Physical Sciences

Improved OTEC System for a Submarine Robot
This system supplants a related, previously proposed OTEC system.

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An ocean thermal energy conversion (OTEC), now undergoing development, is a less-massive, more-efficient means of exploiting the same basic principle as that of the proposed system described in "Alternative OTEC Scheme for a Submarine Robot" (NPO-43500), *NASA Tech Briefs*, Vol. 33, No. 1 (January 2009), page 50. The proposed system as described previously would be based on the thawing-expansion/freezing-contraction behavior of a wax or perhaps another suitable phase-change material (PCM). The power generated by the system would be used to recharge 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.

At one phase of its operational cycle, the previously proposed system would utilize the surface ocean temperature (which lies between 15 and 30 °C over most of the Earth) to melt a PCM that has a melting/freezing temperature of about 10 °C. At the opposite phase of its operational cycle, the system would utilize the lower ocean temperature at depth (e.g., between 4 and 7 °C at a depth of 300 m) to freeze the PCM. The melting or freezing would cause the PCM to expand or contract, respectively, by about 9 volume percent. The PCM would be contained in tubes that would be capable of expanding and contracting with the PCM. The PCM-containing tubes would be immersed in a hydraulic fluid. The expansion and contraction would drive a flow of the hydraulic fluid against a piston that, in turn, would push a rack-and-pinion gear system to spin a generator to charge a battery.

The present system was conceived because the previously proposed system was found to be too heavy and inefficient for the intended application. The main difference between the present and previously proposed systems is that in the present system, the flow of hydraulic fluid drives a hydraulic motor instead of a piston.

The operational cycle of the present system involves three phases of flow of the hydraulic fluid and is best understood by reference to the figure. In phase 1, near the ocean surface, valve 1 is held open and valves 2 and 3 are held closed, and the expansion of PCM upon heating to >10 °C pushes the hydraulic fluid through valve 1 into the bellows in a gas-spring/bellows chamber, charging
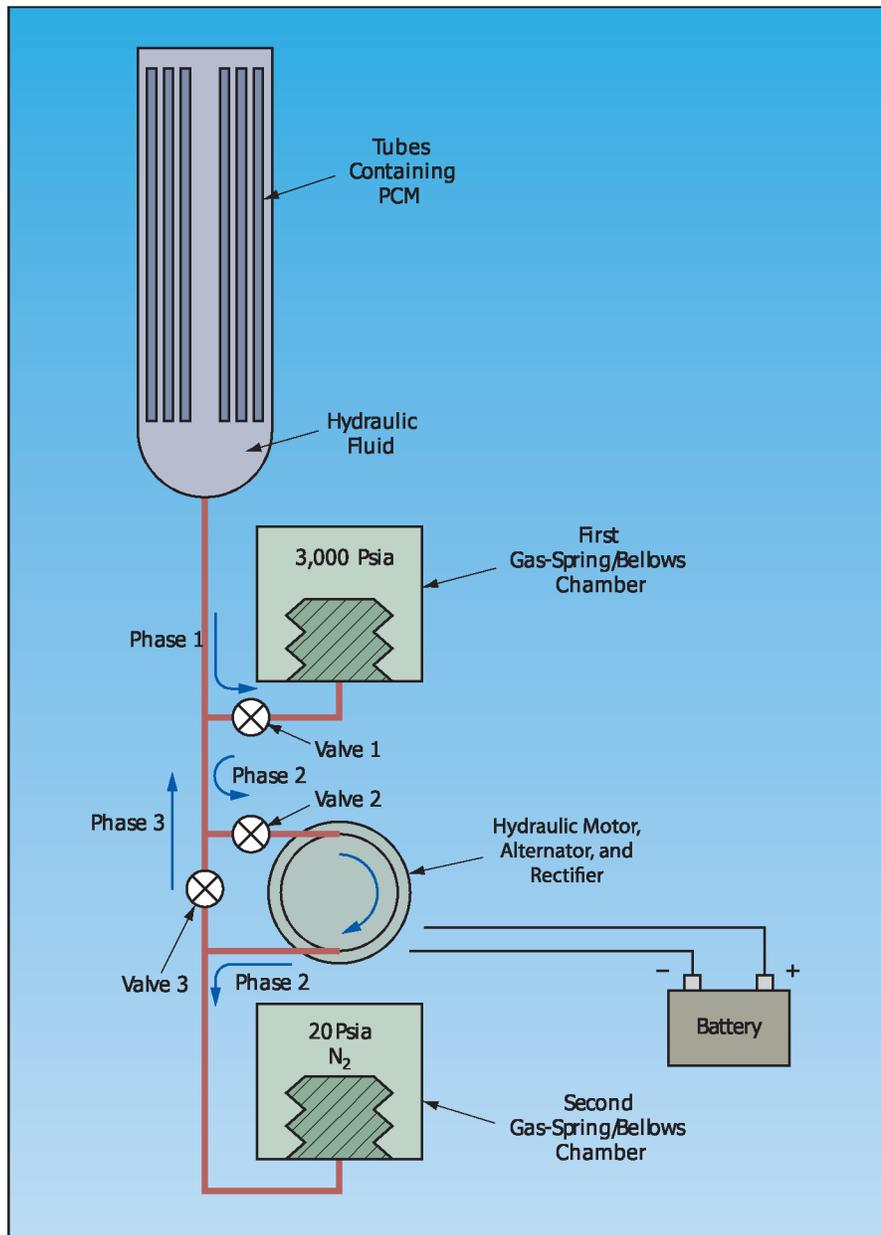
The **PCM Expands and Contracts** upon melting near the ocean surface and freezing at depth, respectively. The expansion and contraction causes the hydraulic fluid to flow cyclically through the hydraulic motor to drive the alternator to charge the battery.

