NYSEARCH Natural Gas RD&D

QIS QUALITY INTEGRATED SERVICES

IMPACTS OF H2-ENRICHED NG FOR FEEDSTOCK OF LNG LIQUEFACTION

PHMSA LNG WORKSHOP NOVEMBER 15, 2022

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NYSEARCH

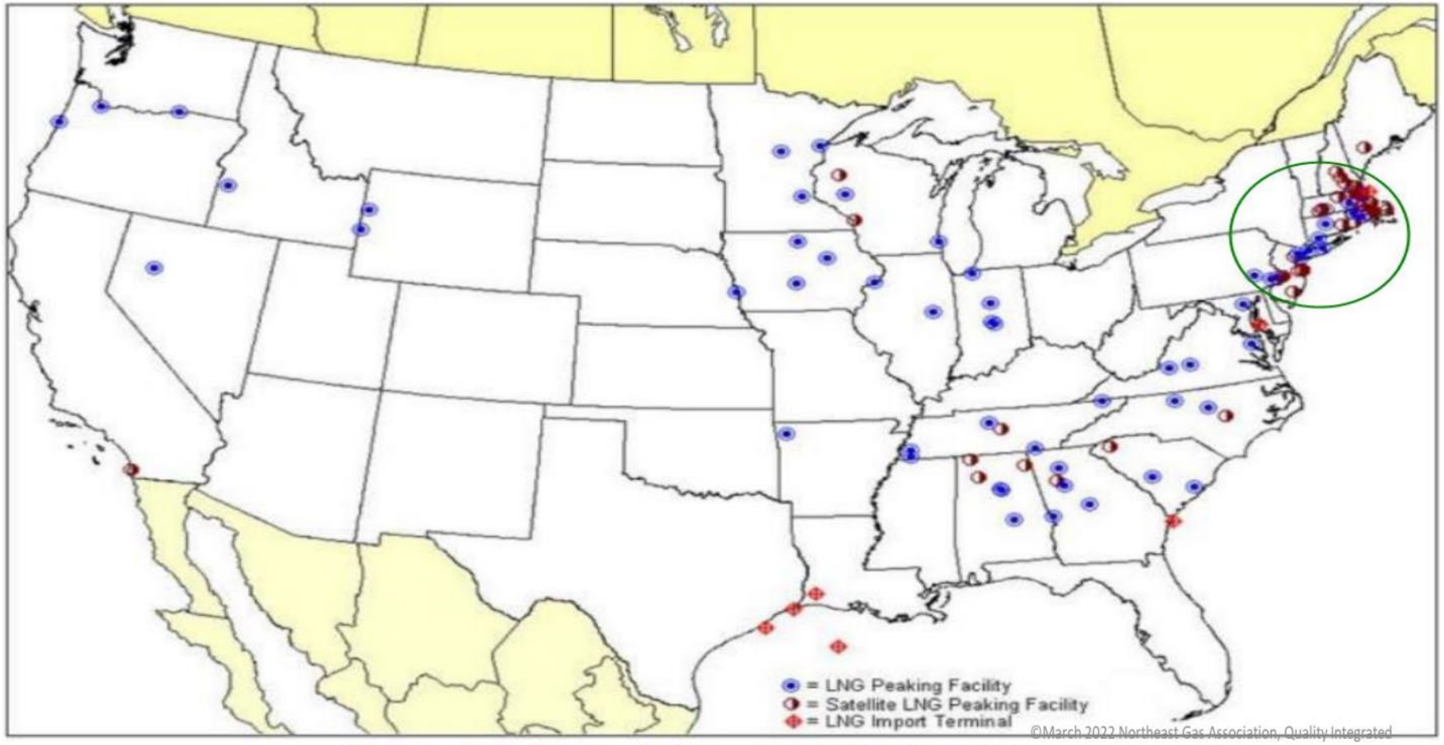
- NYSEARCH is a sub-organization of NGA that conducts voluntary RD&D on behalf of 20+ utilities located in the United States and Canada
- Serving the gas utility industry by identifying and executing research programs to advance the safety, integrity, and efficiency of the gas utility
- Voluntary-based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

