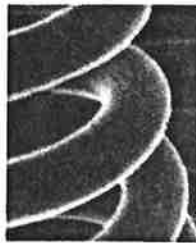


Technical Information Bulletin



Rod and Wire

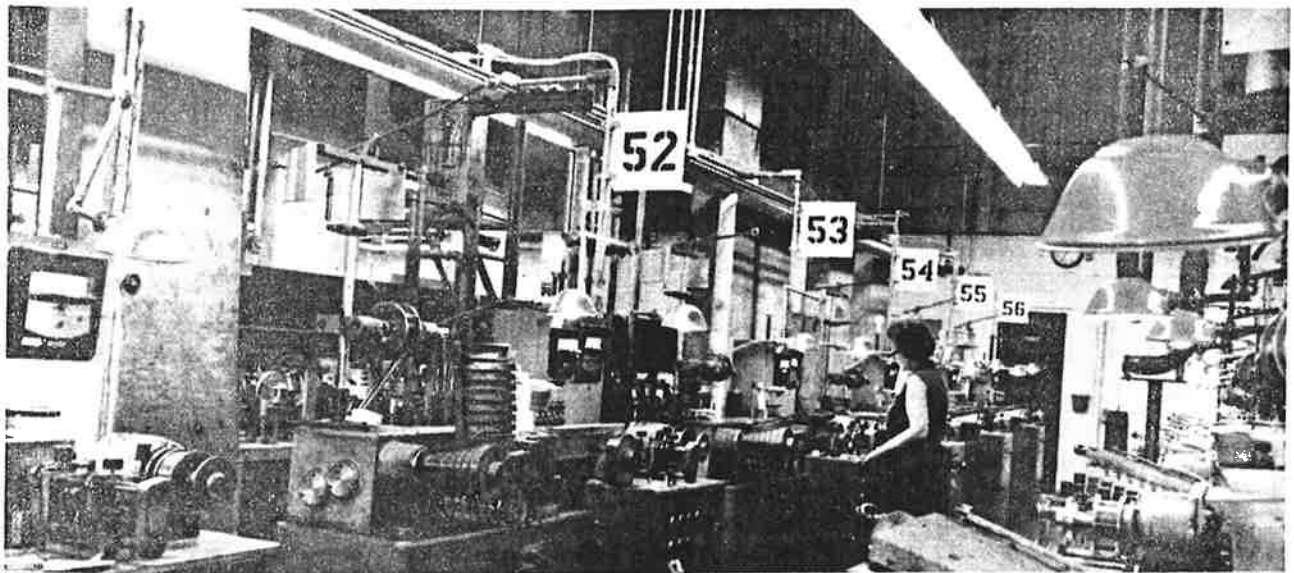
TUNGSTEN WIRE

The Chemical and Metallurgical Division of GTE Products Corporation is a leading manufacturer of tungsten wire, which is sold under the Sylvania brand for a broad range of applications in the lamp, electronic-tube, photocopy, computer, vacuum-metallizing, and electric-furnace industries, and in the making of fiber-reinforced materials. Sylvania Tungsten Wire is available in selected combinations of four types and thirteen process variations in diameters from 0.3 to 65 mils (0.008 to 1.65 mm) either on returnable containers or as self-coils, depending on the diameter.

Generally, tungsten wire is made from doped powders, that is, powders in which small quantities of potassium, silicon, and aluminum have been incorporated. Their purpose is to influence the recrystallized grain structure to reduce the creep rate at the high temperatures of incandescent filaments. The powders are consolidated under

high pressure, sintered at high temperatures and worked by rolling and swaging to heavy rod suitable for drawing.

Tungsten wiredrawing is accomplished by coating the wire with a graphite lubricant, heating to a red heat, and then drawing through tungsten carbide or diamond dies. The process is sometimes referred to as hot cold-working, which means that, while the wire is hot, the temperature is still below the recrystallization range. Accordingly, as the cross-sectional area is reduced, strength and ductility increase. The as-drawn wire at finished size subsequently may be cleaned, straightened, or annealed. Through various drawing methods and annealing steps, GTE produce different physical characteristics in wire of a given size. Our control of each manufacturing step from tungsten ore to finished wire assures reliability and reproducibility.



TYPES OF TUNGSTEN WIRE

Types can be divided into two groups based on diameter.

Group I - Available in ultrafine through heavy sizes.

