Tungsten Compounds, Rods and Wires

TUNGSRAM

CONTENTS

GENERAL

Tungsten products

Tungsten compounds:

- — Ammonium paratungstate
- — Tungsten blue oxide
- — Tungsten metal powders (pure; doped with K, Si, Al)

Tungsten metal products:

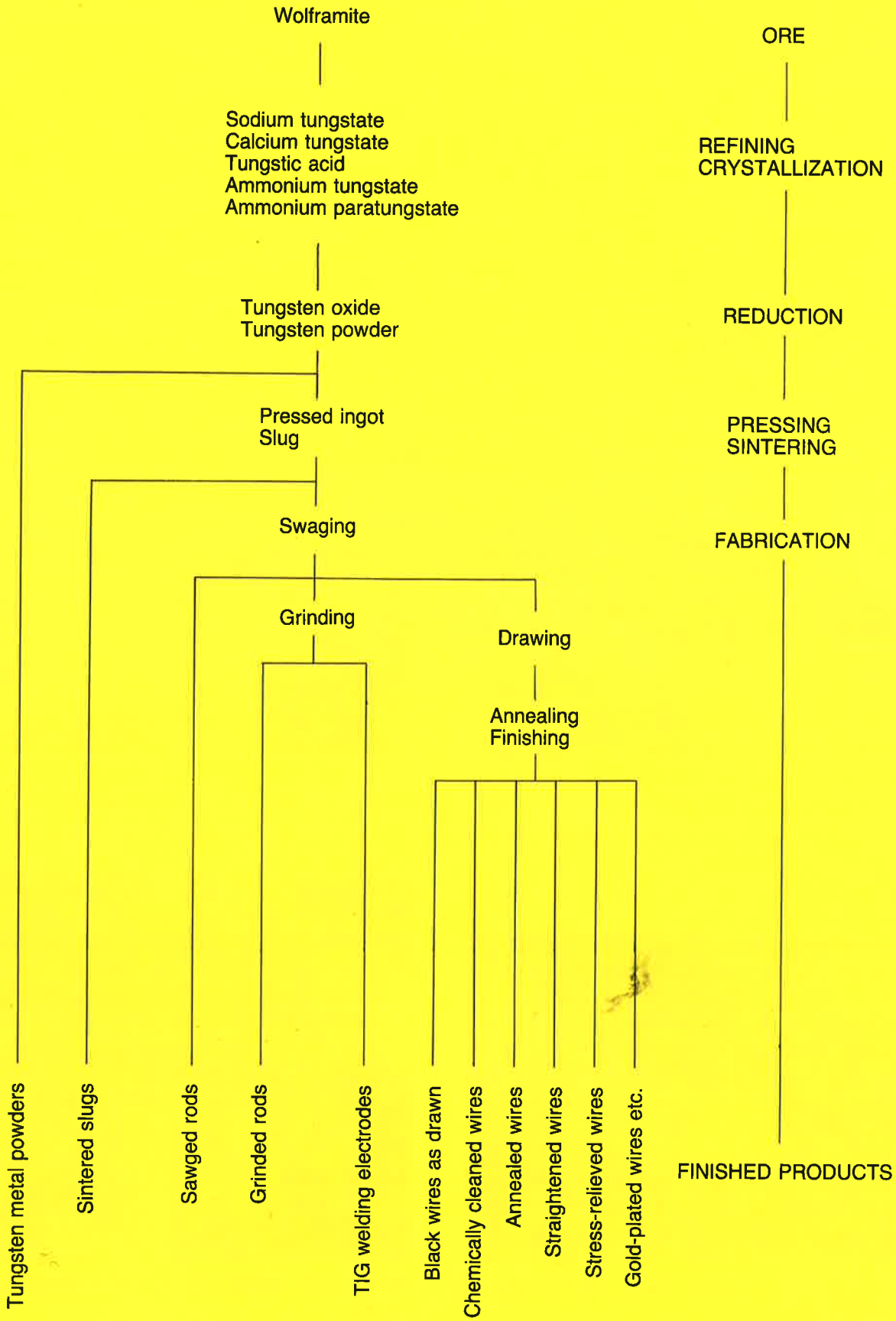
- — Tungsten rods:
  - Swaged — uncleaned, straight
  - cleaned, straight
  - retreated, straight
  - centerless ground
- — Tungsten wires:
  - Black (lubricant-coated)
  - Straightened
  - Cleaned
  - Cleaned, straight
  - Cleaned, annealed
  - Stress-relieved
  - Stress-relieved, straight
  - Gold-plated

