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SHASTA
Subsurface Hydrogen Assessment, Storage, and Technology Acceleration

Regulations, Codes, and Standards Review for Underground Hydrogen Storage

SHASTA: Subsurface Hydrogen Assessment, Storage, and Technology Acceleration Project

April 2024

Prepared for the U.S. Department of Energy, Office of Fossil Energy and Carbon Management by:

Sandia National Laboratories: Melissa S. Louie, Brian D. Ehrhart

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National Energy Technology Laboratory
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Acronyms and Abbreviations

API	American Petroleum Institute
CFATS	Chemical Facility Antiterrorism Standards
CFR	Code of Federal Regulations
CISA	Cybersecurity and Infrastructure Security Agency
NFPA	National Fire Protection Association
OSHA	Occupational Safety and Health Administration
PHMSA	Pipeline and Hazardous Materials Safety Administration
RCS	regulations, codes, and standards
RP	Recommended Practice
scf	standard cubic feet
UGS	underground gas storage
UHS	underground hydrogen storage
UNGSF	underground natural gas storage facility

Contents

Tables

1.0 Introduction

Hydrogen continues to show promise as a viable contributor to achieving energy storage goals such as energy security and decarbonization in the United States. However, many new and expanded hydrogen use applications will require identifying methods of larger-scale storage than the solutions that currently exist for smaller storage applications [1] One possibility is to store large quantities of gaseous hydrogen below ground level. Underground storage of other fuels such as natural gas is already currently utilized, so much of the infrastructure and basic technologies can be used as a basis for underground hydrogen storage (UHS). A few commercial UHS facilities currently exist in the United States, including salt caverns owned and operated by Air Liquide [2], Linde [3], and Conoco Philips [4], but UHS is still a relatively new concept that has not been widely deployed. It is necessary to understand the safety risks and hazards associated with UHS before its use can be expanded and accepted more broadly. Many of these risks are addressed through regulations, codes, and standards (RCS) issued by governing bodies and organizations with expertise in certain hazards. This report is a review of RCS documents relevant to UHS, with a particular lens on potential technical gaps in existing guidance. These gaps may be specific to the physical properties of hydrogen or due to the different technologies relevant for hydrogen vs. natural gas storage. This is meant to be a high-level review to identify relevant documents and potential gaps. Formally addressing the individual gaps identified here within the codes and standards themselves would involve a more intensive analysis and differ based on the code or standard revision processes of the various publishing organizations. Therefore, presenting specific recommendations for revising the verbiage of the documents for UHS applications is left for future work and other publications.

1.1 RCS Documents Considered

Several federal regulations currently exist for handling hydrogen, such as the Chemical Facility Antiterrorism Standards (CFATS) issued by the Cybersecurity and Infrastructure Security Agency [5], as well as the Code of Federal Regulations (CFR) documents 29 CFR 1910.103 [6] and 29 CFR 1910.119 [7], which are issued by the Occupational Safety and Health Administration (OSHA). While these regulations address worker safety associated with hydrogen storage, regulations covering the construction, operation, monitoring, and maintenance of bulk underground ground storage are not currently promulgated at a federal level in a manner comparable to requirements for underground natural gas storage. The Pipeline and Hazardous Materials Safety Administration (PHMSA) recently published 49 CFR 192.12, a federal regulation that applies to underground storage of natural gas [11]. This regulation references documents published by the American Petroleum Institute (API) in Recommended Practices (RP) 1170 [12] and 1171 [14]. API RP 1170 applies to storing natural gas in underground salt caverns created by solution-mining while API RP 1171 applies to natural gas storage in depleted underground hydrocarbon reservoirs. While these recommended practices are general in their descriptions of how to handle and maintain underground natural gas storage and can likely also apply to hydrogen, there are potential risks of underground storage specific to hydrogen that should be considered as a part of the siting, construction, and operation processes for either type of well. One standard development organization that has established standards relevant to bulk storage of hydrogen is the National Fire Protection Association (NFPA). NFPA is not a federal organization, but the NFPA 2 code contains many requirements for bulk hydrogen storage and has been adopted by many state and local jurisdictions [8].

Table 4-1 is provided as a summary table at the end of this document and is referenced throughout.