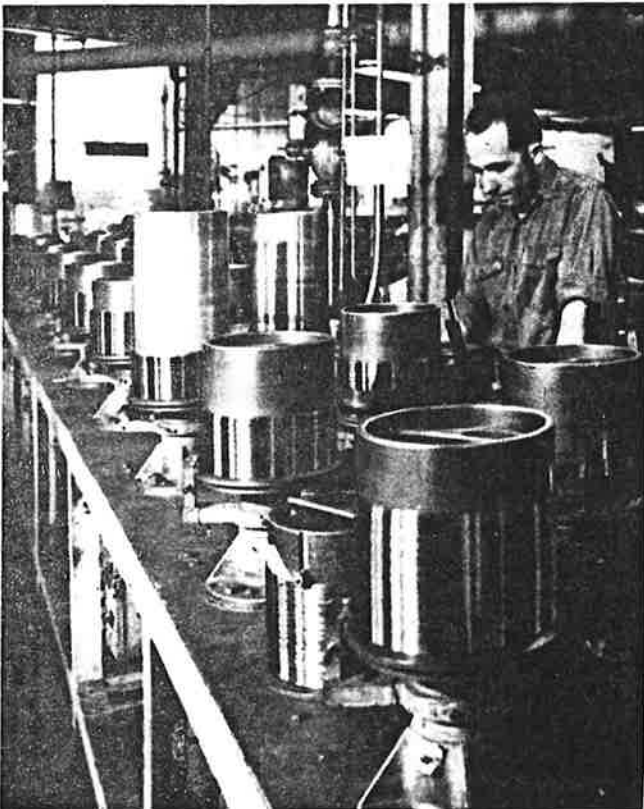
NS - Nonsag wire for coiled filaments and for supports in fluorescent and incandescent lamps, electronic-tube grids and heaters, and electric-furnace elements. It is available in the broadest range of standard processes (finishes) for the widest variety of applications.

HG - Nonsag, high purity wire for use in high-temperature halogen lamps where trace impurities must be very low to avoid blackening of the glass en-

velope. It is also used in infrared lamps.

3RW - Wire containing 3.25% rhenium which raises the recrystallization temperature, inhibiting recrystallization during use. Wire remains ductile, making it appropriate for lamps subject to shock or vibration, such as sign lamps.

1TH - Wire containing 1% thoria. Its principal use is for power-tube filaments and for some types of incandescent lamps for vibration service.



Capstan drawing



Heavy tungsten wire ready for further drawing

GROUP I - Processes (Finishes) and Sizes

	Size Ranges Available*	
	Minimum	Maximum
10 . . As-drawn wire suitable for forming and featuring a black finish from the graphite drawing lubricant.	0.20 mg 0.008 mm	65 mils 1.65 mm
15 . . As-drawn wire suitable for redrawing and featuring a black finish from the graphite drawing lubricant.	100.00 mg 0.183 mm	65 mils 1.65 mm
20 . . Process 10 wire which has been straightened.	2.00 mg 0.026 mm	55 mils 1.40 mm
30 . . Process 10 wire which has been chemically cleaned.	0.45 mg 0.012 mm	65 mils 1.65 mm
50 . . Wire which has been cleaned, straightened, and annealed to a low tensile strength. It is generally used in electronic-tube grid and heater applications where optimum straightness and excellent dimensional control during coiling are required.	0.45 mg 0.012 mm	50.00 mg 0.13 mm
52 . . Applies to Type 3RW wire only. Similar to Process 50. For CRT heater wire requiring maximum ductility.	4.00 mg 0.036 mm	30 mils 0.76 mm
55 . . Wire which has been chemically cleaned and straightened. The wire has good straightness and intermediate tensile properties, finding broad usage wherever a cleaned and straightened wire is required.	0.45 mg 0.012 mm	55 mils 1.40 mm
56 . . Wire which has been cleaned and straightened. The wire has been processed especially for sealed-beam-headlamp filaments.	30.00 mg 0.10 mm	200.00 mg 0.26 mm
60 . . Wire which has been partially straightened under heat and tension, and chemically cleaned, retaining tensile strength nearly as high as that of the as-drawn wire.	0.45 mg 0.012 mm	70.00 mg 0.15 mm

-continued-

*Notes:

- Milligram values are the weights of 200-mm lengths of wire.
- 1 inch = 1000 mils = 25.40 mm.
- Larger sizes can be supplied as rod.
- 1TH wire is available only as Processes 10, 15, 20, 30 55, and 60. The minimum size is 1.00 mg/200 mm.

