Grooved Fuel Rings for Nuclear Thermal Rocket Engines

Improvements in performance, fabrication, and reliability are anticipated.

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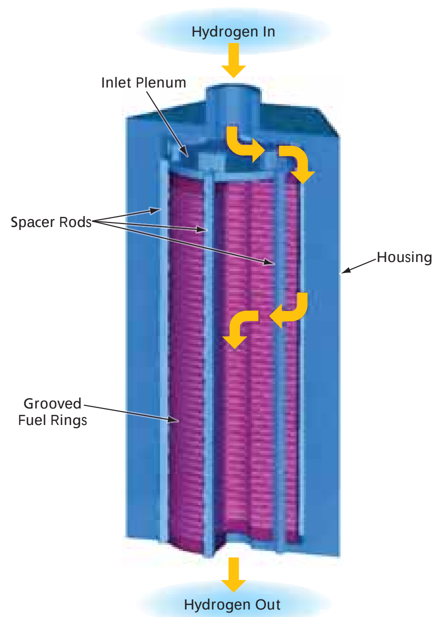
An alternative design concept for nuclear thermal rocket engines for interplanetary spacecraft calls for the use of grooved-ring fuel elements. Beyond spacecraft rocket engines, this concept also has potential for the design of terrestrial and spacecraft nuclear electric-power plants.

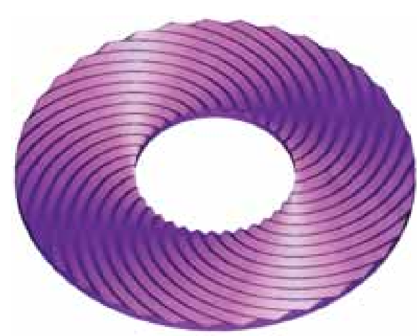
Nuclear thermal rocket engines can produce high thrusts at specific impulses at least twice those of today's best chemical rocket engines. In a nuclear thermal rocket engine, a nuclear reactor is used to heat hydrogen propellant to high temperatures. The resulting expansion and expulsion of the hydrogen exhaust through a nozzle produces thrust. The performance of nuclear engines is restricted primarily by the limited ability of the nuclear fuel to withstand the extremely high operating temperatures and by the corrosive effects of the hot hydrogen propellant.

The grooved ring fuel element design addresses some of the problems encountered with an alternate fuel design concept used in the Particle Bed Reactor (PBR). In the PBR, the fuel element consists of two concentric porous pipes (called frits) in between which is supported a bed of tiny fuel particles. Hydrogen propellant flows through the walls of the outer cold frit, through the fuel particle bed where it was heated to high temperatures, and finally exits through the walls of the inner hot frit. The propellant then leaves the fuel element through the central cavity where it is expelled through a nozzle. Because of the high surface-to-volume ratio of the fuel particles in the PBR concept, extremely high heat transfer rates were thought possible, which, had the concept proved successful, would have resulted in a very compact reactor with a high thrust-to-weight ratio. Unfortunately, because the particle bed design does not constrain the hydrogen propellant to following well-defined flow paths, the fuel element proved to be thermally unstable. This instability was manifest during testing by the appearance of potentially dangerous local hot spots within the fuel bed.

The grooved ring fuel design attempts to retain the best features of the particle bed fuel element while eliminating most of its design deficiencies. In the grooved ring design, the hydrogen propellant enters the fuel element in a manner similar to that of the PBR fuel element. Once inside the fuel element, however, the hydrogen propellant enters a stack of fuel rings rather than a bed of fuel particles. The hydrogen propellant flows radially along the grooved faces of the individual fuel rings, finally exiting into the central cavity where it is expelled from the fuel element. The fuel rings are held in place by a hexagonal structure, which may or may not contain moderating material, depending upon whether the reactor is designed to be a fast reactor or a thermal reactor.



CUTAWAY VIEW OF FUEL ELEMENT



ENLARGED VIEW OF ONE FUEL RING

A **Fuel Element** as proposed would contain grooved fuel rings. The grooves would constitute well-defined flow paths that could be shaped to optimize flow and heat-transfer characteristics.

The advantages of this design concept include the following:

- The surface-to-volume ratios of the grooved fuel rings should approach that of particle-bed reactors, thus permitting the high heat-transfer rates, which would allow the design of compact reactors with high thrust-to-weight ratios.
- Unlike the particle bed reactor fuel element design, the grooved surface of the fuel rings offers well-defined flow paths for the hydrogen propellant, thus permitting the control of thermal instabilities.
- The cross-sectional areas of these flow paths may be optimized so as to meet a desired set of thermal hydraulic parameters.
- The grooved fuel ring design eliminates the need for the difficult-to-construct and prone-to-failure hot and cold frits required by the particle bed fuel element configuration.

The grooved fuel rings should be relatively easy to fabricate using such straightforward techniques as pressing and sintering. This ease of fabrication should allow fuel elements to be made of fairly exotic high-performance materials such as uranium tricarbide, which is generally quite difficult to work with under normal circumstances.

This work was done by William (Bill) Emrich of Marshall Space Flight Center.

This invention is owned by NASA, and a patent application has been filed. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32342-1.