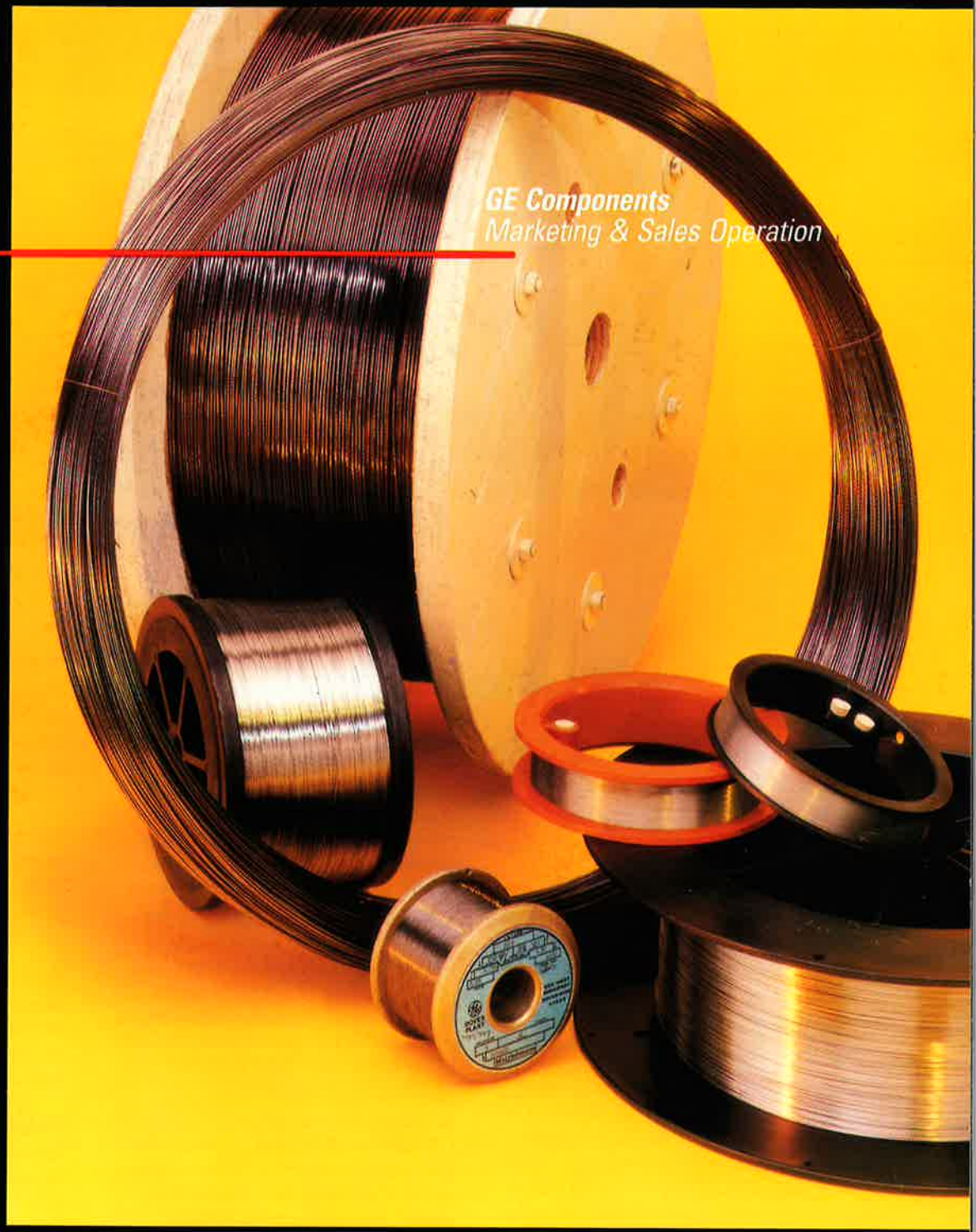


GE Components
Marketing & Sales Operation

Molybdenum Wire

Molybdenum Wire:

A High Temperature Material For Demanding Applications

With its excellent high temperature properties, molybdenum has been a key structural material in incandescent lamps and vacuum tubes for over fifty years.

That role continues with new and improved forms of the material emerging for higher performance lighting and electronic products, as well as for a number of exciting applications outside the lamp industry.

Molybdenum, one of the most widely used of the refractory metals, offers a number of desirable properties for high performance applications. They include excellent strength at high temperatures, low thermal expansion, a high melting point of 2622°C (4720°F), low vapor pressure, and better than average electrical and thermal conductivity.

GE is a major producer of molybdenum wire and a leader in developing improved or special grades of this unique material. With our extensive manufacturing and engineering facilities, we can meet a wide variety of molybdenum wire requirements.

Molybdenum wire is made to a number of chemical specifications at GE, and is often clad or otherwise processed to meet particular applications. The material is readily cut, rolled, formed, machined and welded end-to-end with itself or other materials in the fabrication of finished products. In addition to round, ribbon, square and hexagonal cross sections of these wires are available.

Regular grades of molybdenum wire are used primarily in lamps and electronic tubes. Here the material serves as a structural support for the filament in incandescent lamps and as a mandrel for coiling tungsten filaments.

In addition to its regular grade, GE offers two grades that are chemically enriched at the powder stage to achieve higher recrystallization temperatures and superior tensile strength at elevated temperatures.

These properties are useful in high voltage mandrel applications and high temperature lamps. All three grades are described in greater detail in the next sections of this catalog.

Nickel and platinum clad molybdenum wire, which provide enhanced welding characteristics and improved oxidation resistance compared to bare molybdenum, are also available.

Nickel clad molybdenum wire is used for side rods in electronic tubes and two piece lamp filament supports in which bare and nickel clad molybdenum are welded together. Platinum clad wire serves primarily as a welding flux in two-part molybdenum leads for high performance lamps.

Molybdenum ribbon, made by flattening both bare and nickel clad molybdenum wire, is used for cross straps in frame grids, lead-ins and tabs in electronic tubes, traveling wave tube helices, power switches and conductive high temperature or corrosion resistant springs.

Uses of molybdenum wire range from hard glass sealing wire in halogen lamps to traveling wires for electrodischarge machining.

Outside the lamp industry, GE molybdenum wire for electrical discharge machining operations (EDM) is growing in acceptance.

With molybdenum's high tensile strength, the traveling wire can withstand greater wire tensions than other materials used for EDM machining, and it also exhibits superior resistance to high temperature softening and spark erosion.

GE produces a special split-free molybdenum wire designed to achieve the close dimensional tolerances required in traveling wave tube helices, another important application.

Molybdenum wire is also used for furnace windings in high temperature electric furnaces operating with inert or reducing gas atmospheres, or vacuum.

Types Of Molybdenum Wire

Molybdenum wire is a very versatile material that can be adapted for a wide range of uses. The highly specialized nature of most applications requires great care in manufacture and, often times, special processing to insure performance under demanding service conditions.

