ANGELES LINK PHASE 1

EVALUATION OF APPLICABLE SAFETY REQUIREMENTS

FINAL REPORT – DECEMBER 2024

SoCalGas commissioned this Evaluation of Applicable Safety Requirements from Burns & McDonnell. The analysis was conducted, and this report was prepared, collaboratively.

Table of Contents

Table of Contents

1.0 LIST OF ABBREVIATIONS AND ACRONYMS

ABET	Accreditation Board for Engineering and Technology
AGA	American Gas Association
AICHE	American Institute of Chemical Engineers
ANSI	American National Standards Institute
API	American Petroleum Institute
API RP	American Petroleum Institute Recommended Practice
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BVPC	Boiler and Pressure Vessel Code
BTU	British Thermal Units
BC	Business Continuity
CBO	Community Based Organizations
CBOSG	Community Based Organizations Stakeholder Group
CCM	Control Center Modernization
CFR	Code of Federal Regulations
CGA	Compressed Gas Association
CHS	Center for Hydrogen Safety
CISA	Cybersecurity and Infrastructure Security Agency
CPUC	California Public Utilities Commission
DOT	Department of Transportation
EERE	U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy
ERM	Enterprise Risk Management
ESD	Emergency Shutdown Devices

FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
GO	General Order
GTI	Gas Technology Institute
HAZOP	Hazard and Operability Study
HCA	High Consequence Areas
HySafe	International Association for Hydrogen Safety
ICS	Incident Command System
ILI	Inline Inspection
ISO	International Organization for Standardization
LNG	Liquified Natural Gas
MAOP	Maximum Allowable Operating Pressure
MJ	Megajoule
mol	Mole
MSP	Material Specification
NFPA	National Fire Protection Association
NPS	Nominal Pipe Size
O&M	Operations and Maintenance
OPM	Optical Pipeline Monitoring
OQ	Operator Qualifications
OSHA	Occupational Safety and Health Administration
PAG	Planning Advisory Group
PDCA	Plan-Do-Check-Act
PHMSA	Pipeline and Hazardous Materials Safety Administration

PIR	Potential Impact Radius
ppb	Parts per billion
PPE	Personal Protective Equipment
ppm	Parts per million
RAMP	Risk Assessment Mitigation Phase
SCADA	Supervisory Control and Data Acquisition
SCC	Standards Council of Canada
scf	Standard Cubic Foot
SIF	Serious Injuries and Fatalities
SMS	Safety Management System
SMYS	Specified Minimum Yield Strength
SoCalGas	Southern California Gas Company
THT	Tetrahydrothiophene
TSA	Transportation Security Administration

2.0 EXECUTIVE SUMMARY

Southern California Gas Company (SoCalGas) is proposing Angeles Link to develop a clean renewable hydrogen[1] pipeline system to facilitate transportation of clean renewable hydrogen from multiple potential regional third-party production sources to various delivery points and end users in Central and Southern California, including in the Los Angeles Basin. The CPUC Phase 1 Decision[2] requires SoCalGas to, among other things, evaluate safety concerns involved in the pipeline transmission, storage, and transportation of clean renewable hydrogen.

An evaluation of safety concerns involved in pipeline transmission, storage, and transportation consistent with the California Public Utilities Commission (CPUC) Decision (D.22-12-055, Ordering Paragraph [OP] 6 (f)) was conducted. In response to stakeholder feedback, for added clarity the title of this study has been changed from “A Plan for Applicable Safety Requirements” to “Evaluation of Applicable Safety Requirements.” As detailed herein, this Evaluation of Applicable Safety Requirements (Safety Study) demonstrates that Angeles Link can be safely designed, constructed, operated, and maintained in accordance with existing regulations and industry standards and best practices pertaining to hydrogen; adapting corollary safety regulations and industry standards to suit the specific properties and characteristics of hydrogen; and developing new standards and practices specific to the transport of hydrogen.

Key Findings

- **Existing Hydrogen-Specific Requirements, Codes, and Industry Standards Will Help Promote Safety.**

  Regulatory requirements and industry-standard codes exist for the transportation of hydrogen gas by pipeline, primarily anchored by Title 49 Code of Federal Regulations (CFR) Part 192 Subparts A through P governing natural gas transmission and distribution and addressing flammable gases, such as hydrogen. Current federal minimum safety standards for pipelines transporting natural and other gases, including hydrogen, often do not specify differences and considerations for hydrogen specifically versus natural gas (and other gases) except in limited situations. Other hydrogen-specific standards and specifications also exist and are applied in the industry (e.g., American Society of Mechanical

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[1] In the California Public Utilities Commission (CPUC) Angeles Link Phase 1 Decision (D).22-12-055 (Phase 1 Decision), clean renewable hydrogen refers to hydrogen that does not exceed 4 kilograms of carbon dioxide equivalent (CO2e) produced on a lifecycle basis per kilogram of hydrogen produced and does not use fossil fuels in the hydrogen production process, where fossil fuels are defined as a mixture of hydrocarbons including coal, petroleum, or natural gas, occurring in and extracted from underground deposits.

[2] CPUC Decision 22-12-055.

Engineers (ASME) B31.12 or National Fire Protection Association (NFPA 2)), although they are not specifically incorporated into 49 CFR Part 192 by direct reference. There are approximately 1,600 miles of hydrogen pipelines operating in the United States today that are regulated via industry standards. In addition, at the state level, CPUC General Order (GO) 112-F addresses the pipeline transport of gas and includes provisions that would also apply generally to hydrogen.

- **Existing Requirements Applicable to the Natural Gas System Can Be Leveraged and Tailored to Promote the Safe Transportation of Hydrogen for the Benefit of the Public, Our Employees, Contractors, and Our Infrastructure.**

  A clean renewable hydrogen system (gaseous hydrogen) can leverage many of the existing requirements of an analogous natural gas system. Where hydrogen's physical and chemical properties differ from natural gas, SoCalGas's existing natural gas system plans, including safety systems, specifications, procedures, and training can provide a strong starting point for the standards for designing, constructing, and operating Angeles Link. SoCalGas's catalog of specifications and standards for its existing natural gas pipeline system (as of August 2023) implements federal and state pipeline safety requirements, industry standards, and best practices across the required aspects of design, material sourcing, construction, operation, maintenance, inspection, and reporting for a natural gas transmission and distribution system. In consideration of Angeles Link, SoCalGas will leverage existing specifications and standards and develop new specifications and standards (as appropriate), including but not limited to material specifications, fabrication and welding requirements, safety plans, quality management plans, approved manufacturer's lists, operator qualification procedures, fire protection and prevention strategies, corrosion control requirements, inspection requirements, and reporting requirements.

- **Safety Will Be Foundational and Factored into All Aspects of System Design, from Material Selection to Sizing and Compression Requirements and Control Room Operations, and Risk Mitigation, from Personal Protective Equipment to Odorization, Cybersecurity, Etc.**

  Safety considerations for transmission pipeline construction, operations, and maintenance of a clean renewable hydrogen system can take into account the various existing SoCalGas safety systems that promote safety for the public, infrastructure, SoCalGas employees, and contractors. Major topics reviewed in this assessment include safety considerations with respect to material, design, construction requirements, operations, inspections and maintenance activities, Personal Protection Equipment (PPE), security (both physical and cyber), and odorization of 100% clean renewable hydrogen.

A preliminary design basis will include the identification of key factors such as the operating and design characteristics of clean renewable hydrogen for Angeles Link, which will be used in the determination of preliminary pipeline sizing, compression requirements, and pipeline material selection. Subsequently, construction, operation, and maintenance requirements, such as 49 CFR Part 192, will contribute to that design basis. In addition to the federal regulations, there are applicable and/or hydrogen-specific industry codes and standards that are already in existence and will be considered, such as American Petroleum Institute (API) 5L, API 1104, and ASME B31.12[3]. New federal rules or changes to existing federal rules would go through the rulemaking process as described by the Federal Register (Office of the Federal Register).[4] This process includes stages for development, rule proposal, soliciting comments from the public and those directly affected by the proposed rule, finalizing the rule, integration of the rule, and providing interpretation (if necessary).

In general, PPE used by SoCalGas employees, contractors, or any other personnel accessing a SoCalGas facility (or as otherwise required by SoCalGas at a project or work site), is covered by California Occupational Safety and Health Administration (OSHA) regulations and addressed within NFPA 2112. Special considerations must be made for PPE to be used in connection with hydrogen service, due to hydrogen's low ignition energy, flame temperature, and flame speed. Anti-static and flame-resistant clothing or coveralls and non-metallic (or non-sparking materials) will be considered. Prior to commencing operations, SoCalGas intends to review its procedures to determine if changes should be made regarding PPE for employees working on hydrogen pipelines.

Hydrogen, like natural gas, is odorless. Assessing odorizing the 100% clean renewable hydrogen transported through the proposed Angeles Link infrastructure to indicate the presence of hydrogen is an important consideration in the development of applicable safety protocols. The selection of the appropriate odorizing agent is important to avoid impacts on downstream customers that require relatively pure hydrogen for their uses and may require downstream customers to "scrub" the odorant from the received hydrogen. Industry research on the implications of odorant in a pure hydrogen system is ongoing and SoCalGas intends to monitor odorant developments during the development of Angeles Link to identify industry best practices.

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[3] API 5L pipe specifications. American Piping Products. https://amerpipe.com/products/api-5l-pipe-specifications/ Energy API. (n.d.)., https://www.api.org/products-and-services/standards/important-standards-announcements/1104,B31.12 - Hydrogen Piping & Pipelines: Digital Book. ASME. (n.d.). https://www.asme.org/codes-standards/find-codes-standards/b31-12-hydrogen-piping-pipelines.

[4] The Federal Register. Federal Register: Request Access. (n.d.). https://www.federalregister.gov/.

Control room operations are critical elements to safely and efficiently operate hydrogen pipeline infrastructure and can provide early opportunities to mitigate risk. The control room operators monitor the pressure and flow of gas in the system utilizing a supervisory control and data acquisition (SCADA) system 24 hours a day, 365 days a year. SCADA provides live data which is used to quickly detect potential abnormalities in pipeline operation, including potential leaks and changes in pressure and flow. In addition, SoCalGas's existing monitoring, and installations of rupture-mitigation valves and automated valves are consistent with Pipeline and Hazardous Materials Safety Administration (PHMSA)'s valve rules in case of rupture. SoCalGas uses a SCADA system today to monitor the gas-transmission system including associated pipelines, line compressor stations, and underground storage facilities. A hydrogen system may require a separate SCADA system to monitor the pipeline and compressor station operations. In order to make this determination, SoCalGas anticipates conducting a more detailed analysis in subsequent phases as the project progresses and data is available.

Physical and cyber security requirements are primarily addressed by the Transportation Security Administration (TSA) as part of Homeland Security.[5] It is envisioned that a clean renewable hydrogen pipeline system could follow the same philosophy SoCalGas currently uses for the physical and cyber security of its existing natural gas system. Physical and cyber security requirements should be addressed with third-party clean hydrogen producers and third-party hydrogen storage providers if applicable.

- **Existing Emergency Response and Public Awareness Plans Can Be Leveraged and Tailored for Hydrogen's Specific Properties and Characteristics.**

Emergency response plans and procedures promote effective emergency incident management and are designed to address unanticipated or emergency situations. This includes employees who are trained and equipped to respond promptly to protect the public, maintain system reliability, and restore the affected system and Company operations to normal status. The emergency response plan should contain hydrogen-specific details and provide the framework for the emergency response protocol, including dispatch of personnel to a potential hydrogen leak site. SoCalGas can leverage its existing Operations and Maintenance (O&M) Procedures (O&M Plan) which include comprehensive safety and emergency response procedures and protocols that address safety of the public and

[5] 49 of the United States Code, Transportation Security Administration, section 114(s); https://www.dhs.gov/publication/2023-biennial-national-strategy-transportation-security

employees during emergencies, and steps to comply with applicable state and federal safety requirements.

SoCalGas should continue compliance with Public Awareness Plans requirements pursuant to 49 CFR § 192.616 that would specify the hydrogen infrastructure to have markers indicating the transported fuel, hydrogen, and an emergency phone number which should be monitored 24/7 by the control room or a separate emergency response desk. Hydrogen control room and emergency response personnel will require hydrogen-specific training in the physical and chemical properties and the execution of the emergency plans. First responder awareness level training can be provided by multiple organizations and provides an overview on hydrogen for fire, law enforcement, emergency medical personnel and others.[6] SoCalGas may also consider separate gas controllers and emergency response teams for the natural and hydrogen gas systems since natural gas and hydrogen are different fuels with different physical and chemical properties. In order to make this determination, SoCalGas anticipates conducting a more detailed analysis in subsequent phases as the project progresses and data is available. Gas controllers' training will require operator qualifications unique to the hydrogen system, including knowledge of the abnormal operating conditions associated with hydrogen compressor and pipeline operations.

- **Hydrogen-Specific Training for Employees and Contractors that Incorporate Industry Lessons Learned Can Be Collaboratively Developed.**

Training on the operational considerations and key risks of hydrogen for SoCalGas employees and contractors will be developed. As an initial start, SoCalGas requires its contractors to review and acknowledge the SoCalGas Contractor Safety Manual (Manual). The Manual outlines general safety requirements and expectations for contractors working for SoCalGas. Additionally, the public should be provided access to information about the risks and safety measures associated with hydrogen, supporting public outreach and long-term project input considerations, similar to the training materials and programs for the public that SoCalGas offers on natural gas. Several organizations and consultants currently offer training specific to the risks associated with designing, constructing, operating, and maintaining a hydrogen system. As the hydrogen energy market continues to grow, additional training and certifications may become available.

[6] This introduction to Hydrogen Safety for First Responders is a Web-based course that provides an "awareness level" overview of hydrogen for fire, law enforcement, and emergency medical personnel. American Institute of Chemical Engineers: Center for Hydrogen Safety, https://www.aiche.org/ili/academy/courses/ela253/introduction-hydrogen-safety-first-responders.

As Angeles Link progresses, safety will remain foundational. Collaboration amongst industry stakeholders, regulatory bodies, research institutions, first responders and communities will play a key role in the continued development of regulations, specifications, standards, and other requirements to safely design, construct, operate and maintain a clean renewable hydrogen pipeline transportation system. SoCalGas is well positioned to build, operate, and maintain a clean renewable hydrogen pipeline system due to its long-standing experience operating and maintaining a highly developed gas transmission and distribution system, existing highly trained and qualified workforce, and comprehensive established integrity management and emergency response procedures.

Stakeholder Feedback

The Center for Hydrogen Safety (CHS) is a global, neutral, and nonprofit resource that supports and promotes hydrogen's adoption and safe handling and use across industrial and consumer applications. To meet the growing need for hydrogen safety evaluation, risk assessment, education, and training, the Hydrogen Safety Panel (HSP)[7] was founded by the U.S. Department of Energy in 2003 to develop and implement guidance, procedures, and best practices for safety in the operation, handling, and use of hydrogen and hydrogen systems. The HSP is a CHS resource and represents a cross-section of expertise from the commercial, industrial, government, and academic sectors.

As a result of feedback received after distributing the draft scope of work in 3rd quarter 2023, CHS was recommended as a resource to SoCalGas. Consequently, SoCalGas engaged HSP in 4th quarter 2023. HSP's extensive hydrogen safety experience has been a valuable resource during the drafting of the Safety Study. HSP's feedback has not only helped SoCalGas confirm relevant hydrogen standards and best practices, but it also provided valuable insights into areas where SoCalGas can supplement its internal procedures and policies. HSP's comments and recommendations will help refine SoCalGas's safety planning for the subsequent phases of Angeles Link that include design, construction, and operational efficiency.

Other input and feedback from stakeholders including the Planning Advisory Group (PAG) and Community Based Organization Stakeholder Group (CBOSG) has also been helpful to the development of this Safety Study. SoCalGas has also periodically met with the CPUC's Safety Enforcement Division to provide updates and to collaborate on Angeles Link. As further detailed in Section 13: Stakeholder Feedback, in response to stakeholder comments received thus far, the Center for Hydrogen Safety, Hydrogen Safety Panel conducted a third-party review of this safety study, with input incorporated,

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[7] The "Hydrogen Safety Panel" was created by the Department of Energy (DOE) to oversee and ensure safety practices in all hydrogen projects funded by the DOE, primarily focusing on the safe operation, handling, and use of hydrogen systems across all applications; it is led by the Pacific Northwest National Laboratory (PNNL). Additional information regarding Hydrogen Safety Panel is available at https://www.aiche.org/chs/hydrogen-safety-panel.

where applicable, into the final report. Additionally, the following topics for: Safety Management Systems (SMS) framework, odorant feasibility, Emergency Response protocols, and Public Awareness Plans, are described in Sections: 4, 8, 9, and 10 respectively.

3.0 INTRODUCTION

The transmission of clean renewable hydrogen across the value chain must prioritize safety and leverage applicable industry experience and best practices, regulations, codes, and standards. Hydrogen has been used for decades across the globe, including for heavy industries (e.g., oil refineries and chemical plants) and transportation (e.g., vehicle fueling stations). In addition, there are over 1,600 miles of hydrogen pipelines currently operating in the U.S. today, owned by merchant hydrogen producers.[8] This industry experience makes the properties and risks associated with hydrogen relatively well known. Additionally, many rules and regulations for natural gas transportation in transmission and distribution pipelines are applicable or can be used to draw sufficiently accurate parallels to transmission and distribution pipelines for clean renewable hydrogen.

SoCalGas is regulated by the CPUC and has over 150 years of experience transporting natural gas via pipeline. Safety is foundational to all aspects of SoCalGas's business[9] and is reflected in the safety plans, programs, policies, standards, and procedures that are designed to support a strong safety culture, as well as the company's comprehensive SMS framework, which is implemented consistent with American Petroleum Institute Recommended Practice (API RP) 1173.[10]

SoCalGas defines safety as the presence of controls for known hazards, actions to anticipate and guard against unknown hazards, and the commitment to continuously improve the ability to recognize and mitigate hazards. SoCalGas's safety focus is comprehensive and systemic and includes all activities – from the office to the field – to advance public safety, infrastructure safety, employee safety, and contractor safety.

Safety is embedded throughout Angeles Link's planning, engineering, and design process as well as through the execution of construction and long-term operation and maintenance. The objective of this Safety Study is to evaluate federal, state, and industry

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[8] Hydrogen pipelines | Department of Energy. (n.d.-b). https://www.energy.gov/eere/fuelcells/hydrogen-pipelines.

[9] Additional information regarding SoCalGas's commitments to safety can be found in Section II of SoCalGas's 2023 Gas Safety Plan, available at https://www.socalgas.com/sites/default/files/2023-Gas-Safety-Plan.pdf.

[10] API 1173 is a "pipeline" safety management system, designed to support the safe delivery of energy with safe pipeline operations by helping pipeline operators understand, manage, and continuously improve safety.

codes, standards, and best practices for their application to pipeline transmission, storage, and transportation of clean renewable hydrogen as applicable to Angeles Link. This evaluation includes providing an assessment of applicable safety requirements for employee, contractor, system, and public safety. This Safety Study identifies potential updates or modifications to SoCalGas's standards, specifications, and procedures (covering construction, operations, and maintenance) to address hydrogen-specific considerations, as applicable. This Safety Study also outlines the unique considerations associated with hydrogen while outlining actively documented mitigations, standards, and procedures.

4.0 SOCALGAS SAFETY MANAGEMENT SYSTEM

SoCalGas has implemented a comprehensive safety management system, consistent with API 1173 to promote the safe and reliable delivery of service to its customers and integrate public safety, infrastructure safety, employee safety, and contractor safety systems. SoCalGas's SMS documents and connects SoCalGas's comprehensive set of safety plans, programs, and procedures that address specific infrastructure or activity areas. The SMS encompasses all aspects of safety relevant to SoCalGas' business, including employee safety, contractor safety, public safety, and infrastructure safety. It applies to all SoCalGas assets and operations as well as to all employees, from senior management to those on the frontline.

SoCalGas designed its SMS to be consistent with API 1173. API 1173 provides a framework for managing safety holistically through the integration of various activities including risk and asset management, formal processes and procedures, systematic decision making, monitoring of program effectiveness, safety culture, audits, and increased communications. While API 1173 is designed to address recommended practices around pipeline safety, SoCalGas has developed its SMS to apply comprehensively to safety at SoCalGas. SoCalGas anticipates that its SMS could be leveraged to similarly manage and advance safety for Angeles Link. SoCalGas's experience in its SMS could also be leveraged if benefits of an alternative, hydrogen-specific safety management approach is identified in future evaluation of a hydrogen pipeline system.

The ten essential elements of API 1173 are detailed below as well as how relevant activities at SoCalGas and the information within this study can be leveraged together for application in the development of Angeles Link.

