Deutscher Verein des
Gas- und Wasserfaches e.V.

DVGW FORSCHUNG

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H2-Verteilnetze/ Infrastrukturen Teil 2 Weiterentwicklung des bestehenden DVGW-Regelwerkes für Wasserstoff-Verteilnetze/ Infrastrukturen

Studie

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Studie

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Zusammenfassung

Der DVGW stellt sich als übergeordnetes Ziel alle betroffenen DVGW-Regelwerke hinsichtlich konkreter wasserstoffspezifischer Anforderungen und Schutzmaßnahmen zu überarbeiten [1]. So wird die Integration des Energieträgers der Zukunft ermöglicht und gleichzeitig Netzbetreibern eine sichere Grundlage für die Planung und den Betrieb der Gasnetze von Morgen geboten. Ein Teil der relevanten Arbeits- und Merkblätter wurde bereits hinsichtlich Wasserstoffs (als Zusatzgas oder Reingas) angepasst, wie bspw. die DVGW G260, die nun grundsätzlich Wasserstoffbeimischungsraten > 10 Vol.-% H_2 ermöglicht und Anforderungen für reinen Wasserstoff definiert hat [2]. Teilweise wurden neue Arbeits- und Merkblätter erstellt, wie bspw. die DVGW G409, die die Umstellung von Gashochdruckleitungen (Stahl, Auslegungsdruck > 16 bar) für den Transport von Wasserstoff beschreiben [3]. Bis 2022 sollen laut DVGW weitere relevante technische Regeln in den Bereichen Gastransport, Gasverteilung, Power-to-Gas, Verdichterstationen, Netzanschlüsse, Gasanwendung und Gas-Druckregel- und Messanlagen um Wasserstoff erweitert werden [4]. vornehmlich im Bereich der chemischen Industrie angesiedelt sind. Eine der wohl bekanntesten nicht-europäischen technischen Standards in Hinblick auf Wasserstoff ist die viel zitierte ASME B31.12 der American Society of Mechanical Engineers. Um für die Regelwerksarbeit des DVGW relevantes Wissen zu bündeln und dieses in die Anpassung und Erstellung von Arbeit- und Merkblättern einfließen zu lassen, wurde diese Studie initiiert.

Inhaltsverzeichnis

1 Einleitung und Hintergrund

Der DVGW stellt sich als übergeordnetes Ziel alle betroffenen DVGW-Regelwerke hinsichtlich konkreter wasserstoffspezifischer Anforderungen und Schutzmaßnahmen zu überarbeiten. So wird die Integration des Energieträgers der Zukunft ermöglicht und gleichzeitig Netzbetreibern eine sichere Grundlage für die Planung sowie den Betrieb der Gasnetze von Morgen geboten. Ein Teil der relevanten Arbeits- und Merkblätter wurde bereits hinsichtlich Wasserstoffes (als Zusatzgas oder Reingas) angepasst, wie bspw. das DVGW-Arbeitsblatt G260, welches nun grundsätzlich Wasserstoffbeimischungsraten größer 10 Vol.-% H_2 ermöglicht und Anforderungen für reinen Wasserstoff definiert hat. Teilweise wurden neue Arbeits- und Merkblätter erstellt, wie bspw. das DVGW-Merkblatt G409, welches die Umstellung von Gashochdruckleitungen (Stahl, Auslegungsdruck größer 16 bar) für den Transport von Wasserstoff beschreibt. Weitere relevante technische Regeln in den Bereichen Gastransport, Gasverteilung, Power-to-Gas, Verdichterstationen, Netzanschlüsse, Gasanwendung sowie Gas-Druckregel- und Messanlagen sollen um Wasserstoff erweitert werden. Eine der wohl bekanntesten nicht-europäischen technischen Standards in Hinblick auf Wasserstoff ist die ASME B31.12 der American Society of Mechanical Engineers. Um für die Regelwerksarbeit des DVGW relevantes Wissen zu bündeln und dieses in die Anpassung sowie Erstellung von Arbeit- und Merkblättern einfließen zu lassen, wurde diese Studie initiiert.

2 Identifizierung der nicht-europäischen Wasserstoff-Kernregionen (Teil 1)

2.1 Kernregionen und DVGW-äquivalente Institutionen

Um die Kernregionen existierender Wasserstoffsysteme zu bestimmen, wurden zunächst eine Reihe von Bewertungskriterien aufgestellt. Die Kernregionen wurden anhand der folgenden Kriterien ermittelt:

1. Vergleich der Längen und/ oder Ausbaustufen vorhandener Pipelinesysteme
2. Anzahl der Wasserstoffprojekte (neben konventioneller Erzeugung)
3. Kapazitäten (Produktionsrate) in den Ländern
4. Wasserstoffimport
5. Wasserstoffproduktionskapazität (einschließlich konventioneller Erzeugung)
6. Vergleich Regionen mit hoher Wasserstoffproduktionskapazität in Raffinerien

Die Analyse der Kernregionen unter Einbeziehung der Kriterien erfolgte ausführlich im Teil 1 des Berichtes. Dort wurde ermittelt, dass die folgenden fünf Länder die nicht-europäischen Wasserstoff-Kernländer sind: USA, Kanada, Japan, Indien und Südkorea.

Die in diesen Ländern zuständigen DVGW-äquivalenten Institute und Behörden wurden recherchiert und in Tabelle 1 zusammengestellt. Um weitere Erkenntnisse zu den länderspezifischen gültigen technischen Standards zu gewinnen, wurden die Einrichtungen zu einer DBI-erstellten Umfrage eingeladen.

Tabelle 1: Institutionen / Unternehmen (ähnliches Spektrum zu) DVGW

Land	Institut
USA	American Petroleum Institute (API)
USA	AGA (American Gas Association)
USA	FERC (Federal Energy Regulatory Commission)
USA	U.S. Department of Transportation (DOT)
USA	U.S. Department of Energy (DOE)
USA	American Society of Mechanical Engineers (ASME)
Kanada	CGA (Canadian Gas Association)
Kanada	CER (Canada Energy Regulator)
Japan	JGA (Japan Gas Association)
Indien	Ministry of Petroleum and Natural Gas
Südkorea	KGU (Korean Gas Union)
Südkorea	KEA (Korean Energy Agency)
Südkorea	Korea Ministry of Government Legislation

2.2 Inhalt der Umfrage

Um die Regelungen in den identifizierten Kernregionen richtig einzuordnen und diese als Grundlage für die kommenden deutschen/europäischen wasserstoffspezifischen Regelungen nutzbar zu machen, wurden die Fragen in Anlehnung an das aktuelle DVGW-Regelwerk formuliert. Die Umfrage ist als Anhang 1 zu diesem Bericht zu finden.

Folgende Regelwerke lagen der Befragung zugrunde:

1. DVGW-Arbeitsblatt G 468-1: Qualifikationskriterien für Gasleitungsnetzinspektionsunternehmen
2. DVGW-Merkblatt G 468-2: Gasspürgerät, Ausbildungsplan
3. DVGW-Arbeitsblatt G 452-2: Anbohren und Absperren; Teil 2: Abquetschen von Kunststoffrohrleitungen für Gas mit Drücken bis 5 bar und Außendurchmessern bis 315 mm
4. DVGW-Arbeitsblatt G 459-1: Gasleitungsanschlüsse für maximale Betriebsdrücke bis einschließlich 5 bar
5. DVGW-Arbeitsblatt G 462: Gasrohrleitungen aus Stahlrohren bis 16 bar Betriebsdruck; Errichtung
6. DVGW-Merkblatt G 465-3: Leckstellen an Gasrohrleitungen in Gasleitungsnetzen - Ortung, Klassifizierung, Behandlung von Leckstellen
7. DVGW-Merkblatt G 465-4: Gerätetechnik für die Inspektion von Gasrohrleitungen und Gasanlagen
8. DVGW-Arbeitsblatt G 472: Gasrohrleitungen aus Kunststoffrohren bis 16 bar Betriebsdruck; Installation Prüfgrundlage VP 601: Prüfgrundlage Gas- und Wasserhauseinführungen

3 Auswertung der Umfrage (Teil 2)

3.1 Kürzung der Umfrage

Aufgrund der hohen Anzahl der Fragen in der Umfrage und die damit mögliche Verminderung der Teilnahmebereitschaft, war eine weitere Konsolidierung der Fragen erforderlich. Dabei wurde die Umfrage in fünf Hauptkategorien gegliedert: Ausbildung und Qualifikationen, Zertifizierungen, Sicherheit und Vorschriften, Kunststoffrohre sowie Undichtigkeit. Auf diese Weise konnte die Anzahl der Fragen von 79 auf 34 reduziert werden, womit die Chance auf eine freiwillige Teilnahme der kontaktierten Parteien erhöht werden sollte.

Im Folgenden wird die reduzierte Umfrage dargestellt.

3.1.1 Trainings and Qualifications

1. Are there trainings that are required for handling hydrogen carrying pipes? If yes are there theorical as well as practical trainings? How to deal with the lack of experience with H2?

2. The important building blocks of H2-specific training are hydrogen production and fuel-specific properties (ignition limits, flame velocity, flame temperature, detonation behavior). What additional content should be imparted as a matter of urgency?

3. How far contents on the technical execution of gas supply systems are adapted in the training courses, H2 influences are seen here in particular regarding pressure stages, areas of application of pipe materials, identification of armatures, cause of leakage points, gas losses and their elimination as well as in the adaptation of inspection periods.

4. In terms of personnel and construction supervision, what qualifications do the H2 pipeline construction company and construction supervision need? Can pipeline construction companies have construction supervision as well?

5. Which certificates of welders are required?

3.1.2 Certifications

6. Is there a national standard for testing and certification of H2-compatible measuring instruments and equipment? Does it consider different H2 content according to the measuring methods, measuring accuracy and cross sensitivities?

3.1.3 Safety and Regulations

7. Will existing regulations concerning hydrogen be adjusted or will new ones be created?

8. How far is hydrogen considered in terms of corrosive, electrical and thermal influences in new regulations? Keyword: H2 embrittlement

9. Is hydrogen considered from a material point of view in house entries (H2 embrittlement acting from the inside)?

10. How far are underground pipelines marked in the case of H2 routing or is the H2 content designated?

11. In general: Will the limit value for the pressure level (in Germany 5 bar) for gas network connections remain unchanged or will there be changes?

12. Are there any required changes for the use of hydrogen in any of the following cases:

    - Dimensioning of network connections and calculating ground movements?
    - Routing regarding local conditions?
    - Minimum distances? (Supply and disposal lines, power cables, wind turbines, constructions)?
    - Pipe coverage for different pressures?
    - Pipeline construction? (e.g., bending radii)
    - Welding procedures (Approved welding consumables, non-destructive test methods)?
    - Structural specifications for shut-off devices?
    - Approved arrangements of main shut-off devices outside buildings? (Group shut-off, gas flow monitor)
    - Approval for pipes, piping components, shut-off valves, blow-out devices and other components?
    - Corrosion protection with hydrogen?
    - The suitability of house connection rooms in the case of gas connection for H2?
    - Specified connection types necessary regarding the manufacture of pipe connections? (approved threads, fittings, flanges)
    - Pressure tests for gas network connections?
    - Leak tightness tests?
    - Quality controls?

