THE ARROW
A Technical Blog Straight from GATE Energy SMEs

TECHNICAL ARTICLE

Renewables II: How to Use Existing Petrochemical Infrastructure & Integrity Management Expertise for Hydrogen Generation

The challenge for hydrogen generation is that the current, most cost-effective means of generating hydrogen is steam-reforming of methane, as shown in the following reaction:

$$2H_2O + CH_4 \rightarrow 4H_2 + CO_2$$

Steam reforming is considered a "gray" process as the principal by-product is carbon dioxide (CO_2) but the source of the CO_2 is methane from natural gas.

A "greener" process is electrolysis, the electrochemical separation of water, as in:

$$2H_2O + \text{renewable power} \rightarrow 2H_2 + O_2$$

This produces no greenhouse gas but is generally energy intensive.

There are several developments in the area of electrolysis which seek to reduce the cost, increase the yield, or even change the source of transportable hydrogen. These include:

- The development of improved catalysts that will reduce the cost
- Improving the effective yield of electrolysis
- Using solar or wind energy systems to power electrolysis

The development of alternative sources of hydrogen "separation" is ongoing, with some involving high temperatures or improved catalysis, both implying that further work on associated corrosion and degradation mechanisms will also be needed. [1]

Existing Infrastructure

The existing transmission and distribution infrastructure is expected to be acceptable for safe use. Figure 1 shows what the existing natural gas systems in the US consist of. How this lays out as transmission and distribution is shown in Figure 2.

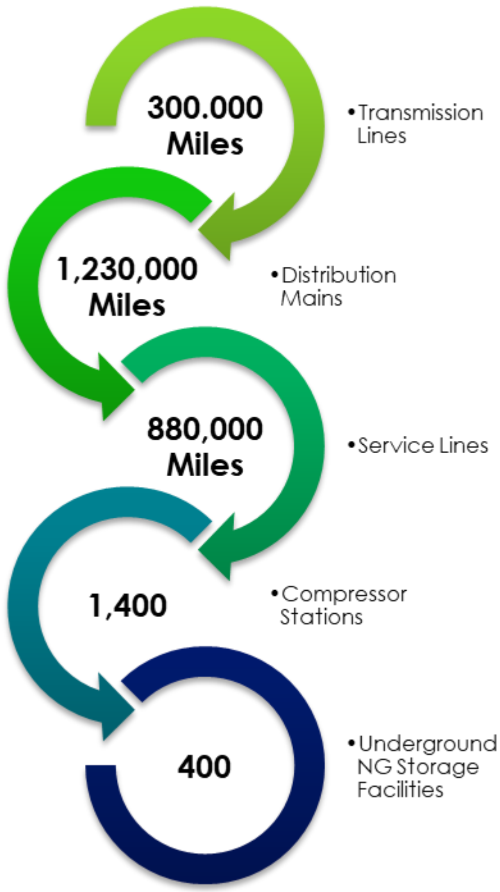

Figure 1: Natural gas infrastructure breakdown [2]

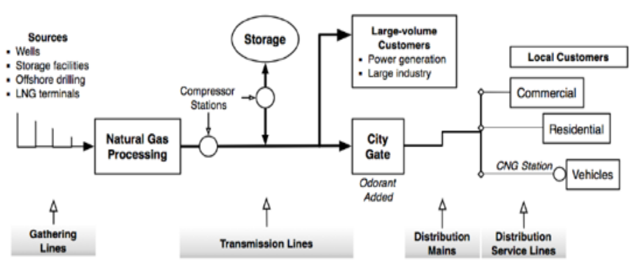

Figure 2: Natural gas supply chain from sources to customers [2]

Difficulties When Switching to A Hydrogen/Natural Gas Delivery System

A good bit of work has been performed to determine what difficulties are likely to be encountered in switching to a hydrogen/natural gas (HNG) delivery system.

A major question initially was whether the H_2/CH_4 blend can be directly used by existing commercial and residential users.

Several studies performed on behalf of the energy industry, including several governments, have determined that for basic end uses (stoves, boilers, heating systems), up to 20% hydrogen requires minor modification. Above 25% hydrogen, some allowance needs to be taken for the variation in flammability and fuel/oxygen ratio required.

The existing infrastructure for natural gas transmission, primarily carbon steel with the remainder largely wrought iron or plastic, is expected to work quite well for delivering a mixture of hydrogen and natural gas. For these lines, the principal threats to the materials of construction are the same as those encountered in natural gas transmission – hydrogen embrittlement, internal corrosion, and external corrosion from soil contact – and can be routinely managed in the same fashion:

- Hydrogen embrittlement – controlled hardness metallurgies, resistant materials
- Internal corrosion – internal coatings, corrosion inhibition, dehydration, UT inspection
- External corrosion – external coatings, cathodic protection, visual and instrumented NDE

Mixing hydrogen with natural gas does result in an increase in leakage through seals in existing systems, with the risk increasing if hydrogen content is above 25%. While the flammability risk is somewhat higher, the rate of dispersion is also somewhat higher. The result is a higher risk of combustion close to a leak and a lower risk further away.

Integrity Management in Design & Operation

'What a thing is made of and what it does determines how it fails' is a truism of materials engineering. In the design of all systems and especially those handling hazardous materials, it is vital to distinguish between those failure modes that:

1. Cannot be precisely predicted before and cannot be stopped after they start.

2. Are generally predictable and can be measured, managed, and/or observed as they progress.

The first needs to be "designed out" – that is the selected materials and fabrication methods prevent those kinds of failures.

The second needs to be "managed" – systems of control and feedback that permit safe operation within a suitable window of conditions that the failure can be predicted and controlled, and equipment inspected and refurbished or replaced before failure.

As said above, the design and operation of HNG transmission systems will be very similar to existing natural gas systems. The risks are the same and the mitigation measures are, as well.

More changes may be required in the design and operation of HNG distribution systems as there is more variety in the materials used between the "city gate" and the end user service point.

New materials such as thermoplastic/carbon fiber composites for piping and highly-engineered low permeation tubing are currently undergoing development (ref. "SoluForce" and DNV-GL JIP) but more options need to be developed and standards adopted.

GATE Energy Can Help

With our legacy of experience in process design, materials selection, risk assessment, and systems analysis, we can provide effective and efficient design, fabrication, and operational support as the energy industry moves into a renewable future.

1. **"Hydrogen Production by Membrane Water Splitting Technologies"**, Mohd Fadhzir Ahmad Kamaroddin,Nordin Sabli and Tuan Amran Tuan Abdullah, Advances in Hydrogen Generation Technologies, Chapter 2, 2018.

2. "**Blending Hydrogen into Natural Gas Pipeline Networks: A Review of Key Issues",** M. W. Melaina, O. Antonia, and M. Penev, NREL/TP-5600-51995, March 2013