1. Leadership and Management Commitment is demonstrated through organizational goals, objectives, and a company culture that encourages openness and prioritizes learning from incidents and events. SoCalGas plans to begin integrating hydrogen safety goals into its programs and plans such as including hydrogen safety awareness in employee and contractor safety dialogues and forums. To lead these efforts, SoCalGas created a Senior Vice President of Engineering & Major Projects and Chief Clean Fuels Officer position that leads Angeles Link and

other hydrogen projects. This position reports directly to SoCalGas's President and integrates core engineering and construction functions that are vital to current safe work practices and clean fuels projects of the future.

2. Risk Management is advanced by developing a systemic and systematic way to evaluate risks to safety and then develop strategies on how to manage them through preventive controls, monitoring, and mitigation measures. SoCalGas advances its structured enterprise risk management efforts through a Chief Risk Officer and Enterprise Risk Management (ERM) organization. Two key components of SoCalGas's approach to enterprise risk management are (1) the development and filing of a Risk Assessment Mitigation Phase (RAMP) Report to the CPUC every three years and (2) the ongoing maintenance of an enterprise risk registry. SoCalGas plans to integrate hydrogen and hydrogen assets into this existing risk management process. Initial Risk Management considerations are detailed in Section 6: Risk Management.

3. Stakeholder Engagement is promoted through structured processes and plans for communication and engagement with internal and external stakeholders regarding risk and safety. SoCalGas maintains robust processes for stakeholder engagement as noted in Section 10: Awareness, Education, and Training and is implementing additional stakeholder engagement for Angeles Link.[11]

4. Operational Controls are addressed through procedures for safe work practices to promote operations, maintenance, control of materials, and emergency response activities. As detailed in this study, SoCalGas recognizes that existing practices, policies, and procedures will need to be evaluated and evolve to transport hydrogen. SoCalGas is in the process of reviewing and updating existing operational controls to provide for the safe transportation of hydrogen (See

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[11] SoCalGas established a Planning Advisory Group (PAG) to receive technical advice and to collaborate on Project design and development. The stakeholders include government entities, environmental justice nonprofits, environmental nonprofits, labor groups, industry, academia, and ratepayer advocates. Through the PAG, SoCalGas coordinates with stakeholders on hydrogen market issues, technical issues, environmental impacts, and environmental justice issues. SoCalGas also established a separate and parallel Community Based Organization Stakeholder Group (CBOSG) engagement process. The CBO stakeholder group is composed of 25 organizations that represent disadvantaged communities (DACs), social justice and environmental justice groups, faith-based organizations, school groups, and tribal organizations. It was established to preliminarily provide these members a better understanding of Angeles Link and engage in a collaborative process where the needs and concerns of represented communities are heard.

Appendix A).[12] These updates will further enhance its capacity to systematically review a change, including the assessment and mitigation of risks associated with the change. Management of Change is a continuously expanding component of the Operational Controls, a structured process for identifying potential risks associated with changes. Management of Change is an important, enterprise-wide process to safely integrate changes related to hydrogen transportation.

5. Incident Investigation, Evaluation, and Lessons Learned details practices for investigating, evaluating, and learning from incidents and near-misses. SoCalGas has established incident investigation procedures for analyzing natural gas related accidents and failures for the purpose of determining the causes of the failure and identifying learnings to minimize the possibility of recurrence, consistent with federal PHMSA and Department of Transportation (DOT) regulations (see 49 CFR §192.617, Investigation of Failures), which provide a foundation for application to hydrogen pipelines. SoCalGas has also integrated new and emerging practices related to Human and Organizational Performance by developing a Learning Team framework to assess and improve practices and activities while partnering with employees closest to the work. SoCalGas routinely references lessons learned published by the Pacific Northwest National Laboratories H2Tool website as noted in Section 11: Lessons Learned.

6. Safety Assurance is advanced by regularly assessing whether expected progress toward effective risk management and improved safety performance are being achieved. SoCalGas gathers and maintains data related to its activities and safety performance. Key safety performance metrics (e.g., third party dig ins, Serious Injuries and Fatalities [SIFs], Gas In-line Inspection [ILI] mileage) are reported publicly to the Commission as part of the Commission's Safety Performance Metric Reporting process. Furthermore, SoCalGas's Quality Management Department performs quality assurance on major pipeline and infrastructure projects and maintenance activities such as leak survey, leak detection, and locate and mark of infrastructure on both its distribution and transmission system. Many of SoCalGas's existing metrics and measures would be similarly applicable to hydrogen safety (for example, integrity assessments, damage prevention rates, first responder outreach, job safety observations, near miss / stop the job

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[12] For example, SoCalGas has developed and collaborated with manufacturers to support operation of hydrogen assets; uses company operations standards to guide system-wide consistency in daily operations or event-driven operation; uses material specification (MSP) sheets to specify SoCalGas's requirements for material(s) used in pipeline construction and company operations; uses line classes to specify the allowable piping components for a given service and define the governing code(s). Standards, MSPs, and line classes are also shared with contractors when appropriate to provide transparency and information in regard to safely operating SoCalGas assets.

reporting) and SoCalGas plans to develop additional safety performance metrics specifically related to hydrogen.

7. Management Review and Continuous Improvement is demonstrated through the review of performance to determine the extent to which goals and objectives have been met. SoCalGas engages in external benchmarking efforts through trade organizations; relationships with peer companies; and through its Advisory Safety Council, which provides feedback on SoCalGas's approach to safety through independent members with deep experience and proven leadership in the areas of safety management systems, public safety, community relations, regulatory oversight and industry safety. In addition to existing internal processes for performance and goal review and continuous improvement, with respect to Angeles Link specifically, SoCalGas's review process for the Angeles Link Phase 1 studies includes subject matter expert reviews internally and externally. This also includes the review and feedback coordinated through the PAG and CBOSG engagement process, and third-party review of this Plan for Applicable Safety Requirements by the Hydrogen Safety Panel (HSP), which was founded by the U.S. Department of Energy to develop and implement guidance, procedures, and best practices that would support safety in the operations, handling, and use of hydrogen and hydrogen systems.

8. Emergency Preparedness and Response is promoted through procedures that detail plans to address potential types of emergencies, notification requirements, identification of response resources, use of Incident Command Structure, communication plans, training and drill requirements, and improvement processes. SoCalGas's Emergency Management department is a centralized and dedicated department that supports business operations with first responder outreach and emergency response, preparedness, and recovery. Furthermore, Emergency Management maintains SoCalGas's business continuity (BC) program that addresses continuity of operations and essential functions in the event of a business disruption. The BC program contains multiple BC plans that contain the assessment of potential impacts, mitigations of risks, and processes and procedures to continue operations and essential functions in the event of a business disruption. SoCalGas utilizes the Federal Emergency Management Agency (FEMA) Incident Command System (ICS), which allows for a multi-level emergency response, and is a nationally recognized standardized approach to incident management. SoCalGas regularly conducts outreach to first responders in accordance with 49 CFR § 192.615(c), California Public Utilities Code § 956.5 and API 1162 as noted in Section 9: Control Room and Emergency Response. SoCalGas has already met with first responders such as local fire departments to coordinate and share knowledge on hydrogen safety-related preparedness and response.

9. Competence, Awareness, and Training is demonstrated through processes to evaluate, determine, and enable the appropriate level of competence, including education, training, and experience. SoCalGas has administered hydrogen safety education facilitated by third parties for employees supporting hydrogen projects. SoCalGas has proactively joined with supporting organizations to present hydrogen awareness information to CBOSGs as well as strengthen the connections within academia. SoCalGas has also collaborated with other industry partners to develop pathways to acquire hydrogen training for various levels of personnel. For additional information see Section 10: Awareness, Education, and Training.

10. Documentation and Recordkeeping is advanced through procedures for the identification, distribution, and control of required documents. SoCalGas maintains a comprehensive Information Management Policy, detailed Record Retention Schedule(s), and every employee is responsible to review, evaluate, and manage Company-related information (records and non-records) within their possession or control in accordance with these policies. These same processes will be used in maintaining documentation and recordkeeping related to Angeles Link.

5.0 PHYSICAL AND CHEMICAL PROPERTIES OF HYDROGEN

The safe transmission, compression, storage, and transportation of hydrogen must account for physical and chemical properties associated with pure hydrogen. To illustrate the properties of hydrogen, Table 1 *Properties of Hydrogen Compared to Natural Gas*, compares hydrogen's properties and characteristics to natural gas.

Table 1 - Properties of Hydrogen Compared to Natural Gas

Property / Characteristic	Hydrogen Gas	Natural Gas	Comparison / Comment	Management
Visibility	Colorless	Colorless	Both natural gas and hydrogen are colorless	N/A
Odor	Odorless	Odorless	Both natural gas and hydrogen are odorless	Addition of an odorant, such as mercaptans, which are currently used to odorize natural gas

Property / Characteristic	Hydrogen Gas	Natural Gas	Comparison / Comment	Management
Toxicity	No toxicity risk when inhaled in small quantities.	No toxicity risk when inhaled in small quantities.	Neither hydrogen nor natural gas are toxic in their pure forms. Both gases can potentially displace oxygen in an enclosed space, resulting in an asphyxiant hazard.	Leak detection, hydrogen gas detectors, addition of odorant
Flammability Range	4% to 75% in air	5% to 15% in air	With hydrogen's wider flammability range, it can combust in a broader set of circumstances than natural gas.	Leak detection, hydrogen gas detectors, and addressing hazards in an electrical area
Combustion Byproduct	Water Nitrous Oxides (NO_X)*	Carbon Dioxide, Carbon Monoxide, NO_X, Sulfur Oxides (SO_X)*	Combustion temperatures and fuel quality and composition influence combustion byproducts	See the discussion below regarding adiabatic flame temperatures

Property / Characteristic	**Hydrogen Gas**	**Natural Gas**	**Comparison / Comment**	**Management**
Molecular Weight/Size	H_2 Very light/small (2.02 g/mol)	CH_4 (Methane) Heavier/larger chains (16.04 g/mol)	The hydrogen (H_2) molecules are relatively much smaller than methane (CH_4) and can permeate into the base materials containing the hydrogen. Permeation into base materials may result in increased embrittlement in steel pipes, resulting in cracking/fracturing. While methane and hydrogen are lighter than air, hydrogen will rise and disperse more quickly than methane when released into the atmosphere.	Material selection and internal coating (pipelines/tanks) considerations to reduce the potential for cracking/fracturing and embrittlement

Property / Characteristic	**Hydrogen Gas**	**Natural Gas**	**Comparison / Comment**	**Management**
Corrosivity	Inherently non-corrosive	Inherently non-corrosive	While both hydrogen and natural gas are non-corrosive, they can impact materials in certain conditions. As indicated previously, hydrogen can act to embrittle steel in certain conditions. Additionally, hydrogen can interact with metals to form metal hydrides. For hydrogen and natural gas, impurities (like water) can result in metal degradation and corrosion.	Commodity purity requirements Regular inspections
Ignition Energy	0.02 mJ (or lower)	0.25 mJ – 0.5 mJ (or higher)	Hydrogen and natural gas ignition energy can vary depending on the mixture, temperature, and pressure. Hydrogen's lower ignition energy indicates it is more easily ignited than natural gas, given an identical ignition energy source.	Precise hydrogen ignition control equipment; Non-spark personal protective equipment

Property / Characteristic	**Hydrogen Gas**	**Natural Gas**	**Comparison / Comment**	**Management**
Heating Value (lower/higher)	51,600 / 61,000 Btu/lb 290 / 340 Btu/scf	20,300 / 22,500 Btu/lb 980 / 1,100 Btu/scf	To match the energy content of natural gas, hydrogen must be provided at a greater volumetric flow rate.	Design the pipeline on a volumetric basis to meet desired energy needs.
Flame Speed	~200-300 cm/s	~30-40 cm/s	Hydrogen's flame speed is approximately ten times faster than that of natural gas. A hydrogen flame propagates more rapidly than natural gas, impacting combustion systems (e.g., an engine designed for a natural gas fuel source cannot run reliably on a hydrogen fuel source without modification).	Modifications to combustor design to manage flame speed
Adiabatic Flame Temperature	~4,000 °F	~3,565 °F	Hydrogen's adiabatic flame is approximately 500 °F hotter than that of natural gas, which requires considerations for proper materials and mitigating potential increases in oxides of nitrogen (NO_X) emissions.	Select materials that can withstand the increase in temperature, modify the combustion air/fuel ratios, control flame hot spots, and increase emission treatment. *See section on materials within the Pipeline Sizing and Design Study*

Compressibility	Additional compressor horsepower is required per unit of energy vs natural gas due to lower molecular weight.		Due to its low molecular weight relative to natural gas, hydrogen requires additional power to compress, given a consistent compression ratio. Due to hydrogen's low volumetric energy density compared to natural gas, additional hydrogen must be compressed to transmit an equivalent amount of energy. Natural gas typically increases in temperature when compressed and decreases when depressurized. Hydrogen has a negative Joule-Thomson coefficient, which has a slight cooling effect as hydrogen is compressed adiabatically, but the added energy from compression results in an overall temperature increase. The negative Joule-Thomson coefficient also causes an increase in	Appropriate compression and hydrogen cooling/heating system design

Property / Characteristic	Hydrogen Gas	Natural Gas	Comparison / Comment	Management
			temperature during depressurization.	

In summary, there are many similarities between hydrogen and natural gas operations and gas handling. While there are some differences in their properties and characteristics, a variety of existing practices can be modified to manage these differences. Risk management of any gas system should be similar in prioritizing safety measures for materials, design, operation, and maintenance. Eliminating hazards and detecting leaks are a critical component of monitoring and mitigating risk.

6.0 RISK MANAGEMENT

SoCalGas has established a unified systemic approach to managing safety across the enterprise, and includes the necessary organizational structures, accountability, policies, and procedures. The system is comprehensive and iterative in nature, and designed to identify, manage, and reduce risks and help prevent or mitigate the likelihood and consequences of safety incidents, including serious injuries to employees, contractors, or the public, as well as unintended releases or Abnormal Operating Conditions. A Process Hazard Analysis (PHA) is a systematic approach to identifying, assessing, and managing risks associated with hazardous chemical processes. It plays a crucial role in risk management by supporting worker safety, public safety, and environmental protection.

Risk management is an element of SoCalGas's SMS, and the existing risk management approach will be beneficial in incorporating and addressing hydrogen infrastructure. SoCalGas's ERM is modeled after International Organization for Standardization (ISO) Standard 31000 and is a comprehensive framework to identify, assess, respond to and report on key risks. The SMS utilizes Plan-Do-Check-Act (PDCA), which serves as a core component of SoCalGas's SMS. The PDCA cycle is iterative and intended to continuously improve safety at SoCalGas. Furthermore, execution of the PDCA supports the ERM framework.

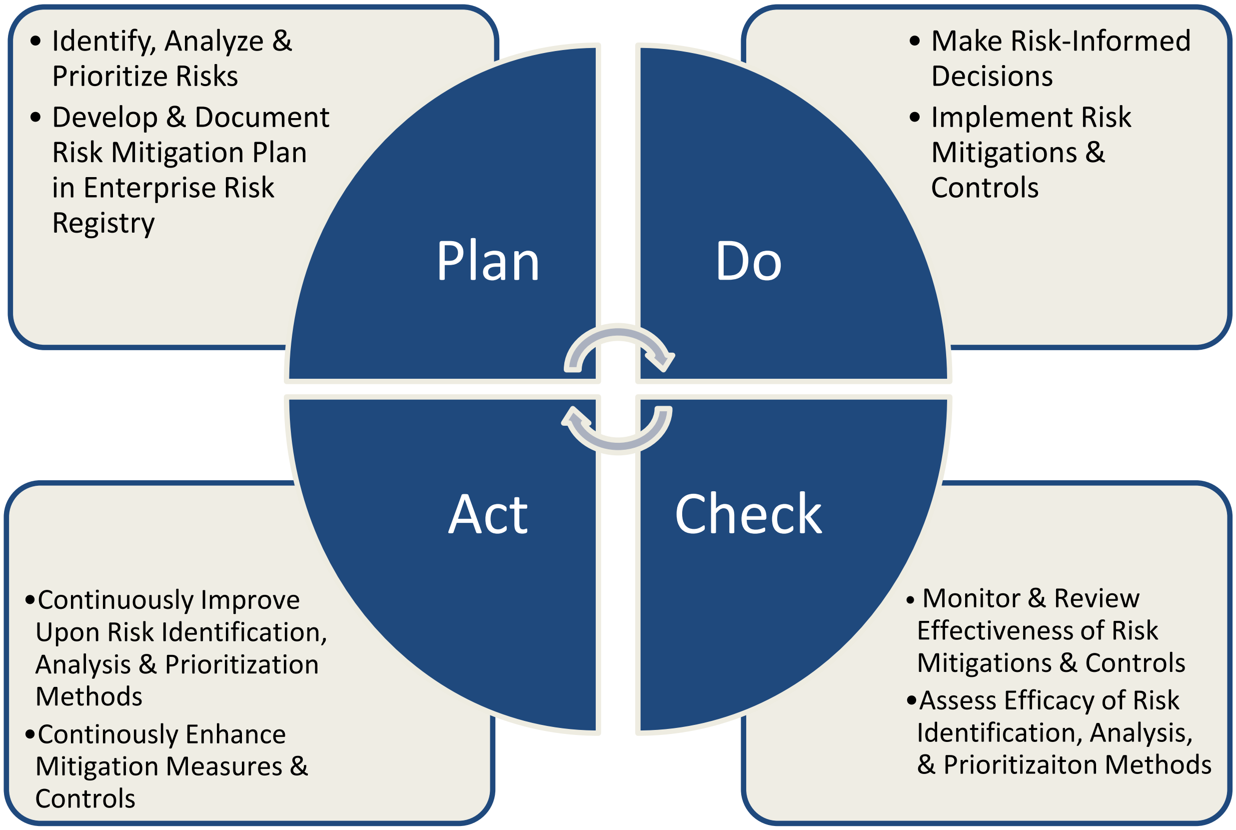

Figure 1 – Risk Management

Table 2, *Risk Management* below identifies potential considerations regarding the transportation of fuel by pipeline, as well as potential risk management. The management of risk would include considerations for internal integrity management processes, training, design, engineering, and implementation of regulatory requirements mandated by PHMSA and the CPUC. The following table outlines these considerations for transmission, compression, storage, and transportation and includes potential management. As with any installation, site and situation-specific mitigations must be considered.

Table 2 – Risk Management

Description of Risk	Potential Consequences	Potential Management
People - Stakeholder engagement and safety training	Public Awareness Plans and local first responder liaisons are not specific to hydrogen, leading to potentially inappropriate reactions to incidents.	Update Public Awareness Plan material for hydrogen infrastructure to inform the public and emergency responders on the fundamentals of hydrogen and differences versus natural gas (what may be familiar). For internal and external resources, widespread safety training from Subject Matter Experts (SMEs), industry associations and organizations like Gas Technology Institute (GTI), Center for Hydrogen Safety (CHS), and others.
Equipment - Design, construction, operations & maintenance	Equipment failures, leaks/accidents could create a potential risk of fire or explosion. If a significant failure occurs, the shutdown could lead to fuel shortages and service disruptions, impacting areas adjacent to the failure location(s) and the end users.	Monitoring specific hydrogen safety codes and standards listed in section 7: Key Safety Codes and other organizations' research and development of hydrogen pipe specifications to incorporate current industry best practices. Conduct preliminary/final hazard analysis methods - What-If; Checklist; Hazard and Operability (HAZOP) Study; Failure Mode and Effects Analysis (FMEA); Fault Tree Analysis; an equivalent method.
	Properties of hydrogen that differ from natural gas are not appropriately accounted for in design and construction, leading to failures and impacting areas adjacent to the failure location(s) and the end users.	For purposes of this report, it is assumed that Angeles Link infrastructure would be an entirely new system constructed with 100% hydrogen-compatible material, compatible welding specifications, and the latest industry best practice construction techniques, helping to minimize damage and leak events. Conduct preliminary/final hazard analysis methods - What-If; Checklist; HAZOP Study; FMEA; Fault Tree Analysis; an equivalent method.

Description of Risk	Potential Consequences	Potential Management
	Potential for ignition, which could create risk of fire or explosion.	Regular maintenance and compliance with all safety regulations, including leak detection, monitoring, and conducting regularly scheduled leakage surveys. Conduct preliminary/final hazard analysis methods - What-If; Checklist; HAZOP Study; FMEA; Fault Tree Analysis; an equivalent method.
Environment - Natural disasters and third-party damages	Higher populated areas increase the risk of threats like third-party damage and impacts on people and property affected.	Angeles Link infrastructure would be an entirely new system constructed with hydrogen-compatible material, compatible welding specifications, and the latest industry best practice construction techniques, helping to minimize damage and leak events. Additionally, the pipeline will be buried with adequate cover and signage along the route in accordance with federal and state pipeline safety standards. The SoCalGas Public Awareness Plan will help inform the public about hydrogen, the specific pipeline route, emergency contacts, and additional relevant information.
	Damage to aboveground assets/equipment could create a potential risk of fire or explosion.	Upgrade physical security with technology designed to minimize occurrences of vehicles driving through gates or penetrating fences, such as bollards or concrete barriers.

