NYSEARCH
Natural Gas RD&D

QUALITY INTEGRATED SERVICES

Risk Assessment of H_2-Enriched (HENG) Natural Gas on LNG Plants

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NYSEARCH

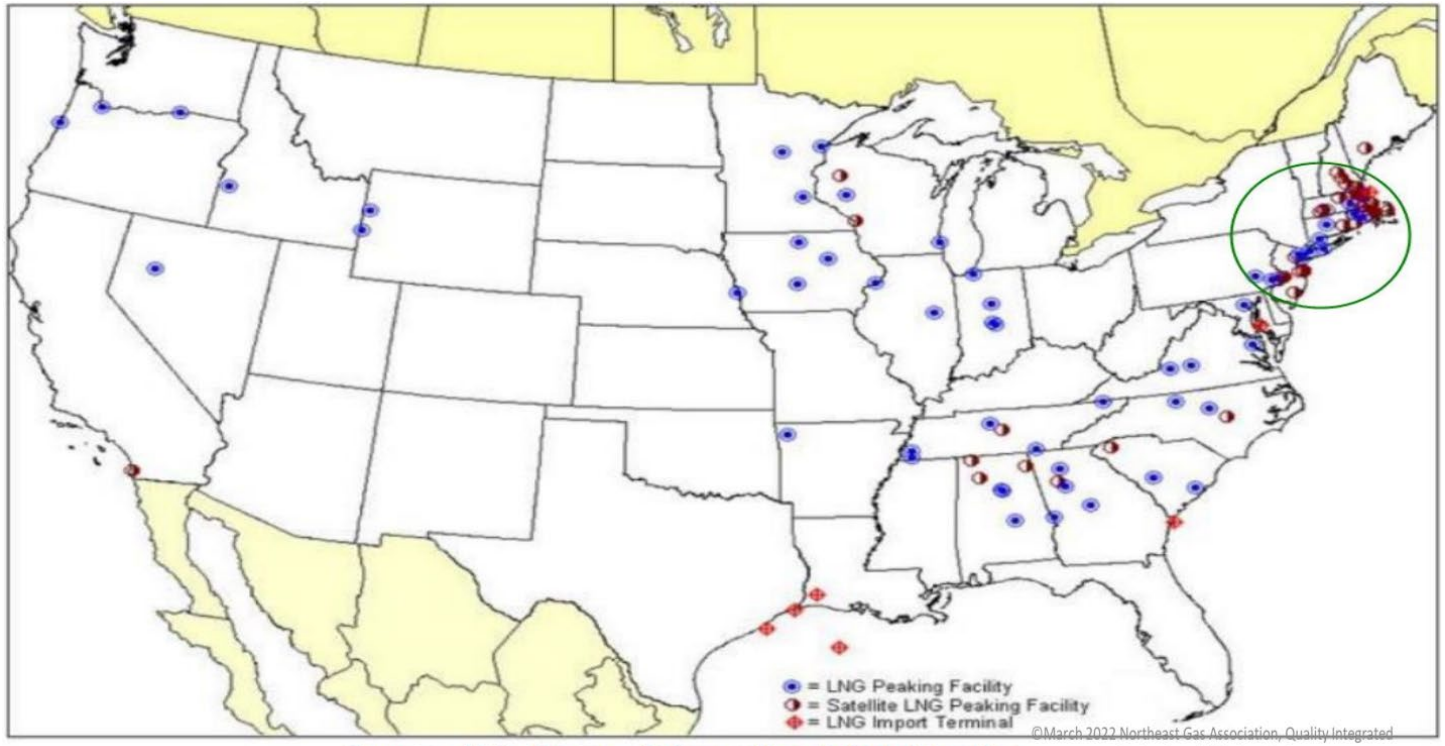
- NYSEARCH is a sub-organization of NGA that conducts voluntary RD&D on behalf of 20+ utilities located in the United States and Canada
- Serving the gas utility industry by identifying and executing research programs to advance the safety, integrity, and efficiency of the gas utility
- Voluntary-based funding
- High leverage of R&D dollar
- Unique access to this collaborative group provides information on state-of-the-art technologies and knowledge from member companies that experience similar, if not the same, challenges in operations

NYSEARCH Natural Gas RD&D

NGA NORTHEAST GAS ASSOCIATION

BACKGROUND

- November 2021, NGA conducted an H_2 Enriched NG Technical Workshop
- Thank you to the companies funding the project
  - Con Edison, National Grid, Baltimore Gas and Electric, Dominion Utah, Southwest Gas, Connecticut Natural Gas, and Eversource



Source: U.S. Energy Information Administration

POTENTIAL RISKS WITH H_2 IN THE FEED GAS

Potential for increased leaks and material embrittlement throughout the LNG Plant

