Callite Tungsten Corporation

TUNGSTEN MOLYBDENUM AND SPECIAL ALLOYS

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It is not intended to be a detailed engineering text on the multitudinous applications of tungsten and molybdenum products but merely an introduction to this phase of the metallurgical field.

Callite Tungsten Corporation Union City, New Jersey

BRANCH OFFICES: Chicago, Illinois · Cleveland, Ohio

CABLE ADDRESS: "Callites"

catalog number 156

contents

patents

Callite Tungsten products are manufactured under one or more of the following U. S. patents.

	1,866,634	2,018,073	2,120,562	2,284,288
1,701,541	1,874,575	2,044,853	2,202,108	2,317,205
1,788,243	1,877,431	2,084,349	2,207,380	2,319,331
1,828,493	1,891,050	2,090,946	2,214,742	2,325,092
1,842,103	1,922,497	2,107,122	2,222,669	2,373,405
1,853,568	1,922,498	2,114,426	2,244,070	U. S. Design
1,858,244	1,989,236	2,116,977	2,276,048	128,049
1,858,300	1,991,510	2,120,561	2,281,446	

introduction

With this catalog we introduce you to the Callite family of metallurgical products. We want you to be thoroughly familiar with this family and the place its highly specialized members have won in their various fields. During preparation, we were guided by a determination to make this a helpful book for you, rather than just a "catalog" of our products. Accordingly, in addition to listing our products, we've included — an outline of the manufacturing processes behind each product — major applications — data on chemical and physical properties — and numerous tables and graphs. The contents have been sectionalized to permit ready reference to any one of our divergent products. However, it should be borne in mind that such a division is not absolute, inasmuch as one section frequently bears an interlocking relationship to some other section. Thus, the tungsten and molybdenum sections are vital complements to those portions devoted to electronic tubes and incandescent lamps. We hope you will find this catalog of assistance in your daily work. Comments and suggestions will be gratefully received, and will be used to improve future editions. Finally, we want you to remember that the Callite Research and Engineering Staffs are ever ready to cooperate with you in the solution of any problem. Callite Tungsten Corporation, Union City, New Jersey, U. S. A.

credits

Tungsten ore as photographed page 8, courtesy of Dr. K. C. Li, Wah Chang Trading Corporation.

Molybdenite photograph page 40, courtesy of the American Museum of Natural History.

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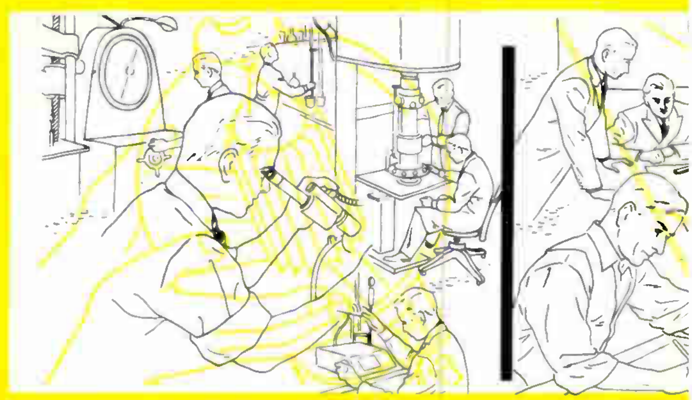
Callite research and engineering

Here at Callite, Research and Engineering always work hand in hand with Production. For the successful manufacture of all of our specialized products it could not be otherwise. Engineering maintains constant supervision during manufacturing operations to assure the clos-



est adherence to your specifications that is commercially possible. This vigilance includes numerous tests from the raw materials to the finished product. In the case of wire, for example, 49 separate tests are applied during production. These range from chemical analysis of the ore to microscopic examinations of grain structure and checks on the size, temper and finish of the final product. As an added safeguard, and insur-

ance for you, performance tests are then conducted under actual operating conditions. Research adapts new alloys and new products to the widening needs of industry, improves production methods to better our products and their performance, and develops new control tools and procedures. The experience and ability of our Engineering and Research staffs can be a powerful aid in meeting your most exacting demands and requirements.

If you have a difficult problem, call Callite.

tungsten

Tungsten has become one of the most important metals of our age. Although discovered in 1783, more than a century passed before practical processes were developed to obtain high-purity tungsten from the ores in which it is found.

Originally, the name, "Tung sten" (Swedish for heavy stone), was given to a very heavy mineral, calcium tungstate, which is now known as scheelite—after C. W. Scheele, who discovered it in 1765. From this mineral Scheele extracted a new acid which he called "tungstic acid". However, it was not until 1783 that the element "Tungsten" was isolated from this tungstic acid by the Spanish D'Elhujar brothers who worked with Scheele. And they called the new metal "wolfram". The origin of the word "wolfram" has had many explanations. The word itself may be of German origin "wolf" meaning "beast of prey" and "ram", "froth". The explanation seems to tie in with the experiences of the early tin miners of Cornwall, England. These miners found that tin ores containing iron-manganese-tungstate, (now known as "wolframite") were difficult to reduce and hence, the mineral had the attributes of a "wolf swallowing the tin".

"W", the first letter of "wolfram" has, therefore, become the symbol for tungsten in the international language of chemists. Besides scheelite, tungsten later was discovered in a number of other minerals—mainly wolframite, ferberite and hubnerite. While one or more of these minerals is found in almost every country in the world, the principal sources of present-day high-grade ores are China, Australia, South America and the United States.

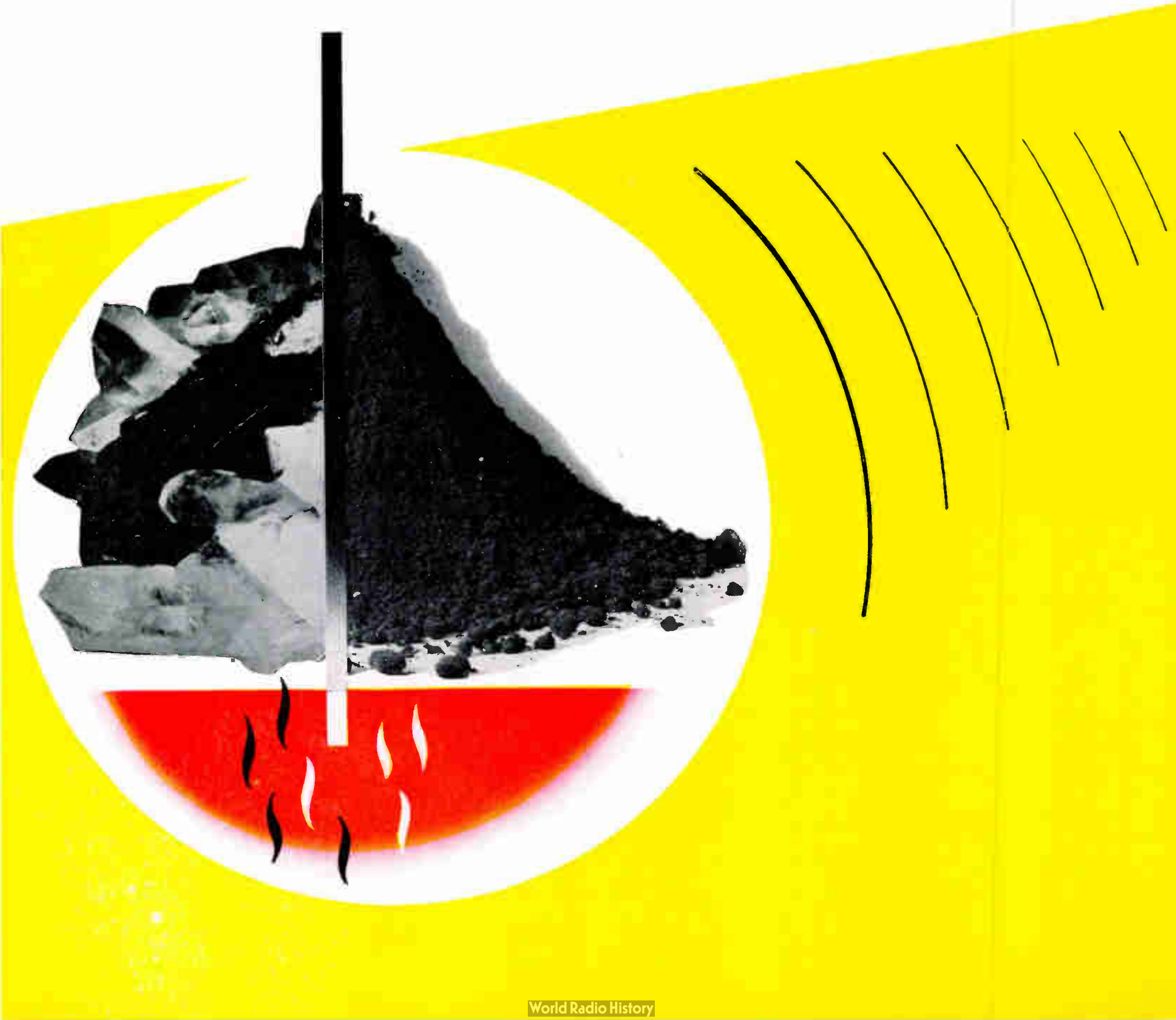
Photograph on facing page shows wolframite ore embedded in quartz.

extracting tungsten from the ore

Tungsten is never found in a pure metallic state. Its ores are tungstates in which the tungsten oxide is combined with the oxides of calcium, iron or manganese. A lengthy and tedious process is necessary to extract tungsten of high purity from these ores.

The Callite process of producing ductile tungsten involves fine-grinding of the ore, alkaline fusion, extraction of the soluble sodium tungstate, repeated crystallization of tungstate crystals, subsequent precipitation of the pure tungstic acid, and the reduction of the purified tungstic oxide in hydrogen to give a finely-divided, pure metallic tungsten powder.

Throughout these complex operations, exact control of such factors as time, temperature, concentration, and purity determines to a large extent the quality of tungsten metal obtained.



grading of tungsten metal powder

FIG. 1

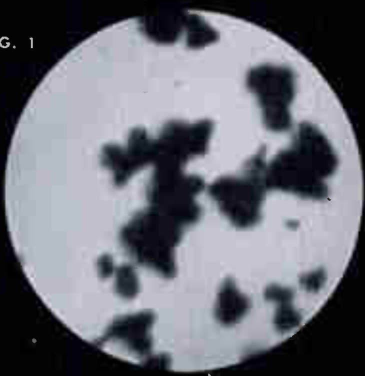


FIG. 2

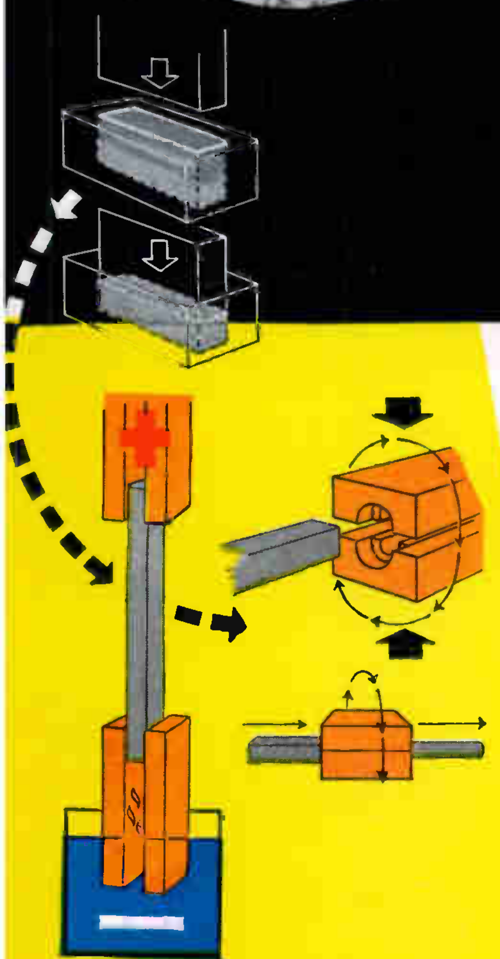
FIG. 3

FIG. 4

The particle size of tungsten metal powder ranges from ½ to 60 microns or more. As the physical and mechanical properties of metallic tungsten products depend upon the particle size and purity of the powder from which they are made, Callite Tungsten powder for the manufacture of tungsten rod and wire is a selected blend of particles between ½ and 30 microns in diameter.

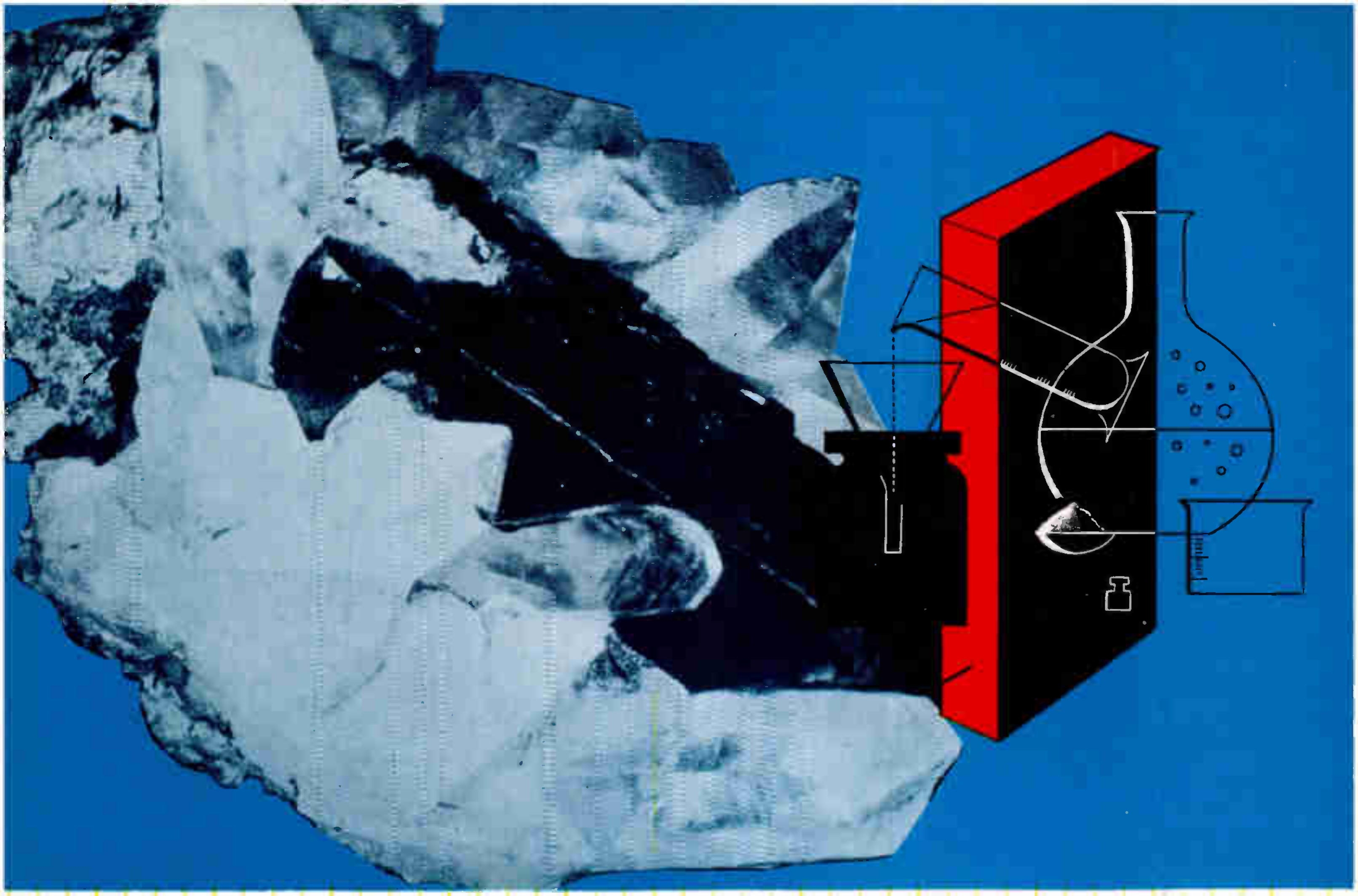
Careful grading and blending is one of the steps responsible for maintaining the quality, uniformity and other desirable properties of Callite Tungsten products.

1—COARSE TUNGSTEN POWDER 1000X • 2—FINE TUNGSTEN POWDER 1000X • 3—TREATED TUNGSTEN (FINE) SLUG 1000X • 4—TREATED TUNGSTEN (COARSE) SLUG 1000X



pressing, sintering and swaging

After grading, the tungsten powder is pressed under hydraulic pressure in a mould. The ingot, as pressed, is fragile and requires a presintering heat treatment in a hydrogen atmosphere to about 1000 degrees Centigrade, to facilitate handling. Next, in a special hydrogen-filled "bottle" the ingot, mounted between water-cooled electrodes, is heat-treated and fully sintered by the passage of an accurately controlled electric current. The fully treated ingots are then hot swaged into various sized rods as desired. This rod is then further swaged, drawn into wire, or otherwise worked to meet the many modern uses of tungsten and tungsten alloys.



chemical properties of tungsten

Tungsten is rather stable at room temperature, although it eventually loses its bright luster. When heated at low temperatures, a superficial layer of oxide is formed. At red heat, tungsten oxidizes to tungstic oxide, WO_3. In an atmosphere of oxygen, oxidation proceeds very rapidly. Tungsten is unaffected by water but can be oxdized to WO_3 by water vapor at red heat. In the presence of organic vapors such as carbon monoxide, carbon dioxide, methane, ethane, benzene, etc. and also when in contact with finely divided carbon, tungsten will form tungsten carbide at temperatures of about 1000° C.

REACTION OF TUNGSTEN WITH HALOGENS

Tungsten reacts with bromine and iodine vapor at red heat. The more active fluorine will react with tungsten at room temperatures. At temperature of 250° to 300° C., pure, dried chlorine forms tungsten hexachloride, but in the presence of air or moisture, tungstic oxychloride will form.

REACTION OF TUNGSTEN WITH SULPHUR

Tungsten will not react with sulphur at its melting point temperature. Tungsten even at low red heat, shows no appreciable reaction in hydrogen sulphide.

REACTION OF TUNGSTEN WITH NITROGEN

Tungsten, at red heat, does not react with nitrogen. At very high temperatures particularly in nitrogen filled lamps a nitride is formed.

REACTION OF TUNGSTEN WITH ACIDS

There is no reaction in dilute sulphuric acid, but concentrated sulphuric acid shows a slight reaction when hot. Hydrochloric acid of any concentration does not react with tungsten in either hot or cold solutions; the same holds true with hydrofluoric acid. Hot nitric acid slowly reacts with tungsten to form a superficial oxide. The same is true of aqua regia. A mixture of nitric acid and hydrofluoric acid will dissolve tungsten rapidly.

REACTION OF TUNGSTEN WITH ALKALIES

Hot, concentrated potassium or sodium hydroxide will tend to form only small amounts of potassium or sodium tungstates. Fused alkalies in the presence of oxidizing agents such as alkali nitrates, chlorates, or peroxides, will attack tungsten vigorously.

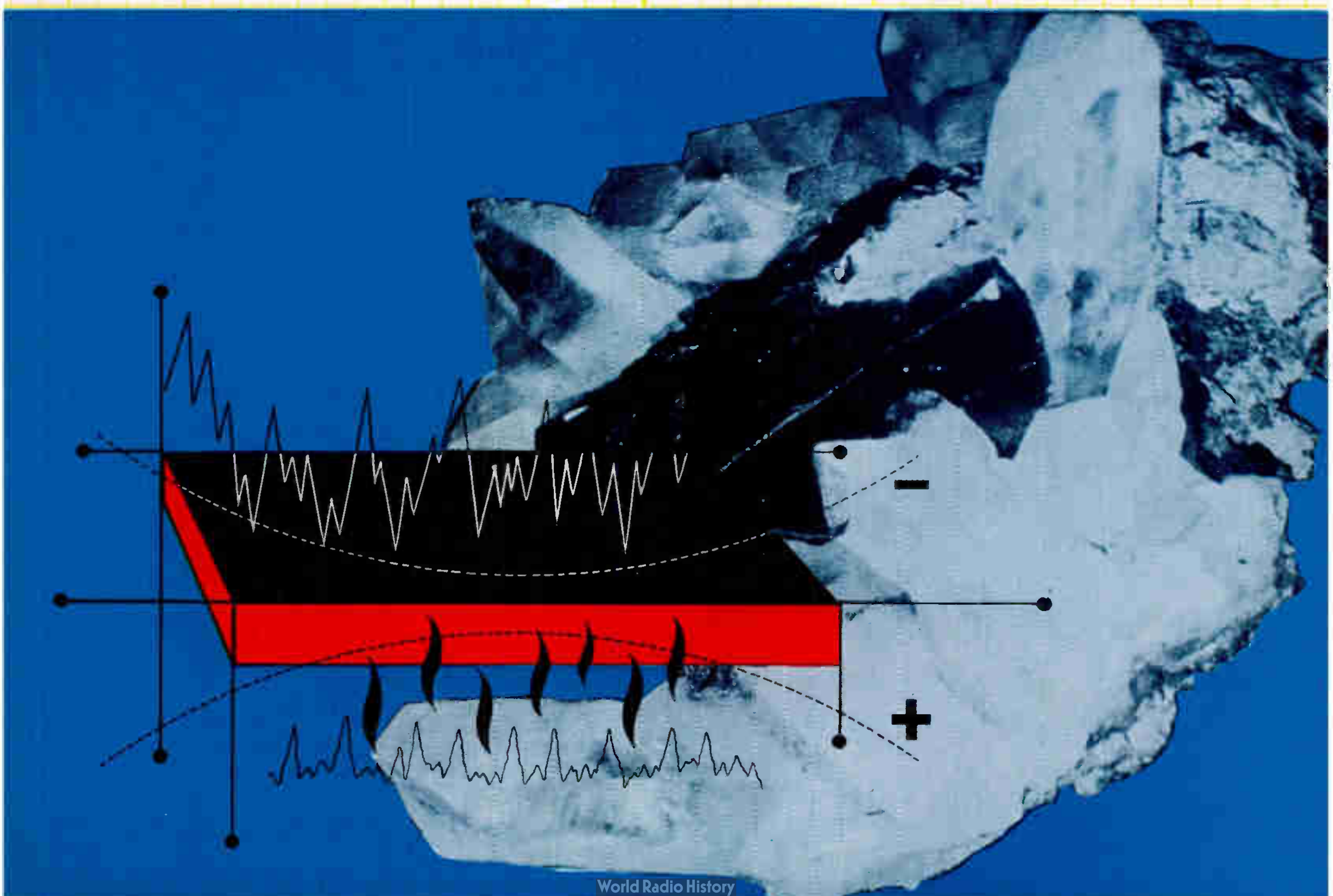
physical properties of tungsten

Tungsten has an atomic number of 74, has a body-centered cubic lattice equal to 3.160 Angstrom. There are four isotopes 182, 184 and 186, the percentage of abundance of each being 22.6, 17.2, 30.1. 30.0. respectively.

The atomic weight is usually accepted at 184. The atomic volume is 9.59 (based on atomic weight 184 and specific gravity of 19.2).

The density: presintered at about 1400°C is 10 to 12; fully sintered at about 3100°C is 16.9 to 17.2. Swaged from 17.2 to 19.2. Drawn 19.2 to 19.35. The melting point: 3400°C.

When pressed tungsten powder is sintered into a so-called "slug" or "ingot" at a temperature of approximately 3100° C, the resultant density is approximately 17.0 grams per cm^3. As the metal bar is swaged it increases rapidly in density. After a 75% reduction in area, the density usually will be 19.1. After further swaging and drawing the density increases up to a maximum of about 19.35 - the usually accepted value for drawn tungsten wire.



mechanical properties of drawn tungsten wires

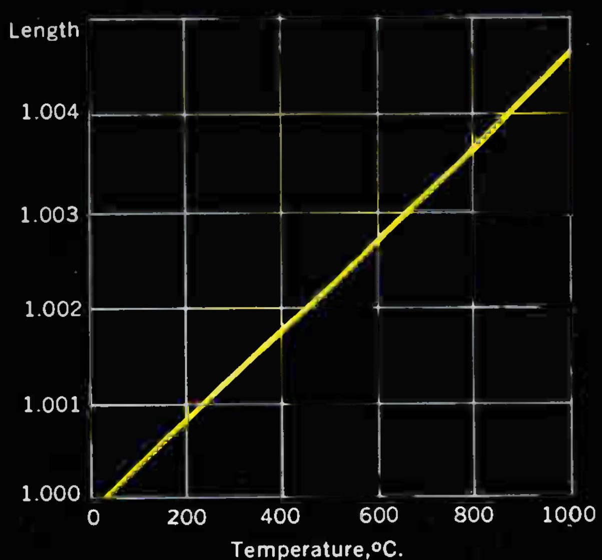
Cold working has an amazing effect upon the strength of the finer diameters of tungsten wire. The sintered bar has a tensile strength of less than 10 tons per square inch, whereas the finest wires drawn from this bar will show a tensile strength exceeding 300 tons per square inch. This remarkable increase in strength is shown in the accompanying table.

