



# Pressed and Sintered Tungsten & Molybdenum

When processing temperatures exceed 1000°C, very few materials can stay in the running with tungsten and molybdenum.

With a melting point of 3410°C, tungsten is among the strongest of the pure metals at temperatures from 1000° to 3000°C. Molybdenum, with a melting point of 2622°C, is close behind.

- **Unparalleled Performance At High Temperatures**
- **Available As Starting Materials Or Finished Parts**

These refractory metals also offer other important properties, including low thermal expansion, good electrical and thermal conductivity, low vapor pressure at elevated temperatures, high elastic modulus, and high specific gravity.

Tungsten and molybdenum are widely used for high temperature parts in lamps and electronic tubes as well as in such non-lamp applications as kiln furniture, furnace boats, heating elements, and heat shields on rockets.

### Powder Metallurgy

Many powder metallurgy techniques for producing tungsten and molybdenum parts were developed to their present state-of-the-art by GE.

Some tungsten and molybdenum parts are pressed directly into final shape, but generally GE produces round bar, square bar, tubes, slabs, rings and other basic forms that are used as starting materials for various processing operations. Extrusion,

forging, rolling, machining and other processes are used to convert the basic shapes into fabricated components.

GE maintains extensive production facilities for machining and fabricating pressed and sintered shapes at its Dover, Ohio, Products Plant and the Tungsten Products Plant in Cleveland, Ohio.

In the powder metallurgy process, modified to accommodate the special nature of tungsten and molybdenum, a preform is created by cold isostatic pressing. The pressed shape is further consolidated in a sintering furnace, developing its final physical properties in a hydrogen atmosphere at temperatures above 1800°C (3272°F). Sintering bonds the powder particles to produce a minimum density of 92% of theoretical.

*The excellent erosion resistance of tungsten makes it an ideal material for nozzles for high pressure discharge of molten glass, molten refractory fibers and other high temperature liquids and semi-liquids.*

*Electrodischarge machining is utilized for making holes, profiling and other cuts in large-sized tungsten and molybdenum powder metallurgy parts.*



### Machinability

Pressed and sintered tungsten and molybdenum shapes are readily machinable when proper techniques and tools are utilized. Generally, no coolant or heat is required, but considerable tool wear should be expected because of the abrasiveness of these materials, especially tungsten. High speeds and feeds are recommended.



# Tungsten

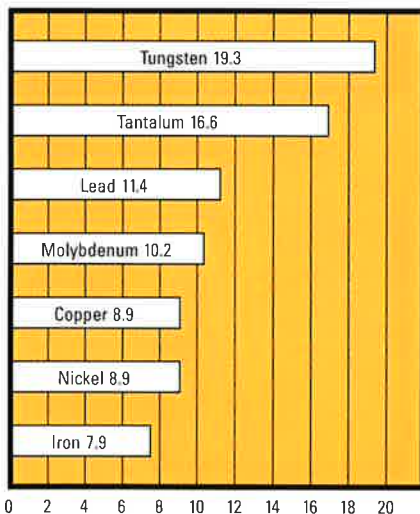
Pressed and sintered tungsten is used primarily for large parts in high temperature non-oxidizing furnaces. The shapes are usually machined to final dimensions, but they may be extruded, forged or rolled.

Parts are pressed from high purity, hydrogen-reduced powder processed from selected ores. The process is carefully controlled to maintain high purity. Powders are specifically blended to create the proper particle size distribution, sintered density and microstructure according to each intended use.

The tungsten shapes have a minimum density of 92% of theoretical. Up to 95% minimum can be supplied at slight additional cost. Typical densities are 96 to 98%.

The material can be doped or alloyed to further improve specific properties, including high temperature strength, creep resistance, mechanical stability, recrystallized ductility, vibration damping, thermionic emissivity, and machinability.

## Theoretical Densities g/cc



*Cold isostatic pressing, shown here, utilizes pressures in excess of 30,000 psi to mold the powdered tungsten into a preform.*

Although brittle at room temperature, tungsten is ductile at elevated temperatures and can be extensively worked. To prevent oxidation, applications of tungsten at temperatures greater than 400°C are normally limited to vacuum, inert, or reducing atmospheres.

