material with an open-cell metallic foam that provides noise-reduction benefits and a sacrificial material in the first layer of the containment system.

An open-cell foam was evaluated that behaves like a bulk acoustic liner, serves as a tip rub strip, and can be integrated with a rotor containment system. Foams can be integrated with the fan-containment system to provide sufficient safety margins and increased noise attenuation. The major innovation is the integration of the foam with the containment.

The uniqueness of the innovation is the ability to reduce turbomachinery noise for aircraft engine applications while providing sufficient blade containment and minimal (if any) aerodynamic penalty. The innovation can be applied to compressors, turbines, and fans. Space is usually limited over the rotors due to the need for containment systems. The innovation replaces the first layer of the containment system with a foam that behaves like an acoustic bulk liner. The material properties of the foam can be tailored for temperature, density, porosity, and weight to suit the application. Existing turbofan engines do not use acoustic treatment placed directly over the rotor. The innovation enables this due to the foam behaving like a rub strip and an acoustic liner. Full-scale testing of production turbofan engine resulted in 5-dB total attenuation.

This innovation can be applied to other turbomachinery where noise reduction is needed from the rotors; for example, ground power systems, cooling/ventilating fans, and ducted propellers.

This work was done by Dennis L. Huff and Daniel L. Sutliff of Glenn Research Center; Michael G. Jones of Langley Research Center; and Mohan G. Hebsur of the Ohio Space Institute.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-18438-1.

Metering Gas Strut for Separating Rocket Stages

Marshall Space Flight Center, Alabama

A proposed gas strut system would separate a liquid-fueled second rocket stage from a solid-fueled first stage using an array of pre-charged struts. The strut would be a piston-and-cylinder mechanism containing a compressed gas. Adiabatic expansion of the gas would drive the extension of the strut. The strut is designed to produce a force-versus-time profile, chosen to prevent agitation of the liquid fuel, in which the force would increase from an initial low value to a peak value, then decay toward the end of the stroke.

The strut would include a piston chamber and a storage chamber. The piston chamber would initially contain gas at a low pressure to provide the initial low separation force. The storage chamber would contain gas at a higher pressure. The piston would include a longitudinal metering rod containing an array of small holes, sized to restrict the flow gas between the chambers, that would initially not be exposed to the interior of the piston chamber. During subsequent expansion, the piston motion would open more of the metering holes between the storage and piston chambers, thereby increasing the flow of gas into the piston chamber to produce the desired buildup of force.

This work was done by Brian Floyd of Integrated Concepts Research Corp. for Marshall Space Flight Center. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32660-1.

Large-Flow-Area Flow-Selective Liquid/Gas Separator

A two-phase flow separator for fuel cells operates between 2 and 10 kW in multi-g environments.

Lyndon B. Johnson Space Center, Houston, Texas

This liquid/gas separator provides the basis for a first stage of a fuel cell product water/oxygen gas phase separator. It can separate liquid and gas in bulk in multiple gravity environments. The system separates fuel cell product water entrained with circulating oxygen gas from the outlet of a fuel cell stack before allowing the gas to return to the fuel cell stack inlet. Additional makeup oxygen gas is added either before or after the separator to account for the gas consumed in the fuel cell power plant. A large volume is provided upstream of porous material in the separator to allow for the collection of water that does not exit the separator with the outgoing oxygen gas. The water then can be removed as it continues to collect, so that the accumulation of water does not impede the separating action of the device.

The system is designed with a series of tubes of the porous material configured into a shell-and-tube heat exchanger configuration. The two-phase fluid stream to be separated enters the shell-side portion of the device. Gas flows to the center passages of the tubes through the porous material and is then routed to a common volume at the end of the tubes by simple pressure difference from a pumping device. Gas flows through the porous material of the tubes with greater ease as a function of the ratio of the dynamic viscosity of the water and gas. By careful selection of the dimensions of the tubes (wall thickness, porosity, diameter, length of the tubes, number of the tubes, and tube-to-tube spacing in the shell volume) a suitable design can be made to match the magnitude of water and gas flow, developed pressures from the oxygen reactant pumping device, and required residual water inventory for the shell-side volume.

The system design has the flexibility to be configured in a few different ways. Special configurations of the tube geometry could aid the operation of the re-