13. Are modified signs created for pure H2 pipelines or mixtures as well as for shut-off devices, is there an explicit reference to H2?

14. Are tests according to the visual method with the operating gas H2 by using foam-forming agents or the use of suitable gas concentration measuring devices permitted for individual pressure tests?

15. Is the venting of an H2/air mixture to the open-air permitted when gas is admitted to network connections the same as for natural gas?

16. Is the closure of H2-carrying and not yet completed network connections with conventional means such as plugs, caps, etc. permissible?

3.1.4 Plastic Pipes

17. Is the diffusion behavior of hydrogen considered regarding the squeezing of plastic piping? (Surface expansion, tension)

18. Are modified conditions required for squeezing H2 pipelines?

19. Do the procedures for visual inspection and marking of squeezing points must change?

20. Will the test principles be modified regarding gas tightness during squeezing?

21. What should be the bedding layer thickness in cm for polyamide and plastic pipes?

3.1.5 Leakage

22. From which hydrogen concentration is a detection in the soil considered as evidence? Example: Natural gas >0.1% by volume in the probe hole

23. From which hydrogen concentration is a detection in the structure/cavity considered as evidence?

24. From which hydrogen concentration is gas-free?

25. How is the detection range defined for hydrogen? (gas concentration)

26. Will the qualifications and certificates for the network operator's specialists and specialist companies be adapted to hydrogen?

27. Will the causes of leaks because of hydrogen be reformulated? (H2 embrittlement)

28. How far are the following influencing variables re-evaluated regarding the gas propagation of hydrogen? The density of the fuel gas; impermeability of the surface, type of soil and pipe cover; creep paths of the gas in the soil; the inclination of the pipe; soil climate, weather influences; bacterial activity and gases from decomposition processes in the soil.

29. Are leakage points for hydrogen re-evaluated in terms of leakage classes, safety measures and reaction?

30. Which following characteristics of the equipment technology regarding hydrogen have been changed? - display of measuring result (ppm, vol.-&); ATEX approval; operating principle; cross sensitivities; response time (T90); relative measuring error?

31. Are changes in the measuring procedure necessary for hydrogen-carrying pipes? (distance pipe, seal; measuring time)?

32. How far are changes made to the handling of the equipment in terms of inspection, testing of display accuracy, maintenance, repair?

33. How far are there changes regarding specifications for visual and/or audible signals for hydrogen detection in the following applications: Above ground inspection, ground air/gas purity testing, building/exposed piping systems testing, work area monitoring.

34. Are other sealing materials and grouting materials used?

3.2 Umfrageergebnisse

Die in Tabelle 1 genannten Institute und Behörden wurden mit der Anfrage zur Teilnahme an der Umfrage kontaktiert. Zusätzlich wurden weitere Einrichtungen identifiziert, die an der Wasserstoffregulierung oder/und -forschung beteiligt sind. Dazu gehören Pipeline and Hazardous Materials Safety Administration (USA), Ministry of Renewable Energies (Indien) sowie Bureau of Indian Standards (Indien). Diese wurden ebenfalls zur Umfrage eingeladen. In Tabelle 2 sind die kontaktierten Institute und Behörden mit entsprechender Umfrageantwort gelistet.

Tabelle 2: Zusammenfassung der Umfrageergebnisse

Institut	Land	E-Mail	Telefonnummer	Antwort
American Petroleum Institute (API)	USA	Kontakt-Formular	+12026828000	Keine Antwort
AGA (American Gas Association)	USA		+12028247000	Keine Antwort
FERC (Federal Energy Regulatory Commission)	USA	customer@ferc.gov	+18662083372	Die Agentur antwortet nicht auf Umfragen. Sie gab an, dass sie Wasserstoff nicht reguliert und daher diesbezüglichen keine Normen oder Spezifikationen hat.
U.S. Department of Transportation (DOT)	USA	cheryl.freeman@dot.gov Kevin.Leary@dot.gov	+12023664545 +12025105815 +12023662944 +12026031647	Laut PHMSA ist diese nicht die geeignete Stelle für die Beantwortung der Umfrage. DBI erhielt jedoch eine Einladung zu PHMSA's Pipeline Transportation; Hydrogen and Emerging Fuels Research and Development (R&D) Public Meeting and Forum, das vom 30. November bis 2. Dezember 2021 stattfindet.
U.S. Department of Energy (DOE)	USA	The.Secretary@hq.doe.gov	+12025865000	Folgende Links wurden dem DBI zur Verfügung gestellt, ohne dass die Umfrage beantwortet wurde: - H2IQ Hour: Overview of Federal Regulations for Hydrogen Technologies in the United States: Text Version | Department of Energy (siehe Link) - Technology Acceleration Overview (energy.gov) (siehe Link) - H2-Regulatory-Map-Report_SAND2021-2955.pdf (sandia.gov) (siehe Link)
American National	USA	info@ansi.org	+12126424900 +12022938020	Keine Antwort

Institut	Land	E-Mail	Telefonnummer	Antwort
Standards Institute				
American Society of Mechanical Engineers (ASME)	USA	Customer-Care@asme.org	+18008432763	Keine Antwort
CGA (Canadian Gas Association)	Kanada	info@cga.ca Brian.P.Murphy@ul.com	+16137480057 +16137552729	Es wurde an die kanadische Wasserstoff- und Brennstoffzellenvereinigung und die Kanadische Normenvereinigung verwiesen.
Canadian Hydrogen and Fuel Cell Association	Kanada	nhilario@chfca.ca	+16042831040	Keine Antwort
Canadian Standards Association	Kanada	member@csa-group.org	+18004636727 +14167474124	Keine Antwort
CER (Canada Energy Regulator)	Kanada	info@cer-rec.gc.ca joe.paviglianiti@cer-rec.gc.ca	+14032924800 +14034713125	Es wurde der technische Leiter für Forschung und Innovation, Joe Paviglianiti, kontaktiert. Keine Antwort.
JGA (Japan Gas Association)	Japan	takeichi.atsunori@gaf.or.jp	+81335020194	Es wurde eine Telefonnummer bereitgestellt, die jedoch ungültig ist.
Ministry of Petroleum and Natural Gas	Indien	amitesh.iras@gov.in pstomin.png@gov.in sec.png@nic.in	+911124362288	Es wurde an das Ministerium für erneuerbare Energien verwiesen.
Ministry of renewable energies	Indien	amahajan@nic.in saji.ka@nic.in	+911124360548 +911124361891	Keine Antwort
Bureau of Indian Standards	Indien	info@bis.gov.in pcd@bis.gov.in	+911123230131 +911123235432	Keine Antwort
KGU (Korean Gas Union)	Südkorea	global@kgu.or.kr	+8225638107	Keine Antwort
KEA (Korean Energy Agency)	Südkorea	kea@energy.or.kr	+82529200114	Keine Antwort
Korea Ministry of Government Legislation	Südkorea		+82442006900	Keine Antwort

Die Ermittlung von Ansprechpartner*innen erwies sich als große Herausforderung, die verschiedene Hürden aufzeigten (nicht verfügbare oder falsche Kontaktinformationen, unbeantwortete E-Mails oder Telefonanrufe usw.). Des Weiteren wurden Kontakte aufgrund von Datenschutz- und Vertraulichkeitsbedenken nicht übermittelt. Es wurden daher zusätzlich Netzwerke wie LinkedIn oder auch das eigene DBI-Netzwerk externer Partner von GERG und Marcogaz unterstützend herangezogen, um darüber mit Mitarbeiter*innen der Einrichtungen Kontakt aufzunehmen. Es konnten dadurch lediglich zwei Ansprechpartner*innen aus den USA und Kanada ermittelt werden. Diese wurden verständigt, jedoch blieb die Beantwortung der Umfrage offen.

Zudem ist das DBI der Einladung zum Seminar von PHMSA gefolgt und konnte folgende relevante Erkenntnisse gewinnen:

- Der Vertreter der PHMSA hat erklärt, dass die USA immer noch über die Entwicklung von Normen und Vorschriften speziell für den Wasserstoffsektor nachdenkt. Das bedeutet, dass sich ihre Bemühungen um eine Standardisierung von Wasserstoff in einem sehr frühen Stadium befinden und in naher Zukunft nicht zu erwarten sind.
- Ein Vertreter der OTD (Operations Technology Development), einer Forschungsgruppe, der 27 Mitglieder aus den USA, Kanada und Frankreich angehören, hat ihre laufenden und künftigen Projekte vorgestellt. Dazu gehört auch eine Studie über Wasserstoffnormen und -vorschriften, die 2022 anlaufen soll.

In Abstimmung mit der Projektbegleitgruppe wurde zusätzlich für eine direkte Kontaktaufnahme versucht Unternehmen in Asien zu identifizieren, welche Infrastrukturen mit Wasserstoff bzw. Wasserstoffgemischen betreiben.

Tabelle 3: Zusammenfassung der Ergebnisse der asiatischen Vertriebsnetzbetreiber

Gasnetzbetreiber	Land/Region	E-Mail	Telefonnummer	Antwort
U-Tech Engineering Company Limited (Subsidiary of Towngas)	Hongkong	utech@towngas.com	+85227655666	keine Antwort
City Energy	Singapur	Kontakt-Formular	+6566729952 +6565787643	keine Antwort
Energy Market Authority	Singapur	ema_enquiry@ema.gov.sg	+6568358000	keine Wasserstoffbeimischung bzw. H_2-Transport

Die Recherchen ergaben, dass in Japan kein rohrleitungsgebundener H_2-Transport stattfindet. In Singapur und Hongkong[1] wird Stadtgas (mit signifikanten H_2-Anteilen) verteilt.

[1] https://www.towngas.com/en/About-Us/Hong-Kong-Gas-Business/Gas-Production

4 Zusammenfassung und Handlungsempfehlung

Im Ergebnis wurden Wasserstoff-Kernregionen außerhalb Europas identifiziert und eine Umfrage erstellt. Die Umfrage diente dazu aktuelle wasserstoffspezifische Regelungen zu verstehen und einzuordnen. Die zuständigen länderspezifischen Institute wurden herausgearbeitet und kontaktiert. Die Beteiligung an der Umfrage war sehr gering und konnte durch Kürzung der Umfrage sowie verschiedenen Kontaktversuchen nicht erhöht werden. Darüber hinaus waren die ergänzenden Versuche, mit asiatischen Netzbetreibern in Kontakt zu treten, ebenfalls nicht erfolgreich.

Gemäß der zugrunde gelegten Quelle existieren in den USA, Kanada, Südkorea und Japan Regelungen/Richtlinien für Wasserstoffsysteme[2]. Die meisten dieser Normen befassen sich speziell mit Brennstoffzellensystemen und fallen daher nicht in den definierten Anwendungsbereich. Die folgende Tabelle fasst entsprechende Normen zusammen.