GROUP I - Processes (Finishes) and Sizes (Continued)

	<u>Size Ranges Available*</u>	
	<u>Minimum</u>	<u>Maximum</u>
80 . . Smooth, electropolished wire with a high tensile strength.	0.08 mg 0.005 mm	200.00 mg 0.26 mm
85 . . Electropolished wire with a low tensile strength. Straightness and tensile strength comparable to those of Process 50.	0.45 mg 0.012 mm	50.00 mg 0.13 mm
86 . . Electropolished wire with tensile strength and straightness comparable to those of Process 55.	0.70 mg 0.015 mm	200.00 mg 0.26 mm
87 . . Partially straightened, etched wire with high tensile strength. Straightness and tensile strength comparable to those of Process 60. Recommended for electron-tube grids for which high tensile strength and improved straightness are required for efficient operation of automatic grid-winding machines.	0.17 mg 0.008 mm	0.70 mg 0.015 mm

***Notes:**

- Milligram values are the weights of 200-mm lengths of wire.
- 1 inch = 1000 mils = 25.40 mm.
- Larger sizes can be supplied as rod.
- 1TH wire is available only as Processes 10, 15, 20, 30 55, and 60. The minimum size is 1.00 mg/200 mm.

GROUP II - Available at and above 0.51 mm (20 mils)

- | | |
|---|---|
| <p><u>PW</u> - Undoped high purity wire for lamp coils in which sag is not important, as in supported coils. The recrystallization temperature is lower than that of NS, and it is less resistant to sag at high temperatures.</p> | <p>maximum ductility, but less-critical nonsag characteristics.</p> |
| <p><u>VM</u> - Wire furnished in either stranded or single-wire form for vacuum metallizing. The wire should also be specified for other applications requiring</p> | <p><u>LA</u> - Wire similar to VM, except that it is an ultrapure low-alkali grade for vacuum metallizing for integrated circuits.</p> |
| | <p><u>2TH</u> - Wire containing 2% thoria for applications requiring high electron emission, such as for lamps and power tubes.</p> |

GROUP II - Processes (Finishes) and Sizes

	<u>Maximum Size</u>
10 . . As-drawn wire suitable for forming and featuring a black finish from the graphite drawing lubricant.	65 mils 1.65 mm
15 . . As-drawn wire suitable for redrawing and featuring a black finish from the graphite drawing lubricant.	65 mils 1.65 mm
20 . . Process 10 wire which has been straightened.	55 mils 1.40 mm
30 . . Process 10 wire which has been chemically cleaned.	65 mils 1.65 mm
55 . . Wire which has been chemically cleaned and straightened.	55 mils 1.40 mm

MEASUREMENT OF WIRE SIZE FOR GROUP I

Group I wire diameters below 0.76 mm (30 mils) are determined and expressed as milligrams per 200 millimeters (mg/200 mm). Cutting and weighing are easier and more accurate than direct measurement of diameter. The weight of a piece of wire is proportional to its cross section and to the square of its diameter.

The relationship of rating to diameter is

$$\text{mg}/200 \text{ mm} = F D^2$$

in which F is a conversion factor and D is the diameter. The following values of F may be used to convert diameter values to ratings (mg/200 mm):

	<u>Values of F</u>	
	<u>Diameter</u> <u>in mils</u>	<u>Diameter</u> <u>in mm*</u>
<u>Clean Wire</u>		
NS & HG	1.943	3011
3RW	1.948	3020
1TH	1.925	2983
2TH	1.907	2955

	<u>Values of F</u>	
	<u>Diameter</u> <u>in mils</u>	<u>Diameter</u> <u>in mm*</u>
<u>Black Wire</u>		
NS & HG	1.92	2975
3RW	1.93	2990
1TH	1.90	2947
2TH	1.88	2913

* If the diameter is given in micrometers (formerly microns), convert to millimeters by dividing by 1,000, then use factors as given in this column.

Example: Determine rating of 5-mil clean NS wire. $\text{mg}/200 \text{ mm} = 1.943 (5^2) = 1.943(25) = 48.58$. That is, a 200-mm length of clean 5-mil wire will weigh 48.58 mg.

TOLERANCE

Orders for wire specified in mg/200 mm will be entered at the centersize rating of the specified tolerance range. Rating is designed at three places beyond the decimal below 0.68 mg/200 mm. For wire 0.68 mg/200 mm and above, rating is designated at two places. See Tolerance Tables for standards.

Since most fine tungsten wire is used for electrical current-carrying purposes, rating is the appropriate control for cross-sectional area. However, there are instances, generally above 0.25 mm, in which diameter tolerances are important for tight-fitting devices. To assure proper clearance, an "out-of-roundness" (OOR) or ellipticity limit may also be required.

A maximum diameter range may be derived from rating and OOR tolerances by adding the two tolerances and dividing by two. For example:

A wire with a $\pm 2\%$ rating tolerance may have the maximum diameter variation of $\pm 1\%$. A wire with a 4% OOR tolerance may have the maximum diameter variation of $\pm 2\%$ due to OOR. So, the diameter of a wire with a $\pm 2\%$ rating tolerance and a 4% OOR tolerance will vary by no more than $\pm 3\%$.