Wire Diameter		Tensile Strength		Modulus of Elasticity. Kg./mm.²	Modulus of Rigidity. Kg./mm.²
inches	mm-lcm	Kg./mm.²	Tons/in.²		
Sintered bar		13	8		
.19685	5	40	25		
.11811	3	75	48		
.07874	2	100	64		
.03937	1	140	89		13,000
.01969	0.5	185	118	—	15,200
.01181	0.3	220	140	9,000	16,000
.00591	0.15	270	172	26,000	16,800
.00394	0.10	300	190	31,500	17,200
.00197	0.05	345	220	33,200	17,800
.00118	0.03	385	245	34,000	18,400
.00079	0.02	425	270	—	—
.00059	0.015	470	300	—	—

thermal expansion of tungsten . . . .

As shown by the curve below, from 0 to 1000° C., the linear thermal expansion of tungsten is almost a straight-line function of the temperature. This curve shows the change in length for a tungsten rod 3 millimeters in diameter, which had previously been heated above the recrystalization temperature. From this curve, the following mean co-efficients of expansion were obtained:

20° to 580° C.—4.45 x 10^{-6}
600° to 1000° C.—5.20 x 10^{-6}



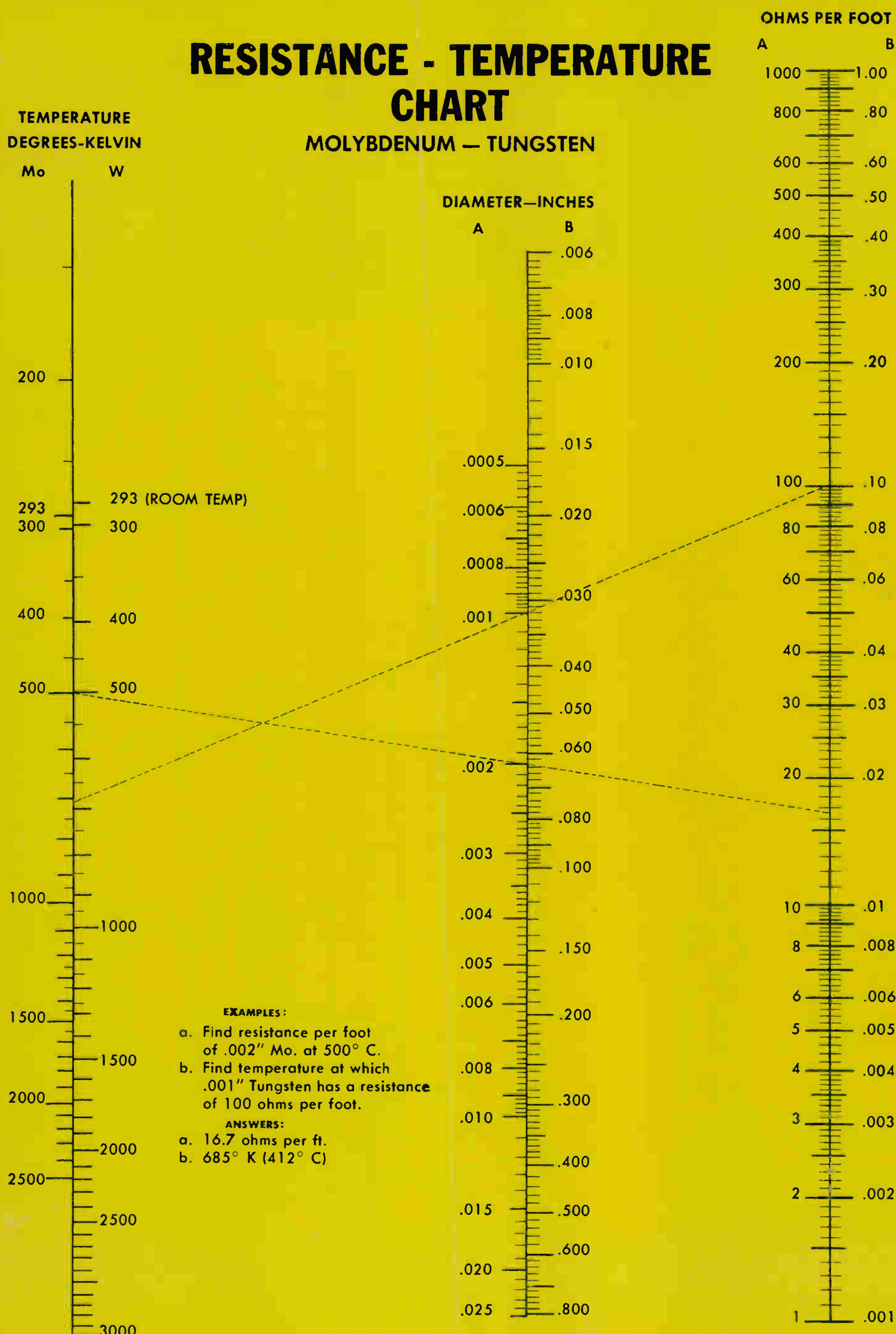
Thermal expansion of a tungsten rod 3 mm. diameter

electrical resistivity of tungsten . . . . .

The electrical resistivity of an annealed tungsten rod is 5.00 x 10^{-6} ohms per cubic centimeter at zero degree centigrade or 5.49 x 10^{-6} ohms per cubic centimeter at 20° C. If, however, the resistivity of worked tungsten wire is measured at various stages of the manufacturing process, several interesting phenomena are observed. Initially, the resistivity falls, corresponding to the increase in density produced by the first swaging operation. After, however, the resistivity increases as an exponential function of the diameter. The resistivity of tungsten wire also increases as the wire temperature increases.

RESISTANCE - TEMPERATURE CHART

MOLYBDENUM — TUNGSTEN



EXAMPLES:

a. Find resistance per foot of .002″ Mo. at 500° C.

b. Find temperature at which .001″ Tungsten has a resistance of 100 ohms per foot.

ANSWERS:

a. 16.7 ohms per ft.

b. 685° K (412° C)

properties of tungsten

1 TEMPER-ATURE °K	2 Total Radiation W/cm²	3 Specific Resistance ohms — cm	4 Hot Resistance Ratio R_t/R_{293}	5 Heat Conductivity W/cm Grad
273		5.00×10^{-6}	0.91	
293		5.49	1.00	
300	3.1×10^{-5}	5.65	1.03	
400	2.0×10^{-3}	8.065	1.467	
500	9.7×10^{-3}	10.56	1.924	
600	3.0×10^{-2}	13.23	2.41	
700	7.6×10^{-2}	16.09	2.93	
800	0.169	19.00	3.46	
900	0.322	21.94	4.00	
1000	0.602	24.93	4.54	0.84
1100	1.027	27.94	5.08	0.87
1200	1.66	30.98	5.65	0.90
1300	2.57	34.08	6.22	0.93
1400	3.83	37.19	6.78	0.96
1500	5.52	40.36	7.36	0.99
1600	7.74	43.55	7.93	1.02
1700	10.62	46.78	8.52	1.04
1800	14.19	50.05	9.12	1.07
1900	18.64	53.35	9.72	1.09
2000	24.04	56.67	10.33	1.11
2100	30.5	60.06	10.93	1.13
2200	38.2	63.48	11.57	1.15
2300	47.2	66.91	12.19	1.17
2400	57.7	70.39	12.83	1.19
2500	69.8	73.91	13.47	1.21
2600	83.8	77.49	14.12	$\left[\frac{W}{cm\ Grad}\right] = 0.239 \left[\frac{cal}{cm\ sec\ Grad}\right]$
2700	99.6	81.04	14.76	
2800	117.6	84.70	15.43	
2900	137.8	88.33	16.10	
3000	160.5	92.04	16.77	
3100	185.8	95.76	17.46	
3200	214.0	99.54	18.15	
3300	245.4	103.3	18.83	
3400	280.0	107.2	19.53	
3500	318.0	111.1	20.24	
3600	360.0	115.0	20.95	
3655	382.6	117.1	21.34	
	Jones	and	Langmuir	Worthing

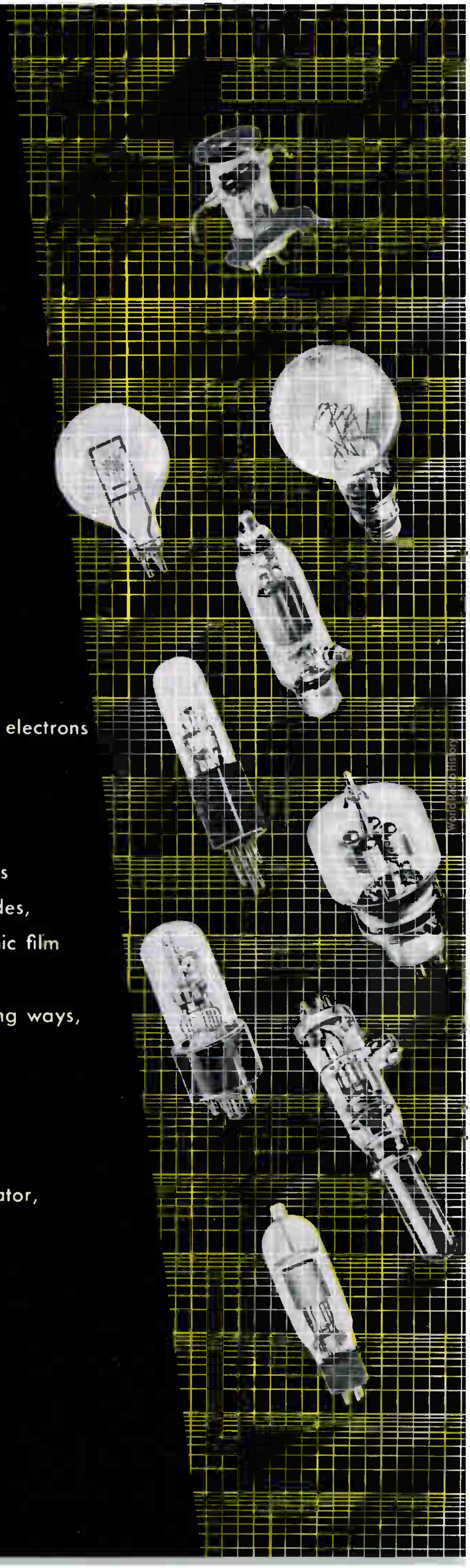
6 Thermal Expansion $\frac{l_t - l_{293}}{l_{293}}$	7 Rate of Evaporation g/cm² sec	8 Vapor Pressure dynes/cm²	9 Light Intensity lumens/watt	10 Electron Emission amps/cm²	11 Electron Work Function amps/watt	12 Temperature °C
						0
						20
						27
0.5×10^{-3}						127
1.0						227
1.4						327
1.8						427
2.3						527
2.8						627
3.2		1.98×10^{-29}	6.93×10^{-4}	1.07×10^{-15}	1.77×10^{-15}	727
3.6		1.22×10^{-25}	3.44×10^{-3}	1.52×10^{-13}	1.48×10^{-13}	827
4.1		1.87×10^{-22}	1.26×10^{-2}	9.73×10^{-12}	5.88×10^{-12}	927
4.6		8.18×10^{-20}	3.55×10^{-2}	3.21×10^{-10}	1.24×10^{-10}	1027
5.2		1.62×10^{-17}	8.99×10^{-2}	6.62×10^{-9}	1.73×10^{-9}	1127
5.7	1.69×10^{-22}	1.54×10^{-15}	0.199	9.14×10^{-8}	1.65×10^{-8}	1227
6.3	1.69×10^{-20}	8.43×10^{-14}	0.395	9.27×10^{-7}	1.20×10^{-7}	1327
6.9	9.90×10^{-19}	2.82×10^{-12}	0.724	7.08×10^{-6}	6.66×10^{-7}	1427
7.5	3.61×10^{-17}	6.31×10^{-11}	1.19	4.47×10^{-5}	3.15×10^{-6}	1527
8.1	8.83×10^{-16}	1.01×10^{-9}	1.94	2.28×10^{-4}	1.22×10^{-5}	1627
8.8	1.47×10^{-14}	1.33×10^{-8}	2.84	1.00×10^{-3}	4.18×10^{-5}	1727
9.4	2.01×10^{-13}	1.28×10^{-7}	4.08	3.93×10^{-3}	1.28×10^{-4}	1827
10.1	2.09×10^{-12}	9.88×10^{-7}	5.52	1.33×10^{-2}	3.48×10^{-4}	1927
10.8	1.82×10^{-11}	6.47×10^{-6}	7.24	4.07×10^{-2}	8.75×10^{-4}	2027
11.6	1.28×10^{-10}	3.52×10^{-5}	9.39	0.116	2.01×10^{-3}	2127
12.4	7.58×10^{-10}	1.71×10^{-4}	11.72	0.298	4.26×10^{-3}	2227
13.2	3.92×10^{-9}	7.24×10^{-4}	14.34	0.716	8.55×10^{-3}	2327
14.0	1.78×10^{-8}	2.86×10^{-3}	17.60	1.631	1.64×10^{-3}	2427
14.8	7.40×10^{-8}	9.84×10^{-3}	20.53	3.54	3.01×10^{-2}	2527
15.6	2.76×10^{-7}	3.00×10^{-2}	23.64	7.31	5.31×10^{-2}	2627
16.4	9.47×10^{-7}	9.20×10^{-2}	27.25	14.15	8.82×10^{-2}	2727
17.2	3.00×10^{-6}	0.250	30.95	26.44	0.142	2827
18.1	8.85×10^{-6}	0.613	34.70	47.84	0.224	2927
18.9	2.44×10^{-5}	1.51	38.90	84.45	0.344	3027
19.8	6.35×10^{-5}	3.41	43.20	142.1	0.507	3127
20.7		7.52	47.15	233.2	0.734	3227
21.6		15.3	50.70	373.5	1.04	3327
22.1		23.3	53.10	479.9	1.25	3382
Smithells	Zwikker	Jones and Langmuir				

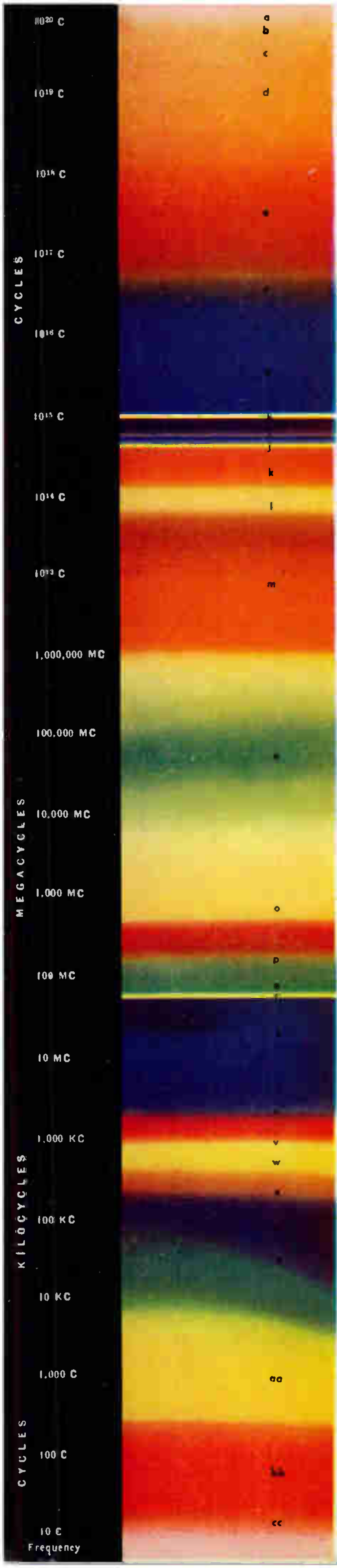
callite tungsten components cover the electronic spectrum

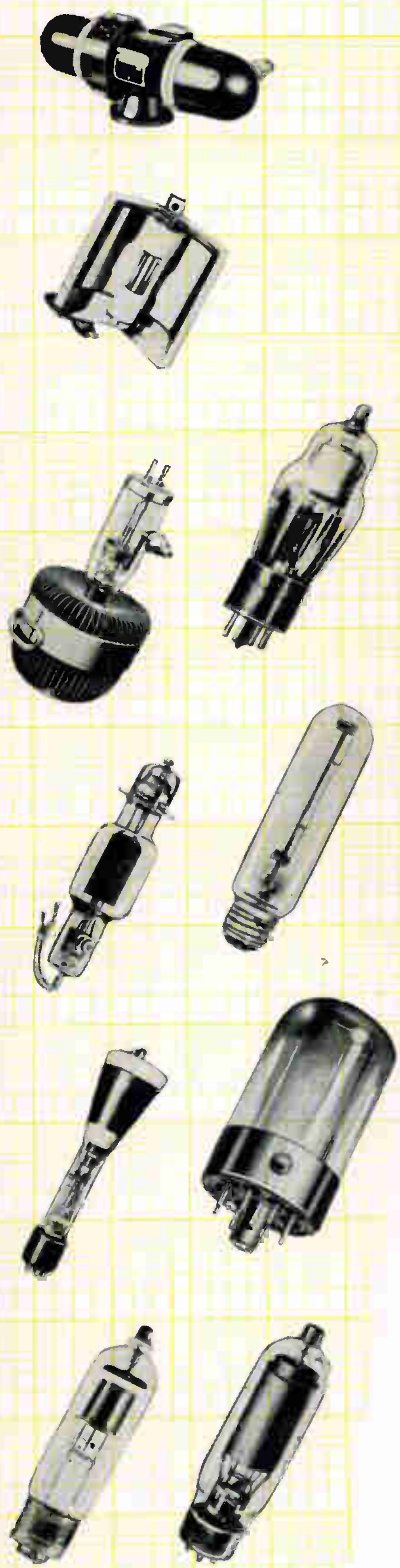
The discovery of the "Edison effect" in 1883 might be said to mark the beginning of the modern electronic tube. Today, the emission of electrons by hot bodies as observed and noted by Edison has become the foundation of ELECTRONICS.

Three types of thermionic emitters, or cathodes, are used in modern electronic tubes — filaments of pure metals, oxide-coated cathodes, and metal filaments with an absorbed monatomic film of an electro-positive metal These may appear in various shapes and may be heated in differing ways, but all are based upon the fact that a metal when heated to a sufficiently high temperature will give off a stream of electrons.

When properly utilized, these electrons enable the tube to function as a rectifier, oscillator, amplifier, modulator, or detector.

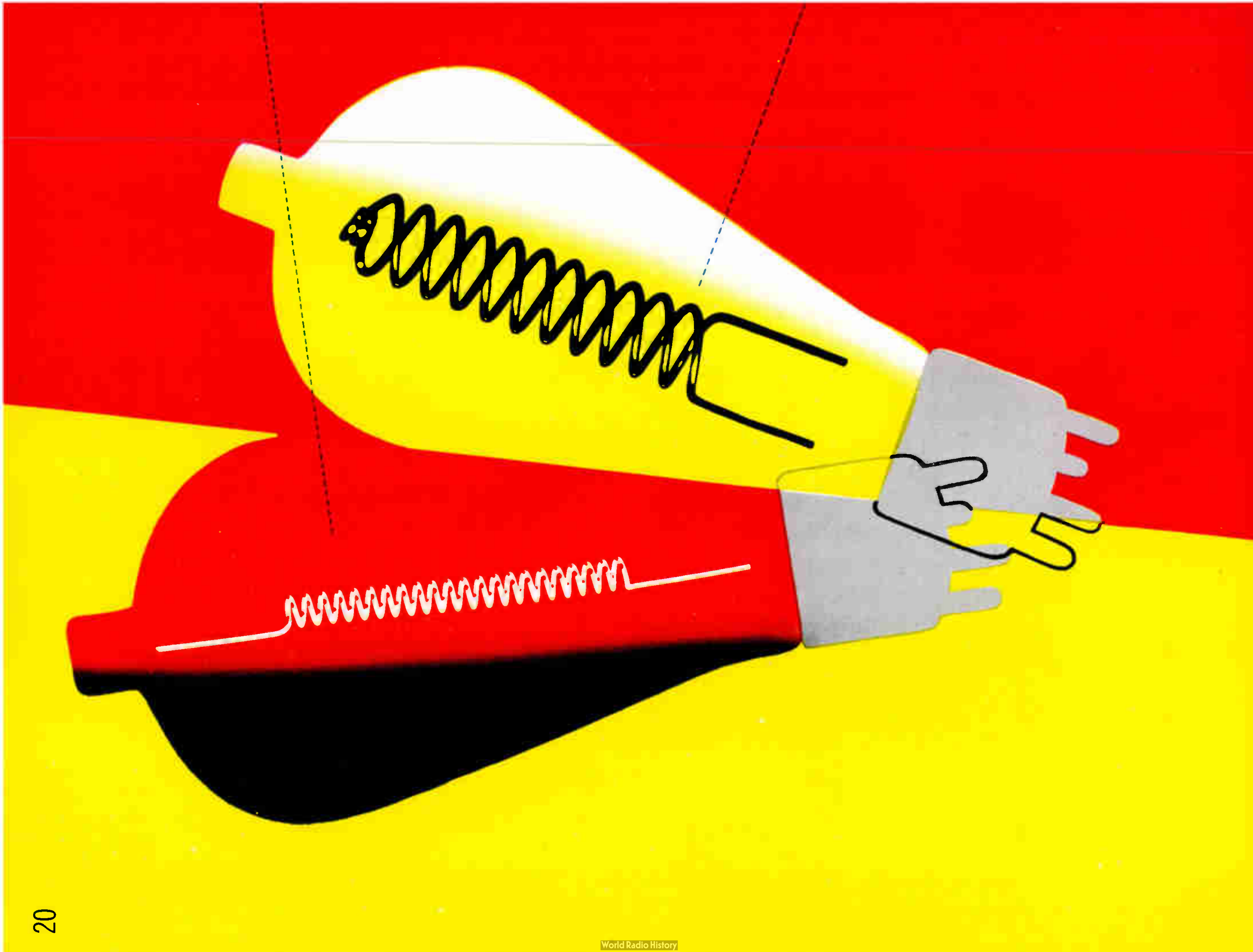




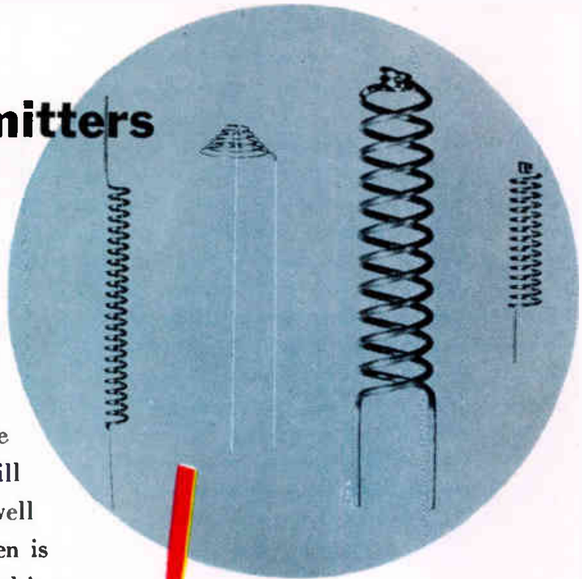


callite tungsten components can be found in finished products operating in every one of the following frequency classifications

a Million-Volt X-Rays
b Industrial X-Rays
c Hard X-Rays 100,000 Volts
d Diagnostic X-Rays 10,000 Volts
e Industrial X-Rays
f Soft X-Rays
g Little-Known Region
h Germicidal Rays
i Ultra-Violet
j Light
k Infra-Red Drying
l Radiant Heat
m Little-Known Infra-Red Frequencies
n Little-Known Radio Frequencies
o Developmental Region
p Radio and Television Relay Transmission
q Television
r FM Radio
s Therapeutic Oscillators
t Short-Wave Communication Visual and Aural
u Electronic Heating
v Radio Broadcasting
w Electronic Heating
x Sea and Air Navigational Aids
y Supersonics
z Power-Line Carrier-Current Applications
aa Audio Frequencies
bb Power Transmission and Distribution
cc Subsonic



pure tungsten emitters



When heated to a sufficiently high temperature, all metals will emit electrons in accordance with Richardson's classic equation. However, at the same temperature, every metal does not emit electrons at the same rate. The rate of emission among other factors depends upon the inherent characteristics of the metal used. For use as filaments of pure metal, only those metals are practical which will emit a copious stream of electrons at temperatures well below their melting and vaporizing points. Tungsten is ideal for use as a filament because of its high melting point and low rate of evaporation.

