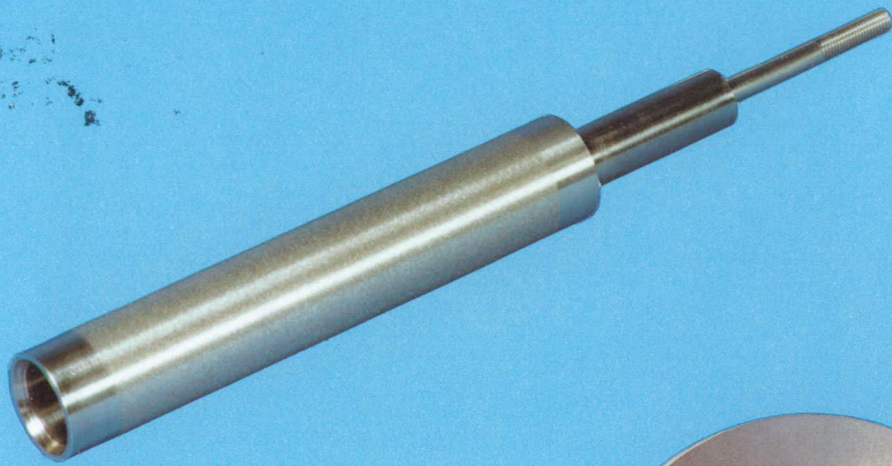
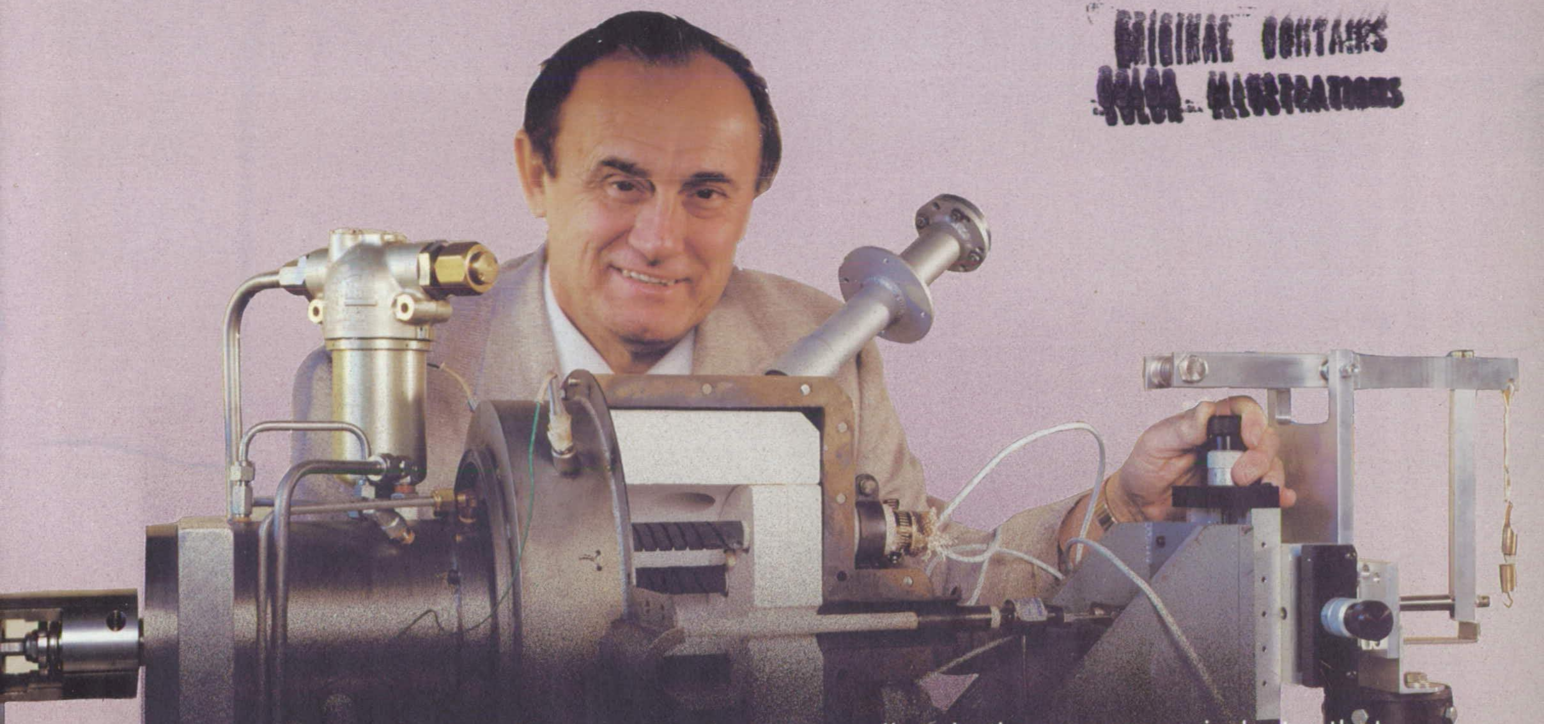
PM200 PS200