TOLERANCE TABLE

Wire Size Ranges	Size Tolerance			OOR ^(a) Tolerance, %	
	Expressed As	Standard	Other	Standard	Other
Types NS, HG, 3RW, 1TH					
0.080 to 0.67 mg/200 mm (0.20 to 0.59 mils)	mg/200 mm	± 0.010 to ± 0.030 depending on center size. Re- fer to price sheets.		6.5	None
0.680 to 194 mg/200 mm (0.60 to 9.9 mils)	% of mg/200 mm	$\pm 3^{(b)}$	$\pm 2 \frac{1}{2}, \pm 2$ $\pm 1 \frac{1}{2}, \pm 1$	4.0	None
195 to 777 mg/200 mm (10 to <20 mils)	% of mg/200 mm	$\pm 3^{(b)}$	$\pm 2 \frac{1}{2}, \pm 2$ $\pm 1 \frac{1}{2}, \pm 1$	4.0	3 $\frac{1}{2}$, 3 2 $\frac{1}{4}$, 1 $\frac{1}{2}^{(c)}$

^(a) Defined as the difference between the maximum and minimum diameters expressed as a percent of the diameter.

^(b) Except that Process 15 is $\pm 4\%$.

^(c) 1 $\frac{1}{2}\%$ OOR is not available with a $\pm 1\%$ mg/200 mm tolerance for ratings below 777 mg/200 mm.

- continued -

TOLERANCE TABLE (continued)

Wire Size Ranges	Expressed As	Size Tolerance		OOR ^(a) Tolerance, %	
		Standard	Other	Standard	Other
<u>Types NS, HG, 3RW, 1TH</u>					
0.51 to 1.65 mm (20 to 65 mils)	% of diameter	$\pm 1\ 1/2^{(a)}$	$\pm 1\ 1/4, \pm 1$	OOR will be within the diameter tolerance specified	
<u>Types PW, VM, LA, 2TH</u>					
0.51 to 1.65 mm (20 to 65 mils)	% of diameter	$\pm 1\ 1/2$	$\pm 1\ 1/4, \pm 1$	OOR will be within the diameter tolerance specified	

- (a) Defined as the difference between the maximum and minimum diameters expressed as a percent of the diameter.
- (b) Except that Process 15 is $\pm 4\%$.
- (c) $1\ 1/2\%$ OOR is not available with a $\pm 1\%$ mg/200 mm tolerance for ratings below 777 mg/200 mm.
- (d) Except that Process 15 is $\pm 2\%$.

TENSILE STRENGTH

An important physical property that determines the performance of a particular tungsten wire in a particular application is tensile strength. Tungsten is not typical of most metals, in which low tensile strength improves formability. Instead, tungsten wires having low tensiles are generally less formable, particularly in higher diameters, but may be necessary, for example, to improve dimensional control, cutability or redraw properties. High tensile strength, while generally increasing formability, may cause excessive breakage or splitting.

Standard tensile strengths have been developed for all types, size ranges, and finishes for most applications. Where specific requirements may need special tensiles, the wire can be tailor-made to provide the most trouble-free operation.

Tungsten fine-wire sizes are expressed in mg/200 mm corresponding to cross-sectional areas. Therefore, the tensile strength is specified in grams per mg/200 mm. This is obtained by dividing the breaking load (grams) by the wire rating (mg/200 mm).

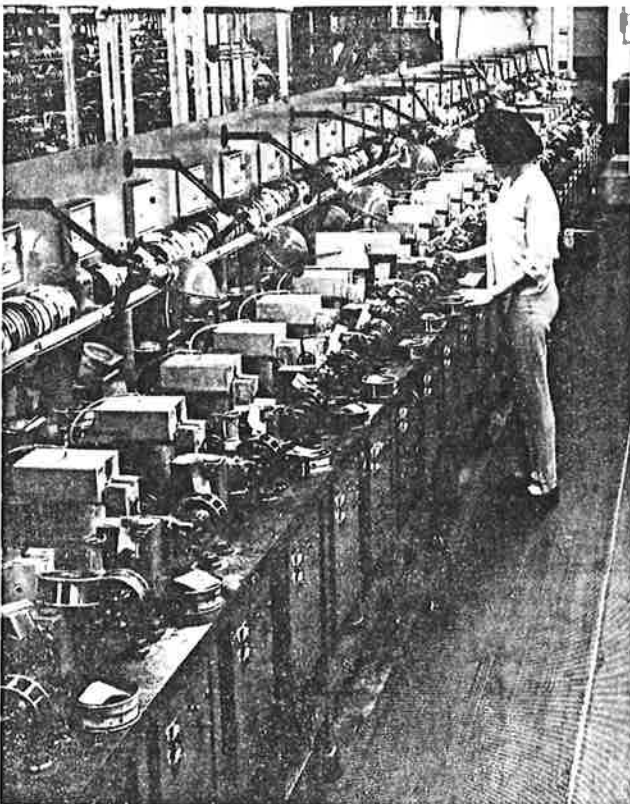
The tensile strength, TS, of unalloyed tungsten wire may be expressed otherwise by the following formulas:

In pounds per square inch --

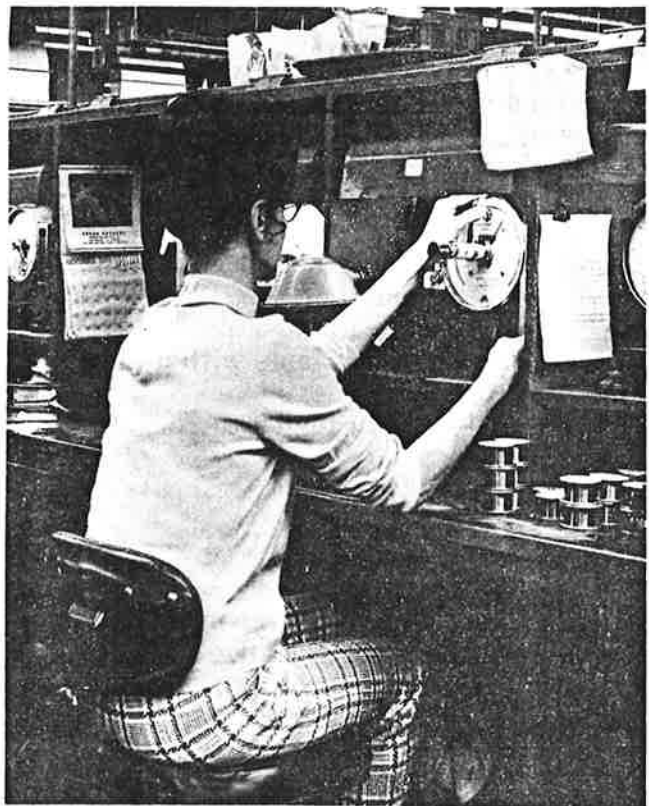
$$TS_{(psi)} = 5460 \times TS_{(g/mg/200\text{ mm})}$$

In megaPascals --

$$TS_{(MPa)} = 37.65 \times TS_{(g/mg/200\text{ mm})}$$



Fine wiredrawing



Rating

Since tensile values vary with gauge length and rate of loading, it is important that like testing procedures are followed to obtain correlation. At GTE, tensile measurements are based

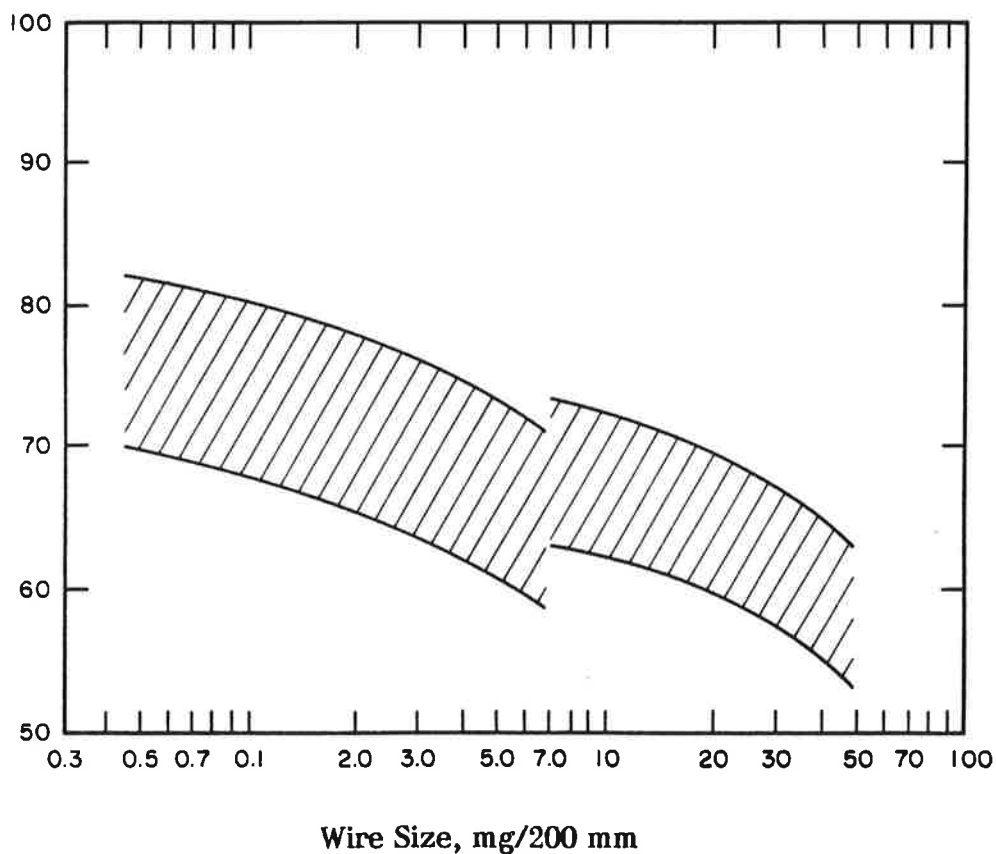
on the Instron Tester, which measures and records under constant rate of loading. A 10-inch gauge length and a loading rate of one inch per minute are used.