R Wire

Most molybdenum wire produced by GE is Type R. It is made from high purity (99.95% min.) molybdenum powder and is suited for all general and many highly specialized applications.

Type R has the lowest filament contraction and the best room temperature formability among the molybdenum grades.

Type HV and KW molybdenum wire are made from the same high purity starting material. They are examples of the structural and mechanical property changes that can be imparted to molybdenum wire by making specific chemical additions at the powder stage and utilizing special processing. Tailor made wire from both types are described in GE engineering ES series of specifications.

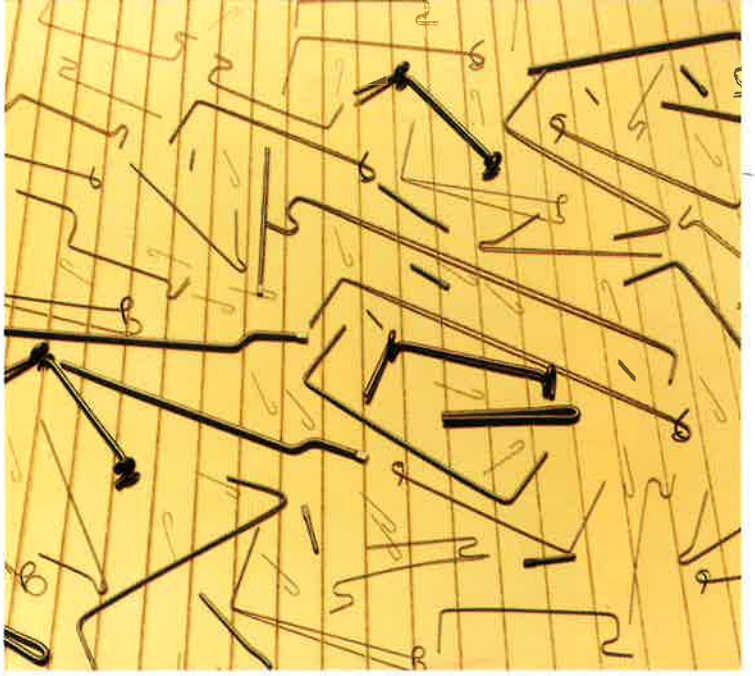
HV Wire

Type HV is a moderately doped molybdenum wire which retains its ductility after exposure to temperatures as high as 1700°C and offers better formability above 200°C than Type KW. The material is used for high voltage mandrel applications as well as for supports and lead anchors.

KW Wire

Type KW, with higher levels of dopant than Type HV, was developed for sealing with hard glass and quartz in the manufacture of lamps. It has a coefficient of expansion that is compatible to those materials, and, compared to Type R, exhibits better room temperature ductility after cycling through elevated temperatures.

With 40% higher tensile strength than Type R at elevated temperatures, Type KW is also used where retardation of recrystallization is necessary or when greater room temperature stiffness is important. Room temperature bend ductility of KW wire is the same as Type R and HV. KW wire must be heated to 200°C or above to exhibit good flattening characteristics.



High temperature hardware for lamps and electronic tubes make up the bulk of applications for molybdenum wire. These parts include filament supports for lamp and side rods for electronic tubes (shown above) and mandrels for winding tungsten filament.

Within the KW designation, different processing steps can be taken to customize the wire for specific types of lamps or lamp manufacturing. These variations are covered in GE Engineering Specifications (ES).

Series ES 3400, for example, is for sealing with quartz lamps. It retains good working behavior in temperatures up to 1900°C and remains ductile thereafter for further processing.

There are also custom made variations for sealing with the many varieties of hard glass used to make halogen lamps. Type KW provides the desired coefficient of expansion to seal with hard glass while retaining its ductility after exposure to high sealing temperatures.

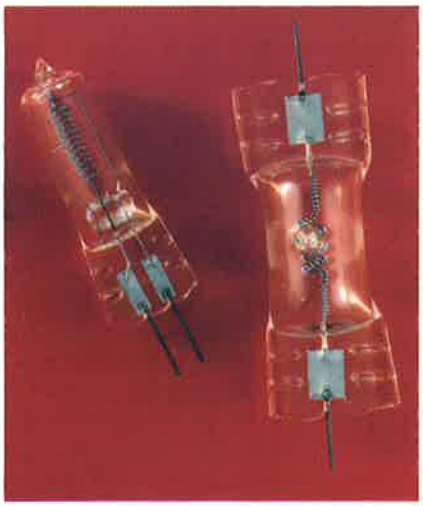
In this application, the wire is butt welded to a nickel plated iron outer lead and used as a combination filament support and glass sealing wire. These wires, designated as the ES 3300 series, can be formed after exposure to temperatures up to 1700°C. They have the metallurgical integrity to assure that no leaking will occur through the seal.

Platinum Clad

This product consists of a pure platinum sheath metallurgically bonded to molybdenum wire. It is used primarily as a welding flux in the manufacture of quartz high intensity, halogen, and other high performance lamps. Platinum is 15% of the construction by weight and makes up 4% of the diameter.

For many of these applications, the material is rolled into a foil thin ribbon. Short tabs of this material are used at the welding interface between lengths of molybdenum or tungsten wire, making it possible to weld at lower temperatures. This lessens the chance of burning through the joint area, a critical factor in dealing with small diameter wire.

Platinum clad molybdenum wire is also widely used for grids in vacuum power tubes because of its ability to control the flow of electrons between the cathode and the plate, creating a more efficient emission.



Molybdenum wire and ribbon clad with a thin sheath of either nickel or platinum provides better cross welding characteristics when making two-part leads or other fabrications with molybdenum wire. Cladding also gives the material improved oxidation resistance properties.

The wire is available in diameters from 5 mils (.127 mm) to 50 mils (1.270 mm), with most uses calling for diameters in the 9-18 mil (0.229 mm – 0.47 mm) range. (Further information provided in GE Product Data Sheet 7220-B)

Nickel Clad Wire & Rod

Molybdenum wire with a heavy nickel cladding provides much greater oxidation resistance during storage, processing and use than bare molybdenum wire. It also exhibits superior cross welding strength. This is because welding takes place at lower temperatures, so there is less chance of creating the brittle interface that sometimes occurs in joining two pieces of bare molybdenum wire.

Major applications of this product are side rods in electronic tubes, welded assemblies of bare and nickel clad molybdenum for supports, and starting materials for nickel clad molybdenum ribbon.

