HyTech - The Hydrogen Technology Laboratory at Savannah River (U)

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Abstract

The Savannah River Site in Aiken, SC recently announced the formation of the Hydrogen Technology Laboratory (HyTech) to work with industry and government in the development of technologies based on the site’s four decades of experience with tritium and other forms of hydrogen. HyTech will continue to sustain the site’s ongoing role in hydrogen technology applications for defense. In addition, the laboratory will work with the chemical, transportation, power, medical and other industries to develop and test related technologies.

HyTech, which is located in the Savannah River Technology Center (SRTC), will make use of its facilities and staff, as well as the infrastructure within the site’s Tritium Facilities. More than 80 SRS scientists, engineers and technical professionals with backgrounds in chemistry, engineering, materials science, metallurgy, physics and computer science will work with the laboratory.

This paper describes some of HyTech’s current initiatives in the area of hydrogen storage, transportation, and energy applications.

Introduction

For over 40 years, the Savannah River Site (SRS) has produced and processed the nation’s supply of tritium, a radioactive isotope of hydrogen used in national defense. SRS has been awarded nine patents for technologies related to work with tritium and other forms of hydrogen; six others are pending.

SRS - especially the Savannah River Technology Center, SRS’s applied research and development arm - has already been working in partnership with industry on various hydrogen-related projects. HyTech, which is based in the
Savannah River Technology Center, has become the umbrella organization for these projects, making it simpler for industry to explore potential partnerships with the site.

In recent years, SRS scientists have applied their expertise to the development of technologies for use in the site's new Replacement Tritium Facility (RTF), which began operation in 1993 as the nation's principal facility for purifying and recycling tritium. Many of the technologies used in the RTF can be applied in other settings. For example, RTF makes extensive use of metal hydrides - metals that absorb hydrogen isotopes like a sponge, allowing the hydrogen to be stored and handled in a solid, stable form. A major oil company has entered into a $1.6 million partnership with SRS to develop a method for using metal hydrides to recover hydrogen from the waste emissions produced by oil refineries.

HyTech is also leading SRS's role in an international effort to develop an experimental fusion reactor, which would rely on hydrogen isotopes. This alternative source for power generation would be environmentally safe and produce no high-level radioactive waste.

These and other HyTech supported activities will be described in more detail below.

**Tritium and Fusion Technology**

In support of ongoing defense and future fusion missions, HyTech has developed many new technologies in support of tritium processing. One of the principal technologies developed is metal hydride technology. Since the late 1970's, SRS has been applying metal hydrides to its tritium and other hydrogen isotope processing operations. The new Replacement Tritium Facility or RTF which is a defense related facility for processing hydrogen isotopes makes extensive use of metal hydride technology. The RTF may be the single largest and most extensive facility utilizing metal hydride technology in the world.

In the RTF, storage, pumping, compression, separation, and purification of hydrogen isotopes are all performed by metal hydride processes. Hydrogen isotopes are stored in large 7.5 cm in diameter, 1 meter long vessels loaded with a
lanthanum-nickel-aluminum metal alloy. The vessels are designed so that they can maintain an internal hydrogen pressure below an atmosphere to minimize any possible leaks of tritium to the environment. The storage vessels also have the ability to be gently heated so that the hydrogen species can be desorbed or "pumped" to other parts of the process. If higher hydrogen pressures are required a specially designed metal hydride compressor is available. The metal hydride compressor uses two metal hydride vessels in series to compress the hydrogen from an atmosphere pressure to over 100 atmospheres if required [1].

In addition to hydrogen storage and compression, the RTF also has the capability of purifying hydrogen from other species and separating hydrogen isotopic species using metal hydrides. Several large "flow through" vessels filled with supported metal hydride material have been designed to absorb hydrogen species from mixed gas streams. These vessel are subsequently heated to produce desorbed hydrogen isotopes with purities greater than 99%. Another application developed by the scientists at HyTech is the Thermal Cycling Absorption Process or TCAP. This process uses a chromatographic, metal hydride column to selectively absorb and desorb tritium from the other hydrogen isotopes. By applying successive heating and cooling cycles (thermal swing absorption and desorption) and computer control of the process feeds and draw offs a continuous isotope separation process is established. The TCAP system can be made smaller, simpler, and more cost effective to operate than competing cryogenic distillation systems [1].

In addition to metal hydride technology, SRS has over 40 years of practical experience in safely handling tritium and hydrogen isotopes. Much of this experience can be made available to support efforts in the international fusion community. SRS is an active member of the US ITER Home Team in the tritium area and is also being considered as one of the possible US siting locations for the large-scale, International Thermal Nuclear Experimental Reactor (ITER).

