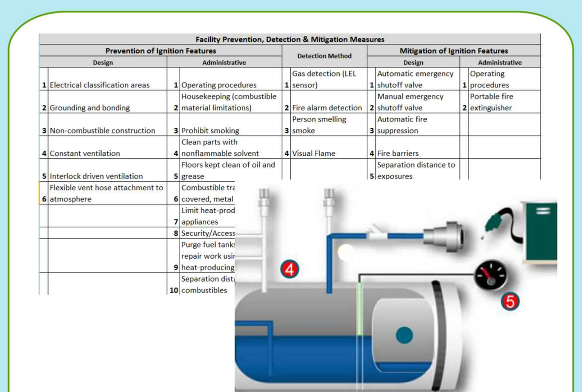




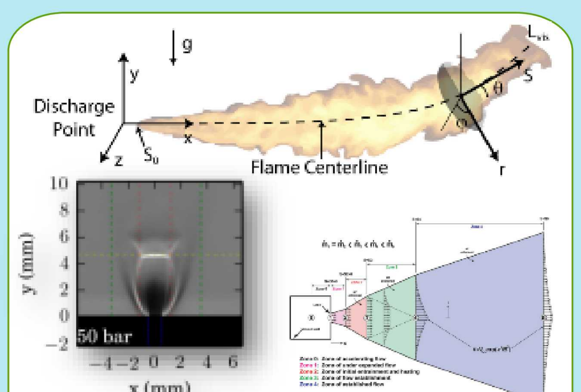
Using scientifically rigorous analysis and modeling to provide technical assistance to DOE, Clean Cities stakeholders, and end-users to address technical challenges in bringing advanced transportation technologies to market.

Overview

- Vehicles using pressurized alternative fuels, such as natural gas and hydrogen, present new and unique safety challenges compared to their liquid fueled predecessors.
- Sandia is using scientific modeling and risk analysis to assess potentially hazardous scenarios involved in using these fuels.
- Significant work has been performed for liquid and compressed hydrogen (LH_2 and H_2) vehicles. Comparable analysis is now taking place for liquid and compressed natural gas (LNG and CNG) vehicles.



Develop risk analysis for determining key, high risk scenarios to further analyze



Develop and validate scientific models to predict hazards from liquid releases, flames, etc.

Apply scientific models to high risk scenarios in alternative fuel operation and infrastructure

