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Modeling and Risk Assessment of Hydrogen/Natural Gas Blends

Project ID: SCS035

DOE Project Award #: CPS # 9686

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DOE Hydrogen Program

2024 Annual Merit Review and Peer Evaluation Meeting

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This presentation does not contain any proprietary, confidential, or otherwise restricted information

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Project Goals

Develop a rigorous **scientific & engineering** basis for assessing the differential safety risk of natural gas/H_2 blends compared to traditional natural gas compressor stations and **investigate the impact of blends** in electrical code classification

- Evaluate the difference in leak frequency between natural gas/H_2 blends and natural gas for use in a differential QRA
- Validate reduced-order models and tools in an integrated framework (HyRAM+) to support a safer deployment of new natural gas/hydrogen blend technologies
- Inform electrical code classification requirements for the compressor stations along pipelines utilizing blended gas
- Demonstrate leadership in the international harmonization of standards for natural gas/hydrogen blends, including compressor stations

Overview

Timeline and Budget

- Project Start Date: 12/13/2022
- Project End Date: 11/15/2024
- Total Project Budget: $700,000
  - Total DOE Share: $490,000
  - Total Cost Share: $210,000
  - Total DOE Funds Spent: $171,603
  - Total Cost Share Funds Spent: $121,901
    - *As of 03/06/2024

Barriers

- Risk informed codes and standards
- Safe deployment of new blend technologies
- Harmonization of electrical codes

Partners

- Austin Glover (PI, Sandia National Laboratories)
- Industry & Research Collaborators:
  - PRCI, 40+ organizations using HyRAM+
- Codes and Standards Evaluation:
  - NFPA 70, NFPA 497

Relevance/Potential Impact

SCS Goals

- Facilitating the creation, adoption, and harmonization of regulations, codes, and standards (RCS) for hydrogen and fuel cell technologies
  - Through analyzing the frequency and consequence of blend leaks in compressor stations, this project can help inform the specific codes and regulations that benefit this emerging area
- Conducting research to generate the valid scientific bases needed to define requirements in developing RCS
  - Investigating the impact of blends on electrical code classification will inform application of regulations, codes, and standards in compressor stations
- Performing R&D to inform deployment and enable compliance with RCS
  - The analysis will directly impact ongoing efforts at PRCI to collaboratively address research priorities related to blending hydrogen into the pipelines. By performing this analysis prior to the implementation of hydrogen blending, member pipelines will be able to assess the risk at different blend percentages and inform necessary facility modifications to ensure compliance with current RCS and reduce safety risk
- Developing and enabling widespread dissemination of safety-related information resources and lessons learned
  - The validation of blend physics models in HyRAM+ and the risk analysis will be critical to the implementation of large-scale hydrogen blending. It will help pipeline owners know the applicable code classification and what modifications may be necessary to accommodate blended gas

Approach and Milestones

- Perform a differential quantitative risk assessment of blended hydrogen and natural gas systems compared to that of a pure natural gas system
  - Perform probabilistic comparisons of leak rates for hydrogen and natural gas components to gain insight into leak size and frequency for blended gas
  - Validate the physics models in HyRAM+, such as dispersion, flammability, ignition energy, and heat flux for mixtures of hydrogen and natural gas
- Identify differences between Group requirements in Class 1, Division 2 in the electrical code classification and investigate necessary facility modifications
  - Perform a literature survey to identify the metrics utilized in group requirements and identify the thresholds of blend percentages moving into the different groups
  - Examine the potential for existing equipment within the compressor stations to comply with the group safety requirements and identify possible facility modifications

Software available at hyram.sandia.gov.