High boiling point causing hydrogen to stay mostly as a vapor in the Boil-Off-Gas (BOG)

ONGOING NYSEARCH MULTI-PHASE PROGRAM

- Objectives:
  - Determine and evaluate the impacts of HENG on plant materials and plant operations
  - Determine potential feedstock pretreatment and hydrogen rejection options

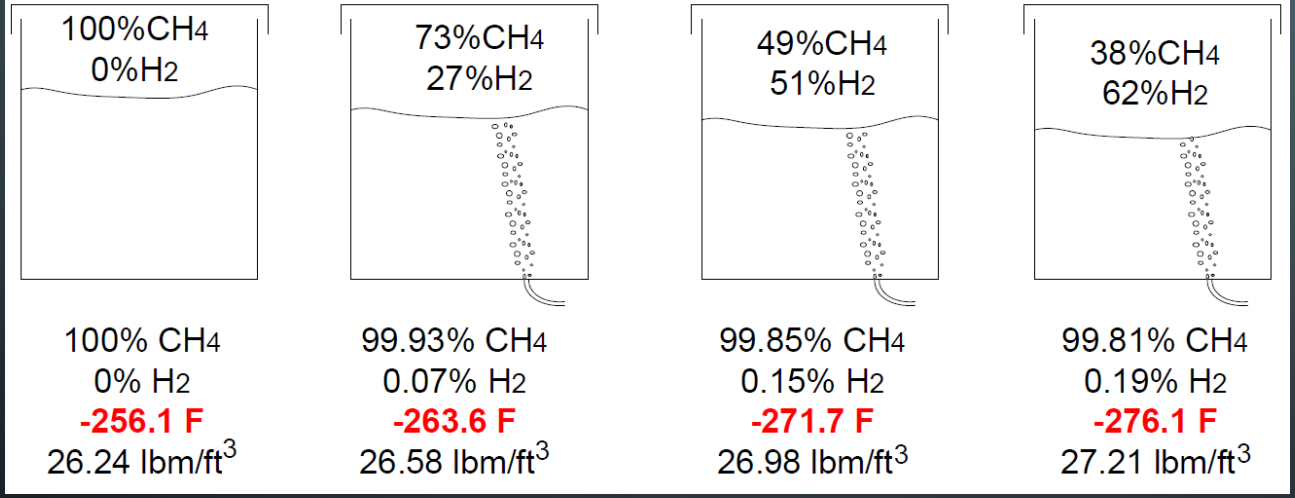
NYSEARCH PROJECT PHASE I

Phase I: HENG LNG Feedstock Implications Study

- Develop an inventory of materials from the participating funders
- Perform detailed analysis of four participating funder facilities
- Identify any additional needs for further research

THERMODYNAMIC MODELS WITH LIQUID METHANE

Well insulated tank at 16.5 paia and hydrogen bubbled through the liqiud methane
Using a combination of REFPROP and HYSYS data



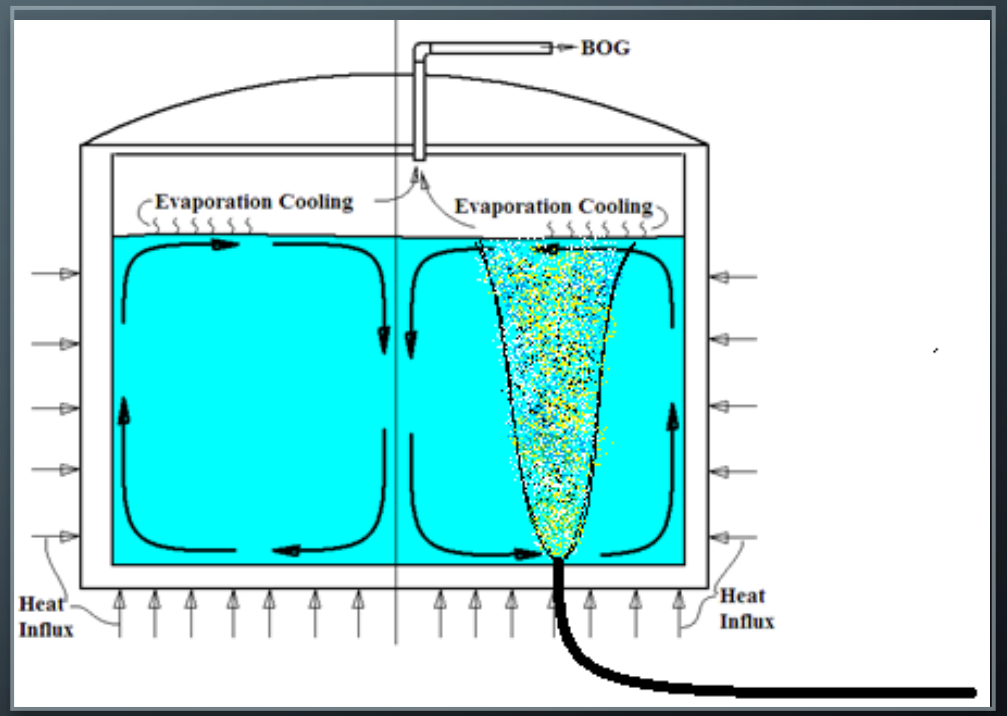
100% CH_4	99.93% CH_4	99.85% CH_4	99.81% CH_4
0% H_2	0.07% H_2	0.15% H_2	0.19% H_2
-256.1 F	**-263.6 F**	**-271.7 F**	**-276.1 F**
26.24 lbm/ft^3	26.58 lbm/ft^3	26.98 lbm/ft^3	27.21 lbm/ft^3