Description of Risk	Potential Consequences	Potential Management
	A seismic event could damage the pipeline if not appropriately designed. This damage could create a potential risk of fire, explosion, and potential fuel shortages and service disruptions.	Available seismic notifications systems and resulting system shutoffs, including actuated mainline valves with pressure monitoring for line break scenarios installed on either side of a major fault crossing. Installation of low-density backfill material (i.e., Geofoam) to account for pipeline displacement and reduce stresses. Other design considerations include minimizing pipeline changes across fault lines to reduce stress concentrations of an earth load applied to the pipeline due to a seismic event.
	Individuals could gain access to the pipeline infrastructure aboveground assets or equipment, intending to vandalize or do harm. This could result in infrastructure damage and lead to significant repairs and disruptions to service.	100% security camera coverage of all aboveground sites with real-time monitoring in a central security center or control room. All doors into buildings are locked and equipped with intrusion detection capabilities.

Process Hazard Analysis

A PHA is a systematic review used to identify and analyze potential hazards associated with the processing or handling of hazardous chemicals or natural disasters, to mitigate risks. The PHA can be used to identify the causes and consequences of, but not limited to, fires, explosions, releases of toxic or flammable chemicals, and major spills and it focuses on equipment, instrumentation, utilities, human actions, and external factors that might impact the process. It is one of the elements of OSHA's program for Process Safety Management.

There are several methodologies that can be used to conduct a PHA, including checklists, hazard identification (HAZID) reviews, what-if reviews, HAZOP Studies, FMEA, etc. The selection of the methodology to be used depends on a number of factors, including the complexity of the process, the length of time a process has been in operation, if a PHA has been previously conducted, and if the process is unique, or industrially common.

The SoCalGas existing gas standard provides the policy and procedure for projects to follow in conducting a PHA. The policy requires projects to include safety reviews of the design throughout the stages of the project. The PHA is used to identify and analyze potential hazards and make design changes to reduce those hazards. To identify and evaluate potential hazards, the scope of the PHA shall include but not be limited to the following:

1. Identification of the hazards associated with the Covered Process.
2. Identification of any previous incident which could have a likely potential for hazardous or catastrophic consequences in the workplace.
3. Identification of engineering and administrative controls applicable to the hazards and their interrelationships.
4. Identification of consequences of failure of administrative and engineering controls.
5. Stationary Source siting and the risk to onsite & offsite receptors.
6. Human factors.
7. A qualitative evaluation of a range of the possible safety and health effects on employees in the workplace or the public caused by failure of controls.
8. Consideration of external events, including seismic events.

Ultimately, applicable statutory and regulatory drivers and SoCalGas's safety best practices will frame the appropriate PHA to identify potential hazards for Angeles Link and assess associated risks to improve safety and reduce the consequences of hazardous materials to employees, contractors, public, and infrastructure.

7.0 KEY SAFETY CODES

There are numerous existing codes, specifications, standards, and regulatory requirements applicable to transporting gas in a pipeline. SoCalGas is familiar with, and actively implements applicable codes and standards in connection with its existing natural gas transportation system. Certain codes and standards, including PHMSA's regulations contained in 49 CFR Part 192, also apply to the transportation of hydrogen. Specific natural gas codes and standards such as from the American Society of Mechanical Engineers (ASME) provided a basis for hydrogen codes and standards that have been developed and continue to support the evolution of hydrogen standards. In addition, there are a number of hydrogen-specific industry standards that provide best practices that should be considered for hydrogen pipelines.

Federal Regulations

1. 49 CFR Part 192, *Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards and Integrity Management*, is a comprehensive federal code covering design, materials, welding, testing, and topics in operations, maintenance, and operator qualifications (OQ). Under 49 CFR Part 192, code section 192.7 contains the documents incorporated by reference partly or wholly which include industry codes and standards, some of which may apply to hydrogen assets. Current federal minimum safety standards for pipelines transporting natural and other gases include hydrogen and do not specify differences and considerations for hydrogen specifically versus natural gas (and other gases).
2. 49 CFR Part 191, *Transportation of Natural and Other Gas by Pipeline; Annual, Incident, and Other Reporting* covers the requirements for reporting incidents, safety-related conditions, annual pipeline summary data, and other reporting. 49 CFR Part 191 would apply to hydrogen pipelines with potential changes to the format of the forms associated with reporting. 49 CFR Part 191 does not distinguish between natural gas, hydrogen, liquefied natural gas (LNG) or liquid pipelines. Part 191 is primarily a reporting section and requires establishing an Operator ID (OPID) before constructing new transportation assets.
3. 49 CFR Part 173, *Shippers – General Requirements for Shipments and Packaging* provides the requirements for transporting hazardous materials, including hydrogen, in mobile storage containers and pressure vessels. Part 173 covers the classification (hydrogen is classified as a Class 2.1 flammable gas), packaging, hazard communication, and the required transport driver training(s). Additionally, referencing 49 CFR 178, Part 173 covers the requirements for pressure vessels should hydrogen be transported as a compressed gas.[13]
4. Occupational Safety and Health Administration (OSHA), Code of Federal Regulations, Title 29, Part 1910, Subpart H. Hazardous Materials – This code addresses hydrogen as a hazardous material. 29 CFR Section 1910.103 is specific to hydrogen.

State Requirements

1. The CPUC is the agency authorized by PHMSA to oversee intrastate gas pipeline facilities in California. CPUC General Order (GO) No. 112-F, *State of California Rules Governing Design, Construction, Testing, Operation, and Maintenance of Gas Gathering, Transmission, and Distribution Piping Systems within the State of California*, is focused on many of the same regulatory requirements as 49 CFR Part 192. General Order No. 112-F incorporates by reference the current version

[13] This Safety Study references 49 CFR Part 173 for shipments and packaging for containers that may contain hydrogen gas as a potential consideration but does not imply it will be incorporated within Angeles Link, as Angeles Link is proposed as a pipeline infrastructure project.

of 49 CFR Part 192 and specifies additional rules and requirements to the Federal Pipeline Safety Regulations (49 CFR Parts 191, 192, 193, and 199).

2. The California Health and Safety Code contains requirements that govern the handling, storage, and transmission of hazardous materials:
    a. Division 20, Chapter 6.95, *Hazardous Materials Release Response Plans and Inventory* – This plan aims to prevent or minimize harm to public health and safety and the environment from a release or threatened release of a hazardous material.
    b. Sections 25531 - 25543.3, California Accidental Release Prevention (CalARP) program – The purpose of this program is to prevent accidental releases of those substances determined to potentially pose the greatest risk of immediate harm to the public and the environment.
3. Cal/OSHA Code of Regulations. Title 8, General Industry Safety Orders – This code establishes minimum workplace safety standards. Part 5473 includes language specific to hydrogen systems and storage (refer to Subchapter 7, Group 20, Article 138).

Industry Codes and Standards

1. NFPA 2, *Hydrogen Technologies Code* – This code provides fundamental safeguards for hydrogen generation, installation, storage, piping, use, and handling. For information on deflagration venting for hydrogen see NFPA 68. Both codes are backed by a knowledgeable technical committee and are a valuable resource as an industry best practice, although not incorporated by reference into 49 CFR Part 192.

2. NFPA 69, *Standard on Explosion Prevention Systems* – This code provides guidance to prevent ignition caused by dust particles, gases, or vapors. It provides basic information including control of active/passive isolation, ignition suppression, and oxidant concentration. This code is not incorporated into 49 CFR Part 192 but is an industry best practice.

3. API RP 1162, *Public Awareness Programs for Pipeline Operators* – This recommended practice, incorporated by reference into 49 CFR Part 192, addresses the development, implementation, evaluation, and documentation of pipeline public awareness programs. The content of an operator's public awareness program should be modified when referring to a hydrogen pipeline versus a natural gas pipeline even though API 1162 does not distinguish between natural gas and hydrogen from a procedural perspective. This recommended practice is focused on creating awareness with the affected public, excavators, and local governments on the location of gas infrastructure and steps that can prevent incidents/accidents and providing information on how to report emergencies.

4. California Government Code 4216, *Protection of Underground Infrastructure* – This code is related to damage prevention for underground infrastructure. 49 CFR § 192.614 also has specific requirements related to damage prevention, including the requirement to participate in a public service program, such as a one-call system. These requirements would also apply to hydrogen pipelines.

5. API RP 1173, *Pipeline Safety Management Systems* – This recommended practice relates to all pipeline systems and includes roles and responsibilities within the operator's company from the top down. This recommended practice will continue to guide the development and maintaining of a pipeline safety management system for hydrogen pipelines. This process standard is commodity/fuel agnostic and outlines the process for creating a safety management plan.

6. *ASME Boiler and Pressure Vessel Code (BPVC)* – BPVC is a set of codes and standards developed by ASME to regulate the design, construction, inspection, and maintenance of boilers and pressure vessels. Pressure vessels used for hydrogen storage would incorporate the requirements of BPVC, including, but not limited to:
    a. BPVC Section VIII -Division 3 Article KD-10 provides special requirements for stationary pressure vessels in high-pressure hydrogen service.
    b. BPVC Section XII provides the requirements for tanks and pressure vessels used for transportation up to 3,000 psig and volumes greater than 120 gallons.

7. ASME B31.8, *Gas Transmission & Distribution Piping Systems* – This code is applicable to the design, fabrication, installation, inspection, and testing of pipeline facilities used in the transportation of gas. Safety aspects of the operation and maintenance of those facilities, such as emergency plans, training programs, and prevention of accidental ignition are also covered. This code is considered an existing industry best practice, standard, and reference document although it is not wholly incorporated by reference into 49 CFR Part 192 (per §192.7).

8. ASME B31.12, *Hydrogen Piping and Pipelines* – This code is applicable to piping and pipelines in gaseous hydrogen service. Guidelines are provided for the design, construction, and operation of hydrogen piping and pipeline systems for the safety, integrity, and reliability of these systems. The code covers a wide range of system components, including pipes, fittings, valves, pressure vessels, and associated equipment and is one of the most reputable hydrogen codes adopted by regulatory authorities. ASME B31.12 is not currently incorporated by reference into 49 CFR Part 192.

9. *Compressed Gas Association (CGA) G-5, Hydrogen* – This specification is intended to provide background information and recommended practices covering the manufacture, distribution, and use of hydrogen. It summarizes the chemical and physical properties of hydrogen and provides guidance on critical aspects of

hydrogen system design, including pressure relief and venting. This specification is referenced in NFPA 2 while it is not incorporated by reference into 49 CFR Part 192.

As the hydrogen economy further develops, additional industry best practices and technical specifications will likely emerge. [14] 49 CFR § 192.7 contains the list of documents incorporated by reference partly or wholly. The list will likely expand as more standards, best practices and technical specifications are developed for hydrogen pipelines. Existing codes and standards are not considered regulations or requirements unless incorporated by reference in the Code of Federal Regulations. Industry best practices may be beneficial as reference points in the development of hydrogen infrastructure, as well as to review, and potentially incorporate, as appropriate.

International codes can be used as a starting or reference point for development of similar codes or best practices in the US. Table 3, *Listing of Available Key International Codes and Standards Related to Hydrogen*, contains a list and high-level descriptions of the current and existing key international codes outside the U.S.

Table 3 – Listing of Available Key International Codes and Standards Related to Hydrogen

International Code or Standard	**Description/Use**
Canadian Standards Association (CSA) - The CSA Group is actively working on standards and codes for various aspects of hydrogen, including production, storage, various transportation modes, and end-use.	
CSA Z662 - Oil and Gas Pipeline Systems	Addresses safety requirements for fuel cell systems used in residential, commercial, and industrial applications, covering electrical and hydrogen safety aspects.
CSA C22.2 No. 62282-1 - Fuel cell technologies - Part 1	Provides terminology related to fuel cell technologies, including terms specific to hydrogen safety.
CSA C22.2 No. 62282-2 - Fuel cell technologies - Part 2	Addresses safety requirements for fuel cell modules, including those related to hydrogen.

[14] Core objectives of the hydrogen industry are supported by SoCalGas's collaboration with and support of organizations such as: Pipeline Research Council International (PRCI), NYSEARCH (Natural Gas RD&D), and Low-Carbon Resources Initiative (LCRI).

International Code or Standard	Description/Use
International Organization for Standardization (ISO) - A global network of the world's leading standardizers that develop international standards by assembling groups of experts representing many sectors.	
ISO 14687	Specifies the quality requirements for hydrogen used in fuel cell vehicles. It covers aspects such as purity levels, impurity limits, and other characteristics.
ISO 14689	Provides guidelines for the safe use of gaseous hydrogen at hydrogen fueling stations. Addresses these facilities' design, construction, operation, maintenance, and safety aspects.
ISO 16111	Outlines the requirements for the safety of equipment used for compressed hydrogen gas fueling stations.

Access to these international codes may provide value in understanding certain best practices for similar systems as well as potential application(s) to enhance safety.

8.0 SPECIFICATIONS, STANDARDS & PROCEDURES EVALUATION

In accordance with PHMSA and CPUC regulations, SoCalGas has an extensive set of specifications, standards, and procedures for its existing natural gas system, which can be modified for hydrogen as appropriate. The evaluation conducted as part of this work scope focused on the existing specifications, standards, and procedures provided by SoCalGas. The methodology applied is discussed in Appendix A, *SoCalGas Standards Review Summary*. The critical identifier is "Transportation," which places hydrogen pipeline infrastructure involved in transporting hydrogen from third-party production and third-party storage to end users under the jurisdiction of PHMSA. If new codes and standards are developed and released for incorporation into the federal safety standards, SoCalGas should update and revise the necessary specifications, standards, and procedures to comply with the requirements for safe hydrogen transportation. Currently, industry best-practice standards are available for hydrogen-specific pipelines. For example, until hydrogen-specific codes for pipe specifications and design, welding, weld flaw criteria and evaluation, and inspection and testing are developed, regulations and standards like ASME B31.12 could be used for guidance.

Recommendations for updates to procedures that will cover operations and maintenance of the hydrogen pipeline during normal operating conditions, abnormal operating conditions, leak investigation, repairs, and emergency response are contained in Appendix A, *SoCalGas Standards Review Summary*. Procedures to be developed will follow industry best practices to meet the requirements set out by PHMSA and the CPUC to include information and details such as the following:

1. Code specific language
2. Discussion of the requirements of the procedure
3. Methodology of "How To" execute the procedure
4. Records required and retention time

The following sub-sections discuss the existing specifications, standards, and procedures applicable to SoCalGas's natural gas system, and explain how these specifications, standards, and procedures should be reviewed by SoCalGas to determine whether they could apply to Angeles Link, whether modifications would be required for Angeles Link, or whether new specifications, standards, and procedures may be necessary for Angeles Link.

Pipeline Materials, Design, Construction, and Testing Evaluation

Transmission pipeline construction is identified in 49 CFR Part 192 Subpart B through Subpart G and Subpart J. Construction qualifications for hydrogen facilities will require pipe material specifications, welding specifications, and other typical construction activities specific to hydrogen and may overlap with existing qualifications. The following regulations listed below include many of the requirements that SoCalGas should consider for review.

- 49 CFR Part 192 Subpart B, requirements for pipeline material selections, as prescribed in 49 CFR § 192.51, the minimum requirements for the selection and qualification of pipe and components for use in pipelines. Further information regarding material selection can be found in the *Pipeline Sizing and Design Criteria Study (*Design Study*).*
- 49 CFR Part 192 Subpart C, requirements for new pipelines incorporates API Specification 5L "Specification for Line Pipe" by reference. Pipe manufacturers will seek API 5L certification that the pipe manufactured and tested in accordance with API 5L will be acceptable for hydrogen service.
- 49 CFR Part 192 Subpart D lists the minimum requirements for design and qualification of pipeline components including prescribing minimum requirements for the design and installation of pipeline components and facilities, along with protection against accidental over pressuring.
- 49 CFR Part 192 Subpart E, *Welding of Steel in Pipelines*, addresses welding procedures, welding qualifications, and other issues. 49 CFR Part 192 also incorporates by reference other API Recommended Practices for transporting pipe, and API Standard 1104 "Welding of Pipelines and Related Facilities" is also incorporated by reference. These Standards and Recommended Practices must be updated to include specific hydrogen specifications.

Operations & Maintenance Procedures Evaluation

Existing SoCalGas natural gas operations and maintenance (O&M) procedures provide a basis for evaluations for hydrogen-specific requirements. O&M procedures were reviewed to provide guidance, including with respect to hydrogen safety, abnormal operating conditions, PPE required, and other topics. Specifically, procedures for leak survey/detection, fire prevention/detection, and purging hydrogen systems will be needed during pipeline, compressor, and other maintenance activities.

Typical O&M safety considerations for 100% hydrogen systems were reviewed to guide pipeline and facilities handling hydrogen; many of the O&M tasks will be structured similarly for hydrogen as they are for natural gas. 49 CFR Part 192 is the primary federal code for O&M of gas pipeline systems. GO 112-F contains additional requirements by the CPUC.

Potential for Future Odorization

Based on known factors and existing general management best practices, an odorant may be required under 49 CFR §192.625, *Odorization of gas*. For Angeles Link transmission pipeline infrastructure, the criteria in §192.625(b) will determine the requirements for odorization.

There have been several studies on the feasibility of odorizing hydrogen and the options for doing so. One such study, performed by DNV GL and SGS Nederland in 2020 for Gasunie Transport Services B.V. and Netbeheer Nederland (DNV GL and SGS Nederland, 2020), tested various types of odorants with various samples/mixtures of natural gas and hydrogen, including a 100% hydrogen sample. A panel was exposed to each sample, and several questions were asked regarding the odor and familiarity of the smell. The results of the study conclude that the mixtures of natural gas and hydrogen and pure hydrogen can be sufficiently odorized with existing odorants.

Another study conducted by MARCOGAZ in 2021 (MARCOGAZ, 2021) investigated odorization of hydrogen and hydrogen and natural gas blends. The report cites several studies from various countries, including the one performed by DNV GL/SGS Nederland. These studies concluded that all the odorants were judged suitable for use in a 100% hydrogen gas for combustion applications. Further research would be required if the intention is to supply hydrogen to stationery fuel cells or fuel cell vehicles. Experience in this matter is limited as most pure hydrogen pipelines to date are strictly for industrial purposes and are not odorized.

The MARCOGAZ report identifies potential areas for further study:

- Possible effects on odorization due to differences in physical properties of the mixture of gas and odorant (density, vapor pressure, etc.)
- Possible chemical reaction between hydrogen and odorant at high-pressure condition

- Possible effects of high concentrations of hydrogen on gas odorant
- Influences from possible impurities from hydrogen production

A discussion on odorants with Arkema Inc. was also conducted. Arkema is a global producer/manufacturer of chemicals, including odorants, for natural gas pipelines. They have also conducted tests similar to the DNV GL/SGS Nederland study and found that odorizing hydrogen will likely be feasible, and that the odorant will not interfere with leak detection technology or explosimeters. If the hydrogen is intended for fuel cells, injected odorant may need to be scrubbed out as it may impact fuel cell system performance. From the discussion with Arkema, hydrogen for use in fuel cells must be >99.97% pure; for more general use, such as combustion or blending, it can be >98% pure.

Per the studies and discussions conducted, the odorant known as tetrahydrothiophene (THT) has been identified to be compatible with a pure hydrogen system. Complementary to the studies discussed, another research study conducted by DNV GL in 2022 for Stedin and Gaz Reseau Distribution France (GRDF) (DNV GL 2022), identified three sulfur free odorants and their suitability for hydrogen in the gas grid. Due to the disadvantages of using THT in hydrogen such as for fuel cell systems, alternative sulfur-free odorants were investigated for hydrogen distribution. The odorant 2-hexyne was found not to have an adverse effect on the performance of fuel cells and was able to maintain stability in hydrogen, therefore appeared suitable for use as a sulfur-free odorant in hydrogen. As research on odorizing hydrogen gas continues, studies are revealing odorization of 100% hydrogen gas is likely to be feasible.