NYSEARCH Natural Gas RD&D

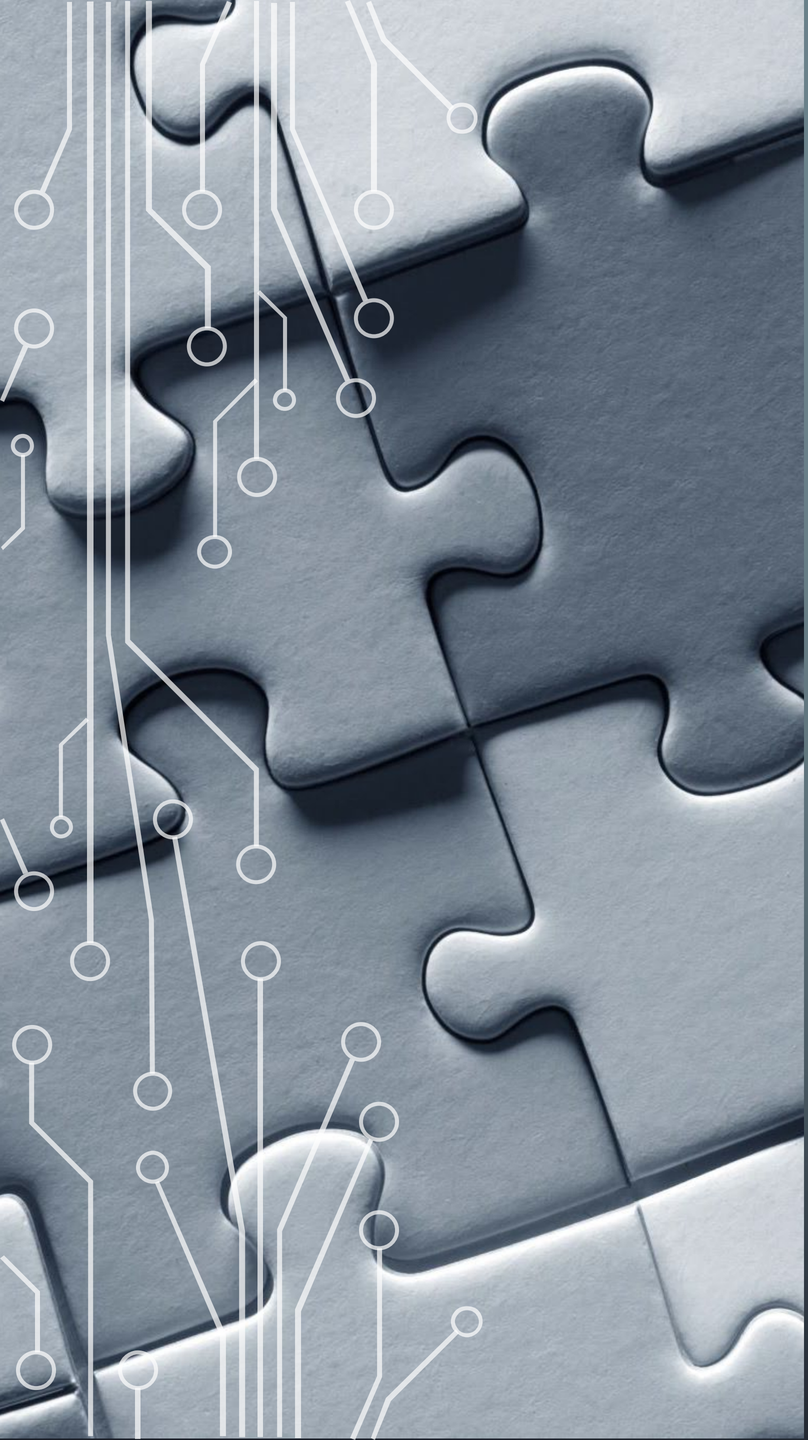
Northeast GAS ASSOCIATION

BACKGROUND

- November 2021, NGA conducted an H2 Enriched NG Technical Workshop
  - NGA, AGA, NYSEARCH, and other companies who attended the workshop endorsed the idea to investigate the challenges and mitigation techniques should NG liquefaction pipelines include H2



