

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) aerody-

amic 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 mo-

tion 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-

quired second stage to manage the continual accumulation of water in the shell-side volume. An example would be with the circularization of the tubes so that water would tend to be swirled or slung to the outside of the tube bundle for subsequent removal by a second stage of the separator intended for the fine separation of remaining gas from the product water stream before it exits the separator. Another version could in-

clude in-separator reactant pressure regulation, ejector-based reactant pumping, and reactant pre-humidifying thermal control through the use of in-separator thermal conditioning.

The system has few moving parts and is not subject to degradation of performance due to changes in material properties (surface wetting characteristics, etc.). The design eliminates the possibility of flooding of the fuel cell stack dur-

ing nominal operations, reduces the complexity of the task of maintaining the residual water volume of the separator during periods of non-use of the fuel cell power system, and can be packaged in a manner suitable for spacecraft fuel cell power systems.

This work was done by Arturo Vasquez and Karla F. Bradley for Johnson Space Center. Further information is contained in a TSP (see page 1). MSC-24157-1.

⚙️ Counterflowing Jet Subsystem Design

Marshall Space Flight Center, Alabama

A counterflowing jet design (a spacecraft and trans-atmospheric subsystem) employs centrally located, supersonic cold gas jets on the face of the vehicle, ejecting into the oncoming free stream. Depending on the supersonic free-stream conditions and the ejected mass flow rate of the counterflowing jets, the bow shock of the vehicle is moved upstream, further

away from the vehicle. This results in an increasing shock standoff distance of the bow shock with a progressively weaker shock. At a critical jet mass flow rate, the bow shock becomes so weak that it is transformed into a series of compression waves spread out in a much wider region, thus significantly modifying the flow that wets the outer surfaces, with an attendant

reduction in wave and skin friction drag and aerothermal loads.

This work was done by Rebecca Farr, Endwell Daso, Victor Pritchett, and Ten-See Wang of Marshall Space Flight Center. For more information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32604-1.

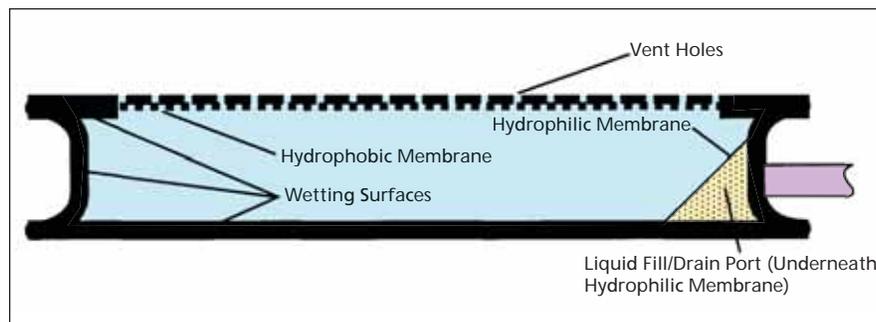
⚙️ Water Tank With Capillary Air/Liquid Separation

Tank is filled and emptied as needed in microgravity.

Lyndon B. Johnson Space Center, Houston, Texas

A bladderless water tank (see figure) has been developed that contains capillary devices that allow it to be filled and emptied, as needed, in microgravity. When filled with water, the tank shields human occupants of a spacecraft against cosmic radiation. A membrane that is permeable by air but is hydrophobic (neither wettable nor permeable by liquid water) covers one inside surface of the tank. Grooves between the surface and the membrane allow air to flow through vent holes in the surface as the tank is filled or drained. A margin of wettable surface surrounds the edges of the membrane, and all the other inside tank surfaces are also wettable. A fill/drain port is located in one corner of the tank and is covered with a hydrophilic membrane.

As filling begins, water runs from the hydrophilic membrane into the corner fillets of the tank walls. Continued filling in the absence of gravity will result in a



This functional schematic shows key components of the Radiation-Shield Water Tank.

single contiguous air bubble that will be vented through the hydrophobic membrane. The bubble will be reduced in size until it becomes spherical and smaller than the tank thickness. Draining the tank reverses the process. Air is introduced through the hydrophobic membrane, and liquid continuity is maintained with the fill/drain port through the corner fillets. Even after the

tank is emptied, as long as the suction pressure on the hydrophilic membrane does not exceed its bubble point, no air will be drawn into the liquid line.

This work was done by Eugene K. Ungar, Frederick Smith, and Gregg Edeen of Johnson Space Center and Jay C. Almlie of Hernandez Engineering, Inc. Further information is contained in a TSP (see page 1). MSC-23251-1