Purging

Pipelines are purged to prevent the presence of a combustible mixture of gas and air. Safe purging practices are essential for maintaining the integrity and safety of pipeline operations. As emphasized by the Hydrogen Safety Panel's comments, purging will be considered in Angeles Link's design and operations. Purging gas safely in pipelines is important for several reasons:

- Safety: Proper purging removes flammable, toxic, or reactive gases, reducing the risks of fires, explosions, and health hazards to personnel
- Preventing Reactions: It prevents unwanted chemical reactions that could damage the pipeline or its components
- Operational Efficiency: Confirms the environment within the pipeline is suitable for subsequent processes like welding, maintenance, or repairs
- Compliance: Adhere to safety standards and regulations

SoCalGas maintains and implements policies and procedures for safely purging natural gas pipelines, which include an approved written plan for all purging procedures. These procedures can be readily modified or supplemented with hydrogen specific purging procedures as applicable. As a recommended best practice by H2 Tools,[15] to avoid creating a combustible mixture of air and hydrogen inside any part of a hydrogen system, the air, oxygen, and any other oxidizers must be purged from the system prior to introducing the hydrogen. Similarly, when preparing a system for maintenance, the hydrogen must be purged from the system prior to opening the piping or equipment in order to avoid releasing hydrogen into the air where it could create a combustible mixture. Inert gases, such as nitrogen, may be used as a part of purging procedures, and for leak checks.

There are three general approaches to purging a system:

- **Flowing gas purge** uses an inert gas flowing into one part of the system and out of another part of the system. The success of this technique is dependent on the system geometry, e.g., it is more difficult to apply to a multi-branched system. Vent gases are directed to a safe location, e.g. a vent stack, to eliminate asphyxiation potential.
- **Pressurizing-venting cycle purge** uses alternating pressurizing with inert gas and venting to atmospheric pressure. This procedure stepwise dilutes the contents of a volume until the desired mixture concentration is obtained. This method can be used in systems that have long dead ends but requires pausing the purge when pressurized to allow the gases to mix. Pressurizing-venting cycle purge is typically used for purging Type IV cylinders and other components which cannot tolerate Vacuum Purging.
- **Vacuum purging** involves 1) venting the system to atmospheric pressure, then 2) pumping to a relatively low pressure with a vacuum pump, then 3) re-pressurizing with inert gas to a positive pressure and 4) venting to atmospheric pressure. Depending on the goal of the purge and the capability of the vacuum pump, more than one cycle may be required. The vacuum pump must be suitable for the gases being evacuated, typically hydrogen, air, and the inert gas.

The above three methods are general purging methods that may apply to certain situations, and would be implemented as appropriate based on many factors, such as system geometry, purge medium, practicality, etc. After selection of a purging method, one of the essential steps in the process is to eliminate all possible sources of ignition. When selecting venting locations, care should be taken to prevent accidental ignition during purging operations. The importance of a written plan will provide the guidance to execute the essential steps for all purging procedures. The SoCalGas standards would incorporate hydrogen specific details outlined in the written plan to include, but not be

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[15] H2 Tools is intended for public use. It was built, and is maintained, by the Pacific Northwest National Laboratory with funding from the DOE Office of Energy Efficiency and Renewable Energy's Hydrogen and Fuel Cell Technologies Office; Purging | H2tools | Hydrogen Tools

limited to, the required purging method, location of isolation points, injection set up, injection pressures and flow rates, venting location and stack size, operational sequences, an equipment list and provisions for a communication system.

Electrical Area

Within SoCalGas's inventory of SSPs, there are guidelines and requirements to identify and categorize the electrical classification of hazardous areas at all its facilities and specify the requirements for electrical equipment, installation and wiring in areas where volatile gases and liquids are handled, processed, or stored. Electric Area considerations for safety for hydrogen differ from natural gas due to the flammability range for pure hydrogen. Specific regulations such as IEC 60079-10 NFPA 497, and NFPA 70 can be used to determine appropriate distances for electric areas. All electric equipment must be bonded and grounded. Classifications such as the component being used and which zone it is, determine the distance the equipment should be from potential ignition sources. Zone 1 is a 15ft radius from the source outdoors. Zone 2 is a 15ft radius in a properly ventilated indoor facility[16]. Precise distances are given for different components as well as their operating pressures[17]. Using this expertise in combination with preexisting standards for electric areas can prepare SoCalGas to implement and layout safe distances for equipment within hydrogen infrastructure.

Leak Survey, Detection, Mitigation, and Repair

Leak management is a critical component of system operations and maintenance for several reasons including safety, environmental protection, resource conservation, and infrastructure integrity. SoCalGas has a record of successful application and continuous improvement of leak management, including the adoption of best practices such as aerial monitoring, electronic recordkeeping, use of artificial intelligence, and increased survey frequency. SoCalGas projects such as the Control Center Modernization (CCM) will utilize new field assets such as Optical Pipeline Monitoring (OPM) stations and above ground methane sensors in High Consequence Areas (HCAs).

As hydrogen pipelines are designed and installed, SoCalGas should evaluate inclusion of multiple methods of leak detection. This comprehensive leak detection system should leverage design and construction standards which may include the installation of fiber optic cables for the Angeles Link pipeline. Fiber optic technology may be used to detect and alert SoCalGas to potential events such as unauthorized digging, ground movement, heavy equipment mobilization, subsidence, and pipeline leakage/rupture. Identifying potential gas leaks and other indicators of potential leaks through continuous monitoring utilizing technologies suggested in Table 3, below, would enhance safety and operation of the pipeline. In addition, pipeline patrols performed by trained and qualified individuals

[16] Electrical | H2tools | Hydrogen Tools; https://h2tools.org/bestpractices/electrical

[17] 410092_ Hazardous zones.doc (h2tools.org); https://h2tools.org/sites/default/files/2019-08/410092.pdf

within structured scheduled times that meet or exceed Federal and State requirements will provide further active monitoring and safety enhancement. Monitoring systems would alert SoCalGas to potential leaks or ruptures along the pipeline route and enable automatic response and deployment of the appropriate resources to respond and mitigate safely and efficiently.

SoCalGas's existing processes, technology, reporting, compliance, and safety notifications related to leak survey and leak detection would require certain modification for hydrogen leak consequences, but the framework from the natural gas system can be used as a starting point. The areas that will be focused on will be:

1. Leak survey and identifying "Abnormal Operating Conditions" for hydrogen.
2. Leak detection – using the appropriate equipment for detection, including confirmation of equipment calibration.
3. Leak mitigation and repair – requiring engineering and technical support.

Leak Survey

The existing SoCalGas leak survey processes, technology, reporting, compliance, and safety notifications provide a basis for applicability to the hydrogen pipeline and facilities. Current federal regulations (e.g., 49 CFR Part 192) in conjunction with stricter California GO112F regulations require Transmission pipeline leak surveys to be conducted:

- At least twice each calendar year, not exceeding 7.5 months
- Twice each calendar year, not exceeding 7.5 months, for non-odorized pipelines in a Class 3 location[18], and
- Four times each calendar year, not exceeding 4.5 months, for non-odorized pipelines in a Class 4 location[19].

Leak Detection

Leak detection equipment is available and can be utilized for hydrogen detection. Leak detection equipment can be categorized into the following uses:

- Permanently Mounted
- Mobile (Personal and Deployable)
- Aerial Leak Survey

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[18] A Class 3 location is: (i) Any class location unit that has 46 or more buildings intended for human occupancy; or (ii) An area where the pipeline lies within 100 yards (91 meters) of either a building or a small, well-defined outside area (such as a playground, recreation area, outdoor theater, or other place of public assembly) that is occupied by 20 or more persons on at least 5 days a week for 10 weeks in any 12-month period. (The days and weeks need not be consecutive.)

[19] A Class 4 location is any class location unit where buildings with four or more stories above ground are prevalent.

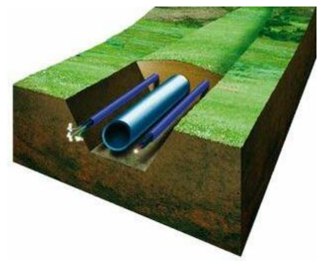
Permanently Mounted Hydrogen Detectors

Per federal regulation 49 CFR §192.736, *Compressor stations: Gas detection*, each compressor building in a compressor station must have a fixed gas detection and alarm system, unless the building is constructed so that at least 50% of its upright side area is permanently open or is located in an unattended field compressor station of 1,000 horsepower or less.

Permanently mounted detection equipment should be installed near all above ground assets, in compressor stations, and at underground storage locations. Table 4, *Permanently Mounted Hydrogen Detectors*, lists various equipment identified as options for SoCalGas to consider.

Table 4: Permanently Mounted Hydrogen Detectors

Equipment Name/Model	**Specifications/Details**
SBS-H2 Hydrogen Gas Detector (Exponential Power, n.d.) 	• Electronic spec sheet available (SBS) • Alarm at 1% and 2% hydrogen • Fail safe mode in event of loss of power
Nitto: Hydrogen Detection Tape (Nitto, Inc., n.d.) 	• Color changing tape that detects hydrogen • Can be used on welds, fittings, equipment • Mainly used at stations
OptaSense: Fiber optic pipeline detections: Real-time Pipeline Leak Detection System (Luna Innovations, 2023)	• Uses multimode leak detection (temp, pressure, ground strain, acoustic changes) • Detects 0.1% leak size

Equipment Name/Model	Specifications/Details
Omnisens Lynx: Pipeline - Securing asset integrity (Omnisens, n.d.) 	• External fiber optic cable used to detect leaks, ground movement, and 3rd party intrusion • Continuous, real-time monitoring • Leak detection based on temperature change along the line • Geohazard and 3rd party intrusions detected by strain and/or vibrations

Mobile Hydrogen Detection Equipment

Detection equipment to monitor and alarm for the presence of hydrogen should be worn or carried by operations personnel as appropriate during operations and maintenance activities. As pointed out by the Hydrogen Safety Panel, qualifying site conditions before personnel entry is imperative because existing personal monitoring devices are the most effective only when in the path of a hydrogen jet stream leak. Table 5, *Mobile Hydrogen Detection Equipment*, lists the available equipment for consideration by SoCalGas for personal wear.

Table 5: Mobile Hydrogen Detection Equipment

Equipment Name/Model	Specifications/Details

Industrial Scientific – Multi-sensor: MX6 iBrid® | Multi-Gas Detector (Industrial Scientific Corporation, n.d.)

 	
	• Electronic spec sheet available (Industrial Scientific Corporation, 2019)
	• Up to 6 gases monitored simultaneously
	• Optional integral sampling pump with strong 30.5 m (100 ft) sample draw; 20 hour run time with pump, 36 hours without pump
	• Operating temperatures range from -4°F to 131°F
	• Full-color graphic LCD is highly visible in a variety of lighting conditions
	• Powerful, 95 dB audible alarm
	• Hydrogen:
	  o Range 0-2,000 ppm range, 0.10 ppm resolution
	  o Response time: T50: 25 seconds, T95: 60 seconds
	  o Calibration gas: 100 ppm hydrogen
	  o Accuracy: +/-6%

Industrial Scientific – Single Gas: GasBadge® Pro | Single-Gas Detectors (Industrial Scientific Corporation, n.d.) 	• Electronic spec sheet available (Industrial Scientific Corporation, 2017) • Range: 0-2,000 ppm • Event logger for 15 alarm events • Replaceable battery with a 2,600-hour run time

Equipment Name/Model	Specifications/Details

Dräger: X-am 8000, 5000, 2500, 5600 all can be combined with Hydrogen sensors, Hydrogen H2 – Detectors & Protection Equipment (Dräger, n.d.)

	• Electronic spec sheet available (Dräger, 2022)
	• 1-5 gas sensors
	• 40-hour charge time
	• Normally 1 second measuring interval
	• Sensors range: 0-2,000 ppm
	  ○ DrägerSensor XXS CO/H2 Compensated
	  ○ DrägerSensor XXS H2

Grainger Industrial Supply (Various other hydrogen gas detectors)	• Combustible Gas Detectors

Industrial Scientific – Radius® BZ1 | Area Gas Monitor (Industrial Scientific Corporation, n.d.)

	• Electronic spec sheet available (Industrial Scientific Corporation, n.d.)
	  ○ Rechargeable battery
	  ○ Temp range: -4F to 131F
	  ○ 108 Decibel alarm @ 3.3ft away
	  ○ H2 range: 0-2,000 ppm
	  ○ Logs 60 events
	  ○ H2 sensor: 17156650-C Part #

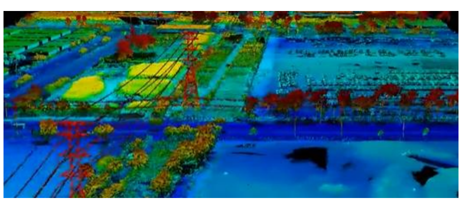
Aerial Leak Survey Hydrogen Detection Equipment

Equipment that could be mounted on drones or manned aircraft is presented in Table 6, *Aerial Leak Survey Equipment for Hydrogen Detection*, for SoCalGas's consideration. Drone options present advantages as they can fly at lower altitudes and slower speeds for more accurate hydrogen detection compared to manned aerial aircrafts.

Table 6: Aerial Leak Survey Equipment for Hydrogen Detection

Equipment Name/Model	Specifications/Details

Sniffer 4D – Mobile Air Pollutant Mapping System – Drone-based Air Pollutant Mapping System (TPI, n.d.)	• Attachable to drones, planes, trucks/cars, and is wearable.
	• Wide-range H2 Sensing Module
	  ○ Detection method: electrochemistry
	  ○ Range: 0-5,000ppm
	  ○ Detection limit: 17ppm

	○ Repeatability: <5%FS ○ Overall response time (t90): <55s (0-400ppm) ○ Theoretical resolution: <0.7ppm ○ On-chip proprietary individual difference compensation algorithms ○ Support “Dormant Mode,” warm-up time from a cold start: <10s ○ Zero drift: <±20ppb/year (in laboratory environment) ○ Est. service life: >24months ○ Operating temperature: -30-50°C ○ Operating humidity: 15-90%RH • Sniffer4D – Mobile Air Pollutant Mapping System (TPI, n.d.) comprises of various components that can be mounted on a moving platform. • Electronic spec sheet available (TPI, 2023)
Hawkeye Helicopter – Fixed wing airplane or rotor-wing aircraft (Hawkeye Helicopter, n.d.)   	• Variety of top technology partners nationwide • Detect leaks, encroachment, and/or erosion • Laser aerial leak detection capable of detecting minute PPM levels at ground level • Aerial video including GIS centerline data as well as a host of other references • Aerial photography to assist in right-of-way certification, project planning and maintenance, structure counts, and more • High-density LiDAR data • Infrared and Corona inspections

Furthermore, the *Supraparticles for Bare-Eye H2 Indication and Monitoring: Design, Working Principle, and Molecular Mobility* (Adv. Funct. Mater. 2022) research article recognizes sensors and indicators for hydrogen are essential in safely managing hydrogen by applying sensing agents to make hydrogen visible. This research introduces sensors with the capability to enable bare-eye detection of hydrogen leaks and can be applied as powders, inks, paints, or coatings. The research concluded the ability to synthesize and investigate a particulate additive for real-time monitoring and the presence of hydrogen gas, detectable by the bare eye for a wide variety of applications during hydrogen production, transport, and storage.

As summarized in this study, there are known leak detection options and equipment for hydrogen pipelines. Multiple vendors have been identified that can provide leak detection equipment specifications for hydrogen detection for permanently mounted, mobile detection equipment, fiber optics, and options for aerial leak detection. Information regarding other hydrogen detection equipment based on literature review is provided in the parallel "Leakage Report."

Leak Mitigation and Repair

Field workforce responsible for operating and maintaining Angeles Link must be trained appropriately to enable rapid leak response. The following actions may be required in response to an identified leak depending on the specific circumstances:

- Steps and measures to protect public and operator personnel per 49 CFR §192.711 – Requirements and techniques for temporary and permanent repairs on a hydrogen pipeline may differ from natural gas pipelines and would require operator qualifications specific to those tasks.
- Report the safety-related pipeline condition per 49 CFR §191.23 and SoCalGas procedures – These requirements and procedures would likely not require changes to operator's skill or tasks related to Angeles Link.
- Communicate emergency incidents per 49 CFR §192.615 and SoCalGas procedures.
- Pipeline section isolation – The Angeles Link pipeline infrastructure would be required to follow the PHMSA Valve Installation and Minimum Rupture Detection Standards, rupture mitigation valves and isolation criteria, which would align with SoCalGas's natural gas system requirements for new construction and certain replacement projects.
- Traffic diversion at road crossings.
- Compressor station sites placed in Fail-Safe Mode.

49 CFR §§ 191.15 and 191.17 contain the requirements for incident reporting and annual reports. 49 CFR §§ 191.23 and 191.25 contain the requirements for safety-related condition reporting. For repairing leaks, PHMSA has proposed a new addition to the 49 CFR Part 192 code to establish minimum criteria for leak grades and associated repair schedules to be prioritized by safety and environmental hazard (Pipeline and Hazardous Materials Safety Administration, 2023). This proposed rule aims to define the criteria and repair schedules to prioritize environmental risks along with the risks to persons and property.

Integrity Management

Transmission integrity management is governed by 49 CFR Part 192 Subpart O, which prescribes the requirements for an Integrity Management Program for covered segments along a gas transmission pipeline. This regulation requires pipeline operators to assess, identify, and address the safety of assets that are located in HCAs. The future framework for an integrity management program could likely continue to follow current requirements specified in 49 CFR Part 192 Subpart O. Certain processes/calculations and assessment technologies and/or intervals may change as outlined in the following integrity management activities. Damage prevention, Public Awareness Plans, and coordination with local responders increase the effectiveness of educating landowners and the general public about the presence of a new hydrogen pipeline, decreasing the likelihood of damage that can significantly impact the integrity of the pipeline infrastructure.

Class Location - The process for determining class location along a pipeline is to utilize a buffer of 660 feet on either side of the pipeline centerline and identify structures or well-defined outside areas along the pipeline that fall within a one-mile sliding segment (see 49 CFR § 192.5, Class locations).

The gas factor for hydrogen in the equation for calculating the potential impact radius (PIR), utilized for determining HCAs and moderate consequence areas (MCAs) along a pipeline route differs from the factor for natural gas. Per the final report issued by Michael Baker Jr., Inc., June 2005, "TTO Number 13, Potential Impact Radius Formulae for Flammable Gases Other Than Natural Gas Subject to 49 CFR 192", which can be found on PHMSA's website (PHMSA, n.d.), the factor for hydrogen is 0.47, which leads to the following formula for calculating the PIR:

$$r=0.47\sqrt{p \cdot d^2}$$

where:

r = the PIR in feet,

p = the pipeline maximum operating pressure in pounds per square inch, and

d = the nominal pipeline diameter in inches.

Once the PIR is calculated, the HCAs and MCAs can be determined for the hydrogen pipeline using the same methodology as for a natural gas pipeline.

To note, the factor for hydrogen (0.47) is lower than the factor for natural gas (0.69), which results in lower PIR than a similar pipeline carrying natural gas. This could result in fewer HCAs and MCAs identified for a hydrogen pipeline versus a natural gas pipeline, and potentially differing class locations along the pipeline route.

The process for determining class location, HCAs, and MCAs utilizes public data to evaluate structure counts and identified sites via class studies and/or field verification. A pipeline system can be modeled in a Geographic Information System (GIS) which allows for electronic data integration. Operations, integrity management, and technical services teams continually review and update (where needed) this information. Future Angeles Link infrastructure could be comprehensively evaluated using similar methods and processes in order to comprehensively determine the class location along the pipeline.

Threat Identification/Evaluation - Threats to a hydrogen pipeline are similar to threats for a natural gas pipeline while the degree of risk may vary. Data gathering and integration would likely be substantially similar as data sources and methodology would remain the same.

Risk Assessment - The risk algorithm should be adjusted to account for differences in the physical and chemical properties of hydrogen versus natural gas. Risk assessment is an annual process that is completed to support assessment types and scheduling, along with identifying appropriate preventive and mitigative measures.

Pigging – In-line inspection (ILI) of pipelines, such as through the use of smart pigs, may help to identify pipeline integrity issues that could result in pipeline failures. ILI of hydrogen pipelines is possible and can be utilized as one of the assessment methods identified by 49 CFR Part 192 Subpart O, *Gas Transmission Pipeline Integrity Management*, which requires regular assessment of pipeline segments that could affect a high consequence area. One such vendor, TD Williamson (TDW), has successfully inspected hydrogen pipelines via ILI using modifications to their existing tools. They concluded, "In terms of general pigging of new, converting, and operational pipelines carrying pure or blended hydrogen, existing tools can be modified or implemented with minimal engineering or cost. For ILI, combination tools and multiple mission runs can be used to establish needs to be addressed before hydrogen service with no changes required. When hydrogen pipelines are in service, especially those transporting highly pure hydrogen, a significant redesign of the ILI tools is required. However, it has been proven that successful inspection can be achieved under operational conditions." (Romney, Barker, Geren, & Kirkwood, 2021).

