Oct. 6, 1931. W. B. GERO ET AL 1,826,514

TUNGSTEN AND METHOD OF MANUFACTURING THE SAME

Filed Nov. 26, 1926 4 Sheets-Sheet 1

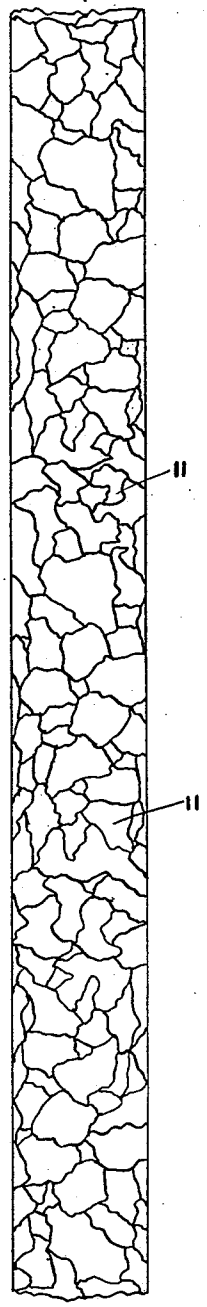

Fig. 1.

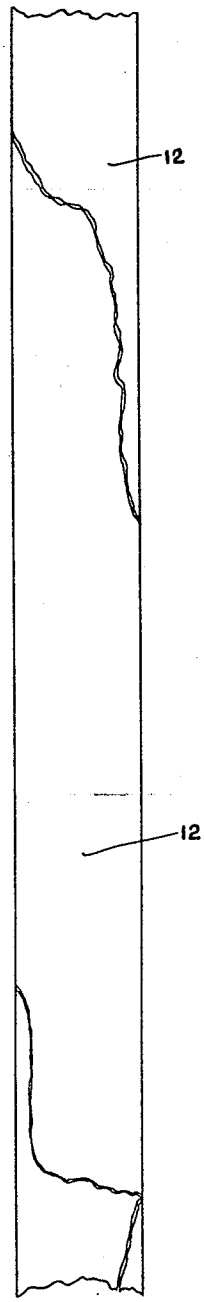

Fig. 2.

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TUNGSTEN AND METHOD OF MANUFACTURING THE SAME

Filed Nov. 26, 1926 4 Sheets-Sheet 2

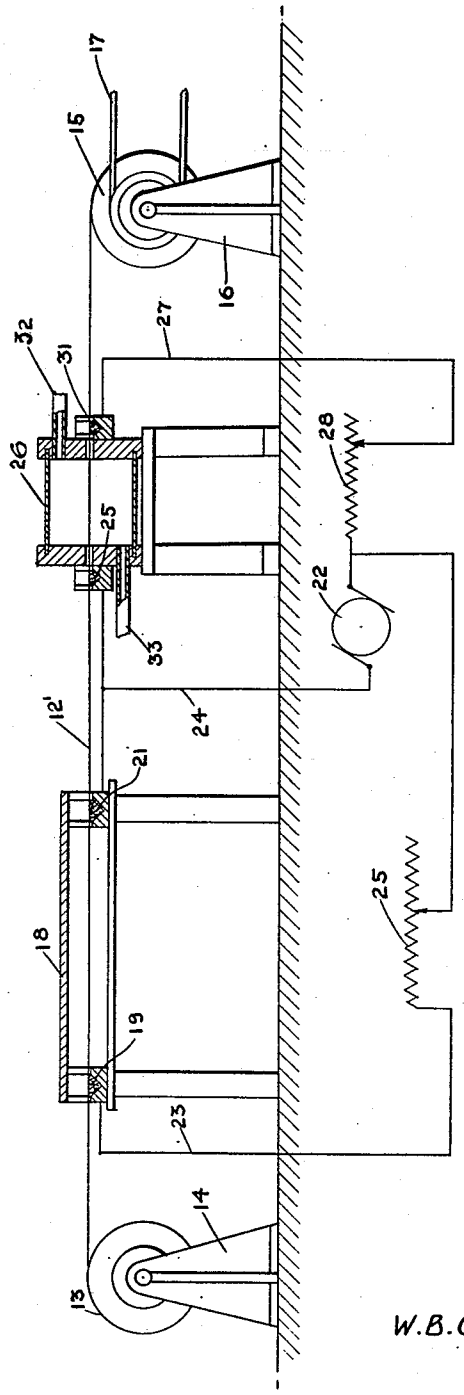

Fig. 3.

