Mechanics/Machinery

Utilizing Ocean Thermal Energy in a Submarine Robot

An OTEC thermodynamic cycle would be divided into surface and depth phases.

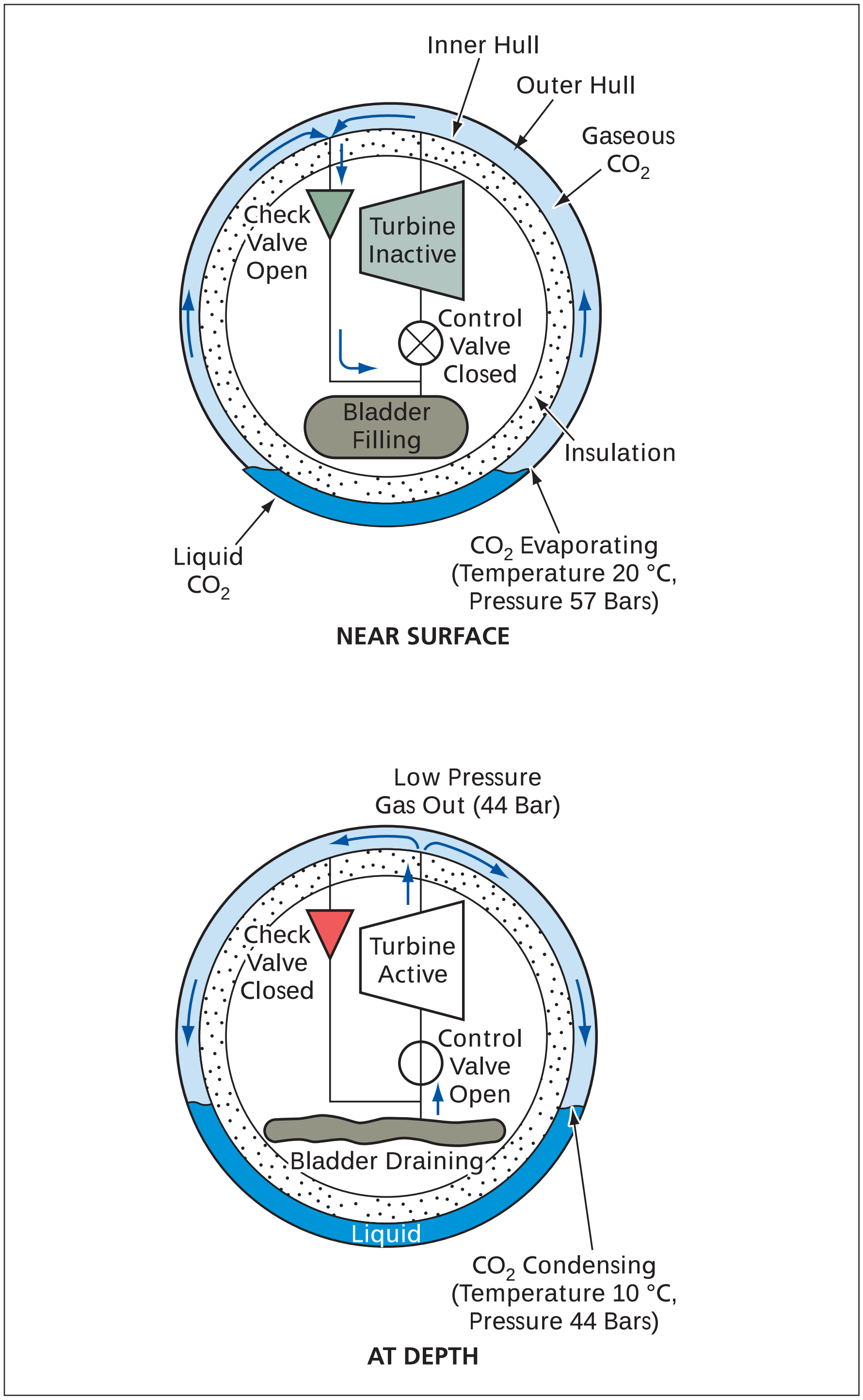
NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed system would exploit the ocean thermal gradient for recharging the batteries in a battery-powered unmanned underwater vehicle [UUV (essentially, a small exploratory submarine robot)] of a type that has been deployed in large numbers in research pertaining to global warming. A UUV of this type travels between the ocean surface and depths, measuring temperature and salinity. The proposed system is related to, but not the same as, previously reported ocean thermal energy conversion (OTEC) systems that exploit the ocean thermal gradient but consist of stationary apparatuses that span large depth ranges.