Enabling methods, data, and tools for LNG/CNG safety

Scientific, Risk-Informed Process for Improving Codes & Standards

Objective

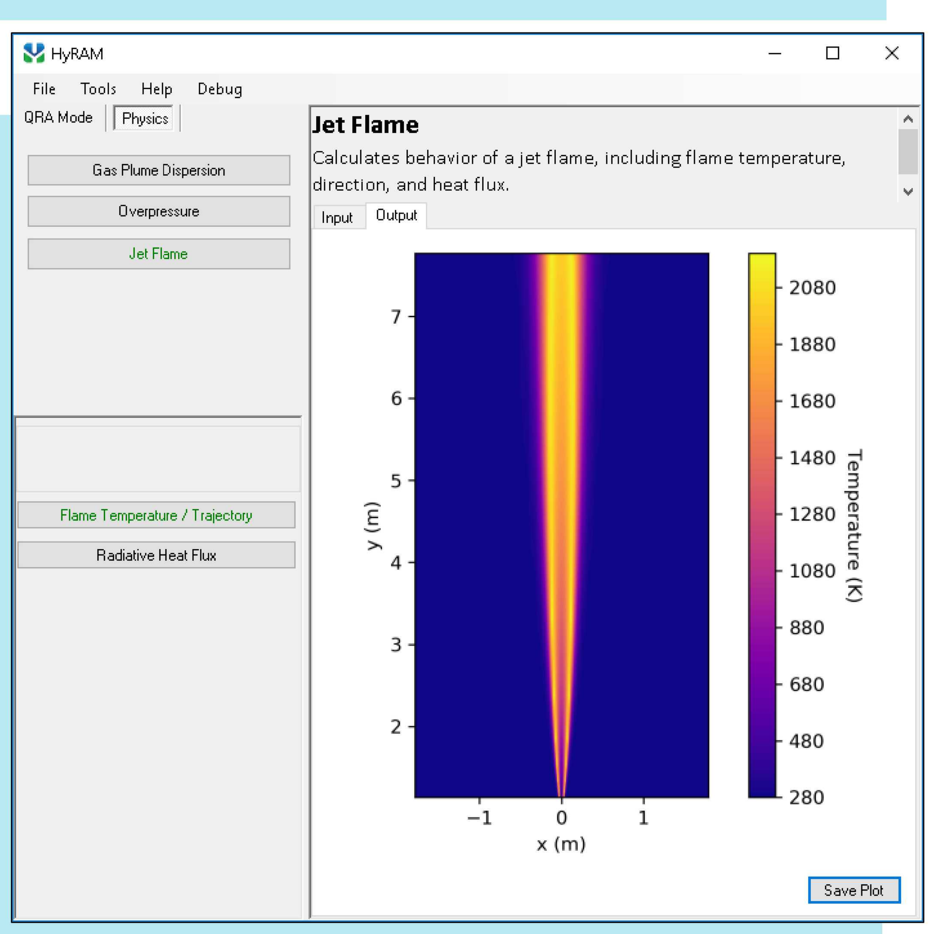
Support LNG and CNG Vehicle Safety Codes and Standards by:

- Adapting H_2 flame physics models to include CNG fuel releases, then using those models to compare CNG and H_2 risks in a worst case, overturned vehicle accident scenario.
- Performing data analysis to experimentally validate LNG cold plume release concentrations obtained from LH_2 cold plume models that have already been adapted to include LNG.

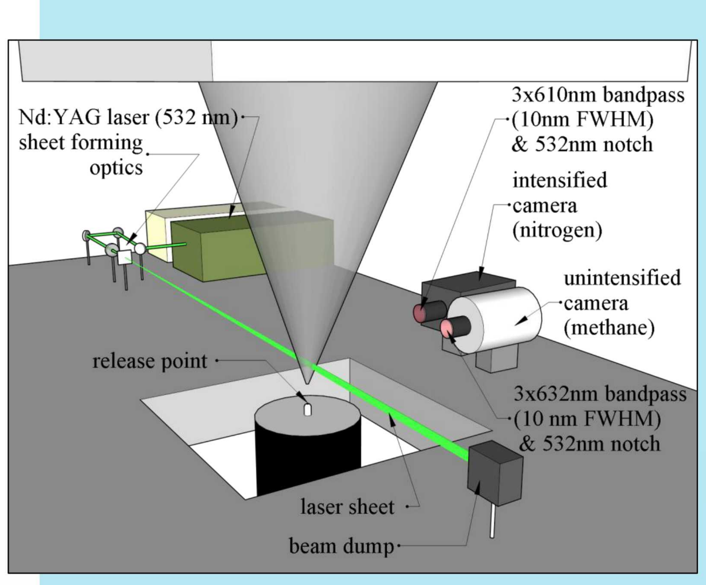
Methods

CNG Model Accident Comparison

- Physical models for characterizing and quantifying hydrogen vehicle hazards have been compiled into an application called HyRAM.
- As part of this work, the HyRAM physical models were expanded to include CNG as a fuel option.
- These models were then used to compare H2 and CNG vehicles in a worst case accident scenario.



