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ELECTRICAL MAKE-AND-BREAK CONTACTS

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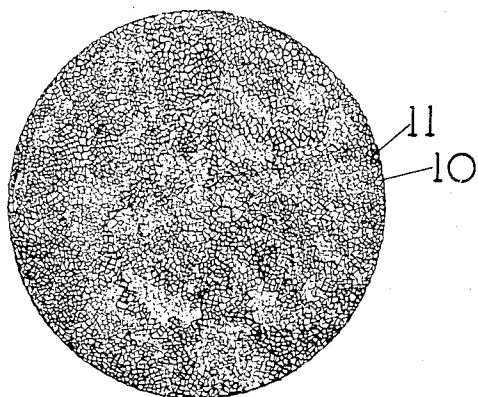


Fig. 1 (x 1000)

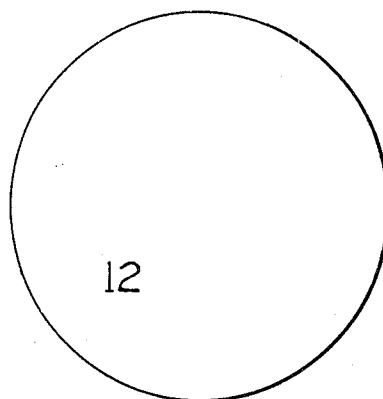


Fig. 2 (x 100)

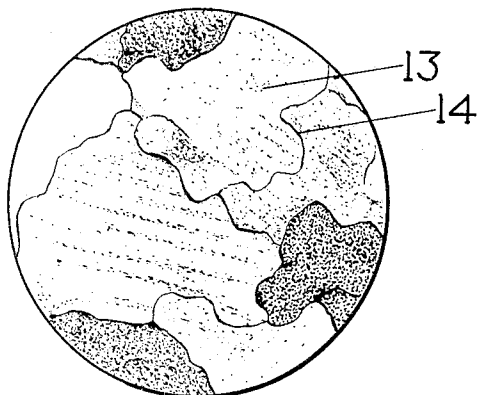


Fig. 3 (x 100)

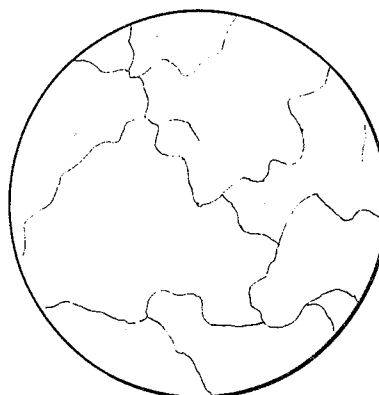


Fig. 4 (x 100)

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ELECTRICAL MAKE-AND-BREAK CONTACT

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18 Claims. (Cl. 204—1)

This invention relates to electrical make-and-break contacts, and more particularly to electrical make-and-break contacts of tungsten.

Primary objects of the invention are the provision of electrical make-and-break contacts having generally improved characteristics, and of methods of forming and treating them.

More specifically, objects of the invention are the provision of contacts of this kind wherein certain of the difficulties which have heretofore caused the failure of such contacts in service are obviated or minimized, and which operate in an improved manner, have longer life under given service conditions than was attainable with contacts hitherto used, are capable of carrying and breaking larger currents than has heretofore been possible while still maintaining satisfactory service life, have a decreased arcing tendency, give superior performance at high and low operating speeds, and have improved contact resistance characteristics during performance.

The invention further contemplates, among other objects, the provision of electrical make-and-break contacts in which the evolution of any oxide coating on the contact surface into more harmful or troublesome types of oxides is substantially obviated or postponed, and wherein the deleterious effects usually incident to arcing are pronouncedly reduced, and pitting of the contact faces, fusion and transfer of material from co-operating contacts are eliminated to a very substantial degree under the conditions to which such contacts are ordinarily subjected.