Approach and Milestones

Projected Completion Date	Milestone Description	Percent Complete
12/31/2022	Define new model for at least 1 of the physics model using data from literature.	100%
3/31/2022	Identify the different requirements of electrical equipment groups.	100%
6/30/2023	Define all necessary new physics models to address blends and begin implementation into the HyRAM+ toolkit	100%
9/30/2023	Examine the potential for existing equipment within the compressor stations to comply with the Group safety requirements.	100%
3/31/2023	Make probabilistic comparisons of leak rates for hydrogen and natural gas components.	25%
3/31/2024	Finalize HyRAM+ modification to address blends.	75%
3/31/2024	Identify facility modifications to comply with the enhanced Group requirements for blends.	50%
6/30/2024	Perform differential quantitative risk assessment for a typical gas compression station by analyzing each component included in this subsystem.	5%
11/15/2024	Final report for the differential risk and electrical code classification changes under blending.	0%

Approach: Safety Planning and Culture

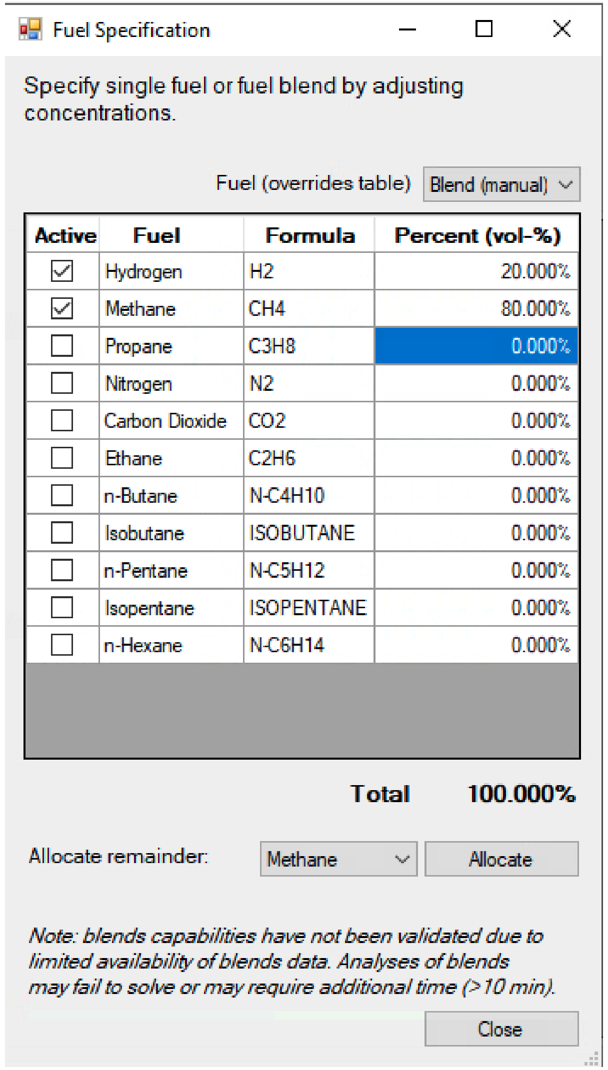
This project was not required to submit a safety plan to the Hydrogen Safety Panel (HSP)

- This project is **analysis-only**

Progress: Hydrogen Blends in HyRAM+

- **Physics model support** for hydrogen/natural gas blends included in HyRAM+ 5.0
- Physics models are currently implemented to characterize the behavior of a hydrogen/natural gas blend leak
- Blends consequence was **validated** with data spanning the composition range

HyRAM+ blends specification menu in graphical user interface



HyRAM+ Hydrogen Plus Other Alternative Fuels Risk Assessment Models

HyRAM+ was validated to support hydrogen/natural gas blends consequence analysis

Progress: Blend Leak Frequency Assessment

- Developed methodology for blend leak frequency analysis
  - Utilize previously defined CNG and hydrogen leak frequency data
  - Incorporate CNG leak frequency data for compressor stations from PRCI partners
  - Identify operating blend leak frequency data
  - Define a typical compressor station for the leak frequency assessment and risk analysis
- Perform base case analysis with multiple sensitivity cases to assess uncertainty

Base Case and sensitivity analyses will assess uncertainty in leak frequency application

Progress: Compressor Station Component Definition

- In order to perform a **differential risk assessment** of compressor stations with natural gas and blends, it is necessary to know the number of components in a typical station
- The **component count** is used with the component level leak frequencies to define the system level leak frequency
- A **literature survey** was conducted to gather publicly available information on component count
- A **walkdown** of a compressor station was performed as an additional data point
- PRCI member pipelines provided **expert judgement** and **additional data** to define the component definition of a typical compressor station
- Since there are multiple size ranges, component definitions were developed for small, medium, and large compressor stations