Self-Lubricating Bearing and Seal Materials for Applications to 900 °C

Materials Division
NASA Lewis Research Center
Cleveland, Ohio



FOREWORD



There are many applications in general industry as well as in the aerospace industry that would benefit from the availability of self-lubricating bearing and seal materials with temperature capabilities well beyond those of the current state of the art. Such materials would be enabling for some designs where high-temperature lubrication is critically needed and would simplify others where the high-temperature lubrication problem is currently ''designed around'' by cooling or other complexities. It was with the goal of developing materials for such needs that the PS/PM200 class of self-lubricating materials described in this brochure was developed by research personnel in the Surface Science Branch of the Materials Division at the Lewis Research Center. PS200 coatings and PM200 free-standing powder metallurgy composites are unique, not only for their self-lubricating capability at high temperature but, perhaps even more importantly, for that self-lubricating capability over the extremely large temperature spectrum of −160 to 900 °C (−250 to 1650 °F). The purpose of this brochure is to communicate information about these unique coatings and powder metallurgy composites to U.S. industry.

NASA funding for the development of the PS/PM200 class of materials was supplemented with support from the Heavy Duty Transport Office of the U.S. Department of Energy. This cooperation underscores the fact that these materials are intended for terrestrial as well as aerospace applications.

H E Sliney

Harold E. Sliney
Senior Scientist
Surface Science Branch

2 TECHNOLOGY NEED

Bearing and seal materials are needed that are self-lubricating at very high temperatures. Such materials must have lubricating capabilities well beyond those of the present oils, greases, and conventional solid lubricants.

RELEVANT APPLICATION AREAS

- **Manufacturing**
  - Glass-forming equipment bearings
  - Metal-working equipment bearings

- **Reciprocating Engines**
  - Cylinder liner coatings
  - Valve guides and seats

- **Rotary Engines**
  - Apex seals
  - Combustion chamber coating

- **Gas Turbine Engines**
  - Shaft seals
  - Variable stator vane bushings
  - Variable geometry gas path mechanisms

- **Auxiliary Turbomachinery**
  - Gas bearings
    Backup lubricant for start-stop
    and high-speed rubs

- **Super- and Hypersonics**
  - Control surface bearings and seals
  - Airframe thermal expansion joints

The PS/PM200 system is a series of self-lubricating composites with a duplex microstructure consisting of a hard carbide phase with soft noble metal and stable fluoride phases.

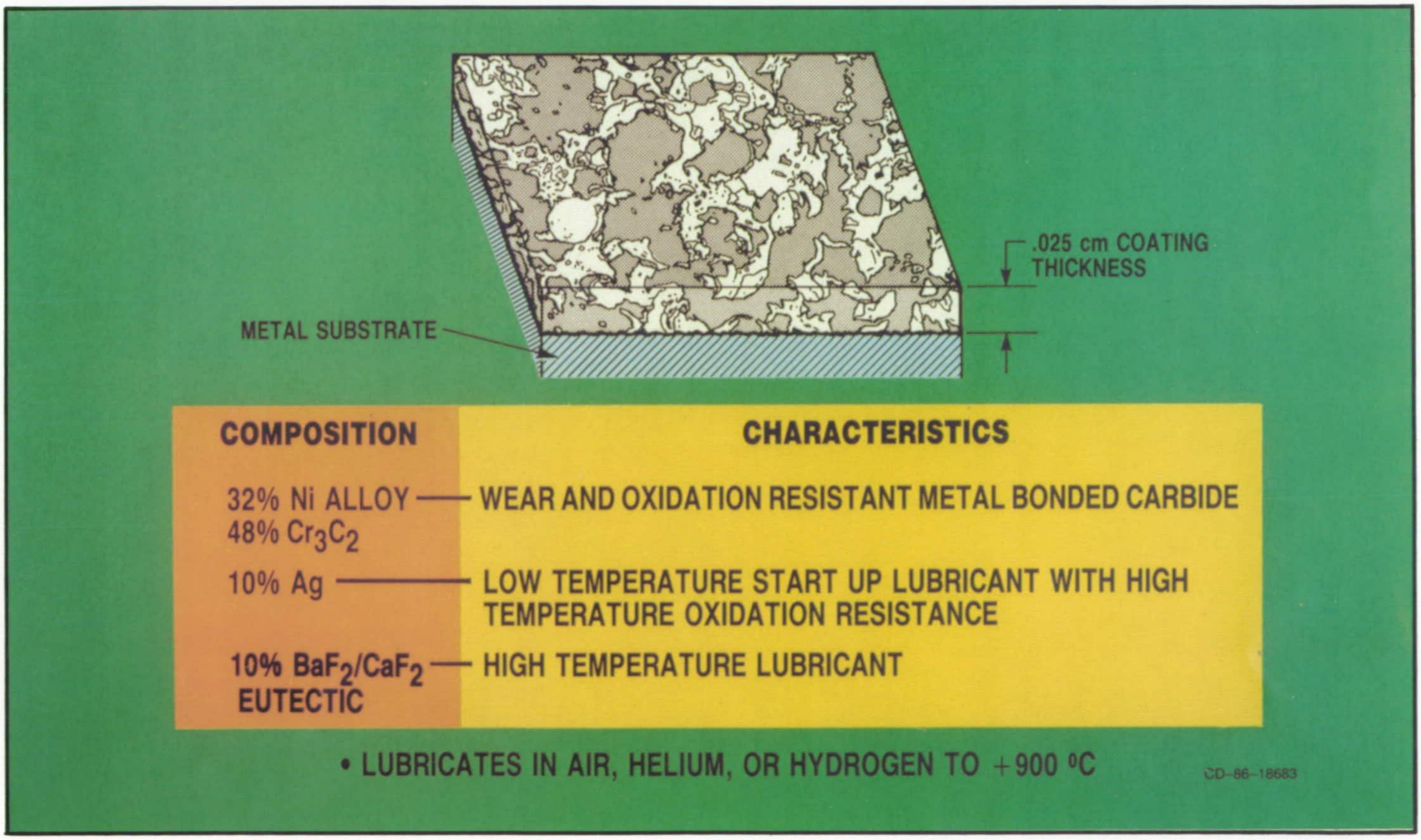
PS200 composites are plasma-sprayed coatings, and PM200 composites are free-standing sintered or hot isostatically pressed (HIPed) Powder Metallurgy parts.