The system would include a turbine driven by working fluid subjected to a thermodynamic cycle. CO_2 has been provisionally chosen as the working fluid because it has the requisite physical properties for use in the range of temperatures expected to be encountered in operation, is not flammable, and is much less toxic than are many other commercially available refrigerant fluids. The system would be housed in a pressurized central compartment in a UUV equipped with a double hull (see figure).

The thermodynamic cycle would begin when the UUV was at maximum depth, where some of the CO_2 would condense and be stored, at relatively low temperature and pressure, in the annular volume between the inner and outer hulls. The cycle would resume once the UUV had ascended to near the surface, where the ocean temperature is typically ≥20 °C. At this temperature, the CO_2 previously stored at depth in the annular volume between the inner and outer hulls would be pressurized to ≈57 bar (5.7 MPa). The pressurized gaseous CO_2 would flow through a check valve into a bladder inside the pressurized compartment, thereby storing energy of the relatively warm, pressurized CO_2 for subsequent use after the next descent to maximum depth.

Upon descent, the outer hull would become cooled — possibly to a minimum



CO_2 Would Be Pressurized by heating near the ocean surface. Later, at depth, pressurized CO_2 would be allowed to expand through the turbine and condensed at lower temperature.

temperature as low as about 4 °C at a depth of about 300 m. The cooling would reduce the pressure of the CO_2 remaining in the annular volume to about 44 bars (4.4 MPa) or less. Then a control valve would be opened, allowing CO_2 from the pressurized bladder to expand through a turbine, thus producing electricity for recharging the battery. After flowing through the turbine and the control valve, the CO_2 would enter the annular volume, where it would be condensed at low temperature and pressure, completing the thermodynamic cycle.

This work was done by Jack Jones and Yi Chao of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). *NPO-43304*