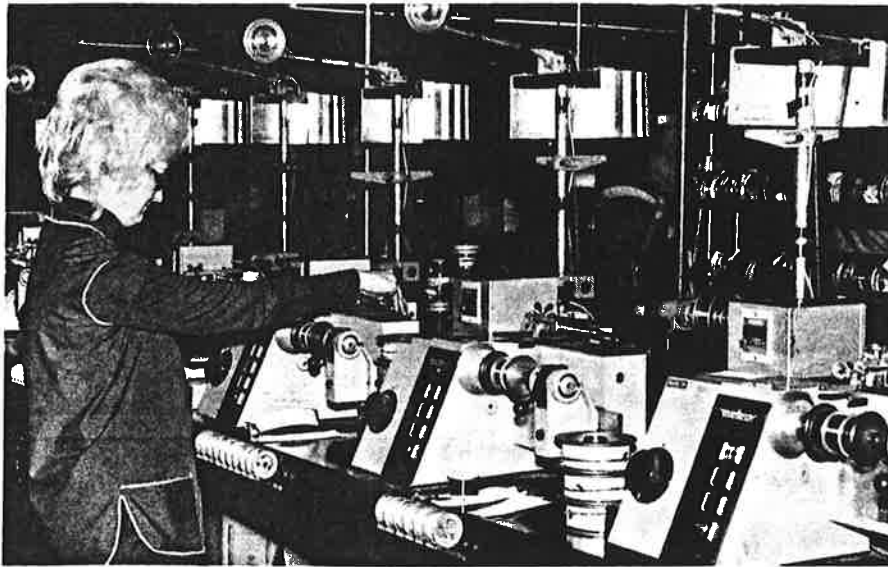
The following table and graphs give typical strength ranges of some NS wires.

**TYPICAL TENSILE STRENGTHS FOR
SOME TYPE NS TUNGSTEN WIRES**

<u>Wire Size</u> mg/200 mm	<u>Tensile Strength</u> g/mg/200 mm	<u>Process</u>
0.20	105 min.	10, 80
0.50	95 min.	10, 30, 60, 80
1.00	85 - 105	10, 30, 60, 80
5.00	85 - 105	10, 20, 30, 60, 80
10.00	80 - 100	10, 20, 30, 60, 80
50.00	70 - 90	10, 20, 30, 60, 80
100.00	65 - 85	10, 20, 30, 80