Source: U.S. Energy Information Administration



NYSEARCH MULTI-PHASE PROGRAM

Phase I: HENG LNG Feedstock Implications Study

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

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

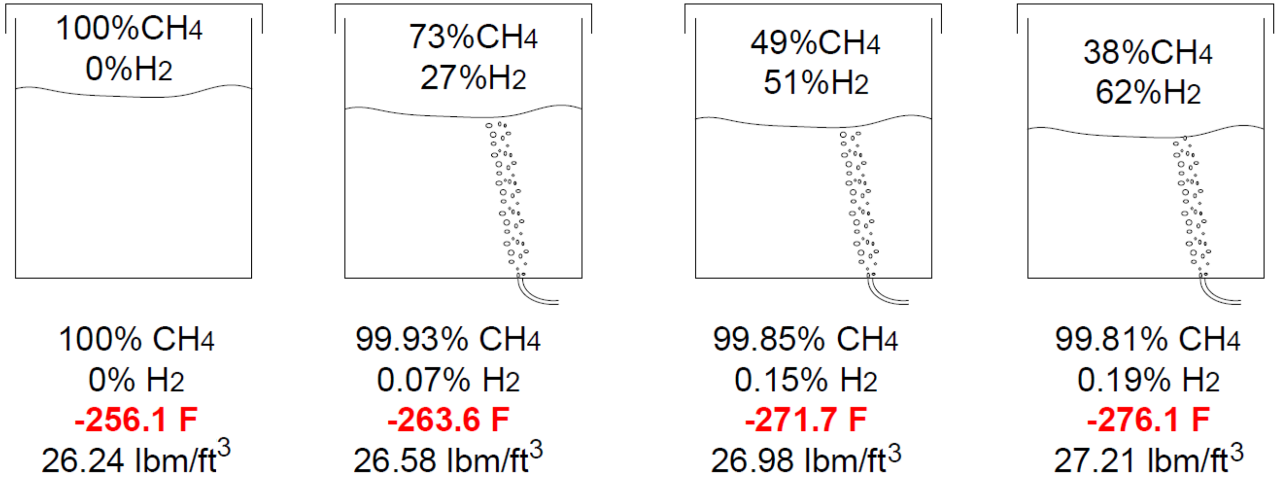
- Consider a range of pre-treatment, recovery, and reinjection options

THINGS ARE CHANGING IN OUR INDUSTRY

- The likelihood of Hydrogen Enriched Natural gas (HENG) coming into the natural gas system is high
- Hydrogen “for the most part” stays a vapor as it passes through a liquefaction plant, but it does behave oddly with phase changes related to pressure and temperature
- During the liquefaction process at higher pressures H2 does see phase changes, which can significantly affect liquefaction capacity and ability to liquefy (CB&I article October 22 “LNG Industry”)
- Our findings involve the impact of very small concentrations of H2 that does liquefy into the LNG inventory if not removed from the LHENG process
  - Hydrogen will most likely need to be removed from the feed gas before liquefaction (GasTech AP presentation 9/29/22)

