

POROUS METAL FOR
AEROSPACE

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Porous metal provides the integrity, durability, formability, and weldability of solid metal, but with the added benefit of pores. In this material, micron-size pores form tortuous interconnected labyrinths similar to those in a sponge, but much smaller. Porous metal versatility is demonstrated by the multitude of industrial filtration and fluid control applications in the aerospace, chemical process, petrochemical, medical, pharmaceutical, and semiconductor industries.

For example, Gulfstream Aerospace (Fig. 1) needed a specially designed sintered porous metal filter for an air bleed system to ensure long term, low maintenance of equipment in a turbofan air bleed system. Gulfstream initially required a retrofit filter to eliminate 'black soot particulate matter' that was bleeding from the turbofan engine and causing failure of the servo air pressure regulator / torque motor.

Over the past ten years, these flight-certified filters have become standard equipment. One such filter design features a media grade 60 sintered metal porous cup of Inconel 600. The porous cup is welded to a modified 304 stainless steel AN bulkhead union. Inconel 600 was chosen because it allows the filter to be easily retrofitted into the aircraft engine's eighth stage bleed air ducting system. It also has the requisite corrosion and temperature resistance, and can be welded for a permanent, leak-free and vibration-tolerant attachment into a standard tube fitting for ease of assembly. The filter assembly also needed to have the unique characteristic of sufficiently low pressure drop to ensure



Fig. 1 — Gulfstream aircraft utilizes a porous metal filter in a critical turbofan application.

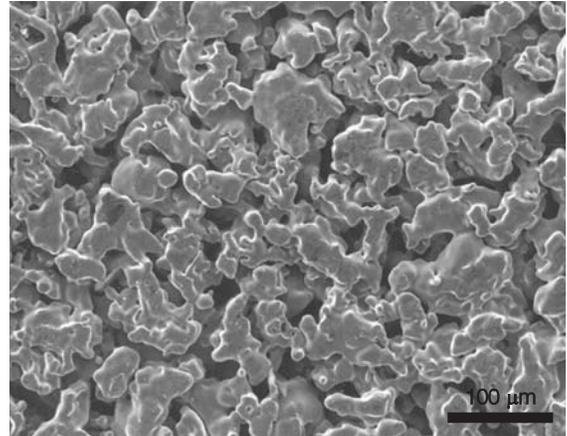


Fig. 2 — Photomicrograph of sintered metal powder media.

no adverse effects to the downstream valve and equipment, while at the same time capturing any particles larger than 70 microns, with little or no maintenance. These parts must pass stringent flight testing program and quality programs.

Sintered PM technology

Sintered metal media are fabricated from various metal alloy powders to meet demanding application requirements. They are manufactured in a controlled process by pressing pre-alloyed powder of controlled size and shape into discs, cups, bushings, tubes, or porous sheet, followed by high-temperature sintering. The combination of powder size and the pressing and sintering operations define the pore size and distribution, strength, and permeability of the porous media. A scanning electron photomicrograph of a typical porous sintered metal powder material is shown in the Figure 2.

Reliable performance and long on-stream service life depend on the alloy, a stable porous matrix, precise bubble point specifications, close thickness tolerances, and uniformity of permeability. Sintered metal media are offered in a wide range of grades with mean flow pores ranging in size from 0.1 to 100 microns. Alloys include 316L stainless steel; Hastelloy B, C-22, C276, N, and X; Inconel 600, 625, and 690; Monel 400; nickel 200; alloy 20; and titanium. Properties are shown in Table 1.

The proper selection of porous media with appropriate pore size, strength, and corrosion resistance enables long-term filter operation with high efficiency particle retention in demanding filtration applications: high temperature, high pressure, and corrosive fluids. The primary benefits of sintered metal media are strength and fracture toughness, high pressure and temperature capabilities, high thermal shock resistance, corrosion resistance, cleanliness, all-welded or sinter-bonded assembly, and long service life.

Table 1 — Elevated-temperature service for selected sintered metal alloys

Alloy	Maximum temperature in oxidizing atmosphere, °C (°F)	Maximum temperature in reducing atmosphere, °C (°F)
316 L Stainless Steel	400 (750)	482 (900)
Inconel 600	593 (1100)	815 (1500)
Hastelloy X	788 (1450)	927 (1700)

Sintered metal filter elements can be supplied to withstand differential pressures over 210 bar (3000 psi). Sintered metal is permanent, with an all welded construction. The material can withstand pressure spikes with no media migration.

Filtration properties depend on the media characteristics, the surface area available, and the process conditions of the application. The degree of filter performance differs between liquid and gas service due to differences in the effectiveness of the operable particle capture mechanisms.

Flow control devices, commonly called flow restrictors, are also made of sintered porous metal. Flow restrictors are static devices with no moving or adjustable components. A porous metal flow restrictor is, in effect, a multiple-orifice device with many (usually hundreds) of small pores, thereby creating a vast array of flow pathways.

Basically, a flow restrictor consists of a precision porous metal element permanently inserted into a bore – located in a variety of standard industrial gas line fittings or application specific customized hardware. In operation, the porous metal element meters or limits the uniform flow of fluid (usually a gas) from high pressure to low pressure in a controlled manner. For a specified flow rate, both the upstream and downstream pressure conditions must be maintained.

