

diaphragm, and, hence, of the volume bounded by this diaphragm. One-way check valves admit gas into this volume from the low-pressure side during expansion and allow the gas to flow out to the high-pressure side during contrac-

tion. Fatigue data and the results of diaphragm stress calculations have been interpreted as signifying that the compressor can be expected to have an operational life of >30 years with a confidence level of 99.9 percent.

*This work was done by Michael G. Izenson and Martin Shimko of Creave, Inc. for Johnson Space Center. For further information, contact the Johnson Technology Transfer Office at (281) 483-3809. MSC-23269*

## ⚙️ Mechanically Biased, Hinged Pairs of Piezoelectric Benders

Unit cells can be stacked to obtain greater stroke for a given voltage.

*Lyndon B. Johnson Space Center, Houston, Texas*

The upper part of the figure depicts an actuator that comprises two mechanically biased piezoelectric benders hinged together at their ends and equipped with tabs at their mid-length points for attachment to the relatively moving objects that are to be actuated. In the example of the figure, the attachment tabs are labeled to indicate that the actuator is used to drive a pump piston relative to a base plate. Actuators of this type could be used to drive low-power, small-volume pumps in consumer, medical, and aerospace applications, and to generate and measure linear displacements in such robotic applications as teleoperation and tactile feedback.

Each bender is a bimorph — a unitary plate that comprises an upper and a lower piezoelectric layer plus electrode layers. Benders may also be made of several layers arranged to produce the same effect at the lower operating voltages. As stated above, each bender is mechanically biased; it is fabricated to have a small permanent curvature (the bias curvature) in the absence of applied voltage. As on other bimorphs, the electrical connections on each bender are

arranged so that an applied voltage of suitable polarity causes the upper layer to expand and the lower layer to contract. In this case, the net effect of applying the voltage is that the plate becomes more concave as viewed from below. Conversely, an applied voltage of the opposite polarity causes the plate to become less concave as viewed from below.

The benders in a hinged pair are oriented with their bias curvatures concave inward, so that there is a bias distance between the attachment tabs. The two benders are connected electrically in parallel, with their connection polarities chosen so that an applied voltage of one polarity causes both benders to become more convex inward (more bent), while an applied voltage of the opposite polarity causes both benders to become less convex inward (less bent). An increase or decrease in bend is accompanied by an increase or decrease in distance between the attachment tabs; this increase or decrease is the linear displacement desired for actuation. Because the displacement can be either positive or negative relative to the bias distance, depending on the polarity of the applied voltage, the overall stroke achievable for

a given magnitude of applied voltage is double the stroke achievable in the absence of mechanical bias.

Each hinged pair can be regarded as a unit cell that can serve as a building block for a larger actuator: Multiple unit cells can be stacked (mechanically connected in series), as shown in the lower part of the figure, and electrically connected in parallel to multiply the overall stroke achievable at a given applied voltage.

*This work was done by Frank E. Sager of Oceanering Space Systems for Johnson Space Center.*

*Title to this invention, covered by U.S. Patent No. 5,889,354, has been waived under the provisions of the National Aeronautics and Space Act {42 U.S.C. 2457 (f)}. Inquiries concerning licenses for its commercial development should be addressed to:*

*Oceanering Space Systems  
Attn: Jeffrey D. Brown, Program Development  
16665 Space Center Blvd.  
Houston, TX 77058-2268  
Phone No.: (281) 228-5300*

*Refer to MSC-22881, volume and number of this NASA Tech Briefs issue, and the page number.*