

The Valve Incorporating the Proposed Improvements is depicted here in a simplified and partly schematic cross section, and not to scale.

proved valve (see figure) would include a base that would contain a seat, an inlet, and an outlet. The piezoelectric stack would be connected to a valve boss at one end and to a rigid valve cap at its other

end. In the absence of an applied potential, the valve boss would be pressed against the valve seat, so that flow would be blocked. The application of a potential of 60 V across the stack would cause the

stack to shrink, pulling the valve boss away from the seat and thereby opening a flow channel between the inlet and the outlet.

In order to increase the spring bias of the valve toward the closed position and thereby help to minimize leakage in the absence of an applied potential, the boss plate would be slightly stretched. The force generated by the piezoelectric actuator would be about 100 N — enough to overcome both the tension in the boss plate and the pressure-aided valve-closing force at an upstream-to-downstream differential pressure as large as 300 psi ( $\approx 2$  MPa).

*This work was done by Eui-Hyeok Yang 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*

*Intellectual Assets Office*

*JPL*

*Mail Stop 202-233*

*4800 Oak Grove Drive*

*Pasadena, CA 91109*

*(818) 354-2240*

*E-mail: ipgroup@jpl.nasa.gov*

*Refer to NPO-30562, volume and number of this NASA Tech Briefs issue, and the page number.*

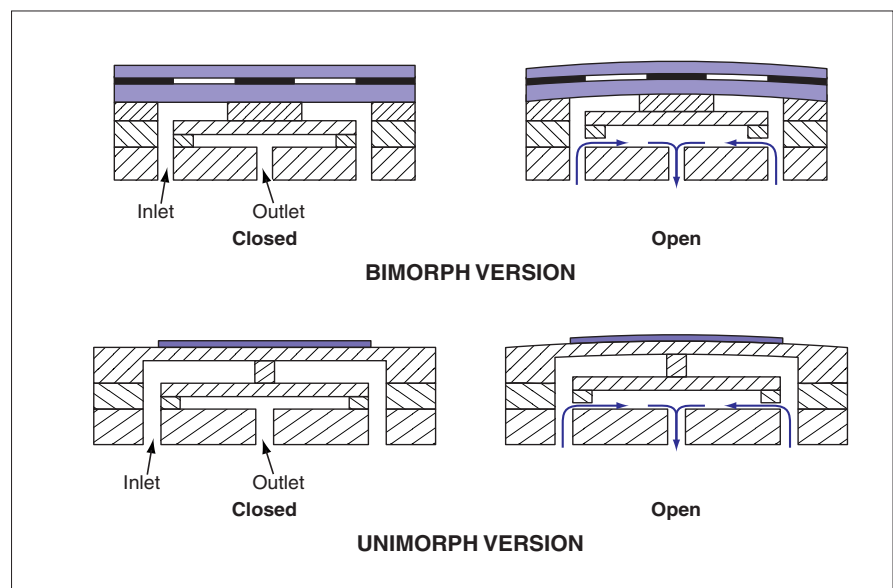
## Larger-Stroke Piezoelectrically Actuated Microvalve

**Liquids carrying small particles could be handled.**

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

A proposed normally-closed microvalve would contain a piezoelectric bending actuator instead of a piezoelectric linear actuator like that of the microvalve described in the preceding article. Whereas the stroke of the linear actuator of the preceding article would be limited to  $\approx 6 \mu\text{m}$ , the stroke of the proposed bending actuator would lie in the approximate range of 10 to 15  $\mu\text{m}$  — large enough to enable the microvalve to handle a variety of liquids containing suspended particles having sizes up to 10  $\mu\text{m}$ . Such particulate-laden liquids occur in a variety of microfluidic systems, one example being a system that sorts cells or large biomolecules for analysis.

In comparison with the linear actuator of the preceding article, the bending actuator would be smaller and less massive. The combination of increased stroke, smaller mass, and smaller volume would be obtained at the cost of decreased actuation force: The proposed actuator would



**Bimorph and Unimorph Versions** of a microvalve actuated by a piezoelectric bender have been proposed. The bimorph version could operate at higher pressure; the unimorph version would be more compact.

generate a force in the approximate range of 1 to 4 N, the exact amount depending on operating conditions and details of design. This level of actuation force would be too low to enable the valve to handle a fluid at the high pressure level mentioned in the preceding article.

