



## Stacked Corrugated Horn Rings

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This Brief describes a method of machining and assembly when the depth of corrugations far exceeds the width and conventional machining is not practical. The horn is divided into easily machined, individual rings with shoulders to control the depth. In this specific instance, each of the corrugations is identical in profile, and only differs in diameter and outer profile. The horn is segmented into rings

that are cut with an interference fit (zero clearance with all machining errors biased toward contact). The interference faces can be cut with a reverse taper to increase the holding strength of the joint. The taper is a compromise between the interference fit and the clearance of the two faces during assembly.

Each internal ring is dipped in liquid nitrogen, then nested in the previous,

larger ring. The ring is rotated in the nest until the temperature of the two parts equalizes and the pieces lock together. The resulting assembly is stable, strong, and has an internal finish that cannot be achieved through other methods.

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## Refinements in an Mg/MgH<sub>2</sub>/H<sub>2</sub>O-Based Hydrogen Generator

Externally generated steam would be needed only briefly to start operation.

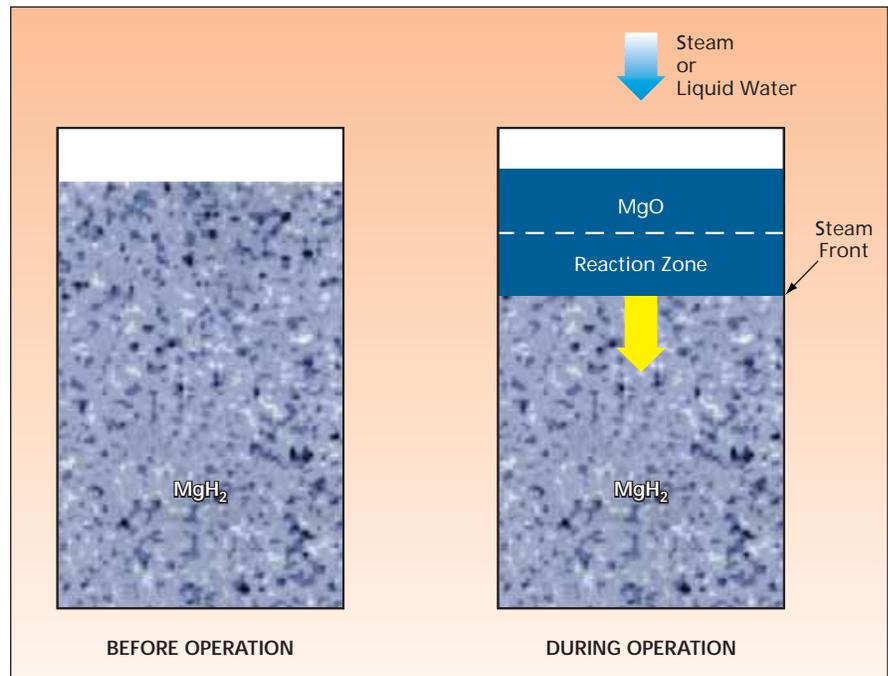
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Some refinements have been conceived for a proposed apparatus that would generate hydrogen (for use in a fuel cell) by means of chemical reactions among magnesium, magnesium hydride, and steam. The refinements lie in tailoring spatial and temporal distributions of steam and liquid water so as to obtain greater overall energy-storage or energy-generation efficiency than would otherwise be possible.

A description of the prior art is prerequisite to a meaningful description of the present refinements. The hydrogen-generating apparatus in question is one of two versions of what was called the "advanced hydrogen generator" in "Fuel-Cell Power Systems Incorporating Mg-Based H<sub>2</sub> Generators" (NPO-43554), *NASA Tech Briefs*, Vol. 33, No. 1 (January 2009), page 52. To recapitulate: The apparatus would include a reactor vessel that would be initially charged with magnesium hydride. The apparatus would exploit two reactions:

- The endothermic decomposition reaction  $MgH_2 \rightarrow Mg + H_2$ , which occurs at a temperature  $\geq 300^\circ C$ , and
- The exothermic oxidation reaction  $MgH_2 + H_2O \rightarrow MgO + 2H_2$ , which occurs at a temperature  $\geq 330^\circ C$ .

Once the initial heating was complete and both reactions under way, the endothermic reaction would be sustained by the heat generated from the exothermic reaction. For every mole of MgH<sub>2</sub> oxidized, sufficient waste heat is



Water Would Be Injected at one end of a reactor bed containing MgH<sub>2</sub> particles. Initially, the water would be in the form of steam as needed to start the reactions. Thereafter, liquid water would be injected, and one of the reactions, which is exothermic, would supply the necessary heat.

generated to decompose an additional three moles of the hydride. As a consequence of these reaction ratios, the major reaction product is Mg, and the minor one MgO. Both have extremely low toxicity. MgH<sub>2</sub> is easily recycled to Mg. In theory, no energy is required because regeneration produces enough

heat to power the process. A practical system would not be 100-percent efficient so it would be expected that there would be a modest energy cost. The MgO can be safely and easily recycled in a magnesium-refining plant for less than the cost of smelting Mg because MgO is an intermediate product of that

process. This concludes the description of the prior art.