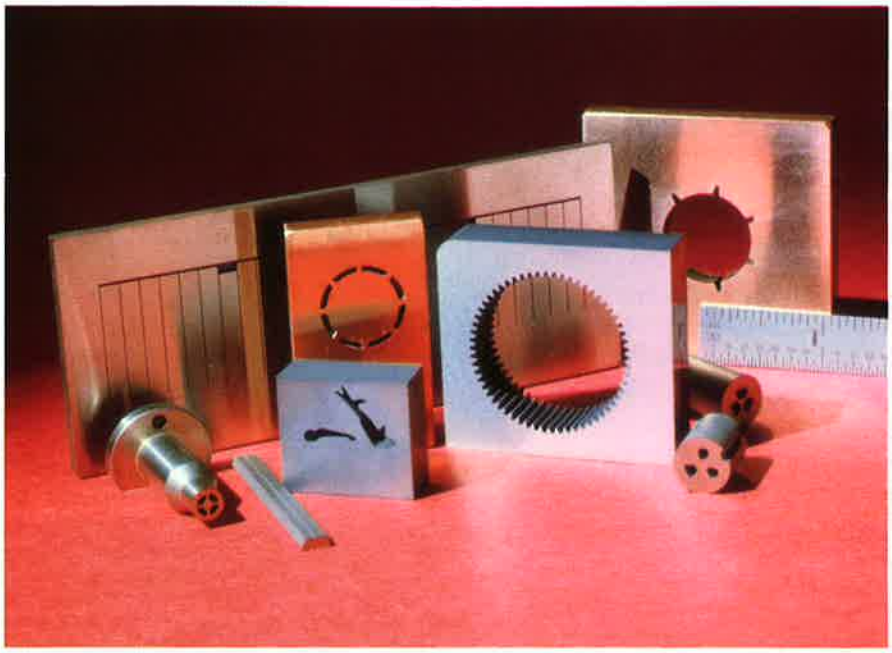
Processing and cladding operations are designed to provide a nickel outer sheath of 17% nickel by weight, or nominally 10% of the wire diameter. The cladding material is 99.00% minimum nickel (plus cobalt), commercially known as Electronic Grade Nickel 200. Processing variables and thermal treatments are controlled so that the nickel outer sheath adheres tightly to the moly core, forming a metallurgical bond. This material will withstand normal fabrication operations without cracking, peeling, or separation of the nickel sheath from the core.

Ribbon

Molybdenum ribbon, both bare and clad, is made by flattening specially processed wire in a precision rolling mill.

For molybdenum tabs used as leads in high temperature lamps, flattened wire ribbon provides a smoother, more burr free edge than comparable strips cut from sheet. It is also used in a number of power tube and receiving tube applications.

Ribbon is available in bare Type R and Type KW molybdenum, as well as nickel clad and platinum clad Type R molybdenum.



Molybdenum wire, both bare and coated, is used for making intricate cuts in the electrodischarge machining process.

Major Applications Of Molybdenum Wire

Support Wire

Support wire for lamp filaments must exhibit straightness, roundness, cleanliness, and ductility. These characteristics are required to provide the necessary filament support in the finished lamp or electronic tube and for adaptability to the automatic manufacturing methods used for producing the support.

For top efficiency in automatic assembly operations, GE supplies support wire in long lengths accurately wound on returnable containers that are carefully maintained. Support wire is available in either Type R or Type KW, depending on size. From 3 mils (0.076 mm) up to 7 mils (0.178 mm), Type R is furnished, with Type KW available on special request. From 7 mils through 30 mils (0.76 mm), Type KW is normally supplied, with Type R on request. For lamp and electronic tube applications a cleaned and annealed (CA) finish is usually specified.

In addition to support wire, GE manufactures formed and finished lamp supports to customer specification. Hundreds of different types are available, and will be quoted on request.

Mandrels

Molybdenum wire is used as a mandrel for winding tungsten lamp filaments when high temperatures are used to anneal the coils. The stability of molybdenum wire during coil heat treating helps prevent coil contamination and controls coil spacing and overall contraction. It is used for winding either single-coil or multiple coil tungsten filaments.

Mandrel wire is made from Type R wire, and every reel is tested to assure mandrel quality after it has been drawn to size. Process controls and final wire dimensions are strictly followed in compliance with the limits imposed on filament construction. Standard diameters range from 2.0 mils (0.05 mm) through 30 mils (0.76 mm), but smaller or larger sizes may be ordered. End-to-end uniformity on each container is essential. In sizes up to 14 mils (.35 mm), end-to-end rate variations are held to 1% maximum. Spool labels show the rating of the inside end of the wire and the outside end of the wire.

Side Rods

Molybdenum side rods for electronic tube grid fabrications are available in Type R, Type KW and nickel-clad molybdenum wire, drawn and electro-cleaned. Characteristics of side rod wires are tight dimensional control, roundness, surface finish, and cleanliness. Coils of wire intended for side rods are made from specially processed and eddy current tested material to meet the high degree of surface soundness and tensile strength required.

When an application requires molybdenum with a higher recrystallization temperature and better elevated temperature tensile strength, Type KW side rod wire is recommended. For oxidation resistance and enhanced cross-weld strength, nickel-clad moly side rod wire should be specified.

EDM Wire

Mo-EM and MolyCarb™ wire were developed by GE to meet the demands of EDM operations. These wires are enhanced through special chemistry and processing controls to provide maximum productivity.

Mo-EM is used as a high temperature traveling wire where high tensile strength and resistance to high temperature softening are required. A wire with an electropolished (EP) surface, it can accept high wire tensions and spark erosion better than other types of EDM wire. (See Product Data Sheet 7220-A)

MolyCarb™ EDM cutting wire has all the desirable properties of Mo-EM wire and adds several important features of its own. It has a coating of graphite over an intermediate layer of oxide. The oxide layer helps bond the graphite coating to the core wire, while the graphite serves two important functions: it lubricates the wire through the wire guides on the EDM equipment and gives a major boost to the energy transfer during the spark discharge.

Combining this with the superior conductivity of molybdenum (approximately equal to that of brass) creates a very high discharge intensity. This, in turn, permits faster cutting speeds while maintaining an excellent surface finish (See MolyCarb bulletin).

Product Guide For Lamp Applications

Selecting the appropriate grade of molybdenum wire often takes an engineering approach.

Type R molybdenum wire will suffice for most applications, but when special requirements must be met, the specifier may want to consider one of GE's two chemically doped grades. The diagram below and the information on the following pages shows how these two grades compare to Type R.