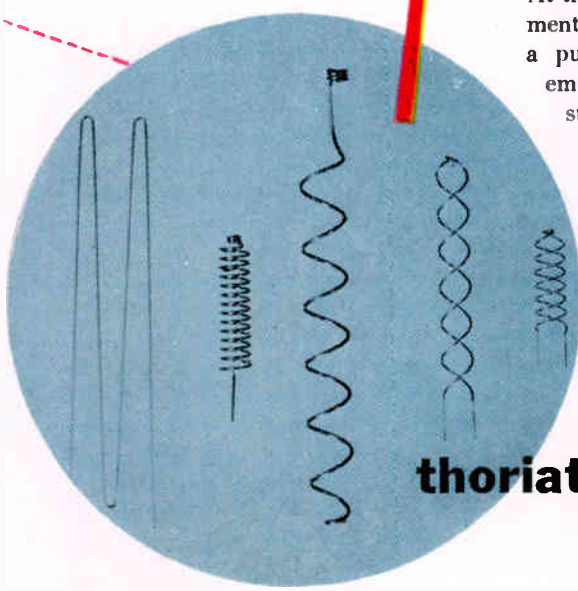
For any pure metal filament, an operating temperature must be chosen that is as high as is consistent with reasonable life. The effective life of a filament is determined by the rate of evaporation and the resultant reduction in cross section. Following the general practice in the industry, 2,000 hours is the basis of life determination. If the reduction in cross section is limited to 10%, the temperature of operation is that temperature which gives this decrease in 2,000 hours.

Evaporation rate is a function of both temperature and surface area, while permissible life is dependent upon the volume of the filament. Consequently, the proper operating temperature varies with filaments of different sizes. Pure Tungsten emitters are used in the large high voltage power tubes, because experience has shown that this type of emitter has given consistently longer life.

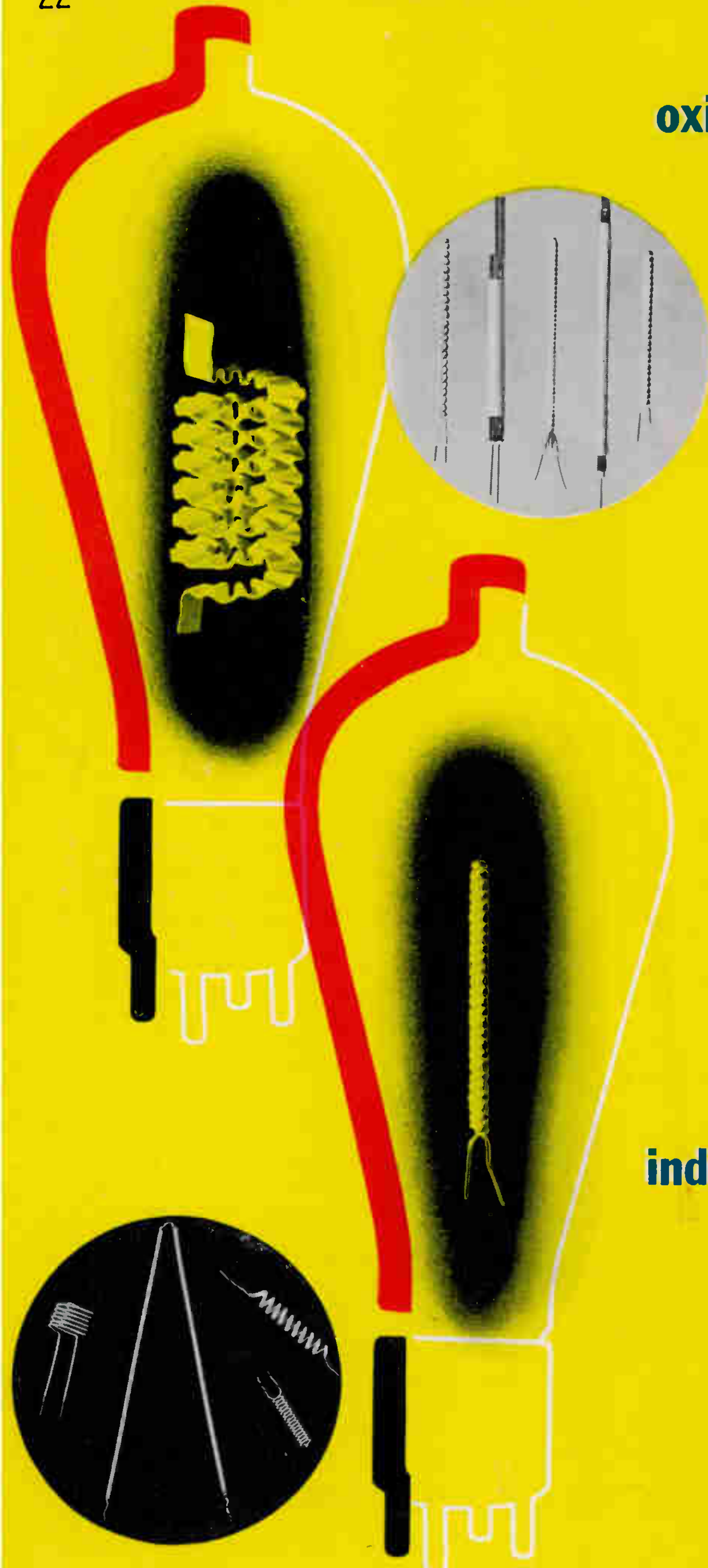
In 1914, Langmuir discovered that thoria additions could tremendously increase the thermionic emission of tungsten filaments. Subsequent investigation showed that metallic thorium (produced by the reduction of the admixed thoria at high temperatures) gradually diffuses to the surface of the filament under proper conditions of temperature and vacuum, to form an active layer, one molecule thick.

The presence of these monotomic layers of thorium atoms on the surface of the tungsten reduces the work function to a very marked degree. Thoriated tungsten filaments are usually activated, which process consists in first flashing the filament for a short time at a high temperature (approximately 2,600° to 2,700° K). This high temperature treatment cleans the surface of the filament and also serves to reduce some of the thoria to thorium on the surface. The temperature is then lowered to approximately 2,200° K to allow metallic thorium to diffuse to the surface. The proper operating temperature for a thoriated filament is approximately 1,900° K at which temperature the evaporation of thorium from the surface is negligible.

At this operating temperature, the emission from the filament will be from 6 to 8 times the electron emission of a pure tungsten filament operating at 2,400° K. The emission reaches its maximum value when the entire surface of the filament is covered with a layer of thorium atoms. In the larger diameters, the thoriated wire is usually carbonized; this consists of flashing the filament in an atmosphere of benzene, naphthalene, or acetylene. This carbonizing treatment produces a thin surface film of tungsten carbide, which reduces still further the rate of thorium evaporation and therefore permits higher operating temperatures, resulting in increased emission efficiencies.



thoriated tungsten emitters



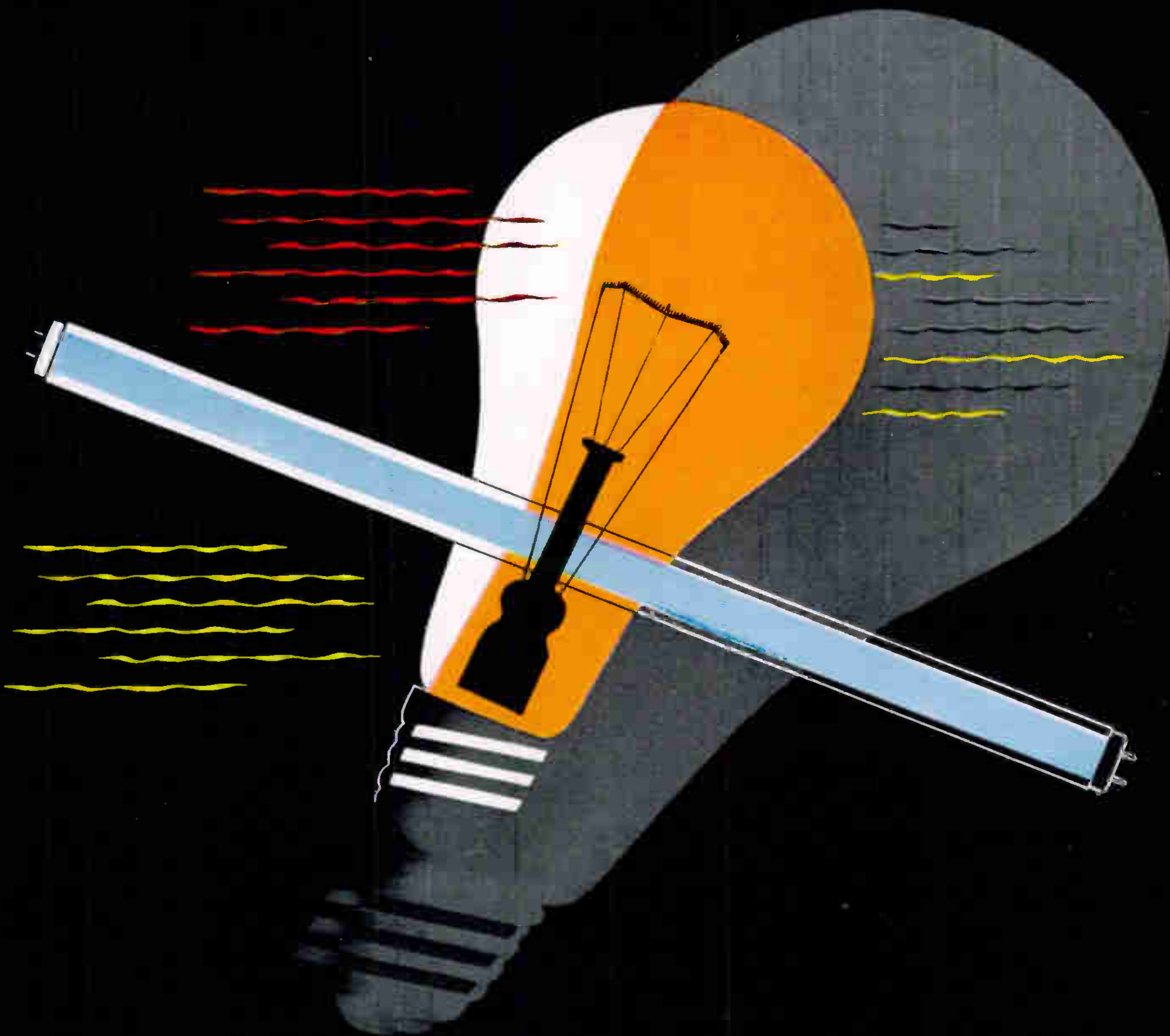
oxide-coated cathodes

Oxide-coated cathodes developed from the discovery of Wehnelt in 1904, that a coating of certain oxides on a metal core gave a copious stream of electrons, even at comparatively low temperatures. Various metals and alloys are now used for the core metal, such as pure nickel and various nickel alloys, in place of the more expensive platinum and platinum-iridum bases used by Wehnelt and subsequent investigators. For the coating of modern oxide-coated emitters, only barium and strontium generally are used. It is generally believed that the emission of oxide-coated cathodes is a case of pure thermionic emission from the particles of the reduced metallic portions of the oxide. The high emission obtained with this type of cathode at low temperatures can be attributed to the low work function of these metals and to the effect of single atomic layers, which aid in the escape of electrons. Oxide-coated cathodes usually operate at a temperature of approximately 1200° K. Activation of the finished oxide coated cathode consists of a thorough conversion of the carbonates to the oxides during the pumping process.

indirect heated cathodes

Indirect heated cathodes consist of a nickel sleeve carrying the oxide coated emission on the outer surface. On the inside of the sleeve is some form of a tungsten heater, insulated with a coating of pure aluminum oxide. These heaters may be in the shape of folded filaments, continuous coils, double helical coils or flat spirals.

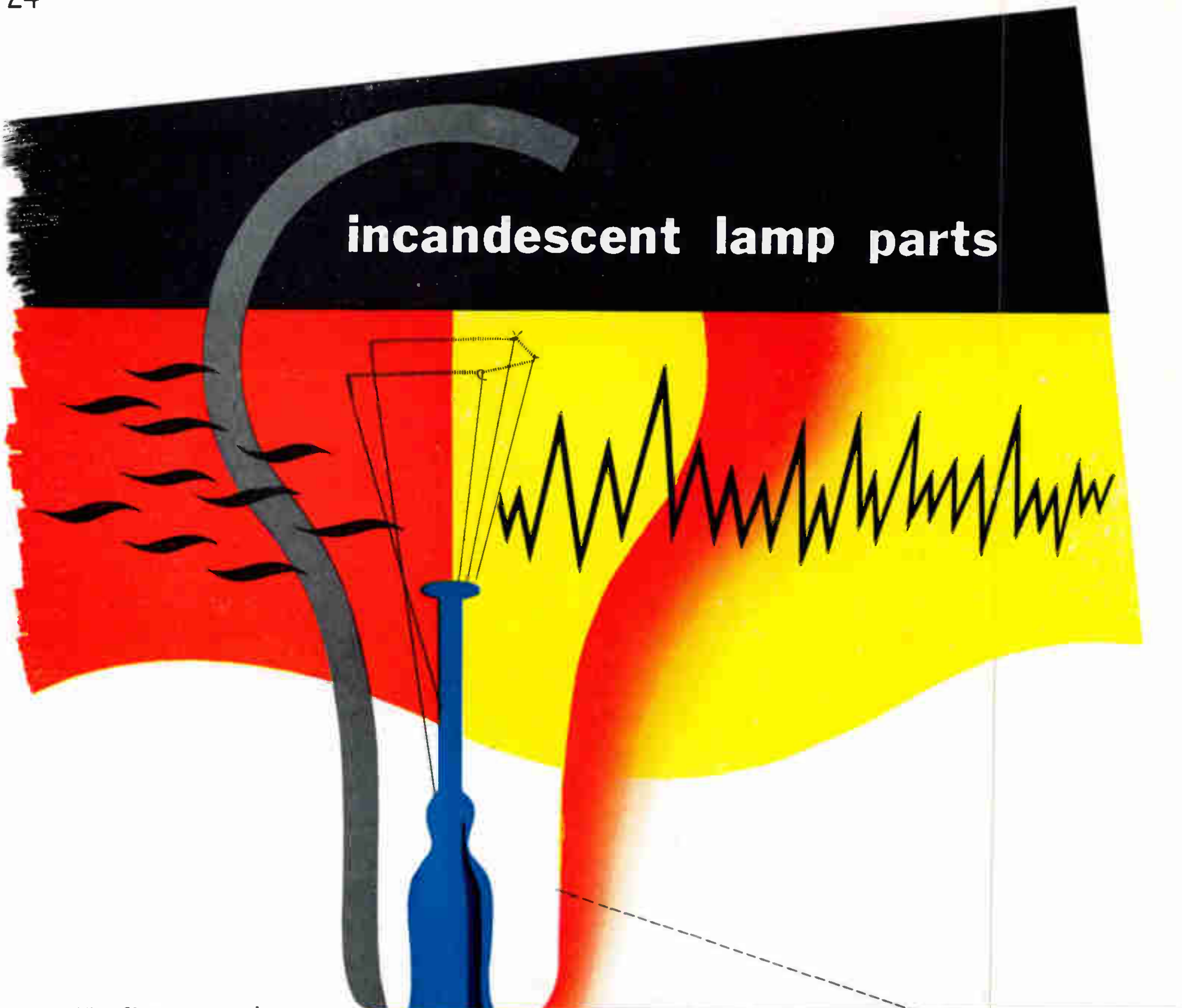
incandescent lamps and fluorescent lamps



Incandescent lamps using ductile Tungsten filaments were first produced in the year of 1910. These lamps had an efficiency of approximately 10 lumens per watt. Since that time many vast improvements have been made both in the methods of lamp making, the equipment used and also in the quality of the Tungsten wire available. Today, standard 500 watt household lamps are available having an efficiency as high as 22 lumens per watt and special purpose lamps with efficiencies as high as 35 lumens per watt. This has been a wonderful achievement considering the fact that approximately 6 per cent of the electrical input is converted into visible light for the smaller lamp and only 12 per cent for the larger high efficiency lamps.

Tungsten at the present time, is the most suitable of all metals used as filament in incandescent lamps. This is due to its extremely high melting point (3380° C), its low rate of vaporization at the operating temperatures encountered in various types of lamps ranging from 2000° C to 3100° C. Other reasons include the high tensile strength and ductility which permits the drawing of Tungsten into extremely fine wires so necessary for the lower wattage lamps. The design and performance of a lamp centers about a satisfactory control of the conditions under which its filament operates.

incandescent lamp parts



The filament must be supported in such a manner that there is a minimum heat loss to the supports and a minimum transmission of vibration or shock from the supports to the filaments. As Tungsten would rapidly oxidize in air at elevated temperatures, the lamp filaments must operate either in a high vacuum or in an atmosphere of inert gas such as nitrogen or nitrogen argon mixtures, specially purified for this purpose.

After an acceptable lamp design has been developed, the selection of tungsten wire becomes important. To be suitable for use as a lamp filament, tungsten wire should have these properties

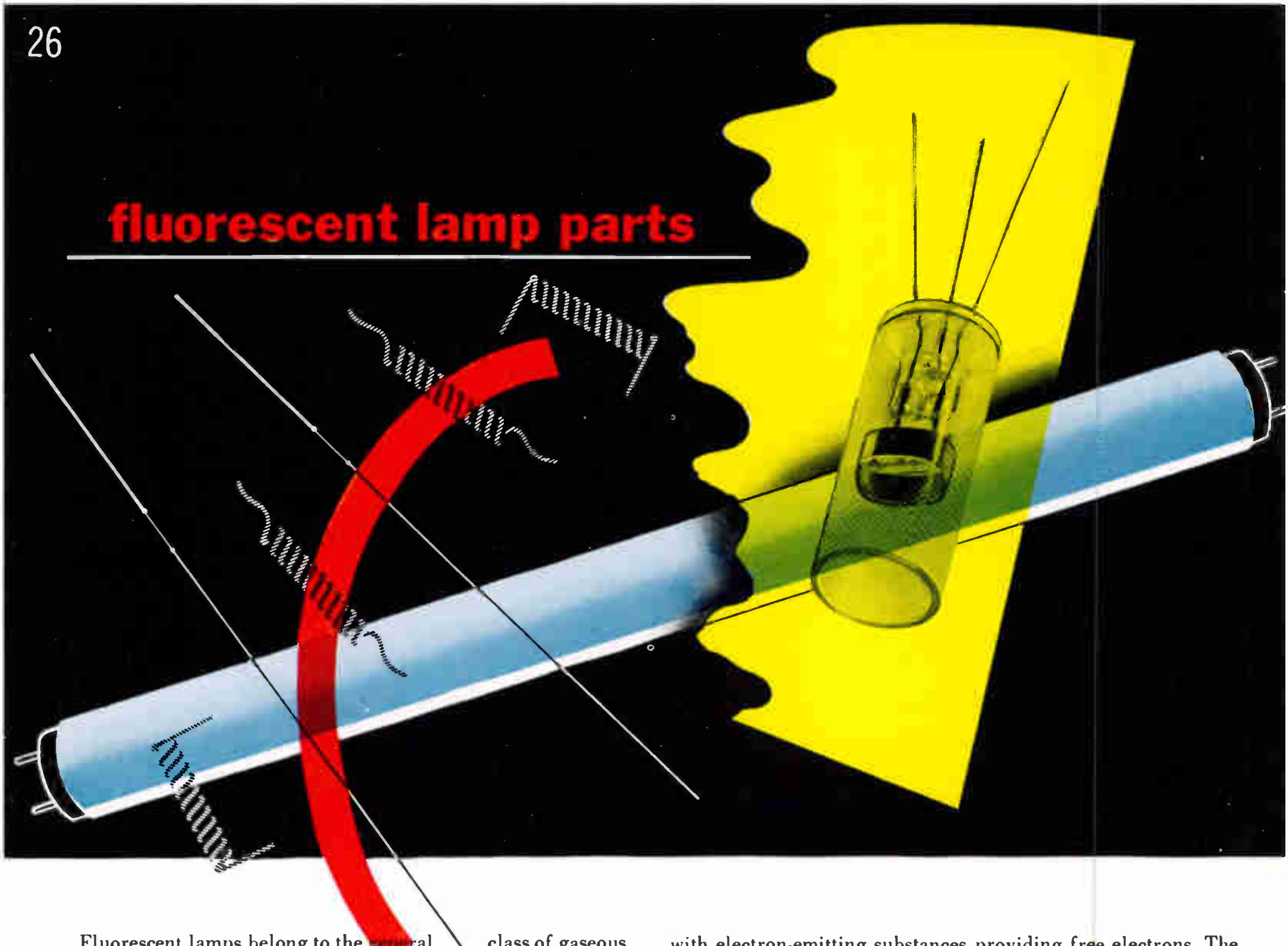
Crystal structure and the degree of purity of the tungsten filament influence the rate of evaporation, its tendency to off-set, its resistance to sag, and its brittleness after many hours of use. Since evaporation of the metal takes places chiefly from the crystal boundaries, the crystals should be large with clean boundaries free from undesirable impurities or aggregates of smaller crystals. For maximum resistance to sagging or fracture at slight mechanical shock, the crystals should be overlapping and interlocking. Such a structure is obtained by the introduction of critical amounts of controlling ingredients and their distribution throughout the metal early in the manufacturing process by a very high temperature treatment which eliminates all but a trace of the impurity, which in the flashing of the lamp will give the desired crystal structure.

During the life of a lamp the filament material vaporizes thereby causing a change in its diameter. All portions of the filament do not operate at a uniform temperature, hence, all parts of the filament are not subjected to the same deteriorating influences. Those portions which operate at higher temperatures known as "hot spots" will burn out sooner. If the surface conditions of the Tungsten filaments are not uniform or if the wire varies in its diameter "hot spots" will result. "Hot spots" can also be caused by non-uniformly wound coils, or coils that distort in the lamp when first flashed.

Non-uniformly wound coils may result from improper adjustment of the coil winding machine and other conditions which will give irregular turns per inch, or by resistance to coiling offered by the wire itself. This characteristic of wires which might be termed "hardness" is controlled by proper particle size in the early stages of metal manufacture by suitable heat treatment through all subsequent processes. To obtain maximum efficiency and life from the tungsten filament used, precise control must be maintained throughout each step of manufacture.

RETENTION OF ORIGINAL SHAPE No sagging at high temperatures because of its own weight. **SHOCK RESISTANCE** — No brittleness, and sufficient strength after many hours of operation to withstand the ordinary shocks and vibrations encountered during use. **LONG OPERATING LIFE** — No deterioration through excessive metal evaporation or crystal offsetting.

fluorescent lamp parts



Fluorescent lamps belong to the general class of gaseous discharge lamps. Essentially, they consist of a tubular bulb having an electrode of a special design sealed at each end. The bulb usually contains a low pressure filling of a rare gas.

When sufficiently high voltage is applied to these electrodes, a luminous discharge will occur between them within the tube. Although this discharge may take place in a vacuum, the presence of a small amount of carrier gas or metallic vapor, lowers resistance to the flow of current, thereby allowing the discharge to take place at much lower voltages. The gases used include neon, argon, helium, and to a lesser degree, Krypton and Xenon. Metallic vapors used are mercury, zinc, cadmium and sodium. Combinations of mercury-vapor and rare gas mixtures have been used extensively for many years in making the gaseous discharge tubes known as "neon signs."

