processed in a manner that would depend on the modulation (if any) applied to the signal and whether the signal was used to transmit power, data, or both.

The basic WAEF concept admits of variations. In one potentially important class of variations, different frequencies (in particular, those of lower- and higher-order resonances) would be used to transmit different signals through a wall in the same direction or in opposite directions. For example, an exterior ultrasonic transducer on a vessel could be excited at the fundamental resonance frequency to transmit power through the wall to an interior ultrasonic transducer to activate instrumentation inside the vessel, while the interior ultrasonic transducer could be excited at the frequency of a higher-order resonance to transmit data signals from the interior instrumentation to an external computer.

An electromechanical-network model has been derived as a computationally efficient means of analyzing and designing a WAEF system. This model is a variant of a prior model, known in the piezoelectric-transducer art as Mason's equivalent-circuit model, in which the electrical and mechanical dynamics, including electromechanical couplings, are expressed as electrical circuit elements that can include inductors, capacitors, and lumped-parameter complex impedances. The real parts of the complex impedances are used to account for dielectric, mechanical, and coupling losses in all components (including all piezoelectric-transducer, wall, and intermediate material layers). In an application to a three-layer piezoelectric structure, this model was shown to yield the same results as do solutions of the wave equations of piezoelectricity and acoustic propagation in their full complexity.

This work was done by Stewart Sherrit, Yoseph Bar-Cohen, and Xiaoqi Bao of Caltech for NASA's Jet Propulsion Laboratory. For further information, contact iaoffice@jpl.nasa.gov. NPO-41157

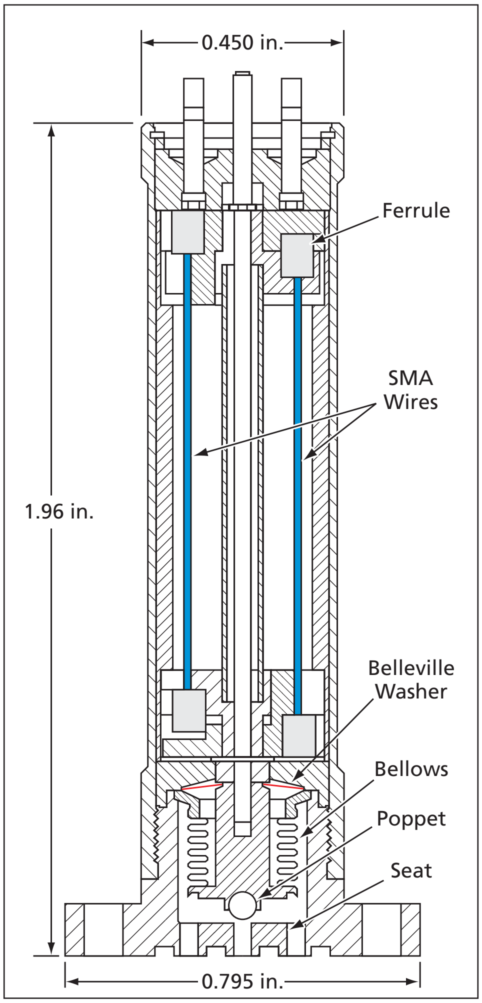
Miniature Latching Valve

This valve remains either open or closed when power is not supplied.

Goddard Space Flight Center, Greenbelt, Maryland

A miniature latching valve has been invented to satisfy a need for an electrically controllable on/off pneumatic valve that is lightweight and compact and remains in the most recently commanded open or closed state when power is not supplied. The valve (see figure) includes a poppet that is moved into or out of contact with a seat to effect closure or opening, respectively, of the flow path. Motion of the poppet is initiated by electrical heating of one of two opposing pairs of nickel/titanium shape-memory alloy (SMA) wires above their transition temperature: heated wires contract to their "remembered" length, applying tension to pull the poppet toward or away from the seat. A latch consisting mainly of a bistable Belleville washer (a conical spring) made of a hardened stainless steel operates between two stable positions corresponding to the fully closed or fully open state, holding the poppet in one of these positions when power is not applied to either pair of SMA wires.

The reason for using SMA wires is that in comparison with other linear actuators of the same mass and size, SMA wires produce more work output. The light weight and compactness of the SMA-wire actuators and the Belleville-washer latch make it possible for this valve to be smaller and less massive than are prior valves of comparable performance.



The **Miniature Latching Valve**, shown here in the open state, is actuated between the open and closed states by means of the SMA wires and the Belleville washer.

To obtain maximum actuation force and displacement, the SMA wires must be kept in tension. The mounting fixtures at the ends of the wires must support large tensile stresses without creating stress concentrations that would limit the fatigue lives of the wires. An earlier design provided for each wire to be crimped in a conical opening with a conical steel ferrule that was swaged into the opening to produce a large, uniformly distributed holding force. In a subsequent design, the conical ferrule was replaced with a larger crimped cylindrical ferrule depicted in the figure.

A major problem in designing the valve was to protect the SMA wires from a bake-out temperature of 300 °C. The problem was solved by incorporating the SMA wires into an actuator module that is inserted into a barrel of the valve body and is held in place by miniature clip rings.

This work was done by A. David Johnson of TiNi Alloy Co. and Glendon M. Benson of Aker Industries for Goddard Space Flight Center.

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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