The ratio of carbide to soft phases can be tailored depending on design requirements such as conformability and hardness.

Typical preferred weight ratios of nickel-alloy-bonded chromium carbide to silver to barium fluoride/calcium fluoride eutectic are as follows:

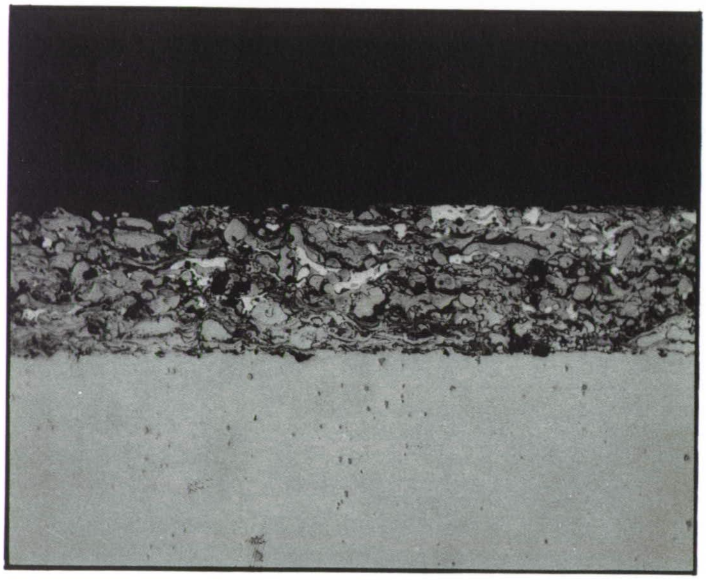
PS200: 80-10-10 PS212 and PM212: 70-15-15