- Considered what happens when we bubble pure hydrogen through an existing inventory of liquid methane
- Found that the methane vapor pressure above the liquid becomes lower as hydrogen is added

CHANGES AFFECTING THE LNG

- Methane bubbles would condense in the subcooled liquid methane at the bottom of the tank

- H_2 bubbles would not condense but rise through the liquid methane
  - H_2 concentration dominates temperature and temperature dominates LNG density



HENG ACROSS A JT VALVE

- Stream 1: Upstream of JT valve
- Stream 2: Downstream of JT valve
- Small amount of H_2 in the LNG made the LNG colder, making LNG denser and lowering the temperature

Run Name	Stream 1					Stream 2					
	Psia	T (F)	Mth	H2	Type	Psia	T	Mth vap	H2 vap	Mth liq	H2 liq
Methane and Hydrogen Only											
1% H_2, C1, 15.5	400	-258	99.00%	1.00%	M/H	15.5	-264.2	75.06	24.94%	99.94%	0.06%
1% H_2, C1, 16.5	400	-258	98.96%	1.04%	M/H	16.5	-263.6	72.76%	27.24%	99.93%	0.07%
5% H_2, C1	400	-258	95.00%	5.00%	M/H	16.5	-271.7	48.70%	51.30%	99.85%	0.15%
10% H_2, C1, 14.5	400	-258	90.00%	10.00%	M/H	14.5	-277.6	40.17%	59.83%	99.83%	0.17%
10% H_2, C1, 15.5	400	-258	90.00%	10.00%	M/H	15.5	-276.8	39.30%	60.70%	99.82%	0.18%
10% H_2, C1	400	-258	90.00%	10.00%	M/H	16.5	-276.1	38.47%	61.53%	99.81%	0.19%
20% H_2, C1	400	-258	80.00%	20.00%	M/H	16.5	-281.4	28.51%	71.49%	99.76%	0.24%

DEFINING THE RISK OF MATERIALS WITH HENG

- Objective: High-level review of candidate materials for compression/refrigeration of 10% hydrogen to the refrigeration of natural gas to LNG
- Low Risk: Successful history of service in similar or comparable hydrogen applications
- Medium Risk: A history of problems or documented failures in hydrogen service
- High Risk: Further study is required to determine the suitability
  - LNG Storage Tanks, Flash Compressors, etc.

NYSEARCH PROJECT PHASE II

Phase II: HENG Feedstock Pre-treatment Mitigation Measure Options to Enable Facility Operations

- Considering a range of pre-treatment, recovery, and reinjection options

HYDROGEN REMOVAL CONCEPTUAL STUDY

- Conceptual study with Air Liquide to determine the feasibility of removing hydrogen from the feed gas to achieve ppm levels of hydrogen in the residue stream

- Feed gas containing 5%-20% hydrogen

Case Number	Inlet H2 Content (Mol%)	Target H2 Content (Mol%)	Target H2 Content with AL Design
1	5%	0.50%	N/A
2	5%	0.50%	0.01%
3	10%	0.10%	N/A
4	10%	0.50%	N/A
5	10%	0.50%	0.01%
6	20%	0.50%	N/A
7	20%	0.10%	N/A
8	20%	0.50%	0.01%

GAPS TO BE ADDRESSED

GAPS BEING ADDRESSED

- What equation of state thermodynamic modeling software is available to examine natural gas/hydrogen blends? (non-convergence/accuracy of REFPROP and HYSYS)?

FUTURE GAPS TO BE ADDRESSED

- Can a laboratory or in-field experiment be made to validate these software outputs?
- Can we determine if stressed 9% Nickel steel will experience Hydrogen Stress Corrosion Cracking (HSCC) at cryogenic temperatures?
- What is the preferred management method of the off-gas that contains hydrogen?

THANK YOU

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