The collision of free electrons with the gas or vapor molecules results in luminosity. On impact, the electron gives up all or part of its kinetic energy to the atom, disturbing the normal positions of the electrons within the atom. If the energy of the impacting electron is sufficiently high, the atom will lose an electron. Light is produced when the excited atom gives up its energy and returns to its normal state.

The current in a gaseous discharge lamp is carried by and through the gas column from an electrode on one side of the tubular bulb to the electrode on the other end. For these electrodes, only metals having a low "sputtering factor" have proved successful. Frequently, the metal electrodes are coated with electron-emitting substances providing free electrons. The ease with which the electrons are given off depends on the operating temperature. Hot cathodes are more emissive than cold, require a lower voltage to start the discharge, and also have a lower operating voltage. Neon signs are typical of cold cathode discharge lamps.

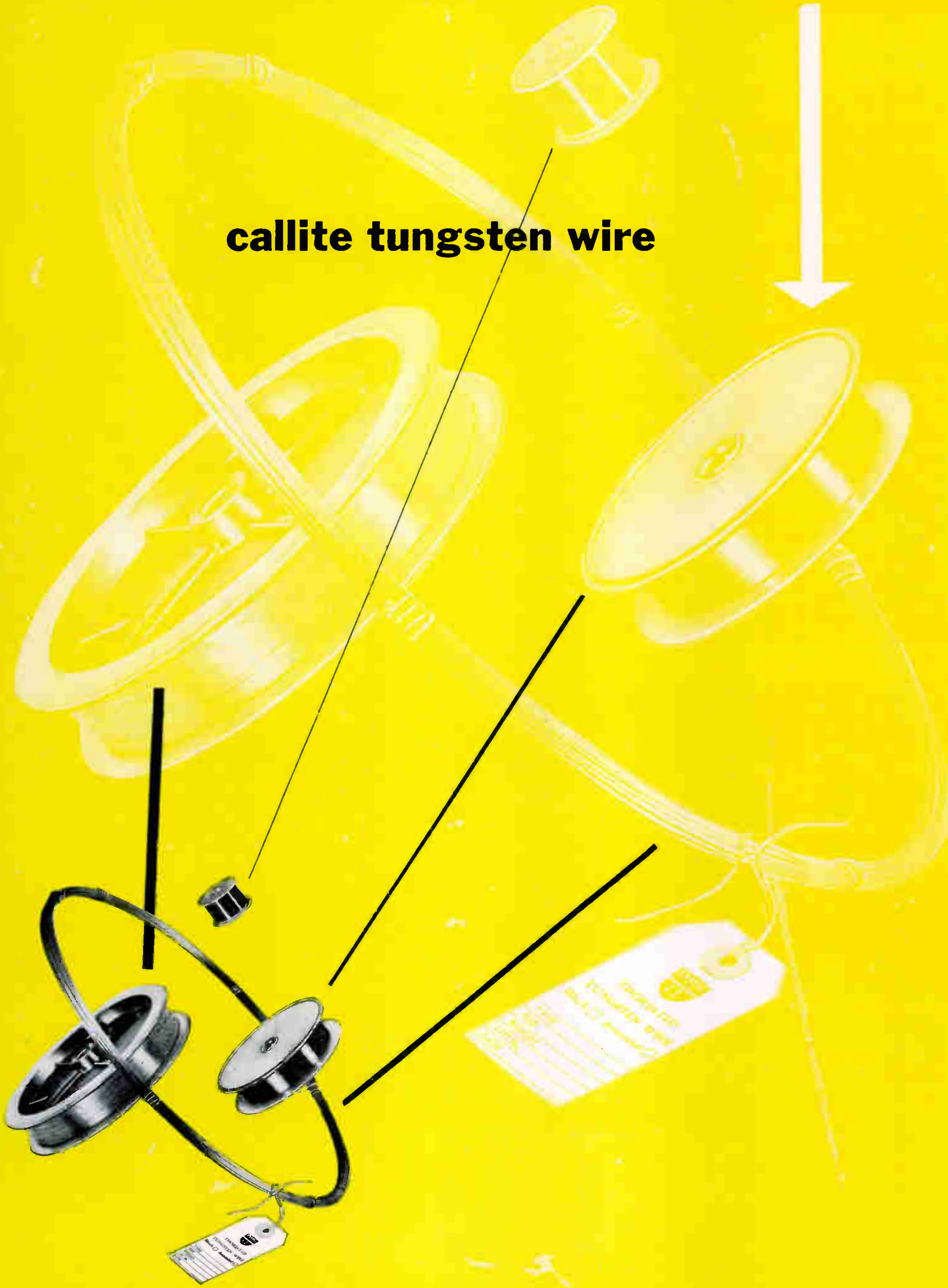
Fluorescent lamps are gaseous discharge lamps having a fairly thin, uniform coating of a fluorescent material of specific composition on the inside walls. Here, too, combinations of argon and mercury vapor are used to produce a large proportion of the energy in the ultra-violet region, specifically at 2537Au.

The gas pressure, current density, and voltage are adjusted to give maximum ultra-violet output and a minimum visible light output for the particular lamp. The ultra-violet light is absorbed by the fluorescent material and re-radiated at a somewhat longer wave length — usually spread over a band of visible wave lengths.

Both cold cathode and hot cathode types of gaseous discharge lamps are being used for fluorescent lighting at present.

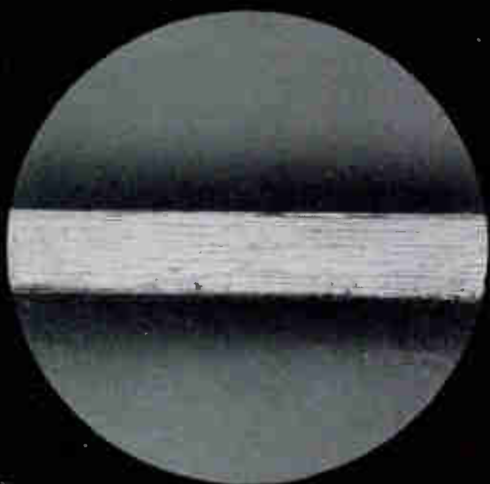
Parts, including leads, coils and emission coating for fluorescent lighting are available for general and special application. Cal-Lux Fluorescent Powders, Coating Solutions and Coated Tubing can be furnished in a full range of colors. Hot and cold cathode electrodes are available in various sizes to meet the requirements of different services and tube diameters. More detailed information may be obtained from bulletin R22.

callite tungsten wire

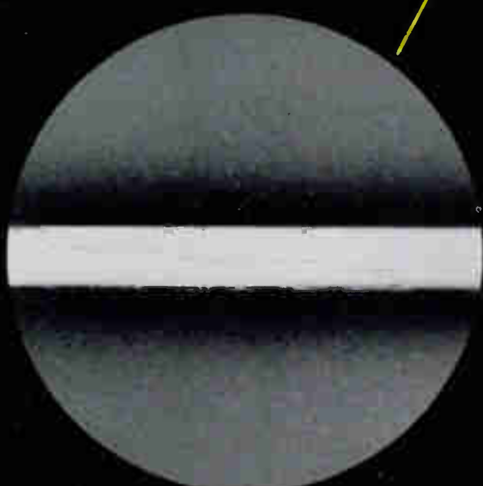


callite tungsten wire

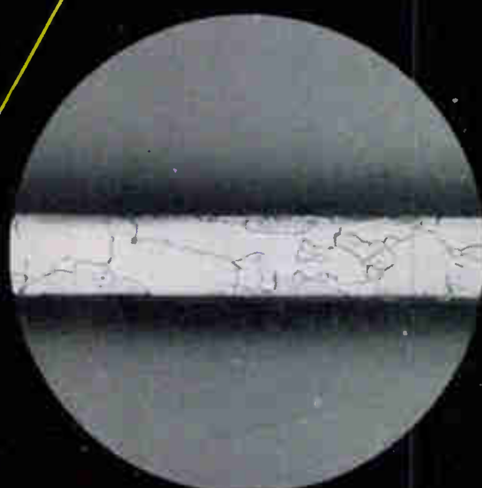
available in seven types for the requirements of incandescent lamps and electronic tubes. Tungsten wire also can be furnished to specifications for special applications.



TYPE 200 N as drawn 200 X



TYPE 200 N (Recrystallized 200X)



TYPE 200 V (Recrystallized 200X)

TYPE 200-N Size Range: From 0.3 mg/200 mm. all finishes. Callite Tungsten Type 200-N is a filament wire for standard line gas-filled incandescent lamps up to and including 500 watt sizes of both high and low voltage types. It combines high tensile strength with good ductility and uniform resistance. It offers good non-sag. non-twist qualities, exceptionally high lumen-maintenance throughout life, and is unaffected by normal vibration in service.

TYPE 200-V Size Range: From 0.75 mg/200 mm. A tungsten filament wire especially developed for long life, high efficiency and lumen maintenance in general-purpose vacuum lamps intended for service under conditions of normal vibration. Cleaning loss on finished coils made from this wire is extremely low. Type 200-V is usually supplied black.

TYPE 200-WC Size Range: From 0.3 mg/200 mm. A tungsten filament wire intended for use in coiled-coils, projection coils and for lamps above the 500 watt size. In the seasoned lamp this tungsten filament wire will develop an interlocking, large crystal structure. Exceptional non-sag. non-twist features effectively reduce the possibility of shorted turns in the coiled filaments. This type is usually supplied black, also cleaned or cleaned and annealed.

TYPE 246-M Size Range: From 0.8 mg/200 mm. A thoriated tungsten filament wire for vacuum lamps. Designed for mill and other vibration services. An extremely fine, interlinked, multi-crystal structure results in a ductile wire, and a filament which will withstand severe vibrations at elevated temperatures. Type 246-M wire has slighly greater sag than type 200-N wire. However, this sag is not sufficient to interfere with its lumen maintenance. Usually supplied black. also available cleaned only.

TYPE 247 Thoriated Wire for electron emission. Size range: From 10.0 mg/200 mm. A special high thoria content tungsten filament wire for radio receiving, amplifying and transmitting tubes. Properly carbonized. Callite thoriated filament gives long life, with constant and dependable electron emission, even under unusually heavy load conditions. Can be supplied black. cleaned or cleaned and annealed.

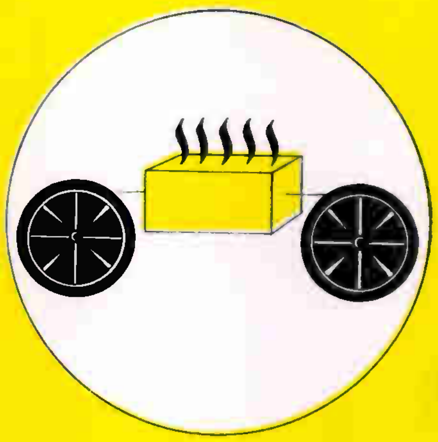
TYPE 200-H—Heater Wire. Size Range: From .3 mg/200 mm. This is standard wire used in the heater elements of electronic tubes. It is noted for its ability to withstand high temperatures without exhibiting brittleness—a feature attributed to special processing of the 200-H metal. Usually supplied cleaned and annealed Can be supplied black or cleaned only.

TYPE 200SW—Hook Wire. Size Range: From 7.7 mg/200 mm. An annealed tungsten hook wire of exceptionally good forming characteristics for use as supports in incandescent lamps and electronic tubes. This wire is also furnished black, mechanically straightened, and has higher tensile strength and greater springiness.

STANDARD TUNGSTEN WIRE FINISHES

1. **BLACK** *unstraightened*
2. **BLACK** *straightened*
3. **CLEANED** *unstraightened*
4. **CLEANED** *and straightened*

Special finishes available upon request

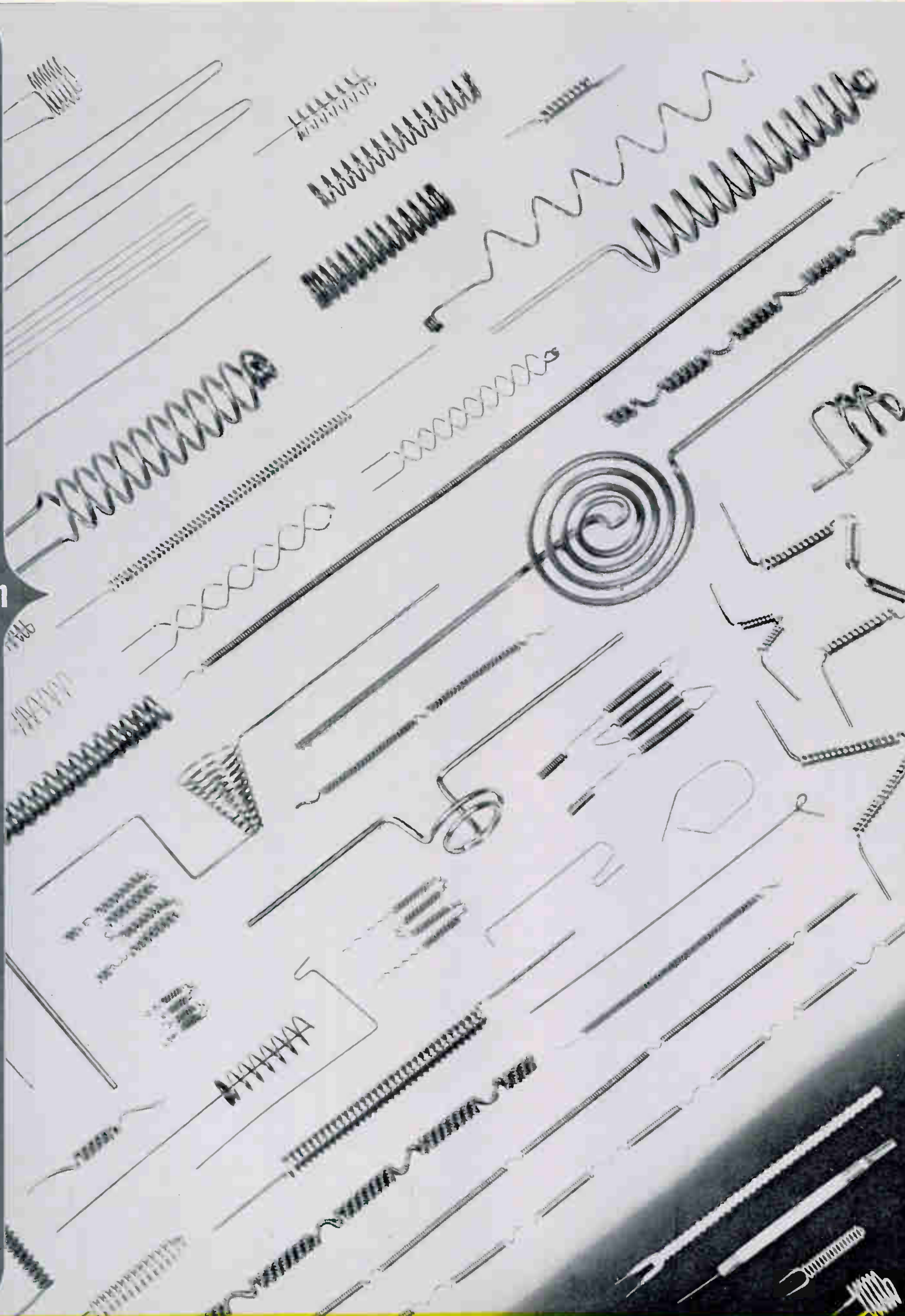


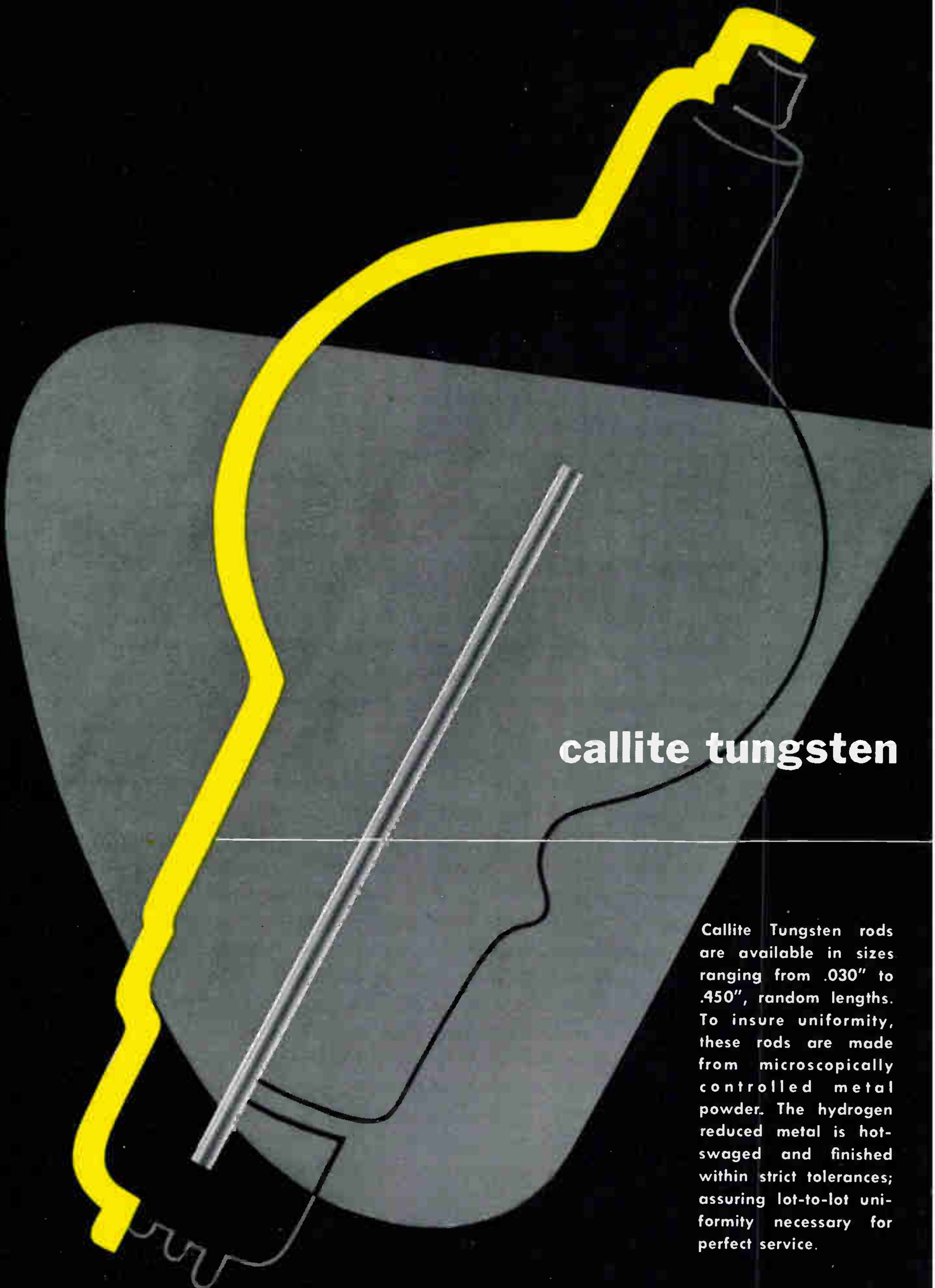
tungsten wire and rod data chart

DIAMETER INCHES	DIAMETER IN APPROX. MILLIMETERS	MILLIGRAMS PER 200 MILLIMETERS	GRAMS PER 1000 METERS	METERS PER KILOGRAM
.00045	.0114	.39	1.94	514,403
.0005	.0127	.48	2.40	416,667
.00055	.0140	.58	2.91	343,642
.0006	.0152	.69	3.46	289,017
.00065	.0165	.81	4.06	246,305
.0007	.0178	.94	4.71	212,314
.00075	.0191	1.08	5.40	185,185
.0008	.0203	1.23	6.15	162,602
.00085	.0216	1.39	6.94	144,092
.0009	.0229	1.55	7.78	128,534
.00095	.0241	1.73	8.67	115,340
.001	.0254	1.92	9.60	104,167
.00105	.0267	2.12	10.59	94,429
.00110	.0279	2.32	11.62	86,059
.00115	.0292	2.54	12.72	78,740
.00120	.0305	2.77	13.85	72,307
.00125	.0318	3.00	15.00	66,622
.00130	.0330	3.25	16.25	61,614
.00135	.0343	3.50	17.50	57,143
.00140	.0356	3.76	18.80	53,135
.00145	.0368	4.04	20.20	49,529
.00150	.0381	4.32	21.60	46,296
.00155	.0394	4.61	23.05	43,290
.00160	.0406	4.92	24.60	40,650
.00165	.0419	5.23	26.15	38,168
.00170	.0432	5.55	27.75	35,971
.00175	.0445	5.88	29.40	34,014
.00180	.0457	6.22	31.10	32,154
.00185	.0470	6.57	32.85	30,395
.00190	.0483	6.93	34.65	28,818
.00195	.0495	7.30	36.50	27,397
.002	.0508	7.68	38.40	26,042
.00205	.0521	8.07	40.35	24,752
.00210	.0533	8.48	42.40	23,585
.00215	.0546	8.88	44.40	22,523
.00220	.0559	9.29	46.50	21,505
.00225	.0572	9.72	48.60	20,576
.00230	.0584	10.16	50.80	19,685
.00235	.0597	10.60	53.00	18,868
.00240	.0610	11.06	55.30	18,083
.00245	.0622	11.53	57.65	17,331
.00250	.0635	12.00	60.00	16,667
.00255	.0648	12.49	62.45	16,000
.00260	.0660	12.98	64.90	15,408
.00265	.0673	13.48	67.40	14,837
.00270	.0686	14.00	70.00	14,286
.00275	.0699	14.52	72.60	13,774
.00280	.0711	15.05	75.30	13,280
.00285	.0724	15.60	78.00	12,821
.00290	.0737	16.15	80.75	12,376
.00295	.0749	16.71	83.55	11,962
.003	.0762	17.28	86.40	11,574
.0035	.0889	23.52	117.60	8,503
.004	.1016	30.72	153.60	6,510
.0045	.1143	38.88	194.40	5,144
.005	.1270	48.00	240.00	4,167
.0055	.1397	58.08	290.40	3,444
.006	.1624	69.12	345.60	2,893
.0065	.1645	81.12	405.60	2,465

DIAMETER INCHES	DIAMETER IN APPROX. MILLIMETERS	MILLIGRAMS PER 200 MILLIMETERS	GRAMS PER METER	METERS PER KILOGRAM
.007	.1778	94.08	.47	2,125.00
.0075	.1905	108.00	.54	1,852.00
.008	.2032	123.00	.62	1,626.00
.0085	.2159	139.00	.70	1,439.00
.009	.2286	156.00	.78	1,282.00
.0095	.2413	173.00	.87	1,156.00
.010	.2540	192.00	.96	1,042.00
.011	.2794	232.00	1.16	862.00
.012	.3048	276.00	1.38	723.00
.013	.3302	324.00	1.62	616.00
.014	.3556	376.00	1.88	531.00
.015	.3810	432.00	2.16	463.00
.016	.4064	491.00	2.46	407.00
.017	.4318	555.00	2.78	360.40
.018	.4572	622.00	3.11	321.50
.019	.4826	693.00	3.47	288.60
.020	.5080	768.00	3.84	260.40
.021	.5334	847.00	4.24	236.10
.022	.5588	929.00	4.65	215.30
.023	.5842	1016.00	5.08	196.85
.024	.6096	1106.00	5.53	180.80
.025	.6350	1200.00	6.00	166.70
.026	.6604	1298.00	6.49	154.10
.027	.6858	1400.00	7.00	142.85
.028	.7112	1505.00	7.53	132.90
.029	.7366	1615.00	8.08	123.80
.030	.7620	1728.00	8.64	115.70
.032	.8128		8.83	101.70
.034	.8636		11.10	90.13
.035	.8890		11.76	85.03
.040	1.016		15.36	65.10
.045	1.143		19.44	51.44
.050	1.270		24.00	41.67
.060	1.524		34.56	28.94
.070	1.778		47.04	21.26
.080	2.032		61.44	16.28
.090	2.286		77.76	12.86
.100	2.540		96.00	10.42
.110	2.794		116.16	8.61
.120	3.048		138.24	7.23
.125	3.175		150.00	6.67
.130	3.302		162.24	6.16
.140	3.556		188.16	5.32
.150	3.810		216.00	4.63
.160	4.084		245.76	4.07
.170	4.318		277.44	3.60
.175	4.445		294.00	3.40
.180	4.672		311.04	3.22
.1875	4.763		337.50	2.96
.190	4.826		346.56	2.89
.200	5.080		384.00	2.60
.225	5.715		486.00	2.06
.250	6.350		600.00	1.67
.275	6.985		726.00	1.38
.300	7.620		866.88	1.15
.330	8.890		1176.00	.85
.400	10.160		1536.00	.65
.450	11.430		1944.00	.51
.500	12.700		2400.00	.42

typical tungsten wire parts made by callite





rod types

Type 200 G: from .030" to .450" Ground Tungsten Rod
(sealing quality)

This rod is specially developed for sealing in hard glass, Corex and Nonex. It has the proper coefficient of expansion to make a vacuum tight seal. Furnished in random lengths or cut to exact specifications. All rod ends are square cut, to facilitate welding when made into lead-ins. All ground seal rods are etched and inspected microscopically for surface imperfections.