The Concept

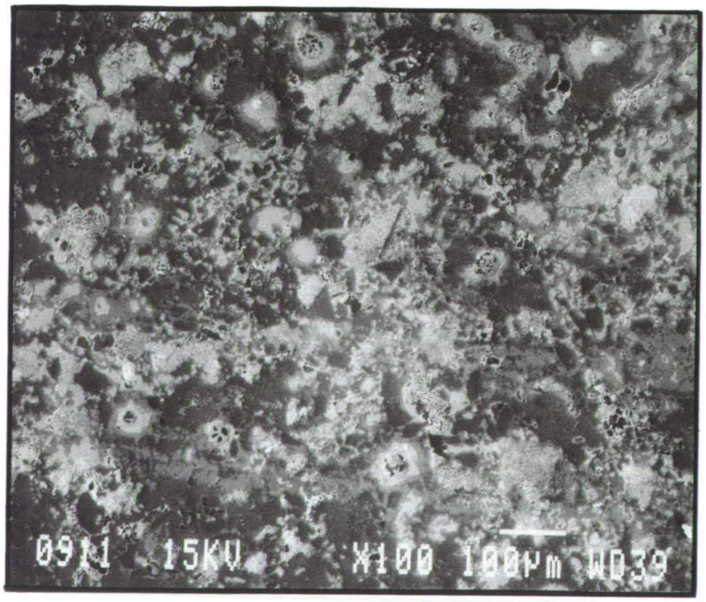


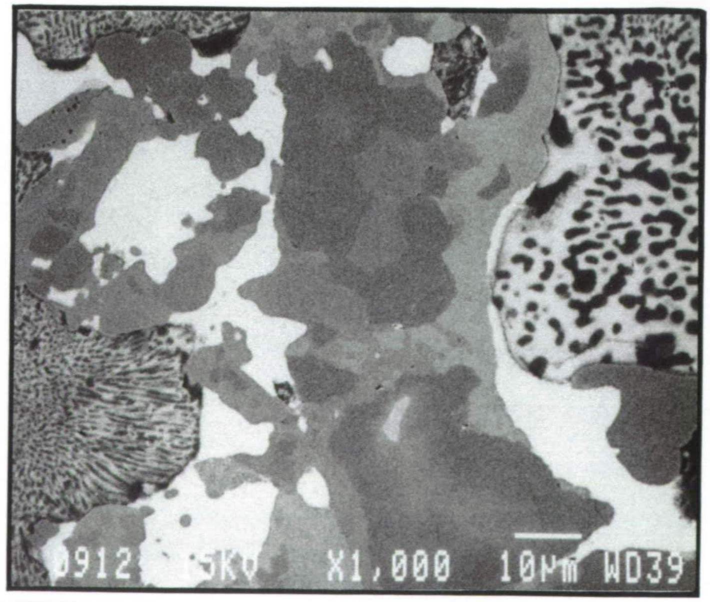
4 MICROSTRUCTURE

These materials consist of a matrix of metal bonded chromium carbide containing dispersed silver and a eutectic of calcium fluoride and barium fluoride. The microstructure of plasma-sprayed PS212 is stratified by the application method—multiple passes with a spray torch. The powder metallurgy versions contain randomly dispersed solid lubricants.