SERVICE TEMPERATURE	Material Type	UNIFORM FILAMENT CONTRACTION	DUCTILITY AFTER 1450°C MAX. EXPOSURE	DUCTILITY AFTER 1450-1700°C EXPOSURE	DUCTILITY AFTER 1700-1900°C EXPOSURE	R.T. FORMABILITY (FLATTEN/CRIMP)	200°C FORMABILITY (FLATTEN/CRIMP)	RECRYSTALLIZATION TEMP.	HIGH TEMPERATURE STRENGTH	RECOMMENDED SIZE RANGE, MM-DIA/MILS DIA.)	PROCESS DESIGNATION	AVAILABLE FINISHES	APPLICATIONS
LOW TEMP.	R-Moly	●	●	○	⊗	●	●	○	○	.051-1.14 (2.0 TO 45.0)	ES1000	D, EC, C	MANDREL 120V LAMP FILAMENT
										.076-.635 (3.0 TO 25.0)	ES1100	CA	SUPPORT, ANCHORS
										.127-.635 (5.0 TO 25.0)	ES1200	EPA	LEADS, HERMETIC SEALS HELIX GRADE
MED. TEMP.	HV-Moly	◐	●	◐	○	●	●	◐	◐	.051-.635 (2.0 TO 25.0)	ES2000	D, EC, C	MANDREL 220 VOLT LAMP FILAMENTS
										.076-.762 (3.0 TO 30.0)	ES2100	CA	SUPPORTS, ANCHORS
HIGH TEMP.	KW-Moly	⊗	●	●	●	⊗	◐	●	●	.127-.762 (5.0 TO 30.0)	ES3100	CA	SUPPORTS, ANCHORS, LEADS
										.127-.635 (5.0 TO 25.0)	ES3200	EPA	HERMETIC SEALS HELIX GRADE
										.179-.505 (7.0 TO 19.9)	ES3300	EPA	LEADS SEALING IN HARD GLASS
										.127-.635 (5.0 TO 25.0)	ES3400	EPA	LEADS SEALING IN QUARTZ

ATTRIBUTE CODE

- ● HIGHEST
- ◐ AVERAGE
- ○ LOWEST
- ⊗ NOT RECOMMENDED

FINISH CODE*

D – BLACK AS DRAWN WITH RESIDUAL GRAPHITE LUBRICANT. T.S. RANGE: 55 TO 110
EC – ELECTRO CLEANED, NO ANNEAL. T.S. RANGE: 55 TO 110
C – FURNACE CLEANED, INTERMEDIATE ANNEALED. T.S. RANGE: 55 TO 65
CA – FURNACE CLEANED, FULLY ANNEALED. T.S. RANGE: 45 TO 55
EPA – ELECTRO POLISHED AND ANNEALED. T.S. RANGE: 42 TO 52
*Units for tensile strength are gms /mg /200 mm

Chemical Composition

All three types of GE molybdenum wire use high purity starting materials, but Types HV and KW are intentionally doped with K, Al and Si to raise the recrystallization temperature and enhance ductility after exposure to elevated temperatures.

A typical chemical composition for each is shown in parts per million (except molybdenum):

ELEMENT	MATERIAL TYPE R	HV	KW
Mo	(99.95%)	(99.9%)	(99.9%)
W	200	225	225
Al	<25	45	105
Si	<25	70	300
K	<25	25	90
O_2	<25	25	130
Fe	<25	25	30

Other impurities, each 25 PPM or less:

Ca Ni Mg Zr Cr Mn
Cu Co Na Ti

Standard Molybdenum Wire Availability

Product Scope	Types Of Product	Form	Dimensions IN	Dimensions MM	Length Range	Surface Finish	Normal Tolerances
Standard Wires	General Purpose R Wire	Spools, Coils, Cut Lengths or Fabricated Parts	.002/.250	.05/6.35	*Cut Wires* thru .020" (.5mm) dia. 12" (305mm) and longer: Specified or Random Length 1 ft. thru 20 ft. *Cut Rod* over .020" (.5mm) dia. 12" (305mm) and longer Specified or Random Length, 12" (305mm) thru 30 ft. (9m)	C, D, EC, CA, EPA	±4% wt. below .030" (.76mm) dia. ±2% dia. .030" (.76mm) dia. and larger Closer tolerances available down to ±1% wt. or ±1% dia. as a function of diameter
	HV Wire		.0035/.250	.09/6.35		C, D, EC, CA	
	KW Wire		.0035/.250	.09/6.35		CA, EPA	
Lamp Wires	Support Wire	Spools	.003.007 dia. (normally R) .007/.030 dia. (normally KW)	.08/.18 .18/.176	Not available in cut lengths	CA	±4% wt. Closer tolerances available down to ±1% wt. ±3% wt. Closer tolerances available down to ±1% wt.
	Mandrel Wire		.002/.030 dia.	.05/.76		D, C, EC, CA	
Redraw Wire	R HV KW	Spools, Coils, or Drums	.020/.250	.5/6.35	to 100 kgs. per drum (in one continuous length)	D	±4% wt. below .030" dia. (.76mm) dia. ±2% dia. .030" (.76mm) dia. and larger
Flattened Wire Ribbon	R KW	Spools, Coils, or Cut Lengths	Thickness Width .002/.100 .010/1.00	Thickness Width .05/2.54 .25/25.40	Subject to quotes and specific orders	C, CA	*Thickness Width* ±0.0002 ±0.001 to ±0.010" to ±0.062" or as negotiated
	Nickel Clad		.002/.010 .015/.155	.05/.25 .38/3.94		CA	
	Platinum Clad		.002/.010 .015/.125	.05/.25 .38/3.18			
Clad Wires	Nickel Clad	Spools thru .040" (1mm) diameter, Coils over that diameter	Diameter .005/.062	.13/1.57	Not common, but subject to quotes	CA	As negotiated for specific applications
	Platinum Clad		.005/.050	.13/1.27		CA	
Side Rod Wires	R	Spools or Coils	.027/.045 (diamond die)	.69/1.14	Subject to quotes and specific orders	CA	As negotiated for specific applications
	Nickel Clad		.046/.065 (carbide die)	1.17/1.65			
Specialty Wires	R KW	Spools, Coils	As defined in GE Engineering Specifications (ES)		Not common, but subject to quotes	As defined in GE Engineering Specifications (ES)	As developed for specific customers Examples: ES 3300 ES 3400

Tensile Strength

Room temperature tensile strength and elongation vary as a function of the molybdenum wire diameter. In general, tensile strength is high and elongation low in as-drawn wire. Special tempers are available to meet the specific applications or specifications.

	TENSILE STRENGTH* gms./mg./200mm
Support Wire (R & KW)	
• 3-30 mil. dia.	
• Cleaned and annealed	45/55
Mandrel Wire (Type R)	
• 2-30 mil. dia., as drawn	55/100
• Cleaned and annealed	55/65
Side Rod	50/60
KW Side Rod	55/65
Nickel Clad Side Rod	45/55

*To convert to psi, multiply by 2885.43. To find Kg/mm^2, multiply by .4928.

For ribbon, tensile strength and elongation are functions of the temper desired in the finished product. Tempers available can range from an as-rolled condition to a soft-annealed condition.