Type 200 B: from .030" to .450" Ground Tungsten Rod
(non sealing quality)

This rod is ground for support purposes, and other varied applications where accuracy in dimension is a requirement. This type rod has high tensile strength, and good ductility, and maintains its alignment at high operating temperatures.

Type 200 E: from .030" to .450" Tungsten Rod

This type rod, furnished with a cleaned or polished surface, is used for support and other purposes.

tungsten kulgrid "C" welds for electronic use

HARD GLASS TYPE

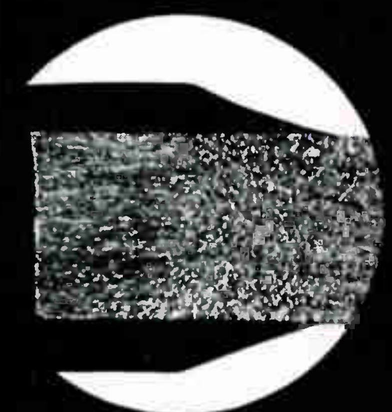


FIG. 1

FIG. 2

FIG. 3

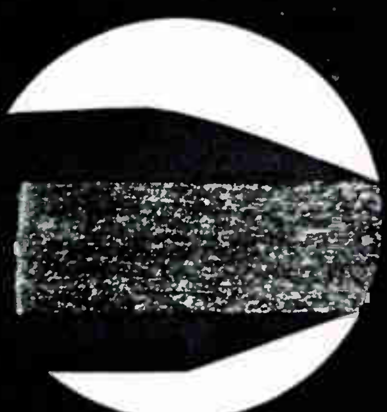


FIG. 4

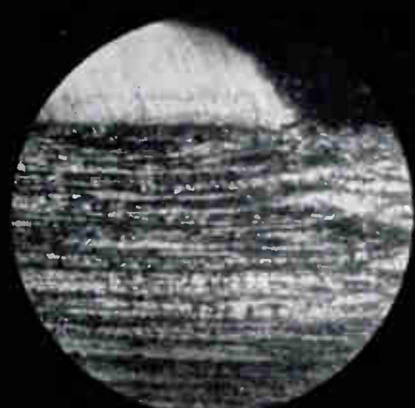


FIG. 5

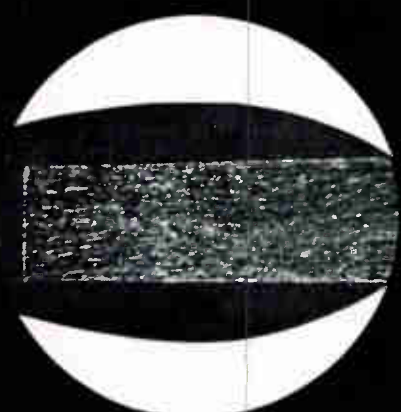


FIG. 6

Leads are the conductors of current from the outside atmosphere of the tube through to the vacuum. A Tungsten ground-seal rod is used as a vacuum tight seal in the stem. The inner elements of the electronic device are then connected to the inner lead of the weld.

An important requirement in the manufacture of vacuum tubes has been a stranded wire which does not oxidize readily at the high temperatures necessary in the successive steps of production such as beading, stem making, sealing in, and exhaust. This composite wire, known as Kulgrid "C", has the necessary high heat and electrical conductivity for efficient operation when used in conjunction with Tungsten in the manufacture of hard glass electronic devices.

With many types of stranded wire used with Tungsten rod for lead-in purposes, excessive oxidation takes place. The oxide flakes off and deposits itself in the press which is very objectionable and may even lead to stem leakage. Frequently the strand becomes brittle and cannot be shaped or formed, and it will therefore fall off at or prior to the basing operation.

In attempting to solve this problem it was found that the composite wire having an inner core of copper alloy bonded to a nickel sleeve, when stranded into a flexible cable, had none of the objectionable points of regular copper strand. Since the nickel sleeving on each strand does not oxidize readily, flake deposits in the tube press are practically eliminated. Moreover, the composite strand does not become brittle when subjected to excessive heat with the result that there is no lead breakage.

The subject of welds was also given consideration and a photomicrographic study was made of various types of Tungsten welds using the composite strand wire as compared with regular copper strand. The Tungsten used was from the same lot, the welds made under the same conditions, the only difference being the type of strand used.

The photomicrographs of Figs. 1 and 2 show the result of a weld between a Tungsten rod and stranded copper with a nickel sleeve.

Considerable re-crystallization is apparent in Fig. 1, and is quite obvious in Fig. 2.

The photomicrographs of Figs. 4 and 5 show the same sort of weld between a Tungsten rod and the Kulgrid strand with nickel sleeve. It will be particularly noted from Fig. 5 that practically no crystallization of the Tungsten has taken place. Compare this with the enlargement in Fig. 2. A study was also made of the relative strength of such welds. Fig. 3 shows a Tungsten rod welded to a copper strand without a nickel sleeve. The weakness in the weld is apparent. In Fig. 6 is shown a Tungsten rod welded to the Kulgrid strand, also without a nickel sleeve. It is apparent that the two metals more readily weld together, with the Kulgrid strand flowing uniformly about the Tungsten, forming a filet all around which adds to the strength.

FIG. 1
Tungsten rod to stranded copper with nickel sleeve. 50X

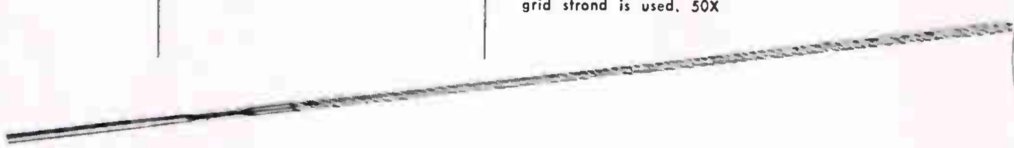
FIG. 2
Enlarged view of fig. 1 showing crystallization of Tungsten when copper strand is used. 200X

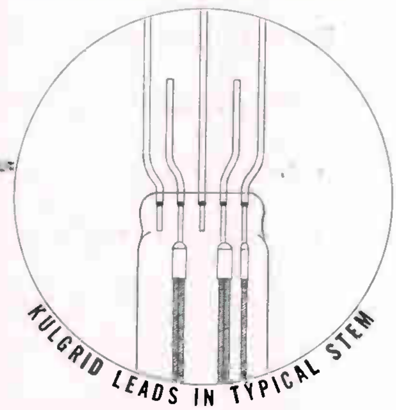
FIG. 3
Tungsten rod to copper strand no sleeve. Showing the weakness of the Weld. 50X

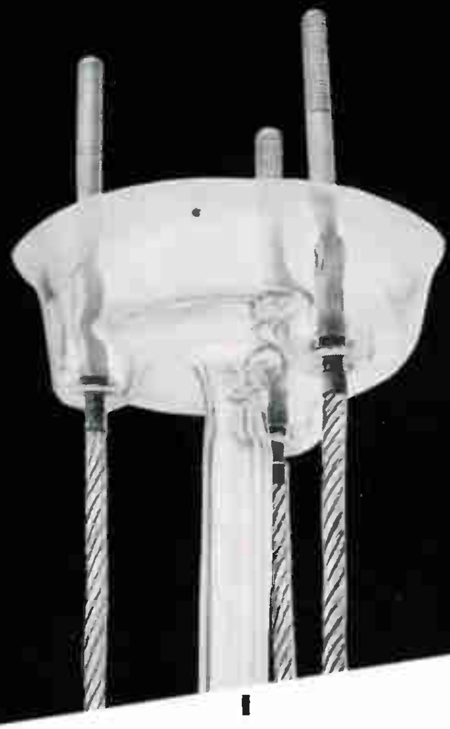
FIG. 4
Tungsten rod to stranded Kulgrid wire with nickel sleeve. 50X

FIG. 5
Enlarged view of fig. 4 showing no crystallization of Tungsten when Kulgrid strand is used. 200X

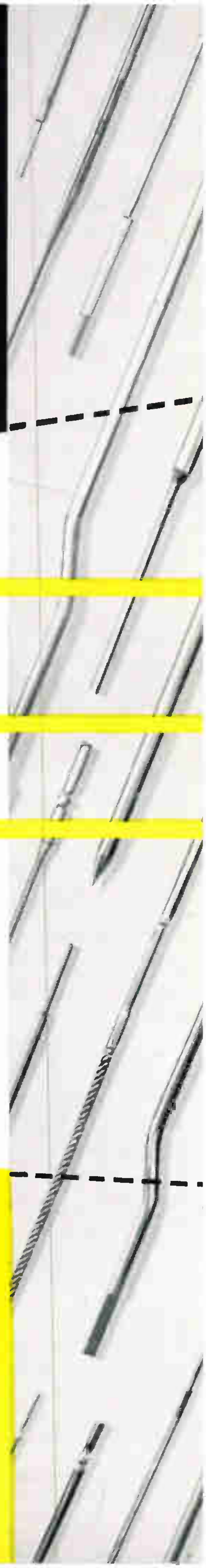
FIG. 6
Tungsten rod to Kulgrid strand no sleeve. This shows the strong, well-balanced weld when Kulgrid strand is used. 50X



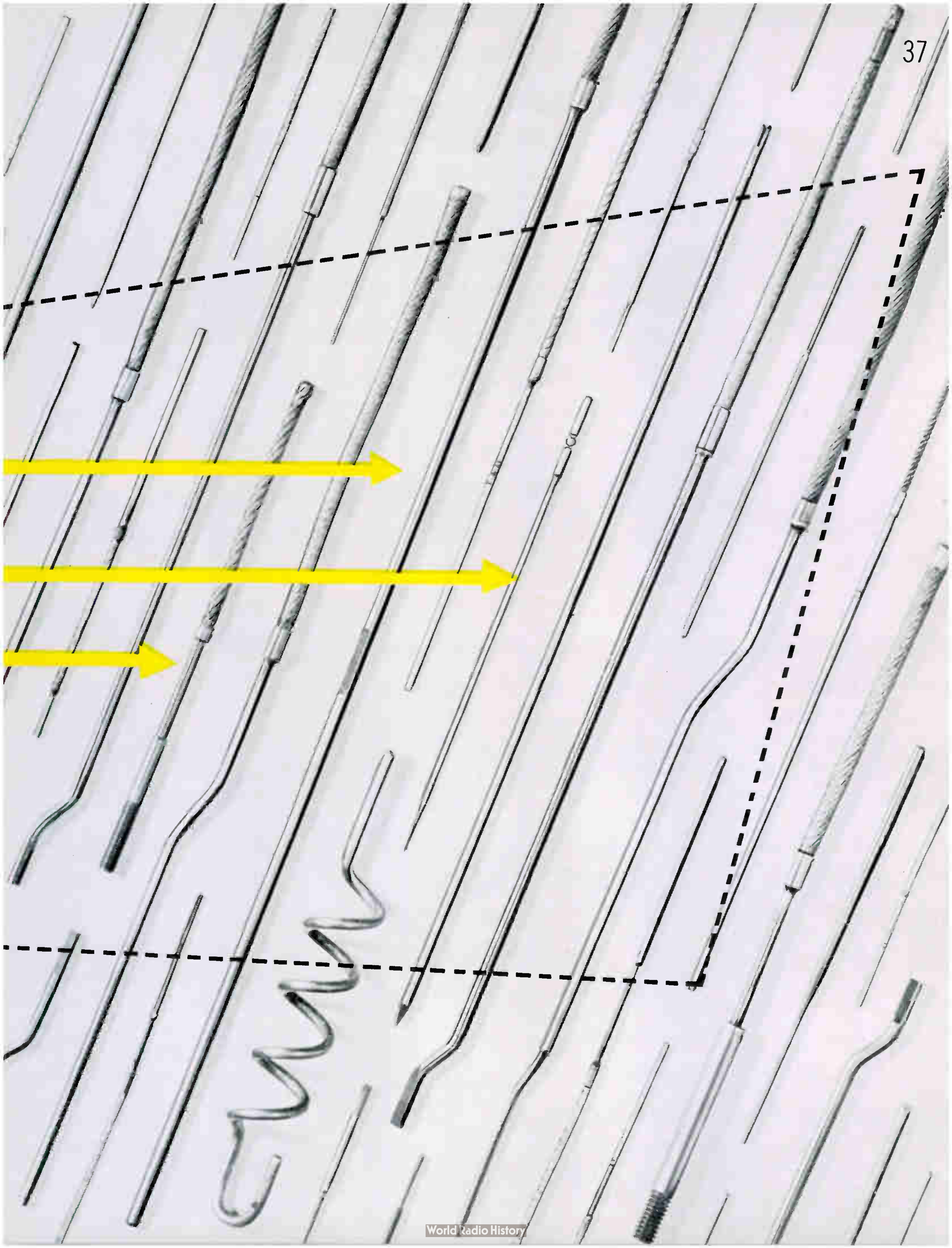


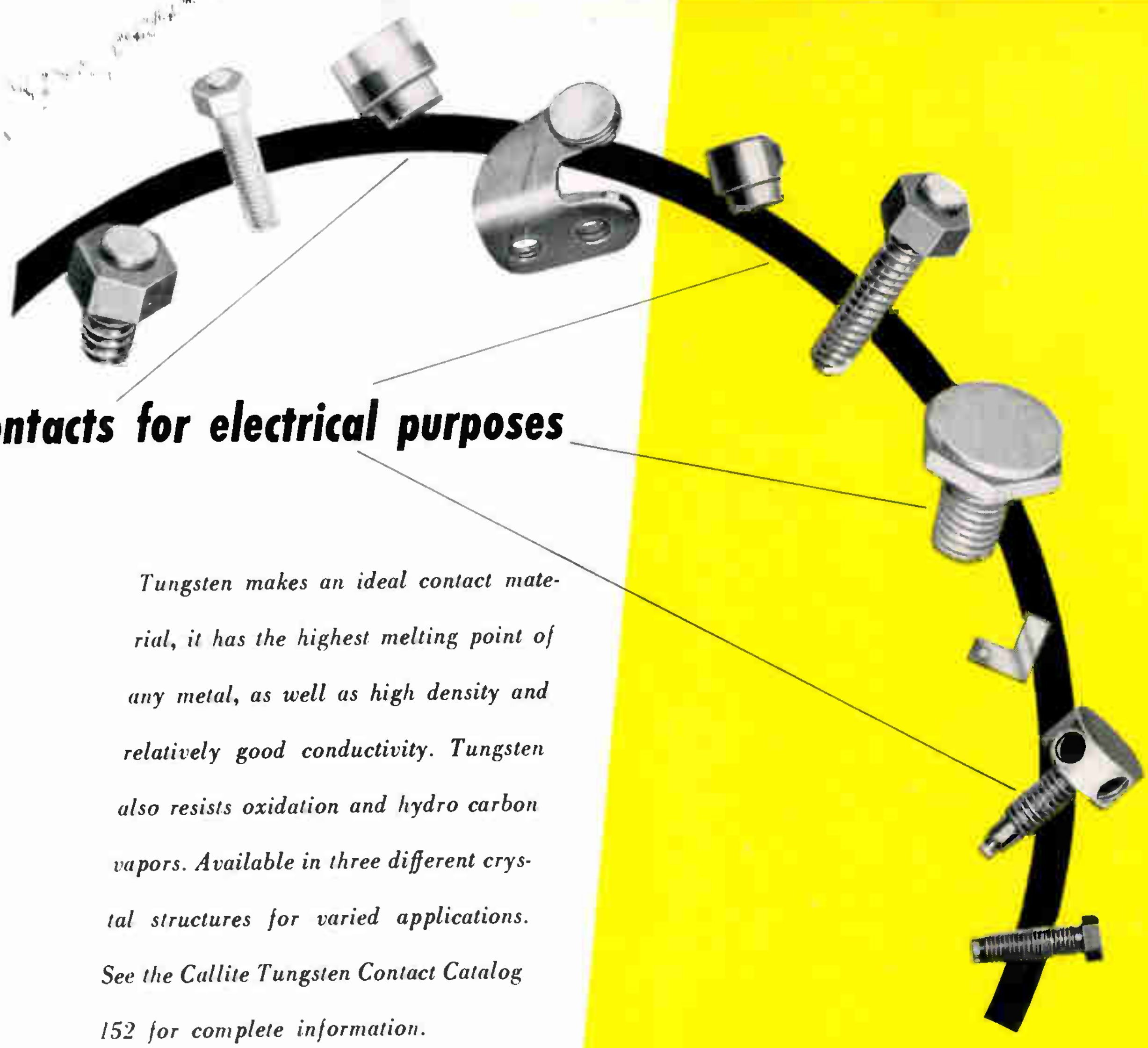


heavy tungsten formed pieces and welds



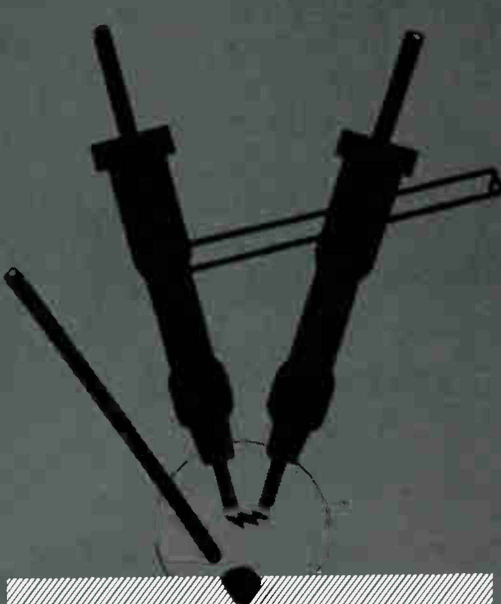
The hard glass stem assemblies shown above use a few of the many parts, illustrated, which are made to specification. Kulgrid strand or copper strand are nickel sleeved at end to be welded to either tungsten or molybdenum of sealing quality. The tungsten and molybdenum may be supplied bent, slotted, pointed or side surface ground. Nickel welded to tungsten or molybdenum may be supplied straight, formed, threaded or slotted.





contacts for electrical purposes

Tungsten makes an ideal contact material, it has the highest melting point of any metal, as well as high density and relatively good conductivity. Tungsten also resists oxidation and hydro carbon vapors. Available in three different crystal structures for varied applications. See the Callite Tungsten Contact Catalog 152 for complete information.

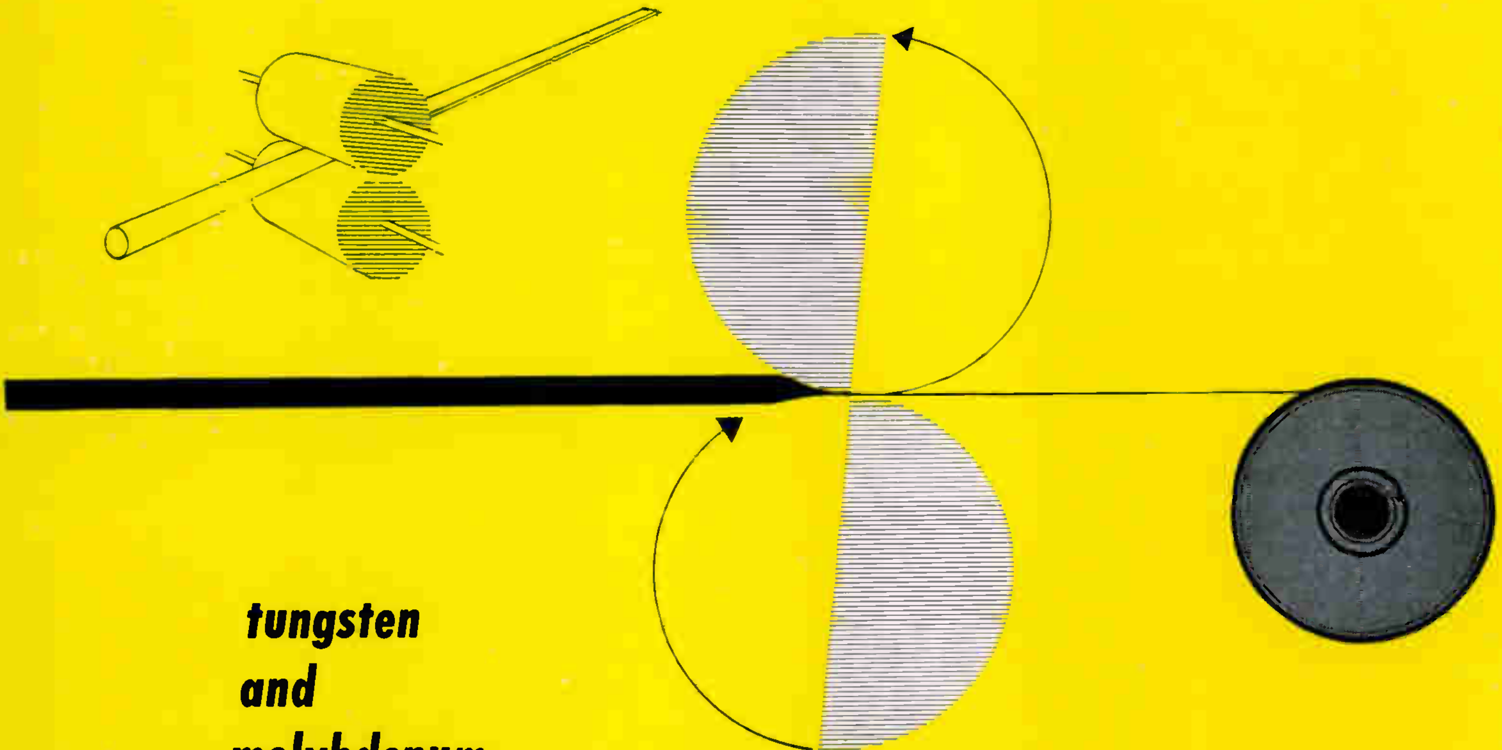


PURETUNG

99% PURE TUNGSTEN WELDING ELECTRODES

"For Atomic Hydrogen, Helium and Argon Arc Welding"

C-T Tungsten Welding Electrodes are made in brittle-standard or special-polished, cleaned and black, 99% pure. Welds made using C-T rod in the atomic hydrogen process are unusually ductile, homogenous and smooth. The rods retain their rigidity in use and are consumed slowly. Send for special bulletin giving detailed information on this process.