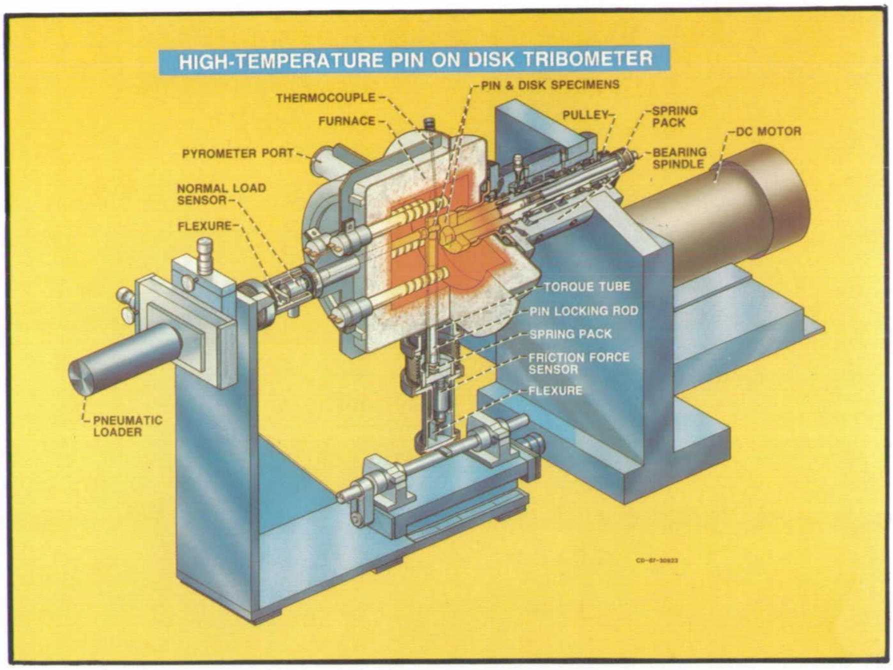
Plasma-sprayed PS212



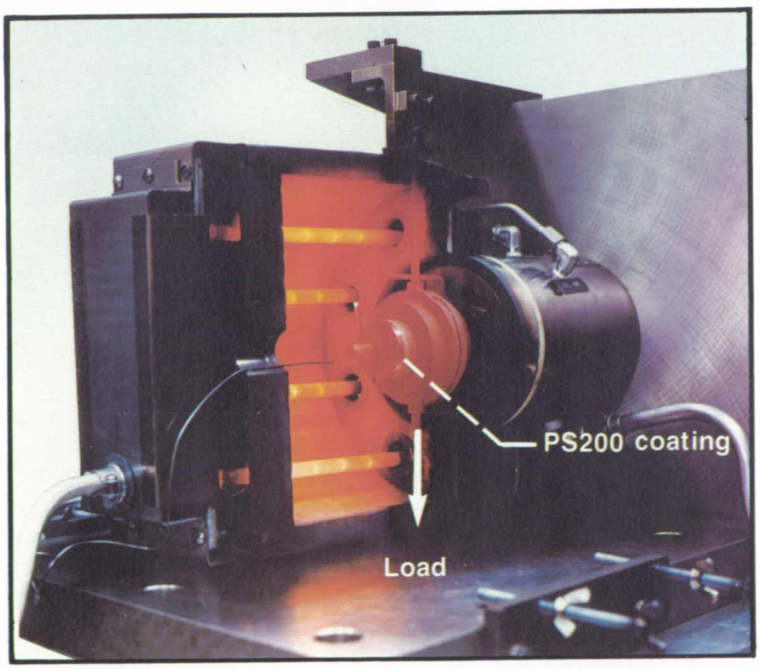


Hot isostatically pressed PM212

HIGH-TEMPERATURE TESTING 5



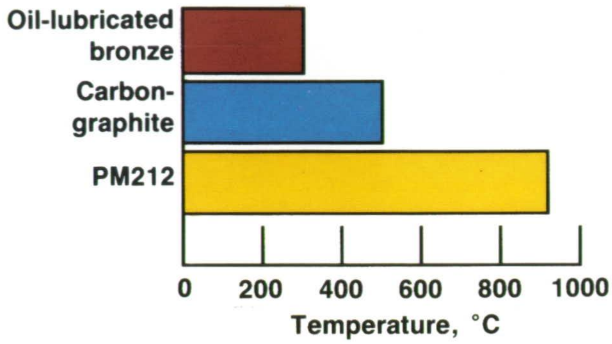
Basic friction and wear properties were measured in atmospheres of air, hydrogen, and helium over a wide range of temperatures and sliding velocities.



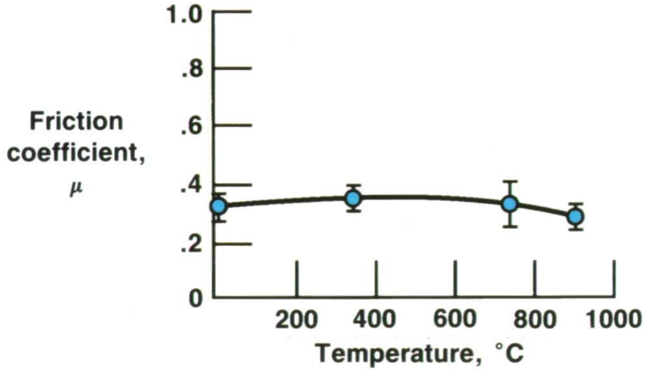
Further evaluation was performed with actual mechanical components such as the PS200-lubricated journal bearing shown under test in this photograph. (One side of the furnace was briefly removed to expose the bearing for this illustration.)

PROPERTIES OF PM212

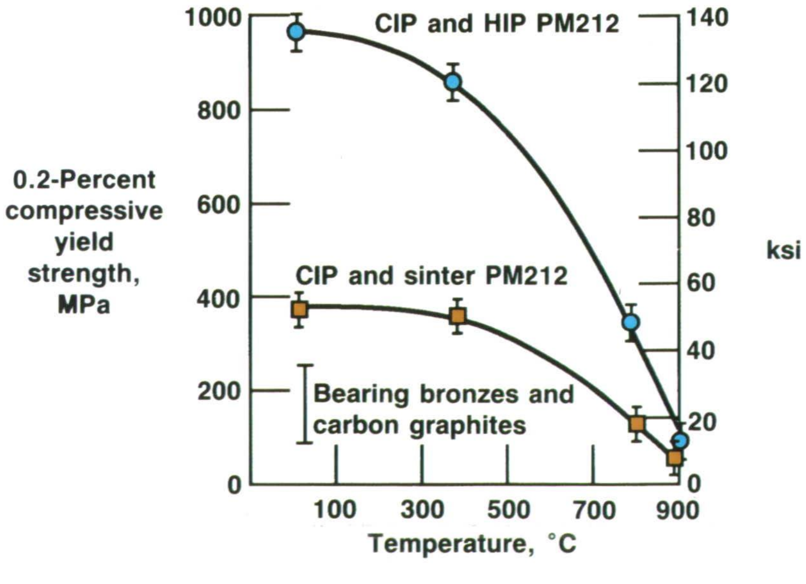
SUPERIOR MAXIMUM SERVICE TEMPERATURE



NONGALLING AND MODERATE FRICTION TO 900 °C



MECHANICAL STRENGTH COMPARES FAVORABLY WITH CONVENTIONAL SLIDING BEARING MATERIALS



LINEAR THERMAL EXPANSION

Material	Temperature range, °C	Thermal expansion coefficient, $°C^{-1}$
PM212	25 to 550 25 to 850	$12.2e^{-6}$ 14.2
Bonded Cr_2C_3 matrix	25 to 550 25 to 850	12.2 13.3
Ag	25 to 900	[a]28.4
CaF_2	25 to 627	[a]36.6
BaF_2	25 to 577	[a]25.8
Cr_3C_2	25 to 927	[a]12.1
Ni	25 to 927	[a]18.3

[a]Touloukian,Y.S., et al., Thermophysical Properties of Matter. Vol. 12 Plenum, 1975.

