HYDROGEN Safety Panel

SAFETY PLAN REVIEW

FirstElement Safety Plan Review

Submission for the California Energy Commission General Funding Opportunity GFO-15-605

Background

At the request of the California Energy Commission, members of the Hydrogen Safety Panel (HSP) reviewed the FirstElement Fuel (FirstElement) Hydrogen Safety Plan. The Panel's feedback on the plan is summarized below, followed by specific comments on the plan. Annex A provides the Panel's evaluation on how adequately the safety plan addresses the required topics.

Summary of Results

The safety plan follows the formatting identified in the HSP safety planning guideline document. While the project team appears to have the necessary expertise and experience, the plan lacks important project-specific detail (an example fueling station "what if" analysis was provided, but no accident scenarios or key vulnerabilities specific to this project were included – see Comment #2). As result of the lack of project-specific detail, the HSP team members could not perform a thorough review of the applicant's submission, and therefore, the safety plan is incomplete, but promising.

Comments

The following comments include specific observations and recommendations that the HSP review team believes will result in a safer hydrogen fueling station. Many of the comments are based on the lack of detail in the safety plan and do not necessarily reflect inadequate safety planning. Alternative approaches may result in a station with equivalent safety, and these specific recommendations are not intended to limit the approach taken by the project team. The project team is encouraged to consider these comments early in the design of the hydrogen fueling station.

Comment 1: Section A.2.a, Organizational Policies and Procedures, discusses how the employees and contractors are trained and how safe work practices occur, and how these tasks are communicated. However, there is no mention of the procedures to be used (e.g., piping design, lockout/tagout, operational readiness Inspections, pressure testing).

Comment 2: Section A.3.a and A.3.b – It is not clear from the text whether the ISV and Risk Reduction information provided consists only of examples or demonstrates analysis done for this project and the intended equipment/locations. ("Appendix A shows an example of an ISV done for a fueling station using the what If analysis. In Appendix B, a HAZOP study is illustrated for a piece of equipment used for the fueling station.") Without a clear statement otherwise, the reviewers have assumed that these are only examples of what will be done, rather than what has been done for the proposed locations. Additional specific comments on the project's risk analysis and risk reduction approaches are as follows:

A. What if Analysis: In general, the what if analysis was confusing, as the nodes were sometimes aligned with consequences or end effects, such as Node 10, Fire & Explosion (consequences), and Node 11, Effect on the Facility or

Surroundings (end effects). Typically, what if analyses start with questions based on the cause, such as[1]:

- What if there is a failure to follow procedures or procedures are followed incorrectly?
- What if procedures are incorrect or the latest procedures are not used?
- What if operators are inattentive or an operator is not trained?
- What if procedures are modified due to upsets?
- What if a process condition is upset?
- What if there is an equipment failure?
- What if instrumentation is miscalibrated?
- What if there are de-bugging errors?
- What if utilities such as power, steam, or gas fail?
- What if there are external influences such as weather, vandalism, or fire?
- What if there is a combination of events such as multiple equipment failures?

B. HAZOP: Although the example provided gives an idea of the parts of the HAZOP, there is no analysis on whether the scenario is of high, medium, or low frequency or consequence. This analysis will assist in risk ranking the scenarios to determine where to best allocate time and resources. In addition, the HAZOP included only process "Sampling System." Significant accident scenarios for the entire system are needed to evaluate of the adequacy of the HAZOP.

C. The what if analysis and HAZOP provide examples of each, but not enough specifics to fully cover the fueling stations. The what if analysis is provided for a sample fueling station, but the HAZOP covers only one piece of equipment (hydrogen sampling). More details are needed to ensure major safety aspects are covered. For instance, how is the public protected from a hose rupture during a refill?

D. Risk Reduction: Once the significant accident scenarios are identified, a discussion on reducing the risk for those scenarios is needed (the action required portion of the HAZOP).

E. Appendix A, What If Analysis:
    1. Some of the "what if" entries are vague. For example, does the ESD entry mean what if the ESD functions, does not function, is not present?
    2. Some of the "what if" entries include safeguard statements that belong in the safeguard column.
    3. Although referenced in the body of the submission, the what if analysis does not include scenarios related to the offloading of tube trailer hydrogen, e.g., hose failure (similar to a Praxair incident in New York).

[1] TM Dougherty. 1999. *Handbook of Occupational Safety and Health*, Second Edition, Chapter 6, Risk Assessment Techniques. Diberardinis (ed.). John Wiley and Sons, Hoboken, NJ, pp. 127-178.

4. For node 1, item 1, consequence 1 should include a reference to the pressure relive valve (PRV) set at the maximum allowable working pressure (MAWP) as a safeguard.
5. For node 1, item 1, consequence 1, safeguard 3 should mention that hydrogen deflected upward is toward open space, not to some other elevated ignition source. Same comment for item 2, consequence 1, safeguard 5.
6. For node 1, item 1, consequence 5 should list the multiple failure safeguards.
7. For node 1, item 6, consequences 1 and 2 should indicate that other wetted parts such as valves, PRVs, and sensors have also been vetted for hydrogen embrittlement susceptibility (similar to a Linde PRV failure in California).
8. For node 2, item 1, consequence 3 should list the use of normally closed valves as a safeguard.
9. For node 7, item 5, there is no mention of consideration of the use of thermally activated pressure relief devices to protect storage.