THERMODYNAMIC MODELS WITH LIQUID METHANE

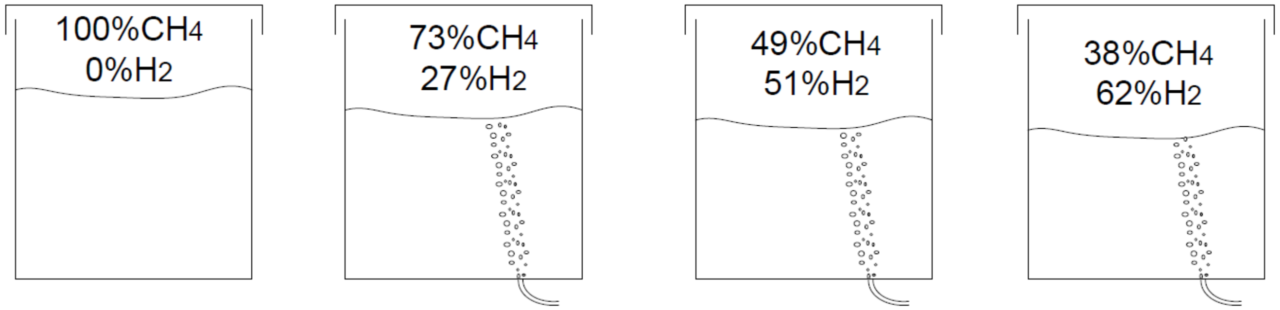
Well insulated tank at 16.5 paia and hydrogen bubbled through the liqiud methane
Using a combination of REFPROP and HYSYS data



- Consider what happens when we bubble pure hydrogen through an existing inventory of LM
- H2 concentration dominates temperature and temperature (not H2 concentration) dominates LM density

HYDROGEN WITH LIQUID NATURAL GAS

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

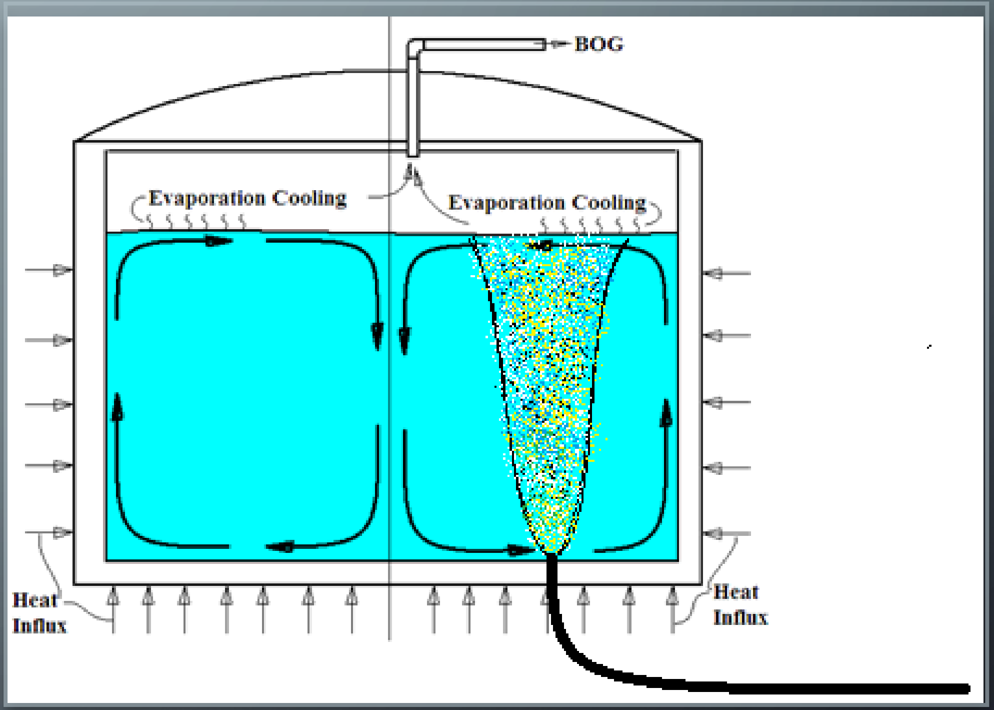


100% CH_4	99.93% CH_4	99.85% CH_4	99.81% CH_4
0% H_2	0.07% H_2	0.15% H_2	0.19% H_2
-256.1 F	**-263.6 F**	**-271.7 F**	**-276.1 F**
26.24 lbm/ft^3	26.58 lbm/ft^3	26.98 lbm/ft^3	27.21 lbm/ft^3

- Consider what happens when we bubble pure hydrogen through an existing inventory of LNG
- Where did the cooling come from?
  - "Forced" additional CH4 evaporation
- The methane vapor pressure above the liquid becomes much lower as hydrogen is added

DENSITY OF THE LNG, STRATIFICATION, AND OUT-GASSING

- Indeterminant
  - When the bubbles are methane, they would condense in the subcooled LM at the bottom of the tank
  - When the bubbles are hydrogen, they do not condense but rise through the LM



ASSUME WE CAN GET THE LIQUEFIER TO MAKE COLD HENG BEFORE THE JT VALVE, THEN WHAT HAPPENS ACROSS THE JT VALVE?