the chamber to an absolute pressure of about 3 kpsi (≈21 MPa). In phase 2, valve 2 is opened, allowing the pressurized hydraulic fluid to flow through the hydraulic motor and into the bellows in a second, lower-pressure gas-spring/bellows chamber. Upon completion of this flow, valves 1 and 2 are closed and valve 3 opened in anticipation of phase 3. In phase 3, which takes place upon cooling to <10 °C at depth, contraction of the PCM upon freezing reverses the pressure gradient in the plumbing, causing the hydraulic fluid to flow from the second gas-spring/bellows chamber back to the chamber containing the PCM.

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

In accordance with Public Law 96-517, the contractor has elected to retain title to this

Reflector Surface Error Compensation in Dual-Reflector Antennas

Real-time detection and compensation of reflector surface errors is enabled for large reflector antennas such as inflatable antennas for Earth and space science applications.

NASA's Jet Propulsion Laboratory, Pasadena, California

By probing the field on a small subreflector at a minimal number of points, the main reflector surface errors can be obtained and subsequently used to design a phase-correction subreflector that can compensate for main reflector errors. The compensating phase-error profile across the subreflector can be achieved either by a surface deformation or by the use of an array of elements such as patch antennas that can cause a phase shift between the incoming and outgoing fields. The second option is of primary interest here, but the methodology can be applied to either case. The patch array is most easily implemented on a planar surface. Therefore, the example of a flat subreflector and a parabolic main reflector (a Newtonian dual reflector system) is considered in this work.

The subreflector is assumed to be a reflector array covered with patch elements. The phase variation on a subreflector can be detected by a small number of receiving patch elements (probes). By probing the phase change at these few selected positions on the subreflector, the phase error over the entire surface can be recovered and used to change the phase of all the patch elements covering the subreflector plane to compensate for main reflector errors. This is accomplished by using a version of sampling theorem on the circular aperture.

The sampling is performed on the phase-error function on the circular aperture of the main reflector by a method developed using Zernike polynomials. This method is based upon and extended from a theory previously proposed and applied to reflector aperture integration. This sampling method provides for an exact retrieval of the coefficients of up to certain orders in the expansion of the phase function, from values on a specifically calculated set of points in radial and azimuthal directions in the polar coordinate system, on the circular reflector aperture. The corresponding points on the subreflector are then obtained and, by probing the fields at these points, a set of phase values is determined that is then transferred back to the main reflector aperture for recovering the phase function. Once this function is recovered, the corresponding phase function on the subreflector is calculated and used to compensate for main reflector surface errors. In going back and forth between sub and main reflectors, geometrical (ray) optics is employed, which even though it ignores edge diffraction and other effects, is shown to be accurate for phase recovery.

This work has direct application to reflector antennas, particularly large spaceborne inflatable antennas at X, Ka, and higher frequency bands. This method can also be effective in scanning or multi-beam reflector antenna systems in which the range of scan can be increased by phase-error compensation on the subreflector.

This work was done by Vahraz Jamnejad and William Imbriale of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-45373

Enriched Storable Oxidizers for Rocket Engines

These oxidizers could be stored at room temperature.

Marshall Space Flight Center, Alabama

The name "enriched storable oxidizers" (ESOs) has been coined for a family of optimized mixtures of between two and four oxidizer fluids. For most applications, the constituents of these mixtures would be nitrogen tetroxide (N_2O_4), nitrous oxide (N_2O), and nitrogen dioxide (NO_2); in some applications, the mixtures might include inhibited red fuming nitric acid [IRFN (which consists of red fuming nitric acid to which some hydrogen fluoride is added to reduce its corrosive effect]. The optimum proportions of these constituents would be different for different applications. ESOs were originally proposed for use in spacecraft and launch-rocket propulsion systems: ESOs could be especially useful in advanced spacecraft propulsion systems that could operate in multiple modes. ESOs might also