2.0 Gap Assessment

RCS documents relevant to UHS were reviewed for potential technical gaps. These gaps can help to identify necessary clarifications or modifications for documents that may have been written with a particular fuel in mind (such as natural gas) but that may still contain useful guidance for UHS systems. Additionally, several documents on hydrogen storage were included because many were written under the assumption that hydrogen would be stored in a tank, either buried or aboveground, rather than directly in the subsurface.

2.1 Federal Regulations

Federal regulations are widely applicable especially for large-scale systems that may affect inter-state gas distribution and storage. Regulations on safety are reviewed here for applicability to UHS systems, as some of these regulations were originally written for different fuels.

2.1.1 6 CFR 27: Chemical Facility Antiterrorism Standards (CFATS)

The CFATS program expired on July 28, 2023, so CISA does not have the authority to enforce the requirements in this document (summarized in Table 4-1 Row 1) as of the time this report was published. However, it is still helpful to take note of this requirement as potentially useful guidance and in case the program is reinstated in the future.

Appendix A of 6 CFR 27 [5] lists hydrogen in excess of 10,000 pounds to be considered a chemical of interest that should be reported to CISA, with particular emphasis on the hazards of its flammable nature. For reference, 10,000 pounds of hydrogen takes up around 1.9 million standard cubic feet (scf), compared to 10,000 pounds of natural gas, which takes up about 0.2 million scf (at 101 kPa and 21°C, as per the scf definition in NFPA 2). It is reasonable to assume that this federal regulation can apply to underground hydrogen storage reservoirs, which are meant to store large quantities of gas, in addition to underground and aboveground hydrogen storage tanks. Clarification may be needed regarding whether the amount stored underground would count the same way towards the storage quantity limits for aboveground storage or not.

This regulation does not apply to facilities under ownership by certain government agencies such as the Department of Energy or the Nuclear Regulatory Commission.

2.1.2 29 CFR 1910.103: Hazardous Materials: Hydrogen

This federal regulation (Table 4-1 Row 2) [6] provides guidance for placing a hydrogen storage system in certain locations as well as required setback distances between hydrogen storage systems and different specified exposures. Clause (b)(2)(i)(b) stipulates, "Systems shall be located above ground," so this document does not currently apply to underground storage. However, if it becomes widely deployed, UHS would benefit from similar guidance. Table H-1 in the document shows allowed and preferred locations for hydrogen storage systems; the locations include "outdoors," "in a separate building," "in a special room," and "inside buildings not in a special room and exposed to other occupancies." The system size is based on the stored volume given in cubic feet. While not explicitly stated in the document, these volumes refer to standard cubic feet, which, as mentioned in the previous section, are defined in NFPA 2 as "An amount of gas that occupies one cubic foot at an absolute pressure of 14.7 psi (101 kPa) and a temperature of 70°F (21°C) [8]. In Table H-1, the stored volumes are sorted into three ranges of under 3000 cubic feet, 3000-15000 cubic feet, and greater than 15000 cubic feet. For reference, 3000 cubic feet of hydrogen at these conditions would fuel a Class 8 truck for around 70 miles, and 15000 cubic feet would fuel a Class 8 truck for around 330 miles[1]. The table states that storage systems in the largest bin of greater than 15000 cubic feet of hydrogen can be located outdoors or in a separate building. 15000 cubic feet is approximately 420 cubic meters; several hydrogen storage caverns currently in operation in the United Kingdom and the United States have similar and larger volumes [10]. Thus, if 29 CFR 1910.103 were expanded to include underground hydrogen storage, it may be helpful to explicitly include larger volume thresholds in guidance such as that given in Table H-1. Alternatively, a separate clause for allowed locations for underground storage systems in particular could be added to the document.

Table H-2 from 29 CFR 1910.103 shows the minimum required setback distances between the hydrogen storage and exposures; there will likely need to be setback distances specified between UHS systems and these exposures as well. The underground component may lead to guidance that considers both the horizontal distance to exposures, as well as the depth of the reservoir in which the hydrogen is stored. Like Table H-1, Table H-2 uses the three storage volume ranges of below 3000 cubic feet, 3000-15000 cubic feet, and greater than 15000 cubic feet. Again, if this document is revised to apply to underground hydrogen storage in the future, there may need to be more setback distances added for storage volumes much larger than 15000 cubic feet.

