HYDROGEN
Safety Panel

Simplified Safety Planning for Low Volume Hydrogen and Fuel Cell Projects

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PNNL-31037

DISCLAIMER

PACIFIC NORTHWEST NATIONAL LABORATORY
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Table of Contents

List of Tables

Attachments

Terms and Units

DOE	Department of Energy
g/hr	gram per hour
HSP	Hydrogen Safety Panel
ISV	identification of safety vulnerabilities
kPa	kilopascal
lb/hr	pound per hour
NFPA	National Fire Protection Association
PNNL	Pacific Northwest National Laboratory
psig	pounds per square inch gauge

A. Introduction

Safe practices in the production, storage, distribution, and use of hydrogen are essential to protect people and property. Improper safety planning risks harm to project personnel, emergency first responders, and bystanders. A catastrophic failure could damage a project team's reputation, permanently shut down a hydrogen project, and negatively influence the public's perception of hydrogen and fuel cells.

This guide was developed by the Hydrogen Safety Panel (HSP) as a simplified approach to document essential safety planning for experienced hydrogen research teams conducting small-scale projects that use small volumes of hydrogen gas or generate hydrogen at low rates and pressures. Compared to the HSP standard template (*Safety Planning for Hydrogen and Fuel Cell Projects,* PNNL-25279), this approach is less complex and requires significantly less data, commensurate with the lower risk level these small-scale projects present. These simplifications are based on an HSP review of multiple safety plans produced by university and small-scale laboratories.

The project team should still review the standard template (PNNL-25279) to understand quality safety planning principles for flammable and explosive gas operations. Even though a simplified approach may be implemented, the project team may add additional information to document safety planning for its unique application and lower the probability and consequences of an incident.

B. Applicability

The following questions (with underlined text as key criteria) determine the applicability of this simplified guide. A "Yes" to any question eliminates the usage of this guide, requiring the project to develop its hydrogen safety plan per the criteria of the standard template (PNNL-25279).

- **Question 1:** Does the project involve liquid hydrogen?
- **Question 2:** Does the project use more than one standardized commercial hydrogen gas cylinder connected to the project equipment, or a central hydrogen supply system?
- **Question 3:** Does the project generate hydrogen gas at a rate greater than 18 g/hr (0.04 lb/hr) or store this generated hydrogen gas at pressures greater than 300 kPa (44 psig) in approved vessel(s)?
- **Question 4:** Does the project setup or facility lack a maintained ventilation and exhaust system?
- **Question 5:** Does the project team have less than 1 year of experience working with hydrogen?
- **Question 6:** Does the project team lack an emergency response program [e.g., a formal protocol documented by procedure(s), poster(s), training, drills, or communication planning]?

C. Safety Plan Document Production

Requirements

1. Use Attachment A as the safety plan cover/title page documenting answers to the applicability questions in Section B, along with validation data, names, and signatures.
2. Complete the safety plan, including the following minimum data in Table 1, as either text, a table, or a combination.

Review Process

1. The HSP will review the safety plan cover/title page (Attachment A) to ensure that the use of this simplified guide is valid. No further review will be conducted if data is missing.
2. The HSP will then evaluate the safety plan against the minimum criteria in Table 1 using its independent expertise. A written report, identifying gaps and weaknesses in the project's safety approach, will then be provided to the project team.

Table 1. Simplified Safety Plan Requirements

Element	Minimum Key Data
1. Description of Work Scope of project	1. Purpose/goal of the project indicating technical details for project success 2. Diagram showing, at a minimum (if applicable): a. Hydrogen source, location, flow rate, and pressures b. Major hydrogen usage or connected equipment c. Hydrogen exhaust flow and ventilation system d. Known ignition sources (e.g., flame, electrical) e. Hydrogen sensors and interlocks f. Fuel cell or reactor system g. Isolation and purge valves h. Pressure-reducing and relief valves i. Safety systems (e.g., emergency stop, fire or smoke detectors)
2. Risk Management [Identification of safety vulnerabilities (ISV) and risk reduction plan]	1. ISV method (see PNNL-25279 for methods) 2. ISV status/schedule or reference if applicable 3. List of significant hazards matched to risk prevention-mitigation items. This data is required regardless if the ISV is not completed; listing should reflect some initial planning and controls. For example: • Fire: fire/smoke detectors, fire extinguishers, fire alarm pull boxes, emergency stops, egress paths • Runaway reaction: emergency stops, relief valves, interlocks, continuous personnel monitoring • Gas leak: pressure-reducing valves, fume hoods and ventilation, hydrogen/oxygen sensors, proper material-of-construction • Ignition sources: certified equipment, grounded electrical sources, purging
3. Management of Change	How changes to equipment, processes, and procedures are communicated to the project team
4. Startup and Maintenance Safety Review	Reviews that are to be completed (e.g., checklists) prior to startup/restart of hydrogen flow/generation, and system maintenance, noting schedule and approvals
5. Training	Experience or list of training requirements needed for project team members
6. Emergency Response	How first responders, safety program personnel, and management are notified of an incident or near miss
7. References	Lists or links to noted formal documentation

D. Final Considerations

Involvement

A thorough and integrated approach to project safety planning needs to identify and involve all parties, project partners, and stakeholders, such as hydrogen equipment suppliers, facility operators, maintenance/repair providers, and local safety authorities with area jurisdiction. Communication is important for successful operation.

Safety Expertise

Safety expertise should be sought early in a project's life to ensure that safety design features and practices are consistently applied as part of project implementation. Work scope could include reviewing designs with the intent of approving or assisting with the approval of the project, assisting with hazard analysis and development of mitigation plans, inspecting the installation, investigating incidents and near-misses, and addressing safety-related change management issues.