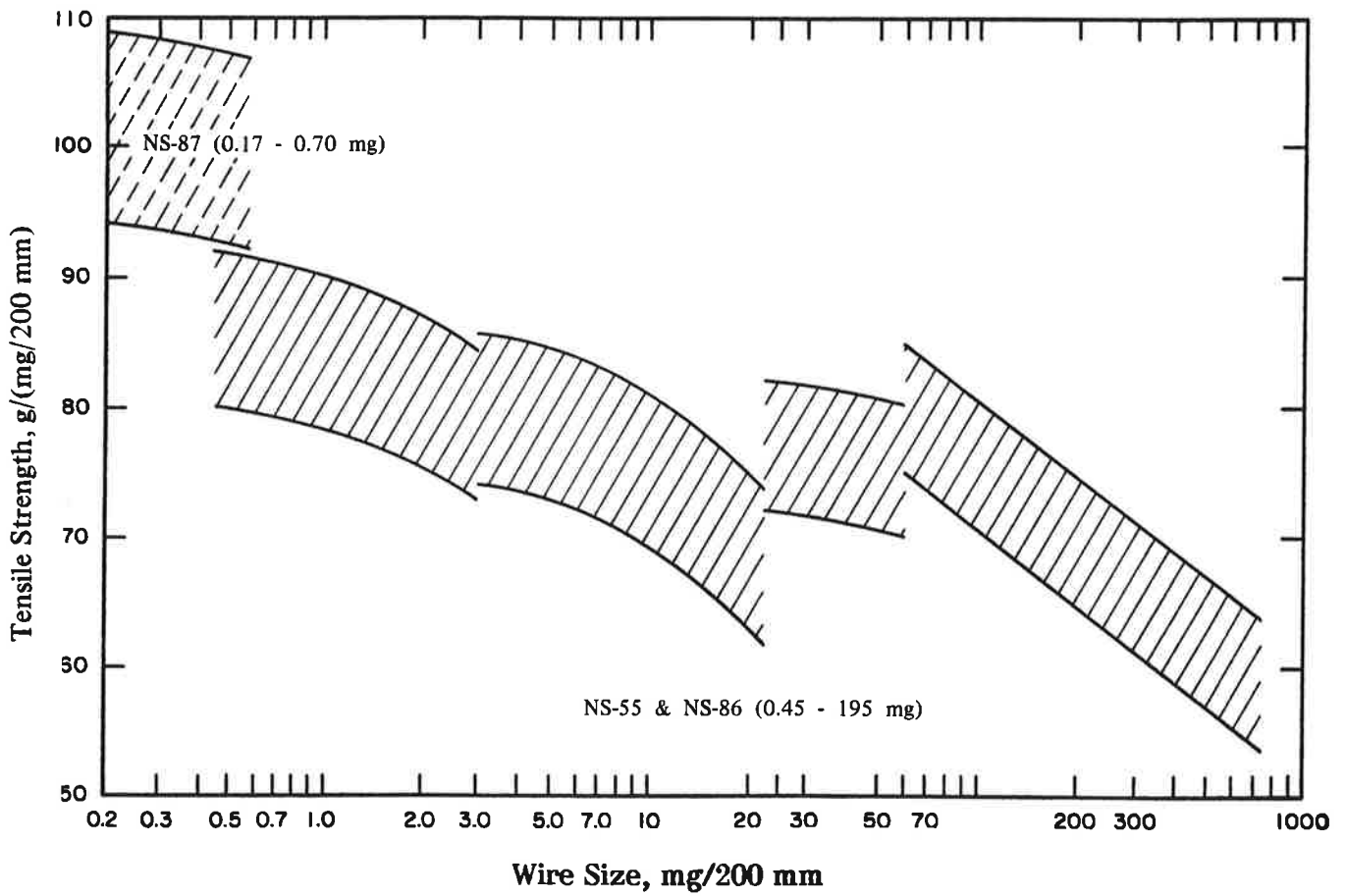
TENSILE STRENGTH NS-50, NS-85





Metering (length measurement) and respooling.