2.1.3 29 CFR 1910.119: Process Safety Management of Highly Hazardous Chemicals

29 CFR 1910.119 is a code regulated by OSHA. Clause (a)(1)(ii) of 29 CFR 1910.119 (Table 4-1 Row 3) [7] stipulates that the document requirements apply to "A process which involves a Category 1 flammable gas…in a quantity of 10,000 pounds (4535.9 kg) or more." This document currently applies to UHS because hydrogen is considered a Category 1 flammable gas. 29 CFR 1910.119 includes requirements for compiling written information on process safety management for the process and for handling of the specific chemicals present, as well as obligations to conduct an initial process hazard analysis and train employees on how to properly operate the process. All UHS facilities should adhere to the requirements in this document. This document is broadly applicable to many chemicals, presumably including hydrogen, because the requirements for documentation and training are general rather than chemical-dependent.

2.1.4 49 CFR 192.12: Underground Natural Gas Storage Facilities (UNGSFs)

PHMSA, a federal administration, issued 49 CFR 192.12 (Table 4-1 Row 4) [11] to set requirements for underground natural gas storage facilities. However, comparable requirements for UHS are not currently available at the federal level. Since natural gas is not currently defined in this regulation as containing any particular molecule or chemical makeup, it is possible that UHS currently falls under the jurisdiction of this document.

49 CFR 192.12 mentions two types of UNGSFs: salt caverns and depleted hydrocarbon reservoirs. "Cavern" is defined in API RP 1170 as an "Underground void developed by the solution mining of a salt formation" and "aquifer reservoir storage" is defined in API RP 1171 as "Porous and permeable rock media originally filled with water and converted to gas storage." Together, these definitions cover the range of UNGSFs considered in 49 CFR 192.12.

49 CFR 192.12 Clause (a) provides references to documents that salt cavern UNGSFs must comply with; the requirements differ slightly based on the date of construction of the facility. The four referenced

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[1] Based on hydrogen at 70°F and 14.7 psi, and using 2019 assumptions for a Class 8 fuel cell powered truck with a fuel economy of 9.4 miles per kg H_2 [9].

requirements are API Recommended Practice 1170, API Recommended Practice 1171, and 49 CFR 192.12 Clause (c) and (d). See Sections 2.2.1 and 2.2.2 for additional discussion on API RP 1170 and API RP 1171, respectively.

49 CFR 192.12 Clause (c) requires the UNGSF operator to provide and follow "written procedures for conducting operations, maintenance, and emergency preparedness and response activities" and that these manuals should be "in place before commencing operations or beginning an activity not yet implemented. Clause (c) also specifies that the manuals containing these procedures should be updated at least once every calendar year, with at most 15 months between consecutive revisions.

49 CFR 192.12 Clause (d) describes requirements for an integrity management program; it should include a framework based on guidance from API RP 1171 Section 8 "Risk Management for Gas Storage Operations." The program should describe the decision-making process for the site and those involved, procedural outlines, roles and responsibilities of onsite staff, a training plan, timelines for implementing program elements (including risk analyses), and a plan for continually updating the program with experience-based lessons. Clause (d) also imposes deadlines for completing baseline risk assessments for reservoirs and caverns, stipulates that integrity management re-assessment should be conducted at the operator's discretion at least once every seven years, and specifies that UNGSF operators must establish written records of procedures and descriptions of compliance with Clause (d).

The specific compliance requirements for each well depend on the type of geological formation it is based in and the date of its construction. The details are provided in Table 3-1 below.

Table 2-1. Summary of 49 CFR 192.12 requirements

Type of UNGSF	Date of Construction	Required Compliance with API RP 1170	Required Compliance with API RP 1171	Required Compliance with 49 CFR 192.12 Clause (c)	Required Compliance with 49 CFR 192.12 Clause (d)
Salt Cavern	On/before 07/18/2017	Section 9, 10, 11 by 01/18/2018	Section 8 by 03/13/2021	All by 01/18/2018	All by 03/13/2021
	07/18/2017–03/13/2020	All by 03/13/2021	Section 8 by 03/13/2021	All by 03/13/2021	All by 03/13/2021
	After 03/13/2020	All before commencing operations	Section 8 before commencing operations	All before commencing operations	All before commencing operations
Depleted Hydrocarbon and Aquifer Reservoir	On/before 07/18/2017	None	Section 8, 9, 10, 11 by 01/18/2018	All by 01/18/2018	All by 03/13/2021
	After 07/18/2017	None	All before commencing operations	All before commencing operations	All before commencing operations

