

produce force along any other axis. Moreover, by eliminating the need for such mechanical connections as flexures used in prior thrust-measurement systems, magnetic levitation of the floating frame eliminates what would otherwise be major sources of cross-axis forces and the associated measurement errors.

Overall, relative to prior mechanical-support thrust-measurement systems, this system offers greater versatility for adaptation to a variety of test conditions and requirements.

The basic idea of most prior active-magnetic-bearing force-measurement systems is to calculate levitation forces on the basis of simple proportionalities between changes in those forces and changes in feedback-controlled currents

applied to levitating electromagnetic coils. In the prior systems, the effects of gap lengths on fringing magnetic fields and the concomitant effects on magnetic forces were neglected. In the present system, the control subsystems of the active magnetic bearings are coupled with a computer-based automatic calibration system running special-purpose software wherein gap-length-dependent fringing factors are applied to current- and magnetic-flux-based force equations and combined with a multipoint calibration method to obtain greater accuracy. All of the inputs required for calibration can be obtained from the control subsystems of the active magnetic bearings (and from magnetic-flux sensors if they are used). Tests have verified that force accuracies characterized by errors or <5

percent of full-scale readings are achievable when using current-based force equations or by errors <0.5 percent of full-scale readings when using flux-based equations.

*This work was done by Joseph Imlach of Innovative Concepts In Engineering LLC and Mary Kasarda and Eric Blumberg of Virginia Polytechnic Institute and State University for Stennis Space Center.*

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## ⚙️ Thermally Actuated Hydraulic Pumps

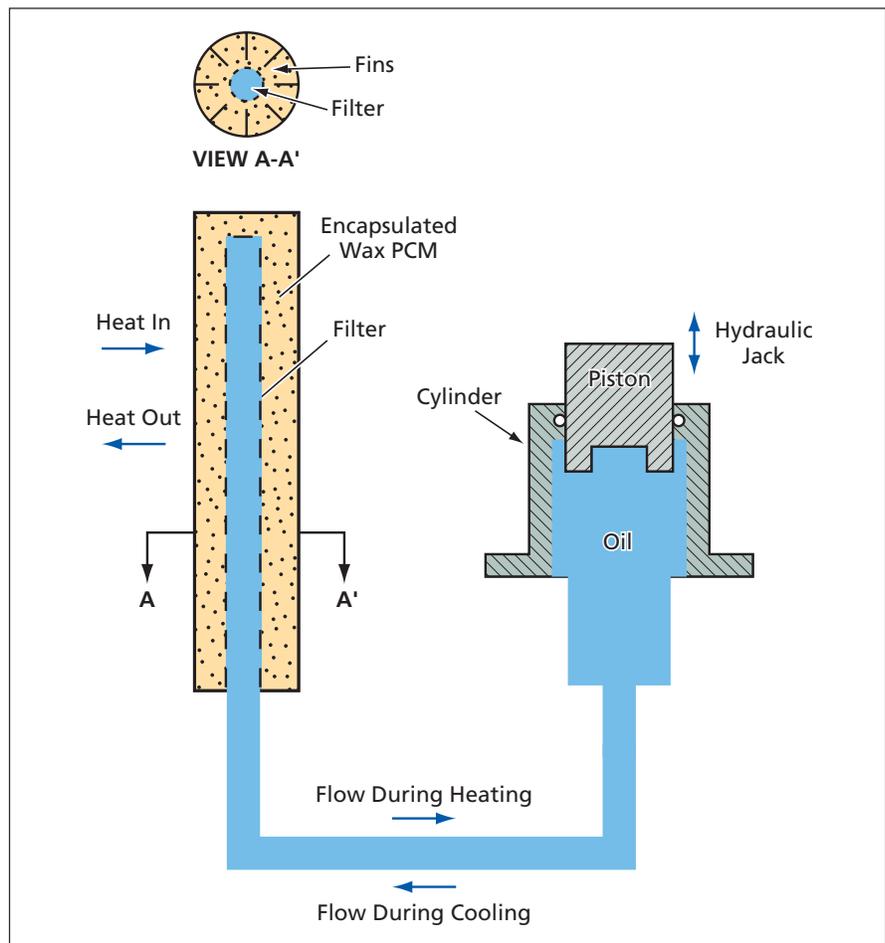
**These pumps would contain no sliding (wearing) parts.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Thermally actuated hydraulic pumps have been proposed for diverse applications in which direct electrical or mechanical actuation is undesirable and the relative slowness of thermal actuation can be tolerated. The proposed pumps would not contain any sliding (wearing) parts in their compressors and, hence, could have long operational lifetimes.

The basic principle of a pump according to the proposal is to utilize the thermal expansion and contraction of a wax or other phase-change material in contact with a hydraulic fluid in a rigid chamber. Heating the chamber and its contents from below to above the melting temperature of the phase-change material would cause the material to expand significantly, thus causing a substantial increase in hydraulic pressure and/or a substantial displacement of hydraulic fluid out of the chamber. Similarly, cooling the chamber and its contents from above to below the melting temperature of the phase-change material would cause the material to contract significantly, thus causing a substantial decrease in hydraulic pressure and/or a substantial displacement of hydraulic fluid into the chamber. The displacement of the hydraulic fluid could be used to drive a piston.