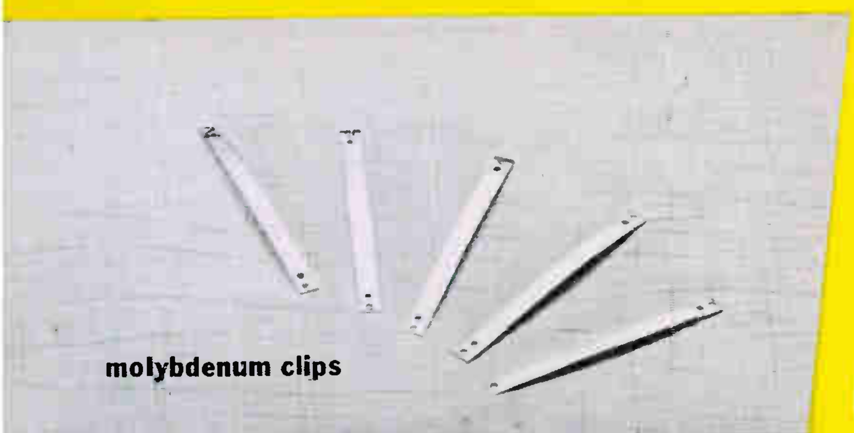
tungsten and molybdenum ribbons

types:

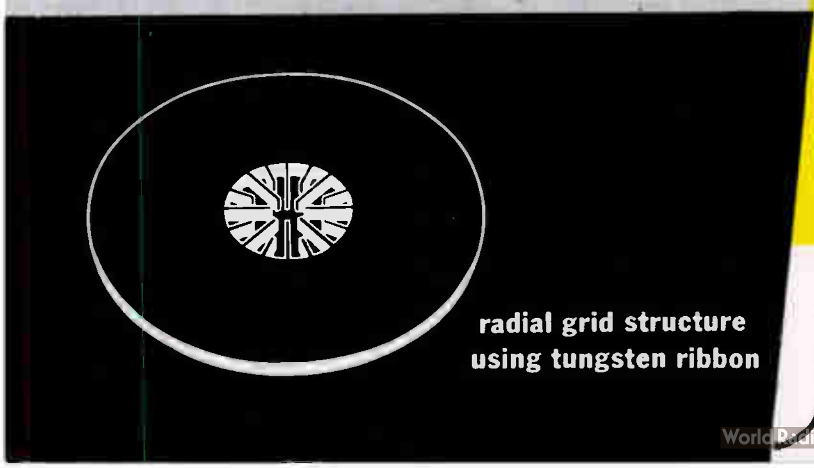
- PURE TUNGSTEN RIBBON TYPE 200 RB
- TUNGSTEN THORIATED RIBBON TYPE 247 RB
- PURE MOLYBDENUM RIBBON TYPE 400 RB

Special ductile wire is rolled into ductile ribbon of varying sizes. Edges of this ribbon are slightly rounded. It readily withstands the strains of crimping, twisting and similar forming operations. Thicknesses from .001" up. Maximum width .125". When ordering specify thickness and width with required tolerances.

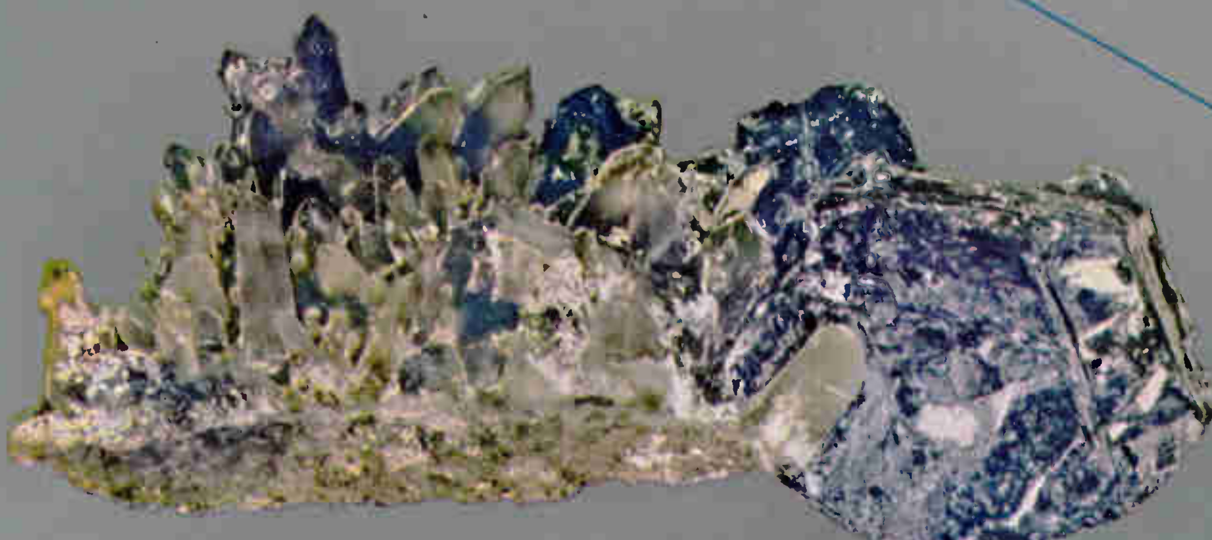
two typical ribbon applications



molybdenum clips



radial grid structure using tungsten ribbon



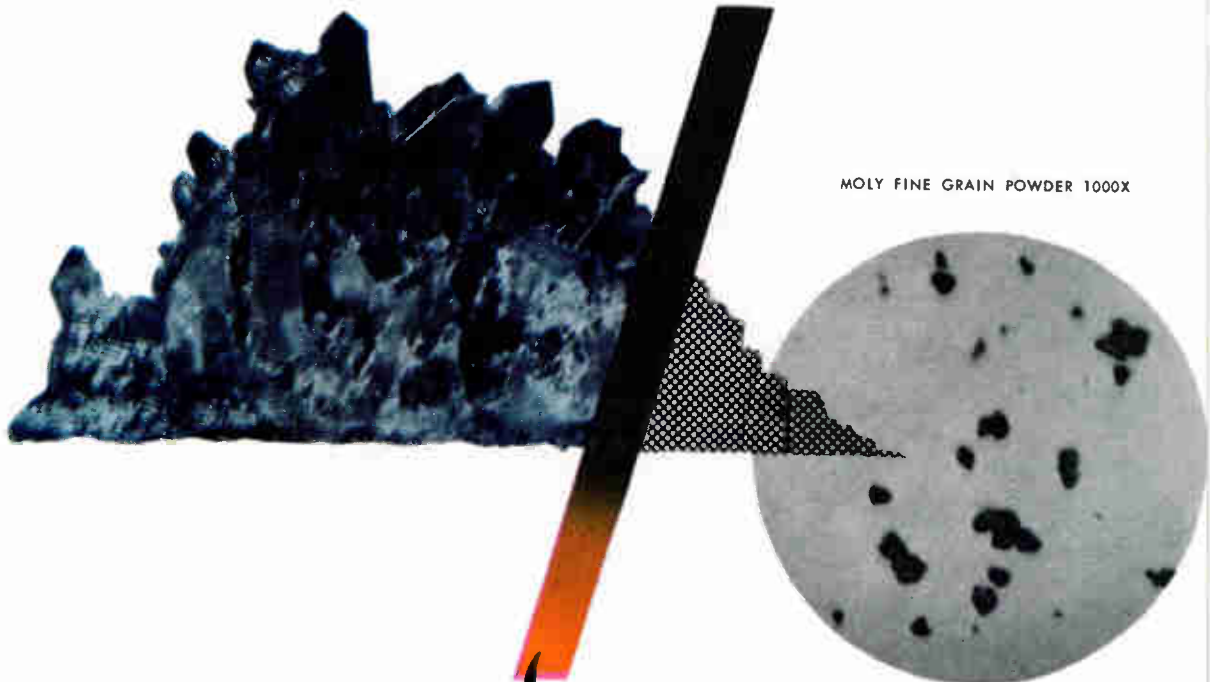
molybdenum

The name molybdenum, or more specifically "molybdena", occurs in the writings of Pliny (1st Century A. D.) where it was indiscriminately applied to various substances containing lead. Pliny borrowed this term from the Greeks, who used "molybdos" as the designation for lead. Carelessness in terminology soon led to the use of molybdena as the name for any substance resembling lead ores in physical appearance. By the middle of the 18th century, molybdena was applied solely to graphite and molybdenite—molybdenum sulphide, the chief ore of molybdenum. This common usage of the same name for two different materials was due to the similar scale-like formations of their natural deposits. In 1778, C. W. Scheele first pointed out the difference when he showed that a "peculiar white earth" with acidic properties could be obtained from molybdena. To this substance he assigned the name "molybdic acid". Four years later, Hjlem prepared the metal, and definitely identified it as an element in 1790. However, molybdenum was not produced on a large scale until 1909.

Only two ores are commercially important—molybdenite (MoS_2), the sulphide of molybdenum, and wulfenite (a lead molybdate, ($PbMoO_4$) Of the two, molybdenite is the more easily processed and commonly used. These are fairly well scattered over the earth, but the United States is by far the largest producer. In normal times, Colorado accounts for approximately 70% of the world's output.

Photograph of molybdenite ore is shown on facing page.

extracting molybdenum from molybdenite ore



MOLY FINE GRAIN POWDER 1000X

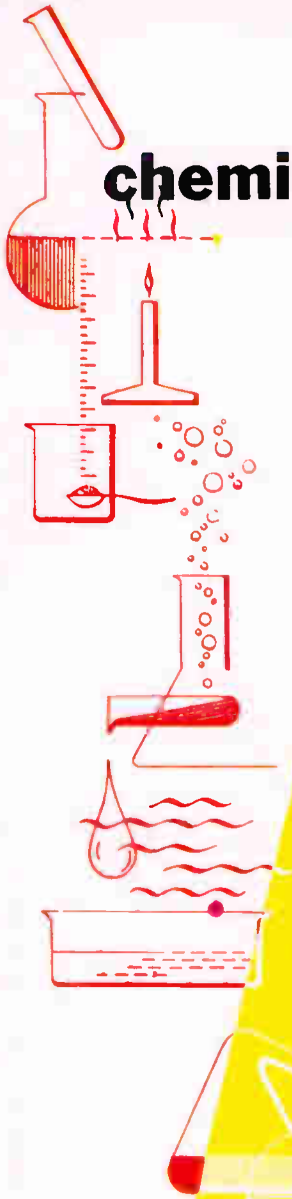
Due to its extremely high melting point, and affinity for oxygen at elevated temperatures, molybdenum (like tungsten) cannot be produced or refined by ordinary smelting processes. Instead, methods of powder metallurgy are used to produce the pure metal. One of the methods of purifying the molybdenum ore consists of roasting the ore to remove sulphur, followed by a leaching step with ammonia to produce a commercial grade of ammonium molybdate. This ammonium molybdate must be further purified to make it suitable for molybdenum powder production of the required purity for electronic applications.

preparing the metal

These purified intermediate products are then reduced to metallic molybdenum powder in a gas fired or electric furnace (having a hydrogen atmosphere) under controlled conditions of temperature and time to produce a metal powder of the required particle size. The powdered molybdenum is then hydraulically pressed into bars and sintered in a hydrogen atmosphere at temperatures closely approaching the melting point.

Sintering of the powdered molybdenum bar causes a brittle crystal structure to form. Ductility is obtained by hot working of the bars. In turn, these are drawn into wire or rolled into sheets.

chemical properties of molybdenum



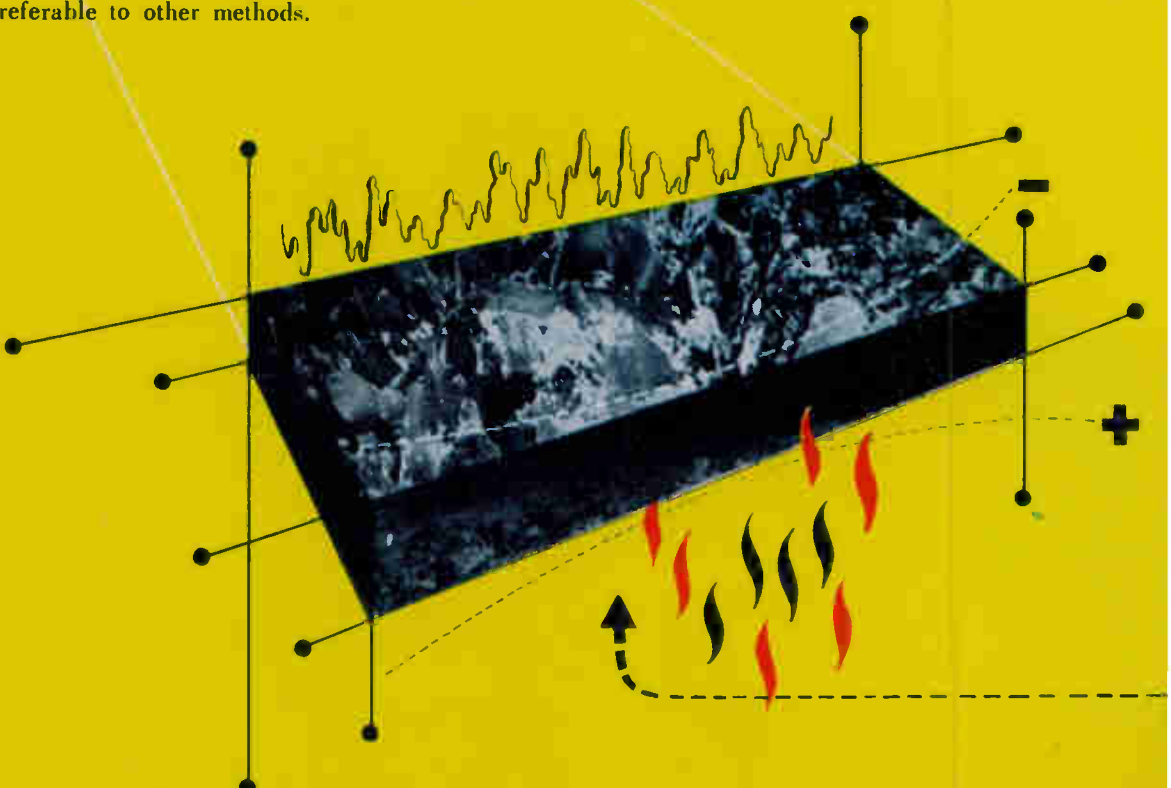
Molybdenum is not appreciably affected by air at ordinary temperatures, but at a dull red heat the oxide is slowly formed. Hydrochloric acid or dilute sulphuric acid attacks molybdenum, while nitric acid rapidly dissolves it. Hydrofluoric acid is without effect. Aqua regia rapidly reacts with the metal. Hot, concentrated aqueous solutions of potassium or sodium hydroxide have no noticeable effect on molybdenum. Fused alkalies, oxidizing salts, or combinations thereof, rapidly react with the metal. At elevated temperatures, molybdenum will readily combine with sulphur, carbon or silicon.

Nitrogen is only slightly absorbed by annealed molybdenum plate or wire. Unannealed molybdenum, however, absorbs considerable amounts of nitrogen at elevated temperatures, becomes brittle, and when cooled in an atmosphere of nitrogen, forms an unstable nitride.

To obtain ductile wire and sheet, it is necessary to exercise exacting chemical control from the first ore extraction operations to the finished high purity metal. The presence of even minute quantities of impurities greatly reduces or destroys the requisite ductility of the finished product. Rigid temperature control also is necessary in the physical working of the metal, as crystal structure plays an essential part in determining ductility. The most satisfactory crystal structure of molybdenum wire consists of long, closely intermeshed fibres parallel to the axis of the wire. In sheet material, the crystal structure should consist of flat scales or plates in planes parallel to the faces of the sheet and also finely meshed or interlocked.

physical properties of molybdenum

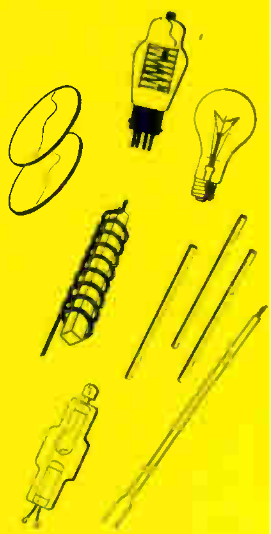
While classed as a hard metal, molybdenum, as compared to tungsten, is softer and more easily worked. It may be rolled into sheets, or drawn into wire through suitable dies. In these forms, it can be bent cold or stamped into the simple shapes. Molybdenum can be machined readily with ordinary tools and can be welded very satisfactorily to iron and nickel, but not so readily to itself. It oxidizes during extended heating in air. Electric welding in a protecting atmosphere is therefore preferred and recommended. Adequate heat at the point of junction should be applied as rapidly as possible (without heating the metal around the weld any more than is necessary). Because of its speed, resistance spot welding is preferable to other methods.



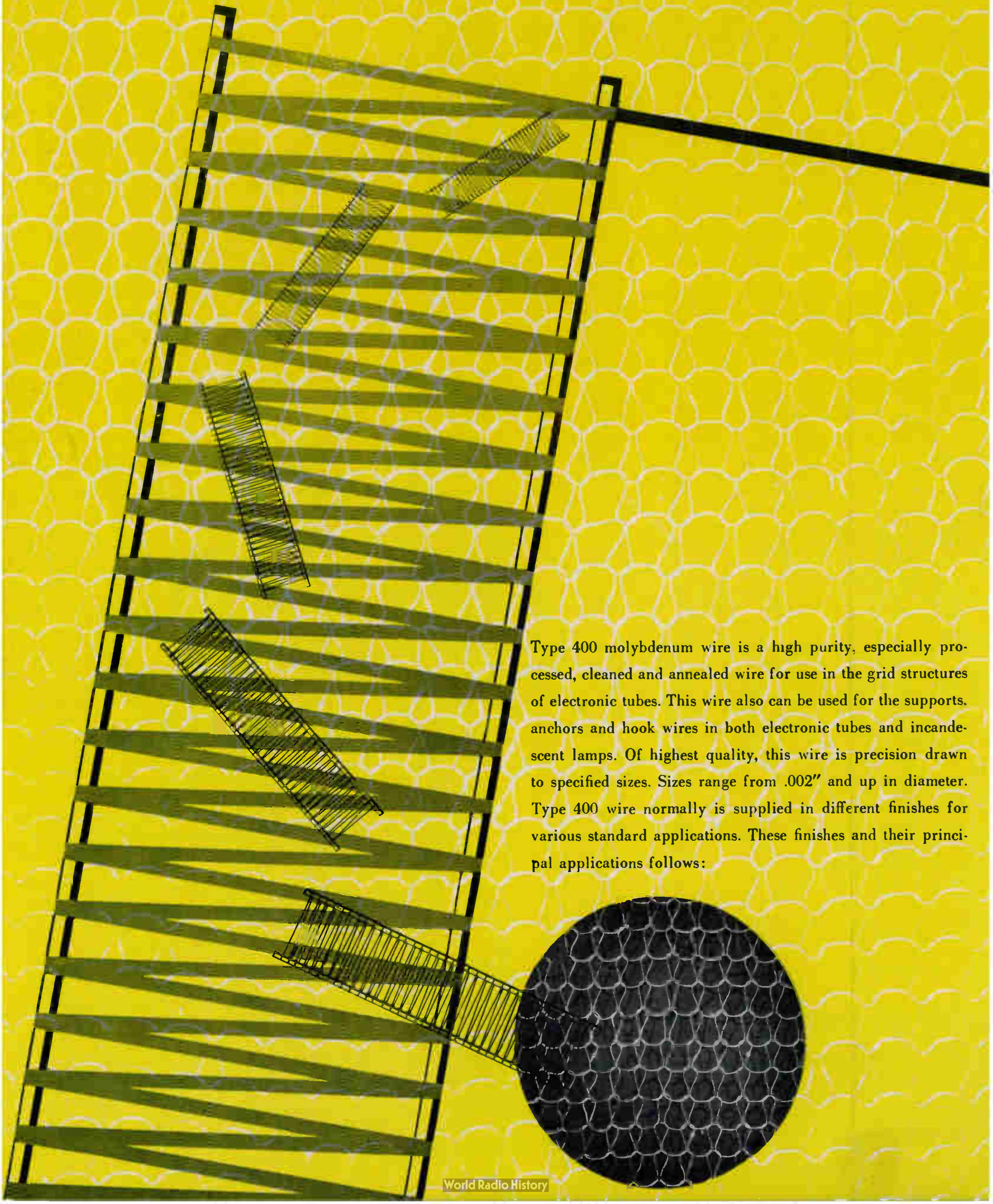
specific gravity	10.2					(1)
melting point (°C)	2620 ± 10					(1)
vapor pressure (mm Hg)	at 1700°C	2000°C	2300°C	3000°C		(1)
	1×10^{-9}	1×10^{-6}	1×10^{-3}	10		
rate of evaporation (gms/cm²sec)	at 1527°C	1727°C	1927°C			(1)
	8.6×10^{-11}	1×10^{-8}	5×10^{-3}			
tensile strength (lbs/in²) **and elongation (%) at 20°C**		Diam.	Tensile Strength	Elong.		(1)
	hard drawn	.050"	198 — 258,000	2-5%		
		.002"	250 — 350,000	2-5%		
	annealed	.050"	100 — 140,000	10-20%		
		.002"	110 — 170,000	10-25%		
elastic limit (lbs/in²)	hard drawn	.004" to .020"	55 — 85,000			(1)
	annealed	.004" to .020"	70 — 85,000			
modulus of elasticity (lbs/in²)	hard drawn	.020 to .040"	$(40-42) \times 10^{6}$			(1)
	annealed	.020 to .040"	45×10^{6}			
brinell hardness (10mm ball-3000 kg load)	hard drawn	160 to 185				(1)
	annealed	147				
specific heat (cal/gm°C)	at 100°C	1400°C				(1)
	0.062	0.080				
coefficient of thermal expansion (cm/cm°C)	at 25°C—100°C	25°C—500°C				(1)
	$(3.7 - 5.0) \times 10^{-6}$	$(4.7 - 5.7) \times 10^{-6}$				
heat conductivity (watts/cm°Ccm²)	at 20°C	1200°C	1800°C	2000°C		(2)
	1.46	1.19	0.89	0.80		
specific resistance (microhm-cm)	at 20°	500°C	1000°C	1500°C	2000°C	(1)
	5.65	18.20	30.4	42.8	55.4	
temp. coeff. of electrical resistivity (ohm/ohm°C)	20°C— 2620°C					(1)
	4.79×10^{-3}					
total radiation (watts/cm²)	at 1000°K	1500°K	2000°K	2500°K		(1)
	0.55	4.40	19.2	57.0		
electron emission (amps/cm²)	at 1000°K	1500°K	2000°K	2500°K		(1)
	3.24×10^{-15}	1.91×10^{-7}	9.06×10^{-5}	4.62×10^{-1}		
thermionic work function (volts)	300°C— 940°C					
	4.15 ± 0.02 (degassed)					
references:	(1). International Critical Tables					
	(2). R. H. Osborn, J.O.S.A., p 428, 1941					

A table showing the various physical characteristics of molybdenum in comparison with other metals appears on page 58.

uses: Molybdenum finds a wide range of application as a metal. This range is constantly being extended by diligent research. At present, pure molybdenum finds its greatest application in the electronic field, where uniform high purity and freedom from occluded gases make molybdenum wire, ribbon and sheet ideally suited for use as grids, plates, supports, hooks and anchors in electronic tubes of all types. Molybdenum hooks and supports are used in incandescent lamps because of the ease with which they can be formed in the cold and their retention of shape and rigidity at high temperatures.

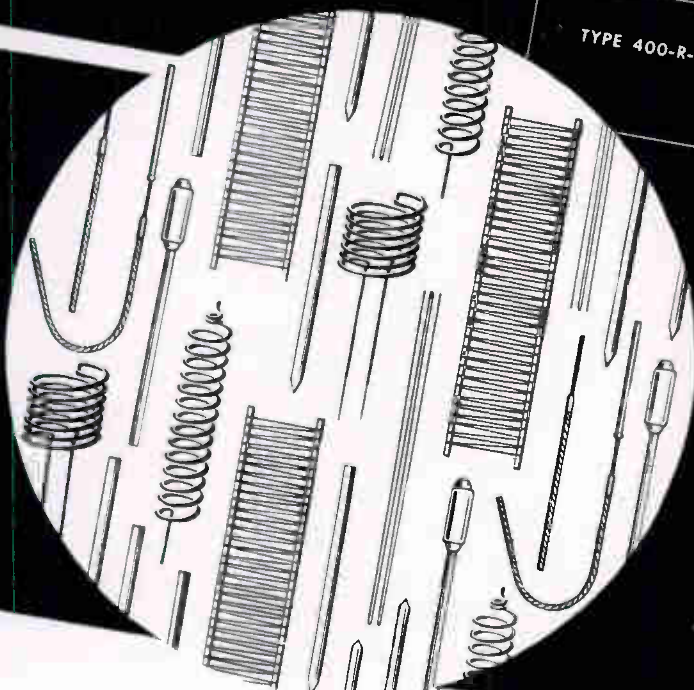


Molybdenum wire is highly desirable as the heating element in electric furnaces. Temperatures up to 2000 degrees Centigrade may be obtained if suitable refractory materials are employed. A protective atmosphere must be used in the furnace, however, to protect the molybdenum from oxidation. Molybdenum is well-suited, in many cases, for use as the electrodes in spot-welding operations. It possesses excellent thermal conductivity and, compared with copper, has superior strength and rigidity, with practically no tendency to pit, wear or stick to the work being welded. Molybdenum welding electrodes are particularly desirable when welding parts for vacuum tubes, for should minute particles of the molybdenum electrode adhere to the parts being welded, no harm will result. This possibility of contamination is a hazard when using electrodes of other materials. Molybdenum also is employed as the anode in X-ray tubes, mandrel wire and contact points in many electrical devices. It is also used with tungsten as a thermocouple in high temperature work, and has proved its usefulness in dentistry and in the manufacture of standard weights and laboratory vessels. Molybdenum is extensively employed to prepare alloys having characteristics specifically applicable to unusual operating conditions.