**Table I. Availability\***

Form	Size, Inches	Length, Inches
Round Bar	diameters 1 through 9	1 through 29
Square Bar, Slabs	most combinations of cross sectional dimensions, in half-inch increments, that can be inscribed in, or encircled by, a 9-inch circle. Minimum thickness: 3/4	1 through 29
Tubes	OD - 1 to 1 3/4 ID - 1/4 through 1/2  OD - 1 3/4 through 12 ID - 1/4 through 7/8  OD - 1 3/4 through 12 ID - over 7/8 to ID which equals but does not exceed three quarters of the OD.	1 through 12
*Dimensions outside these limits available on request.		

## Chemical Composition

The composition of tungsten is determined by the powders from which the material is made.

Metallic impurities indicated in Table 2 are determined by direct reading spectrographic analysis while carbon, oxygen, hydrogen and nitrogen content are identified using state-of-the-art laboratory equipment. Weight percentages shown are specification values, that is, the maximum that would normally be reported for the stated material.

**Table II. Chemical Composition**

Element	PPM (Maximum)
Aluminum	15
Calcium	75
Silicon	30
Iron	60
Chromium	30
Nickel	30
Copper	20
Molybdenum	200
Manganese	15
Magnesium	15
Tin	30
Cobalt	10
Lead	10
Titanium	55
Zirconium	30
Carbon	30
Oxygen	15
Hydrogen	10
Nitrogen	10

Tungsten 99.95% minimum (by difference)

## Weight Tolerances, Round Bars

Weight tolerances for pressed and sintered tungsten, expressed as a total on the plus side, are shown by diameter size and piece weight range in the table below. These tolerances can also be expressed with plus or minus values, as long as the tolerance range does not exceed the total tolerance shown below.

Table III.

ROUND BAR STANDARD SIZES AND TOLERANCES			
Diameter, Inches	Tolerance, ± Inches	Diameter, Inches	Tolerance, ± Inches
1	1/16	4	3/16
1 1/4	1/8	4 1/2	3/16
1 1/2	1/8	5	3/16
1 3/4	1/8	5 1/2	3/16
2	1/8	6	3/16
2 1/4	1/8	6 1/2	3/16
2 1/2	1/8	7	3/16
2 3/4	1/8	7 1/2	3/16
3	1/8	8	1/4
3 1/2	1/8	8 1/2	1/4
		9	1/4

Table IV.

WEIGHT TOLERANCES - ROUND BAR PIECES				
Diameter, Inches	up to 15 lb	15 to 30 lb	30 to 100 lb	over 100 lb
1	+7%	+7%		
2	+7%	+7%	+4%	
3	+7%	+7%	+4%	+4%
4	+10%	+7%	+3%	+2%
5	+10%	+7%	+3%	+2%
6		+7%	+3%	+2%
7		+7%	+3%	+2%
8			+3%	+2%
9			+3%	+2%

## Molybdenum

Because of its ability to operate in the high temperature environment of incandescent lamps, molybdenum is now being utilized in a number of important applications outside of the lighting industry. The material's high temperature strength and extreme purity makes it useful in such applications as propulsion engines, atmospheric re-entry surfaces, furnace heating elements, and other components requiring high strength in hot environments.

Pressed and sintered molybdenum starting materials are typically extruded, forged, or rolled to final shape. But some applications, such as furnace boats and crucibles, require little or no working of the metal.

The material is available in billets up to 12" diameter, 35" long and weighing over 1500 pounds. Standard diameters and lengths are indicated in the tables below. Product shapes and sizes not listed, including preforms and discs, will be quoted on request.

### Composition

Pressed and sintered molybdenum shapes are consolidated to a minimum density of 95% of theoretical. Metallic impurities, determined by spectrographic analysis and other state-of-the-art methods in our modern refractory metal laboratories, are shown in Table 8. These data are maximum impurity levels in parts per million.

