HYDROGEN SAFETY CODES AND STANDARDS

Sandia National Laboratories has a rich history of science-based engineering and systems engineering with respect to hydrogen isotopes that has led to impactful work with hydrogen as an energy carrier. Sandia provides deep, quantitative understanding and scientific basis for hydrogen effects on materials employed to produce, store, and use hydrogen. Sandia's expertise extends to risk analysis, the creation of risk-informed standards, and understanding the behavior of hydrogen as a thermofluid.

UNDERSTANDING HYDROGEN EFFECTS, BEHAVIOR, AND RISK

Sandia has a comprehensive understanding of materials' interactions with hydrogen, hydrogen behavior, and risk assessment that is applied to safety codes and standards.

Hydrogen Effects on Materials

Hydrogen degrades mechanical properties by accelerating fatigue crack growth rates and decreasing fracture toughness. Fatigue and fracture data in hydrogen are necessary to assess the structural integrity of pressurized components. Sandia has developed unique testing capabilities to evaluate the mechanical behavior of materials in high-pressure gaseous hydrogen. Our work focuses on optimizing the reliability and efficiency of test methods to generate critical hydrogen compatibility data that can be used as the technical basis for regulations, codes, and standards which are necessary for technology deployment.

Hydrogen Behavior

Hydrogen is a colorless, odorless, flammable gas at room temperature, or an extremely cold (-253°C) flammable cryogenic liquid. A quantitative understanding of the dispersion, flame radiation, and combustion overpressure properties of hydrogen is needed to accurately model different accident scenarios that could develop as hydrogen is used in various applications. We perform novel experiments on high-pressure and cryogenic hydrogen that provide validation data for models and use our experimental results and expertise to guide model development.

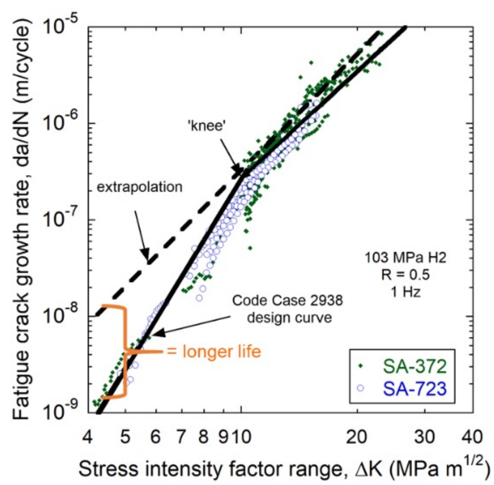
Risk Assessments

Quantitative risk analysis combines behavior and material physics with probabilistic mathematics, providing insights into prevention and mitigation strategies to improve safety. We have incorporated many of our probabilistic and behavior models into the HyRAM+ toolkit that provides a framework and platform for calculations. Risk assessments are critical to enabling new alternative technologies by improving overall safety and informing regulations, codes, and standards.

REGULATION AND CODE APPLICATIONS

Hydrogen Storage Vessel Lifetimes

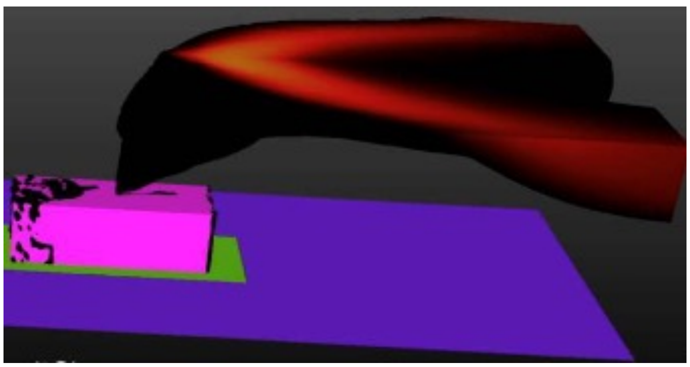
Sandia's work to quantify fatigue in high-pressure hydrogen storage vessels was accepted into the American Society of Mechanical Engineers (ASME) Section VIII Division 3 Code Case 2938 in December 2018 in the form of master design curves. This work applies to steels commonly used in high-pressure hydrogen storage vessels at hydrogen refueling stations. The design curve is the solid line in the figure below which shows better fit to the data and a much lower crack growth rate than the previous design basis (shown in the extrapolated curve). Several case studies have shown that using the Code Case 2938 curves can nearly triple the design life for vessels compared to the previous design basis. Acceptance of this code case harmonizes design curves, removes the need for expensive testing, and reduces cost as it leads to longer pressure vessel life.