The requirements for new and old wells are largely the same, except that there are some additional requirements for wells constructed later (for example, salt cavern wells constructed after July 18, 2017, must follow all requirements in API RP 1170 whereas older wells only needed to follow certain sections). These requirements and compliance deadlines may need to be adjusted for applicability to UHS. Clause (c) does explicitly mention that its requirements should be complied with before beginning wellhead operations or any new activity in the well; therefore, a UHS facility converted from an existing UNGSF would presumably need to comply with this clause before operations could start. However, Clause (a) and

(b) only provide guidance for compliance with the API RP and Clause (d) based on the well construction date. This guidance is ambiguous for UHS facilities converted from existing UNGSFs since the construction date could be interpreted as the original UNGSF construction date even if it may be more appropriate to use the new UHS construction date. Additionally, the deadlines for achieving compliance would need to be revised to reflect future dates at which these requirements should be met for old UNGSFs converted into UHS facilities.

2.2 Recommended Practices

There are multiple types of recommended practice documents published by various groups and organizations. However, specific recommended practice documents were referred to in the UNGSF regulations as described above, so these documents are the focus of this section.

2.2.1 API RP 1170: Design and Operation of Solution-mined Salt Caverns Used for Natural Gas Storage

American Petroleum Institute (API) Recommended Practice (RP) 1170 (Table 4-1 Row 5) [12] details standards for siting and maintaining an underground natural gas storage facility in solution-mined salt caverns. According to the PHMSA regulations in 49 CFR 192.12, Sections 5-7 of API RP 1170, which mainly concern construction of the caverns, must be followed for all caverns constructed after July 18, 2017. Sections 9-11 of API RP 1170 describe best practices for maintaining and operating the salt cavern storage facility and are relevant to all caverns constructed before or after July 18, 2017. Section 8 of API RP 1170 is a recommended practice for risk management; the corresponding section in API RP 1171 is used in the PHMSA regulations 49 CFR 192.12 for both salt cavern and depleted hydrocarbon or aquifer reservoirs (see Section 2.1.4).

API RP 1170 Section 5 details recommendations for how to evaluate a potential site for an underground salt cavern for natural gas storage. Siting considerations include the confining formations that will contain the stored gas, the caprock over the cavern, and the geomechanical properties and structural integrity of the cavern. API RP 1170 Section 6 explains a typical process for designing the well and equipment used to operate it, such as the wellhead and casing, while API RP 1170 Section 7 provides guidance for how to drill into the well and which equipment to use. API RP 1170 Section 8 gives recommendations on elements to include in a risk assessment, including recommended data sources and common threats and hazards relevant to underground salt caverns wells. While these sections are currently not required by PHMSA, they are still a useful point of reference for UNGSFs under construction. The guidance provided is quite general, as it does not specify equipment materials, well volumes, or other properties that might only be compatible with or applicable to certain stored gases. Thus, if analogous standards are developed for hydrogen, they may not differ significantly from the requirements of API RP 1170 Sections 5-8.

API RP 1170 Section 9 discusses how to design the cavern geometry and what to consider when solution mining. Like the previous chapters in the document, this section is general in its recommendations. One notable requirement is the statement, “While the cavern is being solution mined, the injection water and brine produced should be periodically monitored for sulfur reducing bacteria and acid producing bacteria along with dissolved oxygen.” Monitoring and awareness of microbial activity in the underground salt caverns is especially relevant to hydrogen storage, as the presence of sulfur-reducing microbes can convert stored hydrogen into hydrogen sulfide, thus resulting in a loss of usable hydrogen [13]. Another essential stipulation of API RP 1170 Section 9 is that “a full geomechanical analysis of the cavern should be completed. The analysis should review the cavern’s relationship to adjoining caverns and to the edge of salt, and the cavern shape as it affects maximum and minimum pressures under cycling conditions. Further analysis should include stress, strain, and dilation of the salt pillar between the cavern and other caverns in the field." Such analysis is relevant to integrity management of hydrogen caverns as well, but it is important to note that extraction and injection cycles of hydrogen to and from underground storage caverns are likely to be more frequent than the current cycles used for natural gas, so the stress and strain calculations should account for this difference, along with relevant materials compatibility considerations. This is because hydrogen has less energy per unit volume than natural gas, meaning that there would be significantly more volumetric flow into or out of a UHS to add or remove the same stored energy.