General properties of tungsten

Physical properties		
	SI units	**Practical units**
Atomic number	74	74
Atomic mass	183.82	183.82
Melting point	3,683±20 K	3,410±20 °C
Boiling point	6,203 K	5,930 °C
Thermal conductivity at 20 °C	178 $W \cdot m^{-1} \cdot K^{-1}$	0.43 $cal \cdot cm^{-1} \cdot s^{-1} \cdot °C^{-1}$
Lattice type	Body centered cubic	
Lattice constant	$3.1585 \cdot 10^{-10}$ m	3.1585 Å
Density	$19.26 \cdot 10^{3}$ $kg \cdot m^{-3}$	19.26 $g \cdot cm^{-3}$
Coefficient of linear expansion		
at 20 °C	$4.5 \cdot 10^{-6}$ K^{-1}	$4.5 \cdot 10^{-6}$ $°C^{-1}$
at 1,000 °C	$5.2 \cdot 10^{-6}$ K^{-1}	$5.2 \cdot 10^{-6}$ $°C^{-1}$
at 2,000 °C	$7.3 \cdot 10^{-6}$ K^{-1}	$7.3 \cdot 10^{-6}$ $°C^{-1}$
Specific heat at 20 °C	134 $J \cdot kg^{-1} \cdot K^{-1}$	$3.2 \cdot 10^{-2}$ $cal \cdot g^{-1} \cdot °C^{-1}$
Electrical resistivity		
at 24 °C	$5.89 \cdot 10^{-4}$ Ωm	5.89 μΩ · cm
at 700 °C	$22.43 \cdot 10^{-4}$ Ωm	22.43 μΩ · cm
at 1,500 °C	$49.66 \cdot 10^{-4}$ Ωm	49.66 μΩ · cm
at 2,100 °C	$69.61 \cdot 10^{-4}$ Ωm	69.61 μΩ · cm
Heat of fusion	$255.4 \cdot 10^{3}$ $J \cdot kg^{-1}$	61 $cal \cdot g^{-1}$
Young's modulus	405 MPa	$41.5 \cdot 10^{3}$ $kg \cdot mm^{-2}$

Chemical properties		
Substance	**Temperature**	**Reaction**
Air or oxygen	20 °C	No reaction
	400 °C	Oxidation begins
	Above 1,400 °C	Rapid oxidation
Hydrogen	Below 1,200 °C	No reaction
	Above 1,200 °C	Very slight absorption
Ammonia		No reaction
Nitrogen	1,500 °C	No reaction
	2,500 °C	Nitride formed
Water		No reaction
Steam	Above 700 °C	Rapid oxidation
CO	Above 1,000 °C	Carburization
CO_2	Above 1,200 °C	Oxidation
Fluorine	20 °C	Fluoride formed
Chlorine	Above 300 °C	Chloride formed
Bromine	Red heat	Bromide formed
Iodine	Red heat	Iodide formed
Sulfur		Slow reaction
Phosphorus	Red heat	No reaction
Carbon, solid	Above 800 °C	Carbide formed
Hydrocarbon	Above 700 °C	Reaction
Silicon	Above 1,000 °C	Silicide formed
Mercury vapour		No reaction
Sodium	600 °C	No reaction
Gallium	600 °C	No reaction
Magnesium	20 °C	No reaction
NaOH, 10% solution	20 °C	No reaction
NaOH, fused		Attacked rapidly
H_2SO_4, diluted	20 °C	No reaction
	100 °C	Attacked slightly
H_2SO_4, conc.	20 °C	Attacked slightly
	110 °C	Attacked slowly
HCl, conc.	20 °C	No reaction
	100 °C	Attacked slightly
HNO_3, conc.	100 °C	Attacked slightly
HF	100 °C	Attacked slightly
$HF+HNO_3$	20 °C	Attacked rapidly
Argon		No reaction
Helium		No reaction
Potassium or sodium nitrite or nitrate		Aqueous solution: very slight reaction Molten: completely soluble (explosive)
Oxidizing agents		Rapid oxidation
Sulphuric acid	Cold	No reaction
	Warm	Slight reaction

Manufacturing process of tungsten



TUNGSTEN METAL POWDERS

TUNGSRAM offers standard types of tungsten metal powders shown in the table below. Upon request a wide range of special powder grades are available.