The figure illustrates a simple example of a hydraulic jack driven by a thermally actuated hydraulic pump. The pump chamber would be a cylinder con-



A Thermally Actuated Hydraulic Pump would displace oil, which would displace a piston in a hydraulic jack.

taining encapsulated wax pellets and containing radial fins to facilitate transfer of heat to and from the wax.

The plastic encapsulation would serve as an oil/wax barrier and the remaining interior space could be filled with hydraulic oil. A filter would retain the encapsulated wax particles in the pump chamber while allowing the hydraulic oil to flow into and out of the chamber.

In one important class of potential applications, thermally actuated hydraulic pumps, exploiting vertical ocean temperature gradients for heating and cooling as needed, would be used to vary hy-

draulic pressures to control buoyancy in undersea research vessels. Heretofore, electrically actuated hydraulic pumps have been used for this purpose. By eliminating the demand for electrical energy for pumping, the use of the thermally actuated hydraulic pumps could prolong the intervals between battery charges, thus making it possible to greatly increase the durations of undersea exploratory missions.

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

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## ⚙️ A New, Highly Improved Two-Cycle Engine

Performance is improved while mechanical complexity is reduced.

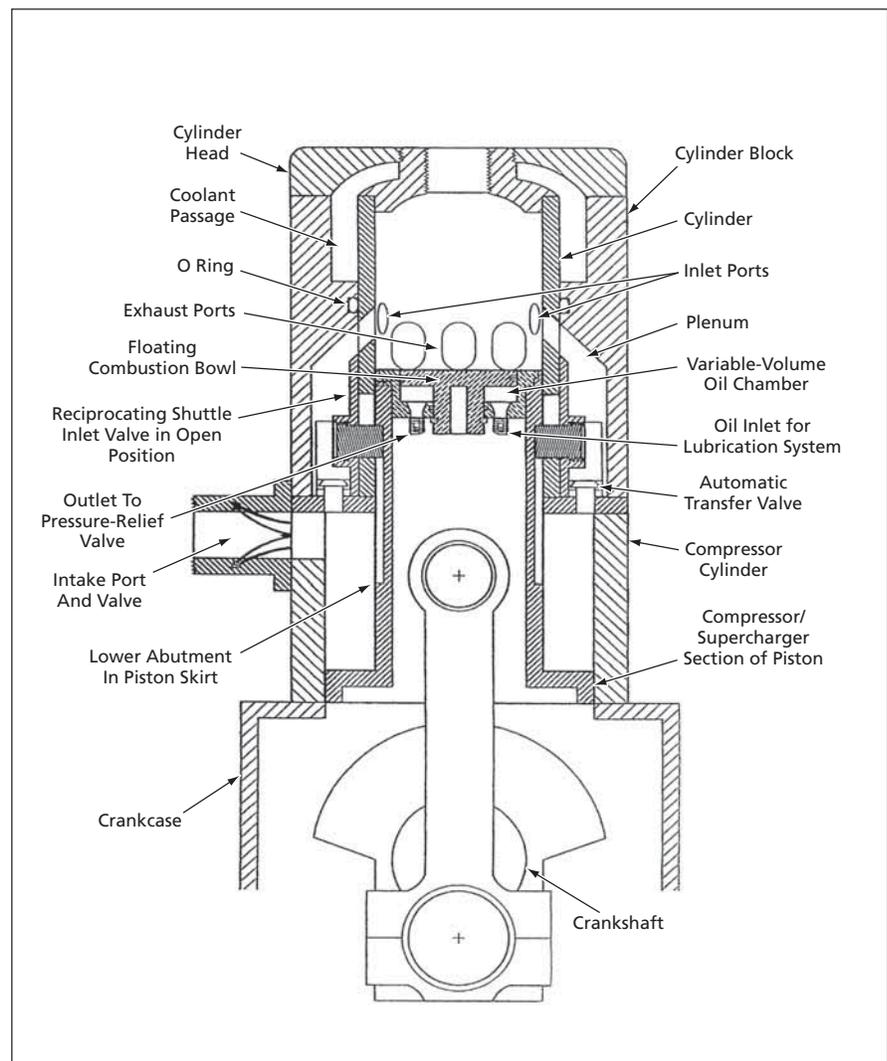
*John H. Glenn Research Center, Cleveland, Ohio*

The figure presents a cross-sectional view of a supercharged, variable-compression, two-cycle, internal-combustion engine that offers significant advantages over prior such engines. The improvements are embodied in a combination of design changes that contribute synergistically to improvements in performance and economy. Although the combination of design changes and the principles underlying them are complex, one of the main effects of the changes on the overall engine design is reduced (relative to prior two-cycle designs) mechanical complexity, which translates directly to reduced manufacturing cost and increased reliability. Other benefits include increases in the efficiency of both scavenging and supercharging. The improvements retain the simplicity and other advantages of two-cycle engines while affording increases in volumetric efficiency and performance across a wide range of operating conditions that, heretofore have been accessible to four-cycle engines but not to conventionally scavenged two-cycle ones, thereby increasing the range of usefulness of the two-cycle engine into all areas now dominated by the four-cycle engine.

The design changes and benefits are too numerous to describe here in detail, but it is possible to summarize the major improvements:

- *Reciprocating Shuttle Inlet Valve*

The entire reciprocating shuttle inlet valve and its operating gear is constructed as a single member. The shuttle valve is actuated in a lost-motion arrangement in which, at the ends of its stroke, projections on the shuttle valve



This **Internal Combustion Engine Design** features improved performance and reduced mechanical complexity.