Rosen Group (Rosen) has also been researching and developing solutions for assessing hydrogen pipelines via ILI. (ROSEN Group, n.d.)

Pipeline operators also have an option of "batching" ILI tools, meaning the tool is loaded into the middle of two isolation pigs (one in front of the ILI tool and one behind) and the ILI tool is in a compatible pressurized gas, such as nitrogen (or a slug of diesel if the tool requires a liquid coupling). ILI inspections are one potential component of the overall Integrity Management Program governed by Subpart O of 49 CFR Part 192. Overall, the hydrogen industry is actively pursuing enhancing pigging solutions to proactively design, construct, or retrofit pipelines to incorporate the appropriate ILI tools to identify hydrogen pipeline integrity concerns. ILI vendors are currently developing and modifying ILI tools to perform assessments in pure hydrogen service.

Hydrostatic Testing – Hydrostatic testing (hydrotesting) of transmission pipelines is governed by 49 CFR Part 192 Subpart J, *Test Requirements*, which generally requires hydrotesting of new gas pipelines prior to placing into service. Testing will be dependent on pipe grade, pipe diameter, wall thickness, planned Maximum Allowable Operating Pressure (MAOP), hoop stress as a function of Specified Minimum Yield Strength

(SMYS), and Class Location. The testing requirements remain applicable to hydrogen pipelines.

Cathodic Protection – Cathodic Protection is governed by 49 CFR Part 192 Subpart I, *Requirements for Corrosion Control*. This subpart contains all the requirements for cathodic protection and other external and internal corrosion control. Requirements for external corrosion control are expected to be the same between natural gas and hydrogen pipelines as they will be exposed to the same environments regardless of commodity transported; external coatings and other external protection mechanisms are effective for both pipeline systems. Internal corrosion control, such as internal tank coatings, will be specifically based on the physical and chemical properties of hydrogen.

Emergency Shutdowns

Emergency shutdown systems are a collection of devices that are primarily located at compressor stations and may also be located at other facilities. They are governed by 49 CFR §192.167, *Compressor Stations: Emergency Shutdown*, which contains all the requirements for emergency shutdown devices (ESD). ESD Systems must meet the following requirements listed in 49 CFR §192.167(a):

- ESD Systems must be able to block gas out of the compressor station and blow down the station piping.
- ESD Systems must discharge gas from the blowdown piping at a location where the gas will not create a hazard.
- ESD Systems must provide means for the shutdown of gas compressing equipment, gas fires, and electrical facilities in the vicinity of gas headers and in the compressor building, except that:
    - Electrical circuits that supply emergency lighting required to assist Station Personnel in evacuating the compressor building and the area in the vicinity of the gas headers must remain energized; and
    - Electrical circuits needed to protect equipment from damage may remain energized.
- ESD Systems must be operable from at least two locations, each of which is:
    - Outside the gas area of the compressor station;
    - Near the exit gates if the compressor station is fenced or near emergency exits if not fenced; and
    - Not more than 500 feet (153 meters) from the limits of the compressor station.

An ESD system is ultimately an engineered assembly of control devices. When activated during an emergency they will stop equipment that is part of a specific operating system, close certain valves to isolate that system, and may open other valves to cause the system to depressurize to atmosphere. The objective of an ESD is to get the system to a safe condition.

Other Safety Factors

Hydrogen PPE

Wearing PPE is a common practice in the pipeline industry to increase the personal safety of personnel in the work environment. By providing proper PPE to SoCalGas personnel, SoCalGas provides protective equipment in case an unanticipated event occurs during the performance of work on pipeline infrastructure or while responding to abnormal operating conditions or emergencies. SoCalGas will advise contractor personnel of the minimum PPE requirements. Contractors should be informed of the need to provide PPE to contractor personnel and the minimum standards for hydrogen PPE. Testing and performance of PPE should also account for any applicable changes in specifications for use for hydrogen systems. PPE may be grouped into the following two categories:

- PPE for routine O&M
- PPE worn for emergency events

Mobile leak detectors like those worn by operating personnel are also a form of PPE; there are available options for hydrogen detection, which are covered in the *Workforce Planning & Training Evaluation* study, under the *Leak Survey, Detection, Mitigation, and Repair* section. Research from Bulwark Protection, a leading industry PPE and flame-resistant clothing expert and supplier, is summarized in this section to present data on fire and heat rating capabilities of PPE clothing and gear in the event of a hydrogen fire.

The flame resistance of the PPE was reviewed, which is the property of a material/clothing whereby combustion is prevented, terminated, or inhibited following the application of a flaming or non-flaming source of ignition (i.e., a flame or electric arc), with or without subsequent removal of the ignition source.

Standards reviewed include NFPA 2112, NFPA 2113, and ASTM 1930 (Manikin Test). Table 7, *PPE Standards and Uses*, summarizes the standards related to PPE and how they are utilized.

Table 7 – PPE Standards and Uses

Standard	Description	Use

NFPA 2112, Standard on Flame-Resistant Clothing for Protection of Industrial Personnel Against Short-Duration Thermal Exposures from Fire	Specifies performance requirements and test methods for flame-resistant fabric and garments. (National Fire Protection Association, 2023)	Protects workers from flash fire exposure and injury through the specified requirements and test methods for constructing flame-resistant garments.
		
		Per Bulwark Protection;
		
		• Materials should be tested for a Heat Transfer Performance (HTP) of at least:
		  - Spaced (layered) 6 cal/cm²
		  - Base layer “skin contact” 3 cal/cm²
		• Test for thermal shrinkage
		• Emblems are placed on the exterior of the garment.
		  - Standard for all flame-resistant garments.
		• Standard against flammable dust, gas, and liquids.
		• Utilizes the Manikin test (ASTM F1930) for material testing.
		• Utilizes standard propane as the source gas for the flame test.
		• Exposure for 3 seconds to flame. (3 seconds is defined as the upper limit of flash fire).
		• Must have >50% 2nd and 3rd degree body burn combination to pass.

Standard	Description	Use
NFPA 2113, Standard on Selection, Care, Use, and Maintenance of Flame-Resistant Garments for Protection of Industrial Personnel Against Short-Duration Thermal Exposures from Fire	Specifies selection, care, use, and maintenance requirements for garments compliant with NFPA 2112. (National Fire Protection Association, 2020)	Reduce health and safety risks associated with incorrect selection, use, and maintenance, and contamination and damage of flame-resistant garments.
ASTM 1930, Standard Test Method for Evaluation of Flame-Resistant Clothing for Protection Against Fire Simulations Using an Instrumented Manikin	This test method predicts human skin burn injury for single-layer garments or protective clothing ensembles mounted on a stationary upright instrumented manikin, which is then exposed in a laboratory to a simulated fire environment with controlled heat flux, flame distribution, and duration. The average exposure heat flux is 84 kW/m2 (2 cal/s·cm^2), with durations up to 20 s. (American Society for Testing and Materials, 2023)	Measures the thermal protection provided by different materials, garments, clothing ensembles, and systems when exposed to a specified fire. Provides predicted skin burn injury for a specific garment or protective clothing ensemble when exposed to a laboratory simulation of a fire.

In summary, NFPA 2112, combined with ASTM F1930, is the material standard that dictates how materials should be tested and how results are accepted/recorded. NFPA 2112 is currently the only industry standard covering various fuels and is widely accepted by the oil & gas industry. Continued dialogue with PPE vendors is recommended to address anti-static issues and other specific concerns with materials used in coveralls, earmuffs, and other items.

Security (Physical and Cyber Security Procedures)

The TSA/Homeland Security define Critical Infrastructure in the Energy Sector to include assets, systems, or networks both physical and virtual, that are considered so vital to the United States that their incapacitation or destruction would have a debilitating effect on security, national economic security, national public health or safety, or any combination thereof.[20] This definition includes natural gas pipeline infrastructure currently owned and operated by SoCalGas. As such, existing SoCalGas security policies regarding both physical and cyber security should be reviewed and updated accordingly to include references to hydrogen infrastructure, as appropriate. SoCalGas may also consider a review with third-party owners/operators of hydrogen production sites and hydrogen storage that Angeles Link interfaces with to evaluate the compatibility of their physical and cybersecurity plans with that of SoCalGas. For example, hydrogen production sites may be considered Critical Infrastructure if the loss of production negatively impacts downstream users as defined by TSA/Homeland Security Guidelines.

Physical Security

Physical security at Critical Infrastructure sites is a requirement of and is subject to audit by TSA/Homeland Security. These requirements include access controls such as: perimeter security fences, locked gates, and site security cameras for these sites. Site specific security measures are also required for facilities including valve sites, receipt meter stations, delivery meter stations, and compressor/regulator stations. Other physical concerns may be facility related such as gates, fence height, razor wire, electronic access to sites, door alarms, security cameras, and other physical access concerns.

SoCalGas's physical requirements for perimeter security at compressor stations, block valve sites, and meter/regulator stations are based on the TSA/Homeland Security Guidelines to prevent intrusion by non-SoCalGas personnel. SoCalGas should consider the same physical security procedures for all Angeles Link sites as specified by TSA/Homeland Security Guidelines for Critical Infrastructure. SoCalGas may also consider a review with third-party owners/operators of hydrogen production sites and hydrogen storage for their physical and cybersecurity plans and compatibility with SoCalGas's physical and cybersecurity plans.

Cyber Security

The threat environment in the cyber security realm is continuously changing, so security practices must also advance. The TSA/Homeland Security provides guidelines for security measures to protect Critical Infrastructure for natural gas and hazardous liquid transmission pipeline systems, natural gas distribution pipeline systems, and liquified natural gas facility operators within the TSA "Pipeline Security Guidelines" document.[21]

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[20] Critical Infrastructure Sectors: CISA. Cybersecurity and Infrastructure Security Agency CISA. (n.d.). https://www.cisa.gov/topics/critical-infrastructure-security-and-resilience/critical-infrastructure-sectors.

[21] Pipeline security guidelines. (n.d.-c). https://www.tsa.gov/sites/default/files/pipeline_security_guidelines.pdf.

The Cybersecurity and Infrastructure Security Agency (CISA) conducts specialized security and resilience assessments on the nation's critical infrastructure.[22] Applicability of CISA's assessment requirements for Angeles Link has yet to be determined as it will depend on the completion of the final route selection and design of the pipeline system. If an assessment is required, the pipeline's SCADA system would be evaluated for compliance with TSA/Homeland Security Guidelines and may be based on the same activity for the natural gas system. Critical Infrastructure and the necessary Physical Security requirements are based on the location of pipeline assets; therefore, an assessment must be conducted on the hydrogen system once the detailed design is developed.

SoCalGas has hardened security measures implemented for its critical gas facilities and the alarm response protocols that have been established will support a Critical Infrastructure analysis. After the Critical Infrastructure analysis is completed and submitted to the TSA, SoCalGas's next steps would be to perform a security vulnerability assessment and inventory for cyber-sensitive assets, including SCADA system and control center/backup centers. After completing these steps, SoCalGas would determine the need to install cybersecurity protection systems.

Other DOT Requirements (Drug & Alcohol Testing)

DOT drug and alcohol testing requirements are specified by 49 CFR Part 199. Part 199 applies to the transportation of natural gas, hydrogen, LNG, and liquids pipelines rather than a specific fuel. Therefore, drug and alcohol testing pursuant to 49 CFR Part 199 is not dependent on the fuel being transported and would apply to the potential workforce personnel for the proposed Angeles Link as defined in the SoCalGas Drug & Alcohol Plan. The Drug & Alcohol Plans specifies testing pools and the number of drug/alcohol tests required yearly. In addition, all new employees joining SoCalGas for the hydrogen system that are in positions subject to drug and alcohol testing would require pre-employment drug/alcohol testing. SoCalGas's construction contractors would need to provide verification that construction personnel have followed testing procedures stated in the construction contractor's Drug & Alcohol Plan.

9.0 CONTROL ROOM AND EMERGENCY RESPONSE

SoCalGas operations are driven by safety and, accordingly, SoCalGas has an Emergency Management Preparedness and Response Policy, which illustrates SoCalGas's commitment to safety and strategies for preparedness. SoCalGas's preliminary evaluation of Specifications, Standards, and Procedures (SSPs) conducted in the Safety Study was an initial step to be continued in subsequent phases to determine if Angeles Link operational tasks will be similar to existing natural gas procedures or unique

[22] Critical infrastructure assessments: CISA. Cybersecurity and Infrastructure Security Agency CISA. (n.d.-a). https://www.cisa.gov/critical-infrastructure-assessments.

to conform to hydrogen properties. As SoCalGas's procedures and policies concerning hydrogen mature, certain aspects of the emergency response procedures may require modification and updates to apply more specifically to hydrogen assets.

Gas Control & Control Room Management

SoCalGas is an existing pipeline operator and, as such, has Control Rooms where Gas Control operations personnel monitor and/or control pipeline facilities in real-time, 24 hours a day, seven days a week. This monitoring covers both SoCalGas and San Diego Gas & Electric's combined gas-transmission systems, including associated pipelines, line compressor stations, and underground storage facilities. Therefore, SoCalGas has a comprehensive Control Room Management Plan which can be leveraged and subsequently tailored specifically to hydrogen operations.

Supervisory Control and Data Acquisition System

SCADA systems consist of both software and hardware components and enable remote and on-site monitoring of data gathered from various equipment and systems at different geographical locations. Pieces of data are continuously collected in real-time from multiple sources along the pipeline and at other related appurtenances or facilities and then displayed in the Control Room through a Human Machine Interface (HMI). Attributes can be assigned within the electronic system to automatically trigger alarms or notifications if conditions deviate from preassigned thresholds or parameters. These SCADA systems allow for the integration of a variety of different technologies in the field with an electronic management information system.

The hydrogen pipeline system is anticipated to require a SCADA system to allow for remote monitoring and operation of the pipeline and compressor station components. SoCalGas may elect to integrate this system as appropriate to their existing SCADA operations and/or train existing System Operators.

Control Center Modernization (CCM)

Independent of Angeles Link, SoCalGas is in the process of implementing the CCM project, which will further digitalize the existing natural gas transmission and distribution pipeline system with new field assets such as OPM stations and HCA methane sensors. The CCM project will drive the change or creation of new and existing business processes that will enhance the following:

- OPM stations and HCA methane sensors on the transmission system;
- Alarm response, planned/unplanned incidents, and maintenance activities related to the newly deployed distribution and transmission field assets;
- Coordination with Distribution Field Operations, Dispatch, Transmission, and Emergency Management and Preparedness organizations; and
- Data analysis through new situational awareness platforms being introduced via CCM technologies.

The system design, and new and enhanced processes developed for the CCM project may be beneficial and potentially leveraged in the planning and implementation of Angeles Link.

Emergency Response Procedures

The Emergency Management Preparedness and Response Policy documents how SoCalGas prepares and responds to emergencies by using the Plan-Do-Check-Act (PDCA) cycle for continuous improvement of its processes. This document provides an overall guide to SoCalGas's employees and contractors when responding to health and safety related incidents to protect employees, contractors, customers, the public, and property. SoCalGas Emergency Management Department is staffed with a Watch Office that provides 24/7 monitoring of its service territory and oversees an Emergency Operations Center (EOC) which may be activated when there are large impacts or a natural disaster event that may require coordination and communication with multiple internal and/or external organizations. The Watch Office provides real-time data monitoring, using tools such as Data Capable, to increase situational awareness and identify potential hazards, create executive notifications, convene situational awareness meetings, and timely regulatory reporting to external agencies. Based on the evaluation of the incident, the Watch Office will then recommend if an EOC activation is required. Once activated, one of the objectives of the EOC is to offer timely, accurate information to government officials, regulatory authorities, employees, customers, the public, and the media. Furthermore, SoCalGas Regional Public Affairs department provides courtesy notifications to local public officials when there is a leak on a transmission line or a reportable incident. Existing SoCalGas emergency response procedures, programs, technology, reporting, and safety plans should be updated for applicability to hydrogen pipeline and facilities. The existing emergency response procedures focus on the SoCalGas natural gas system, comprising transmission pipelines, storage fields, compressor stations, and extensive distribution systems – including residential, commercial, and industrial meters. Emergency Response personnel, including Control Room personnel and field personnel responding to indications of leaks or rupture incidents, require detailed training on hydrogen's physical and chemical properties.

Emergency response requirements are specified in 49 CFR § 192.615 and, in compliance with these requirements, SoCalGas has established written procedures to minimize hazards that result from a gas pipeline emergency. SoCalGas's existing emergency response procedures for the natural gas system provide a foundation and framework for emergency plans that are specific to hydrogen.

Notification of Leaks

SoCalGas receives notifications of potential leaks for its existing infrastructure through a variety of ways such as monitoring systems, leak surveys and patrols, as well as customer calls. Depending on odorization or equipment selections, leak notification procedures may need updates to address a 100% hydrogen system. The process by which leak notifications are received, and personnel are dispatched may need modification, and personnel receiving the notifications may need specific language to communicate to the person(s) making the notification and to first responders at the location of the reported leak.

Leak notifications may be received from compressor station sites and valves, meter, and regulator sites along the pipeline routes, as well as the third-party hydrogen production sites and third-party hydrogen storage sites. They can be received in several ways, including notifications from SoCalGas employees through regular monitoring, public notifications, gas-detecting equipment and instrumentation, and emergency response (fire, police, and other law enforcement). Leak notifications should be corroborated with leak detection equipment located at each site, with SoCalGas operations personnel dispatched for emergency response to confirm and mitigate leaks immediately.

Liaison with Local Emergency Response

Coordination with local emergency responders may include hydrogen-specific information and training, including proper equipment and awareness of the differences between hydrogen and natural gas. As hydrogen's physical and chemical properties differ from those of natural gas (refer to Section 5: *Physical and Chemical Properties of Hydrogen*, of this study), emergency response personnel should be trained to handle mitigating and preventing situations involving hydrogen. This may include hydrogen-specific training and changes to equipment utilized for emergencies.

To be prepared in the event of an emergency, it is important to liaise with the local emergency responders and appropriately communicate potential differences in their response, equipment, and resources for incidents involving hydrogen, as opposed to natural gas. SoCalGas's existing Emergency Management Preparedness and Response Policy has a robust external stakeholder engagement outreach program that can be leveraged for Angeles Link. The outreach program includes a First Responder Program developed to educate first responders (fire and police) on safely working with SoCalGas personnel when responding to natural gas-related incidents. The program also establishes local contact between SoCalGas field operations and first responders and provides information about SoCalGas's response capabilities and the level of participation during a unified command.

Damage Prevention

A damage prevention program to prevent damage to a pipeline from excavation activities is required pursuant to 49 CFR § 192.614. The One Call system, also known as 811,[23] is a critical tool for preventing accidental damage to underground utility assets during construction or excavation. Contractors and excavators use this system before digging to identify the location of utility assets such as natural gas, water, electricity, and telecommunications. Contractors or anyone digging can call the toll-free 811 number or submit an online request, providing details about the proposed excavation location. The One Call system then notifies all relevant utility owners in the vicinity. Utility personnel mark the exact location of their facilities on the ground, enabling safe excavation practices. While the system primarily covers existing utility assets, it is essential to include emerging hydrogen infrastructure. Overall, the One Call system enhances safety, protects critical infrastructure, and promotes responsible construction practices while mitigating damages before they occur.

10.0 AWARENESS, EDUCATION, AND TRAINING

Hydrogen has been used in various forms for decades across a variety of industries, but it is acknowledged that public awareness of the transmission and distribution of pure hydrogen as part of an energy utility delivery system is relatively new. SoCalGas employees and contractors will require appropriate documented and accredited training to construct, operate, and safely maintain hydrogen transmission and distribution systems. Furthermore, the public should be provided access to educational materials on hydrogen safety. Given the global interest in the implementation of hydrogen as a clean energy source, there are several organizations currently providing training to owners, operators, contractors, and other interested parties. As the adoption of hydrogen continues to accelerate, additional resources and new accreditations and certifications may become available and must be evaluated.

Public Awareness Plans

PHMSA requires pipeline operators to develop and implement public awareness plans and damage prevention programs (see 49 CFR § 192.616 and § 192.614). Public awareness plans must comply with the requirements of API RP 1162, first edition. API RP 1162 includes guidance for pipeline operators to develop and implement Public Awareness Programs to communicate safety and other relevant information to all stakeholders, emergency response agencies, and local government officials, and excavators. The existing SoCalGas Public Awareness Plan for natural gas infrastructure can serve as a template. SoCalGas's damage prevention program contains additional

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[23] Pipeline Safety Stakeholder Communications. PHMSA. (n.d.). https://primis.phmsa.dot.gov/comm/cbyd.htm.

requirements that can also be incorporated and can follow closely with SoCalGas natural gas infrastructure language.

