MYTH: HYDROGEN FUEL IS THE FUTURE

The use of hydrogen as a power plant fuel is all over the news. Several manufacturers actively promote their capability to burn hydrogen as a gas turbine (GT) fuel. We saw a similar kind of fervor in the 1970s surrounding coal gasification plants, in the 1990s for carbon capture and sequestration initiatives, and now in what is effectively a hydrogen-for-energy-storage play.

There was an entire U.S. Department of Energy program for many years on GT combustion with high-hydrogen fuels. Several OEMs demonstrated their GTs with up to 100% hydrogen fuel.

Let us review the rationality of this trend, beginning with the source of hydrogen. There are two processes commonly used to obtain hydrogen in large quantities.

1. Partial oxidation via synthesis gas from coal or natural gas using gasification or steam reforming. This is the most common process used by process, refinery and chemical companies to make hydrogen in industrial quantities. If the argument for hydrogen production is driven by atmospheric decarbonization, hydrogen production from fossil fuels does not resolve the greenhouse gas issue.
2. Electrolysis of water. It only makes sense if water is cheap or freely available. The conversion efficiency of electrolysis is less than one on an electric energy in (in electric kW-hr) versus hydrogen chemical heat energy out (in Joules or BTU) basis.) This concept only works for energy storage applications where electricity is available from intermittent power plants, such as wind or solar. Hydrogen from electricity, then, is effectively nothing more than an energy storage option, and possibly an energy transportation alternative if one considers hydrogen transport by pipeline or truck.

Now let us talk about using hydrogen for power. From the GT perspective, hydrogen is an excellent fuel. It is flammable, has good flame stability and has a reasonable heating value.

There are drawbacks:

- A low auto-ignition temperature and delay time
- A high flame speed, which can cause flashback difficulties
- A higher water percentage in the exhaust, which may require a firing temperature reduction to keep hot-section parts' life unaffected.

Hydrogen combustion also requires a secondary liquid or gas fuel and purge skid for safety during startup and shutdowns.

Hydrogen combustion up to 100% in GTs has been done for the last 40 years by multiple vendors for gasification, steel mill and refinery applications. A customized combustor and fuel gas supply system is required.

But otherwise hydrogen-fueled GTs are a manageable engineering challenge. Obviously, package safety must be considered, and special purge cycles must be implemented to avoid explosion risk during failed starts.

Originally, most GT hydrogen combustors were diffusion flame with a diluent for NOx control. More recently, there have been developments for lean pre-mixed combustors for hydrogen with high-velocity pre-mixers, micro-mixers or staged combustion systems.

There is a reason that hydrogen in its pure form does not occur abundantly in nature unlike other fuels, such as coal, natural, gas and oil. It is highly reactive and, thus, very explosive.

This makes it difficult to handle, store and transport. Does this sound like a great energy storage medium? It is not necessary go all the way back to the Hindenburg airship or Challenger Space Shuttle accident to find problems with hydrogen. Recent hydrogen fueling station explosions in California and Norway are reminders that it is must be handled carefully.

Aside from volatility, there are major economic challenges. The roundtrip energy-storage efficiency of hydrogen-based systems is low. Production from electrolysis based on energy in versus energy stored is 70% to 80% for modern systems.

State-of-the-art efficiency of heat engines is below 65%. Therefore, total storage roundtrip is at best 50% without considering parasitic and auxiliary losses. Once compression power, leakage and electrical losses are included, roundtrip efficiency of 45% is optimistic. And then there is transportation to consider.

Rather than 100% hydrogen, it may be more practical to spike natural gas with the produced hydrogen. Mixing lower levels of hydrogen into existing pipelines is a viable option with current technology and infrastructure.

A natural gas-hydrogen mixture with moderate levels of hydrogen can be burned in more or less standard lean pre-mix systems, the gas compressors already installed in pipelines can remain in service, and safety issues regarding failed starts or leaks are manageable.

Several studies have shown that this approach works with up to 5% hydrogen and can possibly be extended to 10% without significantly affecting transportation requirements and power plant operation.

However, natural gas with hydrogen above that percentage becomes expensive since all existing pipelines and power plants would need to be re-engineered and retrofitted. Also, transporting hydrogen in higher concentrations in pipelines is inefficient since it is a light gas.

There is nothing on the horizon to indicate that the necessary infrastructure is being built to generate hydrogen from renewables in an amount that would even create a 1% hydrogen content in natural gas pipelines.

At current prices, hydrogen is too valuable to be burned in a GT. It takes too much energy to make and transport it and its roundtrip efficiency is low.

Bottom line: hydrogen power may be all over the news, but like the Hindenburg, this trend will ultimately go up in flames. ■

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