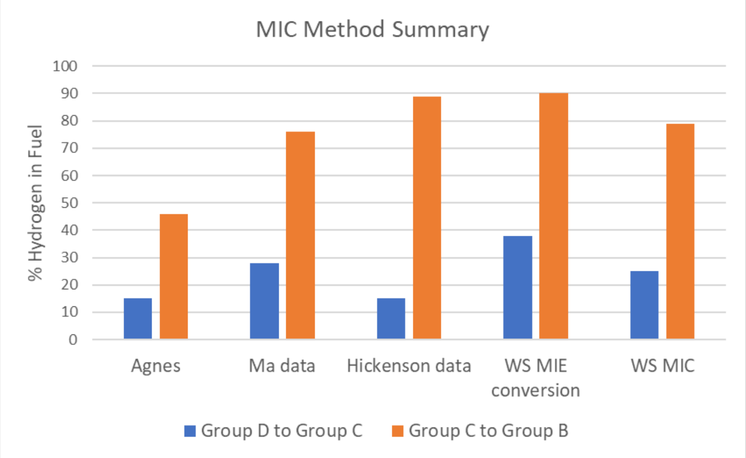
The compressor station component definition was developed as an input to the leak frequency assessment

Progress: Electrical Code Classification Blend Assessment

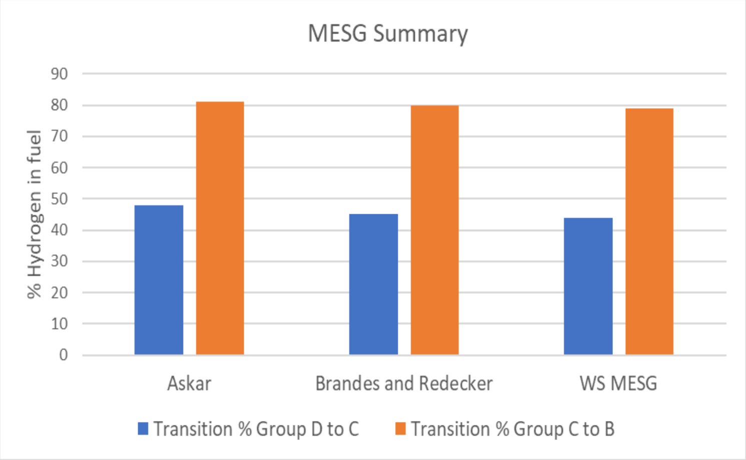
- Performed literature review of electrical code classification in NFPA 70
  - Class 1, Division 2, Group B and D requirements are based on the following metrics
    - MESG: Maximum experimental safe gap
    - MIC Ratio: Minimum current to ignite gas of interest divided by minimum current to ignite methane
  - Experiments and models with regard to MESG and MIC ratio in blends have been identified and threshold calculations have been performed
  - This will help define the hydrogen percentage at which the group transition occurs
- Currently identifying equipment specifications for the different groups within the division boundaries

Class 1, Division 2, Group transition calculations have been performed to inform the code classification assessment

Summary of MIC Ratio Calculation Methods and resulting transition %



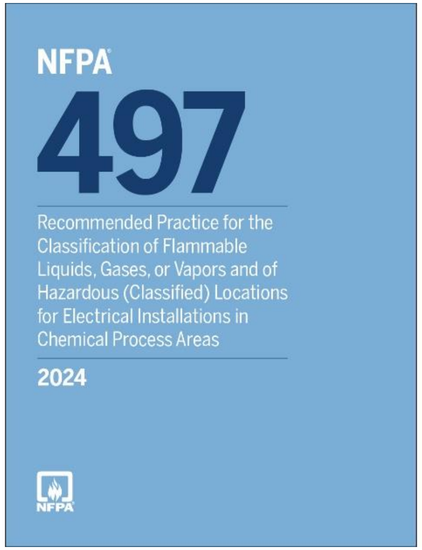
Summary of MESG Calculation Methods and resulting transition %



