also assisted by locating the air exit ports downstream of the liquid drain port. Additionally, any droplets not contained in the capillary vanes are re-entrained downstream by a third opposing capillary vane, which directs liquid back toward the liquid drain port. Finally, the dual air exit ports serve to slow the airflow down, and to reduce the likelihood of shear. The ports are stove-piped into the cavity to form an unfriendly capillary surface for a wetting fluid to carryover. The liquid drain port is located at the start of the containment region, allowing for draining the bulk fluid in a continuous circuit.

The functional operation of the SPS involves introducing liquid flow (from a human body, a syringe, or other source) to the two-phase inlet while an air fan pulls on the air exit lines. The fan is operated until the liquid is fully introduced. The system is drained by negative pressure on the liquid drain lines when the SPS containment system is full.

This work was done by Evan A. Thomas and John C. Graf of Johnson Space Center and Mark M. Weislogel, independent consultant. Further information is contained in a TSP (see page 1).

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center, (281) 483-1003. Refer to MSC-24441-1.

Gimballing Spacecraft Thruster

Marshall Space Flight Center, Alabama

A gimballing spacecraft reaction-control-system thruster was developed that consists of a small hydrogen/oxygen-burning rocket engine integrated with a Canfield joint. (Named after its inventor, a Canfield joint is a special gimbal mount that is strong and stable yet allows a wide range of motion.) One especially notable aspect of the design of this thruster is integration, into both the stationary legs and the moving arms of the Canfield joint, of the passages through which the hydrogen and oxygen flow to the engine. The thruster was assembled and subjected to tests in which the engine was successfully fired both with and without motion in the Canfield joint.

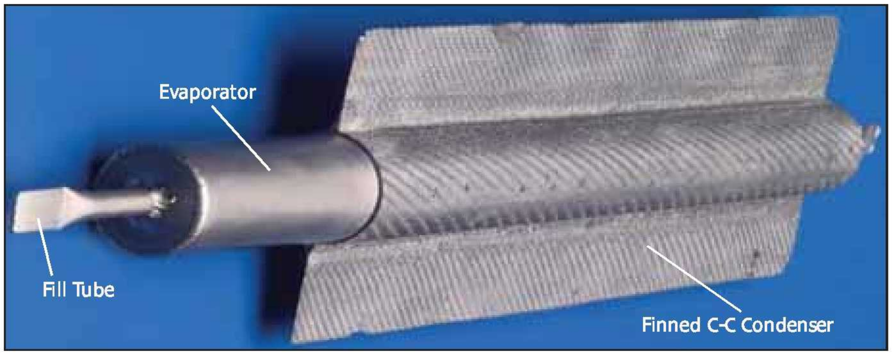
This work was done by Tim Pickens and John Bossard of Orion Propulsion, Inc. for Marshall Space Flight Center. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32520-1.

Finned Carbon-Carbon Heat Pipe With Potassium Working Fluid

The heat pipe can be used in terrestrial power plants.

John H. Glenn Research Center, Cleveland, Ohio

This elemental space radiator heat pipe is designed to operate in the 700 to 875 K temperature range. It consists of a C–C (carbon-carbon) shell made from poly-acrylonitride fibers that are woven in an angle interlock pattern and densified with pitch at high process temperature with integrally woven fins. The fins are 2.5 cm long and 1 mm thick, and provide an extended radiating surface at the colder condenser section of the heat pipe. The weave pattern features a continuous fiber bath from the inner tube surface to the outside edges of the fins to maximize the thermal conductance, and to thus minimize the temperature drop at the condenser end. The heat pipe and radiator element together are less than one-third the mass of conventional heat pipes of the same heat rejection surface area.



The finned **Carbon-Carbon Heat Pipe** is shown with an Nb-1Zr evaporator liner.

To prevent the molten potassium working fluid from eroding the C–C heat pipe wall, the shell is lined with a thin-walled, metallic tube liner (Nb-1 wt.% Zr), which is an integral part of a hermetic metal subassembly which is furnace-brazed to the inner surface of the C–C tube. The hermetic metal liner subassembly includes end caps and fill tubes fabricated from the same Nb-1Zr alloy. A combination of laser and electron beam methods is used to weld the end caps and fill tubes. A tungsten/inert gas weld seals the fill tubes after cleaning and charging the heat pipes with potassium.

The external section of this liner, which was formed by a "Uniscan" rolling process, transitions to a larger wall thickness. This section, which protrudes beyond the C–C shell, constitutes the "evaporator" part of the heat pipe, while the section inside the shell constitutes the condenser of the heat pipe (see figure). The metal liner contains a concentric tubular perforated wick sized and located to form an annular gap between itself and the inner surface of the liner. The wick is fabricated from molybdenum foil and contains evenly spaced circular perforations. One end of the wick is welded to the evaporator end cap, while the other end is left free.

