ABSTRACT

The Advanced High-Temperature Reactor (AHTR) for Producing Hydrogen to Manufacture Liquid Fuels

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Conventional world oil production is expected to peak within a decade. Shortfalls in production of liquid fuels (gasoline, diesel, and jet fuel) are expected to be offset by increased production of fuels from heavy oils and tar sands. The Western Hemisphere (Canada, Venezuela, the United States, and Mexico) contains the world's largest deposits of these resources. However, massive quantities of hydrogen (H_2) are required to convert heavy oils and tar sands to liquid fuels. If these hydrocarbon resources are to be used while simultaneously minimizing greenhouse emissions, nonfossil methods for the production of H_2 are required.

Nuclear energy can be used to produce H_2. The most efficient methods to produce H_2 from nuclear energy involve thermochemical cycles in which high-temperature heat and water are converted to H_2 and oxygen. Depending upon the choice of thermochemical process, heat must be provided at temperatures between 700 and 850EC. The peak nuclear reactor temperatures must be significantly higher to transport heat from the reactor core to an intermediate heat transfer loop and from the intermediate heat transfer loop to the chemical plant.

A new high-temperature reactor concept is being developed for H_2 and electricity production: the Advanced High-Temperature Reactor (AHTR). This reactor is designed explicitly to meet the challenges of nuclear H_2 production with passive safety systems equivalent to those of modular high-temperature gas-cooled reactors (MHTGRs). The fuel is a graphite-matrix coated-particle fuel, the same type that is used in MHTGRs. The coolant is a clean molten fluoride salt with a boiling point near 1400EC. The AHTR has many similarities to MHTGRs. However, in the AHTR, the high-pressure helium is replaced by a low-pressure molten-fluoride-salt coolant.

Hydrogen production requires temperatures at the limits of practical engineering materials. Using a low-pressure molten-fluoride-salt coolant reduces the peak reactor fuel and coolant temperatures 100 to 200EC relative to those of a MHTGR—assuming that the heat is delivered to the thermochemical plant at the same temperatures. Liquids are better heat transfer fluids than gases, thus reducing three primary temperature losses in the system: (1) heat transfer from the fuel to the reactor coolant, (2) heat transfer across the heat exchanger from the reactor coolant to a molten-salt intermediate heat-transfer loop, and (3) heat transfer across the heat exchanger from the intermediate heat transfer loop to the chemical plant. The third temperature loss is reduced for both helium and molten-salt cooled reactors that use a molten-salt intermediate heat transport system. These characteristics reduce the high-temperature challenges of making H_2 using nuclear energy.

The high heat capacity of liquid molten salts significantly reduces equipment size. The low-pressure liquid coolant allows construction of a 2400 MW(t) AHTR with passive safety systems whereas MHTGRs are limited to ~600 MW(t) with passive safety systems. This greatly improves the economics. The reactor and heat transfer system are described and compared with equivalent MHTGRs.