Tabelle 4: Zusammenfassung der aktuellen Wasserstoffnormen nach FCHEA [2]

Institut	Land	Reglung/Richtlinie
American Society of Mechanical Engineers (ASME)	USA	ASME B31.12 Hydrogen Piping and Pipelines ASME STP-PT-006 Design Guidelines for Hydrogen Piping and Pipelines
Canadian National Standards	Kanada	CAN/BNQ 1784-000 Canadian Hydrogen Installation Code
Compressed Gas Association	Kanada	CGA Publication G5 Hydrogen CGA Publication G5.4 Hydrogen Piping Systems at Consumer Sites CGA Publication G5.5 Hydrogen Vent Systems CGA Publication G5.6 Hydrogen Pipeline Systems (EIGA DOC 121/04)
CSA America	Kanada	ANSI/CSA CHMC 1 Test Method for Evaluating Material Compatibility in Compressed Hydrogen Applications – Phase I – Metals ANSI/CSA CHMC 2 Test Method for Evaluating Material Compatibility in Compressed Hydrogen Applications – Phase 2 - Polymers
Süd Korea Standards	Südkorea	KS B ISO 15916 Basic consideration for the safety of hydrogen systems

Als neuen Ansatz für die möglichen nächsten Schritte dieser Studie werden folgende Handlungsempfehlungen gegeben:

- Länder wie die USA haben noch keine neuen föderalen wasserstoffspezifischen Vorschriften entwickelt. Ihre derzeitigen Vorschriften sind in Anhang B erläutert. Nach PHMSA sind derzeit keine wasserstoffspezifischen Regelungen in Arbeit oder in naher Zukunft zu erwarten. Diese würden keinen nennenswerten Mehrwert mit sich bringen, da Wasserstoff einfach als ein weiteres gefährliches Gas z.B. im Transportwesen angesehen wird. Es fehlen auch Informationen über die Bemühungen Indiens, eine eigene Wasserstoffnormung zu entwickeln.

[2] Fuel Cell & Hydrogen Energy Association: http://fuelcellstandards.com/home.html

- Es ist ggf. von Vorteil, wenn der DVGW e.V. zunächst einen direkten Kontakt zu diesen Institutionen aufbaut, der anschließend für weitere Kontaktaufnahmen sowie Umfragen genutzt werden kann.
- Eine Zusammenarbeit mit der Forschungsgruppe OTD wäre von Vorteil, um mehr potenzielle Kooperationspartner zu erreichen.

Anhang

Umfrage

QUESTIONNAIRE

DBI

Worksheet G 468-1 (Technical Rule)	Qualifikationskriterien für Gasrohrnetz-Überprüfungs-unternehmen	Qualification criteria for gas pipe network inspection companies

Scope of application

This worksheet contains the personnel and technical requirements for companies that carry out inspection work (except for cathodic corrosion protection) on gas pipe networks in public gas supply as well as the customer's own facilities in accordance with the terms of DVGW worksheets G465-1, G465-3, G466-1 und G466-2.

The [...] listed qualification criteria are a prerequisite for the certification of gas pipe network inspection companies to be conducted by the DVGW Certification Body.

Summarized questions

G 468-1 contains basic requirements for appropriate companies with regard to regular training for test procedures. The requirements are described in detail in the worksheet. With regard to hydrogen the following questions are addressed:

1. How far is the necessary qualification of the training centers for the inter-company training of skilled workers related to hydrogen?
2. Are there theoretical as well as practical training courses for handling hydrogen-carrying pipes?
3. Is there a uniform national standard for testing and certification of H_2-compatible measuring instruments and equipment?
4. Does the reorganization of the regulations include a consideration of different H_2 contents with regard to measuring methods, measuring accuracy and cross-sensitivities?
5. Will existing regulations concerning hydrogen be adjusted or will new ones be created?
6. Is there any training on measuring principles, abrasion and handling within the scope of further training?
7. General: How to deal with the lack of experience in dealing with H_2 due to time constraints? Is there a preliminary of further training measures compared to the first occurrence of hydrogen and mixtures in public gas networks?

QUESTIONNAIRE

Worksheet G 468-2 (Technical Note)	Gasspürer, Schulungsplan	Gas Detector, Training-Plan

Scope of application

This sheet contains the basis for a training course as well as a review of the level of knowledge of the specialists (gas detectors) responsible for the practical implementation of the gas pipe network inspection using gas concentration measuring devices. It does not replace the annual training required by DVGW worksheet G 468-1, section 4.1.3. The training and examination will be carried out by the DVGW training center.

Summarized questions

G 468-1 contains basic requirements for corresponding companies regarding Gas Detector Training Plan. The requirements are described in detail in the worksheet. With regard to hydrogen the following questions are addressed:

1. How far will hydrogen be included as a primary component in the training plan or will separate training for H_2-carrying pipelines be offered for this purpose?
2. How far is the issue of the lack of practical experience taken into account in the transition phase?
3. Are there already H_2-specific regulations in general that are imparted in the training courses?
4. The important building blocks of H_2-specific training are hydrogen production and fuel-specific properties (ignition limits, flame velocity, flame temperature, detonation behaviour). What additional content should be imparted as a matter of urgency?
5. How far contents on the technical execution of gas supply systems are adapted in the training courses, H_2 influences are seen here in particular with regard to pressure stages, areas of application of pipe materials, identification of armatures, cause of leakage points, gas losses and their elimination as well as in the adaptation of inspection periods.
6. How far are underground pipelines marked in the case of H_2 routing or is the H_2 content designated?
7. Are training courses for accident prevention and construction site safety in connection with H2 created and offered separately?
8. In terms of practical training for H_2 supply systems with H_2 concentration meters, what practical activity is required?

QUESTIONNAIRE

DVGW G 452_2 (A) Technische Regel - Arbeitsblatt	Anbohren und Absperren; Teil 2: Abquetschen von Kunststoffrohrleitungen für Gas mit Drücken bis 5 bar und Außendurchmesser bis 315 mm	Tapping and Shutting off; Part 2: Squeezing off Plastic Pipelines for Gas with Pressures up to 5 bar and Outer Diameters up to 315 mm

Scope of application

[...] applies to the temporary squeezing [...] of [plastic pipelines for gas] (with hydrogen contents of 0 to 100% by volume) with pressures up to 5 bar (0.5 MPa) [...] and outer diameters up to 315 mm

Summarized questions

G 468-1 contains basic requirements for appropriate companies with regard to Squeezing off Plastic Pipelines for Gas with Pressures up to 5 bar and Outer Diameters up to 315 mm. The requirements are described in detail in the worksheet.

With regard to hydrogen the following questions are addressed:

1. Is the diffusion behaviour of hydrogen taken into account with regard to the squeezing of plastic piping? (Surface expansion, tension)
2. Are modified conditions required for squeezing H2 pipelines?
3. Do the procedures for visual inspection and marking of squeezing points have to change?
4. Will the test principles be modified with regard to gas tightness during squeezing?

QUESTIONNAIRE

DVGW G 459-1 (A) Technische Regel _ Arbeitsblatt	Gas-Netzanschlüsse für maximale Betriebsdrücke bis einschließlich 5 bar	Service lines for maximum operating pressures up to and including 5 bar

Scope of application

[…] for the installation (planning, construction, testing and commissioning) and operation of network connections in accordance with NDAV for the supply of gas to end consumers operated at a maximum permissible operating pressure of up to and including 5 bar […]

Summarized questions

G 459-1 (A) contains basic requirements for corresponding companies with regard to gas network connections for maximum operating pressures up to and including 5 bar. The requirements are described in detail in the worksheet. The following questions arise in regard to hydrogen:

1. In general: Will the limit value for the pressure level (in Germany 5 bar) for gas network connections remain unchanged or will there be changes?
2. Will H_2-specific qualification be mandatory in the future for pipeline construction companies and specialists when handling H_2-leading gas network connections?
3. In general: Are changes necessary with regard to structural specifications for shut-off devices?
4. Does the use of hydrogen require changes in approved arrangements of main shut-off devices outside buildings? (Group shut-off, gas flow monitor)
5. Are changes necessary with regard to the minimum distance of grid connection lines to already existing supply or disposal pipelines?
6. Which changes are to be fulfilled concerning the suitability of house connection rooms in the case of gas connection for H_2?
7. Replacement/ adjustment of the required measurement and calculation for H_2 and H_2 mixtures; In relation to, dimensioning of network connections and calculate ground movements.
8. Are changes to the specified connection types necessary with regard to the manufacture of pipe connections? Example: approved threads, fittings, flanges
9. Are modified signs created for pure H_2 pipelines or mixtures as well as for shut-off devices, is there an explicit reference to H_2?
10. Are pressure tests for gas network connections adjusted with regard to hydrogen or is there an adjustment of the test pressure compared to the max. permissible operating pressure?
11. Are tests according to the visual method with the operating gas H_2 by using foam-forming agents or the use of suitable gas concentration measuring devices permitted for individual pressure tests?
12. Is the venting of an H_2/air mixture to the open-air permitted when gas is admitted to network connections the same as for natural gas?
13. Is the closure of H_2-carrying and not yet completed network connections with conventional means such as plugs, caps, etc. permissible?

QUESTIONNAIRE

DVGW G 462 (A) Technical Rule _ Worksheet	Gasleitungen aus Stahlrohren bis 16 bar Betriebsdruck; Errichtung	Gas Pipework made of Steel Pipes for an Operating Pressure up to and including 16 bar

Scope of application

This worksheet applies to the construction (planning, construction, testing and commissioning) of pipelines made of steel pipes which serve to supply the general public with gas for a maximum permissible operating pressure of up to 16 bar in which gases are transferred in accordance with DVGW worksheet G 260 [...]

Summarized questions

G 462 (A) includes the construction (planning, construction, testing and commissioning) of pipelines made of steel pipes for an operating Pressure up to and including 16 bar. The requirements are described in detail in the worksheet. With regard to hydrogen the following questions are addressed:

1. How is the (still) lack of experience and expertise regarding hydrogen addressed?
2. Are changes in gas composition regarding H_2 and H_2 mixtures taken into account in the welding procedures? (Approved welding consumables, non-destructive test methods).
3. In contrast to natural gas, will there be changes to the routing for hydrogen with regard to local conditions?
4. In contrast to natural gas, will there be changes in the routing of hydrogen with regard to minimum distances? (Supply and disposal lines, power cables, wind turbines, constructions)
5. Will there be changes in routing for hydrogen with respect to pipe coverage, unlike natural gas?
6. What should be the pipe coverage for different pressures?
7. Are there any adjustments regarding approval for pipes, piping components, shut-off valves, blow-out devices and other components?
8. Are there any adjustments regarding corrosion protection with hydrogen?
9. Are there any modifications regarding welding requirements for H_2 gas pipelines?
10. Are there any adaptations to the pipeline construction for H_2 pipelines? (e.g., bending radii)

QUESTIONNAIRE

DVGW G 465-3 (M) **Technical note– Data sheet** Mai 2019	**Leckstellen an Gasleitungen in Gasrohrnetzen – Lokalisation, Klassifikation, Umgang mit Leckstellen**	**Leaks in pipework in gas distribution systems – localisation, classification, handling of leaks**

Scope of application

This worksheet applies to the inspection of leaks in gas pipe networks for the supply of gas to the general unit as well as to the associated energy facilities on the plant premises and in the area of operational gas use, which are used to transport gases in accordance with DVGW worksheet G 260….

