Infiltrated Tungsten

INTRODUCTION

Tungsten base infiltrated metals with either copper or silver as infiltrants have been widely used in industry for many years. The major uses include missile vector control vanes, nozzle and throat materials, missile plume deflector shields, electrical contacts, resistance welding contacts, and porous emitters. Recently, the aerospace industry has opened up an entirely new field for both tungsten-silver and tungsten-copper composites. These, with approximately 90 weight % tungsten have proven highly advantageous because of their excellent machinability. Complicated forms of nozzles and inserts can now be machined from a powder metallurgy product. Excellent thermal shock resistance, especially during firings, ablative cooling by silver vapor or copper vapor, and approximately 10% less weight than pure Tungsten, with much easier handling, are additional benefits of infiltrated compounds.

A summary of the advantages and superior products is as follows:

- Evaporation transpiration cooling capability.
- Increased ambient temperature toughness provided by the ductile infiltrant.
- Good machinability as a result of ductile infiltrant.
- Lowered thermal stress gradients resulting from increased thermal conductivity.
- Lower density than pure Tungsten.
- Design versatility.
- Pricing is competitive with forged Tungsten.

TYPICAL COMPOSITION

Table 1. Major Constituents

	Tungsten Silver	Tungsten Copper
W	79 + 4 volume percent (approx. 87 + 3 wt. percent)	79 + 4 volume percent (approx. 89.3 + 2.5 wt. percent)
Ag	Balance	---------
Cu	---------	Balance
Infiltrated billets and preforms will have a minimum of 90% of the existing pore space filled with infiltrant.		

Table 2. Other Elements (maximum parts per million)

Al	50 ppm	Si	1500 ppm
Nb	100 ppm	Ta	100 ppm
Cr	100 ppm	Ti	50 ppm
Fe	100 ppm	C	200 ppm
Mn	100 ppm	O2	100 ppm
Mo	200 ppm	H2	100 ppm
Ni	100 ppm	N2	100 ppm

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PHYSICAL PROPERTIES

Density

Tungsten silver: 16.84-17.78 gms/cc3 (0.608-0.643 lbs/in^3)
Tungsten copper: 16.50-17.39 gms/cc3 (0.596-0.634 lbs/in^3)

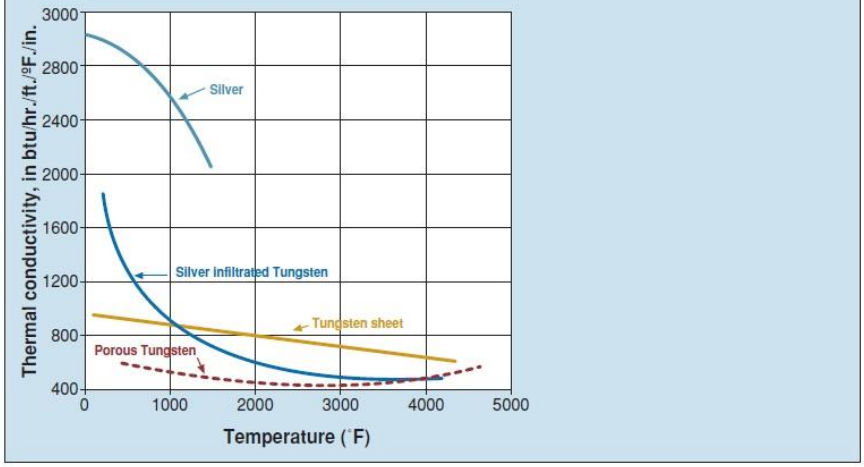
Thermal Expansion

Tungsten silver and tungsten copper have the same thermal expansion as unalloyed tungsten.

Thermal Conductivity

1. Tungsten silver—See Figure 1.
2. Tungsten copper—Believed to be similar to Figure1.

Figure 1. Thermal conductivity of Silver infiltrated Tungsten. (Typical of 80 volume % Tungsten)



Electrical Conductivity…approximate determined values

10 w/o Cu	22	$\frac{m}{\text{Ohm mm}^2}$
10 w/o Ag	24	$\frac{m}{\text{Ohm mm}^2}$

Compressivity
Comparable with sintered tungsten (dependent on sintered density).

MECHANICAL PROPERTIES

Tensile Properties
Room and Elevated Temperatures. See Figure 2 below.

