Technical Information Bulletin

Tungsten and Molybdenum Stranded Wire

Tungsten and Molybdenum Stranded Wire for Vacuum Metallizing and Resistance Heating

OSRAM SYLVANIA Products Inc.'s Chemical & Metallurgical Products offers a full selection of tungsten and molybdenum stranded wires for vacuum-metallizing and resistance-heating elements. The stranded wires or cables are sold to vacuum metallizers and furnace manufacturers who want to design their own configurations. The strand sometimes contains one individual wire of the metal to be evaporated; e.g., aluminum or a nickel-chromium alloy.

The emphasis in this bulletin is on strand for metallizing, usually from tungsten wire only, but sometimes containing a strand of a second metal as discussed more in- depth below.

Vacuum-Metallizing Applications

■ VM-Grade Tungsten Strand

VM-grade tungsten wire, used in VM strand, is made by controlled processing techniques starting from the ore and continuing through doping and wiredrawing. Highly purified tungsten oxide, which has been reduced to tungsten powder in pure hydrogen, is pressed into bars, sintered, and worked into wire. The wire, drawn to size, is cleaned and stranded in various combinations as desired. As a result, our high-purity doped strand is produced to provide a uniform and controlled recrystallization rate important in the vacuum-metallizing process. The techniques allow achievement of a high number of flashes per coil by eliminating premature coil brittleness, distortion, and sag, the major causes of failure during reloading and processing.

■ Surface Finish

Stranded wire is supplied with a clean bright finish free of slivers and visual contamination such as oxide and drawing lubricants. However, tungsten oxidizes slowly in air and more rapidly in polluted air, so that the bright finish is not indefinitely maintained. Generally, a slight tarnish is not detrimental.

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Vacuum-Metallizing Applications (cont.)

■ Vacuum Metallizing

The amount of molten metal which can be retained by a metallizing coil depends, among other things, on the surface area of the tungsten wire and on the configuration of the cable. An aluminum strand among the tungsten strands in a cable provides an open structure which will retain more molten aluminum. After the first operation, aluminum clips ("staples") are hung on the coil. As the clips melt, the aluminum flows by surface tension into the open structure, from which it then evaporates.

Furnace-Element Applications

■ Molybdenum Strand

Molybdenum strand or cable is often used in place of single-wire molybdenum for furnace element windings. Its purpose is to obtain an equivalent current carrier with the higher degree of ductility required in some muffle shapes. Also, higher watt loading per unit length can be achieved by virtue of the increased surface, leading to equivalent power dissipation at lower element temperature and therefore to longer furnace life and more uniform temperature distribution. Because of molybdenum's inherent ductility, strands from larger wire sizes are available, some of which are listed in the table of **Standard Strand Types**.

STANDARD STRAND TYPES

	Pitch ipt	Nom OD mils	Equivalent Single-Wire Diameter D mils	Standard Tungsten Strand kg/1000 m	kg/1000 ft	m/kg	ft/kg
I. TUNGSTEN – VM							
4X 15 mil	1/4	36	30	9.06	2.76	110.4	362.1
3X 20 mil	5/16	43	35	11.98	3.65	83.5	273.8
3X 25 mil	3/8	54	43	18.73	5.71	53.4	175.1
2X 30 mil	1/2	60	42	17.79	5.42	56.2	184.4
3X 30 mil	1/2	65	52	26.83	8.18	37.3	122.2
4X 30 mil	9/16	72	60	39.93	10.95	27.8	91.3
3X 40 mil	5/8	86	69	47.86	14.59	20.9	66.6
3X 25 mil w/25 mil Al Core	3/8	70	43	20.28	6.18	49.3	161.7
3X 30 mil w/25 mil Al Core	1/2	75	52	28.23	8.61	35.4	116.2
II. MOLYBDENUM							
3X7X 22 mil	5/8	143	100	57.11	17.41	17.5	57.4
6X 27 mil	5/8	61	66	23.25	7.09	31.0	101.7
4X 30 mil	9/16	72	60	18.99	5.79	52.7	172.7
7X 30 mil	3/4	90	79	33.35	10.17	30.0	98.4
4X 32 mil	9/16	77	64	21.70	6.62	46.1	151.1
3X 40 mil	5/8	85	69	25.31	7.72	39.5	129.6
7X 45 mil	3/4	143	119	77.79	23.72	12.8	42.1
3X 50 mil	3/4	108	86	39.66	12.09	25.2	82.7
3X 60 mil	3/4	129	103	57.79	17.62	17.3	56.7
7X 70 mil	1	210	185	179.59	54.74	5.6	16.7

Straightness

All strand is put through a straightening operation prior to spooling to minimize camber.

Chemical Composition

Analyses are by emission spectrometry except where footnoted.

Element Symbol	Typical Values, ppm VM	Mo	ML
Al	5	15	40
Ca	0.6	<2	20
Cr	2	25	80
Cu	0.2	<1	10
Fe	8	50	100
Mg	<1	<1	20
Mn	<1	<1	10
Mo	<10	—	—
Ni	5	150	100
Si	6	150	250
Sn	1	40	100
W	—	90	250
Na (a)	<6	10	50
K (a)	40	20	50
C (c)	14	25	50
N (c)	1	5	100
O (c)	11	40	500
All Others	<10	<10	<10

(a) Atomic absorption.
(c) Chromatographic analysis.

Strand Design

Strand design is most easily described in terms of the head of the stranding machine, which has up to six holes in a circular pattern and one hole in the center. A wire fed through the center is called the core. Occasionally a cable will be wrapped with a single wire by passing the cable through the center, and a single strand ("overwrap") in one of the outer positions.