Summarized questions

G 465-3 (M) includes the leakage spots on gas pipes in gas pipe networks. The requirements are described in detail in the worksheet. With regard to hydrogen the following questions arise:

1. Relating to requirements for grid operators, specialized companies and skilled workers; What qualifications and certificates do the skilled workers of the grid operator or specialized companies need?
2. From which hydrogen concentration is a detection in the soil considered as evidence? Example: Natural gas >0.1% by volume in the probe hole
3. From which hydrogen concentration is a detection in the structure/cavity considered as evidence?
4. From which hydrogen concentration is gas-free?
5. How is the detection range defined for hydrogen? (gas concentration)
6. Will the qualifications and certificates for the network operator's specialists and specialist companies be adapted with regard to hydrogen?
7. Will the causes of leaks due to the effects of hydrogen be reformulated? (H_2 embrittlement)
8. How far are the following influencing variables re-evaluated with regard to the gas propagation of hydrogen? The density of the fuel gas; impermeability of the surface, type of soil and pipe cover; creep paths of the gas in the soil; the inclination of the pipe; soil climate, weather influences; bacterial activity and gases from decomposition processes in the soil.
9. Are leakage points for hydrogen re-evaluated in terms of leakage classes, safety measures and reaction?

QUESTIONNAIRE

DVGW G 465-4 (M) **Technical note– Data sheet** Mai 2019	**Gerätetechnik für die Überprüfung von Gasleitungen und Gasanlagen**	**Technical equipment for the leakage survey of gas pipework and gas stations**

Scope of application

This worksheet applies to Portable Equipment for Gases...

To determine detection of leaks and damages in gas pipelines, transport, distribution, installation and customer-owned and industrial gas installations.

To estimate the risk of explosion in working areas and

For the determination of special gas components…

Summarized questions

G 465-4 (M) includes the technical equipment for the leakage survey of gas pipework and gas stations. In the worksheet, the requirements are described in detail. Regarding hydrogen, the following questions arise:

1. How far are training courses, further training measures for instructed persons, specialists and experts carried out regarding hydrogen and the handling of device technology for detection?
2. Which following characteristics of the equipment technology regarding hydrogen have been changed? - display of measuring result (ppm, vol.-&); ATEX_approval; operating principle; cross sensitivities; response time (T90); relative measuring error?
3. Are changes in the measuring procedure necessary for hydrogen-carrying pipes? (distance pipe, seal; measuring time)?
4. How far are changes made to the handling of the equipment in terms of inspection, testing of display accuracy, maintenance, repair?
5. How far are there changes regarding specifications for visual and/or audible signals for hydrogen detection in the following applications: Above ground inspection, ground air/gas purity testing, building/exposed piping systems testing, work area monitoring.

QUESTIONNAIRE

DVGW G 472 Technical Rule _ Worksheet	Gasleitungen aus Kunststoffrohren bis 16 bar Betriebsdruck; Errichtung	Gas Pipework made of Plastic Pipes for an Operating Pressure up to and including 16 bar

Scope of application

This worksheet applies to the construction (planning, construction, testing and commissioning) of pipelines made of plastic pipes which serve to supply the general public with gas for a maximum permissible operating pressure of up to 16 bar in which gases are transferred in accordance with DVGW worksheet G 260 [...]

Summarized questions

G 462 (A) includes the construction (planning, construction, testing and commissioning) of pipelines made of plastic pipes for an operating Pressure up to and including 16 bar. The requirements are described in detail in the worksheet. Regarding hydrogen the following questions are addressed:

1. What should be the maximum allowable working pressure for a given diameter range of solid wall pipes made of polyethylene and polyamide, and multi-view pipes for gas pipelines?
2. In terms of personnel and construction supervision, what qualifications do the H_2 pipeline construction company and construction supervision need? Can pipeline construction companies have construction supervision as well?
3. Which certificates of welders are required?
4. Are changes in gas composition regarding H_2 and H_2 mixtures considered in the welding procedures? (Approved welding consumables, non-destructive test methods).
5. How is the (still) lack of experience and expertise regarding hydrogen addressed?
6. In contrast to natural gas, will there be changes to the routing for hydrogen regarding local conditions?
7. In contrast to natural gas, will there be changes in the routing of hydrogen regarding minimum distances? (Supply and disposal lines, power cables, wind turbines, constructions)
8. Will there be changes in routing for hydrogen with respect to pipe coverage, unlike natural gas?
9. What should be the pipe coverage for different pressures?
10. Are there any adjustments regarding approval for pipes, piping components, shut-off valves, blow-out devices and other components?
11. Are there any adjustments regarding corrosion protection with hydrogen?
12. Are there any modifications regarding welding requirements for H_2 gas pipelines?
13. Which requirement must a pipe bend for H_2 pipes fulfill?
14. Are there any adaptations to the pipeline construction for H_2 pipelines? (e.g., bending radii)
15. What should be the bedding layer thickness in cm for polyamide and plastic pipes?

QUESTIONNAIRE

DBI

Test basis VP 601 (Technical Rule)	Prüfgrundlage Gas- und Wasser-Hauseinführungen	Test basis Gas and water house entries

Scope of application

This test specification applies to requirements and tests for house entries in accordance with Sections 3.1.1 to 3.1.3 in house end pipes made of steel up to DN 50 or polyethylene up to d63 for gas and water supply. The test shall cover gas house entries and house entries that can be used for both gas and water supply. In gas and water supply, house entries are used in accordance with this preliminary test specification for house connections as per DVGW worksheet G 459-1 or DVGW datasheet W 404.

The requirements of this test specification do not apply to the drinking water supply if the service pipe is fed into the building by other means.

…..

Summarized questions

Test specification VP 601 contains test specification requirements for corresponding companies with regard to gas and water house entries. On a test basis, the requirements are described in detail. With regard to hydrogen the following questions arise:

1. How far is hydrogen taken into account in terms of corrosive, electrical and thermal influences in new regulations? Keyword: H2 embrittlement
2. Is hydrogen taken into account from a material point of view in house entries (H_2 embrittlement acting from the inside)?
3. How are leakages of hydrogen handled in house entries with respect to safe discharge to the outside? Background: Different diffusion behavior of hydrogen
4. Are other sealing materials and grouting materials used?
5. Are there changed test principles for seals, pipe materials, shut-off valves, potting materials (material certificates for H_2 suitability)?
6. Are electrical isolating points in H_2 lines subject to modified test procedures?
7. Are there modified test procedures regarding leak tightness? (Test pressure, leakage rate, test setup)
8. How far are quality controls (self-monitoring and control testing) changed when hydrogen is used?

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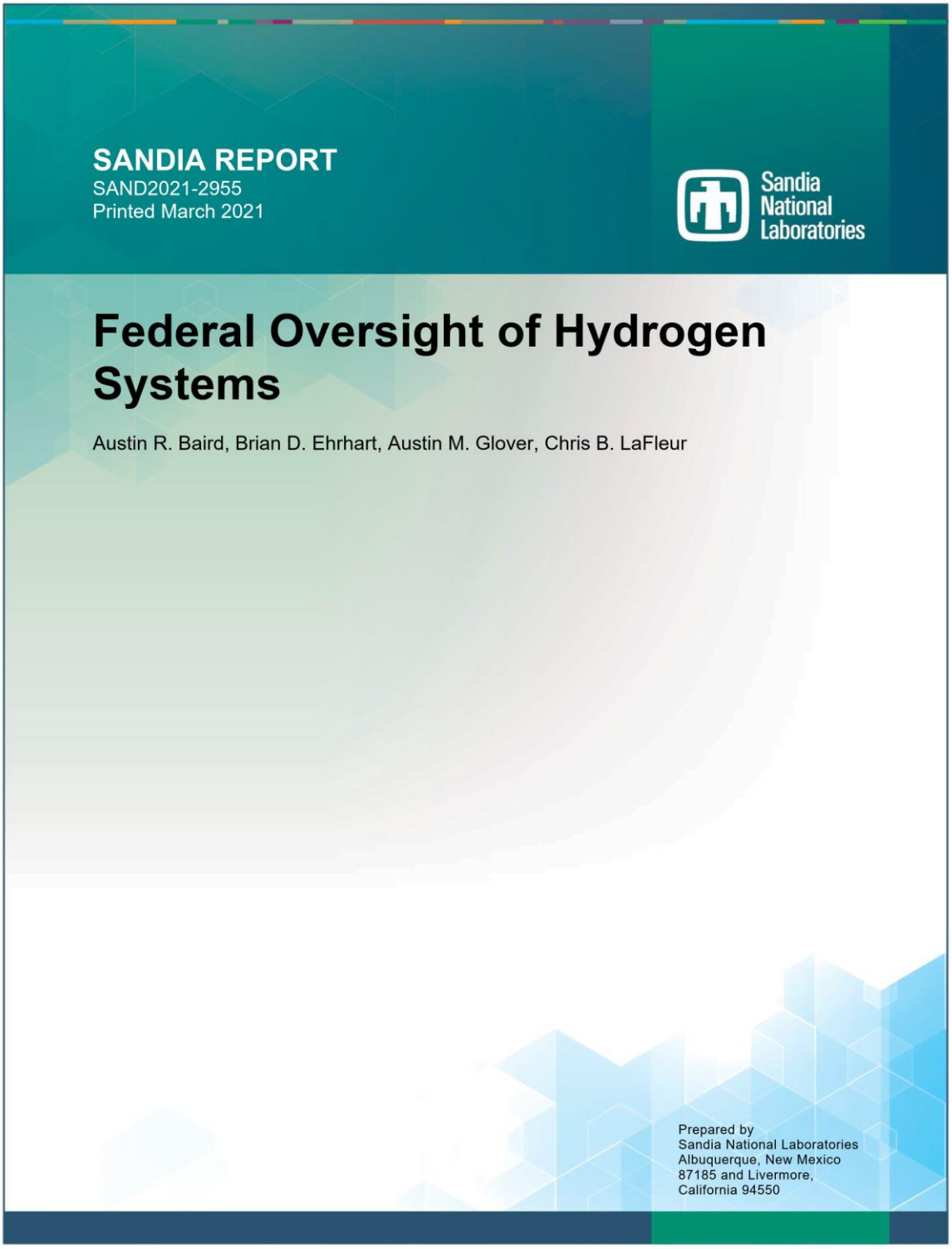

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Federal Oversight of Hydrogen Systems

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ABSTRACT

The application of hydrogen as an energy carrier has been expanding into industrial and transportation sectors enabling sustainable energy resources and providing a zero-emission energy infrastructure. The hydrogen supply infrastructure includes processes from production and storage, to transportation and distribution, to end use. Each portion of the hydrogen supply infrastructure is regulated by international, federal, state, and local entities. Regulations are enforced by entities which provide guidance and updates as necessary. While energy sources such as natural gas are currently regulated via the Code of Federal Regulations and United States Code, there might be some ambiguity as to which regulations are applicable to hydrogen and where regulatory gaps may exist. This report contains an overview of the regulations that apply to hydrogen, and those that may indirectly cover hydrogen as an energy carrier participating in a sustainable zero emission global energy system. As part of this effort, the infrastructure of hydrogen systems and regulation enforcement entities are defined, and a visual map and reference table are developed. This regulatory map and table can be used to identify the boundaries of federal oversight for each component of the hydrogen supply value chain which includes production, storage, distribution, and use.