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TUNGSTEN AND METHOD OF MANUFACTURING THE SAME

Filed Nov. 26, 1926 4 Sheets-Sheet 3

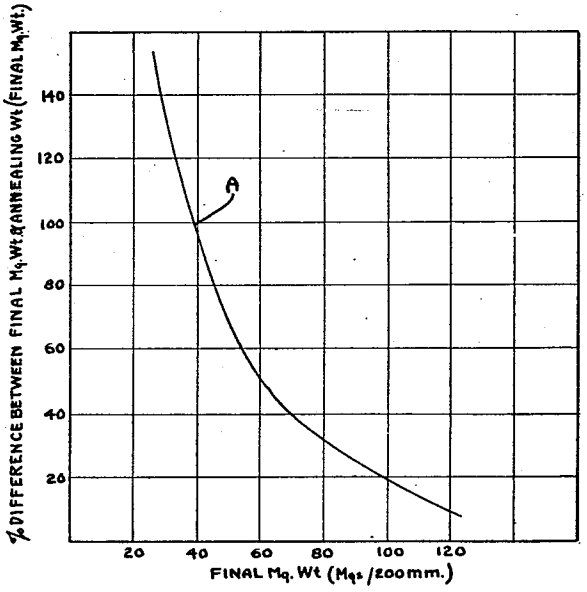

Fig. 4.

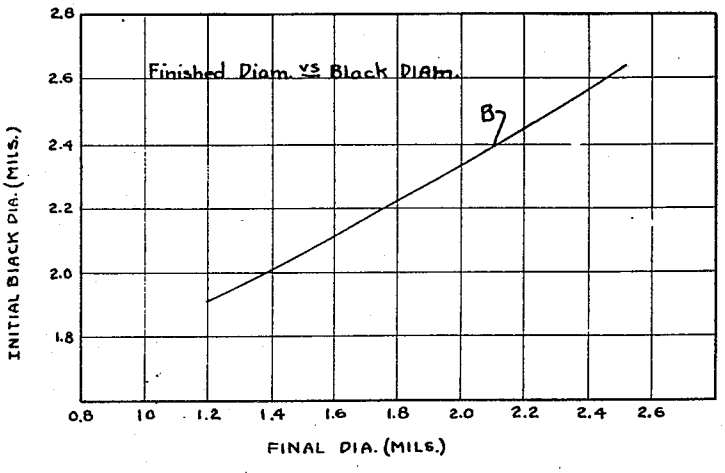

Fig. 5.

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TUNGSTEN AND METHOD OF MANUFACTURING THE SAME

Filed Nov. 26, 1926 4 Sheets-Sheet 4

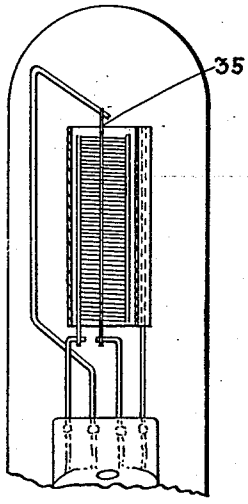

Fig. 6.

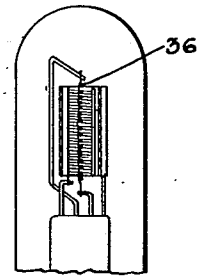

Fig. 7.

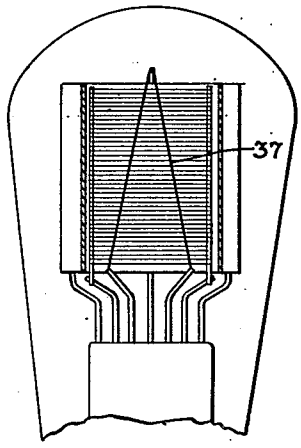

Fig. 8.

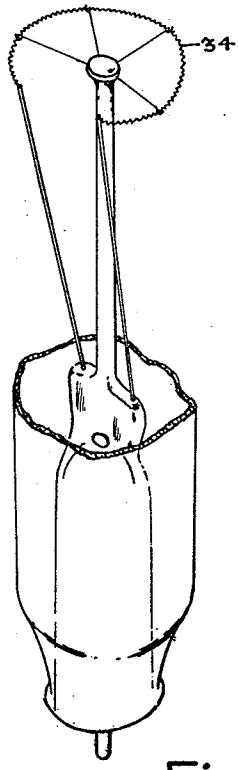

Fig. 10.