In addition to PHMSA's requirements, SoCalGas must comply with California Public Utilities Code Section 956.5, which requires that at least once per calendar year, owners and operators of intrastate transmission and distribution lines shall meet with each local fire department having fire suppression responsibilities in the area where those lines are located to discuss and review contingency plans for emergencies involving the intrastate transmission and distribution lines within the jurisdiction of the local fire department.

In compliance with 49 CFR § 192.616, SoCalGas implements an existing Public Awareness Program for its natural gas system, which includes the following:

- Enhance safety through increased public awareness and knowledge;
- Reduce third party damage to pipeline facilities; and
- Provide better understanding of pipeline emergency response.

These objectives are achieved by educating the public on:

- The existence and purpose of pipelines;
- Use of a one-call notification system prior to excavation and other damage prevention activities;
- Possible hazards associated with unintended releases from a pipeline facility;
- Physical indications that such a release may have occurred; and
- Steps that should be taken for safety in the event of a pipeline release and procedures to report such an event.

The current SoCalGas Public Awareness Plan follows the guidance provided in API RP 1162, *Public Awareness Programs for Pipeline Operators*. Specifically, the plan identifies the audiences to be considered for targeted communications, the frequency of messages, the messages to be delivered to each audience, and the methods and vehicles for delivering the messages. Furthermore, SoCalGas has specific measures to evaluate the effectiveness of its public awareness program and materials. The public awareness plan identifies communications for sharing pipeline safety risk information with those residing near the pipelines and defines a mechanism whereby the public can report safety risk issues to SoCalGas.

SoCalGas's public awareness program implements the public awareness plan to inform and educate customers, affected public, pertinent public officials and municipal staff, first responders/emergency officials, and persons engaged in excavation-related activities about the prevention and recognition of gas pipeline emergencies. This program also includes the process for reporting an incident to SoCalGas and the appropriate public officials including first responders. SoCalGas's First Responder Outreach program networks with over 200 agencies to acquaint first responders with gas pipeline emergencies response, types of gas pipeline emergencies and to engage in mutual assistance to minimize hazards to life or property. Accordingly, the specific details on what information is conveyed and the product descriptions will differ depending on the type of gas being transported. An example of a key difference is the use of pipeline markers/signage along a pipeline route. API RP 1162 has prescriptive language for the size, lettering, and marker information. The existing SoCalGas line markers indicate natural gas is being transported through the pipeline; therefore, for a dedicated clean renewable hydrogen pipeline, SoCalGas will need to create line markers to indicate hydrogen gas is being transported through the pipeline. Leveraging the SoCalGas existing public awareness program will lay the groundwork to make the necessary adjustments required to reflect the operations of a dedicated clean renewable hydrogen pipeline.

Education and Safety Training

SoCalGas is continually increasing its knowledge, education, and understanding of hydrogen through training materials and courses offered by outside accredited organizations. As SoCalGas's knowledge base and expertise continue to grow, and hydrogen-specific codes and regulations take shape, safety training requirements will be developed for inclusion into the Angeles Link O&M manual and OQ training program. Skillsets related specifically to hydrogen pipeline systems will be evaluated and operating and maintenance procedures will be identified to meet the requirements of 49 CFR Part 192 Subpart N, *Qualification of Pipeline Personnel*. Pipeline personnel will be trained, tested, and evaluated according to a written qualification program. Furthermore, as preliminarily identified in Appendix A, *SoCalGas Standards Review Summary*, the training associated with the standards and procedures potentially applicable to Angeles Link should be updated or created for the applicable job classifications. Training conducted prior to completion of the O&M plan and OQ training program could incorporate the physical and chemical properties of hydrogen, PPE, and leak detection, providing a basis for hydrogen safety training. Additional considerations for hydrogen education and training for the workforce for Angeles Link are included in the *Workforce Planning & Training Evaluation* study.

SoCalGas's [H2] Innovation Experience[24] is a fully integrated demonstration project that shows how renewable hydrogen could be used to safely transition to clean and resilient energy systems of the future. Providing public awareness and visibility into these advancements, along with collaboration with industry experts to help prepare additional

[24] [H2] innovation experience: SoCalGas, A Sempra Energy utility. (n.d.-b). https://www.socalgas.com/sustainability/h2home.

standards for dedicated pipelines for hydrogen transport, support the development of transmission pipeline procedures inclusive of safety requirements.

Accredited Organizations

Several organizations are accredited to provide hydrogen safety training and operator training. The following organizations are summarized below for SoCalGas to consider for further information and potential outreach:

AIChE – Center for Hydrogen Safety[25]

The American Institute of Chemical Engineers' (AIChE's) Center for Hydrogen Safety (CHS) is a global non-profit organization promoting hydrogen safety and best practices worldwide. The CHS provides education and resources for several aspects of hydrogen, including publications, conference information and proceedings, first responder training, safety training, webinars, and other general information.

AIChE is a member society of the Accreditation Board for Engineering and Technology (ABET). It plays a role in the accreditation process for chemical engineering programs to verify specific quality standards are met.

Baker Engineering and Risk Consultants, Inc. (BakerRisk)[26]

BakerRisk is an international consulting firm with over 175 qualified/certified scientists and engineers in the U.S., Canada, and the U.K. offices. Through specialized testing services and research and development (R&D) for studying various hazards, BakerRisk aims to support its clients in preventing, quantifying, and mitigating accidents. BakerRisk provides training on hydrogen safety and offers in-person and virtual training options.

Canadian Standards Association (CSA Group)

The CSA Group, accredited by the Standards Council of Canada (SCC), is internationally recognized, and its standards and certifications are often accepted and adopted globally. The CSA Group collaborates with regulatory authorities and government agencies to align the developed standards and certification programs with regulatory requirements.

As part of the growing interest in hydrogen as a fuel source, the CSA Group established the CSA Hydrogen Advisory Group (H2AG), which includes participants from various representative categories across the hydrogen ecosystem, to actively monitor hydrogen activities and engage with stakeholders to evaluate and address potential standardization needs. Participants in the H2AG represent various categories from production to end use

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[25] CHS: Center for Hydrogen Safety. AIChE. (2024, May 1). https://www.aiche.org/chs.

[26] Risk management, training, engineering services. BakerRisk. (2024, January 25). https://www.bakerrisk.com/.

in industries like transportation, fuel and appliances, petroleum and natural gas, and natural resources.

Dräger[27]

Dräger is an international company with a presence in over 190 countries. Dräger manufactures medical and safety technology products in hospitals, fire departments, emergency services, authorities, and mining industries. Dräger offers several types of safety solutions/technologies for detection and PPE, also including providing guidance on planning, installing, and maintaining safety and gas detection systems.

Gas Technology Institute (GTI)[28]

GTI Energy is a research and training organization aiming to advance economy-wide decarbonization of energy systems. For the past 80 years, GTI Energy has been mainly focused on natural gas and energy training, but also conducts workshops and hosts conferences.

GTI Energy also collaborates with industry experts to conduct research, product development, and demonstration projects focused on clean hydrogen production, storage, delivery, and use through its GTI Energy's Hydrogen Technology Center.

International Association for Hydrogen Safety (HySafe)[29]

HySafe is an international association that focuses on hydrogen safety through collaboration, research, and the exchange of information among professionals and organizations. The association contributes to developing guidelines and publications addressing various aspects of hydrogen safety, including production, storage, transportation, and utilization. HySafe also organizes conferences, workshops, and events to provide a forum for presenting research findings and discussions and disseminating information related to hydrogen safety.

U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE)[30]

The EERE accelerates development and facilitates the deployment of energy efficiency, renewable energy technologies and market-based solutions that strengthen U.S. energy

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[27] Welcome to dräger us. Leading Medical & Safety Technology. (n.d.). https://www.draeger.com/en-us_us/Home.

[28] Home. GTI Energy. (2024, May 14). https://www.gti.energy/.

[29] Safety, I. A. for H. (n.d.). HySafe. https://hysafe.info/.

[30] Office of Energy Efficiency & Renewable Energy | Department of Energy. (n.d.-c). https://www.energy.gov/eere/office-energy-efficiency-renewable-energy.

security, environmental quality, and economic vitality. The Hydrogen Safety Panel (HSP) and the Hydrogen Tools Portal (H2Tools) are two initiatives of the EERE.

The HSP was established in 2003 and consists of members assembled to provide guidance and expertise on hydrogen safety, including considerations for hydrogen technologies, safety engineering, and related fields. The HSP offers recommendations, best practices, collaboration, and insights to support the safe handling, transportation, storage, and use of hydrogen.

H2Tools was developed by the Pacific Northwest National Laboratory through support from EERE, whose goal is to support the implementation of the practices and procedures that will support safety in the handling and use of hydrogen in various fuel cell applications. The portal combines and enhances the utility of various tools and web-based content on the safety aspects of hydrogen and fuel cell technologies to help inform those tasked with designing, approving, or using systems and facilities and those responding to incidents.

11.0 LESSONS LEARNED

API RP 1173 Pipeline Safety Management Systems emphasizes learning from internal and external events to enhance pipeline safety operations. As suggested by the Hydrogen Safety Panel and other stakeholders, SoCalGas has expanded the discussion in this study to explain how lessons learned are captured and addressed under SoCalGas's systems and protocols. One of the ways that SoCalGas incorporates lessons learned into its process is the Event Learning Process (ELP). The Event Learning & Continuous Improvement (EL&CI) department works with SoCalGas Subject Matter Experts (SMEs) and external SMEs to proactively assess company policies and processes, identify areas for improvement and prioritize enhancements to prevent similar incidents. The ELP provides guidance for performing and determining the root cause analysis for events that may have enterprise-wide impacts on the safety of employees, public, the environment, or the integrity or reliability of the natural gas pipeline system. The ELP is designed to identify enterprise-wide and/or systematic enhancements as the result of an incident or similar trends of reoccurrences and will be applied to evaluate the safety system, policy and/or process root cause(s) from many incidents by conducting the following:

1. Establish procedures for analyzing the root cause of an incident.

2. Determine the cause(s) that led to the conditions that allowed the event to occur including the need to enhance existing operational policies or procedures.

3. Identify corrective actions that would minimize the possibility of a reoccurrence.

4. The event learning process finding (causes, contributing factors, recommendations to prevent recurrence) and lessons learned are communicated with appropriate personnel and stakeholders.

SoCalGas routinely analyzes National Transportation Safety Board's (NTSB) reports to identify corrective actions or enhancements that could lead to enterprise-wide process improvements. Other resources include The Hydrogen Safety Panel, which collected incidents involving various hydrogen infrastructure and documented them in the March 2020 "Hydrogen Incident Examples" (Pacific Northwest National Laboratory, 2020).[31] While these incidents do not involve SoCalGas, the lessons learned from these incidents are valuable for SoCalGas's continued hydrogen safety planning and are compiled in the H2Tools.org Lessons Learned database.[32] SoCalGas summarized the failure process of several incidents and focused on the root cause analysis. SoCalGas acknowledges that there are injuries/deaths associated with these incidents, however, the intent of this section is to focus on the design/safety root cause of each incident and the lessons learned. A sample of the incidents identified and the lessons learned, which involve pressure relief devices, hydrogen cylinders, small diameter piping, fueling stations and compression equipment, are summarized in Table 8 below, *Hydrogen Safety Lessons Learned*, with specific emphasis on the facts and lessons relevant to a hydrogen pipeline system.

Table 8 - Hydrogen Safety Lessons Learned

Incident Category	**Description/Root Cause**	**Lessons Learned**
Pressure Relief Device Incidents	- On January 15, 2002, an uncontrolled hydrogen release occurred due to the rupture of a hydrogen storage tube's burst disc. This disc failed due to being overloaded by mechanical stresses developed as water expanded and formed ice while in direct contact with the burst disc. The degraded condition of the vent cap (defective	- Eliminate burst discs from hydrogen storage assembly. Redesign venting system for the pressure relief valves to prevent or inhibit moisture build up and allow moisture drainage. - Contract documents for the hydrogen and nitrogen supplies will stipulate that suppliers of potentially hazardous equipment will provide plant management

[31] Hydrogen incident examples. (n.d.-b). https://h2tools.org/sites/default/files/Hydrogen_Incident_Examples.pdf.

[32] Lessons learned | hydrogen tools. (n.d.-d). https://h2tools.org/lessons?search_api_fulltext=.

Incident Category	Description/Root Cause	Lessons Learned
	equipment) enabled water to access the burst disc. - On Jan 8, 2007, an explosion occurred during a delivery of compressed hydrogen gas at a coal-fired power plant. Evidence pointed to the premature failure of a pressure relief device rupture disk, which had been repaired by the vendor six months before the explosion.	with written documentation describing the supplier's preventive maintenance program. - Verify that all pressure relief devices contain fuse-backed adapters. - Explore eliminating rupture disk pressure relief devices and substituting spring-style relief valves. - Confirm that temporary offices/facilities are not co-located with hazardous chemical storage sites. - Job Hazard Analysis (JHA) to be done on unloading hydrogen - A competent plant employee must be present during all hydrogen unloading activities.
Hydrogen Cylinder Incidents – Hydrogen Gas Regulator Failure	On February 6, 2013, a single-stage regulator "failed" while flowing hydrogen gas from a standard 200 ft^3 gas bottle. During the event, a solenoid valve was opened to allow hydrogen to flow when a loud noise was noted, and gas began flowing out of the pressure relief valve on the side of the regulator. It was noted that the low-pressure gauge on the regulator was "pegged" at the high side (200 psi). The valve on the bottle was shut off, and the hydrogen flow was immediately stopped. Hydrogen flowing out of the relief	- Without additional protection, downstream components can be exposed to pressures exceeding the set pressure to the full bottle pressure. If items downstream of the regulator are not rated for full bottle pressure, it is recommended that protection be added to the system. - Pressure relief device discharges need to be routed to a safe location. In a pressure-relieving event, the flow must be directed

Incident Category	Description/Root Cause	Lessons Learned
	valve did not ignite. With the bottle shutting off, the regulator was replaced with another regulator of the same type, and activities continued. The failed regulator was taken apart to determine the failure's cause. A small elastomeric ring that seals the internal nozzle to the seat assembly was deformed and lodged in the nozzle orifice, preventing the seat assembly from properly seating and allowing high-pressure hydrogen to flow into the low-pressure side of the regulator continuously. The regulator has a pressure relief valve as protection, and it operated properly, relieving the pressure in the system. Fortunately, nothing downstream of the regulator was damaged. What led to the failure of the elastomer ring has yet to be discovered (at the time of reference writing).	away from personnel, preferably so that the shut-off valve can be accessed safely. - Adequate ventilation is an important consideration in the layout of a compressed gas system. Inert gases (as potential asphyxiants) and toxic and flammable gases can pose a significant hazard if not properly ventilated.
Piping Incidents – Failure of Stainless-Steel Valves due to Hydrogen Embrittlement	On August 19, 1986, difficulties were experienced with two solenoid-operated globe valves in a charging system. When shut, the valves could not be reopened without securing all charging pumps. During a refueling outage, the two valves were disassembled and examined to determine the cause of the malfunction. It was found that the springs of the disc guide assembly in both valves had	- Onsite personnel must verify that vendors receive comprehensive specifications on the application, use and service conditions associated with all stainless-steel valves implemented in applications susceptible to hydrogen embrittlement. - A web-based resource developed by Sandia

Incident Category	Description/Root Cause	Lessons Learned
	undergone complete catastrophic failure. The springs initially had 25 coils and were found in sections of only 1-2 coils. Metallurgical analysis of the failed springs attributed the probable cause of failure to hydrogen embrittlement. The springs are made of 17-7 PH stainless steel. Discussion with the valve manufacturer revealed that similar failures occurred on three previous occasions. These spring failures were also attributed to hydrogen embrittlement.	National Laboratories to provide data on hydrogen embrittlement of various materials is available at Technical Reference for Hydrogen Compatibility of Materials.
Piping Incidents – Hydrogen Leak from Underground Pipe and Explosion	On October 31, 1980, an explosion occurred at a NASA hydrogen storage and use facility that had been in a non-operational mode for several months while undergoing modifications for future tests. No one was in the facility at the time of the explosion. The facility's other supply systems and utilities had been severed or ruptured. Shrapnel and debris were ejected up to 540 feet away. Firefighters and emergency medical personnel were sent to the area to verify that no one was injured and to extinguish small residual fires. Damage was significant, including the destruction of two support buildings. Costs incurred from the explosion were estimated to be approximately	- Active H_2 sensors should be installed and continuously monitored in all enclosed buildings near H_2 sources. All buildings near areas where hydrogen is used should be designed to preclude H_2 entrapment (e.g., sloping roof with ventilation at the highest point). - Underground carbon steel lines beneath concrete pad areas should not be used for H_2 transmission. All H_2 lines are now stainless steel and above ground at this NASA location. - H_2 transmission lines buried underground should be proof-tested and leak-checked periodically. - Any below-grade piping installation should be in

Incident Category	Description/Root Cause	Lessons Learned
	$5.9 million. Detectable levels of gaseous hydrogen were recorded at several locations adjacent to the concrete pad for five days following the event. The findings of the investigation board were as follows: - The explosion was the result of a hydrogen leak. - A gaseous hydrogen leak occurred in an underground NPS 3 ASTM A106 Grade B, XXS WT carbon steel pipe. The pipe was coated with coal tar primer and coal tar enamel, wrapped with asbestos felt impregnated with coal tar, covered with a second coat of coal tar enamel, and wrapped in Kraft paper in accordance with American Water Works Association Standard G203. The source of the leak was an oval hole about 0.15 x 0.20 inches at the pipe's inner surface and about 2 inches in diameter at the outer surface of the pipe. Upon excavation of the pipe, it was noted that the coating was not present at the leak point. This resulted in galvanic corrosion over 15 years and the eventual rupture when high-pressure gas was applied to the thin pipe membrane. The pipe	open trenches covered by grating. - Facilities should be protected from H_2 at a safe distance by manual isolation valves. If remote-operated valves (ROVs) are required for operational isolation, the ROVs should be in series with and downstream of the manual isolation valve. - The pressure between isolation valves and stand shut-off valves should be routinely monitored daily. - Field repair of mechanically severable valves in high-pressure systems should be eliminated. - Valves repaired in the field should be subjected to functional and leak checks, including actuator and valve seals at simulated operating conditions. A written procedure should be prepared and used. - Valves utilizing pneumatic actuators should have the actuator piston and piston nut staked (or locked by other positive means) in the installed condition. - All high-pressure gas lines scheduled to be inactive for over six months should be physically isolated from active systems by blind flanges.

Incident Category	Description/Root Cause	Lessons Learned
	was 8 feet 9 inches below the concrete pad. - Before the pipe rupture, a pneumatically operated gaseous hydrogen isolation gate valve, designed for 6000 psi service, and located about 280 feet from the facility, failed in the open position. Pneumatic pressure had been removed earlier in the day, and failure analysis indicated that the valve had been damaged during recent field servicing. This allowed hydrogen gas from two hydrogen storage tanks to enter the pipe. - Gaseous hydrogen was trapped in large quantities in sand and gravel under the apron surface (a 1-foot-thick concrete pad about 160 x 140 feet). The hydrogen then entered the basement of the electrical control and instrumentation terminal building, located immediately adjacent to the facility, through penetrations in the basement wall, including cable ducts, cable pulls, and two 24-inch-diameter air conditioning ducts. Gaseous hydrogen was transported through the air conditioning ducts to a support building about 90	- Supply system status of pressure vessels and lines (pressure and quantity) should be recorded at the start and completion of operations each day. All reservoirs should be isolated each day before weekends and holidays at the close of business. - Corrosion protection systems for underground lines should be reviewed and tested to confirm the adequacy of the systems. - Operational and support buildings at hazardous sites should be isolated (i.e., interconnecting air conditioning systems should be avoided). Seals should physically isolate buildings connected to hazardous sites by tunnels and conduits. If physical isolation is impractical, positive airflow should be maintained in tunnels and conduits. - Explosive gas detection meters should be included in the equipment carried by firefighters and emergency medical personnel. - Fire alarm transmitters should be located at all hazardous locations. - Emergency instructions for isolating H_2 and utilities for hazardous locations should

Incident Category	Description/Root Cause	Lessons Learned
	feet from the terminal building. - An explosion originated in the basement of the terminal building through electrical contact with a sump pump motor. A shock wave traveled through the air conditioning ducts and caused a second explosion of lesser magnitude in the support building. The actual ignition source in the terminal building is unknown; an electrical arc from a sump pump was the most likely source. - The TNT equivalent of the blast was between 100 and 475 pounds, depending on the location. - After that event, no mild steel was again used for high pressure hydrogen piping at that site.	be permanently posted with names and telephone numbers of key individuals to be contacted.
Hydrogen Compressor Incidents – Compressor Piping Incident	On April 5, 2006, the malfunctioning of the non-return valve of the hydrogen compressor caused the pressure between the hydrogen bottle and the compressor to rise to the maximum allowed pressure of 275 bar. The rupture disk of the safety valve broke, and the hydrogen content of the gas bottle and the pipe section involved was released on top of the building. The flame was seen for a very short period by a guard.	The following corrective actions were taken: - The non-return valve was dismantled, cleaned, and tested. After positive testing, the system was restarted and pressurized without further malfunctioning. - The hydrogen discharge pipe was extended from the low roof of the compressor building (2.5 m) to the higher roof of a neighboring

Incident Category	Description/Root Cause	Lessons Learned
	The non-return valve was dismantled, cleaned, and tested. After positive testing, the system was restarted and pressurized without further malfunctioning.	building (6 m). With this modification, potential hydrogen ignition would occur approximately 6 meters from the ground, farther from personnel than the 2.5 meters of the previous situation. - The compressor was sent to the manufacturer for preventive maintenance to lower the frequency of component malfunctioning. - Plans for regular maintenance of the non-return valve will be recorded in the next revision of the Design and Safety Report. - A flame arrestor was purchased and mounted at the end of the exhaust pipe on top of the building.
System Design, Operator, and Maintenance Incidents – Hydrogen Storage Siting [Near Miss]	On April 27, 1989, during an inspection, three potential safety problems were identified concerning the location of a hydrogen storage facility. The hydrogen storage facility was on a building's roof, made of 30-inch-thick reinforced concrete. The following potential safety problems were identified during the inspection: 1. Hydrogen gas leakage from the storage facility near the air intakes of the building's ventilation system had the potential introduce a flammable	The hydrogen facility in this example did not meet industrial guidelines for facilities of this type from the standpoint of (1) the separation distance needed between a hydrogen pipe break and the building ventilation intake to prevent the buildup of a flammable or explosive gas mixture inside the enclosure, and (2) the separation distance needed to prevent damage to safety-related structures resulting from the explosion of an 8,000-scf hydrogen tank.