F. Appendix B, HAZOP:
   1. For node 1, there is no indication of the fueling receptacle's rating (i.e., is it H70 or is an H35 unit also available?).
   2. For node 1, does the pressure regulator have a PRV? Or is the downstream rupture disk used to protect the regulator? If the latter, the project team should carefully consider the use of rupture disks due to their unreliability.
   3. For node 2, it is recommended that the project use PRV instead of a rupture disk to protect pressure regulator (PCV_1) to mitigate potential for uncontrolled release of hydrogen. The plan does not mention the activation pressure of the rupture disk and how this compares to the MAWP of the sampling cylinder (T_H2).
   4. For node 3, is the vent hose (FH_3) conductive?

Comment 3: Section A.3.c, Operating Procedures, discusses maintenance procedures, but there is no mention of design, onsite or construction, or ongoing operations, such as an operational readiness inspection, pressure testing, and drawing reviews. Site evaluation methods and approvals are covered in Section A.4.b, Safety Reviews, and Section C, Additional Documentation. Items that should be covered in the operating procedures include:

- Steps for each operating phase, such as startup, normal operation, normal shutdown, emergency shutdown
- Operating limits
- Safety systems and their functions
- The need to update operating procedures promptly to reflect changes to chemicals and other materials, equipment, technologies, and facilities

Comment 4: Section A.3d, Equipment and Mechanical Integrity, seems to focus on maintenance — there is no mention of proper design principles, testing, or commissioning. The following should also be included:

- Calibration of sensors
- Test/inspection frequency basis
- Documentation

Comment 5: Section A.3.e, Management of Change (MOC) Procedures – Based on information provided in this section and Appendix H, it is not clear that the project team is adequately providing a robust management of change process. The information provided suggests that this is a distinct program/form/process, rather than an approach integrated into design, maintenance, and modification activities. Specific concerns include:

- Section A.3.e appears to indicate that only changes to the station manual are required to have a MOC process. The project team should have a MOC process that will be used to review proposed changes to materials, technology, equipment, procedures, personnel, and facility operation for their effect on safety vulnerabilities.
- Page 56 (Appendix H) indicates that "If the change is for an in kind item or process, then the MOC is not needed. For example, if valve is changed for the exact same valve but from a different manufacturer." This approach is not consistent with the recommended approach found in the safety planning document (https://h2tools.org/sites/default/files/Safety_Planning_for_Hydrogen_and_Fuel_Cell_Projects-March_2016.pdf), which states “if a regulator was replaced with a different model, or one that was constructed of a different material, that would require a documented management of change.”
- Page 56 (Appendix H) states that the “MOC [is] not applicable In this instance the manager deemed the change not feasible for many reasons such as: Cost, Benefit, Practicality or Safety.” Is the intent that the change is “rejected” rather than “not applicable”?
- Page 57 (Appendix H) suggests that the potential impact on the ISV is not considered until the final review. That may be too late in the process to consider the effect of the changes on the original hazard assessment.

Comment 6: Section A.4.a, Training – The safety plan should discuss what training is provided for personnel involved in operating the hydrogen station (facility owners, station attendants, etc.).

Comment 7: Section A.4.b, Safety Reviews – The safety review process does not address safety reviews beyond the activities associated with equipment siting. As discussed in the safety guidance document (https://h2tools.org/sites/default/files/Safety_Planning_for_Hydrogen_and_Fuel_Cell_Projects-March_2016.pdf), the safety plan should describe safety reviews that will be conducted for the project during the design, development, and operational phases, including frequency. The involvement and responsibilities of individual project staff in such reviews and how the reviews will be documented should be included. The ISV is expected to be one of the safety reviews performed for the

project. Other safety reviews may be needed during the life of the project, including those required by organizational policies and procedures.

Comment 8: Section A.4.c, Safety Events and Lessons Learned, provides a suitable reporting structure. However, the back end of implementing lessons learned is vague and the means to drive the lessons learned permanently into the culture is not addressed well. The project team should also consider reporting near misses and incidents to the Lessons Learned database (https://h2tools.org/lessons).

Comment 9: Section A.4.d, Emergency Response, provides a fairly complete example of the Emergency Response Manual, but should also describe the emergency response procedures that are in place, including communication and interaction with neighboring occupancies and local emergency response officials.

Comment 10: Section C.1, Additional Documentation, shows a flow diagram with the high-pressure buffer accepting gas from the gas panel, but no return to the gas panel and on toward the hydrogen heat exchanger. Is this an oversight in the drawing?