During the fabrication process, the finned C–C shell condenser section is exposed to an atomic oxygen (AO) ion source for a total AO fluence of 4×10^{20} atoms/cm^2, thereby raising its surface emissivity to values between 0.85 and 0.90 at design operating temperature, thus reducing the radiator area required for a specified value of heat rejection to space. The prototype heat pipe performed well in initial low power tests. Based on test results and computer modeling, the heat pipe should be capable of transporting heat at a rate of 900 W at evaporator temperatures in the 850 to 875 K range. Computer modeling also indicates that, if scaled up from a prototype length of 36 cm to a full design length of 91 cm, the heat pipe should be capable of transporting heat at a rate of 2.2 kW at the same evaporator temperature range. At its 1.45 kg/m^2 specific mass for two-sided heat rejection, its power-to-mass ratio will be 6.5 kW/kg.

This work was done by Albert J. Juhasz of Glenn Research Center. Further information is contained in a TSP (see page 1).

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-18307-1.

Lightweight Heat Pipes Made From Magnesium

Lyndon B. Johnson Space Center, Houston, Texas

Magnesium has shown promise as a lighter-weight alternative to the aluminum alloys now used to make the main structural components of axially grooved heat pipes that contain ammonia as the working fluid. Magnesium heat-pipe structures can be fabricated by conventional processes that include extrusion, machining, welding, and bending. The thermal performances of magnesium heat pipes are the same as those of equal-sized aluminum heat pipes. However, by virtue of the lower mass density of magnesium, the magnesium heat pipes weigh 35 percent less. Conceived for use aboard spacecraft, magnesium heat pipes could also be attractive as heat-transfer devices in terrestrial applications in which minimization of weight is sought: examples include radio-communication equipment and laptop computers.

This work was done by John H. Rosenfeld, Sergei N. Zarembo, and G. Yale Eastman of Thermacore, Inc. for Johnson Space Center. 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:

Thermacore International, Inc.
780 Eden Rd.
Lancaster, PA 17601
Phone No.: (717) 569-6551
E-mail: info@thermacore.com

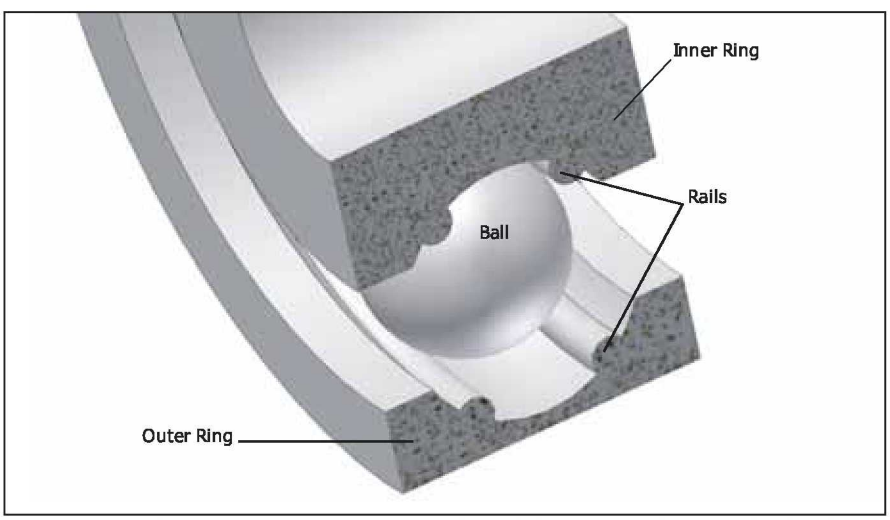
Refer to MSC-23397-1, volume and number of this NASA Tech Briefs *issue, and the page number.*

Ceramic Rail-Race Ball Bearings

These bearings would tolerate dust better than conventional ball bearings.

NASA's Jet Propulsion Laboratory, Pasadena, California

Non-lubricated ball bearings featuring rail races have been proposed for use in mechanisms that are required to function in the presence of mineral dust particles in very low-pressure, dry environments with extended life. Like a conventional ball bearing, the proposed bearing would include an inner and an outer ring separated by balls in rolling contact with the races. However, unlike a conventional ball bearing, the balls would not roll in semi-circular or gothic arch race grooves in the rings: instead, the races would be shaped to form two or more rails (see figure). During operation, the motion of the balls would push dust particles into the spaces between the rails where the particles could not generate rolling resistance for the balls.



A **Ball Bearing as Proposed** would contain rail races instead of conventional races. Preferably, the balls, rings and rail-races would be made of a ceramic or similar hard material.