Type 400 molybdenum wire is a high purity, especially processed, cleaned and annealed wire for use in the grid structures of electronic tubes. This wire also can be used for the supports, anchors and hook wires in both electronic tubes and incandescent lamps. Of highest quality, this wire is precision drawn to specified sizes. Sizes range from .002″ and up in diameter. Type 400 wire normally is supplied in different finishes for various standard applications. These finishes and their principal applications follows:

TYPE 400-F	UNANNEALED BLACK	For heater elements in electric furnaces
TYPE 400-M	ANNEALED	For filament mandrels
TYPE 400-H	ANNEALED	For supports, side rods, hooks, etc., in electronic tubes
TYPE 400-R-1	ANNEALED	For supports in incandescent lamps
TYPE 400-R-3	SOFT ANNEALED	For grids in electronic tubes



Each grade in the above table is especially processed for its intended application. Proper care and engineering supervision also are exercised to obtain the requisite degree of annealing, straightness, roundness, etc.

When Type 400 wire is ordered for a particular application, the appropriate one of the above grades will be supplied, unless the order specifies otherwise.

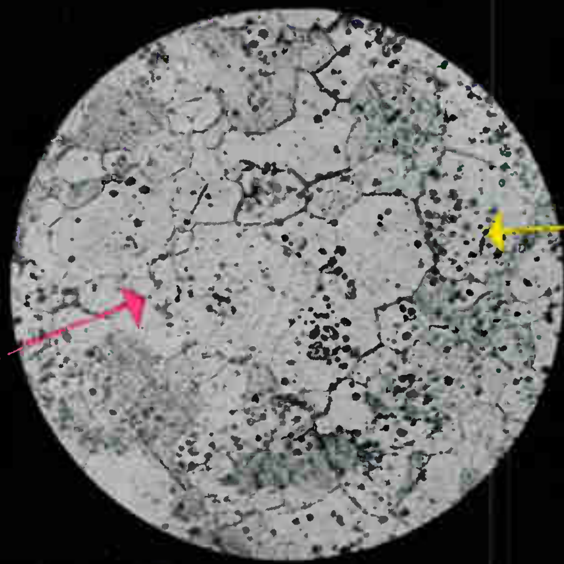
The tables provide data on the relation between weights and diameters of Type 400 pure molybdenum wire.

DIAMETER INCHES	DIAMETER IN APPROX. MILLIMETERS	MILLIGRAMS PER 200 MILLIMETERS	GRAMS PER 1000 METERS *	METERS PER KILOGRAM *
.0015	.0381	2.30	11.40	87145
.002	.0508	4.08	20.40	49019
.0025	.0635	6.38	31.88	31377
.003	.0762	9.18	45.90	21786
.0035	.0889	12.49	62.40	16025
.004	.1016	16.32	81.60	12254
.0045	.1143	20.65	103.20	9689
.005	.1270	25.50	127.50	7843
.0055	.1397	30.85	154.20	6485
.006	.1524	36.72	183.60	5446
.0065	.1645	43.09	215.50	4640
.007	.1778	49.98	249.90	4001
.0075	.1905	57.37	286.80	3486
.008	.2032	65.28	326.40	3063
.0085	.2159	73.69	368.40	2714
.009	.2286	82.62	413.10	2420
.0095	.2413	92.05	460.20	2173
.010	.2540	102.00	510.00	1960
.011	.2794	123.40	617.00	1620
.012	.3048	146.80	734.00	1362
.013	.3302	172.30	861.50	1160
.014	.3556	199.90	999.50	1000
.015	.3810	229.50	1147.00	871
.016	.4064	261.10	1305.50	766
.017	.4318	294.80	1474.00	678
.018	.4572	330.50	1652.50	605
.019	.4826	368.20	1841.00	543
.020	.5080	408.00	2040.00	490
.021	.5334	449.80	2249.00	444
.022	.5588	493.70	2469.00	405
.023	.5842	539.60	2698.00	370
.024	.6096	587.50	2938.00	340
.025	.6350	637.50	3187.00	313
.026	.6604	689.50	3448.00	290
.027	.6858	743.60	3718.00	269
.028	.7112	799.70	3999.00	250
.029	.7366	857.80	4289.00	233
.030	.7620	918.00	4590.00	217

molybdenum wires

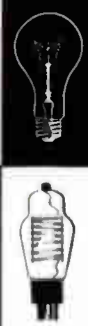
molybdenum alloy wire

By alloying molybdenum with tungsten, characteristics of pure molybdenum can be changed so that it is ideally suited at elevated temperatures for incandescent lamps and electronic tube manufacture. Three such alloys are supplied by the Callite Tungsten Corporation. Where molybdenum-tungsten alloy wires of other compositions may be required for special purposes, Callite is prepared to supply them to your specifications.



TYPE 450 (coarse grain 200X)

THE THREE CALLITE STANDARD MOLYBDENUM–TUNGSTEN ALLOY WIRES ARE: TYPE 410, TYPE 425, TYPE 450.



TYPE 410

A molybdenum-tungsten alloy containing approximately 10% tungsten. It is intended for use where somewhat greater stiffness and strength than is available in pure molybdenum wire of the same size, is desired. The principle application of this alloy wire is for supports, hooks, grids in electronic tubes and incandescent lamps.

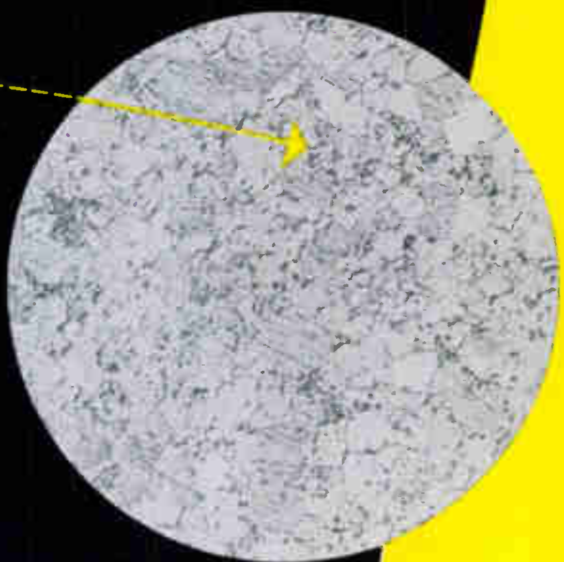
TYPE 425

A molybdenum-tungsten alloy containing approximately 25% tungsten, with the consequent increase in stiffness and strength. Its applications are similar to those for the 410 wire. It can also be used for heater coils in electronic tubes.

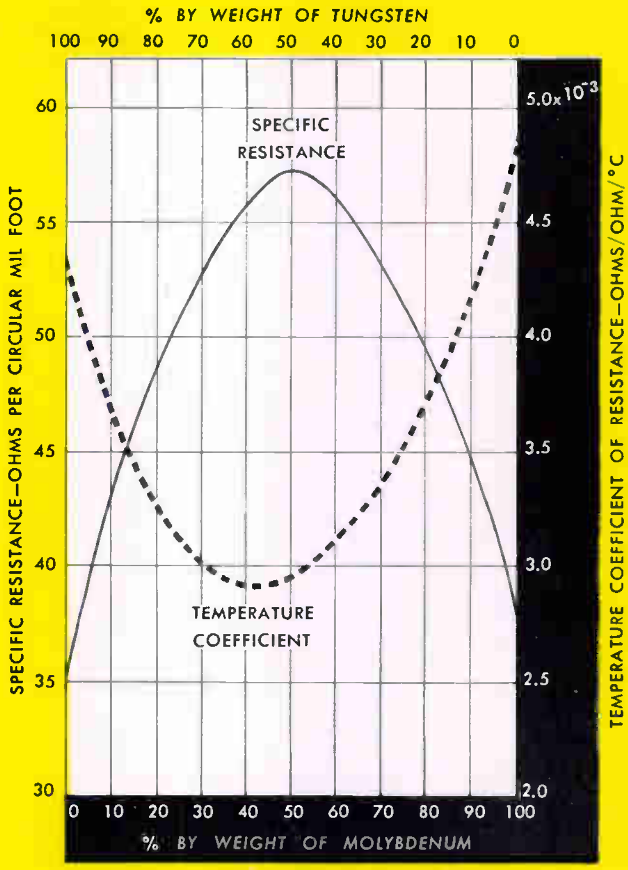
TYPE 450

Similar to Type 425, except that the tungsten content is increased to approximately 50%. This wire finds an important application in heater coils for some electronic tubes. The greater flexibility of this alloy, as compared with tungsten, facilitates coiling. Other applications include its use for supports and hooks in lamps and tubes.

SPECIFIC RESISTANCE AND TEMPERATURE—COEFFICIENT OF MOLYBDENUM—TUNGSTEN ALLOYS



TYPE 450 (fine grain 200X)



To convert ohms per circular mil foot to ohms per cm³ divide the ohms per circular mil foot by 6.05×10^6

For Example:

50 ohms per cir. mil foot $= \frac{50}{6.05 \times 10^6} = 8.3 \times 10^{-6}$ *ohms/cm³*

surface finishes . . .

All grades of Callite molybdenum and Callite molybdenum-tungsten wires normally are supplied with a clean surface finish. Where desired, however, they can be supplied black.

ordering . . .

When specifying, it is important that detailed instructions as to the desired surface finish and temper accompany the order. These instructions may be specified in terms of elongation, tensile strength, or both. When definite specifications are not available, the intended application for the wire should be stated, in order that the proper grade may be supplied. In the case of unannealed wires, if the required surface finish is not specified, black will be supplied.

molybdenum rods

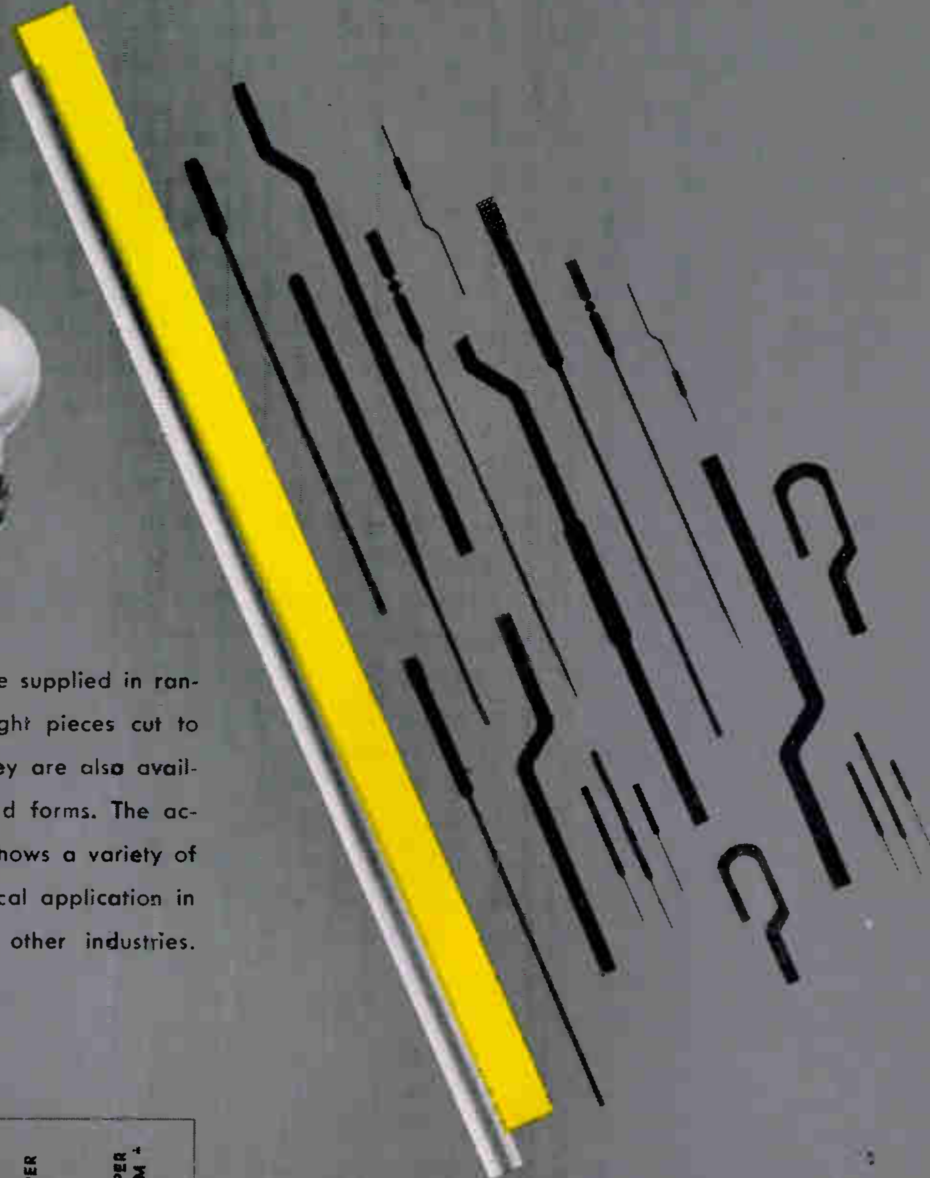
There are many other electronic-tube applications for high-purity molybdenum rods. They are used most extensively in the production of radio tube elements: grids, lead-in wires and supports. Moly rods are also used in the manufacture of electrical contacts.

Callite molybdenum is available in the form of rods, with diameters ranging from .030" to .450" inclusive. This rod can be supplied in the following type variations:

TYPE 400 G: From .030" to .450" Ground Molybdenum Rod (Sealing Quality). Rods of this type are centerless ground to remove all surface imperfections. It has the proper coefficient of expansion to make a vacuum tight seal with hard glass of the Corning 705 AJ type. Rods are square cut to any desired length or supplied in random lengths and are microscopically checked for surface imperfections.

TYPE 400 B: From .030" to .450" Ground Molybdenum Rod (Non-Sealing Quality). For support purposes and other varied applications where accuracy in dimensions is required, this rod maintains its alignment at high operating temperatures.

TYPE 400 E: From .030" to .450" Molybdenum Rod. Furnished with a cleaned or polished surface, used for support purpose.



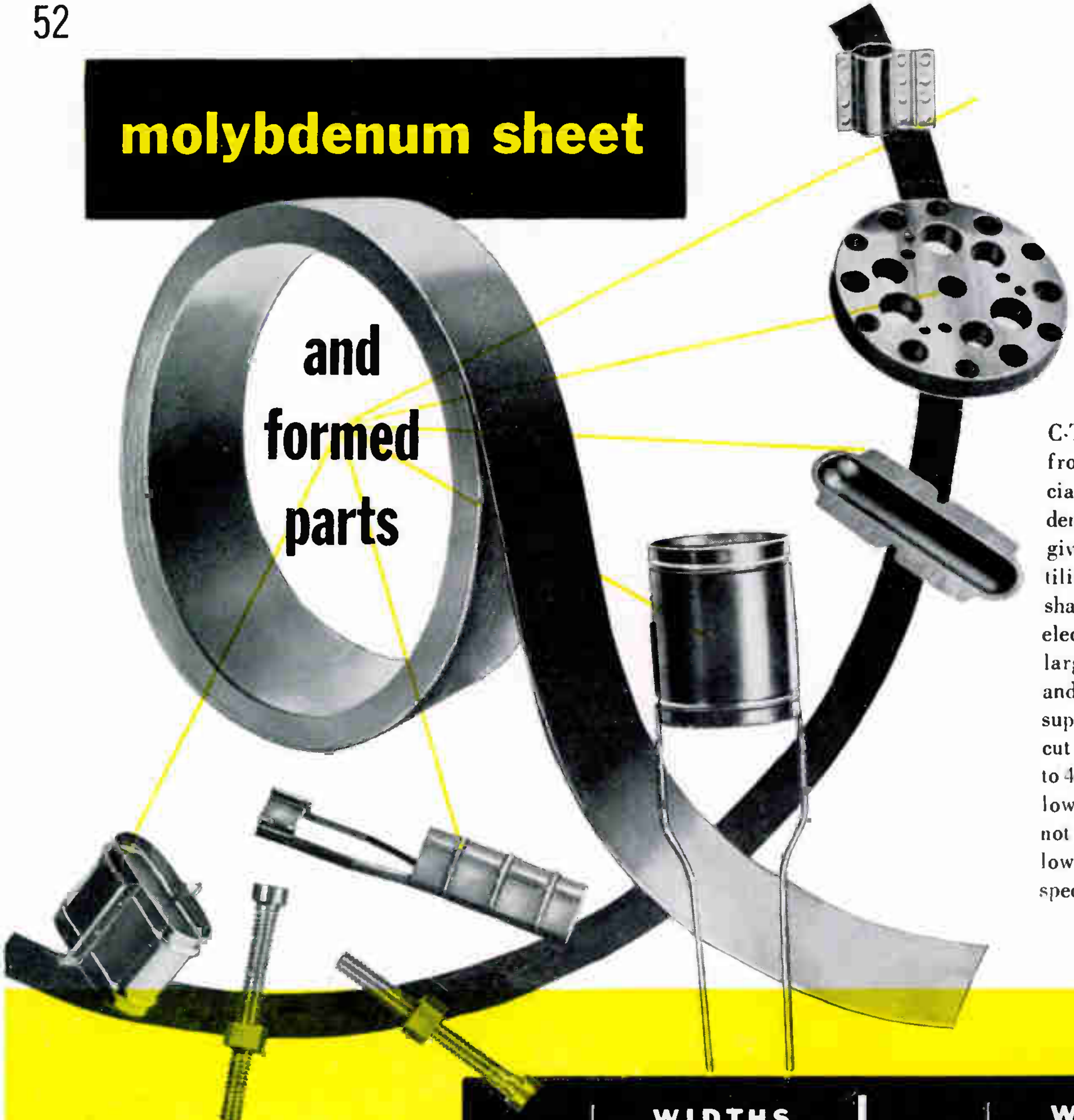
Molybdenum rods can be supplied in random lengths or in straight pieces cut to specified dimensions. They are also available in many shapes and forms. The accompanying illustration shows a variety of shapes which find practical application in the electronic-tube and other industries.

DATA ON MOLYBDENUM ROD

DIAMETER INCHES	DIAMETER IN APPROX. MILLIMETERS	GRAMS PER FOOT *	GRAMS PER METER *	METERS PER KILOGRAM *
.030	.7620	1.39	4.59	217.86
.032	.8128	1.59	5.22	191.57
.034	.8636	1.79	5.89	169.78
.035	.8890	1.90	6.24	160.25
.040	1.016	2.49	8.16	122.54
.045	1.143	3.15	10.32	96.90
.050	1.270	3.89	12.75	78.43
.060	1.524	5.60	18.36	54.47
.070	1.778	7.62	24.99	40.02
.080	2.032	9.95	32.64	30.64
.090	2.286	12.59	41.31	24.21
.100	2.540	15.55	51.00	19.61
.110	2.794	18.81	61.70	16.21
.120	3.048	22.36	73.35	13.63
.125	3.175	24.29	79.69	12.55
.130	3.302	26.28	86.19	11.60
.140	3.556	30.48	99.96	10.00
.150	3.810	34.98	114.75	8.71
.160	4.064	39.80	130.56	7.66
.170	4.318	44.93	147.39	6.78
.175	4.445	47.62	156.19	6.40
.180	4.572	50.38	165.24	6.05
.187	4.763	54.66	179.29	5.58
.190	4.826	56.13	184.11	5.43
.200	5.080	62.19	204.00	4.90
.225	5.715	78.71	258.18	3.87
.250	6.350	97.18	318.75	3.14
.275	6.985	117.58	385.68	2.59
.300	7.620	139.94	459.00	2.18
.350	8.890	190.47	624.75	1.60
.400	10.160	248.78	816.00	1.22
.450	11.430	314.86	1032.75	0.97
.500	12.700	388.72	1275.00	0.78

molybdenum sheet

and formed parts



C-T Moly Sheet is made from a high purity, specially processed molybdenum ingot rolled to give exceptional ductility for formed and shaped parts used in electronic assemblies. A large variety of widths and thicknesses can be supplied in random or cut lengths, from ⅛" to 4½". Thicknesses below .005" and widths not shown in table below can be supplied on special orders.

molybdenum sheet standard widths

THICKNESS	WIDTHS MINIMUM	WIDTHS MAXIMUM	THICKNESS	WIDTHS MINIMUM	WIDTHS MAXIMUM
.500"	½"	1"	.018"	⅛"	4"
.400"	½"	1"	.017"	⅛"	4"
.300"	½"	1"	.016"	⅛"	4"
.200"	½"	1½"	.015"	⅛"	4"
.150"	½"	2"	.014"	⅛"	4"
.125"	½"	2"	.013"	⅛"	4"
.100"	½"	3"	.012"	⅛"	4"
.080"	½"	3"	.011"	⅛"	4"
.070"	½"	3"	.010"	⅛"	4"
.060"	1"	3"	.009"	⅛"	4"
.050"	1"	3"	.008"	⅛"	4"
.040"	1"	3"	.0075"	⅛"	4"
.035"	1"	3"	.007"	⅛"	4"
.030"	1"	3"	.0065"	⅛"	4"
.025"	1"	3"	.006"	⅛"	4"
.021"	⅛"	3"	.0055"	⅛"	4"
.020"	⅛"	3"	.005"	⅛"	4"
.019"	⅛"	4"			

Weight per square inch of sheet .001" thick — 0.167 grams.

other callite products

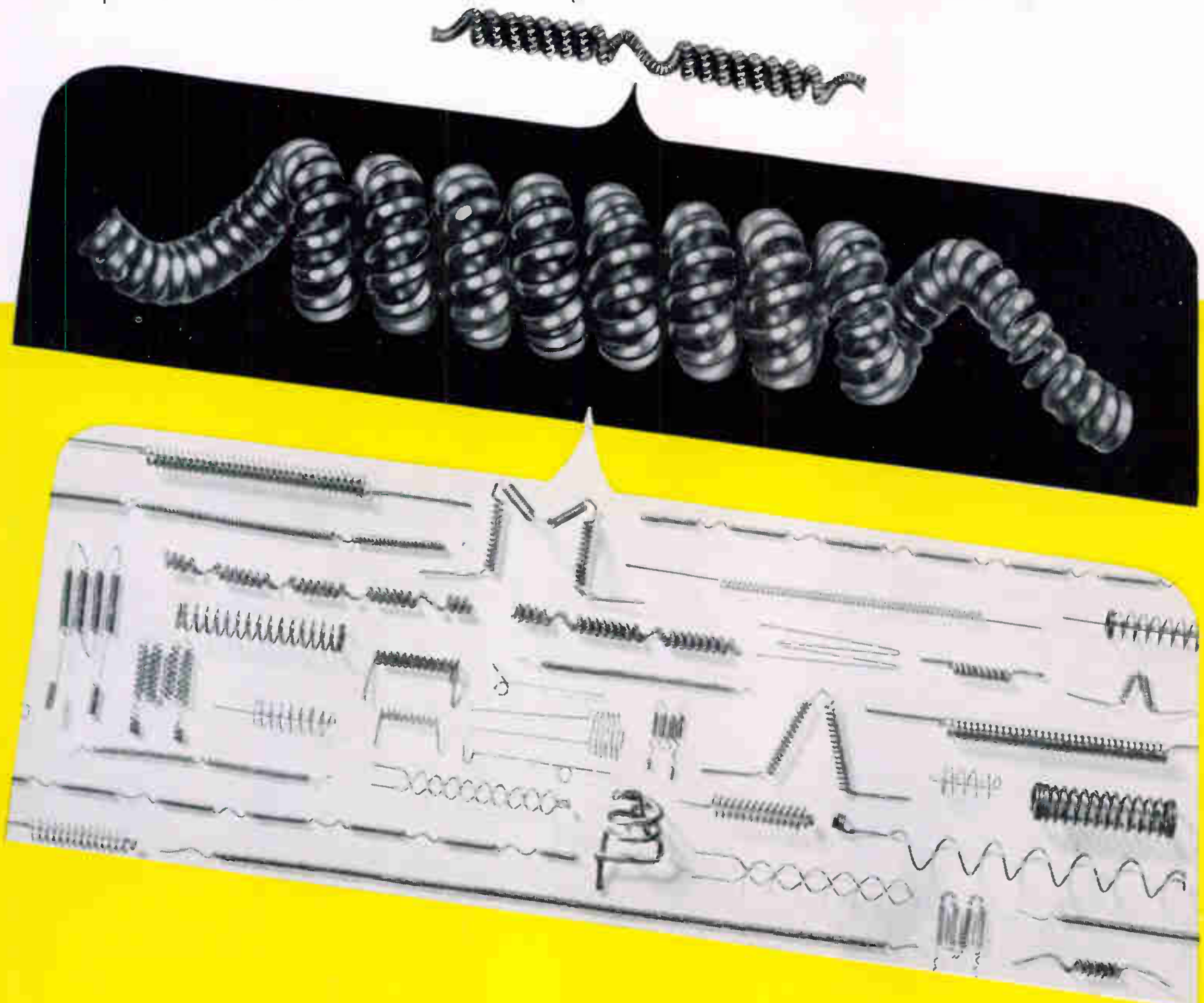
for incandescent and electronic applications