Comment 11: Appendix I, Section 3.2.1, Properties of Hydrogen – The flammability limits of hydrogen in air are incorrect. The correct value is 4% to 75%.

Comment 12: Appendix I, Section 3.2.3, Extinguishing a Hydrogen Fire and 3.6.3, Hazard Mitigation – Are all parts of the station located within a 2-hour rated fire barrier (or is this referring to the bulk storage system, including any tube trailers)? Dispensers are typically outside the barrier and vent/relief lines routinely exceed the height of the fire barrier.

Comment 13: Appendix J does not mention how hydrogen compatibility will be demonstrated for selected materials, e.g., per CSA CHMC 1 and by reference to materials specified in Table B2 in SAE J2579 (Section 3.2.1).

Comment 14: Appendix M does not list several key design codes and standards, e.g., ANSI HGV 4.2 (fueling hoses) and HGV 4.4 (breakaways).

Comment 15: Appendix N – It is not clear from the training matrix what, if any, hydrogen safety training is provided for station operators and maintenance personnel.

Comment 16: Appendix O – The reporting/recording criteria only applies to personnel injuries. Are there any criteria or requirements for unintended hydrogen releases and fires?

Comment 17: Appendix R – The site evaluations are well done, but the delivery vehicle is not shown and the fill connection is not taken into account (as required by NFPA 2, 7.3.2.3.1.1.)

Comment 18: Appendix R – Some of the fueling stations' hydrogen supply locations (including storage tanks and hydrogen equipment enclosures) do not appear to have adequate separation distances to exposures in accordance with NFPA 2. Final siting locations should be in accordance with NFPA 2 or have locations approved by the AHJ based on a technically justified alternative methodology.

ANNEX A: CEC Safety Plan Review Checklist

This checklist is a summary of desired elements for safety plans taken from Safety Planning for Hydrogen and Fuel Cell Projects – March 2016.[2] The checklist is intended to help project teams verify that their safety plan addresses the important elements and can be a valuable tool over the life of the project. The items below should not be considered an exhaustive list of safety considerations for all projects.

GFO SUBMITTER OR TITLE: FirstElement Fuel
DATE: December 20, 2016

Element	The Safety Plan Should Describe	Adequately Addressed? (Yes or No)
Scope of Work	• Nature of the work being performed	Yes
Organizational Policies and Procedures	• Application of safety-related policies and procedures to the work being performed	Yes
Hydrogen and Fuel Cell Experience	• How previous organizational experience with hydrogen, fuel cell and related work is applied to this project	Yes

Identification of Safety Vulnerabilities (ISV)	• What is the ISV methodology applied to this project, such as FMEA, What If, HAZOP, Checklist, Fault Tree, Event Tree, Probabilistic Risk Assessment, or other method
	• Who leads and stewards the use of the ISV methodology
	• Significant accident scenarios identified
	• Significant vulnerabilities identified
	• Safety critical equipment
	• Storage and Handling of Hazardous Materials and related topics
	  ○ ignition sources; explosion hazards
	  ○ materials interactions
	  ○ possible leakage and accumulation
	  ○ detection
	• Hydrogen Handling Systems
	  ○ supply, storage and distribution systems
	  ○ volumes, pressures, estimated use rates
		No

Risk Reduction Plan	• Prevention and mitigation measures for significant vulnerabilities	No
Operating Procedures	• Operational procedures applicable for the location and performance of the work including sample handling and transport • Operating steps that need to be written for the particular project: critical variables, their acceptable ranges and responses to deviations from them	Yes with comments

[2] https://h2tools.org/sites/default/files/Safety_Planning_for_Hydrogen_and_Fuel_Cell_Projects-March_2016.pdf

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Element	The Safety Plan Should Describe	Adequately Addressed? (Yes or No)
Equipment and Mechanical Integrity	• Initial testing and commissioning • Preventative maintenance plan • Calibration of sensors • Test/inspection frequency basis • Documentation	Yes with comments
Management of Change Procedures	• The system and/or procedures used to review proposed changes to materials, technology, equipment, procedures, personnel and facility operation for their effect on safety vulnerabilities	Yes with comments
Project Safety Documentation	• How needed safety information is communicated and made available to all participants, including partners. Safety information includes the ISV documentation, procedures, references such as handbooks and standards, and safety review reports.	Yes
Personnel Training	• Required general safety training - initial and refresher • Hydrogen-specific and hazardous material training - initial and refresher • How the organization stewards training participation and verifies understanding	Yes with comments
Safety Reviews	• Applicable safety reviews beyond the ISV described above	Yes with comments
Safety Events and Lessons Learned	• The reporting procedure within the team • The system and/or procedure used to investigate events • How corrective measures will be implemented • How lessons learned from incidents and near-misses are documented and disseminated	Yes with comments
Emergency Response	• The plan/procedures for responses to emergencies • Communication and interaction with local emergency response officials	Yes with comments
Self-Audits	• How the team will verify that safety related procedures and practices are being followed throughout the life of the project	Yes