API RP 1170 Section 10 has requirements on how to operate the gas storage cavern and facility. The recommendations in this section also seem to be sufficiently general that they could be adapted to generate recommendations for hydrogen. For example, rather than providing an exact maximum flow rate that might be specific to methane-based natural gas, the document explains that the maximum flow rate "can be established based on the area of the tubing or annulus" or "on other criteria based on measured vibration and erosion testing." These tests would likely provide a reasonable advisable maximum flow rate whether the fuel in question is conventional natural gas or hydrogen. Similarly, the maximum allowable operating pressure is referred to generally, but not constrained to any number or range that might not have applied to hydrogen. Like in the previous sections, there are recommended types of equipment for a wellhead, emergency shutdown system, instrumentation, and control systems, but there is no material specified that may have had compatibility issues with hydrogen. API RP 1170 Section 10 states that issues such as corrosion and gas leakage should be monitored regularly. While the exact chemistry or physical mechanism that would cause corrosion or leakage from a hydrogen system may differ from a conventional natural gas system, the concerns themselves are also relevant for UHS systems.

API RP 1170 Section 11 requires that the UNGSF operator maintain a cavern integrity monitoring program. The section includes a table of suggested monitoring methods that "can be evaluated for applicability" to the UNGSF, so similarly appropriate methods can be chosen and used specifically for a hydrogen storage system.

2.2.2 API RP 1171: Functional Integrity of Natural Gas Storage in Depleted Hydrocarbon Reservoirs and Aquifer Reservoirs

API RP 1171 (Table 4-1 Row 6) [14] is organized like API RP 1170, although it applies to using depleted hydrocarbon reservoirs and aquifer reservoirs instead of salt caverns for natural gas storage. 49 CFR 192.12 states that all depleted hydrocarbon and aquifer reservoirs constructed for natural gas storage after July 18, 2017 must comply with the entire API RP 1171 document, while facilities constructed before July 18, 2017 must follow Sections 8-11. As mentioned previously, solution-mined salt caverns must also comply with the risk management practices of Section 8 in API RP 1171. Like in API RP 1170, API RP 1171 Sections 5-7 are recommendations for the construction of the well and facility, while API RP 1171 Sections 8-11 focus on operation and maintenance.

API RP 1171 Section 5 lists and explains considerations for designing the natural gas storage reservoir, including geomechanical and engineering characterizations. When characterizing the geomechanical properties of the reservoir rock, considerations should include "lithology, geo-mechanical competency, porosity, permeability, homogeneity, isotropy, and residual pore fluid saturations." These factors are important to evaluate for the storage of hydrogen as well as methane-based natural gas blends, and when put into practice the differences in properties and storage requirements for each specific fuel should be noted. Similarly, the document states that "the engineering characterization should include a review of records for all existing and abandoned wells that penetrate the formations being characterized." One additional consideration for UHS in API RP 1171 Section 5 are the containment assurance factors, which include an unspecified maximum and minimum reservoir pressure that just requires a documented design basis depending on geomechanical properties of the reservoir.

API RP 1171 Section 6 discusses the design and construction of the natural gas storage well, including stipulations regarding suitable equipment, casing and tubing properties, cementing, remediation, closure, and testing and monitoring. The document states that "Existing wellhead and well equipment is accepted if it has demonstrated containment of maximum operating pressure but shall be evaluated for suitability before increasing the operating pressure beyond the historical maximum." It is possible that, when transitioning from a methane-based fuel storage facility to a hydrogen storage facility, there should be more considerations for reusing existing equipment besides pressures – for example, chemical compatibility with the equipment material. Finally, in the well closure segment of API RP 1171 Section 6, the document states that "The operator shall use cement plugs and/or mechanical plugs to isolate the storage zone from fluid migration." One additional consideration relevant to hydrogen that is not mentioned in this section is that, at certain pressures, cement can be porous to hydrogen; therefore, if this code were adapted to cover hydrogen, it may be necessary to also add pressure requirements or considerations.

API RP 1171 Section 7 is focused on testing, confirming, and monitoring the structural integrity of the well. This section contains requirements about well properties that should be monitored. These monitoring requirements are expected to also be relevant to hydrogen.