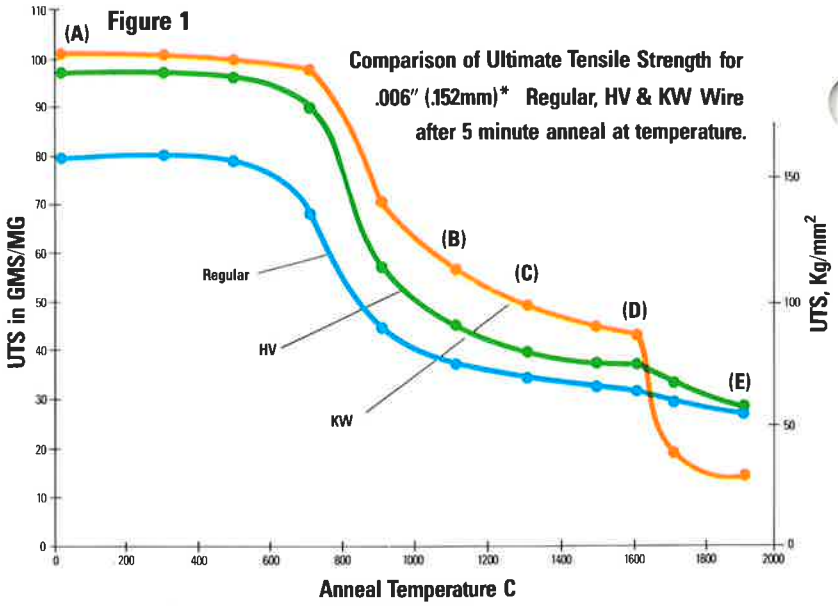
As ambient temperatures increase, however, the performance of molybdenum wire begins to change dramatically. The charts on this page show the changes in tensile strength, elongation and bend ductility after annealing for Types R, HV and KW at different temperatures. After annealing, these values are important determinants of the formability of the material and its performance at high temperatures.

The bend ductility of GE ES molybdenum wire when sealing GE 180 hard glass or quartz is shown below.

	Number of 90° Bends After Exposure To Sealing Temperatures	
	1500°C 180 Glass	1900°C Quartz
13 mil (.33mm) KW (ES 3300) .031" (0.787mm) Bend Radius [.5 lb. wt. (0.23 kgs)]	10-30	(Not Recommended)
23.6 mil (.60mm) KW (ES 3400) .0625" (1.59mm) Bend Radius [1.5 lb. wt. (.680 Kgs)]	10-30	3-15

Figure 1

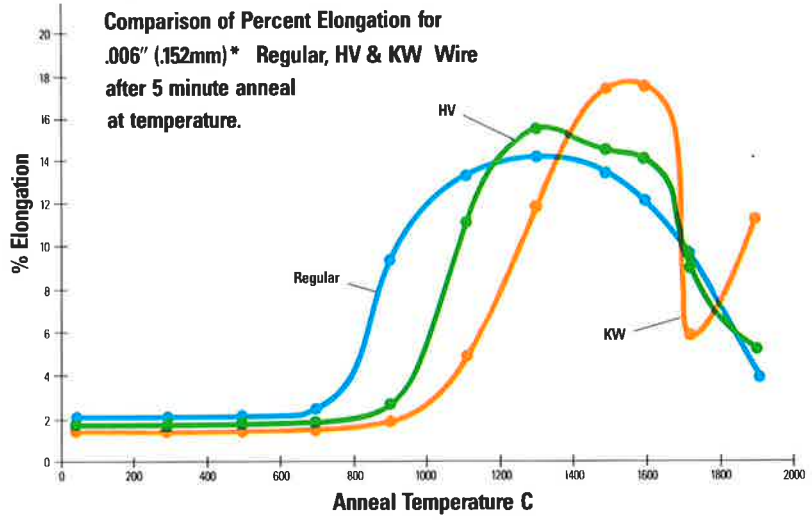
Comparison of Ultimate Tensile Strength for .006" (.152mm)* Regular, HV & KW Wire after 5 minute anneal at temperature.



*10" (254mm) gauge length; 1"/min (25.4mm/min) cross head speed.

Figure 2

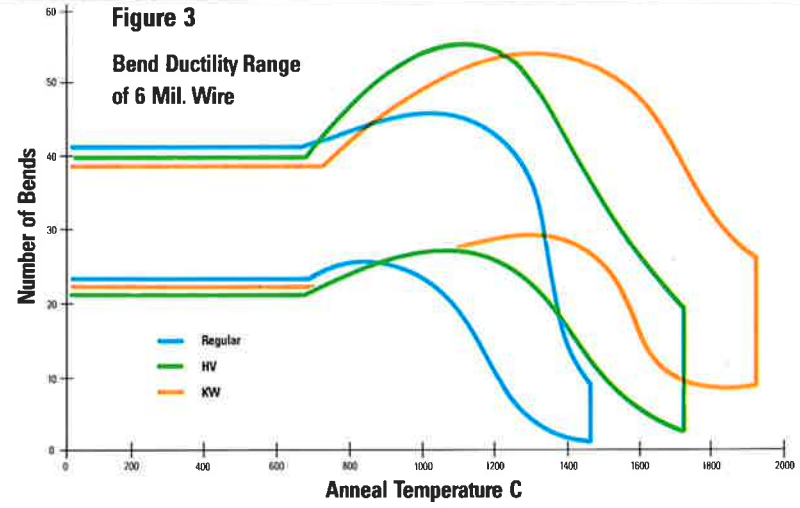
Comparison of Percent Elongation for .006" (.152mm)* Regular, HV & KW Wire after 5 minute anneal at temperature.



*10" (254mm) gauge length; 1"/min (25.4mm/min) cross head speed.

Figure 3

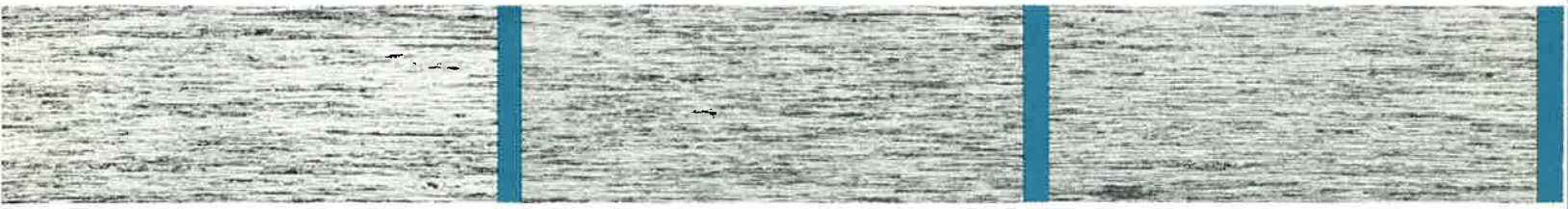
Bend Ductility Range of 6 Mil. Wire



This chart shows the bend ductility of .006" Type R, HV and KW molybdenum wire after a five minute anneal at temperatures shown. Bends are 90° over 1/32" R (.787mm) with a 0.5 lb. (227g) load applied to the wire.