Incident Category	Description/Root Cause	Lessons Learned
	or explosive gas mixture into the enclosure. Because the hydrogen storage facility, containing four 8000-scf hydrogen tanks at up to 2450 psig, was Seismic Category II, a seismic event may result in a hydrogen leak. Furthermore, the pressure relief valves in the hydrogen facility exhausted downward to within 6 inches of the roof near the ventilation system air intakes. 2. A detonation of a hydrogen storage tank could structurally damage and affect the performance of safety-related equipment on the building's roof, such as the ventilation system intake and exhaust structure, the emergency pressurization system, and the building itself. 3. An explosion of the hydrogen delivery truck that provides hydrogen to the facility through a fill line located at ground level on the wall of the auxiliary building could structurally damage safety-related component cooling water pumps located inside the auxiliary building and near the hydrogen fill line.	Safety concerns such as hydrogen leaks and storage tank detonations must be considered and used to create effective new construction designs that mitigate the consequences of such events. Existing buildings that house hydrogen storage tanks must properly analyze the risks associated with using and storing such systems.
System Design, Operator, and Maintenance Incidents – Improper Purging	On December 31, 1969, steam turbines at a power station drove a large, hydrogen-cooled generator. During maintenance shutdowns, the hydrogen cooling loop in the generator was purged with carbon dioxide. After carbon	This incident illustrates the importance of thoroughly purging hydrogen from a large, complex piece of equipment. Uniform mixing and dilution are unlikely in all the partially enclosed spaces, crevices, etc. If a hazardous

Incident Category	Description/Root Cause	Lessons Learned
Procedure Results in Hydrogen Fire	dioxide concentrations were measured with a densitometer to verify the complete removal of hydrogen, the generator was purged with air and the maintenance was performed. This purging procedure was used before the explosion. The carbon dioxide reading was reported to be 100% at the top of the generator. The cooling system was then purged with air, and a 1/2-inch pipe in the cooling loop was cut to install some new instrumentation. When the pipe was cut, pressurized gas was emitted at the opening. Workers assumed the gas was either carbon dioxide or air and proceeded with the new instrument installation. Unfortunately, some hydrogen was still in the pipe and the rest of the cooling loop. When the welder struck an arc, a flame developed at the pipe opening and flashed back into the generator. This caused a low-level explosion within the generator shroud. The explosion damaged the generator's ventilation baffle plates and auxiliary equipment, which caused the plant to be out of service for 26 days.	operation such as welding must be performed with an atmosphere of air (instead of inert gas) in the equipment, then reliable gas concentration measurements should be obtained at several different locations. In the case of the generator, a direct measure of hydrogen concentration was more reliable than the 100 percent CO2 reading on the densitometer. Furthermore, the gas composition should have been determined at the welding site and the generator's top.
System Design, Operator, and Maintenance	On June 8, 1998, during the operation of a succinic acid plant, hydrogen leaked from a flanged joint on a safety valve at the	- Construction errors are more difficult to detect once construction is complete. It is important to develop and

Incident Category	Description/Root Cause	Lessons Learned
Incidents – Flanged Joint Hydrogen Gas Leak and Fire	upper part of a reactor, which generated a hydrogen flame. Before the incident, the safety valve was removed and reattached during an inspection at a turnaround shutdown. An incorrectly sized, smaller gasket was installed in the joint, and the tightening force on the bolts was inadequate. Therefore, a gap was generated as time passed, and unreacted hydrogen leaked.	use a systematic oversight process to minimize construction errors during the construction process. - Thorough control of parts during the construction process is required. - Bolts should be tightened equally and fully. - A new support for distributing the weight of piping is installed. - Thoroughness of checks after construction is going to be initiated.
Fueling Station Incidents – Pressure Relief Device Fails	On May 4, 2012, a pressure relief valve failed on a high-pressure storage tube at a hydrogen fueling station, causing the release of approximately 300 kilograms of hydrogen gas. The gas ignited at the exit of the vent pipe and burned for 2 1/2 hours until the local fire department permitted technicians to enter the station and stop the flow of gas. During this incident, the fire department evacuated nearby businesses and an elementary school, closed adjacent streets, and ordered a high school to shelter in place. The station's operating systems worked as designed for an emergency. All equipment and fuel supplies were completely isolated, and all storage vessels were within acceptable and safe pressure and temperature limits	- These problems could have been avoided by adequate quality assurance/quality control procedures during the design and safety reviews. - The canopy was added to the station after the HazOps review. The prestart-up safety review by all parties and the local authority having jurisdiction did not recognize the setback distance of the canopy. Had an engineering management of change, follow-up HazOp or other form of risk assessment been conducted, the vent likely stacks adjacent to the canopy would have been raised to avoid damage in the event of a fire.

Incident Category	Description/Root Cause	Lessons Learned
	before and throughout the incident. After a thorough analysis of the incident, corrective actions were taken to replace pressure relief valves, heighten vent stacks, modify response procedures, and improve communication procedures with first responders. A considerable amount of time was taken to review the station design, evaluate emergency action plans and procedures, meet with the public, train first responders, and conduct follow-up drills with employees and first responders. The station reopened nine months after the incident and has since been fully operational. Three root causes were noted during the investigation: (1) the use of incompatible materials in the manufacturing of the PRD valve, (2) improper assembly resulting in over-torquing of the inner assembly, and (3) over-hardening of the inner assembly materials by the valve manufacturer.	- Before reopening the station, physical changes were made using the correct PRD valves and higher vent stacks. New and modified procedures were instituted to improve the timely communication of station status during emergencies. Additional training of personnel focused on improving the response time and effective communication between employees, first responders, and the hydrogen equipment supplier.
Fueling Station Incidents – Fueling Station High-Pressure Storage Leak	On June 10, 2019, a hydrogen leak originating from a tank within a high-pressure storage unit serving a hydrogen vehicle fueling station resulted in a fire and explosion. No damage was reported to the separate forecourt hydrogen dispenser or other	- Implement rigorous assembly, verification, and documentation procedures for equipment. - Increase automated leak detection frequency.

Incident Category	Description/Root Cause	Lessons Learned
	major station components within the backcourt compound. The incident's root cause was subsequently identified as an assembly error of a specific plug in a hydrogen tank in the high-pressure storage unit. The inner bolts of the plug had not been adequately torqued. This led to a hydrogen leak, creating an ignited mixture of hydrogen and air. The source of the ignition has not been positively identified. An inspection and integrity verification program for the high-pressure storage units with similar plugs was implemented, including check and re-torque of tank plugs. Additional measures implemented include revised assembly, verification, and documentation of procedures and increased automated leak detection frequency. Depending on the site, additional ignition control measures are considered, including loose gravel removal/smooth surface around the high-pressure storage unit, additional backcourt compound ventilation, and higher extent use of explosion-proof components.	

The main causes of the identified failures were due to component failure or equipment design/selection issues. A general conclusion from these incidents is that there is great importance in safe and proper equipment design and construction as well as development of procedures for O&M. Lessons learned focus on having the right materials and operating procedures for hydrogen service.

12.0 CONCLUSION

The safe transportation of hydrogen gas in pipelines is paramount to harnessing its potential as a clean and sustainable energy source. As illustrated above, the safe transportation of 100% clean renewable hydrogen by pipeline is feasible. The identified safety requirements, ranging from material selection, pipeline design, leak detection and monitoring programs, emergency response procedures, and public awareness plans, form a comprehensive framework to mitigate risks associated with hydrogen transport.

Safe pipeline management is achieved through a combination of codes, regulations, standards, and best practices that are paired with considerations on system architecture, operational controls, procedures, continuous improvement and evaluation, and management of change. This structure and content can be tailored to align with the physical and chemical properties that are unique to hydrogen. Lessons learned can be leveraged to further refine and establish new standards, design, procedures, and best practices as part of continuous improvement.

Evaluation of SoCalGas gas standards and specification sheets resulted in identification of potential impacts, required updates, and/or new processes to be created to accommodate a 100% clean renewable hydrogen pipeline system. The following specification and standard topics that cover SoCalGas's current natural gas operations can be considered for potential modifications or new specifications/standard development for implementation of a clean renewable hydrogen energy transport system:

1. Material requirements
2. Material traceability requirements
3. Facility maps (for new production, transmission, and storage facilities)
4. Control room management plan
5. Equipment specifications (e.g., gas compressor specifications and pressure vessel specifications updated to include specifics for hydrogen service)
6. Fire prevention and protection plan
7. Operator qualification program
8. Corrosion control and monitoring requirements
9. Leak testing and monitoring requirements
10. Integrity management programs

The evaluation provides transparency into how established safety requirements are embedded in the existing framework and confirms that the current natural gas infrastructure Specifications, Standards & Procedures provide a solid foundation for building the hydrogen infrastructure Specification, Standards & Procedures.

The existing SoCalGas Control Room Management and Emergency Response Plan could be leveraged as a basis for Angeles Link. Once the preferred system route of Angeles Link is identified, future discussions with Gas Control and Emergency Response teams are needed to further revise and develop these procedures. For Emergency

Response, SoCalGas may consider hydrogen-specific items such as notification practices, reportability, and coordination between First Responding Agencies (i.e., Local Fire Department, Police Departments, County EOCs, etc.). Hydrogen training for these Emergency and First Responding groups is available and would be a new activity due to the difference in nature of hydrogen and natural gas fuel sources. SoCalGas may consider establishing separate Gas Control and Emergency Response teams for hydrogen.

Education and training requirements for the workforce operating and maintaining hydrogen infrastructure can be applied to the development of training programs and operator qualifications. Organizations already accredited to undertake various hydrogen safety education and training include: AIChE, BakerRisk, CSA Group, Dräger, GTI, HySafe, and EERE. Various resources for education and training are available for both pipeline operators, emergency and first responders, and the public. Additionally, public awareness plans are both required and support safe operations of pipeline facilities and should be developed to support new hydrogen infrastructure as appropriate.

In conclusion, pipeline transportation of clean renewable hydrogen is feasible and can be safely achieved through compliance with Federal and State codes, standards, regulations, and procedures identified within this document. The application of and compliance with these elements must be intrinsically integrated throughout design and development choices, asset management structure, procedures, training, operations, and handling of hydrogen within a hydrogen pipeline system. Industry recommended best practices and lessons learned can be applied. SoCalGas is well positioned to safely build, operate, and maintain a clean renewable hydrogen pipeline system by leveraging its experience operating and maintaining a developed gas transmission and distribution system, existing highly trained and qualified workforce, and comprehensive integrity management and emergency response procedures.

13.0 STAKEHOLDER FEEDBACK

SoCalGas presented opportunities for the PAG and CBOSG to provide feedback at four key milestones in the course of conducting this study: (1) the draft description of the Scope of Work, (2) the draft Technical Approach, (3) Preliminary Findings and Data, and (4) the Draft Report. These milestones were selected because they are critical points at which relevant feedback can meaningfully influence the study.

Table 9 – Key Milestone Dates

Milestone	Date Provided to PAG/CBOSG	Comment Due Date	Responses to Comments in Quarterly Report[33]
1. Draft Scope of Work	July 6, 2023	July 31, 2023	Q3 2023
2. Draft Technical Approach	September 7, 2023	October 13, 2023	Q4 2023
3. Preliminary Findings and Data	April 11, 2024	May 3, 2024	Q2 2024
4. Draft Report	June 21, 2024	July 19, 2024	Q3 2024

Feedback provided at the PAG/CBOSG meetings is memorialized in the transcripts of the meeting. Written feedback received is included in the quarterly reports, along with SoCalGas responses. Meeting transcripts are also included in the quarterly reports. The quarterly reports are submitted to the CPUC and are published on SoCalGas's website.

Feedback was incorporated as applicable at each milestone throughout the progression of the study. Some feedback was not incorporated for various reasons including feedback that was outside the scope of the Phase 1 Decision or feasibility study, or feedback that may be addressed in future phases of Angeles Link.

Key feedback incorporated through the development of the Safety Study is summarized in the table below. Additionally, some minor administrative and other corrections were made to the final Safety Study report for clarification.

[33] Each Quarterly Report can be accessed at https://www.socalgas.com/sustainability/hydrogen/angeles-link

Table 10: Summary of Incorporated Stakeholder Feedback	
Thematic Comments from PAG/CBOSG Members	**Incorporation of and Response to Feedback**
Engagement with the Center for Hydrogen Safety Stakeholders requested SoCalGas engage with the Center for Hydrogen Safety for review of this study.	SoCalGas enlisted the expertise of the Center for Hydrogen Safety's Hydrogen Safety Panel to review and provide comments on the draft *Evaluation of Applicable Safety Requirements*. The Hydrogen Safety Panel identified additional key hydrogen safety codes and safety best practices and made other recommendations for information to consider in the planning of Angeles Link. Changes were made to the Safety Study in Sections 6: Risk Management, Section 8: Specifications, Standards, & Procedures Evaluation, and Section 11: Lessons Learned to address feedback from the Hydrogen Safety Panel. A copy of the Hydrogen Safety Panel's feedback along with SoCalGas's full response to the feedback is included in the Q3 2024 Quarterly Report available on SoCalGas's website.
Odorizing Hydrogen Stakeholders requested more information on what types of odorants are being contemplated and further evaluation of an appropriate odorant for a hydrogen system.	Consistent with this feedback, Section 8: Specifications, Standards & Procedures Evaluation: Potential for Future Odorization includes information regarding odorants and certain end uses. In response to this feedback, SoCalGas also added a statement to this section clarifying that SoCalGas intends to monitor odorant developments during the development of Angeles Link to identify industry best practices. As noted in the Safety Study, "the criteria in §192.625(b) will determine the requirements for odorization."

Risk Analysis/Management Some stakeholders emphasized the limited detail for the risk analysis approach and suggested providing a description of the overall SoCalGas hazard and safety analysis process.	In response to this feedback, additional information was incorporated in section 6: Risk Management that describes SoCalGas's enterprise risk management model and the descriptions of preliminary potential risk and risk management regarding the transportation of fuel by pipeline. The Risk Management table in the study outlines the potential consequences associated with the design, construction, operations and maintenance of Angeles Link, which includes risk of leakage, flammability concerns, and explosions, along with potential management considerations. An explanation of SoCalGas's standard and policy for a process hazard analysis was also added to this section. Comprehensive risk analysis methodologies are expected to be conducted in subsequent phases as more detailed information is available.
Hydrogen Regulation Applicability Stakeholders commented that the applicability of regulations and codes was not clearly defined for hydrogen gas versus natural gas pipelines. Stakeholders also asked if international standards could be included.	Consistent with this feedback, Section 7: Key Safety Codes specifies that many regulatory requirements and industry-standard codes apply to both hydrogen and natural gas such as 49 Code of Federal Regulations (CFR) Part 192 Subparts A through P. Section 7 also includes a summary of hydrogen-specific standards and specifications exist (e.g., American Society of Mechanical Engineers [ASME] B31.12 and National Fire Protection Association [NFPA] 2) and recently recommended NFPA 68 & 69.

	The draft Safety Study stated that international codes can be beneficial as references for informing industry best practices in the development of hydrogen infrastructure. In response to the stakeholder feedback requesting more information about international codes, a new Table 3 listing available international codes has been incorporated into Section 7.
Lessons Learned Stakeholders requested insight into SoCalGas's lessons learned process and how lessons learned are captured and addressed by SoCalGas. Stakeholders also requested additional information on how SoCalGas selected the incidents to summarize in Table 8 and more information related to injuries and/or deaths from the hydrogen safety incidents identified in Table 8 in the Lessons Learned discussion.	In response to this feedback, Section 11: Lessons Learned was added to the Safety Study summarizing recent third-party incident events and how SoCalGas learns from incidents. Lessons learned resources are highlighted in this section along with a summary of SoCalGas's internal procedure for performing and determining a root cause analysis for events that may have enterprise-wide impacts on the safety of employees, public, the environment, or the integrity or reliability of the natural gas pipeline system. In addition, in response to the request for additional information on the third-party incidents summarized in Table 8, clarification has been added to Section 11 stating SoCalGas summarized the incidents with a specific emphasis on the facts and lessons relevant to a hydrogen pipeline system. Clarification was also added that SoCalGas acknowledges that there are injuries and/or deaths associated with some incidents, however, the intent of this section was to focus on the design/safety root cause of each incident and the lessons learned.

Additional Safety Analysis Stakeholders generally requested additional analysis related to the safety of constructing and operating a hydrogen pipeline system.	In response to this feedback, a new Section 14: Future Considerations was added to this study summarizing the additional analysis and information that will be considered at the appropriate stage of project development to safely advance the engineering design, identify specific project requirements and design factors, and to support efficient execution.

14.0 FUTURE CONSIDERATIONS

The Phase 1 studies, including the Evaluation of Applicable Safety Requirements, address the feasibility aspects and establish a foundation for Angeles Link. The future considerations identified within this chapter will be considered at the appropriate stage of project development to safely advance the engineering design, identify specific project requirements, safety and design factors, and support an efficient execution. These following considerations are important to the advancement of Angeles Link, but were not considered part of the feasibility evaluation because it was not a scope of work that could be performed with the level of information available within Phase 1.

1. Hazard Interface Analysis

In Section 6: Risk Management, SoCalGas described the hazard analysis process that is well established in the company procedures and conducted for projects where appropriate. In major infrastructure projects, one critical consideration is the identification and management of interfaces with third parties as places where independent systems meet and interact are important to evaluate to identify potential risks and safety concerns. Effective interface management involves collaboration, clear communication, and proactive risk assessment, therefore planning next steps in managing interfaces with third parties is crucial. In the subsequent phases of Angeles Link, guidelines such as those from the Construction Industry Institute's (CII) Interface Management Implementation Guide can be leveraged for implementing interface management effectively and systematically. Along with safety engineering interface management, incorporating standard contractual provisions can support managing risks as well.

2. Monitoring Odorization Research

Section 8: Specifications, Standards & Procedures Evaluation: Potential for Future Odorization describes various research studies conducted for potential odorants for hydrogen applications and certain end uses. Use of an odorant is one of the potential mechanisms to help safely manage hydrogen operations. Other safety mechanisms and methods are leveraged during design and operation to incorporate safety, such as installing hydrogen compatible materials, monitoring, application of leak detection technologies, and increased survey frequency. SoCalGas will continue to monitor and evaluate options for odorant in subsequent phases of Angeles Link.

3. Refined Standards Evaluation Process

As described in this study, as part of Phase 1, SoCalGas undertook a preliminary evaluation to assess existing SoCalGas specifications, standards, and procedures for applicability to hydrogen gas and the potential for new procedure development. SoCalGas specifications, standards, and procedures were reviewed and categorized for applicability and efficacy for hydrogen infrastructure. Next steps in future phases of Angeles Link are expected to involve a detailed and comprehensive procedures evaluation process to support a thorough assessment and improvement of existing procedures for use with hydrogen. The preliminary assessment from this Safety Study will be leveraged to establish the groundwork for a more extensive review. An analysis and assessment are instrumental to the process to identify areas that need to be updated or changed in the current policies and align with compliance requirements. An internal SoCalGas review process would also be beneficial in order to create draft standards and propose revisions that would reflect diverse feedback. Finally, implementing and monitoring the revised and newly created procedures will support a continuous management of change process.