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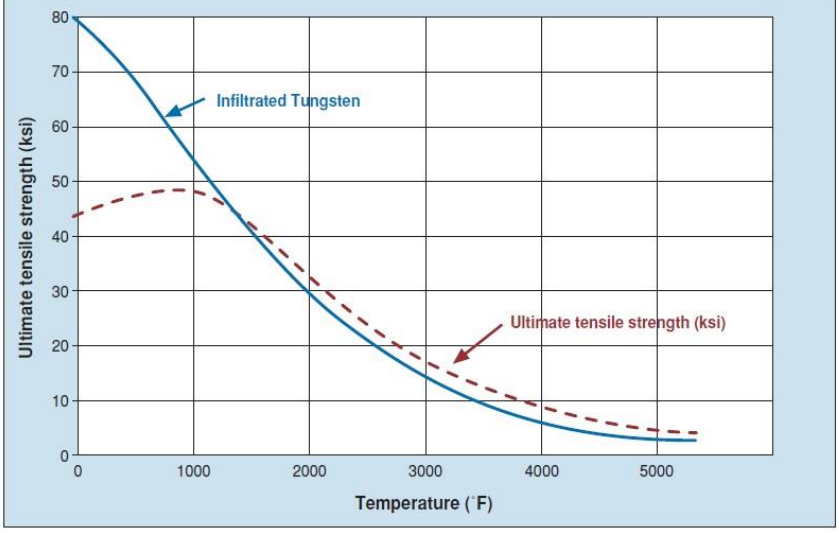
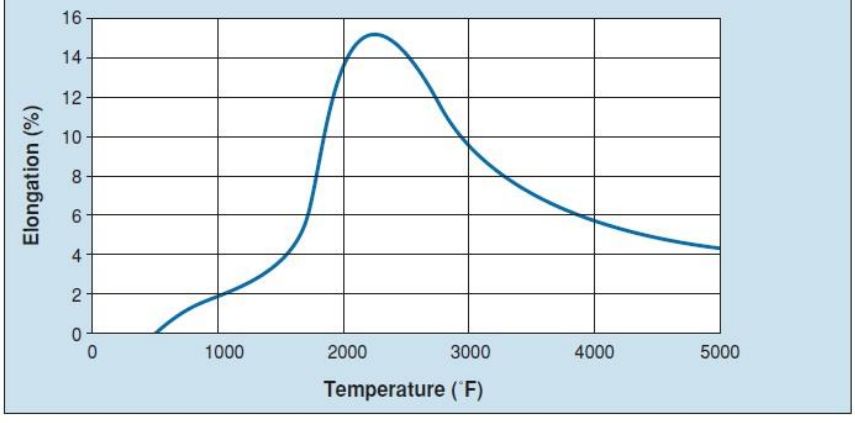
Figure 2. Tensile strength of infiltrated Tungsten. (Typical of 80 volume % Tungsten)



Elongation at Elevated Temperatures. See Figure 3 below.
*Use silver infiltrated tungsten graphs for tungsten copper as properties are very similar.

Figure 3. Elongation of Silver infiltrated Tungsten at elevated temperatures. (Typical of 80 volume % Tungsten)



Yield Strength. See Figure 4 below.*
*Use silver infiltrated tungsten graphs for tungsten copper as properties are very similar.

