tice in the sintering and annealing of conventional powder-metallurgy components. Each tube was packed with high-purity alumina sand to prevent slumping of the thin-walled tubes during heating. Hydrogen was used during the heat treatment of three of the alloys (60Mo/40Re, 75W/25Re, and 95.5W/3.5Ni/1.0Fe) to aid in densification and in the reduction of oxides. Both a liquid-phase sinter (LPS) and a solid-state sinter (SSS) were used on the 95.5W/3.5Ni/1.0Fe alloy. Hydrogen was not used during heat treatment of the 90Ta/10W and 99Nb/1Zr alloys because these alloys are susceptible to the formation of brittle hydrides; instead, these alloys were annealed in vacuum.

Standard metallurgical polishing techniques were used to prepare specimens of the as-sprayed and heat-treated tubes of each alloy. These specimens were then examined in the as-polished and etched conditions, by use of an optical microscope. Quantitative microscopy was used to determine the densities of the specimens. Helium leak tests were performed on the as-sprayed and heat-treated specimens to determine whether any interconnected porosity was open to the surfaces. Some room-temperature compression tests were performed on heat-treated specimens to determine whether there were any improvements in mechanical properties.

The SSS and LPS heat treatments were found to effect significant increases in toughness and ductility of the 95.5W/3.5Ni/1.0Fe alloy, and to result in cartridge helium-leak rates of about 10^{-8} cm^3/s — well below the maximum allowable rate of 10^{-6} cm^3/s. For the other alloys and heat treatments investigated, there was a mix of favorable and unfavorable findings.

This work was done by Richard R. Holmes and Frank R. Zimmerman of **Marshall Space Flight Center** *and J. Scott O'Dell and Timothy N. McKechnie of Plasma Processes Inc. Further information is contained in a TSP (see page 1).*
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Burn-Resistant, Strong Metal-Matrix Composites

Ceramic particulate fillers increase burn resistances and specific strengths of metals.

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Ceramic particulate fillers increase the specific strengths and burn resistances of metals: This is the conclusion drawn by researchers at Johnson Space Center's White Sands Test Facility. The researchers had theorized that the inclusion of ceramic particles in metal tools and other metal objects used in oxygen-rich atmospheres (e.g., in hyperbaric chambers and spacecraft) could reduce the risk of fire and the consequent injury or death of personnel. In such atmospheres, metal objects act as ignition sources, creating fire hazards. However, not all metals are equally hazardous: some are more burn-resistant than others are. It was the researchers' purpose to identify a burn-resistant, high-specific-strength ceramic-particle/metal-matrix composite that could be used in oxygen-rich atmospheres.

The researchers studied several metals. Nickel and cobalt alloys exhibit high burn resistances and are dense (ranging from 7 to 9 g/cm^3). For a space-flight or industrial application in which weight is a primary concern, the increased weight that must be incurred to obtain flame resistance may be unacceptable. Aluminum and titanium are sufficiently less dense that they can satisfy most weight requirements, but they are much more likely to combust in oxygen-enriched atmospheres: In pure oxygen, aluminum is flammable at a pressure of 25 psia (absolute pressure ≈ 170 kPa) and titanium is flammable below 2 psia (absolute pressure ≈14 kPa).

The researchers next turned to ceramics, which they knew do not act as ignition sources. Unlike metals, ceramics are naturally burn-resistant. Unfortunately, they also exhibit low fracture toughnesses. Because a typical ceramic lacks the malleability, durability, and strength of a metal, ceramics are seldom used in outer-space and industrial environments. The researchers theorized that a ceramic-particle/metal-matrix composite might provide the best of both classes of materials: the burn resistance of the ceramic and the tensile strength of the metal. They demonstrated that when incorporated into such low-burn-resistance metals as aluminum and titanium, ceramic particles increase the burn resistances of the metals by absorbing heat of combustion. In the case of such high-burn-resistance metals as nickel and copper, it was demonstrated that ceramic particulate fillers increase specific strengths while maintaining burn resistances.

Preliminary data from combustion tests indicate that an A339 aluminum alloy filled with 20 volume percent of silicon carbide is burn-resistant at pressures up to 1,200 psia (absolute pressure ≈8.3 MPa) — that is, it has 48 times the threshold pressure of unfilled aluminum. The data show that of all the composites tested to date, this composite has the greatest burn resistance and greatest specific strength and is the best candidate for use in oxygen-enriched atmospheres.

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