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND DEFINITIONS

Abbreviation	Definition
AHJ	authority having jurisdiction
ASME	American Society of Mechanical Engineers
BSEE	Bureau of Safety and Environmental Enforcement
CFR	Code of Federal Regulations
CGA	Compressed Gas Association
DHS	Department of Homeland Security
DOE	Department of Energy
DOT	Department of Transportation
EERE	Office of Energy Efficiency and Renewable Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FE	Office of Fossil Energy
FERC	Federal Energy Regulatory Commission
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FMVSS	Federal Motor Vehicle Safety Standards
FRA	Federal Railroad Administration
FTA	Federal Transportation Administration
FTC	Federal Trade Commission
HMR	Hazardous Materials Regulations
ICC	International Code Council
IFC	International Fire Code
LHG	liquefied hazardous gas
LNG	liquefied natural gas
MARAD	Maritime Administration
NFPA	National Fire Protection Association
NHTSA	National Highway Traffic Safety Administration
OCS	outer continental shelf
OORP	Office of Offshore Regulatory Programs
OPS	Office of Pipeline Safety
OSHA	Occupational Safety and Health Administration
PHMSA	Pipeline and Hazardous Materials Safety Administration
USC	United States Code
USCG	United States Coast Guard

1. INTRODUCTION

Hydrogen has been used in chemical and energy industries, particularly as part of oil and natural gas processing; currently, the U.S. produces approximately 10 million metric tons of hydrogen per year [1], and worldwide approximately 70 million metric tons of hydrogen per year are produced [2]. In recent years, hydrogen demand has increased specifically to power fuel cells used in forklifts, light-duty vehicles, and stationary power systems, leading to many new installations of hydrogen systems. Installers of these systems use local building codes, National Fire Protection Association (NFPA) codes, and the International Code Council (ICC) International Fire Code (IFC) for code requirements and engage with the authority having jurisdiction (AHJ) for safety and permitting approvals. The U.S. Department of Energy (DOE) H2@Scale initiative [3] has led to increased interest in new applications for hydrogen systems, including industrial applications, transportation modes, and generally much larger quantities of hydrogen. Larger installations and new transportation modes mean that hydrogen systems are not only subject to local AHJ approval but could be subject to federal oversight as an element of a new sustainable zero emission global energy system. The hydrogen supply value chain includes a variety of steps from production and storage, to transportation and distribution, to end use. The purpose of this effort is to identify the federal regulatory organizations that must be engaged to enable hydrogen to participate in a nationwide sustainable zero emission energy solution.

This effort was inspired and informed by a similar effort by the U.S. Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA) regulatory map "Federal Oversight of Liquefied Natural Gas (LNG) Value Chain" [4]. The LNG regulatory map created by DOT PHMSA provides a schematic of all types of LNG facilities and the ways in which LNG can move between them, as well as different location types for these facilities. It then provides markers of different shapes and colors to denote which federal agency has oversight of a particular facility or transportation mode. While technical application requirements are different when comparing hydrogen and natural gas, the regulatory oversight responsibilities might be similar.

Therefore, the purpose of this report is to examine the Code of Federal Regulations (CFR) and United States Code (USC) in order to verify if federal oversight of hydrogen systems would indeed be similar to LNG systems. Specifically, the goal of this effort is to identify where federal oversight begins and ends with respect to various portions of hydrogen supply value chain, including production, storage, transportation, distribution, and use. In so doing, this report is a resource that identifies which federal agencies have oversight of various hydrogen systems and modes of transport, based on current regulations. Additionally, this report identifies, to the extent possible, whether hydrogen is specifically included or excluded from certain activities, installations, or modes of transport based on the current regulations.

This document is not meant to be a compendium of all regulations, codes, and standards that a hydrogen system must follow. Local jurisdictions can and have adopted many different requirements that must be followed for installations under their purview. This document considers only federal regulatory oversight of the hydrogen supply value chain in order to identify which regulators and agencies need to be engaged by designers, integrators, stakeholders, AHJs, and end users for future development of hydrogen technologies. Effort is made to identify the limits of federal oversight, in particular what types of systems would fall under state/local jurisdiction rather than federal, but this document does not identify which regulations, codes, or standards might be adopted by the state or local jurisdiction.

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2. HYDROGEN SUPPLY VALUE CHAIN & FEDERAL REGULATIONS

The hydrogen supply value chain includes a variety of processes from production and storage, to transportation and distribution, to end use. Each portion of the hydrogen supply value chain is regulated by various federal entities, which is captured in this section.

A general overview of the hydrogen supply value chain is shown in Section 3 (Figure 3-1). This figure helps visualize how the supply, distribution, and end use of hydrogen is connected. This document is not intended to go into technical details of each technology listed, this type of information can be found in the DOE Hydrogen Program Plan [5].

2.1. Production & Storage for Distribution of Hydrogen

The following subsections include hydrogen production and storage for distribution. This is the first part of the hydrogen supply chain infrastructure.

2.1.1. Production Systems

The regulation of hydrogen production in the United States is governed by 40 CFR Part 98 Subpart P – Hydrogen Production. Hydrogen production facilities produce hydrogen that is sold as a product to other entities, process units that produce hydrogen, and hydrogen production facilities located within another facility that are not under direct control of the facility's owner. This CFR requires that owners or operators of facilities that produce hydrogen must report emissions from hydrogen production processes and all other source categories at the facility for which methods are defined in the rule [6]. Note that reporting is contingent upon whether the facility meets the requirements of 40 CFR 98.2, which defines source categories and emissions thresholds for the facility. The Environmental Protection Agency (EPA) is the governing body for this regulation.

There are several codes and standards related to hydrogen production that are subject to approval from state or local AHJs which would adopt and enforce these as regulations. Examples of these codes and standards include but are not limited to NFPA 2, NFPA 70, Compressed Gas Association (CGA) H-5.5, American Society of Mechanical Engineers (ASME) B31, and CGA S-1.1-1.3 [7]. State and local jurisdictions may adopt these or other codes and standards, and different jurisdictions may adopt different editions (year published) of these codes and standards. These codes and standards do not fall under federal oversight and are mentioned here only as examples.

2.1.2. Storage Systems

Regulation of a hydrogen storage system is dependent on the purpose of the storage system and whether the hydrogen is stored in gaseous or liquid form. The U.S. Department of Labor Occupational Safety and Health Administration (OSHA) regulates hydrogen storage through 29 CFR Part 1910 Subpart H – Hazardous Materials. This CFR provides the safety requirements of the structural components and operations of gaseous and liquid hydrogen in terms of storage as well as delivery [8]. Note that there are scope limitations defined for hydrogen storage in this CFR, such as minimum quantity, that depend on whether the hydrogen is gaseous or liquified.

For aircraft and spacecraft launch sites, the DOT Federal Aviation Administration (FAA) regulates hydrogen storage through 14 CFR Part 420, which dictates the separation distance requirements between the storage of liquid hydrogen and any incompatible energetic liquids stored within an intraline distance (the minimum distance permitted between any two explosive hazard facilities in the ownership, possession, or control of one launch site customer) [9]. This regulation stipulates that

each explosive hazard facility must be separated from other hazard facilities, public areas, and public traffic routes in accordance with the minimum separation distance requirement.

There are several codes and standards related to hydrogen storage for distribution that are subject to approval from state or local AHJs which would adopt and enforce these as regulations. One example of such a standard include NFPA 2, which addresses several structural and safety requirements of the hydrogen storage facility.

2.2. Transportation & Distribution of Hydrogen

The next subsections are focused on transportation and distribution of hydrogen as cargo. This includes pipelines, whether repurposed or new installations, as well as transportation via roads, railroads, and waterways. As will be noted in the following sub-sections, the U.S. Department of Transportation (DOT) has oversight over many of these applications through various relevant administrations within DOT.

2.2.1. Transportation by Pipelines

Regulation of hydrogen transported via pipeline infrastructure depends on whether the pipeline is onshore or offshore and if it is interstate or intrastate. 49 CFR Part 192 is the governing law for transportation of natural gas and other gases via pipelines within the limits of the outer continental shelf (OCS), as regulated by PHMSA [10]. The OCS is defined as all submerged lands lying seaward of state coastal waters (3 miles offshore) which are under U.S. jurisdiction [11]. The regulation of natural gas transportation by pipeline is covered by 49 CFR Part 192, and hydrogen would also fall under these regulations as well since other gases are covered by scope and definition.

Currently, interstate and onshore pipelines transporting natural gas are regulated by the Federal Energy Regulatory Commission (FERC) and PHMSA. FERC regulates energy sales and distribution of natural gas through CFR 18 Part 284. Additionally, 18 CFR Part 153 includes regulation of the siting, routing, and overall construction of a natural gas pipeline system. 18 CFR Part 153 also differentiates between pipelines integrated into import and export terminals as discussed in Section 2.2.5. PHMSA also has oversight on design and construction of pipelines. PHMSA regulates pipeline facilities that transport gas in pipelines via 49 CFR Part 192, LNG via 49 CFR Part 193, and hazardous liquids via 49 CFR Part 195. Once the construction of the pipeline system is completed, PHMSA via its Office of Pipeline Safety (OPS) regulates and enforces the pipeline and ensures safety requirements are met. The oversight includes inspections and day-to-day activities [12]. Intrastate pipelines are regulated through either the state agencies or by OPS via an agreement with the states. The agreements between each state and OPS are maintained by PHMSA [13].

Transmission and gathering pipelines in federal waters on the OCS are regulated by either PHMSA OPS or the U.S. Department of the Interior Bureau of Safety and Environmental Enforcement (BSEE) [14]. Pipelines closer to shore which are in state waters are regulated through state agencies or PHMSA OPS [14]. The BSEE Office of Offshore Regulatory Programs (OORP) partner with the U.S. Department of Homeland Security (DHS) and the United States Coast Guard (USCG) as well as other federal and state agencies to manage compliance programs governing oil, gas, and mineral operations on the OCS [15]. While PHMSA OPS regulates through 49 CFR Part 192, BSEE OORP regulates through 43 USC Part 29 [16]. While BSEE OORP and DHS USCG regulations are focused on oil and gas drilling rigs, hydrogen production and transportation from deep-water ports would require regulation. The USCG regulates facilities transferring hazardous materials to as vessel from a facility and discharging from a vessel to a facility through 33 CFR Part 154 [17].

Based on the current landscape of pipeline regulation, pipelines transporting hydrogen across interstate land and water will possibly be subject to the various regulations issued by PHMSA and FERC and intrastate hydrogen pipelines will be subject to similar regulations as well as local state regulations. Offshore regulation of hydrogen transportation is enforced by BSEE and USCG as well as PHMSA which regulates natural and other gases transported via pipeline.