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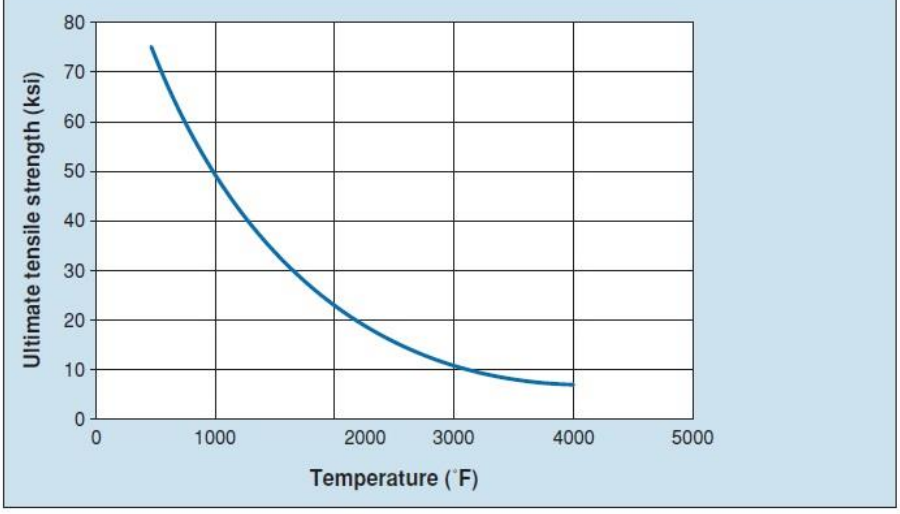
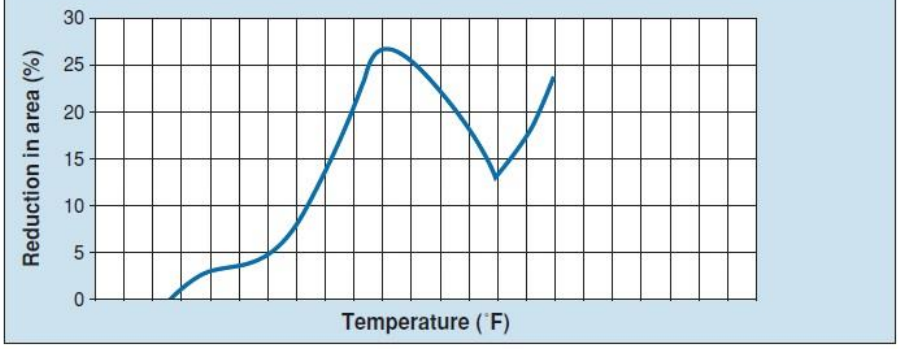
Figure 4. Typical yield strength of Silver infiltrated Tungsten. (0.2% offset)



Reduction in area. See Figure 5 below.

Figure 5. Reduction in area of Silver infiltrated Tungsten.
(Typical of 80 Volume % Tungsten)



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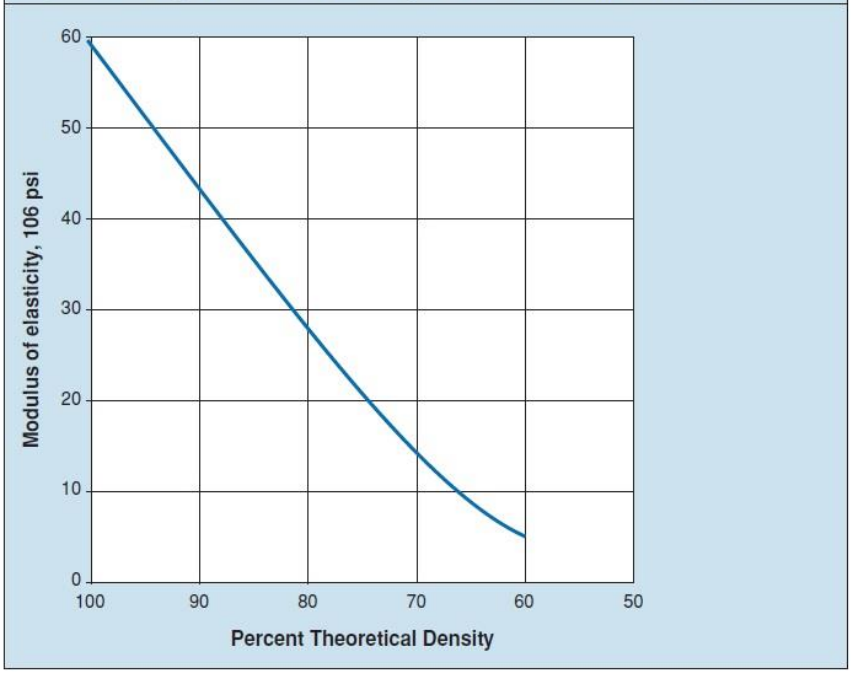
Modulus of Elasticity
The modulus of elasticity is dependent on the tungsten matrix and is practically not affected by the infiltrant. It does, however, vary significantly with density. As the density is lowered, the modulus decreases. Figure 6 shows how property varies with density.

Figure 6. Density vs Modulus of Elasticity of Pressed and Sintered Tungsten



CONTINUATION OF MECHANICAL PROPERTIES

Hardness
DPH - 260 to 300 kg/mm2 typical range (Note: This is a function of the matrix density.)