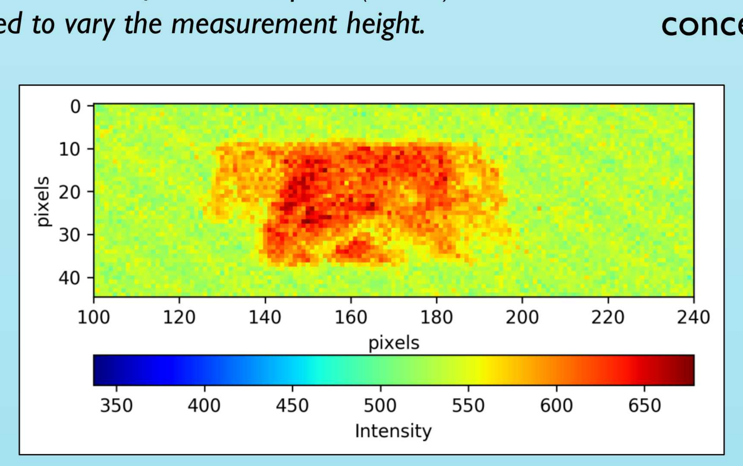
HyRAM is standalone software that incorporates multiple physical models to predict hydrogen risks. The results of a jet flame temperature model are shown.



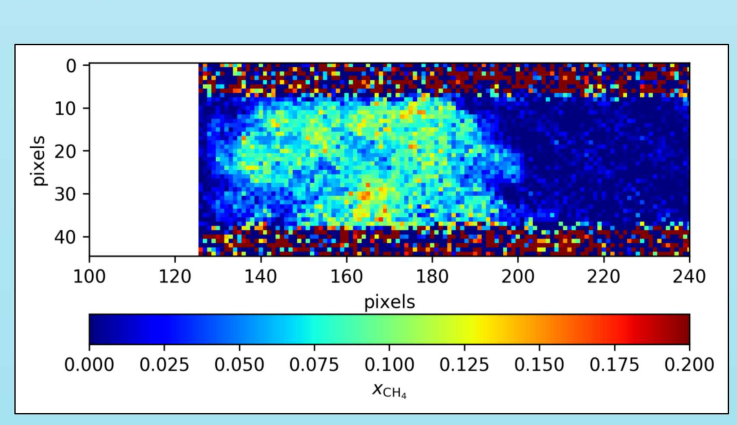
Raman experimental setup for hydrogen and natural gas experiments. The fuel release point (center) can be adjusted to vary the measurement height.

LNG Data Analysis and Model Validation

- The concentration of CH_4 escaping through a small orifice was measured experimentally using Raman scattering.
- The result was then compared to modeled cold plume concentration values.



Example of a raw Raman camera image.

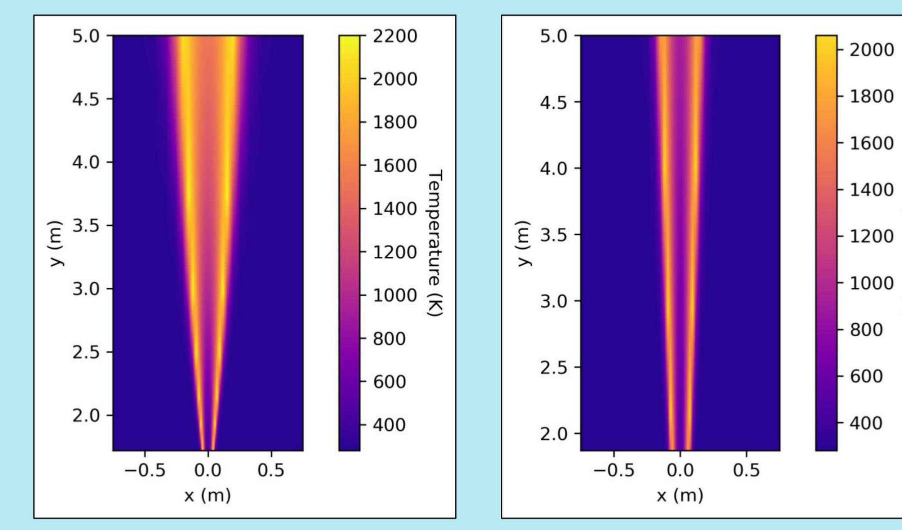


Example of a processed Raman image.