2.2.2. Transportation by Road

The regulation of the transportation of hydrogen over roads as cargo within tanker trucks in the United States is governed by PHMSA through 49 CFR Subchapter C- Hazardous Materials Regulations (HMR). This specifically includes 49 CFR Part 172, 173, and 177. 49 CFR Part 172 lists those materials which PHMSA has designated as hazardous materials for purposes of transportation and prescribes the requirements for shipping papers, package marking, labeling, and transport vehicle placarding applicable to the shipment and transportation of those hazardous materials [18]. T75 and TP5 codes in 49 CFR Part 172 are applicable to portable tanks and fill rate of liquid hydrogen tankers [7]. 49 CFR Part 173 includes specific requirements for the use of insulated MC-338 cargo tanks for cryogenic hydrogen transportation in 49 CFR Part 173.318 and bulk cylinders for compressed, non-cryogenic hydrogen in 49 CFR Part 173.302. Additionally, 49 CFR Part 177 lists loading and unloading practices. 49 CFR Part 178 includes details on the design and approval of shipping containers including cylinders and tanks. 49 CFR Part 180 provides specifications for packaging and containers used for transportation of hazardous materials. The DOT Federal Highway Administration (FHWA) regulates highway safety which includes bridges, tunnels, and other associated elements as part of 23 CFR Part 924 Highway Safety Improvement Program. The DOT Federal Motor Carrier Safety Administration (FMCSA) regulates motor carrier routing (49 CFR Part 356), general motor carrier safety regulations (49 CFR Part 389), and transportation of hazardous materials (49 CFR Part 397). The U.S. Federal Trade Commission (FTC) regulates labeling requirements for alternative fuels via 16 CFR Part 306 which is required when transferring fuel between two entities. Transportation of hydrogen over roads is subject to these regulations by PHMSA, FTC, FMCSA, and FHWA in addition to state and local regulations.

2.2.3. Transportation by Rail

Hazardous materials transported via U.S. rail network are regulated by PHMSA through 49 CFR Part 172 for hazardous materials requirements, 49 CFR Part 173 for shipping requirements, 49 CFR Part 174 for rail transportation, and 49 CFR Part 178 prescribes specifications for packaging and containers used for transportation of hazardous materials. The approval of currently prohibited hazardous materials by rail require either approval by DOT Federal Railroad Administration (FRA) under 49 CFR Part 174.63 or special permit by PHMSA under 49 USC 5117. Special permit by PHMSA does not require separate approval by FRA since the two agencies cooperate when reviewing these applications. This has been applicable to LNG transport by rail up until PHMSA published the "Hazardous Materials: Liquefied Natural Gas by Rail" final rule in 2020 [19] [20]. However, this approval process will not be required for hydrogen transportation, since PHMSA authorizes the manufacture and use of a double-walled, insulated tank car for cryogenic hydrogen, known as a DOT-113A60W. 49 CFR Part 179 and 180 cover the construction and qualification for the DOT-113A60W tank cars. FRA has State Rail Plan Guidance to involve states in railroad network policy, planning, and development [21]. The plan shall address the state's involvement in rail transportation as posed by the state's constitution, laws, or regulations, or by implementation of current or proposed federal regulations. The federal government has preempted state railroad safety regulation but offers each state the ability to participate in federal enforcement through FRA.

Transportation of hydrogen via rail is subject to the regulations by PHMSA with input by FRA in addition to state and local regulations.

2.2.4. Transportation by Waterways

Regulation of hydrogen as cargo transported via waterways in vessels is dependent on whether the route is on federal or state waters and what agreement state and local regulators have with federal oversight. Hazardous materials transported via waterways are regulated by PHMSA through 49 CFR Part 172 for hazardous material requirements, 49 CFR Part 173 for shipping requirements, 49 CFR Part 176 for additional requirements for transportation by vessel, 49 CFR Part 178 prescribes specifications for packaging and containers used for transportation of hazardous materials, and 49 CFR Part 180 provides qualification requirements for inspecting and maintaining packages and containers used to transport hazardous materials. 33 CFR Part 156 – Oil and Hazardous Material Transfer Operations is enforced by USCG [22]. The scope of 33 CFR Part 156 applies to transfer of oil or hazardous material on the navigable waters or contiguous zone of the U.S. to or from vessels with a 250-barrel or more capacity[1]. Additionally, USCG regulates facilities transferring hazardous materials back and forth from a vessel to a facility through 33 CFR Part 154 [17]. 46 CFR Part 38 gives USCG the authority to regulate transportation of liquified or compressed gases which hazardous are primarily the flammability. 46 CFR Subchapter O – Certain Bulk Dangerous Cargoes is also enforced by USCG. 46 CFR Part 150 describes incompatibility of hazardous materials and rules for transporting these materials aboard tanks that are loaded and discharged while on the vessel. 46 CFR Part 151 provides regulations for non-self-propelled ships carrying bulk cargo while 46 CFR Part 153 provides regulations for self-propelled ships carrying bulk cargo. 46 CFR Part 154 provides regulations for self-propelled vessels that contain bulk liquified gases as cargo, cargo residue or vapor.

To summarize, PHMSA regulates transportation of containerized hazardous materials by water through the HMR in cooperation with USCG as well as state/local regulations where applicable.

2.2.5. Import & Export Terminals

Import and export terminals generally involve a pipeline to a facility in which gas can be liquefied for bulk transport by sea. FERC is responsible for authorizing the siting, construction, modification, and operation of near and offshore natural gas import/export facilities through 18 CFR Part 153 [23]. USCG regulates facilities transferring hazardous materials to as vessel from a facility and discharging from a vessel to a facility through 33 CFR Part 154 [17]. While FERC is responsible for the planning and construction of import and export terminals using natural gas, USCG is responsible enforcing regulations to ensure day-to-day safety and security for waterfront facilities [24]. It is expected that these regulations would be modified to include hydrogen as this capability evolves for hydrogen as a participant in the energy infrastructure. If the import or export terminals use pipelines across land or into federal waters, regulations described in Section 2.2.1 would be applicable. PHMSA also regulates pipeline facilities that transport gas via 49 CFR Part 192, LNG via 49 CFR Part 193, and hazardous liquids via 49 CFR Part 195. To the extent that hydrogen transportation could involve the use of deepwater ports, licensing of such facilities might be accomplished through the Deepwater Ports Program implemented jointly by USCG and MARAD. It is likely that some modifications to that program would be needed to expand application to hydrogen.

[1] This capacity would need to be specified for hydrogen.

2.3. Hydrogen End Use

Sections 2.3.1 through 2.3.3 identify the regulations associated with the use of hydrogen for electricity production, heating, and chemical/industrial systems. Electricity can be produced via hydrogen powered fuel cells or through combustion to provide power to generators or produce heat. Additionally, hydrogen may be used directly in gas powered residential/commercial appliances as the fuel source based on the appliance specifications. These applications are relevant to pure hydrogen as well as hydrogen and natural gas blends. Section 2.3.4 identifies which federal entities would regulate blending hydrogen into the natural gas supply value chain. Blending can occur either locally or at the city gate which is where the distributing gas utility receives and measures natural gas from transmission lines [25].

2.3.1. Electricity Production via Fuel Cell and Combustion Systems

FERC regulates cogeneration and small power production facilities that include equipment to produce electricity or thermal energy for the grid through 18 CFR Part 292. Note that the specific requirements for classification as a small power production facility or a cogeneration facility are defined in 18 CFR 292.203. 18 CFR Chapter I gives requirements that FERC enforces regarding interstate electric transmission, interconnections, licensing/permits, etc. The DOE Office of Fossil Energy (FE) regulates alternative fuels through 10 CFR Subchapter E – Alternate Fuels. Both current and new power plants fall under these requirements through 10 CFR Parts 503 and 504, respectively. Additionally, state and local regulations play a role in regulating electricity production and transmission. If hydrogen is used in either fuel cells or combustion systems to produce electricity for the grid, they are subject to possible regulation by FERC, FE, as well as any state/local government regulations.

2.3.2. Residential, Commercial, and Industrial Heating Systems

FERC regulates energy sales and distribution of natural gas through 18 CFR Part 284. DOE Office of Energy Efficiency and Renewable Energy (EERE) through 10 CFR Part 431 provides regulation of commercial heaters, hot water boilers, and similar heating appliances. If hydrogen is used in any capacity for heating systems there are possible regulations by FERC, EERE, and state/local government that would apply.

2.3.3. Chemical and Industrial Use

Hydrogen is widely used for chemical and industrial purposes. Examples include using hydrogen for ammonia production, petroleum processing, and other industrial applications due to the unique physical properties of hydrogen [26]. As shown in Section 2.1 the production and storage of hydrogen are regulated by the EPA and OSHA. 29 CFR Part 1910 is enforced by OSHA and includes specific requirements on safety of the structural components and operations of gaseous and liquid hydrogen systems. The EPA covers greenhouse gas emission reporting requirements through 40 CFR Part 98. Subpart P – Hydrogen Production specifically covers facilities that produce hydrogen. If hydrogen is used in another process or application listed in this regulation, such as Subpart G- Ammonia Manufacturing, there are reporting thresholds listed.

2.3.4. Blending into Natural Gas Supply Value Chain

The blend of hydrogen and natural gas is regulated based on where it is used and where hydrogen is added to the natural gas supply value chain. FERC would regulate the import/export of blended fuels per Section 2.2.5 of this report. Once blended hydrogen and natural gas is introduced into the

pipeline system, PHMSA OPS, BSEE, and USCG would regulate the pipeline based on whether it is onshore or offshore per Section 2.2.1. FERC regulates fuel used in combustion systems for power generation per Section 2.3.1, and FERC regulates fuels used for heating systems per Section 2.3.2. EERE regulates heating appliances where this blended fuel may be used as mentioned in Section 2.3.2. FE also regulates alternative fuels through 10 CFR Part 503 and 504. These regulations include using blends stated in Part 503 for new facilities and Part 504 for existing power plants. These requirements are set for facilities required to meet Title VIII of the National Energy Conservation Policy Act (42 USC Chapter 91) which prohibits a power plant from burning natural gas or petroleum as its primary energy source. There is guidance on allowed exemptions to operate using fossil fuels either permanently, temporarily, or due to an emergency. Additionally, blended hydrogen and natural gas used as a fuel source are subject to state/local regulation.

2.3.5. Auxiliary Power and Alternative Power Supply for Transportation

In addition to being used as a fuel source for transportation systems, hydrogen can be used either via combustion or through fuel cells for both auxiliary power systems for aircraft and ships as well as power systems for refrigerated shipping containers. FHWA regulates additional equipment on commercial vehicles to ensure it does not reduce the overall safety of the vehicle through 49 CFR Part 390. Additionally, FRA regulates electrical systems, electronics, generators, protection from hazardous gases from exhaust and batteries, and crashworthiness for locomotives through 49 CFR Part 229. USCG regulates power supply systems on ships through 46 CFR Part 111. FAA prescribes requirements for electrical generating systems as well as auxiliary and backup power supplies under 14 CFR Parts 23, 25, 27, and 29 for different types of aircraft. Auxiliary power and alternative power supplies are also subject to state and local regulations.

2.4. Transportation Systems using Hydrogen

This section addresses the regulation of hydrogen used as a fuel source (energy carrier) for transportation systems. This includes consumer and commercial road vehicles, as well as rail and maritime use. It should be noted that in addition to the requirements listed below, vehicles that use hydrogen in a combustion process are subject to regulation under 40 CFR Subchapter U- Air Pollution Controls through the EPA.