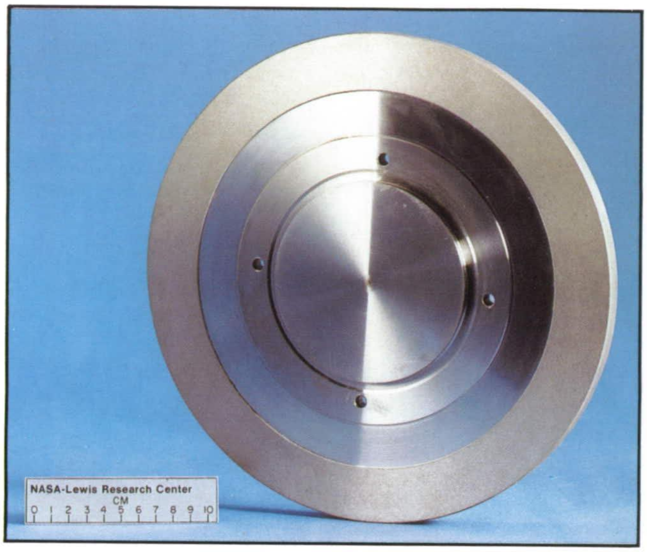
THERMAL CONDUCTIVITY PARAMETERS

Composite	Temperature		Density, gm/cm^3	Specific heat, W·sec/gm·K	Diffusivity, cm^2/sec	Conductivity	
	°C	°F				W/cm·K	$Btu \cdot in./hr \cdot ft^2 \cdot °F$
Sintered PM212	23.0	73.4	5.141	0.4780	0.04050	0.09952	69.01
	100.0	212.0		.5150	.04030	.10670	73.98
	200.0	392.0		.5410	.04070	.11320	78.49
	300.0	572.0		.5570	.04140	.11855	82.20
	400.0	752.0		.5750	.04300	.12711	88.13
	500.0	932.0		.6020	.04350	.13463	93.34
	600.0	1112.0		.5280	.04560	.14722	102.08
	700.0	1292.0		.6570	.04670	.15774	109.37
	800.0	1472.0		.6950	.04670	.16686	115.69
	900.0	1652.0	↓	.7480	.04430	.17035	118.11
HIPed PM212	23.0	73.4	6.566	0.4870	0.04240	0.13558	94.00
	100.0	212.0		.5270	.04240	.14672	101.73
	200.0	392.0		.5570	.04310	.15763	109.29
	300.0	572.0		.5730	.04470	.16818	116.60
	400.0	752.0		.5870	.04670	.17999	124.80
	500.0	932.0		.6130	.04830	.19441	134.79
	600.0	1112.0		.6490	.04930	.21008	145.66
	700.0	1292.0		.6820	.05050	.22614	156.79
	800.0	1472.0		.7190	.05120	.24171	167.59
	900.0	1652.0	↓	.7600	.04860	.24252	168.15

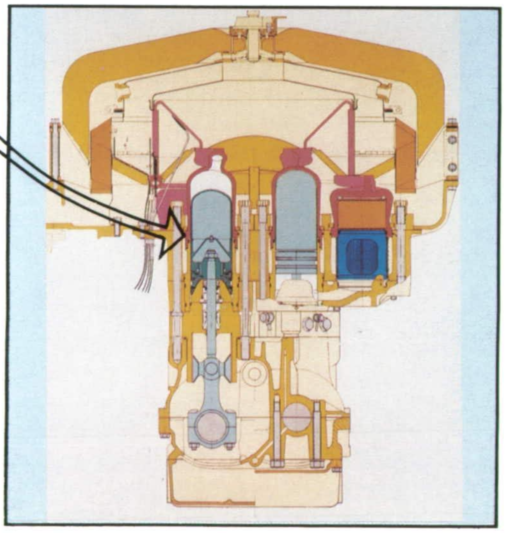
Coatings

Coatings are suitable for areas readily accessible for nearly perpendicular spraying. Some examples of PS200-coated components are illustrated.

