Hydrogen and Safety

Introduction

With global investment in hydrogen and hydrogen derivatives expected to triple from 2025 to 2030 and grow tenfold from 2030 to 2050 – to a projected $10TN annually, many people are asking important questions about hydrogen safety. The good news is that hydrogen and hydrogen safety management are well-known and well-appreciated. This paper addresses some of the key facts about hydrogen and hydrogen safety.

Hydrogen

- The most abundant element in the universe
- The smallest and lightest molecule
- Very diffusive in air
- Non-toxic

Hydrogen Combustion

- Hydrogen combustion has 1/3 the energy content of natural gas combustion on a volumetric basis.
- The temperature of hydrogen flame can be up to ~ 450 degrees F greater than the peak flame temperature of natural gas (in air)
- Hydrogen flames are soot-free and emit less thermal radiation than a natural gas flame.
- Hydrogen has a faster flame velocity compared to natural gas.
- If leaked, the highly diffusive nature of hydrogen (3.6x greater than natural gas) reduces the likelihood of accumulation into a flammable mixture.

Hydrogen Handling and use

Hydrogen has been in use as fuel successfully for many years. During this time, safe design and handling practices have been codified in law worldwide. This includes equipment design and operation, storage design and operation, and transportation.

From the early 1800s until the mid-1900s, manufactured "town gas" fuels, comprised of ~50% hydrogen by volume, were distributed to homes and businesses for cooking and heating. Town gas was made primarily from the volatile by-products of coal. The large amount of hydrogen in the gas was considered desirable since leaks were quickly dissipated into the air.

The advent of large-scale refining and petrochemicals manufacturing as well as advanced metallurgical production methods have now made pure compressed or liquefied hydrogen a commodity product.

Many important industrial processes utilize hydrogen at high pressures and temperatures in the presence of reactive materials. Space launch vehicles may be powered by hydrogen, and hydrogen-powered fuel cells are deployed in automobiles, spacecraft, and stationary applications. Where on-site hydrogen production is not available, gaseous hydrogen is transported via pipeline (close to 1500 miles in the United States alone), on public roads by truck, and even via railcars. Cryogenic liquefied hydrogen is moved via truck, rail, barge, and (recently) a commercial tanker that traverses oceans. Bulk and local hydrogen storage vessels are likewise common at sites of production, distribution, and end-use. In many cases, hydrogen involves a combustion process to utilize the energy contained in the hydrogen. Today, over 75 million metric tons (75 billion kg) of pure hydrogen (and 45 million tons more of hydrogen-containing mixed gases) are produced and consumed each year (source), and that amount has been projected to quadruple by 2030 (source). Below are some of the more important US references for handling hydrogen. These have been established by written best practices and standards as codified by federal law and/or required by local Authorities Having Jurisdiction (AHJs).

> Title 29 of the United States' Code of Federal Regulations (CFR), § 1910.103 (part of the Occupational Safety and Health Standards) mandates that ASME Pressure Vessel and ASME/ANSI piping codes be used for hydrogen-containing equipment. Regulations within Subtitle B of Title 49 (overseen by the Department of Transportation) list specific requirements for shipping and (un)loading of cryogenic and compressed hydrogen by truck, rail, and waterways via the Pipeline and Hazardous Materials Safety Administration (PHMSA) and Federal Motor Carrier Safety Administration (FMCSA). NFPA 2: Hydrogen Technologies Code, which many have adopted for their local codes, aims to establish a comprehensive set of safety standards for all aspects of hydrogen use, and NFPA 55: Compressed Gases and Cryogenic Fluids Code specifies measures for protecting from the explosive and flammability hazards associated with hydrogen in compressed and liquefied forms. The Compressed Gas Association's CGA G-5.5 Standard for Hydrogen Vent Systems and CGA S-1.1 Pressure Relief Device Standards-Part 1-Cylinders for Compressed Gases are incorporated by reference in CFR Title 49 and NFPA documents. By following these and other safety codes and best practices such as conducting a process hazards analysis (PHA) review ahead of adopting new procedures or equipment, those within the hydrogen space can expect their operations to be safe and reliable.

Applicable regulations can also be found on the HTLLC website.

The HTLLC boilers and auxiliary equipment are designed to meet prevailing safety standards and best practices. HTLLC has built safety into all aspects of our boiler design. Most prominently have designed our combustion system so that the hydrogen and oxygen are prevented from mixing until they reach the combustion chamber. The metallurgy of every component of our boiler is appropriate to its use, and our control systems are integrated and redundant. Our partners have been selected not only for their high-quality products but also for their commitment to safety.