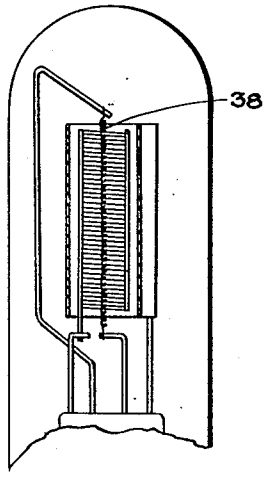

Fig. 9.

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1,826,514

UNITED STATES PATENT OFFICE

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TUNGSTEN AND METHOD OF MANUFACTURING THE SAME

Application filed November 26, 1926. Serial No. 150,763.

This invention relates to filaments for incandescent lamps, power and radio tubes and the like, and more particularly to a filament of a refractory metal, such as tungsten, which may be burned under vibration or shock conditions without detrimental sagging or offsetting.

The concentrated type of filament formed by coiling a fine wire of tungsten or similar material into a small helix is preferred in many types of lamps and is found more desirable generally for certain types of incandescent lamps and similar devices which employ a gaseous environment.

Thoriated tungsten filaments, when employed in such lamps, are burned at a much higher temperature than in the vacuum type of lamp and have been found in the past to become less efficient after a comparatively short period of operation. This loss in efficiency has been primarily occasioned by the filament sagging which results in the turns of the helix being spread apart, thus permitting a more rapid cooling action to take place.

In order to prevent this phenomenon of sagging from occurring, the filament has been improved to the extent that structurally, the crystals are large and arranged in overlapping and interlocking relation. A filament of this type is said to be resistant to sagging and is formed of substantially pure tungsten. However, when a lamp containing a non-sag filament is burned under shock or vibratory conditions without certain constructional features in the lamp to prevent the shock or vibration from reaching the filament, the life of the coil filament is relatively short, due to sagging or other phenomena taking place.

It has been found that thoriated tungsten filaments which contain from ¾% to 1% of thoria, and which are extensively employed in vacuum lamps, resist vibration and shock much better than the non-sag type of filament but cannot be coiled into such small helices as the non-sag wire. Furthermore, when such filaments are coiled and burned at the temperatures prevailing in gas-filled lamps, a slow progressive sagging takes place as a result of the small crystal structure thereof. In addition, an offset crystal structure forms which under vibratory conditions, causes failures to occur.

The present invention contemplates the formation of a thoriated tungsten filament containing the customary percentages of thoria (about 1%) which may be readily formed into helices of small diameter and which possesses an exaggerated or large crystal structure similar to that prevalent in the non-sag type of filament. We have found that our filament is resistant to substantial sagging and offsetting under vibratory and shock conditions and is capable of being burned a commercially useful life.

We have further found that thoriated tungsten filaments manufactured in accordance with our process possesses the unique property of deformation when cold even in extremely small diameter filament sizes. The fact that this property manifests itself is novel in filament manufacture and furthermore enables one to produce exceedingly small sized coils of thoriated tungsten wire without heating the wire during the coiling operation. Filaments of this type are useful not only in the lamp art, but also find utility in the manufacture of radio tubes, particularly that type which employs as the electron-emitting element a tungsten, thorium-activated filament, i. e., a thoriated-tungsten filament having a so-called surface layer of thorium metal, the latter serving as the source of electrons. By reason of our invention, it is now possible to manufacture radio tubes of much smaller sizes and to employ in the various types of tubes a coiled filament which by merely regulating the pitch of the coils or spacing thereof determine the effective length of the filament so as to fit any given size tube. Such an adaptation of coiled thoriated filament wire contributes materially to the standardization of various types of radio tubes.

Therefore, it is an object of our invention to provide a wire of tungsten or similar refractory metal which can be coiled into a very small helix and burned at high temperatures under shock and vibratory conditions without substantial sagging or offsetting during a commercially useful life.

Another object of the invention is to provide a thoriated tungsten filament containing about one per cent of thoria which may be readily coiled cold into small helices.

Another object of our invention is to provide a tungsten filament containing about one percent of thoria which has a large crystal structure.

A further object of our invention is to provide a method of treating regular thoriated tungsten filaments so as to render the same resistant to substantial sagging and offsetting when burned under vibratory and shock conditions.

A further object of our invention is to provide a method of developing in a thoriated tungsten filament a large crystal structure.

A still further object of our invention is to provide a thoriated tungsten filament in the form of a small coil which may be increased in length at will so as to provide different length filaments or cathodes for a standard line of radio tubes.