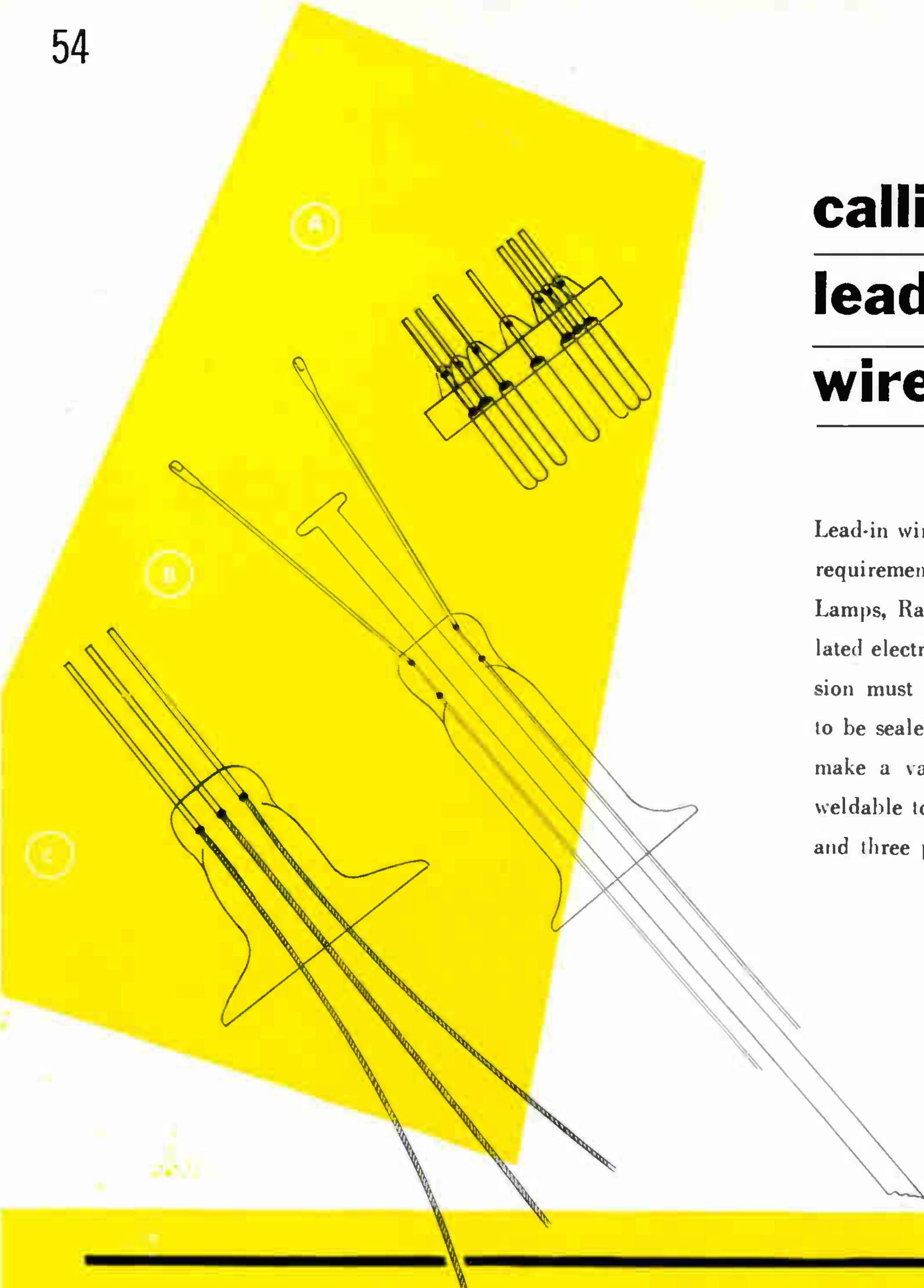
filaments: Callite maintains a fully equipped department for manufacturing tungsten and molybdenum formed parts for electronic tubes and incandescent lamps to your specifications or from Callite's available lamp specifications. A few of these formed parts are illustrated here. The formed parts which Callite manufactures are listed at right:

FILAMENTS FOR INCANDESCENT LAMPS Continuous, gap type, or coiled coil filaments for incandescent lamps are made to standard specifications from 6 to 1500 watts in all voltages. Callite also manufactures filaments for projection lamps, fluorescent lamps, and for metallizing in vacuum.

FORMED FILAMENTS FOR SPECIAL PURPOSE LAMPS Callite manufactures formed filaments for infra-red lamps, ultra-violet lamps and germicidal lamps.

FORMED FILAMENTS FOR ELECTRONIC EMISSION TYPE TUBES Uncoated and coated *M*-shaped filaments; single and double *Helical* filaments; continuous filaments; oxide-coated wire and cathodes; formed and insulated heaters; and spring hooks are manufactured for electronic emission type tubes.





callite lead-in wires

Lead-in wire in unvarying quality is an essential requirement in the production of Incandescent Lamps, Radio Tubes, Neon Signs and other related electronic devices. The coefficient of expansion must be suited to the glass in which it is to be sealed. Its surface must wet the glass and make a vacuum-tight seal. It must be readily weldable to other metals ordinarily used in two and three piece weld construction.

A **RADIO BUTTON STEM**
COPPER CLAD LEADS · SOFT GLASS

B **LAMP STEM**
COPPER CLAD LEADS · SOFT GLASS

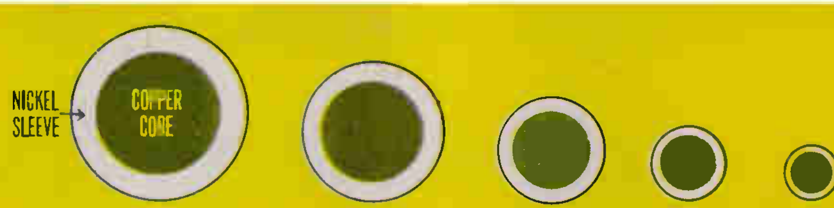
C **ELECTRODE STEM**
SA-50 LEADS · SOFT GLASS

SA-50 ALLOY is a special alloy having physical properties which make it suitable for use as a Lead-in wire through soft glass. It is particularly adaptable for mercury switches, and in places where mercury vapor is present because it does not readily amalgamate with mercury. Available in wire from .008" to .080". Also available in sheet and strip form.

DIAMETER INCHES	DIAMETER M. M.	FEET PER LB.	METERS PER LB.	DIAMETER INCHES	DIAMETER M. M.	FEET PER LB.	METERS PER LB.
.008	.203	5,750	1,750	.028	.711	470	143
.010	.254	3,680	1,120	.030	.761	408	125
.012	.305	2,550	778	.040	1,015	230	70.3
.014	.356	1,878	573	.050	1.27	147	44.8
.016	.406	1,435	438	.060	1.52	102	31.1
.018	.457	1,138	347	.070	1.77	77.5	23.6
.020	.507	920	280	.080	2.03	57.4	17.5
.022	.558	762	232	.090	2.28	49.7	15.1
.024	.610	640	195	.100	2.54	36.8	11.2
.026	.660	544	166				

COPPERCLAD, also known as Dumet, is a copper covered nickel steel wire having the required expansion characteristics for sealing into lead and lime glass. It is drawn to uniform diameter, is soft annealed, and is ordinarily furnished with a borated copper surface. However, for certain applications, an unborated Copperclad, is available.

DIAMETER IN INCHES	DIAMETER MILLIMETERS	FEET PER LB.	METERS PER LB.
.006	0.152	9,720	2962
.007	0.178	7,350	2240
.008	0.203	5,424	1653
.010	0.254	3,472	1058
.012	0.305	2,411	735
.014	0.356	1,771	539
.016	0.406	1,356	413
.018	0.457	1,072	326
.020	0.508	868	264
.025	0.635	556	169
.030	0.762	385	117



kulgrid wire and strand

Kulgrid Wire is available in sizes from .005 and up. Kulgrid strand as described on pages 34 and 35 is available in several sizes as shown in the table below.

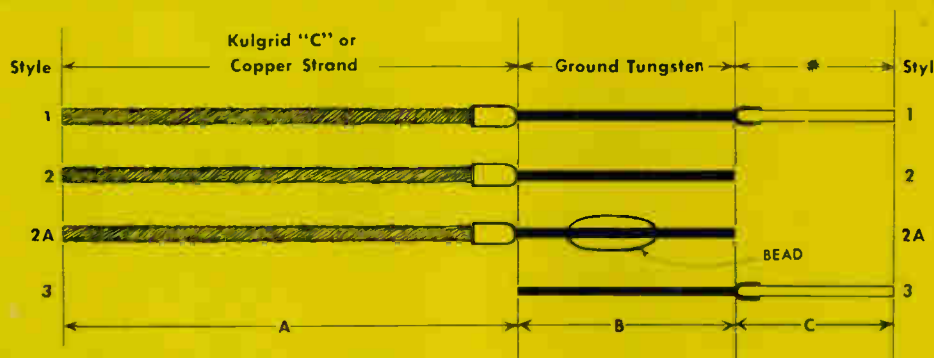
DATA ON KULGRID "C" STRAND			
NO. OF WIRES IN STRAND	DIAMETER EA. WIRE — INCHES	STRAND DIAMETER INCHES	INCHES PER POUND
12	.010	.040	3,260
19	.010	.050	2,080
19	.012	.060	1,415
19	.014	.070	1,130
7 x 6	.010	.090	896
7 x 7	.012	.110	490
7 x 10	.010	.160	240
17 x 31	.006	.190	174
7 x 37	.010	.200	134

Kulgrid wire is available for use as lateral grid supports and other applications where the highly conductive core and the non-corrosive sleeve is of special benefit. Welds readily to itself and to Nickel, Copperclad, Tungsten, Molybdenum and other related metals. Current carrying capacity of Kulgrid wire and strand is approximately 70% of the current carrying capacity of Copper having the equivalent area.

hard glass lead wires

with or without

beads

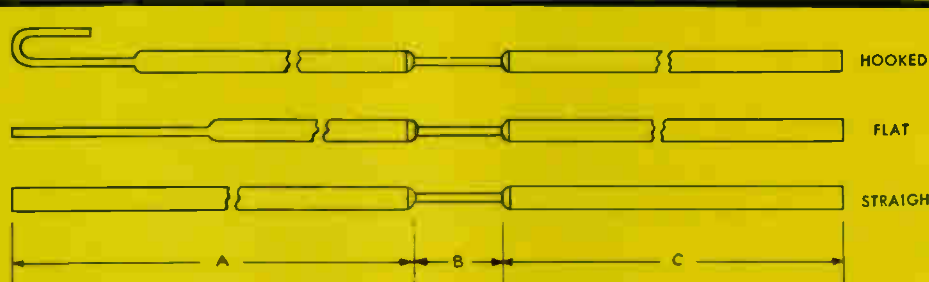


*Kulgrid or Copper Strand, Nickel, Moly, or any other suitable metal.

When ordering give diameter and No. of strands on "A" or give No. of amperes wire is to carry. Unless otherwise noted, length of "B" will be considered as the exposed length. If bead is required give length and position.

soft glass lead wires

made in three styles



These leadwires are supplied either hooked, flat or straight. A can be furnished in Copper, Nickel or Molybdenum; B in Copperclad or SA 50; C in either Nickel, Copper or Kulgrid wire and strand or any suitable related metal. When ordering specify style, length, diameter and material of the various components of the weld.

2 pc. or 4 pc. leadwire can also be furnished. Standard incandescent lamp leadwires are manufactured ranging from 6 Watt to 1500 Watt.

powder metallurgy

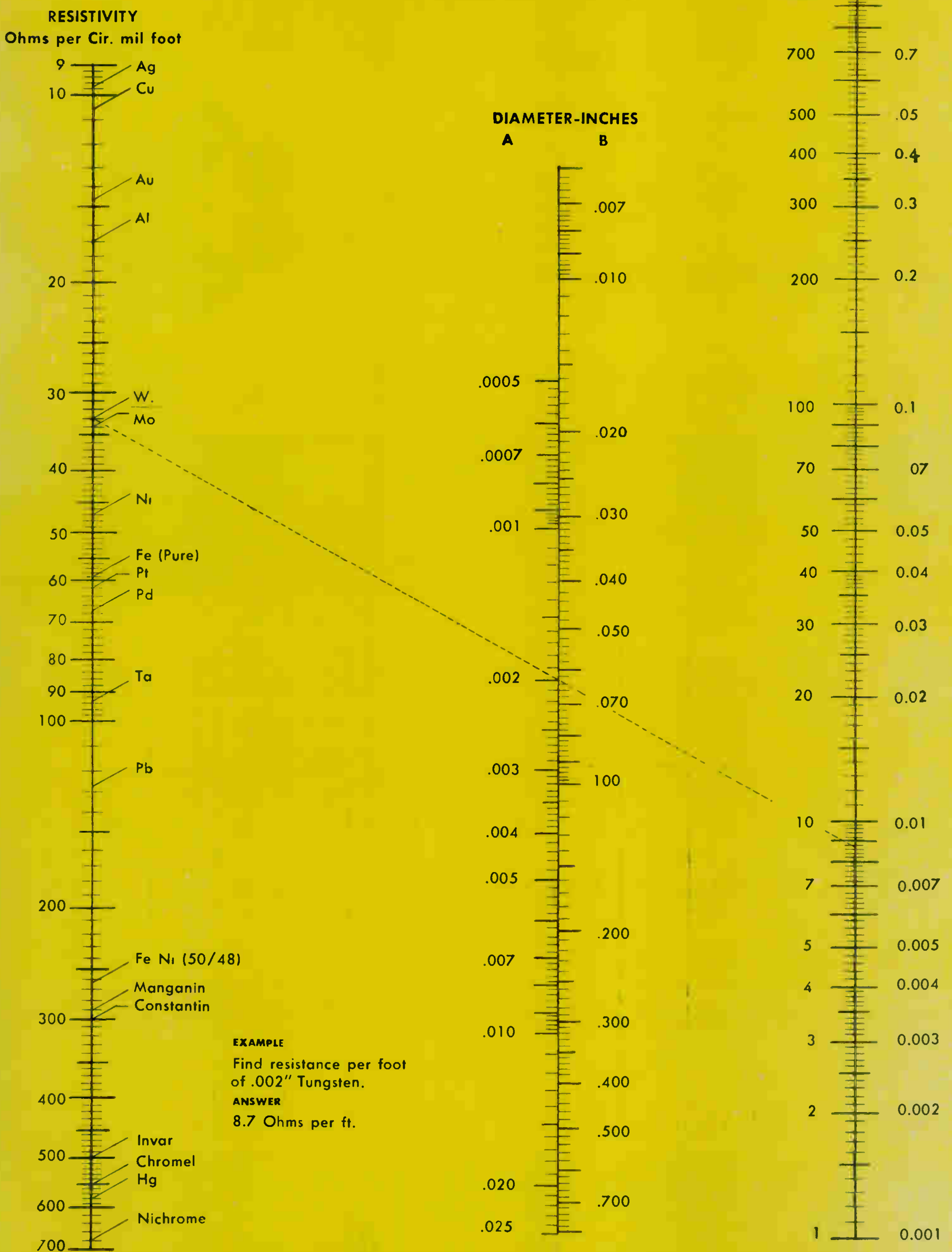
formed parts of tungsten molybdenum and special alloys

Special alloys of tungsten and molybdenum of high density are now available in special shapes, such as those illustrated above. These parts are formed by a newly developed technique of powder metallurgy. Densities are available which approximate the theoretical densities of the pure forged molybdenum or tungsten.

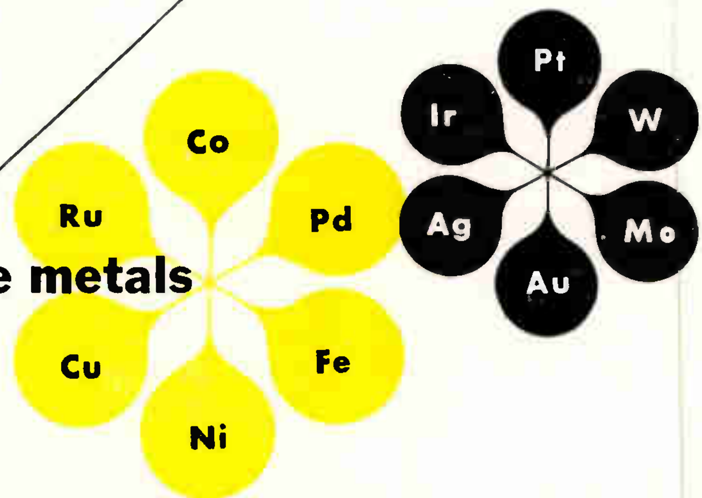
Powder Metallurgy makes possible many alloys and shapes which are not easily available by the usual metallurgical methods of casting and forging. Our laboratory specializes in powder metallurgy using refractory metals and alloys, also combining precious metals with refractory metals. Our broad knowledge and long experience in the problems and manufacturing techniques in this field are reflected in the uniform high quality of these Callite products.

RESISTANCE CHART

(AT 20° C.)



physical properties of pure metals

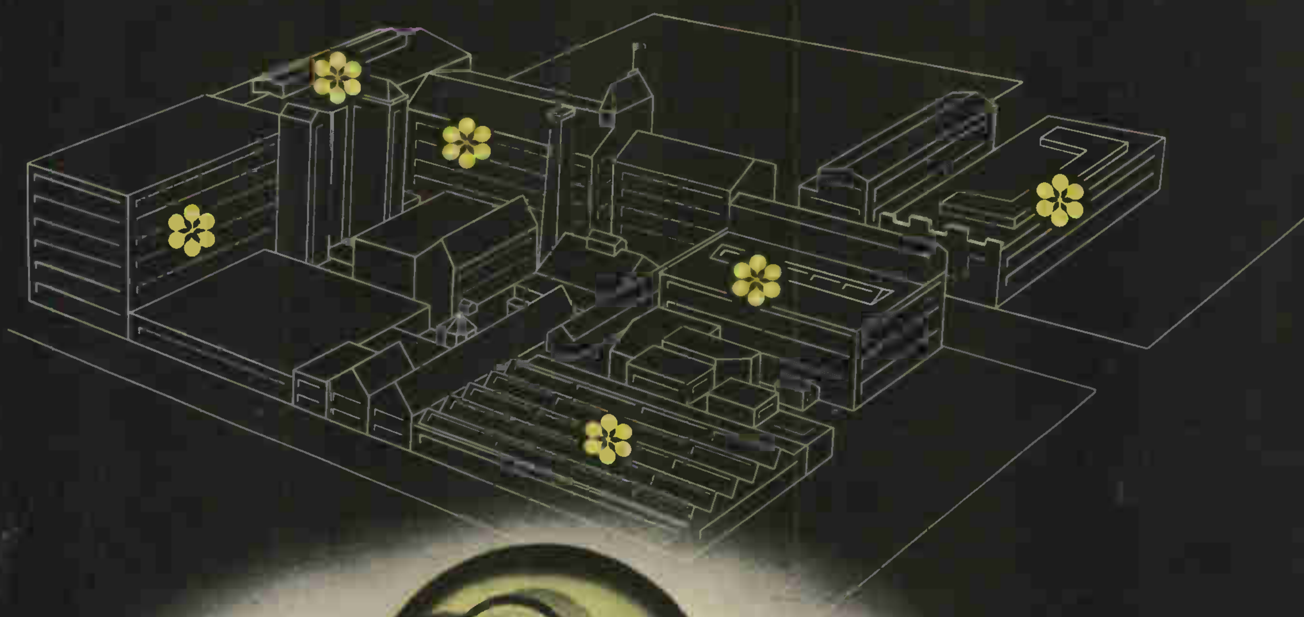


	W TUNGSTEN	Mo MOLYBDENUM	Au GOLD	Ag SILVER	Ir IRIDIUM	Pd PALLADIUM	Pt PLATINUM	Ru RUTHENIUM	Co COBALT	Cu COPPER	Ni NICKEL	Fe IRON
1 Metal												
2 Specific gravity	19.3	10.2	19.3	10.5	22.4	12.0	21.45	12.2	8.9	8.89	8.9	7.86
3 Melting point °C	3370	2620	1063	960	2350	1555	1755	2450	1480	1083	1450	1535
4 Boiling point °C	5900	3700	2600	1950	> 4800	> 3000	4300	> 2700	3100	2300	2900	> 3000
5 Specific heat cal/gm at 20°C	0.034	0.065	0.0310	0.0558	0.0323	0.0538	0.0324	0.0611	0.1001	0.0921	0.1050	0.1075
6 Thermal conductivity watts/cm/°C at 0°C	1.60	1.46	2.96	4.19	0.59	0.67	0.69	....	0.69	3.90	0.59	0.62
7 Coeff. of linear expansion per °C at 20°C (*)	4.0	3.7–5.0	14.2	18.9	6.5	11.8	8.9	9.1	12.3	16.6	12.8	11.7
8 Ultimate Tensile Strength lbs/in² (†)	300–550(1) 140-180(2)	200–350(1) 110-150(2)	35(3)	20 (2)	......	30 (2)	35 (2)	......	96(1)	35 (2)	150 (4)	50–120
9 Hardness B. H. N.	285(1)(5)	147(1)(5)	18(2)(6)	36(2)(6)	172	49(1)(5)	40(2)(6)	220(1)(5)	125(1)(6)	45(2)(6)	(4)(5) 110–300	67–220(9)
10 Specific resistance microhm-cm at 20°C	5.48	5.65	2.4	1.62	6.0	11.0	10.5	......	9.7	1.69	6.9	9.78
11 Coeff. of electl. resistivity per °C at 20°C	0.0045	0.0048(8)	0.004(7)	0.0038	0.0041(7)	0.0038(7)	0.003	......	......	0.0039	0.006	0.0072

(*) All figures are multiplied by 10[illegible]
(†) All figures are multiplied by 10[illegible]

Notes: (1) hard drawn
(2) annealed
(3) pure drawn
(4) cold rolled
(5) 10 mm ball 3000 kg. load
(6) 10 mm ball 500 kg. load
(7) 0 to 100° C
(8) 20 to 2620° C
(9) 5 mm ball 500 kg. load

where callite products are made



On these pages you have met the Callite family of products.

The growth of our physical plant where these products are made has paralleled the growth of the electrical and electronic industries in their steady advance.

We feel, however, that it is not the completeness of our plant alone which is important, but also the men and women within it . . . the Callite team of experienced development and application engineers, metallurgists, executives . . . all the earnest, skillful Callite workers.

We will continue to seek new and better things in metallurgy through investigation and research. We will continue to strive for better production techniques . . . improved products.

We welcome the opportunity to work with you.

Callite Tungsten Corporation • Union City, N. J.

CALLITE TUNGSTEN CORPORATION

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