The proposal encompasses two alternative designs — one featuring a miniature piezoelectric bimorph actuator and one featuring a thick-film unimorph piezoelectric actuator (see figure). In either version, the valve would consume a power of only 0.01 W when actuated at a frequency of 100 Hz. Also, in either version, it would be necessary to attach a soft elastomeric sealing ring to the valve seat so that any particles that settle on the seat would be pushed deep into the elastomeric material to prevent or reduce leakage.

The overall dimensions of the bimorph version would be 7 by 7 by 1 mm. The actuator in this version would gen-

erate a force of 1 N and a stroke of 10  $\mu\text{m}$  at an applied potential of 150 V. The actuation force would be sufficient to enable the valve to handle a fluid pressurized up to about 50 psi ( $\approx 0.35$  MPa).

The overall dimensions of the unimorph version would be 2 by 2 by 0.5 mm. In this version, an electric field across the piezoelectric film on a diaphragm would cause the film to pull on, and thereby bend, the diaphragm. At an applied potential of 20 V, the actuator in this version would generate a stroke of 10  $\mu\text{m}$  and a force of 0.01 N. This force level would be too low to enable handling of fluids at pressures comparable to those of the bimorph version. This version would be useful primarily in microfluidic and nanofluidic applications that involve extremely low differential pressures and in which there are requirements for extreme miniaturization of valves. Exam-

ples of such applications include liquid chromatography and sequencing of deoxyribonucleic acid.

*This work was done by Eui-Hyeok Yang 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*

*Intellectual Assets Office*

*JPL*

*Mail Stop 202-233*

*4800 Oak Grove Drive*

*Pasadena, CA 91109*

*(818) 354-2240*

*E-mail: ipggroup@jpl.nasa.gov*

*Refer to NPO-30563, volume and number of this NASA Tech Briefs issue, and the page number.*

## Innovative, High-Pressure, Cryogenic Control Valve: Short Face-to-Face, Reduced Cost

**This design includes several improvements over prior designs.**

*Stennis Space Center, Mississippi*

A control valve that can throttle high-pressure cryogenic fluid embodies several design features that distinguish it over conventional valves designed for similar applications. Field and design engineers worked together to create a valve that would simplify installation, trim changes, and maintenance, thus reducing overall cost. The seals and plug stem packing were designed to perform optimally in cryogenic temperature ranges. Unlike conventional high-pressure cryogenic valves, the trim size can be changed independent of the body.

The design feature that provides flexibility for changing the trim is a split body. The body is divided into an upper and a lower section with the seat ring sandwiched in between. In order to maintain the plug stem packing at an acceptable sealing temperature during cryogenic service, heat-exchanging fins were added to the upper body section (see figure).

The body is made of stainless steel. The seat ring is made of a nickel-based alloy having a coefficient of thermal expansion less than that of the body material. Consequently, when the interior of the valve is cooled cryogenically, the body surrounding the seat ring contracts more than the seat ring. This feature

prevents external leakage at the body-seat joint. The seat ring has been machined to have small, raised-face sealing surfaces on both sides of the seal groove. These sealing surfaces concentrate the body bolt load over a small area, thereby preventing external leakage.

The design of the body bolt circle is different from that of conventional high-pressure control valves. Half of the bolts clamp the split body together from the top, and half from the bottom side. This bolt-circle design allows a short, clean flow path, which minimizes frictional flow losses. This bolt-circle design also makes it possible to shorten the face-to-face length of the valve, which is 25.5 in. (65 cm). In contrast, a conventional, high-pressure control valve face-to-face dimension may be greater than 40 in. ( $>1$  m) long.

*This work was completed by Karlin Wilkes, Ed Larsen, and Jackson McCourt of Flowserve Corporation for Stennis Space Center. For further information, please contact Flowserve Corporation at (801) 489-8611 or [www.flowserve.com](http://www.flowserve.com).*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Intellectual Property Manager, Stennis Space Center at (228) 688-1929. Refer to SSC-00159.*



The Split-Body Design of this valve accommodates changes in trim. The heat-exchanger fins help keep the plug stem packing warm enough to function at cryogenic temperatures.