Other objects of our invention will become apparent as the following description is read in connection with the accompanying drawings in which:

Fig. 1 is a longitudinal sectional view of a recrystallized thoriated tungsten filament illustrating the usual crystal structure thereof;

Fig. 2 is a longiturinal sectional view of a recrystallized thoriated tungsten filament treated in accordance with our invention and showing the exaggerated crystal structure obtained thereby;

Fig. 3 is a vertical sectional view of the annealing apparatus;

Fig. 4 is a graph showing a curve resulting from plotting the finished milligram weight as abscissæ against the percentage difference between finished milligram weight and selected or initial milligram weight as ordinates;

Fig. 5 is a graph showing a curve obtained by plotting as abscissæ the final diameter in mils of the filament against the size of the filament in mils which would be selected for annealing as ordinates;

Fig. 6 is a vertical sectional view of a standard radio tube of the UV or UX—199 type.

Fig. 7 is a vertical sectional view of a radio tube of the UV or UX—199 type employing a coiled thoriated tungsten filament manufactured in accordance with our invention;

Fig. 8 is a vertical sectional view of a standard radio tube of the UX—201—A type.

Fig. 9 is a vertical sectional view of a radio tube of the UX—201—A size employing a coiled thoriated tungsten filament manufactured in accordance with our invention and illustrating the novel construction made possible by the employment of such a filament; and,

Fig. 10 is a vertical sectional view of a standard incandescent electric lamp employing a cold coiled thoriated tungsten filament of relatively small diameter which is resistant to shock and vibration without substantial sagging or offsetting.

We have discovered that an exaggerated crystal structure may be obtained in a thoriated tungsten filament which is comparable to that obtained by the use of certain alkaline earth or alkali metal compounds when employed in the production of what is commonly termed in the lamp industry as non-sag wire. The discovery is the result of a large number of experiments conducted on thoriated tungsten filaments and a study of their crystal structure after the filaments have been subjected to various treatments.

In the course of our experiments and study of the crystal structure. we have determined that there is a definite law governing the development of crystals in thoriated tungsten filaments. This law is that for a desired finished size of filament in which a large crystal structure is to be had, it is essential to anneal and work the wire a definite amount, such treatments being performed with an initial size wire selected in accordance with the finished size desired.

We have taken thoriated tungsten wires varying in size and annealed the same and then mechanically worked them to different sizes and after heating the same to at least about the temperature at which rapid grain growth takes place have obtained in such wires a crystal structure which is markedly different from that ordinarily obtained in the same wire when fabricated in accordance with the usual commercial processes.

Our invention briefly stated, resides in the discovery that a marked improvement may be made in the properties of a regular thoriated tungsten filament which enables the same to be coiled cold at extremely small sizes and which causes the filament, when burned at elevated temperatures or when heated to at least about the temperature at which rapid grain growth takes place, to have an exaggerated or a large overlapping crystal structure similar to that present in regular non-sag wire formed of substantially pure tungsten metal. These unusual properties are developed in the filament by a specific mode of treatment which latter, concisely stated, comprises first selecting a filament of thoriated tungsten at a definite size larger than the final size desired, annealing the filament and mechanically working the same by drawing through dies or otherwise to the desired final size. It has been found that the annealing treatment reduces the tensile strength of the filament, but that the subsequent mechanical working restores to a considerable extent, this tensile strength. At the same time, this mode of treatment changes the properties of the

filament in such manner that it may be readily deformed cold by bending or otherwise so that it may be formed into coils of small diameter without fracturing the filament. Furthermore, the inherent nature of properties of the filament are such that when the filament is heated to about the temperature at which rapid grain growth takes place, an exaggerated crystal structure is formed. Although no single theory adequately accounts for the unique properties imparted by our process to thoriated filaments, we believe it is a result of putting the wire in a state of critical strain, and that this condition is responsible for the various phenomena exhibited by wires so treated. Repeated experiments have demonstated that thoriated tungsten filaments produced in accordance with our invention possess certain inherent properties which are not present in regular thoriated tungsten filaments.

In accordance with a specific embodiment of our invention a tungsten filament containing from ¾ to 1 percent of thorium oxide, manufactured in accordance with the usual standard processes in which the additive material is incorporated in the tungsten metal oxide prior to reduction, is so conditioned that instead of the resultant filament having a fine crystal structure 11, Fig. 1, it has an exaggerated or large overlapping crystal structure 12, Fig. 2, similar to the crystal structure present in the non-sag wire now in use and also possessing the ruggedness and resistance to crystal growth after the crystals are once formed which is a characteristic property of thoriated tungsten filaments. This change in the crystal structure is effected by modifying the inherent characteristics or properties of the filament by suitable heat-treatment at proper wire sizes followed by a definite and predetermined amount of mechanical working.