Photomicrographs

Regular **HV** **KW**

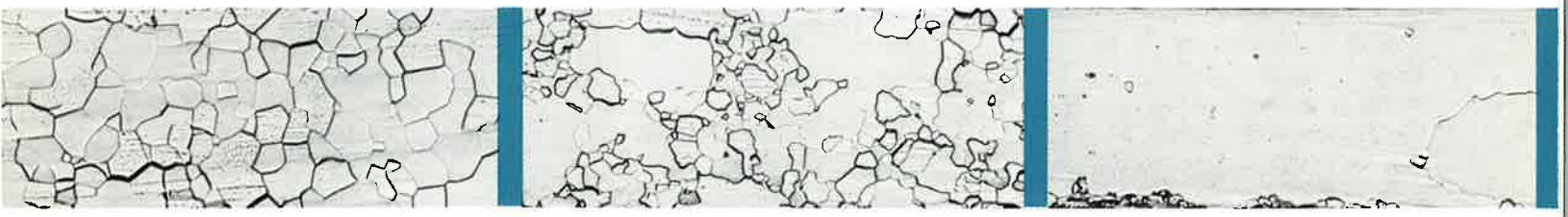


A – Room Temperature

B – 1100°C

C – 1300°C

D – 1600°C



E – 1900°C

The photomicrographs shown above, all at 200X, show the structure of Types R, HV and KW molybdenum wire after five minute anneals in hydrogen at various temperatures. Points A, B, C, D and E in Figure 1 at the top of the opposite page correspond to the temperatures indicated here.

In manufacturing molybdenum wire, ingots produced to very high standards of quality are heated up to 1500°C and rolled into smaller diameters.

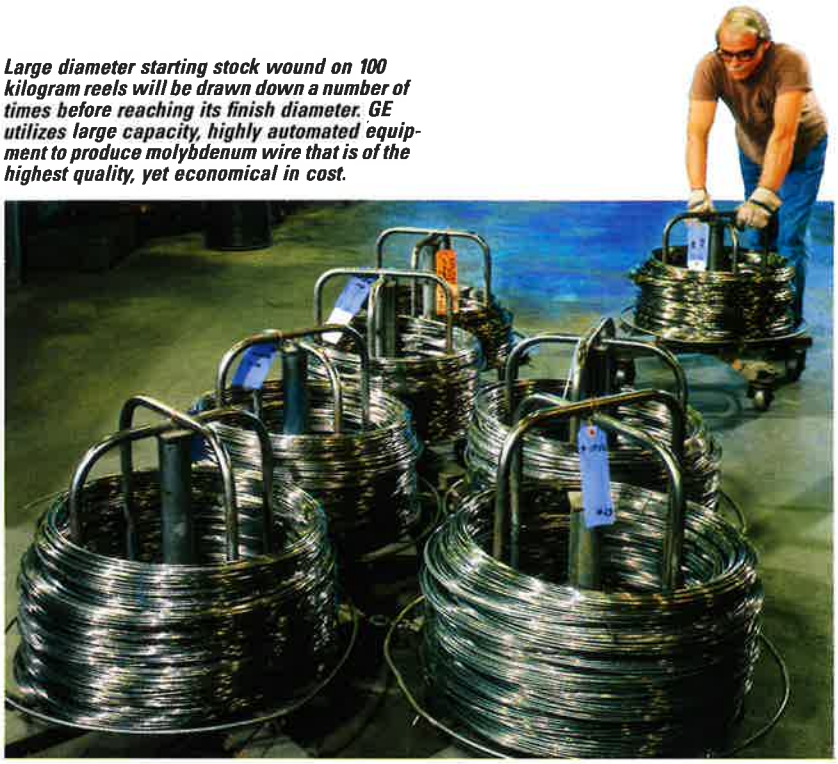
Manufacturing And Quality Control

The production of GE molybdenum wire begins with the powder metallurgy process.

Pure molybdenum powder, sometimes doped with additives to provide special engineering characteristics, is pressed and sintered into ingots that are worked down through successive rolling and reheating operations into rod. It is then swaged and drawn into wire through tungsten carbide and diamond dies.

Quality control and inspection procedures are used throughout the process to maintain elongation, tensile strength, straightness, roundness, size, purity, and metallurgical characteristics at specified levels.

Large diameter starting stock wound on 100 kilogram reels will be drawn down a number of times before reaching its finish diameter. GE utilizes large capacity, highly automated equipment to produce molybdenum wire that is of the highest quality, yet economical in cost.



The diameter of molybdenum wire is reduced in stages on this high capacity drawing line. Multiple drawing heads, with high intensity wire heaters located ahead of each head, bring 100-150 mil (2.5-3.8 mm) starting wire down to 30-50 mil (0.76-1.3 mm) diameters at production rates in excess of 300 feet per minute (91 mts/min.).

In the eddy current tester, the speed of electrical pulses passing through the wire locates and identifies defects on the surface of the wire. Typical defects are "splits" in plain wire, and bonding discontinuities in clad wire.

Tensile strength testing is just one of the many in-plant procedures we use to confirm that material properties have been met.

Coupling an image analyzer to a scanning electron microscope is one of the techniques we use for evaluating materials. This instrument produces quantitative data on particle size distribution, volume fractions, interfacial areas per unit volume, grain count analysis, and grain boundary area per unit volume.

The effect of atmosphere and annealing temperatures on the structure and properties of molybdenum are evaluated in this ultra high vacuum and temperature (UHVT) chamber.

In atomic absorption spectroscopy, samples are dissolved and aspirated into a flame where the radiant energy absorbed identifies the concentration of impurities.

The depth of penetration made by a diamond-shaped indentor on molybdenum samples provides hardness data.

Weighing And Rating Of Molybdenum Wire

Weighing and rating of molybdenum wire is performed with a high degree of precision by experienced operators specifically trained for this important function.

Rating has proven over the years to be the most accurate method for determining wire sizes.

In sizes below 30 mils (0.76 mm), wire is normally weighed and rated in milligrams per 200 millimeters. Cutting blocks are designed to cut wire precisely to a 200 millimeter length, using slight tension of the wire.

Constant checks are conducted to maintain accuracy of the system. Balances are of the most accurate and dependable available and are always calibrated at the nearest point to the wire size being weighed. Working calibration weights are frequently checked against standards traceable to the National Bureau of Standards.

Size Range, mg/200mm	Weighing Precision
Below 60	Nearest 0.01 mg.
60 through 250	Nearest 0.2 mg.

Finish Process Designations

The standard process designations listed below are available for all types of GE molybdenum wire. However, types R, HV and KW can be tailored for specific applications by following special processing described in GE Engineering Specifications (ES). GE engineers will be happy to review the various wire characteristics that are available to fulfill your requirements.