Type	Average particle size, μm	Chemical composition		
		Tungsten, %	Non volatile components, %	Oxygen, %
NTW 08	0.7—0.9	min. 99.9	max. 0.01	max. 0.4
NTW 10	1.0—1.2	min. 99.9	max. 0.01	max. 0.4
NTW 15	1.3—1.7	min. 99.9	max. 0.01	max. 0.1
NTW 20	1.8—2.4	min. 99.9	max. 0.01	max. 0.1
NTW 30	2.5—3.4	min. 99.9	max. 0.01	max. 0.1
NTW 45	3.5—5.4	min. 99.9	max. 0.01	max. 0.1
NTW 60	5.5—6.4	min. 99.9	max. 0.01	max. 0.1

Powder characteristics are considerably influenced not only by the particle size distribution of tungsten metal powders but by their green, bulk and tap densities as well as shapes and agglomerations of particles. Advanced testing methods at TUNGSRAM yield reliable information of tungsten metal powder properties in order to assure a uniform and high quality production.

In the method of photosedimentation, the rate of sedimentation in a uniform dispersion of tungsten metal powders in liquid medium is measured photoelectrically and the weight percent particle size distribution is calculated using Stokes' Law of Sedimentation.

The bulk and tap density can give a good practical information about the morphology of particles; data of green density permit estimations on pressing results expected.

TUNGSRAM produces tungsten metal powders developed for large-size sintered slugs, too.

How to order

Please, specify TUNGSRAM standard metal powders by their type designation. For special requirements, if any, please indicate desired powder parameters.

Fig. 1
Modern analytical instruments as this atomic absorbtion spektrophotometer shown in the photo and advanced testing methods assure the high quality of TUNGSRAM's products

Fig. 4
Leco analyzer for carbon content test in tungsten

Fig. 2
Photosedimentation analyzer intended for use in determining powder particle size distributions

Fig. 5
Scanning electron microscope (SEM) used to test tungsten metal powders

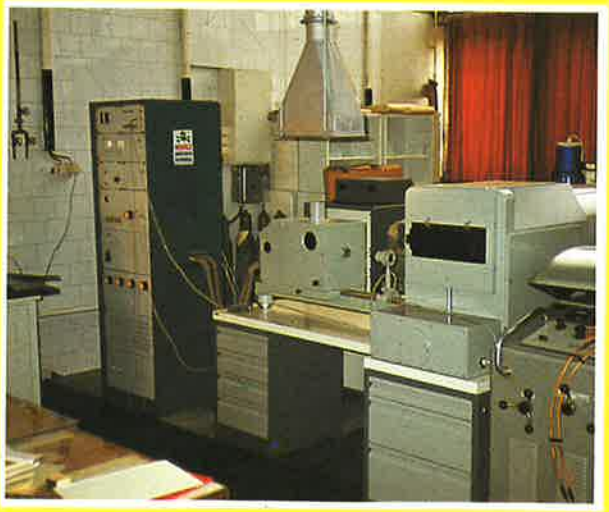


Fig. 3
Spectrograph for analytical tests

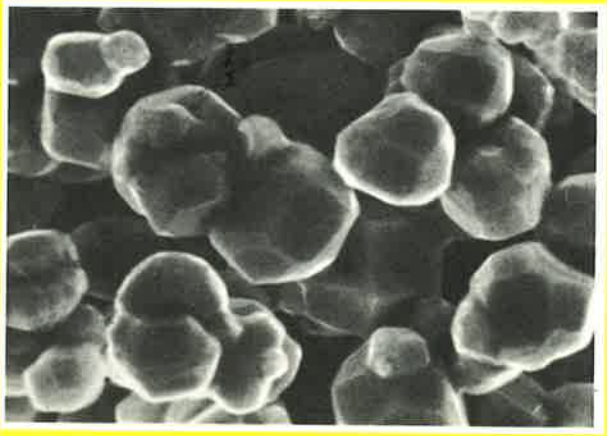


Fig. 6
A SEM photograph of tungsten metal powders

TUNGSTEN RODS AND WIRES

Basic material quality

TUNGSRAM's tungsten rod and wire assortment shown in the following table is based upon two basic material qualities: K, Si, Al doped and thoriated types, respectively.