A further object of the invention is the provision of a tungsten contact and method of treating it, wherein and whereby the usual body structure is so modified as to have improved working characteristics throughout and to present at the contact face a minimum amount of the substance or substances which adversely affect the efficient functioning of the contact.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the several steps and the relation of one or more of such steps with respect to each of the others, and the article possessing the features, properties, and the relation of elements, which are exemplified in the following detailed disclosure, and the scope of the application of which will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention reference should be had to the following detailed description taken in con-

nection with the accompanying drawing, in which:

Fig. 1 illustrates a portion of the contact face of a typical tungsten contact such as has heretofore been used, magnified 1,000 diameters;

Fig. 2 illustrates a portion of the contact face of a tungsten contact embodying certain features of the present invention, magnified 100 diameters.

Fig. 3 illustrates a portion of the contact face of a tungsten contact modified in accordance with one aspect of the present invention, magnified 100 diameters; and

Fig. 4 illustrates a portion of the contact face of a tungsten contact modified in accordance with another aspect of the present invention, magnified 100 diameters.

Heretofore electrical make-and-break contacts of tungsten have been extensively used in various applications, of which the use in automobile ignition systems may be taken as representative. Such contacts up to the present time have been customarily made of wrought tungsten, either by sawing contact discs from a wrought tungsten rod, or by punching them from a rolled tungsten sheet.

Such contacts develop a number of faults in service. For example, the repeated breaking of current which is required results in periodic arcing, attended with transfer of metal from one co-operating contact to the other, with consequent pitting of one contact face and building up of projections on the other. Also, the continued transfer of material from one contact to another often brings about a localization of the contact area, with a resultant increase in current density at such restricted area of contact. This condition, in the case of prior contacts, renders more pronounced the deteriorating action of the arc. The transfer of material under these circumstances sometimes becomes so great that a sufficient amount thereof is built up on one of the make-and-break contacts to prevent the breaking of the circuit by separation of the contacts. In addition, blue or brown oxides often form on the contact faces, increasing the contact resistance. Such factors of deterioration bring about the ultimate failure of the contacts and determine their useful service life.

Also, contacts of the kind heretofore generally used in automobile ignition systems have been subject to certain drawbacks at low starting speeds, and at high operating speeds.

Previous contacts have been characterized by the fact that an increase in the amount of current broken at their faces hastens their deteriora-

tion. Consequently the permissible current densities and amperages which have heretofore been usable in ignition and similar make-and-break systems have been restrictively limited to an amount commensurate with satisfactory service life of the contacts. That is, with contacts of the type hitherto in general use, unless the contact surface was comparatively large, and the amperage comparatively low, the service life of the contacts was unduly shortened.

A proper understanding of these shortcomings in prior contacts, and of the nature of the present invention whereby such unsatisfactory characteristics are eliminated or greatly mitigated, calls for consideration of the microstructure of the contact metal. To study the microstructure the contact surface is polished and then lightly etched with a suitable chemical reagent which serves to develop the grain structure and the boundaries between the grains. The drawing forming a part of this application is a representation of the various structures shown under the microscope.

Microscopic examination of the surface of the best prior art tungsten contacts, as illustrated in Figure 1, shows the presence of very fine grains, in the neighborhood of 30,000 per square millimeter, each of which is surrounded and separated from adjacent grains by material characterized by properties different from those of the main body of the metallic grains. Throughout this specification and in the accompanying claims, such material will be referred to as material in the grain boundary condition, whether it is produced in the course of grain structure formation and actually defines the surfaces of the several grains, or is produced in the working of the contact metal, as by swaging, rolling, grinding, punching, sawing and the like.

Wrought tungsten, though actually fibrous in structure, ordinarily appears to be granular in its microstructure on traverse sections, the grains being quite minute and separated from each other by definite boundaries 11, as shown in Figure 1. The material of the grains 10 is also in the strain-hardened state, which in some ways simulates the grain boundary condition. The tungsten contact points which, prior to the present invention, have given best performance in service, have been made by sawing discs from wrought tungsten rod which has been produced and worked in such a way as to have a minimum of 10,000 grains per square millimeter exposed on the working surface of the contact. (See S. A. E. Handbook, 1930, p. 559). Such contacts have been found to give very uniform and more satisfactory results than contacts having somewhat larger grains, e. g., about 2,500 grains per square millimeter. As shown in Figure 1, the linear length of the grain boundaries 11 (and the material in the grain boundary condition) exposed on the working surface of such contacts is large in proportion to the surface area of the contacts, and in addition the strain-hardening of the material of the grains 10 may contribute to the amount of material in the grain boundary condition.