2.4.1. Use in Road Vehicles

The DOT National Highway Traffic Safety Administration (NHTSA) issues Federal Motor Vehicle Safety Standards (FMVSS) that specify performance and safety requirements for new motor vehicles and equipment. U.S. federal law prohibits any person from manufacturing, introducing into interstate commerce, selling, or importing any new motor vehicle or item of motor vehicle equipment unless the vehicle or equipment item conforms to all applicable FMVSS. There are currently 65 FMVSS in 49 CFR 571 [26]. The 200 series of 49 CFR Part 571 covers crashworthiness requirements such as side impact protection, roof crush resistance, and rear impact protection. The 300 series includes safety standards pertaining to compressed natural gas fuel container integrity used for the fuel system as well as requirements for control systems and impact protection. While the FMVSS specify performance requirements for compressed natural gas fuel system and fuel container integrity, there are currently no FMVSS specific to hydrogen fuel systems and hydrogen fuel containers. FHWA regulates highway safety which includes bridges, tunnels, and other associated elements as part of 23 CFR Part 924 – Highway Safety Improvement Program.

PHMSA regulates the transportation of hazardous materials in commerce, including vehicles when the vehicle is transported as cargo, or when the fuel system is removed from the vehicle and transported with fuel remaining in the system. Current hydrogen vehicle fuel systems for use in vehicles are designed and manufactured to different standards from the HMR. Therefore, such cylinders must be transported under the terms of a DOT Special Permit if they are transported outside of the vehicles they power, with hydrogen remaining in the system.

2.4.2. Use in Rail

PHMSA and FRA cooperate to review and approve the use of alternative fuels used to power locomotives; an example of this is the joint work on the LNG Tender Car Standard known as Association of American Railroads M-1004. In one case that is applicable where an alternative fuel is used, FRA approved the Florida East Coast Railroad to run LNG powered locomotives using a fuel tender [20]. FRA regulates locomotive and passenger safety through 49 CFR 229 and 238. Locomotive safety design and crashworthiness requirements are covered under 49 CFR Part 229. Fire safety, emergency response, and other safety requirements for passenger locomotives are covered in 49 CFR Part 238.

FTA provides both financial and technical assistance to local transit systems including light rail, trolleys, and subways. 49 CFR Part 659 provides guidance for rail fixed guideway systems and the oversight of safety. This includes hazard management as identified in 659.31 and safety and security plans and review per 659.25, 659.27, and 659.29. Additionally, 49 CFR Part 674 is given authority via 49 USC 5329(e) for state safety oversight of rail fixed guideway public transportation systems. FTA provides a National Public Transportation Safety Plan for public transportation systems that receive finding through 49 USC Chapter 53. This includes safety performance criteria for all public transportation modes. Also, FRA has State Rail Plan Guidance to involve states in railroad network policy, planning, and development [21]. The plan developed by each state shall address involvement in rail transportation as posed by the state's constitution, laws, or regulations, or by implementation of current or proposed federal regulations.

2.4.3. Use in Maritime

MARAD is currently supporting and partnering with other federal, state, and local agencies to research hydrogen powered fuel cell designs for maritime applications [27]. 46 CFR Part 24 through 196 gives USCG the authority to regulate the vessel design applications including construction and fire protection requirements [28]. FTA provides a National Public Transportation Safety Plan for public transportation systems that receive funding through 49 USC Chapter 53. This includes safety performance criteria for all public transportation modes including maritime vessels. A combination of USCG and FTA would enforce possible regulations on maritime vessels using hydrogen and hydrogen powered fuel cells as a power source. MARAD, in its role to support the U.S. maritime transportation system and maritime stakeholders, would likely continue to collaborate closely with USCG in the evaluation and development of standards and requirements for vessels operating with fuel cells.

2.4.4. Use in Aviation

Hydrogen fuel systems may be used to power aircraft in some capacity via fuel cells or combustion [29]. FAA regulates aircraft and airworthiness through 14 CFR Parts 23, 25, 26, 27, 29, and 33. The FAA would determine requirements for hydrogen transportation and hydrogen powered aircraft.

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16

3. SUMMARY & DISCUSSION

The hydrogen supply value chain is being regulated by various entities through both CFR and USC. Some of these entities have direct regulations for hazardous materials and gases, which are specifically applicable to hydrogen. Figure 3-1 gives a visual depiction of the regulating entities for the hydrogen supply value chain.

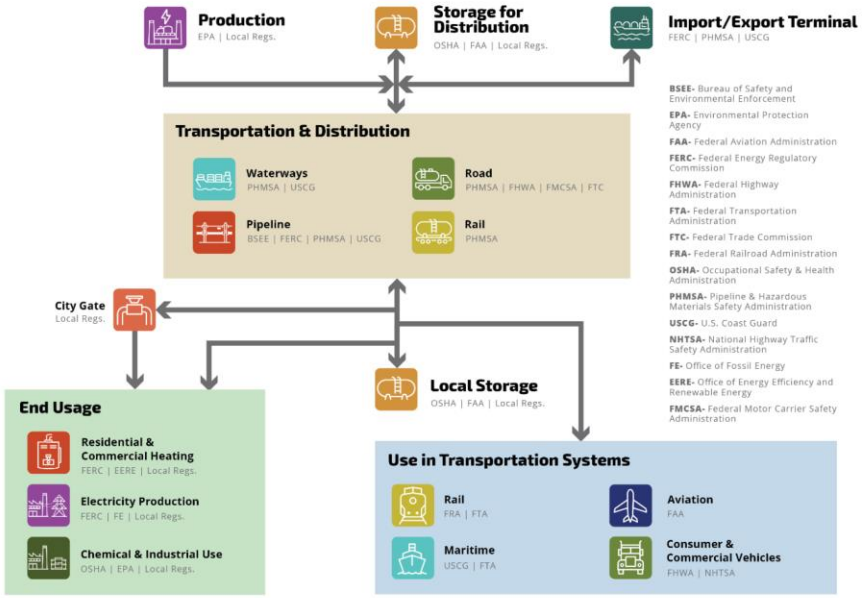

Figure 3-1. Hydrogen Regulatory Map

For hydrogen production facilities and storage systems, hydrogen regulations currently exist for emissions reporting and safety. Hydrogen specific regulations also exist for the distribution of hydrogen through tanker trucks, rail, and waterways, as well as hydrogen used as a fuel source for consumer/commercial road vehicles. However, other entities currently regulate similar materials (e.g., natural gas) and hydrogen will fall under that entity's authority with additional or modified regulations. The use of hydrogen or natural gas/hydrogen blends for electricity production and heating systems are subject to similar oversight as current natural gas systems. Rail, maritime, and aviation transportation using hydrogen as a fuel source will be regulated similar to current natural gas regulations.

Table 3-1 summarizes applicable regulations and regulatory bodies for each category of system along the hydrogen value chain. Table 3-1 also notes which regulations currently have hydrogen directly listed (green), regulations that cover general flammable or otherwise hazardous gases or liquids that should indirectly cover hydrogen (olive green), and regulations that specific to some other material (such as natural gas) that will need to be modified to include hydrogen (orange). Note that this readiness is based on a current assessment by the authors and is subject to regulatory interpretation and changes in the future.

Table 3-1. Overview of Regulation and Oversight of Hydrogen Systems

System	Oversight	Reference	Summary	H_2 Ready?
Production	EPA	40 CFR Part 98	Defines source categories and emissions thresholds for a hydrogen production facility	Yes - production of gaseous hydrogen is specifically regulated through reporting thresholds
Storage	OSHA	29 CFR Part 1910	Dictates the safety of the structural components and operations of gaseous and liquid hydrogen storage and delivery	Yes - specifies requirements for and quantities for gaseous hydrogen storage
	FAA	14 CFR Part 420	Dictates the separation distance requirements for storage of liquid hydrogen and any incompatible energetic liquids	Yes - provides criteria for liquid hydrogen storage separation distances
Transportation by Pipeline	BSEE	43 USC Part 29	Manage compliance programs governing oil, gas, and mineral operations on the OCS	No - requirements for facilities and operations specifically for development and production of oil and gas
	FERC	18 CFR Part 153	Regulation of the siting, routing, and overall construction of the pipeline system, as well as the distribution and interstate and intrastate sale of natural gas	No - authorizes construction, operation, and modification for import and export facilities for natural gas only
		18 CFR Part 284	Filing requirements of the siting, construction, and operation of facilities used for the import or export of natural gas	
	PHMSA	49 CFR Part 192	Prescribes minimum safety requirements for pipeline facilities and the transportation of gas, including pipeline facilities and the transportation of gas within the limits of the outer continental shelf	Yes - sets requirements for natural gas transported via pipeline but other flammable gases are included in scope and definition
		49 CFR Part 193	Prescribes safety standards used for LNG facilities that are used to transport gas via pipeline	
		49 CFR Part 195	Prescribes safety standards for pipeline facilities that transport hazardous liquids	
	USCG	33 CFR Part 154	Regulations for facilities transferring hazardous materials back and forth from a vessel to a facility	Yes - sets requirements for transferring bulk hazardous materials in a vessel
Transportation by Road	PHMSA	49 CFR Part 172	Lists and classifies hazardous materials for transportation, and prescribes requirements for papers, markings, labeling, and vehicle placarding	Yes - prescribes transportation and packaging requirements for hazardous materials on public highways
		49 CFR Part 173	Provides requirements for preparing hazardous materials for shipment, and inspection, testing, and other requirements for transportation containers	
		49 CFR Part 177	Provides additional requirements when transporting hazardous materials via public highways	
		49 CFR Part 178	Prescribes specifications for packaging and containers used for transportation of hazardous materials	
		49 CFR Part 180	Provides qualification requirements for inspecting and maintaining packages and	

System	Oversight	Reference	Summary	H_2 Ready?
			containers used to transport hazardous materials	
	FMCSA	49 CFR Part 356	Motor carrier routing requirements	Yes - general safety and routing requirements for hazardous materials
		49 CFR Part 389	General motor carrier safety regulations	
		49 CFR Part 397	Transportation of hazardous materials	
	FHWA	23 CFR Part 924	Regulates highway safety which includes bridges, tunnels, and other associated elements	Yes - nothing is specified for transportation of hazardous materials
	FTC	16 CFR Part 306	Describes the certification and posting of automotive fuel ratings in commerce	Yes - specifies labeling requirements including all alternative fuels
Transportation by Rail	PHMSA	49 USC 5117	Gives the authority to authorize a variance that is still at the same safety level, special permit is required to use an alternative fuel that does not have a safety standard	Yes - specifies all requirements for transporting hazardous materials including tank car design, inspection, preparation, and testing
		49 CFR Part 172	Lists and classifies hazardous materials for transportation and prescribes the requirements for papers, markings, labeling, and vehicle placarding	
		49 CFR Part 173	Provides requirements for preparing hazardous materials for shipment as well inspection, testing, and other requirements for containers, including usage instructions for DOT-113A60W tank cars	
		49 CFR Part 174	Provides additional requirements for transportation of hazardous materials in or on rail cars	
		49 CFR Part 178	Prescribes specifications for packaging and containers used for transportation of hazardous materials	
		49 CFR Part 179	Provides construction requirements for DOT-113A60W tank cars	
		49 CFR Part 180	Provides qualification requirements for inspecting and maintaining containers used to transport hazardous materials, including DOT-113A60W tank cars	
Transportation by Waterways	PHMSA	49 CFR Part 172	Lists and classifies hazardous materials for transportation and prescribes the requirements for papers, markings, labeling, and vehicle placarding	Yes - specifies all requirements for transporting hazardous materials including package inspection, preparation, and testing
		49 CFR Part 173	Provides requirements for preparing hazardous materials for shipment, as well inspection, testing, and other requirements for containers	
		49 CFR Part 176	Requirements for transportation by vessel	