Results

CNG Model Accident Comparison

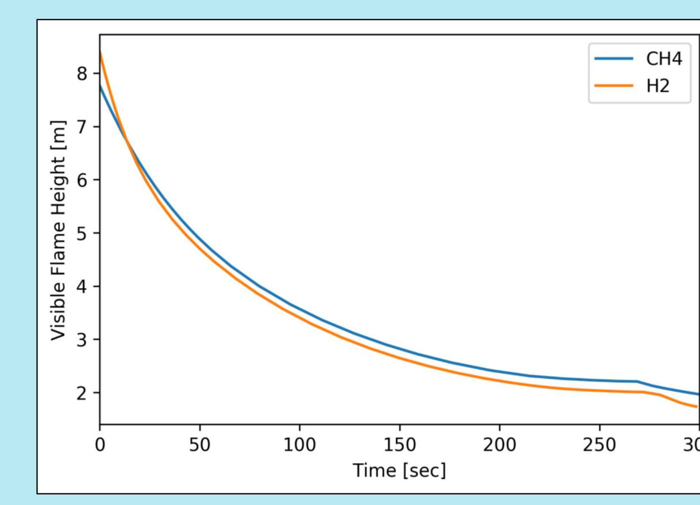
- Using the expanded HyRAM physics models, H_2 and CNG vehicle hazards were compared in a worst case accident. In this scenario the pressure relief device on an overturned vehicle has failed, releasing a jet flame directly at the roof of a tunnel.
- The information obtained from this analysis will be used by other models to compute the heat transferred and resultant damage to tunnel infrastructure and occupants.



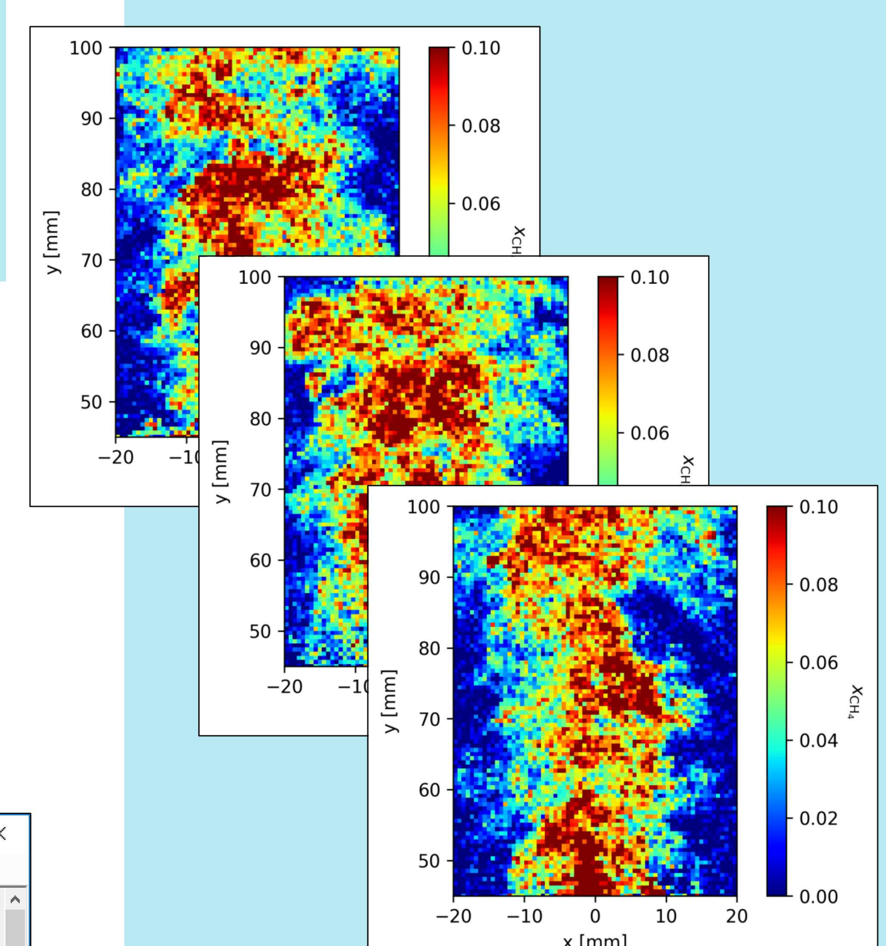
Spatially resolved jet flame temperature through a vertically oriented pressure relief device, for H_2 (left) and CNG (right) per the conditions shown in the table at left.