- HYSYS was used to flash LM and LNG across a JT valve from 400 psia to tank pressure.
- We know LNG production would be reduced due to:
  - Reduced residence time in heat exchangers
  - Cooling of vapor that refuses to liquefy – that cold vapor enters and then leaves the tank
  - Heat transfer to a vapor is much less than to a liquid
- Presume these issues are overcome and we have the refrigerated Liq/Vap HENG upstream of the JT valve. What happens after the JT valve?

HENG ACROSS A JT VALVE

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%
LNG including Methane, Ethane, Propane, Nitrogen and Hydrogen											
1% H_2, LNG	400	-229	94.30%	1.00%	LNG	16	-258.6	90.13%	7.62%	94.92%	0.02%
2% H_2, LNG	400	-229	93.30%	2.00%	LNG	16	-260.2	84.04%	13.87%	94.83%	0.04%
3%, H_2, LNG	400	-229	92.30%	3.00%	LNG	16	-261.6	78.80%	19.16%	94.75%	0.06%
4% H_2, LNG	400	-229	91.30%	4.00%	LNG	16	-262.8	74.42%	23.74%	94.66%	0.07%
5% H_2, LNG	400	-229	90.30%	5.00%	LNG	16	-263.9	70.81%	27.46%	94.57%	0.80%
6% H_2, LNG	400	-229	89.30%	6.00%	LNG	16	-264.8	67.73%	30.64%	94.47%	0.08%
7%, H_2, LNG	400	-229	88.30%	7.00%	LNG	16	-265.7	65.00%	33.45%	94.38%	0.11%
8%, H_2, LNG	400	-229	87.30%	8.00%	LNG	16	-266.4	62.57%	35.96%	94.28%	0.12%
9%, H_2, LNG	400	-229	86.30%	9.00%	LNG	16	-267.2	60.37%	38.23%	94.18%	0.12%
10% H_2, LNG	400	-229	85.30%	10.00%	LNG	16	-267.8	58.37%	40.28%	94.08%	0.13%
20% H_2, LNG	400	-229	75.30%	20.00%	LNG	16	-272.5	46.12%	52.92%	94.11%	0.19%

SUMMARY OF FINDINGS

- A full 1 BCF tank contains ~ 42,500,000 lbm of LM
- Amount of heat needed to lower 42,500,000 lbm of LM 5°F would be 177,000,000 Btu (Cp = 0.835 Btu/lbm °F).
- All the cooling is from the evaporation of methane forced by the lower vapor pressure of methane.
  - Fick's Law, Daltons Law, LaChatelier's principle
- The amount of heat leak that comes into the tank each day is approximately 42,500,000 lbm x 0.005 X 218 Btu/lbm = 4,600,000 Btu/day.
  - After a long liquefaction run it would take ~ 50 days for BOG to normalize 177,000,000 Btu/4,600,000 Btu/day = 40 -50 days
- The amount of cooling provided by a 5,000,000 scfd liquefier is:
  - 5,000,000 scfd x .04246 lbm/scf x 356 Btu/lbm = ~ 75,800,000 Btu of heat removed per day.

CHALLENGING OPPORTUNITIES IDENTIFIED DURING THE PROJECT

- Can a laboratory or in-field experiment be made to validate these software outputs?

- Further analysis of the materials of construction impacts of hydrogen in legacy liquefaction facilities and assessing material failure risks with feedstock containing hydrogen.

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

- What is the preferred management method of the off-gas that contains hydrogen?

THANK YOU

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