The present refinements reflect the following ideas: In principle, the design and operation of the reactor could be optimized in the sense that the rate of generation of heat in the exothermic reaction, the rate of consumption of heat in the endothermic reaction, and the flow of heat from the exothermic to the endothermic reaction could be tailored to minimize the input energy needed to produce a given amount of  $H_2$ . In turn, the reaction rates could be tailored by tailoring gradients of temperature and chemical composition, which, in turn, could be tailored through adjustments in rates of flow of steam and liquid water into the reactor, recognizing a need to adjust the rates because the gradients of

temperature and chemical composition evolve as  $MgH_2$  is consumed and  $MgO$  is generated.

For the purpose of illustrating the refinements, the figure schematically depicts a reactor that has a simple shape and inlets for steam and liquid water at one end only. One of the refinements would be to inject steam only at the beginning of operation, in no more than the quantity needed to initiate the exothermic reaction. The combination of heating and water vapor provided by steam would initiate both exothermic and endothermic reactions. With initiation of the exothermic reaction, sufficient heat is produced to allow the use of liquid water feed instead of steam. Some of the heat from the exothermic reaction would be consumed in heating

the liquid water to steam. As operation continued, the steam front and the hydrogen-generating region would move farther into the region initially containing  $MgH_2$ , leaving behind the  $MgO$  and  $Mg$  waste product. The rate of the exothermic reaction would be adjusted by adjusting the rate of injection of liquid water. If the reactor were of a more-complex configuration featuring multiple injection points, then the rates of injection of water at those points could be adjusted individually to obtain a more nearly optimum spatial and temporal distribution of temperature throughout the reactor.

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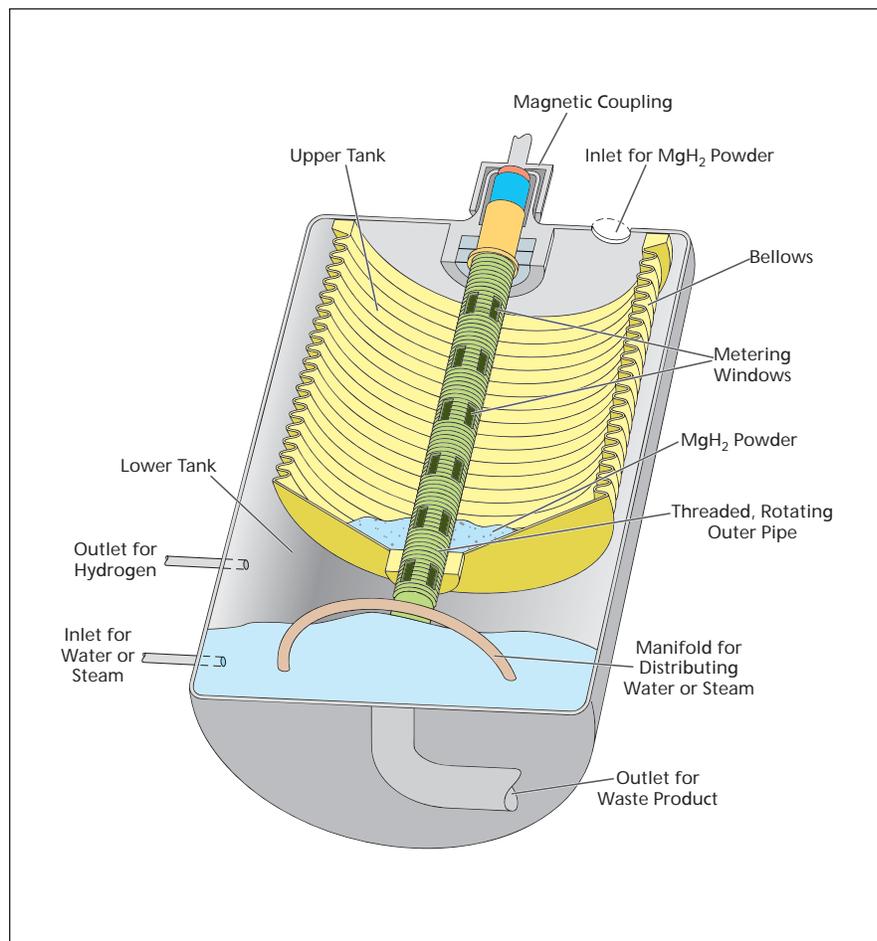
## ⚙️ Continuous/Batch $Mg/MgH_2/H_2O$ -Based Hydrogen Generator

Size and weight would be less than those of prior  $H_2$  generators.

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A proposed apparatus for generating hydrogen by means of chemical reactions of magnesium and magnesium hydride with steam would exploit the same basic principles as those discussed in the immediately preceding article, but would be designed to implement a hybrid continuous/batch mode of operation. The design concept would simplify the problem of optimizing thermal management and would help to minimize the size and weight necessary for generating a given amount of hydrogen.

The apparatus would include a vessel, the interior volume of which would be divided into an upper and a lower tank (see figure). The upper tank would serve as a fuel-storage/feeder unit: It would include a bellows initially filled with  $MgH_2$  powder (the fuel), plus a mechanism that would include a rotating threaded outer pipe with metering windows and a non-rotating, non-threaded inner pipe with metering windows, for feeding the powder into the lower tank at a controlled rate. As the outer pipe was rotated, the windows in the pipes would alternately expose or occlude each other. The mechanism would be driven by an external motor via a magnetic coupling. The mechanism would also serve partly as a valve to prevent the undesired flow of steam from the reactor into the storage volume in



This Hydrogen Generator would function in a hybrid of batch and continuous modes.