Development of a Bearingless Ammonia Pump for Spacecraft Thermal Control

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Advanced Thermal Control Technology for Navy's Future Needs: The potential increase in payload capability of Navy/DoD spacecraft resulting from advances in electronics miniaturization cannot be realized without concurrent advances in thermal management. More and more heat-dissipating electronics have to be packaged tightly in a smaller volume to compete with the other subsystems for limited spacecraft "real estate." In a recent study, projection for the thermal requirement of future Navy spacecraft is about ten times that of today. Current state-of-the-art technologies simply will not meet this demand. Accordingly, NRL's Spacecraft Engineering Department (SED) acquired external sponsorship to initiate a research and development effort in FY2007 in pursuit of an ammonia bearingless pump that enables the Thermal Control Subsystem (TCS) to enhance its heat transport capacity at least tenfold while retaining other operational attributes (e.g., reliability and long life).

Technical Overview: The ammonia bearingless pump belongs to a new class of magnetically driven pumps that exploits the "buoyancy" force to self-center its impeller inside a hermetically sealed housing. The novel pump concept was patented by Advanced Bionics Inc. (ABI) of Minnesota. A cross-sectional view of the bearingless pump is shown in Fig. 8. It consists of two physically separate parts: an impeller housing assembly and an external motor drive. Permanent magnets embedded in the impeller are magnetically coupled to the motor drive (located on the outer surface of the pump housing), which in turn rotates the impeller. Hence, like other magnetically driven pumps, the ABI pump does not need a driving shaft between the motor and the impeller. This allows the fluid system to be hermetically sealed from the surrounding to mitigate fluid leakage.

Central to the ABI impeller design (Fig. 9) is that the effective density of the impeller, including the embedded magnets, needs to be approximately 70% of the fluid density. When the impeller spins, the induced centrifugal gravity field in the fluid compels the lighter-than-the-fluid impeller to float to the center of the pump housing. In other words, the impeller naturally maintains a small clearance between itself and the pump housing. There is no need for bearings to restrain the impeller in any way, resulting in a lubrication-free fluid system. The external motor drive itself is simply a copper winding (solid-state) whose magnetic field is regulated by an electronic controller to maintain the impeller rotational speed to any desired level. In short, the ABI bearingless pump has only one moving part, requiring no shaft, seal, or bearing. Its operational reliability and long life are therefore suitable for unmanned space applications.

Potential Navy Applications: Next-generation Navy/DoD spacecraft will increase the payload capability substantially as the direct result of advances in optics, sensors, and electronics. Forecasts of Navy/DoD spacecraft five to ten years from now indicate that heat transport will increase at least tenfold, rendering today's state-of-the-art devices obsolete. The SED identified several potential applications of the ABI bearingless pump for space-based TCS, as depicted in Fig. 10: (i) high-capacity hybrid ammonia heat transport loop, (ii) steerable radiators, and (iii) spray cooling for ultra high heat flux sources. The hybrid loop combines state-of-the-art technology (capillary-pumped heat transport devices) and the bearingless pump into one system. It retains all beneficial attributes of the capillary loop while the bearingless pump provides a significant increase in the pumping capacity (at least one order of magnitude). The steerable radiator concept is proposed to reduce the overall TCS weight (>50%). The large pressure head provided by the bearingless pump enables ammonia to flow in small-diameter stainless steel tubing flexible enough to allow the steerable radiator to point to any attitude for optimal heat rejection. The bearingless pump can also be utilized in a spray cooling system that atomizes liquid through a nozzle and impinges the liquid droplets onto a high heat flux source (laser diodes).

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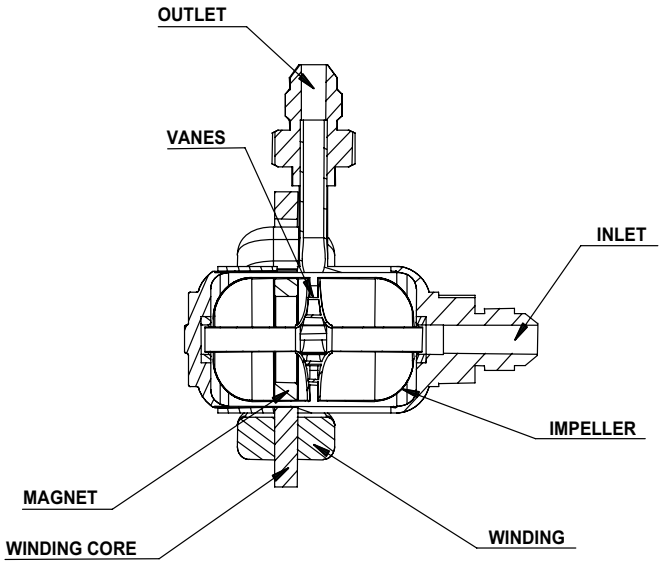