Fatigue crack growth rate design curves accepted into ASME Section VIII Division 3 Code Case 2938, DOE Hydrogen Program of Record

Hydrogen Fuel Cell Vehicles in Tunnels

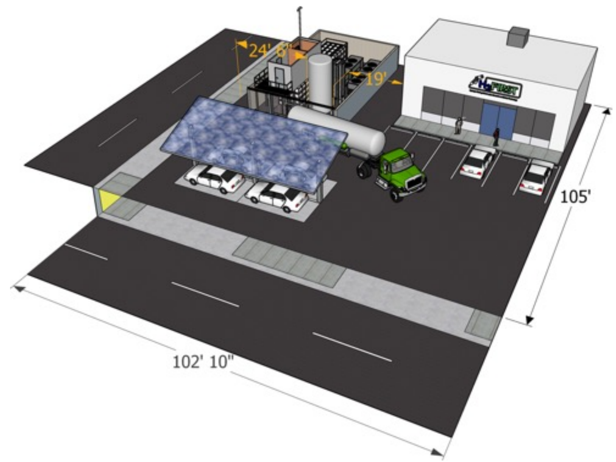
Final regulatory changes in Massachusetts (700 CMR 7.00) now specifically allow private passenger fuel cell vehicles in the Ted Williams and Central Artery North Area (CANA) Tunnels in Boston. These changes went into effect on April 15, 2022 and represent the success of work at Sandia and elsewhere over the past several years. However, it should be noted that other sizes of vehicles are not allowed, and hydrogen vehicles are still disallowed from all other tunnels. Current work is ongoing to provide technical justification to permit fuel cell vehicles in additional tunnels.



Example jet flame plume in a ventilated tunnel to determine fire damage on tunnel ceiling (Source: SAND2017-11157)

Hydrogen Refueling Station Setback Distances

The Technical Committee responsible for the National Fire Protection Association's Hydrogen Technologies Code (NFPA 2) recently accepted revised separation-distance requirements for bulk liquid hydrogen storage systems. These changes reduce the previous 75-foot distance to air intakes by 24%–87% depending on the system parameters. The well documented, risk-informed updates to NFPA 2 enable a reduced footprint for refueling stations and clarifies relevant hazards for future consideration. This accomplishment incorporates risk assessments, behavior models, experimental results, and operating experience to promote safety for liquid hydrogen storage systems through a focus on requirements that enhance safety while allowing for flexibility when safety is unaffected. Sandia developed the underlying calculations and analyses that formed the basis of the revised distances. We collaborated closely with partners from Air Products and Chart Industries, Inc. to develop the analyses, establish independent verification, advance the models, and write code language.



Hypothetical layout of hydrogen vehicle refueling station with compact layout using revised setback distances for liquid hydrogen in NFPA 2

CURRENT R&D

The master design curve concept is being adapted for the blending of hydrogen into existing natural gas infrastructure and future hydrogen dedicated infrastructure. Ongoing experiments with liquid hydrogen and blends of hydrogen and natural gas are providing data for model development and revision. Additional physics and risk capabilities are actively being developed within HyRAM+ including liquid hydrogen pooling, probabilistic modeling of hydrogen release ignition, and the blending of hydrogen with natural gas. Enabling additional HyRAM+ capabilities adds value and relevancy to the quickly emerging alternative fuels economy.

WORK WITH US

Sandia actively seeks opportunities to partner with private companies—large or small—and with state and local government agencies and universities. We offer a wide array of partnership opportunities and strive to cultivate the highest quality relationships with technology partners.

CONTACT:

hydrogen.sandia.gov

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