In rating molybdenum wire, the diameter is indirectly checked by weighing a sample of predetermined length (mg/200mm). The measurement is made with an automatic electrobalance unit equipped with a direct readout digital voltmeter that accurately detects weight changes of 2×10^{-7} grams.

Standard Process Designations

Standard Process Designations	Relative Tensile Strength	Description
D	High	Process D is as-drawn wire and has a residual surface coating of the drawing lubricant. In Type R it is generally specified for mandrels, furnace windings, and spray metallizing.
C	Medium	Process C is Process D wire which has been furnace cleaned and intermediate annealed, removing most of the drawing lubricant. It is generally specified for mandrels.
CA	Low	This is Process D wire which has been furnace cleaned and fully annealed, removing the visible lubricant. In types R and KW, which are generally specified for supports and fabricated parts, it is processed to achieve a relatively high degree of straightness.
EC	High	Process EC is Process D wire which has been electrolytically etched to remove visible lubricant and underlying oxides. The high tensile, low ductility properties of the D wire remain unchanged.
EPA	Low	This is Process D wire electropolished and annealed to remove oxides and visible lubricants. In Types R and KW, it is fully annealed and processed to specified split levels for helix winding and sealing in hard glass or quartz applications.

Size-Weight Relationship Of Molybdenum Wire

The theoretical density of molybdenum is 10.14 grams per cubic centimeter, the value accepted and followed by the American Society for Testing and Materials. Using this standard density, a size/weight relationship can be calculated for molybdenum wire, as follows:

Dia., mils = $0.98647 \sqrt{mg/200mm}$
Mg/200mm = $1.02760 \times (\text{dia., mils})^2$
1 inch = 1000 mils = 25.40mm
1mm = 39.37 mils = 0.03937 in.
1 meter = 39.37 inches = 3.2808 feet
1 kg = 1000 grams = 2.2046 pounds
1 pound = 16 ounces = 453.6 grams

Technical Assistance

GE provides engineering assistance to customers in selecting and processing molybdenum wire to meet their requirements. This includes help in tailoring properties for specific uses, consultation on manufacturing and quality control, and troubleshooting. If you have a potential use for molybdenum wire, or feel your present application may be improved, please let us know.
If required, GE can develop a special ES wire for your application. Call 216-364-5134.

Particular care is taken in packaging GE molybdenum wire to assure its arrival at customer plants in the best possible condition. Shrink packaging is used to seal out dirt and moisture, and dessicants are enclosed to retard oxidation.

Packaging Information

Full product information is provided on each container or coil of molybdenum wire. Labels or tags indicate type of wire, quantity in meters or kilograms, size in milligrams per 200 millimeters or in mils, metal lot number, specification number, letter code, date of packaging, and customer's order number. This information is backed by carefully kept quality control records and makes possible positive identification of every piece of wire manufactured by GE. It is recommended that labels or tags be kept with the wire during storage and use so that it is possible to trace it back through lot, ingot and powder.

An excellent aid to specifying molybdenum wire is this easy-to-use conversion slide chart. It provides diameter to weight ratios, data on wire types and finishes, and other information. It is available in English, Japanese, German and Spanish with data in both English and metric values. Data for tungsten wire is available on the reverse side. For a free copy, write, FAX or call the Components Marketing & Sales Operation at the address shown on the last page.

Ordering Information

Unless otherwise specified, molybdenum wire produced by GE is "drawn" wire with a circular cross section.

Sizes

Wire is available in diameters of 1 mil (.025 mm) through 250 mils (6.35 mm).

Diameters above 250 mils, or cut lengths greater than 20 mils (.508 mm) in diameter and over 12 inches (305 mm) in length, are generally classified as rod. Cut lengths under 12 inches (305 mm) in diameter are considered fabricated parts.

Size Criteria

Wire should be ordered by milligram rating below 30 mils (0.760 mm) and by mils, 30 mils and above.

When ordering by milligram rating, the minimum and maximum of a range should be specified. Normally, the milligram rating of the center size is stipulated along with the percentage tolerance for the range. The following formulas may be used in converting between milligram ratings and diameter in mils (based on ASTM density of 10.14 gms/cm^3):

- Milligrams per 200 mm = 1.02760 × (diameter in Mils)^2
- Milligrams per 200 mm = 1592.787 × (diameter in mm)^2
- Diameter in Mils = .98647 × $\sqrt{\text{Mgs./200mm}}$
- Diameter in mm = .025057 × $\sqrt{\text{Mgs./200mm}}$

Size Specification Tolerances

Below 30 mils (0.760mm), the standard tolerance for molybdenum wire, based on sizes expressed in milligrams, is ±4% per 200 millimeters. Other tolerances available are ±3%, ±2½%, ±2%, ±1½%, and ±1% by weight.

Our Customer Ordering/Manufacturing System (COMS) tracks orders from entry through manufacturing and creates the documentation for shipping the material.

In sizes 30 mils (0.760mm) and larger, the standard tolerance is ±2%. Other available tolerances are ±1½%, ±1%.

For 20 mils (0.508mm) through 35 mils (0.889mm) a ±½% tolerance is available on special request.

For the fastest delivery, a complete wire description and information about its intended use should be specified in the inquiry, as follows:

1. QUANTITY:
   In meters – from 2.0 (0.051mm) through 30 mils (0.76mm)
   In Kilograms – from 30 through 250 mils (0.76mm-6.35mm)
2. TYPE:
   R, HV or KW
3. STANDARD FINISH AND PROCESS DESIGNATIONS:
   D, C, EC, CA, EPA
4. CENTER SIZE:
   In mils or mg/200mm – from 2.0 (0.051mm) through 30 mils (0.76mm)
   In mils – from 30 through 250 mils (0.76mm-6.35mm)
5. PERCENT TOLERANCE:
   By milligram weight: ±4, ±3, ±2½, ±1½, or ±1 from 2.0 (0.051mm) to 30 mils (0.76mm)
   By diameter tolerance: ±2, ±1½ or ±1 for 30 mils (0.76mm) and larger
   For 20 mils (0.508mm) through 30 mils (0.76mm) a ±½ tolerance by weight is available on special request.
6. OTHER INFORMATION:
   Customer end use (supports, leads, mandrels, furnace windings, etc.), special containers and other pertinent instructions.
   For example, a typical order might read: *500,000 meters, 7 mil Type R molybdenum wire, D, ±2%, for mandrel applications.*

To place an order for molybdenum wire, contact your GE sales representative, the Sales Operation in Cleveland, or the molybdenum products plant customer service representative in Dover, Ohio.