Hydrogen Applications and Demonstrations

Much of what has been learned about hydrogen through our defense programs can be readily applied to new initiatives in the area of hydrogen energy. One such program currently underway at HyTech is the development of metal hydride storage vessels for transportation applications.
A metal hydride system for a transit bus has been developed. The system consists of approximately 80 individual vessels which together can store 25 kg of hydrogen. Each vessel is 8.8 cm in diameter and approximately 1.6 meters long [2]. A mischmetal-nickel-aluminum alloy was selected as the metal hydride material based on its stability, reasonable cost, and excellent safety features. HyTech has over 12 years experience with rare earth-nickel-aluminum alloys in processing applications. These material are very stable with respect to both cycling and the introduction of small amount of air and other poisons. Recently, nickel-rare earth alloys are being used more and more as electrode materials for nickel metal hydride batteries. The advent of this new market has made these materials more plentiful in larger quantities and has helped reduce their overall costs. The substitution of aluminum in these materials makes them more stable and allows them to meet a wide range of operating temperature and pressure conditions. Typical pressures for these alloys are on the order of several atmospheres at ambient temperatures making them extremely safe candidates for vehicle applications.

Another application of hydrogen storage using metal hydrides underway at HyTech is storage for fuel cell powered golf carts. Fuel cell technology offers golf carts and small electric utility vehicles considerable more range and improved performance over today's battery technology. Hydrogen storage on metal hydride offers increased safety and high energy density to these systems. Discussions with a fuel cell manufacturer and a major golf cart manufacturer are currently underway to develop a prototype fuel cell/metal hydride golf cart vehicle.

In addition to hydrogen storage, metal hydride can also be used for refrigeration and heat pump applications. As hydrogen is absorbed and desorbed from metal hydride materials, a large heat of reaction occurs. On desorption this reaction is endothermic and can be used to provide significant amounts of cooling. Metal hydride heat pumps and refrigeration systems have been first demonstrated in the mid-1970’s by Argonne National Laboratory [3]. The major problem areas preventing these systems from wide scale commercial application have been poor heat transfer characteristics associated with metal hydride powders and the stability and cost of the metal hydride material. HyTech has partnered with a small industrial company to develop a stable metal hydride compact that can not only exhibit dimensional stability with numerous cycling but also exhibit high heat transfer rates. Metal hydride based refrigeration systems have recently found renewed interest since they
are free of chlorofluorocarbons (CFC) and have the potential for very high efficiencies.

**Hydrogen Processing and Production Technology**

Hydrogen production and infrastructure issues have always been key issues in promoting a hydrogen economy. HyTech has worked with other government laboratories and commercial companies to develop new technology for the efficient recovery of hydrogen from both waste gas and renewable gas sources. HyTech is currently developing a composite metal hydride material that will be able to readily absorb hydrogen from gas mixtures containing CO, H2S and other typical metal hydride poisons. Currently, HyTech has formulated composite materials that have remained dimensionally stable over numerous absorption and desorption cycles and have demonstrated some degree of selectivity to CO. Work is currently underway to improve the selectivity of these new composite materials and to develop efficient processes for large-scale material production.

A recent program funded by the US Department of Energy, Hydrogen Programs will examine the use of composite membranes in a catalytic reactor to efficiently convert natural gas and biomass streams to hydrogen and carbon dioxide. The original concept which was developed by Los Alamos National Laboratory converted tritiated methane and water to elemental hydrogen and carbon dioxide [4]. The process combines a palladium-silver membrane within a reformer/water gas shift reactor to drive the conversion to nearly 100 percent. HyTech has modified this process to use a non-palladium based composite membrane. The composite silica/ceramic membrane, currently under development at HyTech, avoids the problems associate with palladium poisoning and fouling and still permits operation at the elevated temperatures needed to achieve near 100 percent conversion. The eventual goal of HyTech is to develop this Composite Membrane Reactor for both large scale stationary as well as compact onboard vehicle applications.

HyTech, in addition to R&D activities, is partnering with other organizations at the Savannah River Site (SRS) to address safety and infrastructure concerns related to hydrogen applications and systems. SRS has a long history of safe operation with hydrogen isotopes. This excellent safety record and large hydrogen knowledge base are now being used to support hydrogen safety and infrastructure issues. HyTech scientists have over 40 years of experience selecting and specifying
hydrogen compatible materials for storage and processing applications. This expertise is available for new hydrogen applications and processes needed to support the future "hydrogen economy".

Conclusion

A Hydrogen Technology Laboratory, named HyTech, has been established at the Savannah River Site in Aiken, South Carolina. The mission of HyTech has been expanded from supporting defense related hydrogen programs to working with outside industry. Technology developed as part of its 40 years of defense programs can now be transferred to the commercial and private sector for energy, transportation, chemical, and other industrial applications. HyTech is part of the Savannah River Technology Center (SRTC), which is the technology branch of the Savannah River Site, a production facility of the US government. Through SRTC, HyTech can partner with other government agencies and private industry to develop future hydrogen systems and application.

Literature References


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