Basic material quality	Description	Applications
Doped tungsten		
JGK	Good hot strength, ductility, high formable rods and wires, uniform quality at large diameter wires	electrical contacts; supports; electrodes; TIG welding electrodes; metallizing elements; heaters
GK-31	Standard non-sag quality. High formable, high quality rods and wires. Characterized by long grained, recrystallized structures	incandescent lamp filaments; fluorescent lamp cathodes; filaments, heaters and grids in electronic devices
GK-31 C	Standard non-sag quality. High formable, uniform quality rods and wires Characterized by long grained, recrystallized structures	special filament types for incandescent lamps
GK-31 H	Standard non-sag quality with excellent high temperature properties	long life filaments for incandescent lamps; halogen lamp filaments
GK-31 HC	Special high quality wires developed for halogen lamp filaments	for halogen lamps where non-blackening and shock resistance at high temperatures are of paramount importance; long filaments in high power halogen lamps, vehicle lamps, etc.
Thoriated tungsten		
UB	0.75% ThO_2 — — W	vehicle headlight lamp filaments requiring superior strength to resist shocks and vibrations; TIG welding electrodes

Dimension conversion

Above 0.5 mm (incl.), wire diameters are given in mm. For thin tungsten wires with diameters less than 0.5 mm, the mass of a 200 mm long wire is given in mg.
To calculate wire mass the equation
$D^2=329\ G$
is used in which

D=the wire diameter in μm and
G=the mass of a 200 mm long wire in mg.
In this relation, the wire mass is based on a specific gravity of 19.35 g/cm³.
For thoriated wires the equation is
$D^2=337\ G$,
based on a specific gravity of 18.9 g/cm³.

Diameter tolerances

Diameter	Tolerance
Swaged tungsten rods	
>0.5...≤ 1.0 mm	±0.015 mm
>1.0...≤ 2.0 mm	±0.02 mm
>2.0...≤ 4.0 mm	±0.1 mm
>4.0...≤10.0 mm	±0.2 mm
Centerless ground tungsten rods	
>0.5...≤2.0 mm	±0.01 mm
>2.0...≤4.0 mm	±0.015 mm
>4.0...≤6.0 mm	±0.02 mm
>6.0 mm	±0.05 mm
Wires coated with lubricant	
>0.5...≤1.0 mm	±0.015 mm
>1.05...≤2.5 mm	±0.02 mm
	±2%*

* wires for redrawing

Notes:
1. Standard tolerance is ±2% by mg/200 mm and ±1% by diameter for graphite coated wires below 0.50 mm dia.
2. For redrawing, the diameter tolerance is ±3% by mg/200 mm and ±1.5% by dia.
3. For cleaned wires, the tolerance is usually ±1% of the rated diameter.
4. Upon request, tungsten rods and wires with tighter tolerances are available.

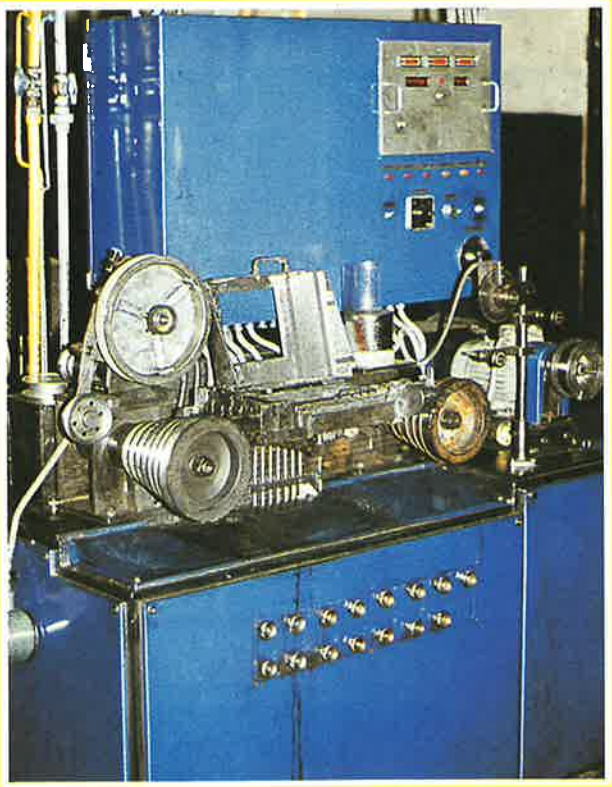


Fig. 7
Multy steps drawing machine

Fig. 8
Continuous diameter checking by measuring the electric resistance of wires