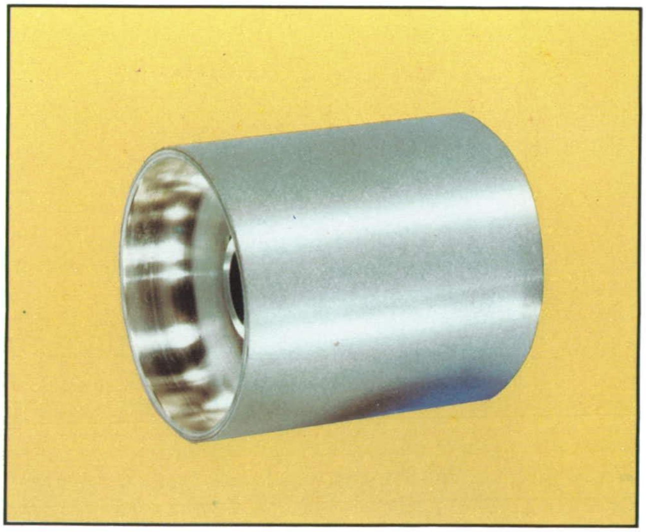
Stirling engine cylinder
after 22-hour engine test



High-speed shaft seal



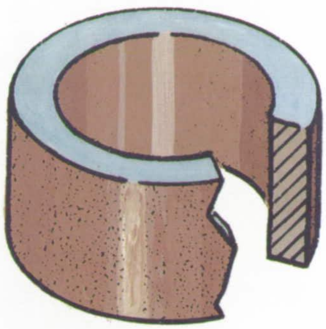
Automotive Stirling engine



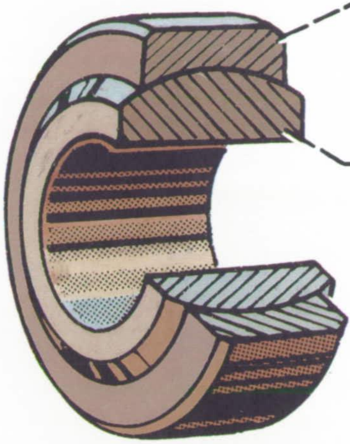
Gas bearing journal

Powder Metallurgy Parts

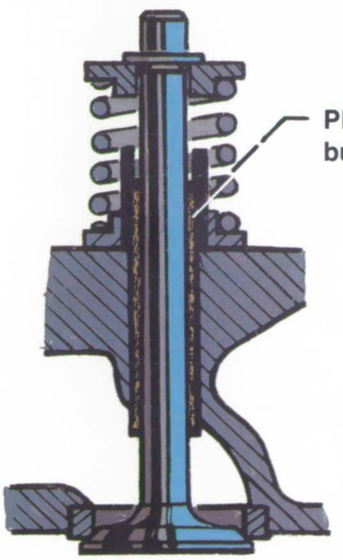
Powder metallurgy (PM) parts are ideal for small bore cylindrical bearings, valve stem guides, variable stator vane bushings for gas turbine machinery, plain spherical bearings, and combustion chamber liners for small engines.