As mentioned above, Section 8 of API RP 1171 contains risk management practices that apply to both solution-mined salt caverns and depleted natural gas reservoirs according to the PHMSA regulation requirements. In both API RP 1170 and 1171, Section 8 contains detailed threats and hazards for a UNGSF; some of these hazards, such as fluid compatibility concerns, geologic uncertainty, and well design apply to both natural gas reservoirs and caverns. API RP 1170 contains threats that are specific to salt caverns, such as salt boundaries and deviations in the cavern leaching plan. The generality and applicability of the hazards in API RP 1171 is likely the reason it is used for both types of storage facilities in 49 CFR 192.12. While the hazards are general and can apply to many types of fuel, it is important to tailor the mitigation actions to hydrogen in practice. For example, one hazard mentioned is well integrity, including "corrosion, material defects, erosion, equipment failures, [and] annular flow." The actual corrosive interactions and equipment failures may differ between methane-based natural gas and hydrogen gas, so the specific fuel chemistries should be accounted for when addressing this risk. Other risks that in practice depend on the type of fuel stored include pressure and volume limits for the reservoir and expansion, contraction, and migration of the storage gas. Finally, the document states that safety protocols for flammables at the surface facility should be reviewed; the flammability properties of hydrogen are different from those of methane-based natural gas and should be handled accordingly.

API RP 1171 Section 9 includes instructions for demonstration, verification, and monitoring of the well and reservoir. This section is most broadly applicable to both methane-based and pure hydrogen fuels since it details the procedures and regularity with which operators must monitor the storage facilities. API RP 1171 Sections 10 and 11 are similar in their applicability; API RP 1171 Section 10 concerns site security and safety while API RP 1171 Section 11 lays out recommended procedures and training protocol for operators.

2.3 Codes Adoptable by Jurisdictions

There are many fire and building codes that are adopted by laws enforced by federal, state, and local authorities. NFPA 2 is a fire code adopted by many state and local authorities, and is discussed below in the context of UHS systems.

2.3.1 NFPA 2: Hydrogen Technologies Code

According to Section 1.3, NFPA 2 (Table 4-1 Row 7) [8] applies to hydrogen in “stationary, portable, and vehicular infrastructure applications.” The exceptions listed do not apply to UHS, which means NFPA 2 can currently be applied to UHS. However, some of the recommendations may require revisions to incorporate the underground configuration. Like 29 CFR 1910.103, the NFPA 2 code provides allowed locations and recommended setback distances between hydrogen storage systems and potential exposures. Separately, NFPA 2 Section 7.3 provides tables with guidance for recommended minimum distances between outdoor bulk gaseous hydrogen systems and three different groups of exposures based on the stored fuel pressure and pipe sizes. The listed Group 1 exposures include equipment such as lot lines and ignition sources, Group 2 exposures include exposed persons not involved in the operation of the system, and Group 3 exposures include buildings, combustibles, and flammable gas storage systems. The setback distances here are informed by a quantitative risk assessment approach, where safe distances are determined based on acceptable levels of risk in the event of an unintentional release of hydrogen. The calculations use the assumption of a steady-state release to determine distances from the leak that would be affected in the event that the released hydrogen ignites and causes a jet fire or an explosion. It is possible that this table would need to be adjusted or extended if the pressures or pipe size ranges for UHS systems differ from the aboveground systems that the codes were originally written for. Additionally, UHS systems would store much larger quantities of gaseous hydrogen than the quantities that were assumed when calculating the current setback distances in the NFPA 2 code. In this case, temporal aspects of a blowdown during an accidental release of hydrogen may become significant, especially for stationary exposures such as buildings that may withstand a certain heat flux from a flame for the entire blowdown time of a smaller storage quantity but that may collapse when subjected to the same heat flux for a much longer blowdown time of a larger stored quantity.

The definition of setback distances may also need to be revised, as there would be a component of storage depth in addition to horizontal distance from exposures. While there are currently sections in NFPA 2 with guidance for underground gaseous hydrogen storage tanks, there should likely be separate recommendations specifically for subsurface storage of gaseous hydrogen in a cavern or reservoir, whether they are included in NFPA 2 or provided in a different standards document. For example, Sections 7.3.2.4.1, 7.3.2.4.5.1, and 7.3.2.4.6 all apply specifically to underground gaseous hydrogen storage, but they all reference “containers.” NFPA 2 defines a container as “A vessel, such as a cylinder, portable tank, or stationary tank, that varies in shape, size, and material of construction,” which would not apply to storing hydrogen directly in the ground.

