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Statistics And Lessons Learned: Insights From Analysis Of Fuelling Station Component Failure Events In HyCReD

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Hydrogen technologies are expected to play a key role in enabling renewable energy integration into the power sector as well as the decarbonization of key end-use applications such as heavy-duty transportation and industrial energy use. Despite the advantages of hydrogen, its unique properties, compared to traditional fuels, require may affect its safe use and wider acceptance. Thus, thorough investigations of safety, risk, and reliability issues in hydrogen systems will be critical to ensuring their safe and profitable operation. An important tool to address these issues is quantitative risk assessment (QRA), which has been applied to many systems including hydrogen fueling stations. However, QRA studies require system-specific reliability data which is currently lacking for hydrogen technologies. To address this gap, the University of Maryland and the National Renewable Energy Laboratory have developed and validated a structure for a hydrogen component reliability database (HyCReD) (Groth et al., 2024). The HyCReD structure leverages a hydrogen fueling station system taxonomy, failure modes, and component failure mode hierarchy developed by (West, 2021). HyCReD is being used to collect and analyze hydrogen component reliability data to be used in QRA and reliability engineering studies, and is being piloted currently for hydrogen fueling stations.

In this work, we present initial results from 30 fueling station incidents that were entered into the database to demonstrate and validate the structure. These events were extracted from a number of sources including H2Tools Lessons Learned (Pacific Northwest National Lab, 2021) and the Hydrogen Incident and Accident Database (HIAD) (European Hydrogen Safety Panel, 2019; Wen et al., 2022). Using the fueling station system taxonomy, we determined that the two leading subsystems in which failures occurred were the dispensing process and bulk storage accounting for 40% and 27% of the events, respectively. Within the dispensing process subsystem, the leading functional group in terms of failure events was dispensing which contains components such as the hose and nozzle. For bulk storage, the containment functional group, which includes gaseous hydrogen storage tanks, was where most failure events occurred. These functional groups accounted for 75% of the events in each subsystem, indicating the importance of the components in those groups. A pie chart illustrating the breakdown of events by subsystem and functional group is shown in Figure 1a.

In addition to system information, our analysis indicated that the dominant overall failure mode was an external leak of hydrogen to the environment, with the 19 events accounting for nearly 65% of the events analyzed. Furthermore, we identified that the two dominant mechanisms for an external leak of hydrogen were leakage and mechanical failure, accounting for nearly 50% and 25% of the 19 events. While this analysis presents overall failure modes and mechanisms, additional data provided by partners will lead to identifying modes and mechanisms for each component in the fueling station. Figure 1b shows the breakdown of failure mechanisms for the external leak of hydrogen failure mode.

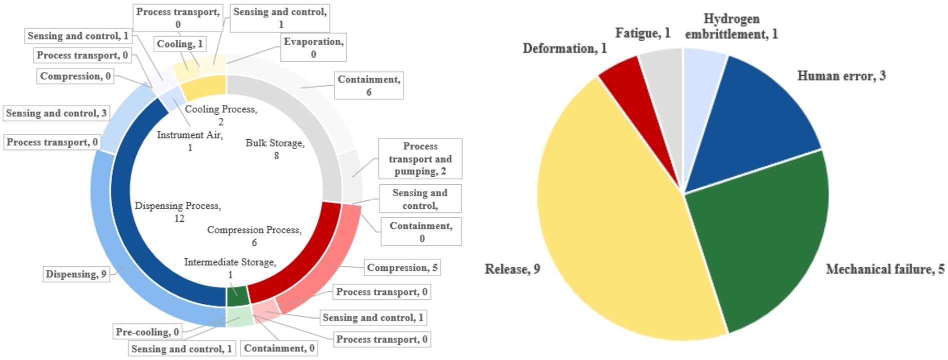

Fig. 1. (a) Breakdown of current HyCReD component failure events by fueling station subsystem and functional group. (b) Breakdown of failure mechanisms for the "External leak of hydrogen" failure mode in HyCReD

The initial results show that the HyCReD taxonomy and reporting structure provide important, detailed insights into the dominant reliability concerns for hydrogen fueling stations. We are actively seeking more participants to provide data for us to code; with more events from participants, we can obtain the first hydrogen-specific component failure rates. These results will provide actionable reliability engineering-based insights to enable prioritizing maintenance activities, eliminate costly downtime, and improve future station designs.

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