It has been found that the material in the grain boundary condition is much more active physically and chemically than the material at the center of the grains. Whether this be due to greater concentration of impurities at the grain boundaries or to amorphous condition of the grain boundary material, or to some other cause, is not as yet positively established. But whatever may be its precise nature, this material

in the grain boundary condition has properties different from those of the grains themselves.

Many observations of make-and-break contacts of tungsten of the types heretofore generally used, have indicated that the effects of deterioration in actual service manifest themselves first and more markedly at the grain boundaries separating the individual grains in the working surface of the contact. It appears that the material in the grain boundary condition has lower resistance to the deteriorating influences imposed under service conditions than has the material comprising the grain proper. It volatilizes more readily than the material of the grains themselves, and these facts together with the other properties peculiar to it, appear to be largely responsible for the arc deterioration and other faulty characteristics of contacts heretofore used. In accordance with the principles of the present invention these faults are substantially eliminated, or at least are markedly ameliorated, and electrical make-and-break contacts of tungsten are produced which, among other advantages, are capable of much longer and more uniform service, have a greater resistance to shattering at high speeds, and are capable of carrying and breaking much larger currents with a satisfactory service life than previous contacts of the same size.

In general, these desirable results are accomplished by treating the contact material in such ways that the grain size is materially increased and/or the material in the grain boundary condition exposed on the working surface of the contact is reduced to a commercially practicable minimum. This may be done in a number of ways as will hereinafter appear.

In contrast with the best practice prevailing up to the time of the present invention, it has now been found that superior contacts are produced by making the grains on the working surface very much larger and thus reducing the proportion of material in the grain boundary condition exposed on the working surface toward a minimum.

In one embodiment of the present invention, the material in the grain boundary condition exposed on the working surface of a contact is substantially eliminated by making the contact in the form of a so-called "single crystal" of tungsten. Such single crystal bodies may, for example, be conveniently developed by crystal growth around a single crystal wire, although other methods may be used if desired.

Such single crystal bodies have been found to be admirably suited for use as electrical make-and-break contacts. After the formation of a slug or bar of single crystal tungsten, it may be sawed or cut into individual contact points, which may be secured to suitable supports in any well-known manner, as for instance, by copper brazing in hydrogen. The working surface of a contact point so formed is substantially free from grain boundaries and hence substantially free from the deterioration attributable to the material in the grain boundary condition, except as a slight amount of such material may in certain cases be produced in the sawing operation. This embodiment of the invention is illustrated in Figure 2 of the drawing wherein 12 denotes the single crystal tungsten substantially free from grain boundaries.

As another embodiment of the present invention, electrical make-and-break contacts may be made in such a way that they are composed of a relatively small number of comparatively large

grains of tungsten, as shown particularly in Figure 3 of the drawing, wherein 13 represents the grains proper, and 14 represents the material in the grain boundary condition.

5 In the embodiment of the invention shown in Figure 3, the tungsten contact point has a grain count as low as or even lower than twenty grains per square millimeter exposed on the working surface. The linear length of the grain boundaries in such a contact surface is less than two per cent. of the length of the grain boundaries in the best contacts of the prior art as shown in Figure 1.

10 Thus the ratio of material in the grain boundary condition to material of the grains proper exposed on the working surface of the contact is minimized. A tungsten body characterized by this changed relationship is admirably fitted for use as a contact. As the material of the grain proper is less readily deteriorated than the material in the grain boundary condition, this reduction of the amount of the latter material accomplishes results in increasing the service life of the contact points which have hitherto been unattainable.

15 Tungsten contacts having these large grains may be formed by the following method, although it is to be understood that the present invention is not limited thereto, but contemplates the provision of large grain tungsten contacts, however produced.