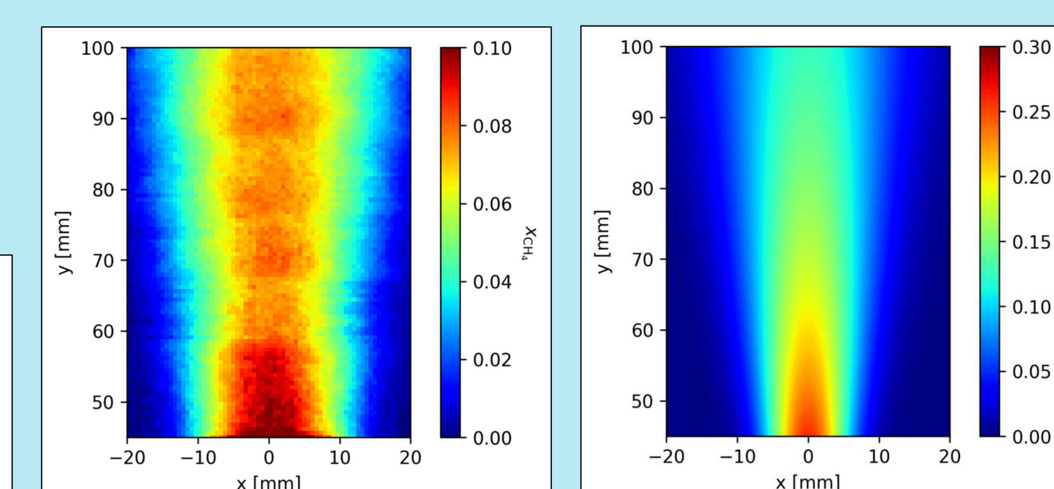
Table of conditions used to generate HyRAM plots shown at right.

	Hydrogen	Natural Gas
Ambient Pressure	101 kPa	101 kPa
Ambient Temperature	15 C	15 C
Tank Temperature	15 C	15 C
Height of leak	1.52 m	1.52 m
Tank pressure	70 MPa	25 MPa
Leak diameter	2.25 mm	6.20 mm
Tank Volume	0.125 m^3	0.370 m^3



Plot of flame length as a function of time for H_2 and CNG per the conditions shown in the table at left.



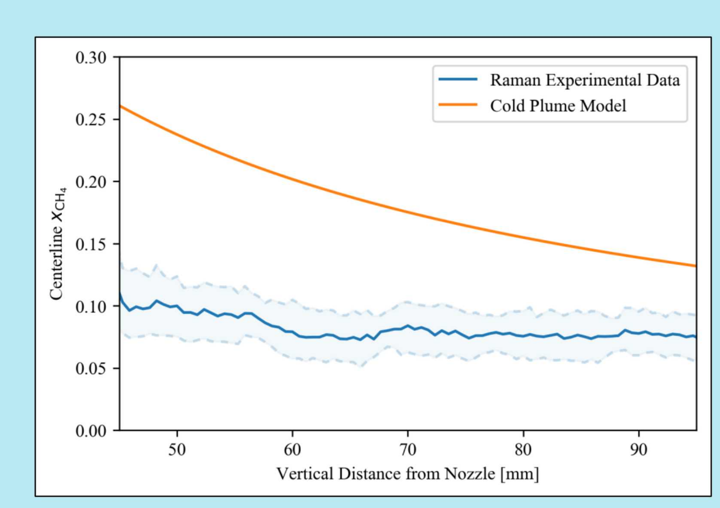


Left: example of three processed Raman images.
Center: averaged Raman image for CH_4 (LNG) molar concentration.
Right: output from the physical model for cold plume (non-reacting) LNG molar gas concentration at conditions matching the Raman measurement. Measured and modeled images are for a LNG 1 bar (gauge) and 180 K exiting a 1 mm diameter orifice.