Properties of the Infiltrants

TABLE 1. Infiltrant Elements		
Infiltrant	Copper	Silver
Symbol	Cu	Ag
Density (g/cc)		
Solid at 200°C (392°F)	8.96	10.49
Liquid at melting point	7.93	9.30
Melting Point, °C (°F)	1083°C (1981°F)	962°C (1763°F)
Boiling Temperature1 °C (°F)		

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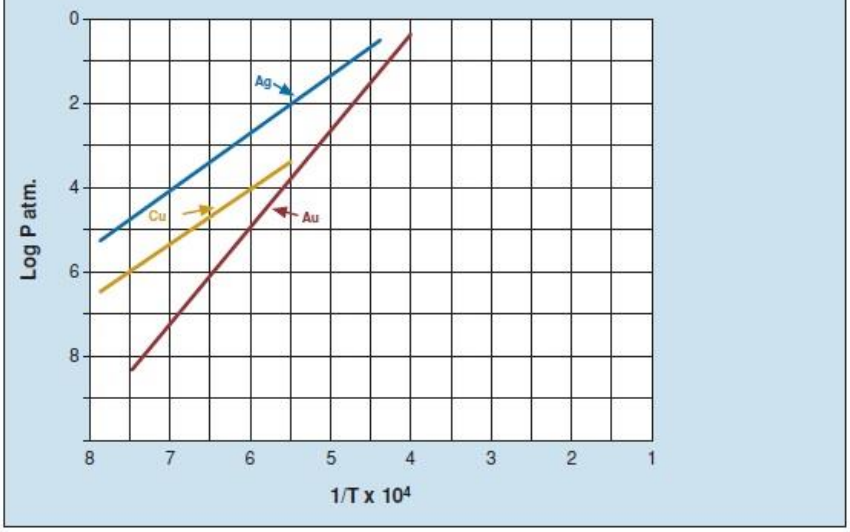
At 1 atmosphere	2547°C (4617°F)	2177°C (3951°F)
At 30 atmosphere	3400°C (6152°F)	2650°C (4802°F)
Thermal Conductivity at 20°C. cal/cm2 /°C./cm/sec	.941	1.0
Specific Heat at 20° C. cal/g/°C.	.092	.0559
Thermal Diffusivity cm^2 /sec	1.14	1.61
Coefficient of Linear Thermal		
Expansion x 10^6	16.5	19.68
Evaporation Energy (cal/cc)	13500	8100

Vapor Pressure of Infiltrants
For tungsten silver, tungsten copper, see Figure 7 below.

Figure 7. Vapor Pressure of Infiltrants for Tungsten Silver and Tungsten Copper



Cu: Log_{10} P atm.=5.618-(15.980/T)(1156°C (2113°F) – 1573°C (2863°F))
Ag: Log_{10} P atm.=5.615-(13.680/T)(860°C (1580°F) – 2152°C (3906°F))
Au: Log_{10} P atm.=6.796-(19.760/T)(1197°C (2187°F) – 1574°C (2865°F))

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DESIGN CONSIDERATION

Consolidation

The infiltrated compounds are produced at ATI by the following process:
1. Tungsten powders are sized (classified) for use.
2. These powders are hydrostatically pressed into preform shapes.
3. These shapes are sintered at temperatures ranging upward to 2500°C (4532°F).
4. The porous sintered body is then infiltrated with either copper or silver.
5. Each shape is dimensionally and non-destructively examined.
6. The approved preform is machined to final configuration per customer requirements.

Production Controls and Testing

Properties of the composite material are dependent upon:
• integrity of the sintered skeleton,
• uniformity of infiltration, and
• control of impurities in the composite, chemical, density, and non-destructive inspection techniques must be applied at various stages of production. Inspection is routinely performed on the preform in the as-sintered, and in the as-infiltrated condition, and frequently on the finish machined part. To insure complete soundness of the part, a combination of x-ray, ultrasonic testing and dye penetrant inspection may be performed. The level to which each inspection is dependent upon the customer specifications.

Availability

Products and sizes currently available are:
• Final machined hardware
• Machining blanks
• Billets up to 10" (254 mm) in diameter by 10" (254 mm) long.
• Slabs up to 6" x 10" x 10" (152 mm x 254 mm x 254 mm).

Fabricability (Machinability)

Excellent. Standard speeds and feeds may be used. High speed tooling works satisfactorily. However, carbide tooling gives better results.

Summary

Silver infiltrated tungsten or copper infiltrated tungsten is considered one of the most satisfactory ways to intricately machine pressed and sintered Tungsten. Ablative properties of this material allow stability of the machined part through a firing cycle for as long as a silver or copper reservoir lasts. This material has been proven very successful in missile vector control and nozzle applications. Excellent machinability and unique mechanical properties at high temperatures makes copper or silver infiltrated Tungsten the choice of engineers throughout the Aerospace and Defense industries.

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