20 The contact material is first worked as by swaging, drawing, rolling, or the like, into the desired shape, which may be in the form of a rod, sheet, or any other suitable form. It is then retreated at a temperature approaching its fusion point in a reducing or neutral atmosphere such as hydrogen, helium, argon, etc., or in a vacuum. More particularly this may be done, for example, by placing suitably worked material such as a tungsten rod in an atmosphere of hydrogen and passing an electric current through it so as to raise its temperature nearly to its fusing point. The amount of current, time, and rate of heating are dependent upon the amount and character of mechanical working to which the contact material has been previously subjected. Ordinarily, good results are obtained by gradually increasing the current to a maximum value ranging from 80 to 90% of the amperes required to fuse the tungsten rod, and then maintaining the current at this value for a short period, such as, for example, five to fifteen minutes. The current is then reduced rapidly to zero and the rod allowed to cool to a temperature at which it will not be seriously oxidized on exposure to air. The retreated rod may then be cut or otherwise formed to the desired shape and size.

25 Alternatively, contact discs may be formed from tungsten rod or tungsten sheet, placed in a tungsten tube, and then retreated at high temperatures in a reducing or neutral atmosphere as described above, by passing electric current through the tungsten tube.

30 The tungsten contact discs thus produced are found to have a microstructure of the type illustrated in Figure 3 in which the grains 13 exposed on the working surface are of large size and the length of the grain boundaries 14 has been substantially reduced, so that the ratio of material in the grain boundary condition to material in the grains proper is substantially reduced. It will thus be apparent that the ideal condition would be the entire absence of grain boundaries. However, the characteristic advantages attendant upon the present invention are

assured by the provision of working surfaces having grain counts up to about 1,000 grains per square millimeter, a grain count of the order of twenty-five grains per square millimeter, however, being preferred. Such discs may be secured to suitable supports by any of the well known methods, as for example by copper brazing in hydrogen.

35 The present invention also contemplates another method of treatment which, among other results, accomplishes the reduction of the proportion of material in the grain boundary condition exposed on the working surface of the contact and imparts improved characteristics to tungsten contacts, which treatment is applicable either to ordinary tungsten contacts such as shown, for example, in Figure 1, or to large grain tungsten contacts prepared as above described and particularly shown in Figures 2 and 3.

40 In carrying out the method embraced in this aspect of the invention, contact discs of wrought tungsten which have been prepared in any of the ways practiced prior to the present invention or in the ways described above, and which have been secured to a suitable support such as a rivet or screw of ferrous metal by any suitable method, as for example, by copper brazing in hydrogen, are connected as the anode in a direct current electrical circuit in a suitable electrolyte and are subjected therein to a process of electrolytic conditioning. A solution of potassium hydroxide in water is a suitable electrolyte for this purpose. Another and an excellent electrolyte comprises sodium hydroxide and sodium tungstate dissolved in water. Potassium or sodium carbonate or bicarbonate may also be used. Other hydroxides, carbonates, and tungstates may be substituted for the potassium or sodium compounds specifically mentioned; but an electrolyte which has been found to produce satisfactory results is made up as follows:

	Parts by weight
Sodium hydroxide	40
Sodium tungstate	4
Water	1,000

45 The cathode in the electrical circuit in the electrolyte may be of copper. Tungsten, carbon and various other materials are also suitable for use as a cathode. Any desired number of contact discs may be electrically connected as the anode in the electrolyte and subjected to the electrolytic conditioning at one time.

50 While the composition of the electrolyte, the voltage applied, and the duration of the treatment, may be varied within wide limits, very satisfactory results have been obtained by electrolytic conditioning of the tungsten contacts in a bath of the composition given above for a period of 45 seconds with a direct current potential difference between the anode and the cathode of 110 volts.

55 For most effective results, the contact discs of wrought tungsten should be mounted upon their supports before being subjected to the electrolytic conditioning, for if the contact discs are first electrolytically conditioned and thereafter attached to their supports, the mounting operation seems to affect adversely the beneficial results brought about by the electrolytic conditioning.