Fig. 9
Eddy current instruments test wires above 30 mg/200 for cracks and splits

Fig. 10
Instron tensile strength testing equipment

Mechanical properties

Fig. 11 shows the variations of the tensile strength depending on the annealing temperature for standard wire GK-31.

Tungsten wires annealed at high temperatures are brittle. Fig. 12 shows the relation between the annealing temperature and the bend ductility.

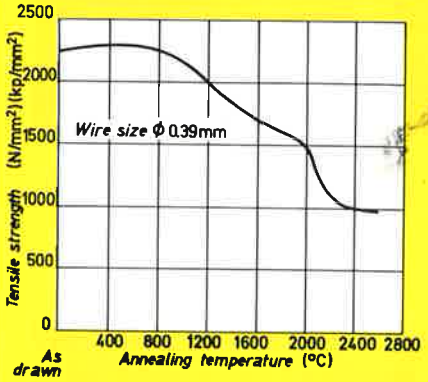


Fig. 11
Tensil strength of TUNGSRAM wires GK-31 versus annealing temperature

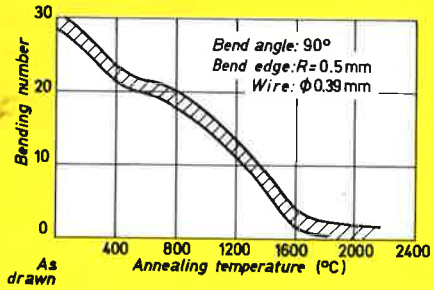


Fig. 12
Bending number of TUNGSRAM wires GK-31 versus annealing temperature

Non-sag characteristics

Non-sag characteristics are largely influenced by the recrystallized grain structure (Fig. 14). A fine dispersion of the doping materials gives high non-sag characteristics by an interlocked large recrystallized grain structure.

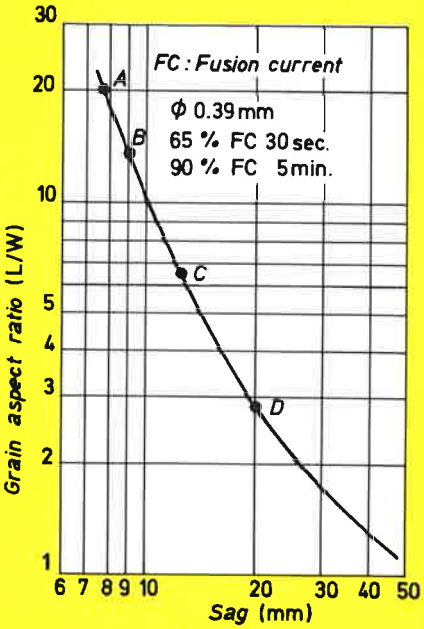


Fig. 14
Relation between high temperature non-sag properties and recrystallized grain structures

High temperature properties

In Fig. 13, the hot tensile properties of standard wire GK-31 is shown. The elongated and interlocked large grain structure with a fine dispersion of the doping material bubbles gives a high tensile strength even over 2,400 K.