4. Hydrogen vs. Natural Gas Workforce Planning

Understanding that there are similarities and differences in physical and chemical properties of hydrogen gas and natural gas, as noted in Section 5: Physical and Chemical Properties of Hydrogen, as Angeles Link develops, SoCalGas intends to further assess how its current and future workforce would carry out the tasks specific to hydrogen as compared to natural gas. As mentioned in the Executive Summary, SoCalGas may also consider separate gas controllers and emergency response teams for the natural and hydrogen gas systems since natural gas and hydrogen are different fuels with different physical and chemical properties, although this decision is not yet ripe in Phase 1. Certain tasks for hydrogen operations and natural gas operations may involve similar work and require similar training, skills, knowledge, and expertise. In order to determine if the differences between the job functions would warrant separate job tasks, additional information will need to be collected on the knowledge and skills required for specific tasks. Conducting future assessments, such as an operator qualifications gap analysis, a detailed procedures evaluation, systems/workflow analysis and/or workforce capacity planning, would support defining job duties and requirements.

15.0 GLOSSARY

Accreditation Board for Engineering and Technology (ABET) - Accredited college and university programs in the disciplines of applied and natural science, computing, engineering and engineering technology at the associate, bachelor's and master's degree levels. [34]

American Institute of Chemical Engineers (AICHE) - World's leading organization for chemical engineering professionals, with more than 60,000 members from more than 110 countries. [35]

American National Standards Institute (ANSI) - A private, nonprofit organization that administers and coordinates the U.S. voluntary standards and conformity assessment system. [36]

American Petroleum Institute (API) - Formed in 1919 as a standards-setting organization and has developed more than 800 standards to enhance operational and environmental safety, efficiency and sustainability. [37]

American Society for Testing and Materials (ASTM) - A nonprofit organization that develops and publishes approximately 12,000 technical standards, covering the procedures for testing and classification of materials of every sort [38]

American Society of Mechanical Engineers (ASME) - A nonprofit professional organization that enables collaboration, knowledge sharing, and skill development across all engineering disciplines, while promoting the vital role of the engineer in society. [39]

Batching of In-Line-Inspection tools - The tool is loaded into the middle of two isolation pigs (one in front of the ILI tool and one behind) and the ILI tool is in a compatible pressurized gas, such as nitrogen (or a slug of diesel if the tool requires a liquid coupling)

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[34] About abet. ABET. (2023, October 2). https://www.abet.org/about-abet/.

[35] About Aiche. AIChE. (2023, July 7). https://www.aiche.org/about.

[36] American National Standards Institute. (n.d.). ANSI introduction. ANSI. https://www.ansi.org/about/introduction.

[37] About API. Energy API. (n.d.-a). https://www.api.org/about.

[38]ASTM International. ANSI Webstore. (n.d.). https://webstore.ansi.org/sdo/astm?msclkid=b5145c8e3c9110b215d53ac1f2f86bb8&utm_source=bing&utm_medium=cpc&utm_campaign=Standards-US&utm_term=ASTM+standards+store&utm_content=ASTM.

[39] About ASME. ASME. (n.d.-a). https://www.asme.org/about-asme#:~:text=Founded%20in%201880%20as%20the%20American%20Society%20of,the%20vital%20role%20of%20the%20engineer%20in%20society.

Boiler and Pressure Vessel Code (BVPC) - Issued once every two years, is comprised of 32 separate volumes which establish rules of safety governing the design, fabrication and inspection of boilers and pressure vessels, including nuclear power systems. [40]

California Public Utilities Commission (CPUC) - Regulates privately owned electric, natural gas, telecommunications, water, railroad, rail transit, and passenger transportation companies, in addition to authorizing video franchises. [41]

Cathodic Protection - A technique to prevent corrosion of a metal surface by making that surface the cathode of an electrochemical cell. [42]

Center for Hydrogen Safety (CHS) - Nonprofit, non-bias, corporate membership organization within AIChE that promotes the safe operation, handling, and use of hydrogen and hydrogen systems across all installations and applications. [43]

Code of Federal Regulations (CFR) - A codification (arrangement of) the general and permanent rules published in the Federal Register by the executive departments and agencies of the Federal Government.

[44]**Community Based Organizations (CBO):** A public or private nonprofit organization representing a community or a significant segment of a community and working to meet community needs. [45]

Compressed Gas Association (CGA) - An American National Standards Institute (ANSI) accredited Standards Developing Organization, CGA works directly with federal,

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[40] 2023 ASME BPVC is now shipping! 2023 ASME BPVC - Boiler Pressure Vessel Code | American Society of Mechanical Engineers. (n.d.). https://store.accuristech.com/pages/bpvc_boiler_pressure_vessel_code?sid=msn&utm_source=bing&utm_medium=cpc&msclkid=f8a6a620c76c16f248c7c0793a9b1a9d&utm_campaign=ASME+BPVC&utm_term=2023+boiler+pressure+vessel+code&utm_content=2023+ASME+BPVC.

[41] Auth, T. (n.d.). About the CPUC https://www.cpuc.ca.gov/about-cpuc/cpuc-overview/about-us#:~:text=About%20the%20California%20Public%20Utilities%20Commission%20%28CPUC%29%20The,transportation%20companies%2C%20in%20addition%20to%20authorizing%20video%20franchises.

[42] The Federal Register. Federal Register: Request Access. (n.d.-a). https://www.ecfr.gov/current/title-40/chapter-I/subchapter-I/part-280.

[43] Center for Hydrogen Safety Fact Sheet. AIChE. (2019, May 24). https://www.aiche.org/CHS/center-hydrogen-safety-fact-sheet

[44] National Archives and Records Administration. (n.d.). Code of federal regulations. National Archives and Records Administration. https://www.archives.gov/federal-register/cfr.

[45] Community-Based Organization (CBO): NIH. Community-Based Organization (CBO) | NIH. (n.d.). https://clinicalinfo.hiv.gov/en/glossary/community-based-organization-cbo.

state, and provincial agencies and fire code officials to promote safe and responsible practices and regulations. [46]

Control Center Modernization (CCM) - Will further digitalize the existing natural gas transmission and distribution system with new field assets such as optical pipeline monitoring (OPM) stations and high consequence area (HCA) methane sensors.

Control Room Operators - Monitor the pressure and flow of gas in the system utilizing a supervisory control and data acquisition (SCADA) system 24 hours a day, 365 days a year.

Covered Process – A process subject to regulatory requirements for process safety.

Cybersecurity and Infrastructure Security Agency (CISA) - Works with partners to defend against today's threats and collaborate to build a more secure and resilient infrastructure for the future. [47]

Department of Transportation (DOT) - A federal agency of the United States government that oversees the transportation system of the country. The DOT aims to ensure the safety, efficiency, accessibility, and sustainability of various modes of transportation, such as air, road, rail, water, and transit. The DOT also supports the development and innovation of transportation infrastructure, technology, and policy.

Emergency Shutdown Devices (ESD) - Systems designed to rapidly shut down the pipeline operation in the event of a detected leak or other hazardous situations that will isolate sections of the pipeline to minimize risks.

Enterprise Risk Management (ERM) - ERM extends beyond compliance and financial risk by using a comprehensive approach to view risks across five categories: compliance, financial, operational, reputational, and strategic. [48]

Federal Emergency Management Agency (FEMA) - FEMA's mission is to help people before, during and after disasters, and our core values and goals help us achieve it. [49]

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[46] What we do. Compressed Gas Association. (n.d.). https://www.cganet.com/what-we-do/.

[47] About Cisa: CISA. Cybersecurity and Infrastructure Security Agency CISA. (n.d.). https://www.cisa.gov/about.

[48] Centers for Disease Control and Prevention. (2020, June 29). Enterprise risk management. Centers for Disease Control and Prevention. https://www.cdc.gov/other/riskmanagement.html#:~:text=ERM%20extends%20beyond%20compliance%20and%20financial%20risk%20by,as%20well%20as%20a%20more%20transparent%2C%20risk-aware%20culture.

[49] About Us. FEMA.gov. (n.d.). https://www.fema.gov/about.

Gas Technology Institute (GTI) - An organization dedicated to advancing the economy-wide transformation needed to deeply decarbonize energy systems while supplying the energy needed to support rising standards of living and economic growth worldwide. [50]

Geographic Information System (GIS) - Geographic Information Systems (GIS) are systems that capture, store, analyze, and display spatial or geographic data. GIS can be used to create maps, models, and simulations that show the patterns, relationships, and trends of various phenomena that occur on the Earth's surface or in the atmosphere.

High Consequence Areas (HCA) - Unusually sensitive environmental areas (defined in 195.6), urbanized areas and other populated places (delineated by the Census Bureau, and commercially navigable waterways. [51]

Hydrotesting - The method used to pressure test an extinguisher's critical components (cylinder, shell, hose assembly, etc.) for leaks and structural flaws by pressurizing them with a liquid. [52]

Inline Inspection (ILI) - A technique used to assess the integrity of natural gas transmission pipelines from the inside of the pipe and is used by SoCalGas as part of its ongoing pipeline integrity program. [53]

International Association for Hydrogen Safety (HySafe) - The focal point for all hydrogen safety related issues. [54]

International Organization for Standardization (ISO) - Brings global experts together to agree on the best way of doing things – for anything from making a product to managing a process. [55]

Material Specification (MSP) - Detail the physical and chemical properties, manufacturing processes, and performance characteristics of the selected materials. This

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[50] Vision. GTI Energy. (2024, May 17). https://www.gti.energy/about/vision/.

[51] HL Im fact sheet. PHMSA. (n.d.-a). https://www.phmsa.dot.gov/pipeline/hazardous-liquid-integrity-management/hl-im-fact-sheet.

[52] ETool: Evacuation plans and procedures - emergency standards - portable fire extinguishers - hydrostatic testing. Occupational Safety and Health Administration. (n.d.-a). https://www.osha.gov/etools/evacuation-plans-procedures/emergency-standards/portable-extinguishers/hydro.

[53] In-line inspection of pipelines - SoCalGas. (n.d.-b). https://www.socalgas.com/documents/news-room/fact-sheets/In-LinePipelineInspection.pdf.

[54] Why to become member? (n.d.). http://www.hysafe.org/WhyMember#:~:text=What%20is%20IA%20HySafe%3F%20The%20International%20Association%20for,by%20the%20European%20Commission%20co-funded%20network%20of%20excellence.

[55] About ISO. ISO. (2024a, March 14). https://www.iso.org/about-us.html.

includes information on strength, durability, finish, and any specific testing or certification required. [56]

Maximum Allowable Operating Pressure (MAOP) - Maximum Allowable Operating Pressure (MAOP) is the maximum pressure at which the equipment may be operated under; in other words, it is the maximum pressure in the new and cold condition of the equipment.

National Fire Protection Association (NFPA) - Started as a Boston-based organization for fire sprinkler codes has grown to become the leading global advocate for the elimination of death, injury, property, and economic loss due to fire, electrical, and related hazards. [57]

Nominal Pipe Size (NPS) - Related to the inside diameter in inches, and NPS 12 and smaller pipe has outside diameter greater than the designated size. [58]

Occupational Safety and Health Administration (OSHA) - Assures safe and healthful working conditions by setting and enforcing standards, and by providing training, outreach, education and assistance. [59]

Operations and Maintenance (O&M) - Activities performed by an individual, or group of individuals, (1) to perform a function on a pipeline facility, or (2) to provide upkeep of a pipeline facility. This includes in-kind replacement of an existing section of pipe necessitated by severe corrosion, where the capacity of the pipe segments is maintained, and service is not expanded. It also includes maintenance and repair tasks performed on the right-of-way or within the confines of a “pipeline facility”, as defined. This would include ordinary repairs to a pipeline, including replacement of one or more pipe joints or segments that have been severely damaged by threats such as corrosion or third-party damage. [60]

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[56] Forehand, L. (n.d.). Chapter 6: Building Materials and Specifications. Building Systems and Codes for Designers. https://lbcc.pressbooks.pub/buildingsystemsandcodes/chapter/building-materials-and-specifications/.

[57] Learn more about NFPA: The National Fire Protection Association. nfpa.org. (n.d.). https://www.nfpa.org/About-NFPA.

[58] PI-21-0008. PHMSA. (2021, September 1). https://www.phmsa.dot.gov/regulations/title49/interp/pi-21-0008.

[59] Occupational Safety and Health Administration (OSHA): Usagov. Occupational Safety and Health Administration (OSHA) | USAGov. (n.d.). https://www.usa.gov/agencies/occupational-safety-and-health-administration.

[60] Pipeline Safety Stakeholder Communications. PHMSA. (n.d.-d). https://primis.phmsa.dot.gov/comm/glossary/index.htm?nocache=5217#OperationsandMaintenanceTasks.

Operator Qualification (OQ) - Each pipeline operator is responsible for developing an OQ program, following their written OQ plan, establishing a covered task list applicable to their system, and defining the training and qualification requirements for personnel performing covered tasks on their pipeline facility. [61]

Optical Pipeline Monitoring (OPM) - The Optical Pipeline Safety Monitoring System (OPM) sends pulses of light the thickness of a human hair through glass that can be measured inside the optical cable. When installed along a pipeline, the technology can detect vibrations, stress, or abnormal changes in temperature to within 20 feet of where a problem may be developing. [62]

Personal Protective Equipment (PPE) - Equipment worn to minimize exposure to a variety of hazards. [63]

Piggability - In-Line Inspection (ILI) tools are referred to as "intelligent" or smart Pipeline Integrity Gauges (PIG's) which are devices that travel inside the pipeline and collect data using various sensors. There are different types of ILI tools, such as: Cleaning PIGs, smart PIGs, etc.

Pipeline and Hazardous Materials Safety Administration (PHSMA) - Mission is to protect people and the environment by advancing the safe transportation of energy and other hazardous materials that are essential to our daily lives. [64]

Potential Impact Radius (PIR) - The radius of the potential impact circle (PIC), measured in feet surrounding the point of failure, within which the potential failure of a pipeline could have significant impact on people or property.

Risk Assessment Mitigation Phase (RAMP) - Identification of major risks to be addressed, examination of alternative mitigation options and their expected risk reduction, and a description of a proposed risk mitigation plan. [65]

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[61] Operator qualification overview. PHMSA. (n.d.-a). https://www.phmsa.dot.gov/pipeline/operator-qualifications/operator-qualification-overview.

[62] SoCalGas' Innovative Optical Pipeline Safety Monitoring System set to expand after successful pilot program: SoCalGas Newsroom. (2023, September 6). https://newsroom.socalgas.com/stories/socalgas-innovative-optical-pipeline-safety-monitoring-system-set-to-expand-after

[63] Personal Protective Equipment. (n.d.-b). https://www.osha.gov/sites/default/files/publications/osha3151.pdf.

[64] PHMSA's mission. PHMSA. (n.d.-a). https://www.phmsa.dot.gov/about-phmsa/phmsas-mission.

[65] Auth, T. (n.d.). Sempra 2021 ramp. California Public Utilities Commission. https://www.cpuc.ca.gov/about-cpuc/divisions/safety-policy-division/risk-assessment-and-safety-analytics/risk-assessment-mitigation-phase/sempra-ramp/sempra-2021-ramp.

Safety - The presence of controls for known hazards, actions to anticipate and guard against unknown hazards, and the commitment to continuously improve the ability to recognize and mitigate hazards.

Safety Management System (SMS) - Formal, top-down, organization-wide approach to managing safety risk and assuring the effectiveness of safety risk controls. It includes systematic procedures, practices, and policies for the management of safety risk. [66]

Specified Minimum Yield Strength (SMYS) - SMYS is the minimum yield strength, expressed in pounds per square inch (psi) gage, prescribed by the specification under which pipe material is purchased from the manufacturer. [67]

Standards Council of Canada (SCC) - A Crown corporation established by an Act of Parliament in 1970 to foster and promote voluntary standardization in Canada. [68]

Tetrahydrothiophene (THT) - Appears as a water-white liquid. About the same density as water and insoluble in water. Vapors heavier than air. Used as a solvent and to make other chemicals. [69]

Transportation Security Administration (TSA) - Protects the nation's transportation systems to ensure freedom of movement for people and commerce. [70]

U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) - EERE's mission is to accelerate the research, development, demonstration, and deployment of technologies and solutions to equitably transition America to net-zero greenhouse gas emissions economy-wide by no later than 2050, and ensure the clean energy economy benefits all Americans, creating good paying jobs for the American

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[66]Safety Management System (SMS). | Federal Aviation Administration. (n.d.). https://www.faa.gov/about/initiatives/sms.

[67] Pipeline Safety Stakeholder Communications. PHMSA. (n.d.). https://primis.phmsa.dot.gov/comm/glossary/index.htm?nocache=5217#SpecifiedMinimumYieldStrength.

[68] SCC. ISO. https://www.iso.org/member/1619.html.

[69] U.S. National Library of Medicine. (n.d.). Tetrahydrothiophene. National Center for Biotechnology Information. PubChem Compound Database. https://pubchem.ncbi.nlm.nih.gov/compound/tetrahydrothiophene.

[70] Transportation Security Administration (TSA): Usagov. Transportation Security Administration (TSA) | USAGov. (n.d.). https://www.usa.gov/agencies/transportation-security-administration.

people—especially workers and communities impacted by the energy transition and those historically underserved by the energy system and overburdened by pollution. [71]

Unified Command (UC) - A collaborative process that allows agencies with different responsibilities for an incident to work together to manage it. It's an application of the Incident Command System (ICS) that's used when more than one agency is involved, or when the incident crosses political jurisdictions.

[71] About the office of Energy Efficiency and Renewable Energy | Department of Energy. (n.d.). https://www.energy.gov/eere/about-office-energy-efficiency-and-renewable-energy.

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17.0 APPENDICES

- Appendix A - SoCalGas Standards Review Summary

Appendix A

SOCALGAS STANDARDS REVIEW SUMMARY

Title 49 CFR Part 192 and GO-112F are the regulatory codes having jurisdiction for pipelines transporting hydrogen and other gases. This applies to both SoCalGas natural gas infrastructure and the proposed Angeles Link hydrogen infrastructure. These regulatory codes cover a wide variety of requirements which can generally be grouped into: Design, Construction, Operations and Maintenance. 49 CFR Part 192.605 contains specific language for a procedural manual for operations, maintenance, and emergencies. Regulatory code(s) for hydrogen transportation in pipelines will impact SoCalGas's existing specifications, standards, and procedures (SSPs) accordingly. Code-specific language is an important component of the SSPs that can drive the workforce training program and operator qualification program for operator personnel.

Methodology for Specifications, Standards & Protocols Evaluation

The evaluation conducted as part of this work scope focused on the existing specifications, standards, and procedures for applicability to hydrogen gas and potential for new procedure development. SoCalGas specifications, standards, and procedures were reviewed and categorized per the following methodology:

1. Specifications, standards, and procedures were reviewed by regulatory codes outlined in the document profile summary (at the end of each SSP), emphasizing 49 CFR Part 192 and CPUC GO-112F requirements. Each SSP was reviewed for applicability and efficacy for hydrogen infrastructure.

    - Not applicable to hydrogen service
    - Changes/editing are not required but are applicable for hydrogen service
    - Changes/editing will be required for hydrogen service
    - New standards, specifications, or procedures that may be needed due to evolving hydrogen regulations

2. The SSP review was documented and formatted to include the SSP number, Title, and applicable 49 CFR Part 192 regulatory codes, along with the above designated categories.

Summary

The following specification and standard topics covering SoCalGas's current natural gas operations should be considered for modifications or new specifications / standard development for implementation of a clean renewable hydrogen energy transport system:

1. Material requirements
2. Material traceability requirements
3. Facility maps (for new production, transmission, and storage facilities)
4. Control room management plan
5. Equipment specifications (e.g., gas compressor specifications and pressure vessel specifications updated to include specifics for hydrogen service)
6. Fire prevention and protection plan
7. Operator qualification program
8. Corrosion control and monitoring requirements
9. Leak testing and monitoring requirements
10. Integrity management programs

Of the approximate 1,600 SSPs reviewed;

- Approximately 21% of SoCalGas's current SSPs are not applicable to hydrogen service
- Approximately 34% of SoCalGas's current SSPs are applicable to hydrogen service and may require changes or revisions
- Approximately 30% of SoCalGas's current SSPs are applicable but may not require changes or revisions
- The remaining 15% of SoCalGas's current SSPs may require a new SSP specific to hydrogen service