LCRI LOW-CARBON RESOURCES INITIATIVE

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EXECUTIVE SUMMARY

Economic Cost, Limitations, Challenges and Opportunities of Utilizing Existing Natural Gas Compressor Systems for Transport of Hydrogen and Hydrogen Blends

Blending of hydrogen with natural gas changes many properties of the gas that would be encountered by fuel gas compressors in the U.S. natural gas pipeline network. This research, focused on the upgrades/changes potentially required to existing natural gas pipeline compressors, studies the effects that lower-molecular-weight gas mixtures have on compression dynamics and anticipates the thresholds of hydrogen blending (e.g. percent volume composition of hydrogen) at which existing compressors would need significant upgrade and/or wholesale replacement to have adequate performance and compatibility with the modified gas mixture (greater percent-hydrogen).

A review of literature and the commercial marketplace was performed to identify past research and product development that has informed this topic. An industry-typical natural gas pipeline compressor station layout was assumed, and evaluations were performed for this layout (both for reciprocating compressors and centrifugal compressors) to determine the likely upgrades that would be needed for such a compressor station to operate with various hydrogen blends up to and including 100% hydrogen. Compressor system performance, capital expenditures (CAPEX) and operating expenditures (OPEX) were estimated for these upgrades.

Key findings highlighted from the full-report (3002028177) include:

- Hydrogen has thermodynamic and combustion properties that are significantly different than those seen with typical pipeline natural gas. These differences affect both the required driving pressures for given flow through a pipeline and the ability of existing compressors to maintain the same pressure rise and heating value throughput (GJ/s or MMBtu/hr also known as Dth/hr) performance.
- Especially for centrifugal compressors, the obtainable pressure rise will be limited when operating on high-percentage blends of hydrogen, due to hydrogen's low molecular weight and low density. The lower density decreases the ability of the rotor(s) in centrifugal machines to convert kinetic energy into a corresponding pressure rise.
- Material-of-construction limitations associated with hydrogen (hydrogen partial pressures) may necessitate wholesale replacement of compressor materials (e.g., impellers).

- For a pipeline compressor station that originally features reciprocating natural gas compressors, those original compressors are estimated to remain useful (in upgraded form, with more-powerful drivers) up to a hydrogen blend percentage of approximately 50% volume hydrogen. Beyond that threshold, wholesale replacement of the reciprocating compressors likely would be needed. Note that this threshold for wholesale replacement was driven by reciprocating compressor original equipment manufacturers generally being uncomfortable updating existing, natural-gas-only rated machines for service with blends above 50% volume hydrogen.
- For a compressor station that originally features centrifugal compressors, those original compressors are estimated to remain useful (in upgraded form with more-powerful drivers and impellers) up to a hydrogen blend percentage of approximately 20% volume hydrogen. Beyond that threshold, wholesale replacement of the centrifugal compressors with reciprocating compressors that perform better with a variety of gas molecular weights likely would be appropriate. Note that this threshold for wholesale replacement was driven by the physics for utilizing the original centrifugal compressor casings (with new/novel impeller replacement) to the maximum extent reasonable. Beyond 20% volume hydrogen, the necessary volume flow rate to sustain reasonable compressor station throughput likely would require at least one more compressor in parallel—and with low-pressure rise available from centrifugal compressors with any further increased-percent hydrogen blends, a sensible choice at that point would be to utilize reciprocating compressors for wholesale replacement of the existing centrifugal units.

Proper compression technology and compressor station configurations are required to enable the hydrogen economy to utilize existing natural gas pipeline infrastructure for prudent purposes. Guidance on the adaptation of existing compressor stations to handle greater amounts of hydrogen blending into natural gas is an area in which additional information and research is needed.

Results from this report may be utilized to help gas pipeline operators determine the maximum extent of hydrogen blending possible in their current systems and understand potential upgrades that could assist future operations. Results of this report also act as a high-level guide to conceptual design of how compressor stations might be upgraded/altered to enable future operation with higher percentages of hydrogen blended in with natural gas.

THE LOW-CARBON RESOURCES INITIATIVE

This report was published under the Low-Carbon Resources Initiative (LCRI), a joint effort of EPRI and GTI Energy addressing the need to accelerate development and deployment of low- and zero-carbon energy technologies. The LCRI is targeting advances in the production, distribution, and application of low-carbon energy carriers and the cross-cutting technologies that enable their integration at scale. These energy carriers, which include hydrogen, ammonia, synthetic fuels, and biofuels, are needed to enable affordable pathways to economy-wide decarbonization by mid-century. For more information, visit www.LowCarbonLCRI.com.

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LCRI CONTACTS

NICHOLAS PILOT, *Technical Leader,* 980.495.7489, npilot@epri.com

MICHAEL GAGLIANO, *Technical Executive,* 704.595.2134, mgagliano@epri.com

ROBERT TRAUTZ, *Senior Technical Executive,* 650.855.2088, rtrautz@epri.com

AGYA ANANE-SEKYERE, *Senior Technical Leader,* 972.556.6567, aanane-sekyere@epri.com

Program:

Low-Carbon Resources Initiative (LCRI),

Delivery & Storage Technical Sub Committee (TSC)

For more information, contact:

EPRI Customer Assistance Center
800.313.3774 • askepri@epri.com

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3420 Hillview Avenue, Palo Alto, California 94304-1338 USA • 650.855.2121 • www.epri.com