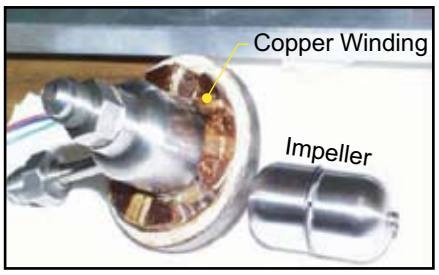

FIGURE 8
ABI bearingless pump.

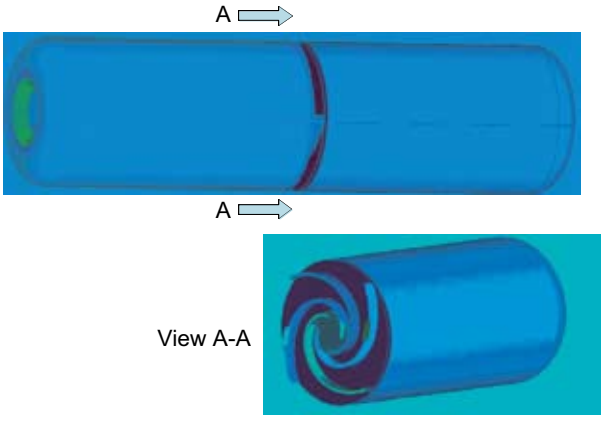

FIGURE 9
Bearingless pump impeller design.

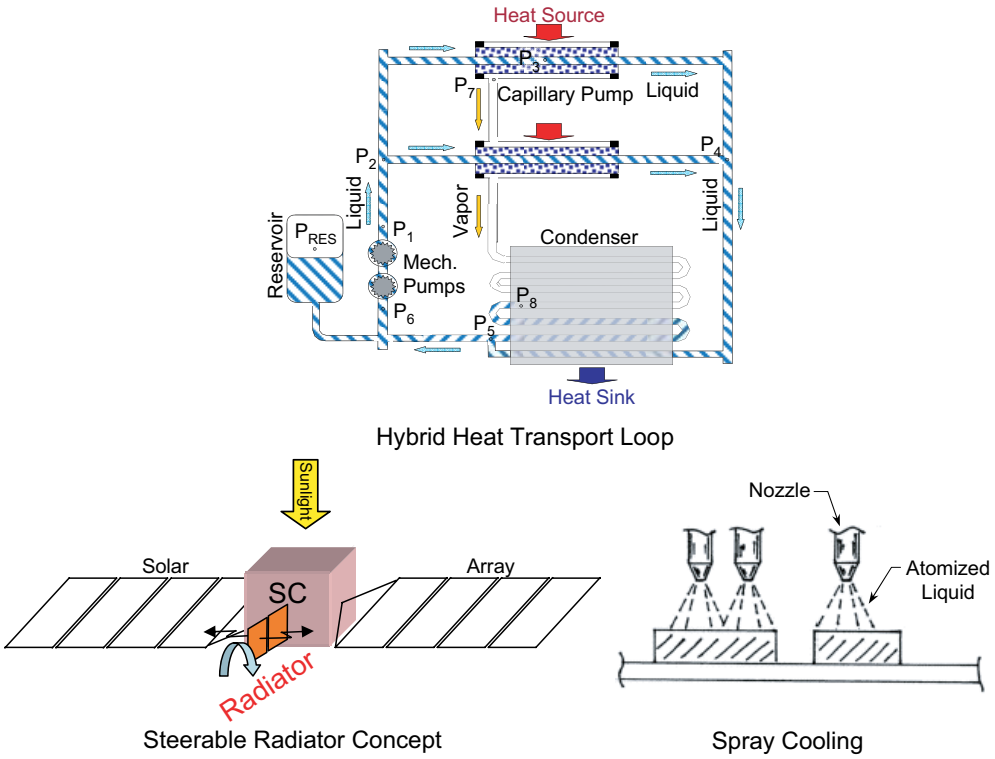

FIGURE 10
Potential applications for the bearingless pump.