Aerospace applications

Porous metal components serve critical functions on spacecraft, landing craft, space instrumentation packages, and aircraft. They range from the routine to exotic, where the unique characteristics of the porous metal are critical to ensure long term service in filtration, flow control, or thermal management.

A common denominator in these applications is the need for robust porous materials that function in a predictable and consistent manner over extensive periods of time (could be several years) in often hostile environments. The operating conditions may include wide temperature ranges, pressures ranging from high vacuum to high pressure, inert or corrosive gases and liquid, and may involve high g-forces, thermal shock, and/or vibration. It is essential that the porous materials exhibit alloy stability and product reliability.

Flow control is one common function of porous metal components in aerospace applications. The porous metal usually serves as a plug that is inserted into a tube fitting or into a flow passageway, and is calibrated to exacting flow rate/pressure drop specifications. Typical examples for space applications are propulsion systems and gas sampling instrumentation.

Flight applications can also exploit other attrib-



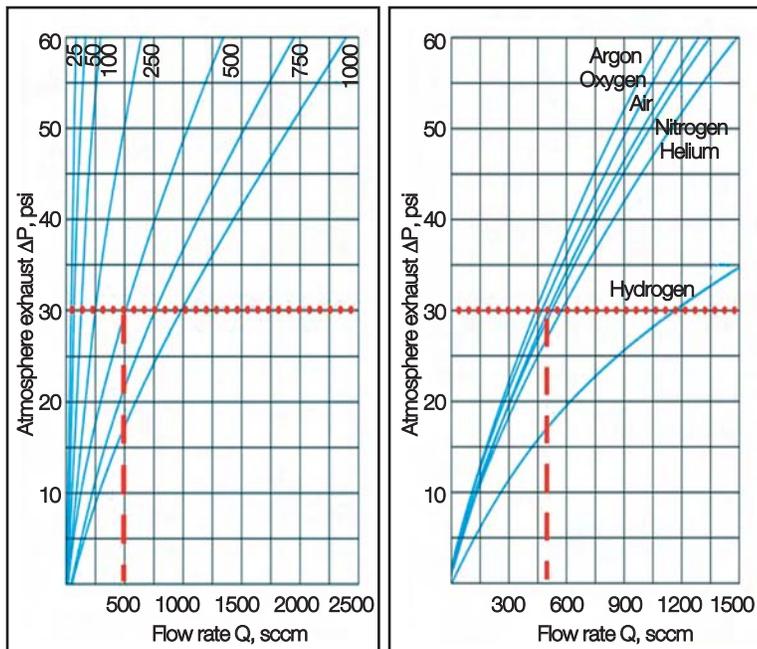
Fig. 3 — Examples of fabricated products made from sintered metal powder media.

utes of porous metal, for example, wicking and thermal properties. An illustrative example would be a heat pump in a cryo-cooler for spacecraft electronics. Nickel and titanium porous metal tubes were chosen to pump liquid ammonia through electronics cooling systems by means of the fluid's capillary action within the pores of porous metal; thereby resulting in a closed loop pumping system with an estimated lifespan of more than 20 years.

Porous metal products are integral components in spacecraft thrusters and ion engines, air sampling instrumentation, and thermal control systems. Examples (Fig. 3) include Inconel porous cups and titanium discs that serve as porous protective covers on sensors on the Sample Analysis at Mars program, and 316LSS cup assemblies for the Lunar Orbiting Laser Altimeter (LOLA).

Porous metal has been a critical component of a laboratory experiment to simulate flight conditions in air and space applications. In one instance, cylindrical filter elements made of Hastelloy X were designed to and proven to withstand the harsh conditions in a NASA Mach 10 wind tunnel. Other examples:

- Flow control of the xenon gas flow for the revolutionary ion propulsion engine on the Deep Space 1 program. Flow restrictors were required to hold the xenon gas flow to +/- 1.5%. This precise flow of gas allowed the Jet Propulsion Laboratory to control and monitor the space probe during its multi-year 86.5 million mile interplanetary travels through space.
- Gas flow control to the thrusters that maintain three-axis stability, control spin, execute minor interplanetary trajectory correction maneuvers, and orbit trim maneuvers on the Cassini-Huygens space probe. The restrictors control a discrete volume of



These graphs illustrate air flow verse differential pressure (left) and common gas flows verse differential pressure for 500 sccm restrictor (right).

compressed monopropellant hydrazine at a precise flow rate and time through flow controllers. This gas flow rate must be well known, precise, and consistent as the probe travels for more than ten years through space.

- Flow control of helium at 4 Kelvins in a sorp-

tion cooler for the European Space Agency.

- Flow control within air sampling instruments on-board the International Space Station, such as the mass spectrometer that monitors air quality.

- Flow control of helium at flow rates of 2.0 - 2.5 sccm and pressures of 1500 psi in experimental propulsion systems and instrumentation packages.

Filters can be designed to achieve various levels of particle filtration, as required by the specific application requirements, e.g., flow rates, pressure drop, particle size, and level of fluid purity. Particle capture efficiencies can range from 99% to >99.9999999% for submicron and larger size particles.

The author included tables and other details not included here. Please contact him for more information.

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