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3.0 Summary and Conclusions

Underground storage of other fuels such as natural gas is currently more widespread than UHS, and many of the infrastructure, technologies, and regulatory requirements can serve as a basis for UHS. This report identifies regulatory requirements in place for underground storage of natural gas that could guide development of future regulations of UHS, RCS currently available for UHS specifically, and technical gaps in existing guidance. Fundamental differences in the physical properties of natural gas and hydrogen may result in different technologies being deployed for UHS, and also may result in different regulatory requirements. This is meant to be a high-level review to identify relevant documents and potential gaps.

The reviewed federal regulations were 6 CFR 27 Appendix A, 29 CFR 1910.103, 29 CFR 1910.119, and 49 CFR 192.12. 6 CFR 27 Appendix A mentions that stored hydrogen in quantities greater than 10,000 lb. should be reported to CISA, which likely would apply to large-scale underground storage of hydrogen if the CFATS program is renewed in the future. 29 CFR 1910.103 currently does not apply to UHS, but, if it were to be made applicable in the future, both the allowed locations and setback distances would need to be defined. 29 CFR 1910.119, which provides process safety management guidance, is relevant to UHS because hydrogen is classified as a Category 1 flammable gas. 49 CFR 192.12 provides requirements for UNGSFs, including both salt caverns and depleted hydrocarbon reservoirs, but it is not applicable to hydrogen.

49 CFR 192.12 refers to the practices in API RP 1170 and 1171. API RP 1170 details practices for using underground salt caverns for natural gas storage and API RP 1171 provides similar best practices for underground depleted hydrocarbon and aquifer reservoir usage for natural gas storage. They both provide guidance regarding topics such as siting, designing, drilling, monitoring, operating, testing, abandoning, and assessing risk of natural gas wells. Like 49 CFR 192.12, the documents are both ambiguous in their definitions of natural gas and do not have explicit fuel-specific guidance, indicating that they can potentially already apply to UHS.

NFPA 2 is a code that can be adopted by jurisdictions for maintaining safe hydrogen storage systems. Currently, the code does not contain language that explicitly excludes UHS, but its suggested setback distances between the system and various exposures were based on a methodology that was based on storage pressure and pipe size rather than volume or quantity of stored hydrogen. NFPA 2 contains a section for hydrogen stored underground in tanks, but not for hydrogen stored directly belowground. Therefore, if NFPA 2 were revised to increase its usability for UHS, it may be advisable to reevaluate the setback distances for larger systems and for underground systems not involving tanks.

A summary of the documents reviewed in this report are provided in Table 4-1.

Table 3-1. List of reviewed documents

Publishing Authority	Document Number	Document Name	Year Last Updated	Gaps and Recommendations
Cybersecurity and Infrastructure Security Agency (CISA)	6 CFR 27	Chemical Facility Antiterrorism Standards (CFATS)	2023	Expired as of July 2023 but seem to apply to UHS if reinstated
Occupational Safety and Health Administration (OSHA)	29 CFR 1910.103	Hazardous Materials: Hydrogen	2007	Does not currently seem fully applicable to UHS; allowed locations and setback distances are for aboveground equipment
	29 CFR 1910.119	Process Safety Management of Highly Hazardous Chemicals	2013	Requirements currently seem applicable to UHS
Pipeline and Hazardous Materials Safety Administration (PHMSA)	49 CFR 192.12	Underground Natural Gas Storage Facilities (UNGSFs)	2020	Requirements currently seem applicable to UHS; date-based requirements may require revision
American Petroleum Institute (API)	RP 1170	Design and Operation of Solution-mined Salt Caverns Used for Natural Gas Storage	2022	Requirements currently seem applicable to UHS
	RP 1171	Functional Integrity of Natural Gas Storage in Depleted Hydrocarbon Reservoirs and Aquifer Reservoirs	2022	Requirements currently seem applicable to UHS
National Fire Protection Association (NFPA)	NFPA 2	Hydrogen Technologies Code	2023	Requirements currently seem applicable to UHS; setback distances and guidance for underground storage may require clarification

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