Table V. Round Bar

O.D.		VOLUME	WEIGHT		AVAILABLE LENGTH	
INCHES	TOL. ±	Cubic Inch Inches/Length	Lb. (Approx. min.)* Inches/Length	TOL. ± lbs.	MIN.	MAX.
1	1/16	.79	.28	0.1	1	to 29
1 1/4	1/8	1.23	.43	0.2	1	to 29
1 1/2	1/8	1.77	.62	0.2	1	to 29
1 3/4	1/8	2.40	.84	0.2	1	to 29
2	1/8	3.14	1.09	0.4	1	to 29
2 1/4	1/8	3.98	1.39	0.4	1	to 29
2 1/2	1/8	4.91	1.71	0.4	1	to 29
2 3/4	1/8	5.94	2.07	0.4	1	to 29
3	1/8	7.07	2.46	0.8	1	to 29
3 1/4	1/8	8.30	2.89	0.8	1	to 29
3 1/2	1/8	9.62	3.35	0.8	1	to 29
3 3/4	1/8	11.05	3.85	0.8	1	to 29
4	3/16	12.57	4.37	1.2	1	to 29
4 1/4	3/16	14.19	4.94	1.2	1	to 50
4 1/2	3/16	15.90	5.53	1.2	1	to 50
4 3/4	3/16	17.72	6.17	1.2	1	to 50
5	3/16	19.64	6.84	1.8	1	to 50
5 1/2	3/16	23.76	8.27	1.8	1	to 50
6	3/16	28.27	9.84	2.5	1	to 50
6 1/2	3/16	33.18	11.55	2.5	1	to 50
7	3/16	38.47	13.39	3.2	1	to 50
7 1/2	3/16	44.16	15.37	3.2	1	to 50
8	1/4	50.27	17.49	4.0	1	to 50
8 1/2	1/4	56.75	19.75	4.0	1	to 50
9	1/4	63.62	22.14	5.0	1	to 50
9 1/2	1/4	70.88	24.67	5.0	1	to 35
10	1/4	78.54	27.33	6.0	1	to 35
10 1/2	1/4	86.59	30.13	6.0	1	to 35
11	1/4	95.03	33.07	7.2	1	to 35
11 1/2	1/4	103.87	36.15	7.2	1	to 35
12	1/4	113.10	39.34	7.2	1	to 35

\* 95% of theoretical density. (THEORETICAL DENSITY = .366 lb. per cu. in.)

**Table VI. Tubes**

O.D.		I.D.			AVAILABLE LENGTH, INCHES
Inch.	Tol. ±	INCHES			
		Min.	Max.	Tol. ±	
1	1/16	1/4	1/2	1/16	1" to 12" Standard for all sizes. Lengths up to 50", quoted on request.
1 1/2	1/8	1/4	1/2	1/16	
2	1/8	1/4 to 3/8	1 1/2	1/8	
2 1/2	1/4	1/4 to 7/8	1 1/8	1/8	
3	1/8	1/4 to 3/8	2 1/4	1/8	
3 1/2	1/8	1/4 to 7/8	2 3/8	1/8	
4	3/16	1/4 to 7/8 to 1 1/2	3	1/8	
4 1/2	3/16	1/4 to 7/8 to 1 1/2	3 3/8	1/8	
5	3/16	1/4 to 7/8 to 1 1/2	3 3/4	1/8	
5 1/2	3/16	1/4 to 7/8 to 1 1/2	4 1/8	3/16	
6	3/16	1/4 to 7/8 to 1 1/2	4 1/2	3/16	
6 1/2	3/16	1/4 to 7/8 to 1 1/2	4 3/4	3/16	
7	3/16	1/4 to 7/8 to 1 1/2	5 1/4	3/16	
7 1/2	3/16	1/4 to 7/8 to 1 1/2	5 5/8	3/16	
8	1/4	1/4 to 7/8 to 1 1/2	6	3/16	
8 1/2	1/4	1/4 to 7/8 to 1 1/2	6 1/4	3/16	
9	1/4	1/4 to 7/8 to 1 1/2	6 3/4	3/16	
9 1/2	1/4	1/4 to 7/8 to 1 1/2	7	3/16	
10	1/4	1/4 to 7/8 to 1 1/2	7 1/2	3/16	
10 1/2	1/4	1/4 to 7/8 to 1 1/2	7 7/8	3/16	
11	1/4	1/4 to 7/8 to 1 1/2	8 1/4	3/16	
11 1/2	1/4	1/4 to 7/8 to 1 1/2	8 5/8	3/16	
12	1/4	1/4 to 7/8 to 1 1/2	9	3/16	

Sizes and lengths shown are standard. Inquiries are invited for combinations not listed. Special forms of PS MOLYBDENUM, such as preforms and discs, will be considered and quoted on request.