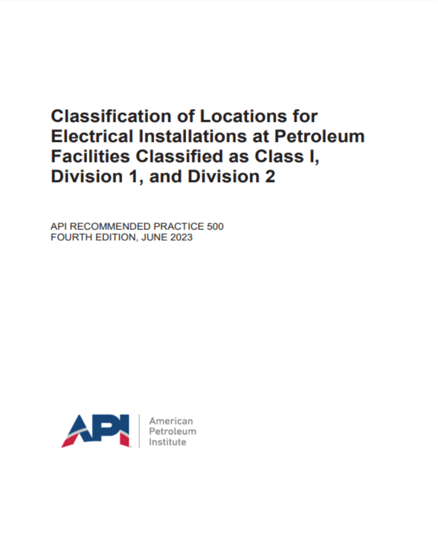
Progress: Electrical Code Classification Standoff Distance

- Physical standoff distances for equipment are defined in NFPA 497 and API RP 500 and 505
- These standoff distances for divisions/groups are a function of the gas physical characteristics
- Research has been conducted on how the standoff distances may change as a function of blend percentage
- The necessary modifications based on the division/group and blend percentage are being evaluated

NFPA 497 Code used for Standoff Distance Calculation



API RP 500 used for Standoff Distance Calculation



The physical standoff distance for divisions/groups are evaluated for the full range of blend percentage

Responses to Previous Year Reviewers' Comments

This project has not been reviewed previously at an AMR

Collaboration and Coordination

- PRCI
  - CRADA participant and Cost Share partner
  - Industry
  - Provide design information, analysis feedback, and general guidance of project
- PRCI is vital to the success of this project, as they bring together leading energy pipeline companies to perform research and development to confront pressing challenges facing pipeline systems. They are providing the project team vital information on the design of the compressor stations to be analyzed. Sandia National Laboratories and PRCI members meet on a monthly basis to discuss progress and exchange information.

DEIA/Community Benefits Plans and Activities

Not required; this project does not have a DEIA or Community Benefits Plan

Remaining Challenges and Barriers

- Limited availability for natural gas/hydrogen blend leak frequency data for relevant conditions
  - Operating blended pipelines are not prevalent
- Determining the necessary modifications to current equipment to comply with the electrical code classification
  - Assessing the equipment specifications in relation to the different metrics and determining the correct application leads to uncertainty in the group classification
- Evaluating the uncertainty in leak frequency methodology for the differential risk assessment
  - Ensuring that the appropriate sensitivity cases are evaluated to determine how the leak frequency methodology affects the overall risk assessment

Proposed Future Work

- Differential Risk Assessment
  - Finalize the incorporation of additional data into the leak frequency methodology (FY24)
  - Perform differential Risk Assessment of natural gas system vs. system with hydrogen/natural gas blends (FY24)
- Electrical Code Classification
  - Examine potential for existing equipment to comply with group safety requirements (FY24)
  - Identify facility modifications to comply with requirements for blends (FY24)

Any proposed future work is subject to change based on funding levels

Summary

Relevance: Through analyzing the frequency and consequence of blend leaks in compressor stations, this project can help inform the specific codes and regulations that benefit this emerging area

Approach:

- Perform a differential quantitative risk assessment of blended hydrogen and natural gas systems compared to that of a pure natural gas system
- Identify differences between Group requirements in Class 1, Division 2 in the electrical code classification and investigate necessary facility modifications

Progress:

- The typical component definition for compressor stations has been developed through a literature survey, expert elicitation, and walkdowns
- Leak frequency methodology has been developed and multiple additional data sources have been identified. Implementation of these sources into the existing data is ongoing
- Identified multiple methods to calculate blend percentage threshold and performed calculations

Future Work:

- Differential Risk Assessment
  - Finalize leak frequency approach
  - Perform differential Risk Assessment
- Electrical Code Classification
  - Examine potential for existing equipment to comply with group safety requirements
  - Identify facility modifications to comply with requirements for blends