

- Uses a twist-lock attachment (an improvement over setscrews).

The high-output flame holder was developed in support of the U.S. Navy's efforts to design a jet engine simulator for infrared plume studies. Previous tests had shown that off-the-shelf components would melt or burn up in a short time. Given these design and performance criteria, NASA developed a ceramic

flame holder that has a much longer life cycle and can be used with a variety of torches or burners. Where the stainless flame holders showed signs of oxidation, flaking after only three hours of testing, NASA's ceramic flame holder has over 150 hours and 200 cycles of use in a casting furnace, and soot marks are the only signs of use; there are no signs of deterioration. NASA expects the new technol-

ogy to help enhance safety through increased reliability and flame control. The total cost of ownership is less due to decreased maintenance and improved efficiency.

*This work was done by Henry Haskin of Langley Research Center. For further information, contact the Langley Innovative Partnerships Office at (757) 864-8881. LAR-17502-1*

## Non-Pyrotechnic Zero-Leak Normally Closed Valve

*Goddard Space Flight Center, Greenbelt, Maryland*

This valve is designed to create a zero-leak seal in a liquid propulsion system that is a functional replacement for the normally closed pyrovalve. Unlike pyrovalves, Nitinol is actuated by simply heating the material to a certain temperature, called the transition temperature. Like a pyrovalve, before actuation, the upstream and downstream sections are separated from one another and from the external environment by closed welded seals. Also like pyrovalves, after actuation, the propellant or pressurant gas can flow without a significant pressure drop but are still separated from the external environment by a closed welded seal.

During manufacture, a Nitinol bar is compressed to 93 percent of its origi-

nal length and fitted tightly into the valve. During operation, the valve is heated until the Nitinol reaches the transition temperature of 95 °C; the Nitinol "remembers" its previous longer shape with a very large recovery force causing it to expand and break the titanium parent metal seal to allow flow. Once open, the valve forever remains open.

The first prototype valve was designed for high pressure [5,000 psi ( $\approx 34.5$  MPa)] and low flow, typical requirements for pressurant gas valves in liquid propulsion systems. It is possible to modify the dimensions to make low-pressure models or high-flow models, for use downstream of the propellant tanks.

This design is simpler, lower risk, and less expensive than the pyrovalve. Although the valve must be in a thermally controlled state (kept below 80 °C) to prevent premature actuation, the pyrovalves and electrically actuated initiators have far more taxing handling requirements.

*This work was done by Rebecca Gillespie of Goddard Space Flight Center. 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, Goddard Space Flight Center, (301) 286-7351. Refer to GSC-15328-1.*

## Fast-Response-Time Shape-Memory-Effect Foam Actuators

**These actuators have application in variable-area chevrons and nozzles in jet aircraft.**

*John H. Glenn Research Center, Cleveland, Ohio*

Bulk shape memory alloys, such as Nitinol or CuAlZn, display strong recovery forces undergoing a phase transformation after being strained in their martensitic state. These recovery forces are used for actuation. As the phase transformation is thermally driven, the response time of the actuation can be slow, as the heat must be passively inserted or removed from the alloy.

Shape memory alloy TiNi torque tubes have been investigated for at least 20 years and have demonstrated high actuation forces [3,000 in.-lb ( $\approx 340$  N-m) torques] and are very lightweight. However, they are not easy to attach to existing structures. Adhesives will fail in shear at low-torque loads and the TiNi is not weldable, so that mechanical crimp

fits have been generally used. These are not reliable, especially in vibratory environments. The TiNi is also slow to heat up, as it can only be heated indirectly using heater and cooling must be done passively. This has restricted their use to on-off actuators where cycle times of approximately one minute is acceptable.

Self-propagating high-temperature synthesis (SHS) has been used in the past to make porous TiNi metal foams. Shape Change Technologies has been able to train SHS derived TiNi to exhibit the shape memory effect. As it is an open-celled material, fast response times were observed when the material was heated using hot and cold fluids.

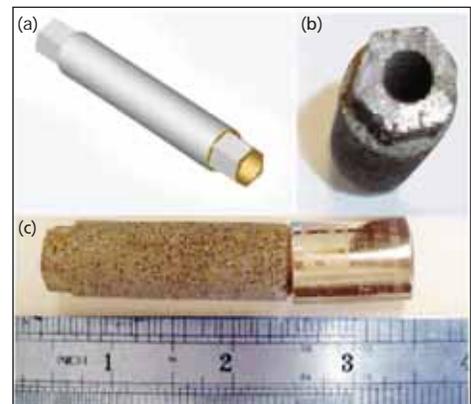


Figure: (a) Schematic Representation of the TiNi Torque Tube. The ends are integrated as hexagonal caps as shown in (b) and (c) shows a processed torque tube with a coupling at a representative length scale.

A methodology was developed to make the open-celled porous TiNi foams as a tube with integrated hexagonal ends, which then becomes a torsional actuator with fast response times. Under processing developed independently, researchers were able to verify torques of 84 in.-lb ( $\approx 9.5$  N-m) using an actuator weighing 1.3 oz ( $\approx 37$  g) with very fast ( $< 1/16$ th of a second) initial response times when hot and cold fluids were used to facilitate heat transfer.

Integrated structural connections were added as part of the net shape process, eliminating the need for weld-

ing, adhesives, or mechanical crimping. Inexpensive net-shape processing was used, which reduces the cost of the actuator by over a factor of 10 over non-porous TiNi made by hot drawing of tube or electrical discharge machining.

By forming the alloy as an open-celled foam, the surface area for heat transfer is dramatically increased, allowing for much faster response times. The technology also allows for net-shape fabrication of the actuator, which allows for structural connections to be integrated into the actuator material, making these actuators significantly less expensive.

Commercial applications include actuators for concepts such as the variable-area chevron and nozzle in jet aircraft. Lightweight tube or rod components can be supplied to interested parties.

*This work was done by A. Peter Jardine of Shape Change Technologies LLC for 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-18526-1.*