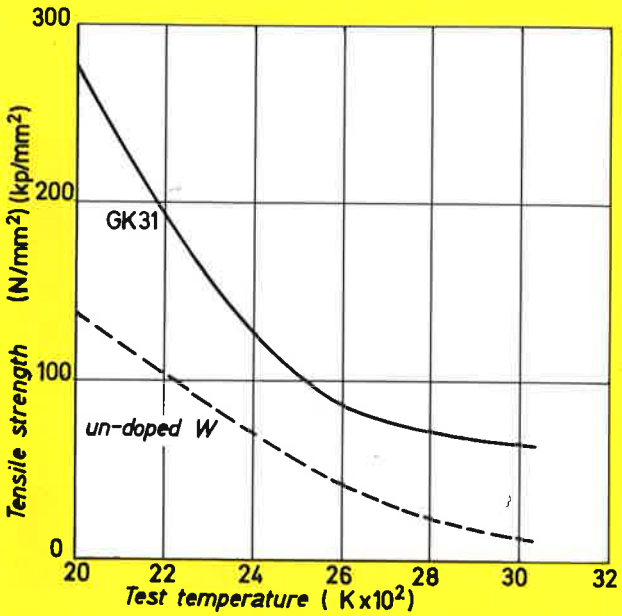


Fig. 13
Tensile strength of TUNGSRAM wires GK-31 versus test temperature

A

B

C

D

Tensile strength

Fig. 15 shows the standard specification of the tensile strength of tungsten wire GK-31 in function of the wire size. Upon request, tungsten wires with other or tighter tensile strengths are available.

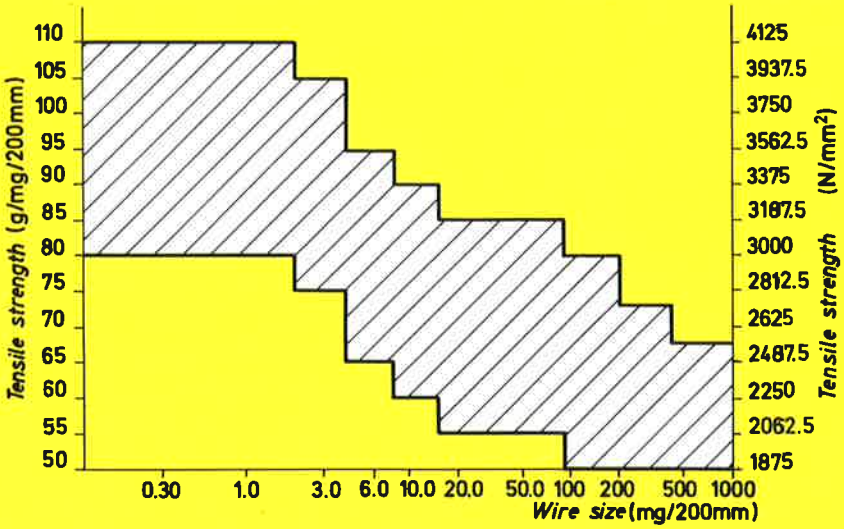


Fig. 15
Tensile strength of TUNGSRAM wires GK-31 versus wire size

Straightness

Straightness of tungsten wires manufactured by TUNGSRAM is min. 500 mm/m. Curl diameters for wires hanging down from a spool are given, too:

Diameter	Curl
0.03...≤0.13 mm	>40 mm
>0.13 mm	>50 mm

Finished tungsten rods and wires

Finish	Designation	Basic material quality					
		JGK	GK-31	GK-31 C	GK-31 H	GK-31 HC	UB
Swaged (or drawn)	SW	×	×	—	×	—	×
Swaged, straightened	SWS	×	×	—	×	—	×
Swaged, straightened, cleaned	SWSC	×	×	—	×	—	×
Swaged, straightened, annealed	SWSA	×	×	—	×	—	×
Swaged (or drawn), ground	SWG	×	×	—	×	—	×
Drawn, black	D	×	×	×	×	×	×
Drawn, cleaned	DC	×	×	×	×	×	×
Drawn, cleaned, straightened	DCS	×	×	×	×	×	×
Drawn, annealed	DA	×	×	×	×	×	×
Drawn, stress-relieved	DT	×	×	×	×	×	—
Drawn, stress-relieved, straightened	DTS	×	×	×	×	×	—
Drawn, cleaned, gold-plated	DCAu	×	×	×	×	×	—

× available
— not available

Standard minimum lengths

Tungsten wire size, mg/200 mm	Minimum length, m
≤20	1,000
>20...≤51	300
>51...≤200	100
>200...≤300	80
>300...≤754	50
>754...≤1,480	25
>1,480...≤2,956	20