The selection of the wire at a definite size above the final size constitutes an important discovery as we have determined from numerous experiments that unless such procedure is followed the ultimate result is not obtainable. The results of our experiments have been plotted and curves obtained thereby which may be followed in practicing our invention. In Fig. 4, the curve "A" is obtained by plotting as ordinates the percentage difference between the final milligram weight and the initial or annealing milligram weight of the wire against the final milligram weight as the abscissæ. By milligram weight is meant the weight in milligrams of a 200 millimeter length of wire.

A simpler curve B and one more readily understood by the layman is that shown in Fig. 5. In this figure the curve is obtained by plotting as ordinates the annealing or initial size in mils of the wire against the final size in mils of the wire. For example, if it is desired to know at which size to anneal the wire in the case where the final size of wire desired is 2 mils it is merely necessary to follow vertically the ordinate corresponding to the 2 mil size to the point where it intersects the curve and then determine the value of the horizontal line meeting this intersection. In the case given, this would be about 2.33 mils. Therefore, the initial or annealing size would be about 2.33 mils.

Having determined the initial or annealing size in the manner indicated, the wire 12′ (Fig. 3) is subjected to the following process.

The selected size of wire on a spool or reel 13 is placed upon suitable supports 14, and the free end thereof attached to a spool or reel 15 mounted on suitable supports 16, the spool being rotated at a suitable speed by a belt 17. The rate at which the wire is moved governs, in addition to the temperatures used in heating the wire, the degree of heat treatment given the wire.

In heat-treating the wire, we prefer first to subject the same to a preliminary heating in air or under oxidizing conditions, although this step is not essential and may be dispensed with. This preliminary heating is accomplished by passing the wire through a preliminary heating chamber 18, about twenty-five inches in length, having electrical contact cups 19 and 21 of mercury. These contact cups are connected to any suitable source of electrical energy 22 by conductors 23 and 24, a resistance 25 being connected in circuit to regulate the current passing through the circuit. The heating current may be passed through the wire 12′ when the latter makes contact with the mercury cups and the resistance 25 is properly adjusted.

The wire is preferably heated in the preheating chamber to a dull red heat, or below, and this temperature is maintained constant throughout the passage of the wire through the preheater.

The wire is then directly passed through an annealing furnace 26, heat being applied by passage of a direct current of electricity through the wire. The current is applied through a circuit 27 connected with a source of energy 22 and resistance element 28, and mercury contact cups 29 and 31, with which the wire being treated makes contact. The resistance 28 is so adjusted as to maintain the temperature of the wire at about a white heat. We have found that with a distance of 6 inches between the contacts 29 and 31 and a voltage between the contacts of from 65 to 70 volts, a wire ranging from 9.67 to 10.02 milligrams per 200 mm. in weight becomes satisfactorily annealed if the speed at which the wire is drawn through the box is about 21.5 meters per minute. A low tension of about 20 grams should be maintained or just sufficient tension to keep the wire taut. Through-

out the annealing of the wire a constant stream of hydrogen is kept flowing through the annealer by means of the conduits 32 and 33, the rate of flow being approximately 4 to 5 cubic feet per hour in an annealer 6 inches between contacts.

We have found that the anneal given the wire is satisfactory in the cited case as well as others if the tensile strength of the wire after annealing has been reduced at least about thirty percent. The duration of the annealing treatment as well as the temperature at which the annealing is performed, may be varied with different sizes and character of wire as long as the foregoing result as to diminution in tensile strength is obtained. The wire when it comes from the annealer is bright and metallic in appearance.

The next step after the wire has been annealed is to mechanically work the wire to the final size. This may be done in any one of several ways but we prefer to first coat the wire with a suitable drawing lubricant and pass the same through diamond dies.

We have found that thoriated wire, treated in accordance with the above-described method, is more readily coiled than similar wire when not given such a treatment. Furthermore, such treatment has made it possible to produce small coils from thoriated tungsten wire of less than a mil in diameter by winding the same about a mandrel without the wire being heated.