Fuel-Cell Power Systems Incorporating Mg-Based H_2 Generators

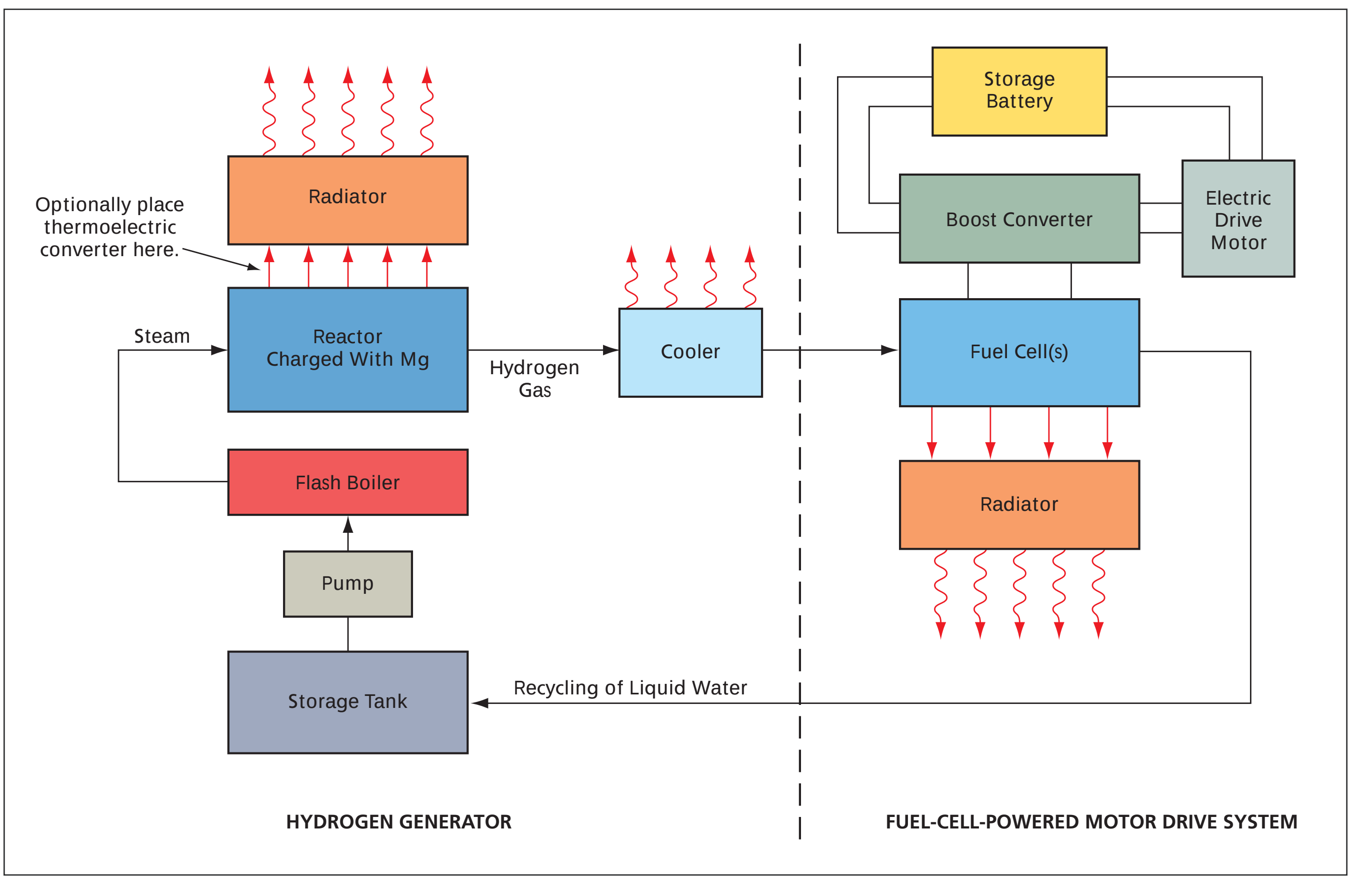
Hydrogen would be generated from magnesium and steam.

NASA's Jet Propulsion Laboratory, Pasadena, California

Two hydrogen generators based on reactions involving magnesium and steam have been proposed as means for generating the fuel (hydrogen gas) for such fuel-cell power systems as those to be used in the drive systems of advanced motor vehicles. The hydrogen generators would make it unnecessary to rely on any of the hydrogen-storage systems developed thus far that are, variously, too expensive, too heavy, too bulky, and/or too unsafe to be practical.

The two proposed hydrogen generators are denoted basic and advanced, respectively. In the basic hydrogen generator (see figure), steam at a temperature ≥330 °C would be fed into a reactor charged with magnesium, wherein hydrogen would be released in the exothermic reaction $Mg + H_2O \rightarrow MgO + H_2$. The steam would be made in a flash boiler. To initiate the reaction, the boiler could be heated electrically by energy borrowed from a storage battery that would be recharged during normal operation of the associated fuel-cell subsystem. Once the reaction was underway, heat from the reaction would be fed to the boiler. If the boiler were made an integral part of the hydrogen-generator reactor vessel, then the problem of transfer of heat from the reactor to the boiler would be greatly simplified. A pump would be used to feed water from a storage tank to the boiler.

Only a small fraction of the heat generated in the reaction would be needed for boiling: For every kilogram of hydrogen produced, about 44.5 kW·h of heat would be generated, while only about 6 kW·h would be needed to boil the requisite amount of water. The remaining 38.5 kW·h of high-grade heat would have to be dissipated via a radiator. Optionally, the flow of heat from the reactor to the radiator could be intercepted by a thermoelectric converter, thereby increasing the overall electric power generated; the net increase in the overall efficiency of the fuel-cell power system has



The **Basic Hydrogen Generator** is shown here as feeding hydrogen gas as fuel to a fuel-cell-powered motor drive system