Containers

Spool type	Spool material	Spool dimensions, mm				Wire diameter range, mm
		A	B	C	D	
CsV 22-01	AlMgSi	28	18	12	10	0.007...0.015
CsV-310	AlSi12Mg	78	64	12	20	0.015...0.036
CsV-510/A	Keripol	80	64	12	20	0.015...0.036
CsV-800	K 24	118	100	98	20	0.015...0.4
CsV-820	Aluminium	192	153	150	30	0.2...1.5
Coil	Self-support (inner dia: 200—400 mm): 0.5...1.5 mm					

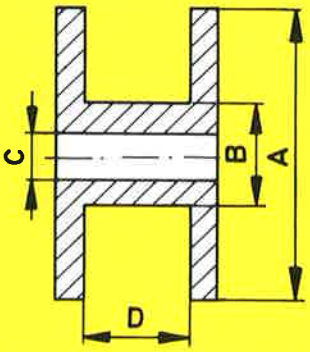


Fig. 16
Dimensions of a wire container

How to order

Please specify TUNGSRAM tungsten wires and rods by indicating:

- — basic material quality (p. 6)
- — quantity in m or in kg (p. 10)
- — finish (p. 9)
- — rated diameter — in mg/200 mm when ∅=0...0.5 mm
  in mm when ∅>0.5 mm
- — diameter tolerance (p. 7)
- — special requirements, if any

TUNGSTEN ELECTRODES

TUNGSRAM production range comprises tungsten electrodes and other tungsten parts intended for use as

- — lead-in wires for lamps,
- — TIG welding electrodes,
- — cathode coils for mercury vapour lamps,
- — heating elements manufactured from grinded rods for operating temperatures of 1,800 to 2,000 °C,
- — contact breaker arms, etc.

Owing to their superior heat resistance, thoriated (ThO_2) tungsten rods are recommended for fixed electrodes in TIG welding in order to stabilize the arc and to extend the operating life.

Type	Chemical composition		Finish	Diameter (d), mm	Length (L), mm
	W, %	ThO_2, %			
GK-31	99.96	—	drawn, polished	0.5...1.8	5...600
			drawn, grinded	1.0...1.8	5...600
JGK	99.96	—	swaged, grinded	1.8...10.0	5...1,000
UB	98.96	1.0	drawn, grinded	0.8...1.8	5...600
			swaged, grinded	1.8...6.0	5...1,000

Diameters, lengths and tolerances according to buyer's requests.

How to order

In addition to type designation please specify as follows:
Ordering example:

Smooth surface, free of cracks and splits.
Ovality within the diameter tolerance, max. 0.015 mm.
Conicality max. 0.005 mm/100 mm.

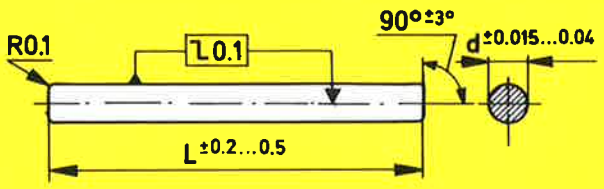


Fig. 17
Ordering example for tungsten electrodes

GOLD-PLATED TUNGSTEN WIRES

Since several decades, TUNGSRAM has been producing gold-plated tungsten wires used in manufacturing electron tubes. While owing to its high electron work function, tungsten assures the suitable quantity of thermoelectrons, gold coatings provide a high efficiency for the process itself.

Gold-plated tungsten wires are manufactured on GK-31 base with a 0.3 to 0.7 μm thick coating from a 99.99% purity gold.

The thickness of the gold layer is calculated from the mass measurements of plated and unplated wires as follows:

$$\lambda = 6.08 \cdot 10^{-3} \frac{G_2 - G_1}{\sqrt{G_1}}$$

where G_1 = the unplated wire mass (mg/200 mm),
G_1 = the plated wire mass (mg/200 mm).

Typ	Rated diameter, mm	Nominal mass, mg/200 mm ±4%	Thickness of gold layer		Tensile strength (Rm), N/mm²	Elongation, %	Curleness, mm/m
			μm	mg/200 mm			
WHA	0.011 0.25	0.364 1.88	0.3...0.7 0.24...0.3	0.204...0.496 0.36...0.45	3,500 2,900	min. 1.0 min. 1.0	min. 650 min. 650

Container: CsV-800

How to order

Please specify:
— type,
— rated diameter,
— thickness of gold layer,
— length.

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