System	Oversight	Reference	Summary	H_2 Ready?
		49 CFR Part 178	Prescribes specifications for packaging and containers used for transportation of hazardous materials	
		49 CFR Part 180	Provides qualification requirements for inspecting and maintaining containers used to transport hazardous materials	
	USCG	33 CFR Part 154	Regulations for transferring hazardous materials back and forth from a vessel to a facility	Yes - specifies requirements for bulk hazardous materials transported via vessel
		33 CFR Part 156	Transfer of oil or hazardous material on the navigable waters or contiguous zone of the U.S.	
		46 CFR Part 38	Requirements for transportation of liquified or compressed flammable gases	
		46 CFR Part 150	Describes incompatibility of hazardous materials and rules for transporting these materials aboard tanks that are loaded and discharged while on the vessel	
		46 CFR Part 151	Regulations for non-self-propelled ships carrying bulk cargo	
		46 CFR Part 153	Regulations for self-propelled ships carrying bulk cargo	
		46 CFR Part 154	Regulations for self-propelled vessels that contain bulk liquified gases as cargo, cargo residue, or vapor	
Import/ Export Terminals	FERC	18 CFR Part 153	Establishes filing requirements to obtain authorization for the siting, construction, operation, place of entry for imports or place of exit for exports	No - requirements specifically for natural gas import and export terminals
	PHMSA	49 CFR Part 192	Prescribes minimum safety requirements for pipeline facilities and the transportation of gas, including pipeline facilities and the transportation of gas within the limits of the outer continental shelf	Yes - sets requirements for natural gas transported via pipeline but other flammable gases are included in scope and definition
		49 CFR Part 193	Prescribes safety standards used for LNG facilities that are used to transport gas via pipeline	
		49 CFR Part 195	Prescribes safety standards for pipeline facilities that transport hazardous liquids	
	USCG	33 CFR Part 154	Regulations for self-propelled vessels that contain bulk liquified gases as cargo, cargo residue, or vapor	Yes - sets requirements for transfer of hazardous liquids and materials on navigable waters
		33 CFR Part 156	Transfer of oil or hazardous materials on the navigable waters or contiguous zone of the U.S.	
Electricity Production	FERC	18 CFR Part 292	Sets requirements for a small power production or cogeneration facility	Yes – fuel cells included in definition of electrical generation equipment

System	Oversight	Reference	Summary	H_2 Ready?
	FE	10 CFR Part 503	Prohibits any new baseload powerplant without the ability to use coal or another alternative fuel as a primary energy source	Yes – alternative fuels do not explicitly include hydrogen, but note that fuels obtained from alternative fuel sources would be included
		10 CFR Part 504	May prohibit existing powerplants from using petroleum or natural gas as a primary energy source	
Residential & Commercial Heating	FERC	18 CFR Part 284	Provides regulation of energy sales and distribution of natural gas	No – these requirements are specifically for natural gas
	EERE	10 CFR Part 431	Provides regulation of commercial heaters, hot water boilers, and similar heating appliances	No - testing requirements for natural gas and oil-fired furnaces, boilers, etc. Definition of gas specific to natural gas and propane.
Chemical and Industrial Use	OSHA	29 CFR Part 1910	Dictates the safety of the structural components and operations of gaseous and liquid hydrogen in terms of storage as well as delivery	Yes - specifies requirements for and quantities for gaseous hydrogen storage
	EPA	40 CFR Part 98	Requires reporting of greenhouse gas emission due to combustion or use of products in a process	Yes - production of gaseous hydrogen is specifically regulated through reporting thresholds
Auxiliary Power and Alternative Power Supply	FHWA	49 CFR Part 390	Regulates additional equipment on commercial vehicles to ensure it does not reduce the overall safety of the vehicle	Yes - requirements are set to ensure that the safety of a commercial vehicles even with additional equipment
	FRA	49 CFR Part 229	Regulations for electrical systems, generators, protection from hazardous gases from exhaust and batteries, and crashworthiness for locomotives	No - Exhaust gases specific to combustion and battery venting are addressed, but not fuel cells
	USCG	46 CFR Part 111	Regulations for power supply systems on ships	No - specifically for boiler, diesel, gas turbine, or steam turbine; does not include alternatives
	FAA	14 CFR Part 23 Subpart E	Requirements for electrical generating systems including auxiliary and backup power for normal category airplanes	Yes – not specific to fuel used
		14 CFR Part 25 Subpart E	Requirements for electrical generating systems including auxiliary and backup power for transport category airplanes	
		14 CFR Part 27 Subpart E	Requirements for electrical generating systems including auxiliary and backup power for normal category rotorcraft	
		14 CFR Part 29 Subpart E	Requirements for electrical generating systems including auxiliary and backup power for transport category rotorcraft	
Use in Consumer/ Commercial Vehicles	NHTSA	49 CFR 571	Provides Federal Motor Vehicle Safety Standards for motor vehicles and motor vehicle equipment	Yes - requirements are specific for CNG vehicles, but have been used for hydrogen vehicles
	FHWA	23 CFR Part 924	Regulates highway safety which includes bridges, tunnels, and other associated elements	Yes - nothing is specific for transportation of hazardous materials

System	Oversight	Reference	Summary	H_2 Ready?
Use in Rail	FRA	49 CFR Part 229	Locomotive safety design and crashworthiness requirements	Yes - includes requirements for alternative designs which would likely be part of alternative fueled locomotives
		49 CFR Part 238	Safety requirements for passenger locomotives	
	FTA	49 CFR Part 659	Provides guidance for rail fixed guideway systems and the oversight of safety, including hazard management and safety and security plans and review	Yes - general requirements for safety and security assessments, not fuel-specific
		49 CFR Part 674	Mandates state safety oversight of fixed guideway public transportation systems	
Use in Maritime	USCG	46 CFR Parts 24–196	Regulation of vessel construction for both passenger and cargo applications as well as general fuel requirements based on the flash point of the fuel	Yes – these requirements include specific requirements for vessels based on the fuel properties the vessel uses
	FTA	49 USC Chapter 53	Requirements for National Public Transportation Safety Plan for public transportation that receives federal funding	Yes – alternative fuels are noted, but hydrogen is not specifically mentioned
Use in Aviation	FAA	14 CFR Part 23	Provides requirements and airworthiness standards for normal category airplanes	Yes - there are requirements to analyze flammable gases, but hydrogen is not specifically listed
		14 CFR Part 25	Provides requirements and airworthiness standards for transport category airplanes	
		14 CFR Part 26	Provides requirements and airworthiness standards for transport category airplanes	
		14 CFR Part 27	Provides requirements and airworthiness standards for normal category rotorcraft	
		14 CFR Part 29	Provides requirements and airworthiness standards for transport category rotorcraft	
		14 CFR Part 33	Provides requirements and airworthiness standards for aircraft engines	

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26

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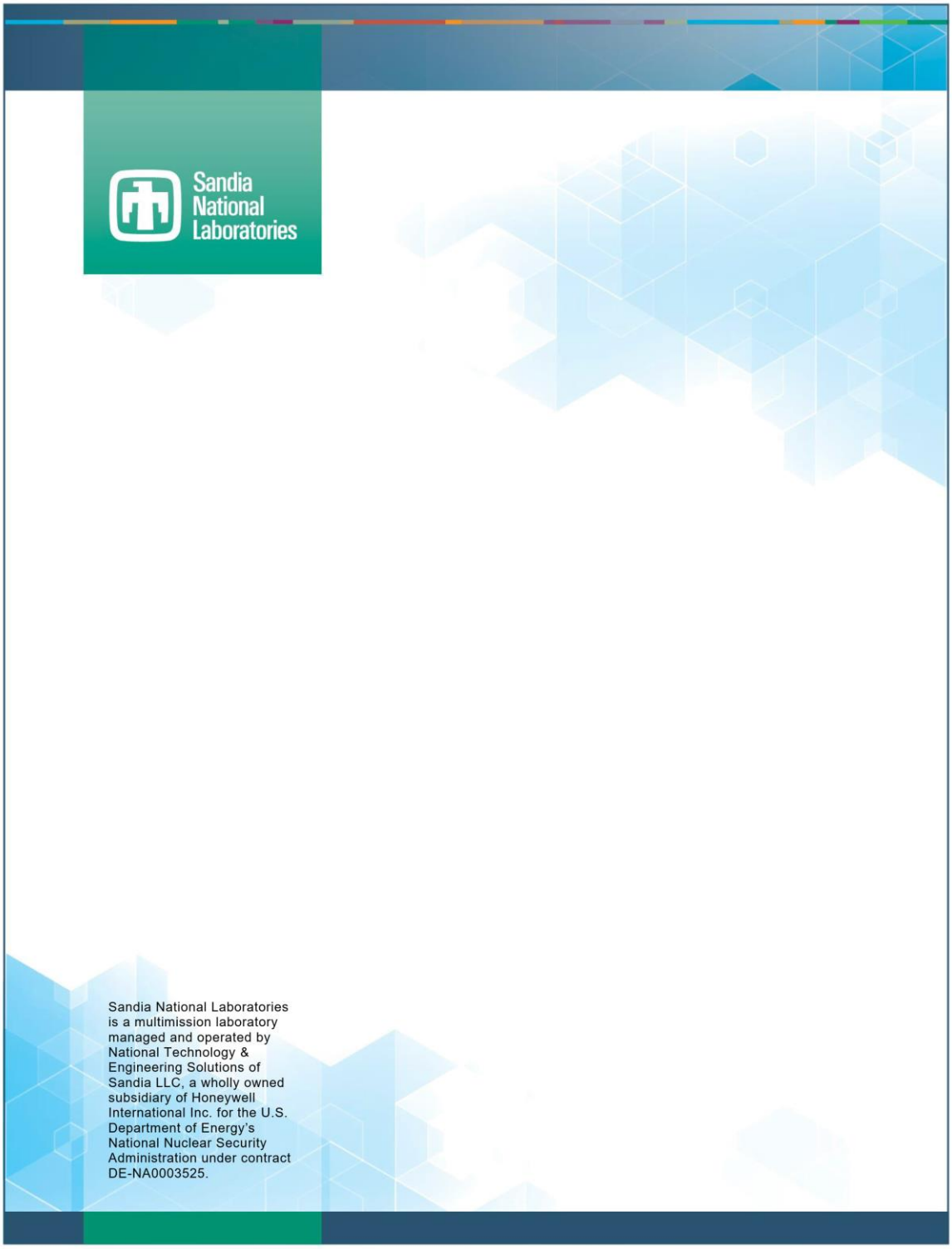
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