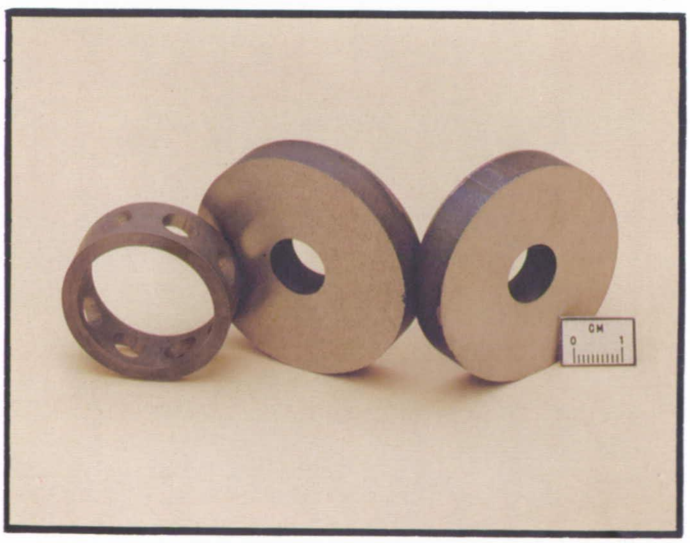
PM bushing



Control surface bearing

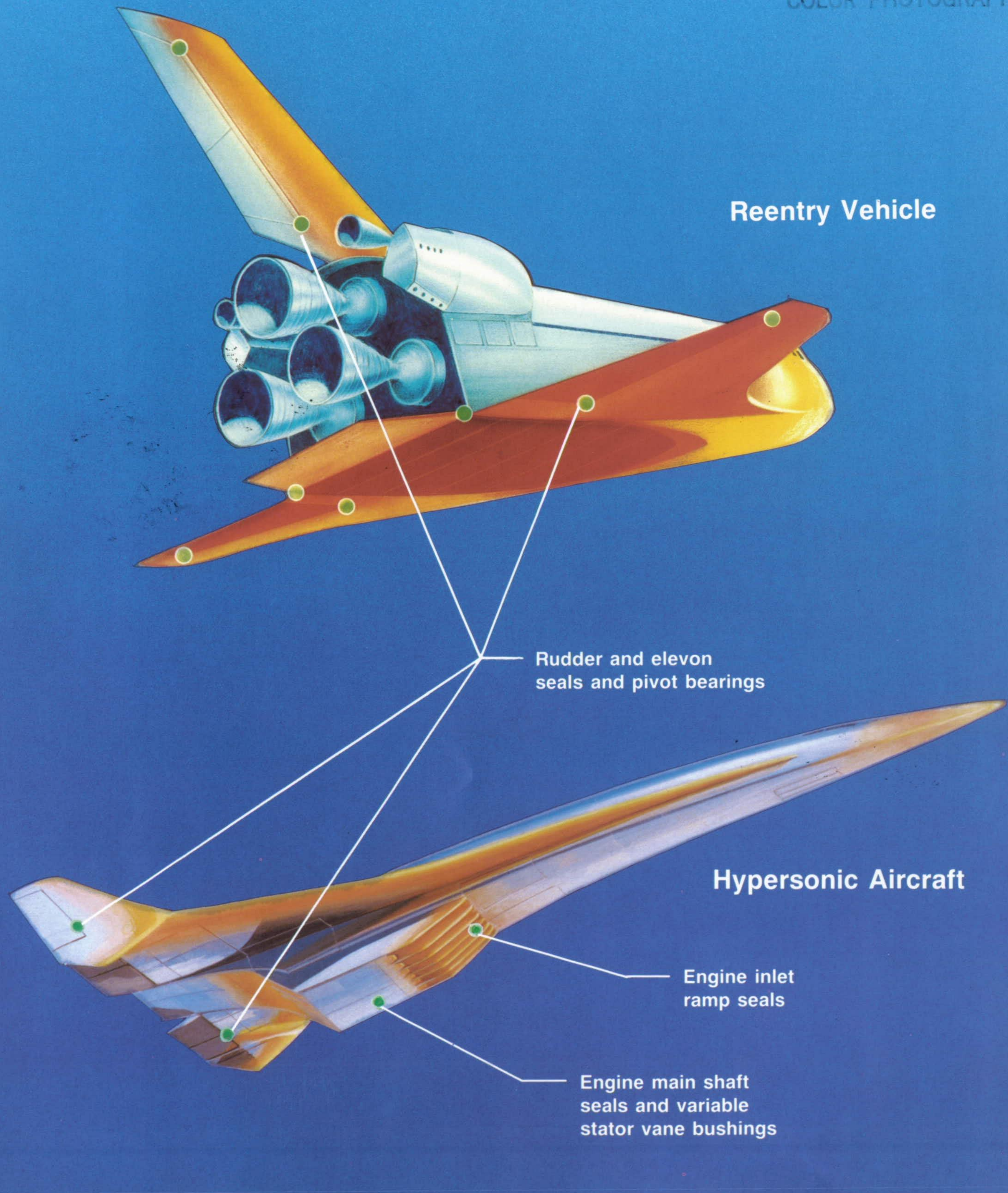


Valve application



HIPed bearing cage and wear test specimens

10 POTENTIAL AEROSPACE APPLICATIONS



PATENT/LICENSING STATUS

The concept of carbide/fluoride/silver self-lubricating composites and the general preparation methods with emphasis on plasma spraying are described in—

U.S. Patent 4,728,488: *Carbide/Fluoride/Silver Self-Lubricating Composites.*
Issued: March 1, 1988
Inventor: Harold E. Sliney
Assignee: U.S. Government, NASA

Method for making free-standing carbide/fluoride/silver parts by metallurgy processes is described in—

U.S. Patent 5,034,187: *Method of Making Carbide/Fluoride/Silver Composites.*
Issued: July 23, 1991
Inventors: Harold E. Sliney and Christopher DellaCorte
Assignee: U.S. Government, NASA

Licensing is available. For details contact:

Office of Patent Counsel
NASA Code—LeLAW
Lewis Research Center
Cleveland, OH 44135

12 BIBLIOGRAPHY

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Report Documentation Page

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15. Supplementary Notes

Responsible person, Harold E. Sliney, (216) 433-6055.

16. Abstract

This brochure is intended to inform both the technical and nontechnical reader of a new class of wear-resistant composite materials that can be prepared as coatings by the plasma spray process or as free-standing bearings by powder metallurgy processing. These new materials can be used over an exceptionally large temperature range from −100 to 900 °C. They are corrosion resistant at high temperatures in strong reducing atmospheres such as hydrogen and in oxidizing atmospheres such as air. The coating (PS200) and free-standing (PM200) variations are complimentary in their applicability. The PM composites can be readily fabricated into parts that cannot be readily plasma sprayed such as bushings and cylinders with small bore diameters and/or large length to diameter ratios. Suggested applications for PS200 coatings and PM200 parts are described.

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