Compliance with Codes and Standards

Compliance with applicable codes and standards [e.g., the *International Fire Code* and National Fire Protection Association (NFPA) 2, *Hydrogen Technologies Code*], is essential for design and operation of flammable gas systems. Most small-scale projects are conducted in existing facilities that may have been retrofitted for flammable gas operations or potentially were never constructed with such operations in mind. Project teams should consult local code and zoning officials early in the project if there are any questions or concerns regarding the facility.

Best Practices and Lessons Learned

Best practices go beyond requirements in codes and standards and incorporate a wealth of experience from multiple projects. Hydrogen-related best practices may be found on the H2tools website, https://h2tools.org. A review of the H2tools website event database or lessons learned summary document could provide valuable data for similar systems and operations.

Conduct of Operations

Understanding and implementing the general protocols of proper conduct of operations in a project will protect personnel and equipment at the highest level and ensure operational success. At a minimum, project activities should be conducted according to written procedures that have been properly reviewed by supervisory, safety, and operational personnel. Additional information can be found in DOE Order 422.1, *Conduct of Operations* (DOE 2019).

Emergency Response Team

A knowledgeable and trained emergency response force is an essential component of a successful hydrogen safety program. Project and safety organization personnel should be trained through formal documents and drills. They should have clear access to project information and safety controls, including information on the hazardous, flammable, and explosive characteristics of hydrogen, and hazards associated with project equipment, e.g., charged electrical circuits and high-pressure storage containers. The project team should also work with their local emergency responders to make them aware of the

activities, hazards, and key safety information (e.g., emergency shutoffs). Resources such as the National Hydrogen and Fuel Cell Emergency Response Training Resource and the online American Institute for Chemical Engineers Introduction to Hydrogen Safety for First Responders may be helpful.

Continuous Improvement

Effective safety planning is a continuous process. A safety plan should be revisited periodically and revised whenever changes are made as part of an overall effort to give continuous and priority attention to project safety.

E. References

DOE 2019, *Conduct of Operations*, DOE Order 422.1, Change 3, October 4, 2019, U.S. Department of Energy, Washington, D.C.

PNNL-25279, *Safety Planning for Hydrogen and Fuel Cell Projects*, Revision 3, January 2020, Pacific Northwest National Laboratory, Richland, WA

Internet Reference Links (in order of document presentation):

PNNL-25279, “Safety Planning for Hydrogen and Fuel Cell Projects”
https://h2tools.org/sites/default/files/Safety_Planning_for_Hydrogen_and_Fuel_Cell_Projects.pdf

Hydrogen Safety Panel Lessons Learned Database
https://h2tools.org/lessons

Hydrogen Safety Panel Listing of Best Practices
https://h2tools.org/bestpractices/best-practices-overview

National Hydrogen and Fuel Cell Emergency Response Training Resource
https://h2tools.org/fr/nt

AIChE Training Introduction to Hydrogen Safety for First Responders
https://www.aiche.org/academy/courses/ela253/introduction-hydrogen-safety-first-responders

DOE Order 422.1, “Conduct of Operations”
https://www.directives.doe.gov/directives-documents/400-series/0422.1-BOrder-chg3-minchg

Attachment A

Simplified Safety Plan Cover/Title Page

Safety Plan/Project Title _____			
Plan/Project/DOE Reference No. _____ Revision _____			
Lead/PI/PM	Name _____		
Topic	*Question*	*Response - ✓*	*Validation Data*
Hydrogen Type	Does the project involve liquid hydrogen?	No:____	None
Hydrogen Supply Volume	Does the project use more than one standardized commercial hydrogen gas cylinder connected to the project equipment, or a central hydrogen supply system?	No: ____, or N/A: ____	Cylinder volume = _____ Cylinder pressure = _____
Hydrogen Production	Does the project generate hydrogen gas at a rate greater than 18 g/hr (0.04 lb/hr) or store this generated hydrogen gas at pressures greater than 300 kPA (44 psig) in approved vessel(s)?	No: ____, or N/A: ____	Mass production rate = ____ Storage pressure = _____ or N/A
Ventilation	Does the project setup or facility lack a maintained ventilation and exhaust system?	No:____	Type of system = _____
Experience	Does the project team have less than 1 year of experience working with hydrogen?	No: ____	Years of experience = _____
Emergency Services	Does the project team lack an emergency response program [e.g., a formal protocol documented by procedure(s), poster(s), training, drills, or communication planning]?	No: ____	Program examples = _____
Preparer	Printed _____ Signed_____ Date_____		
Approver	Printed _____ Signed_____ Date_____		

The **Hydrogen Safety Panel** (https://h2tools.org) was formed in 2003 by the U.S. Department of Energy to help develop and implement practices and procedures that would ensure safety in the operation, handling, and use of hydrogen and hydrogen systems. The primary objective is to enable the safe and timely transition to hydrogen and fuel cell technologies. This is accomplished by:

- Providing expertise and recommendations and assisting with identifying safety-related technical data gaps, best practices, and lessons learned, and
- Ensuring that safety planning and safety practices are incorporated into hydrogen projects.

The 17-member panel has over 500 years of combined experience and is composed of a cross-section of expertise from the commercial, industrial, government, and academic sectors. Panel members participate in a variety of standards development organizations, including the ASME, CSA, ISO, NFPA, SAE, and UL. Panel members also contribute to peer-reviewed literature and trade magazines on hydrogen safety and present at national and international forums. The Panel has reviewed over 389 projects covering vehicle fueling stations, auxiliary power, backup power, combined heat and power, industrial truck fueling, portable power, mobile applications, and R&D activities.

If you have an interest in utilizing the expertise of the Panel, contact the program manager by email at **hsp@h2tools.org**.

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