**Table VII. Square Bar, Slabs**

THICKNESS, INCHES			WIDTH INCHES			AVAILABLE LENGTH INCHES		
INCHES	TOL. ±		INCHES	TOL. ±		INCHES	TOL. ±	
	Pc. to Pc.	Within Piece		Max.	Pc. to Pc.		Within Piece	Max.
1	1/8	1/16	10	1/4	1/4	29	1/2	1/4
1 1/2	1/8	1/16	10	1/4	1/4	29	1/2	1/4
2	1/8	1/16	10	1/4	1/4	29	1/2	1/4
2 1/2	1/8	1/16	10	1/4	1/4	29	1/2	1/4
3	1/8	1/16	10	1/4	1/4	29	1/2	1/4
3 1/2	1/8	1/16	10	1/4	1/4	29	1/2	1/4
4	1/8	1/16	10	1/4	1/4	29	1/2	1/4
4 1/2	1/8	1/16	10	1/4	1/4	29	1/2	1/4
5	1/4	1/8	10	3/8	3/8	29	1/2	1/4
5 1/2	1/4	1/8	10	3/8	3/8	36†	1/2	1/4
6	1/4	1/8	10	3/8	3/8	36†	1/2	1/4
6 1/2	1/4	1/8	9	3/8	3/8	36†	1/2	1/4
7	1/4	1/8	9	3/8	3/8	36†	1/2	1/4
7 1/2	1/4	1/8	8	3/8	3/8	36†	1/2	1/4
8	1/4	1/8	8	3/8	3/8	36†	1/2	1/4

Thickness × Width × .366 × 95% =  $\frac{.348 \text{ lb.}}{\text{in. of l.}}$

† Longer lengths available, depending on thickness.

**Table VIII. Chemical Composition**

Element	PPM (Maximum)
Aluminum	50
Calcium	25
Silicon	60
Iron	50
Chromium	25
Nickel	20
Copper	25
Manganese	15
Magnesium	15
Cobalt	15
Lead	15
Titanium	15
Zirconium	15
Tungsten	400
Carbon	50
Oxygen	50
Hydrogen	20
Nitrogen	20

Molybdenum 99.95% minimum (by difference)

### Technical Assistance

GE works with customers at the design stage to insure that its tungsten and molybdenum products will be used to maximum advantage.

We can assist in preparing and testing of prototypes, in determining the most appropriate tooling or machining practices for these materials, and in providing guidance in other processing operations.

GE can provide material certifications for the chemical and physical quality levels of these materials whenever requested. Standard quality tests include sonic and dye penetrant, hardness, grain count, and density determinations.

### How To Order

To obtain pressed and sintered tubes, bar, slabs, or other specific shapes covered here, please contact the order service department of our Tungsten Road plant, (216) 266-2949, address below.

For machined parts, contact our manufacturing facility in Dover, Ohio.

GE Dover Wire Plant  
200 West Broadway  
Dover, Ohio 44622.  
(216) 343-8841 Extension 224

For engineering or application information, call the Components Marketing and Sales Operation in Cleveland, Ohio.

GE Components  
Marketing & Sales Operation  
21800 Tungsten Road  
Cleveland, Ohio 44117.  
(216) 266-2451

Europe  
GENERAL ELECTRIC  
Components Marketing & Sales Ope.  
21a High Street East, Uppingham  
Leicestershire LE15 9PY, England

Telef: 0572-823748/9  
Telex: 34362 (GELCOS)  
Telefax: 0572-823836



**GE Components**  
**Marketing & Sales Operation**