Numerous experiments and tests made by us have demonstrated that the inherent properties of the metal have been changed to such an extent that the metal is capable of being deformed without exhibiting any detrimental cracks. Furthermore, the improvement made is further indicated by the change in crystal structure which takes place when the wire is heated to at least about the temperature at which rapid grain growth takes place. This crystal structure consists of exaggerated or long overlapping crystals similar to that obtained in non-sag tungsten wire. Our filaments, however, possess the additional desirable property of ruggedness and resistance to further crystal changes after the desired long, overlapping structure has been formed. We attribute this resistance to further crystal growth to the equilibrium established.

Our improvement has found utility in incandescent lamps which are burned under such conditions that the filament is subject to vibration and shock, and has enabled the production of relatively small lamps, such as the 25 watt size, with coiled thoriated tungsten filament. A lamp of this general nature is illustrated in Fig. 10, in which a non-sag and vibration resistant thoriated tungsten filament 34 is shown. It is to be noted that this lamp is of the usual lamp design and does not employ any special form of mount in order to prevent the shocks from being transmitted to the filament.

Another utility for which our invention is capable is illustrated in Figs. 6 through 9. In Fig. 6 a type of radio tube known as UV or UX—199 is illustrated. The filament in such tubes is of straight or uncoiled thorium 35 activated tungsten. By reason of our filament the over-all dimensions of this design of tube can be materially reduced by merely substituting a coiled filament 36 (Fig. 7) for the straight filament, it being appreciated that the same length of wire in the form of a coil occupies considerably less space linearly. Heretofore, such a tube has not been possible, owing to the inability of coiling a thoriated tungsten filament of relatively small diameter.

Furthermore, the present design of UV—201—A radio tube which employs an uncoiled V-shaped filament 37 (Fig. 8) can be modified so that a tube can be formed giving the same electron current by merely substituting a coiled tungsten filament 38 (Fig. 9), of shorter over-all length but having the same effective length from the electron emission standpoint. The tube may be further modified by reason of the employment of such a filament, by using a cylindrical envelope, plate and grid, similar to the present design of UV—199. A standard line of tubes may thus be obtained.

Although a specific mode of treatment and particular ingredients have been described, it is believed that those skilled in the art may modify the same, however, such modifications are contemplated by us as come within the scope of our invention as defined by the appended claims.

What is claimed is:

1. The method of treating drawn thoriated tungsten filament so that the same is inherently capable of exaggerated grain growth, when incandesced to elevated temperatures, which comprises annealing the filament to a white heat under slight tension at a definite size larger than the final size and then mechanically working the filament to the final size.

2. The method of rendering a thoriated tungsten filament inherently capable of exaggerated grain growth when heated to at least about the temperature at which rapid grain growth takes place which comprises annealing under slight tension a selected size of drawn filament larger than the desired final wire size but in definite relation thereto until its tensile strength has been appreciably decreased and then mechanically working the wire to the final size.

3. The method of forming a coil type incandescent lamp filament from drawn thoriated tungsten filament less than 2.0 mil diameter which comprises annealing said filament during the drawing operation at a size larger

than the desired finished size of said filament but in definite relation thereto, to a tensile strength approximately 70 per cent of the tensile strength prior to annealing, then continuing the drawing operation to the desired finished size, and thereafter forming said coil without the application of heat.

4. The method of forming a coil type incandescent lamp filament comprised of tungsten containing approximately 1.0 per cent thorium oxide having an enlarged elongated overlapping crystal structure substantially resistant to sag and offsetting under vibration conditions, which comprises annealing said filament a predetermined amount at a size larger than the desired finished size but in definite relation thereto, drawing said filament to the desired finished size, forming said coil without the application of heat, and thereafter heating said filament to elevated temperatures approximating the zone of rapid grain growth to form the desired enlarged crystal structure therein.

5. The method of forming a shock and vibration resistant filament comprised of tungsten containing from .75 to 1.0 per cent thorium oxide, which comprises imparting to said filamentary body during the drawing process a predetermined amount of working by means of an annealing step followed by a drawing step, said annealing step being applied at a wire size in fixed size relation to the size obtained from said following drawing step, and thereafter forming said drawn filament in any desired shape without the application of heat thereto, and after incorporating into a lamp, heating said filament at elevated temperatures substantially equal to the temperature of rapid grain growth of the cold worked metal body to form the desired elongated, overlapping crystal structure therein.

In testimony whereof, we have hereunto subscribed our names this 22nd day of November 1926.

WILLIAM BENJAMIN GERO.
EDMUND SHARINGTON DAVENPORT.