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 hydraulic 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).

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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Refer to NPO-40844, volume and number of this NASA Tech Briefs *issue, and the page number.*

A New, Highly Improved Two-Cycle Engine

Performance is improved while mechanical complexity is reduced.

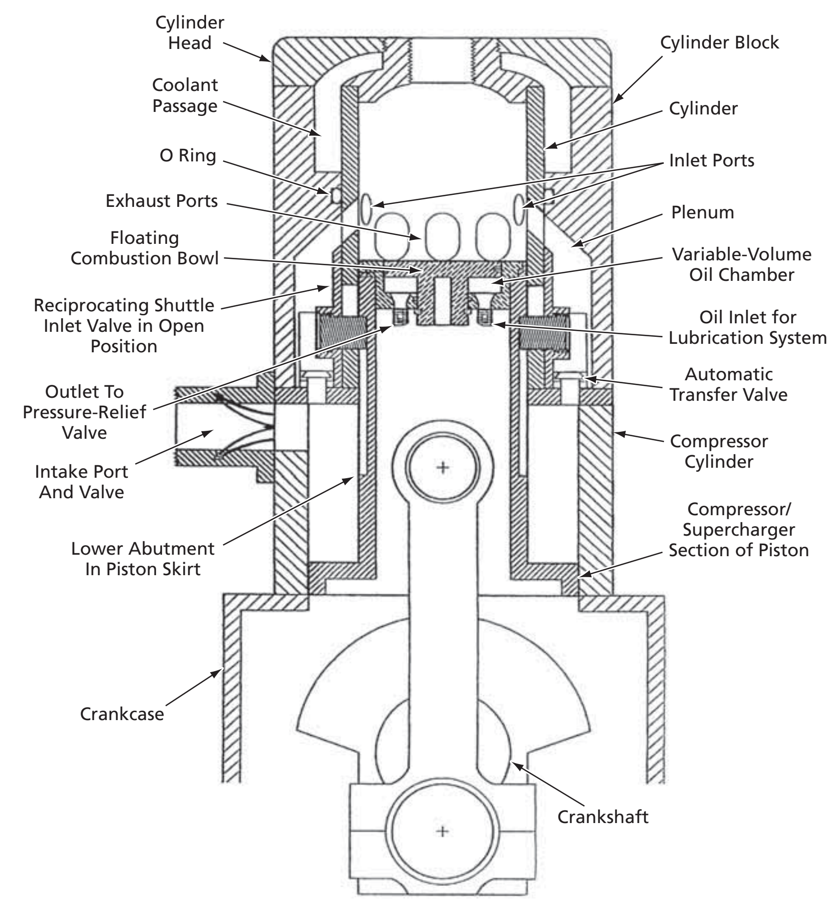
John H. Glenn Research Center, Cleveland, Ohio

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.

come to rest against abutments at the ends of grooves in a piston skirt. This shuttle-valve design obviates the customary complex valve mechanism, actuated from an engine crankshaft or camshaft, yet it is effective with every type of two-cycle engine, from small high-speed single cylinder model engines, to large low-speed multiple cylinder engines.

- *Variable Compression Ratio*

The piston has a stepped configuration: It includes a narrower power section (the upper portion in the figure) and a wider compressor/supercharger section (the lower portion in the figure). The variable-compression-ratio mechanism includes a high-pressure oil lubrication circuit acting in unison with the pulsating flow and pressure of the air caused by the reciprocation of the compressor/supercharger section of the piston. In terms that are necessarily oversimplified for the sake of brevity, the operation of this mechanism involves interactions among pressures and flows of air, oil, and combustion gases, to vary the axial position of a floating combustion bowl in the power section of the piston and thereby vary the compression ratio. The design of the mechanism is such that when the throttle opening is suddenly changed, the compression ratio becomes adjusted relatively quickly to the value at which the engine operates most efficiently.

- *Supercharging*

The stepped-piston arrangement obviates the complication and high cost of "add-on" supercharging mechanisms like those used on prior engines. During the compression stroke, the motion of the compressor/supercharger section of the piston gives rise to a flow of air at high pressure from the compressor cylinder through one-way transfer valves, through a plenum, into the power cylinder. This flow contributes to scavenging and cooling of the power cylinder. The highly compressed air continues to enter the plenum and power cylinder after the exhaust ports are closed and the supercharging of the cylinder has been completed. The compressed air that continues to enter the plenum after the inlet ports are covered by the rising power piston is retained in the plenum under pressure until the end of the expansion stroke, when the lowering power piston opens the exhaust ports. Soon after this, the abutments in the piston skirt make contact with the projections on the reciprocating shuttle inlet valve, forcing the valve to the open position, in which the compressed air rushes from the plenum into the power cylinder, thereby effecting the initial scavenging. An additional benefit of the stepped-piston arrangement is that the blow-by gases and particulate matter that escape past the power-piston rings are isolated from the crankcase and returned to the power cylinder on the following stroke.

This work was done by Bernard Wiesen of Wiesen Engine for Glenn Research Center.

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18043-1.

Flexible Structural-Health-Monitoring Sheets

Marshall Space Flight Center, Alabama

A generic design for a type of flexible structural-health-monitoring sheet with multiple sensor/actuator types and a method of manufacturing such sheets has been developed. A sheet of this type contains an array of sensing and/or actuation elements, associated wires, and any other associated circuit elements incorporated into various flexible layers on a thin, flexible substrate. The sheet can be affixed to a structure so that the array of sensing and/or actuation elements can be used to analyze the structure in accordance with structural-health-monitoring techniques. Alternatively, the sheet can be designed to be incorporated into the body of the structure, especially if the structure is made of a composite material.

Customarily, structural-health monitoring is accomplished by use of sensors and actuators arrayed at various locations on a structure. In contrast, a sheet of the present type can contain an entire sensor/actuator array, making it unnecessary to install each sensor and actuator individually on or in a structure. Sensors of different types such as piezoelectric and fiber-optic can be embedded in the sheet to form a hybrid sensor network. Similarly, the traces for electric communication can be deposited on one or two layers as required, and an entirely separate layer can be employed to shield the sensor elements and traces.

This work was done by Xinlin Qing and Fuo Kuo Chang of Acellent Technologies for Marshall Space Flight Center. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32510-1.

Alignment Pins for Assembling and Disassembling Structures

Simple tooling prevents damage to structures.

John F. Kennedy Space Center, Florida

Simple, easy-to-use, highly effective tooling has been devised for maintaining alignment of bolt holes in mating structures during assembly and disassembly of the structures. The tooling was originally used during removal of a body flap from the space shuttle Atlantis, in which misalignments during removal of the last few bolts could cause the bolts to bind in their holes. By suitably modifying the dimensions of the tooling components, the basic design of the tooling can readily be adapted to other structures that must be maintained in alignment.

The tooling includes tapered, internally threaded alignment pins designed to fit in the bolt holes in one of the mating structures, plus a draw bolt and a