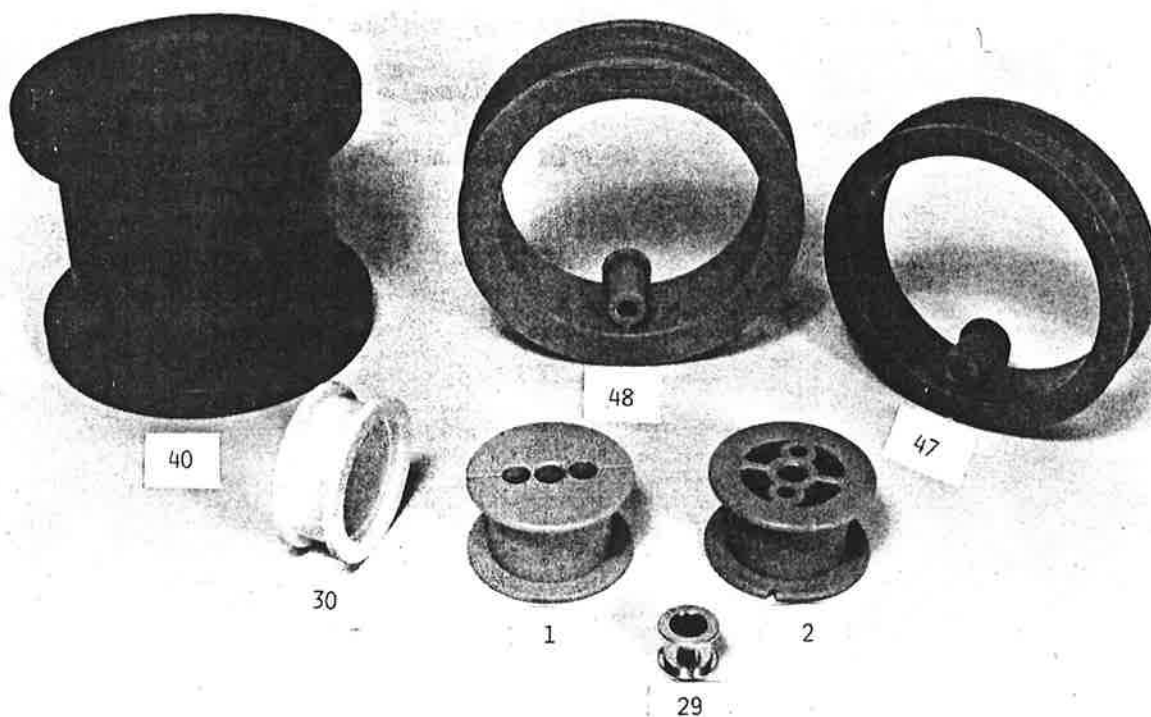
TENSILE STRENGTH NS-55, NS-86, NS-87



CONTAINERS

Sylvania tungsten wire is supplied on returnable containers or as a self-coil depending on the size. The following table lists our standard containers.

<u>Container Number</u>	<u>Description</u>	<u>Bore Diameter, inches (mm)</u>	<u>Barrel Diameter, inches (mm)</u>	<u>Traverse, inches (mm)</u>	<u>Container Weight, grams</u>	<u>Container Capacity, grams</u>
1	hi-impact plastic	3/8 (9.5)	1 5/8 (41)	1 (25.4)	81	360
2	plastic spool	3/8 (9.5)	1 5/8 (41)	1 (25.4)	34	300
29	aluminum bobbin	7/16 (11)	19/32 (15)	27/64 (11)	4	11
30	plastic bobbin	1 9/16 (40)	1 7/8 (48)	5/8 (16)	17	88
40	plastic spool	5/8 (16)	4 (102)	3 (76)	236	3800
47	plastic band	3 3/4 (95)	4 1/4 (108)	12/16 (21)	58	450
48	plastic band	3 7/8 (98)	4 1/4 (108)	1 (25.4)	93	1000



Meters per Container

The approximate maximum number of meters per container for a given wire are determined as follows:

$$M = \frac{200 \times C}{R} \quad \text{where}$$

M = maximum number of meters
 C = maximum number of grams of wire which can be wound on the container (see table)
 R = rating of the wire in mg/200 mm

Example:

Calculate the maximum number of meters of 12.16-mg/200 mm wire that can be wound on a No. 2 container.

$$C = 300 \text{ (from table below)}$$

$$R = 12.16$$

So,

$$M = \frac{200 \times 300}{12.16} = 4,934 \text{ meters}$$

When the container is not specified, the following will be used:

PROCESS 10:

Container No. 1 or No. 2 for all sizes up to 150 mg/200 mm.

Container No. 48 for all sizes at 150 to 777 mg/200 mm.

PROCESS 15:

Container must be specified by customer.

ALL OTHER PROCESSES:

<u>Wire Size</u>	<u>Standard Container Numbers</u>	<u>Alternate Container Numbers</u>
Up to 0.49 mg/200 mm	29	2
0.50 to 0.99 mg/200 mm	2	29
1.00 to 25.99 mg/200 mm	1 or 2	47
26.00 to 760 mg/200 mm	48	47
20 mils (0.51 mm) & above	self-coils	

SELF-COILS

Wire at 0.51 mm (20 mils) and above is supplied in coils as listed below. Each coil is tied securely with a soft tie-wire at three positions.

<u>Wire Diameter</u>		<u>Nominal Coil Diameter</u>			
		<u>Process 10, 15, & 30</u>		<u>Process 20 & 25</u>	
<u>mm</u>	<u>mils</u>	<u>cm</u>	<u>in.</u>	<u>cm</u>	<u>in.</u>
0.51-0.85	20-34	18 or 25	7 or 10	36	14
0.88-1.12	35-44	25 or 30	10 or 12	36	14
1.13-1.45	45-57	30	12	36	14
1.46-1.65	58-65	53	21	-	-

SHIPPING INFORMATION

A nominal deposit charge is made for spools, bobbins, and bands. Credit will be allowed at the prices billed, when containers are returned in good condition to Towanda, Pennsylvania, transportation prepaid, within six months of receipt by the buyer.

All spools, bobbins, bands, and self-coils are either labeled or tagged with complete identification. Only one continuous length of wire is wound on a container. On spools, the outer end of the wire is held by a red cork.

HOW TO ORDER

1. Specify quantity desired in meters or kilograms.
2. Specify wire type and process.
3. Specify wire size and tolerance.
4. Specify container number.

Examples:

1. 500,000 meters
NS-55 tungsten wire
7.00 mg/200 mm, $\pm 3\%$
Supply on Container No. 1.

500 kg
NS-10 tungsten wire
60 mils $\pm 1\ 1/2\%$
Supply in self-coils.

CM-9073 (4/88)