A two-wire strand (2X, "two-by") has no core. Unless otherwise specified, 3X, 4X, 5X, and 6X will be supplied without cores; 7X types will always have a core. Multiple cables are made by stranding two to seven individual cables; strand with over seven single wires can be made only as multiple cables.

There are four major parameters necessary to define a specific strand type:

1. **Diameter of individual wires** — The stranded range is 15 to 40 mils[1] for W, and 15 to 70 mils for Mo and other metals. Other sizes are available.

2. **Strand configuration** — Specifying the number and position of each wire in the transverse cross section of the cable. The configurations available vary from 2X (two-by) to 7X (seven-by) for single-cable types. These in turn can be stranded to make multiple-cable types specified as, for example, 2X7X, 7X2X, etc. The configuration can have or not have a core wire about which the other wires are wrapped, and it can have an overwrap, which is a single wire wrapped around the cable in a secondary operation.

3. **Wire compositions** — Specifying the materials from which the individual wires are made. In mixed strands, the second material is most often 99.45% or 99.99% aluminum. Nickel-chromium alloys; e.g., Tophet® A and Tophet® 30, and copper have been used. Other materials will be considered on request by the customer. The second metal can be in any position in the stranded configuration.

Strand Design (cont.)

4. **Lay and pitch** — Specified by (a) handedness, (b) inches per complete turn of an individual outer wire, and (c) special twist requirements. This specification is analogous to the specification of a screw thread as right- or left-hand. Pitch is specified in inches per turn. Lay is specified as:

   - Standard — close packed.
   - Loose — purposely twisted loosely for more exposed surface area.

   Unless otherwise specified, the lay will be right-hand and standard. See table of **Standard Strand Types** for pitch.

- **General Facts**

  1. Finer wires (requiring a greater number for equivalent cross section) are more ductile and therefore can be deformed more readily.

     a. Tungsten single wires should remain below 40 mils for mild coil forming and 30 mils or below for severe coil forms.
     b. Molybdenum single wires should remain below 70 mils, again with finer wires being easier to form.

  2. Finer wires give more surface area for greater evaporation per meter of strand.

  3. Heavy-wire strand has a lower price per kilogram than fine-wire types.

  4. Nominal outside diameter of cable is controlled by strand type and may be a limitation in certain coil designs.

     Based on simple geometric relationships, the overall diameter may be calculated by use of the Formula $OD = F_s d$

     in which,

     OD = outside diameter (cable diameter)
     d = diameter of individual wires
     F_s = stranding factor (as listed below)

Type	F_s
2X	2.000
3X	2.156
4X	2.414
5X	2.620
6X	3.000
7X	3.000

     Example: OD of 3X 20 mils = 2.156 (20) = 43 mils

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[1]One mil = 1/1000 inch = 0.001"; for example: 0.040" = 40 mils.
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Determination Of Strand Configuration

1. Determine the "equivalent single-wire diameter" that is required for your application. This value, D, is the diameter of a single wire with cross section equal to the total cross sections of the wires in a stranded cable.

   Take into consideration the length of stranded cable to be used in forming a coil or furnace winding, and the temperature to be reached during operation. The power requirements may be calculated for various strand configurations.

   The nomographs may be useful in determining resistance and current for wires of various diameters at various temperatures. Some of the standard tungsten strand types are noted on the nomographs adjacent to their single-wire diameters. If one is found, proceed to **How to Order**, below.

2. If no selection can be made from the nomographs, refer to the table of **Standard Strand Types**, and determine which, if any, matches yours requirement. If one is found, proceed to **How to Order**.

3. If a selection cannot be made from the nomographs or the table, determine the diameter of individual wires (d) corresponding to the desired equivalent diameter (D) with the following formula:

   $d = D\sqrt{n}$

   In which:

   d = diameter of individual wires
   D = equivalent single-wire diameter
   n = number of strands in a cable

   And values of $\sqrt{n}$ are:

Strand Type	n	$\sqrt{n}$
2X	2	1.414
3X	3	1.732
4X	4	2.000
5X	5	2.236
6X	6	2.449
7X	7	2.646

   For example, if an equivalent single-wire diameter (D) of 49 mils is required, the corresponding wire size (d) would be for:

   2X d = 49/1.414 = 34.7 mils
   3X d = 49/1.732 = 28.3 mils
   4X d = 49/2.000 = 24.5 mils

   In some cases, it may be necessary to specify a stranded cable to satisfy your requirement, for example, 3X7X (21 wires).

4. With these facts and considering the particular application, select the wire which will provide adequate ductility and acceptable diameter.

Cut Pieces

Stranded wire can also be supplied as cut pieces, as follows:

Lengths	Tolerances
Up to 4.0 inches	±1/64"
4.01 to 18.0 inches	±1/32"
18.01" to 3 feet	±1/16"
Over 3 feet	±1/4"

How to Order or Request Quotation

Specify:

1. Amount: length or weight, e.g., 1,000 meters.
2. Material: state the number, diameter, and type for the regular strands, plus odd strand(s), core, or overwrap.

   Example: 3X30 VM + 1X40 Tophet A core.
3. Lay: Specify only if "left-handed." Specify twist only if loose, open, or other.
4. Coilability: state minimum-diameter mandrel to which the strand must conform, e.g., "must form around a 0.250" mandrel;" or, when applicable, state "No forming requirement."

   The table represents only some of the standard types currently in production. Please inquire concerning any additional configurations which you need for your specific application.

Packaging

Stranded wire is shipped as self-coils or, if specified, on wooden or plastic spools.

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