LNG Data Analysis and Model Validation

- 10 mm tall processed Raman scans were aligned and linked to create an extended image of the escaping LNG plume.
- The results of each scan were averaged to reduce the impact of individual turbulent fluctuations.
- The averaged experimental image, as well as the corresponding average centerline concentration, will be used to validate the cold plume model for LNG releases.

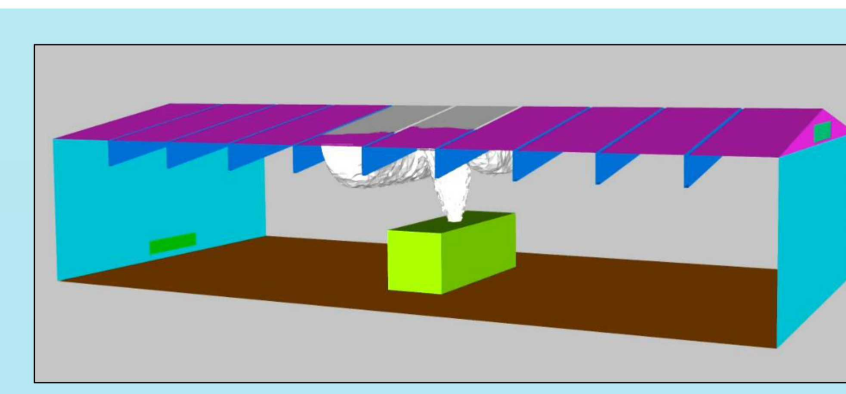
Note that the data processing for these experiments is ongoing. It is anticipated that the measured values will change as the data processing continues.



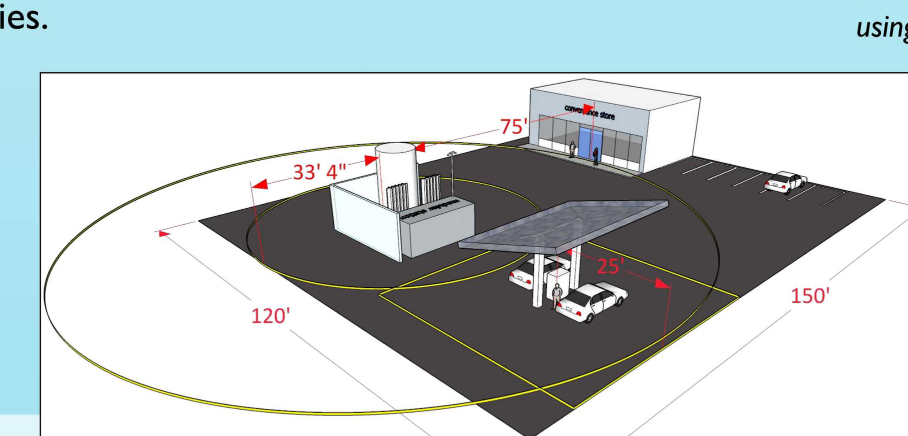
Measured and modeled centerline fuel concentration for a 1 mm diameter orifice venting LNG at 1 bar (gauge). Dashed lines are the 25th and 75th percentile of the measured centerline concentrations.

Conclusions

- CNG and LNG vehicle models have been developed based on existing hydrogen models and validated through experimentation.
- The development and application of these models will assist alternative fuel vehicle stakeholders in understanding hazards and developing risk-informed codes and standards for LNG and CNG vehicles and facilities.



A snapshot of a temporally resolved hydrogen bus tank pressure release device failure in an enclosed maintenance garage created using physical models comparable to those contained in HyRAM.



Sketch of LH_2 fueling station with minimum setback distances marked.

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