GE Components Marketing
& Sales Operation
21800 Tungsten Road
Cleveland, Ohio 44117
Phone:
Domestic – (216) 266-2451
International (216) 266-3295
Telex: 985569 (GECOLCS EUCD)
FAX: (216) 266-3372

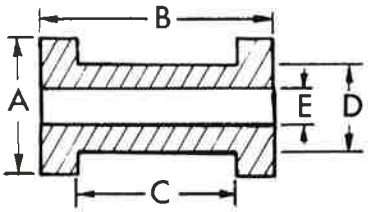
GE Dover Wire Plant
200 West Broadway
Dover, Ohio 44622
Phone: (216) 343-8841
FAX: (216) 364-5134

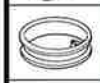
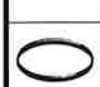
Shipping Information

GE molybdenum wire is packaged for shipping in either self-contained coils or wound on standard spools or bands.

The material is shipped in one continuous length per container or coil, as indicated in the chart below. Any deposit charge made for shipping containers is refunded when containers are returned pre-paid and in good condition.

Designation of Container Dimensions



	Name	Material	GE Drawing No.	Approx. Weight In Grams	CONTAINER DIMENSIONS Units	Flange Diameter (A)	Width (B)	Traverse (C)	Barrel (D)	Hole (E)	Wire Size Range, Standard Processes	Approx. Container Capacity (grams)
	Mandrel Spool	Lexan®	601-C-415	188	mm	82.55	57.15	41.25	49.48	25.48	2.0-13.0 mils .05-.33 mm Black or Clean	500
					in.	3.250	2.250	1.624	1.948	1.003		
	Mandrel Spool	Alum.	601-C-179	302	mm	82.55	57.15	41.25	44.40	25.48		800
					in.	3.250	2.250	1.624	1.748	1.003		
	Special Band	Lexan®	601-C-136	40	mm	112.73	25.40	20.65	100.81	96.04	2.0-12.0 mils .05-.30 mm Clean Support Wire	200
					in.	4.438	1.000	0.813	3.969	3.781		
	Orange Regular Band	Lexan®	A-8166	100	mm	126.21	33.34	25.40	108.36	98.43	12.1-31.0 mils .31-.79 mm Black or Clean	350
					in.	4.969	1.313	1.000	4.266	3.875		
	1S Spool	Plastic	601-B1224	75	mm	63.50	85.73	76.20	44.45	15.88	1-10 mils .025-.254 mm Clean Wire	600
					in.	2.50	3.375	3.00	1.75	0.625		
	4K Reel	Lexan®	601-C-358	774	mm	152.40	96.82	76.20	110.62	15.90	2.0-16.0mils .05-.41 mm Black or Clean	4000
					in.	6.00	3.812	3.00	4.355	0.626		
	12" Reel	High Impact Styrene	WS-874	825	mm	298.45	100.00	92.08	207.95	52.07	12.1-45.0 mils .31-1.14 mm Black or Clean	6000
					in.	11.750	3.937	3.625	8.187	2.050		
	50K Reel	Wood		3900	mm	457.200	203.200	152.400	355.600	38.100	33-67 mil .84-1.7 mm Black	50,000
					in.	18.000	8.000	6.000	14.000	1.500		
	406.4mm / 16" Diameter	Self-Contained Coil									30-125 mils .76-3.18 mm Black or Clean	N/A
	787.4mm / 20" Diameter	Self-Contained Coil									90-190 mils 2.29-4.83 mm Clean	N/A
	1524mm / 60" Diameter	Self-Contained Coil									100-250 mils 2.54-6.35 mm Black	N/A

®Lexan is a registered U.S. Trademark of General Electric Company for polycarbonates.

PACKAGE IDENTIFICATION

The following identification and descriptive information, where applicable, is put on each label: type of wire, standard process designation, quantity of meters or kilograms, size in milligrams per 200 millimeters or in mils, metal lot number, designation of ingot from which wire was drawn, date of packaging, and code number of operator who packaged wire. Information such as this is backed by records of a rigid quality control system and makes possible positive identification of wire made by GE.

It is recommended that labels and tags be kept with the wire so that identification can be made at any time.

Small corks are used to secure wire to spools or bands. A red cork signifies the outer end.

Molybdenum Wire Is Just One Of GE's Versatile Engineering Materials

Although lamp making is the one thing they have in common, the specialized materials and parts marketed through the GE Components Marketing & Sales Operation are making major contributions in other industries. These include semiconductor processing, laser optics, electronic packaging and testing, cutting tools, electrodischarge machining, ceramics, vacuum metallizing and many others.

In addition to molybdenum wire, we produce many other metal products. These include tungsten wire, filaments, metallizing wire and coils, and tungsten carbide powders; Dumet and Cumet copper clad wires; lead wires and lead wire assemblies. Lamp bases and formed and fabricated parts are also part of our metalworking capability.

We manufacture glass in the form of bulb blanks, tubing and pressed ware, supply fused quartz tubing, rod, ingots and crucibles, and produce Lucalox® ceramics, luminescent phosphors and inorganic chemicals.

Every part or material we make is subject to stringent quality control procedures. That's true whether it is destined for our product line or yours.

Because of the special nature of many of these parts and materials, GE is always willing to assist in adapting them to your manufacturing operations, or to work with you in product development or application engineering.

Some products may be available from our inventory or they can be custom made to your specifications.

For more information, contact your regional sales representative or the nearest sales office indicated below.

Sales Offices

Headquarters

Domestic Sales
21800 Tungsten Road
Cleveland, Ohio 44117
(216) 266-2451
FAX: (216) 266-3372

International Sales
21800 Tungsten Road
Cleveland, Ohio 44117
(216) 266-3295
FAX: (216) 266-3702
Telex: 256616

International

EUROPE
G.E. Lighting
Components Marketing & Sales
Melton Road
Leicester LE4 7PD England

Tel: 0116 261 1754
Fax: 0116 261 1499

India
Moly Colloids Private, Ltd.
9 Gulistan
M.L. Dahanukar Marg.
Bombay 400026, India
Phone: 011-91-22-492-7434
FAX: 011-91-22-493-0927
Telex: 011-4254 (IGCCIN)

Japan
Soei Tsusho Company, Ltd.
7-4 Bakuro-machi
chome, Higashi-Ku
Osaka, Japan 541
Phone: 011-816-241-0900
FAX: 011-816-241-0571
Telex: J65156 (SOEICOJ)

Korea
Won Ik Corporation
11th Fl., Seo Woo Bldg.
837-12, Yeok Sam-Dong,
Kang Nam-Ku, C.P.O. Box 399
Seoul, Korea
Phone: 011-82-2-555-4939
FAX: 011-82-2-554-5324
Telex: K22836 (WICORP)

Taiwan
Soei Tsusho Company, Ltd.
4F No. 46 2-Section
Chung Shan N. Road
Taipei, Taiwan R.O.C.
011-886-2-541-7458
FAX: 011-886-2-543-3362

GE Components
Marketing & Sales Operation

4/91 2.5M