60 Tungsten contacts electrolytically conditioned as above described, are found to have a brightness and smoothness which they did not possess

prior to the electrolytic treatment. Microscopic study of the changes which occur on the surface of the contact discs indicates that the first effect of the electrolytic conditioning is to eliminate the shading of the different grains exposed in the surface which appears when the contact is subjected to the ordinary chemical etching processes commonly used for the study of the structure of metals under the microscope. At this stage of the electrolytic conditioning the grain boundaries are quite clearly defined. As the electrolytic conditioning progresses the grain boundaries become less and less evident and the exposed surfaces of the individual grains become smoother. When the electrolytic conditioning proceeds still farther, the grain boundaries become very faint, and some of them become almost indistinguishable; and the exposed surfaces of the individual grains are noticeably smoothed out. Fig. 4 illustrates the microstructure of the electrolytically conditioned working surface of a contact disc having prior to such electrolytic treatment a microstructure of the type illustrated in Fig. 3.

Tungsten contacts of the types heretofore used are markedly improved by subjection to electrolytic conditioning as described above in respect of their satisfactory life under service conditions, their resistance to formation of deleterious oxides in service, their decreased arcing tendency, their lower rate of transfer of metal from one contact to the opposing contact under operating conditions, their lowered contact resistance, and their increased effectiveness at low starting speeds and at high operating speeds, and their decreased tendency to shatter at high operating speeds.

Large grain tungsten contacts made in accordance with the present invention, when electrolytically conditioned as described above, possess to an enhanced degree these desirable characteristics.

Tungsten contacts which have been electrolytically conditioned as described above, have been found to be somewhat harder on the working surface than similar contacts which have not been electrolytically treated. For example, standard contacts of the prior art show a hardness of 71 or 72 on the Rockwell "C" scale with a 60 kg. load, whereas similar contacts electrolytically treated as described above show a hardness of 73 or 74.

The explanation as to why the electrolytic conditioning described above produces the results which have been observed, is not entirely clear, and it is therefore not desired to limit this specification to any particular theory.

As instances of the improved results which are obtained with different embodiments of the present invention, the following are cited:

Single crystal tungsten contacts described above having one-fourth the surface contact area of the fine grain tungsten contacts of the prior art have been found to operate satisfactorily at the same voltage and amperage as the prior art tungsten contacts, and for a longer service life. In other words, the single crystal tungsten contacts are capable of operating at approximately four times the current density of the prior art contacts, with an increased service life. Single crystal tungsten contacts of the present invention tested against fine grain tungsten contacts of the prior art of the same surface contact area and under identical conditions of voltage and current density have shown an increase of fifty per cent. or more in useful service life. They possess lower surface

contact resistance and permit the passage of twenty per cent. or more current both at low starting speeds and at high engine speeds.

Large grain tungsten contacts of the present invention having grain counts of from twenty to thirty grains per square millimeter exposed on the working surface have been found to possess a useful service life twenty per cent. greater than the best fine grain tungsten contacts of the prior art under identical operating conditions. Moreover, such contacts exhibit marked improvement in starting characteristics. In practice, the starting characteristics of contacts for automobile ignition systems are estimated in accordance with the surface contact resistance to the passage of current, measured in terms of the millivolt drop across the contacts with five amperes of electric current flowing. The large grain tungsten contacts of the present invention are found to have a lower surface contact resistance than the best tungsten contacts of the prior art; and in many instances this has been found to be as low as one-half of the surface contact resistance of the best prior art tungsten contacts.

In addition large grain tungsten contacts of the present invention .150" in diameter have been found to be capable of satisfactory operation at 8.25 volts and 6.00 break amperes, making and breaking the circuit 2,200 times per minute, with a useful service life of more than 100,000,000 makes and breaks; whereas the best prior art contacts cannot be operated satisfactorily beyond 8.25 volts and 4.9 to 5.6 break amperes, and then only with a shorter useful service life. Such contacts have a contact surface area of approximately 11.4 square millimeters and are thus seen to be capable of carrying and breaking a current in excess of one-half ampere per square millimeter of contact surface area. The contacts with which the above results were obtained had a grain count of approximately 25 grains per square millimeter exposed on the working surface, or a total of approximately 276 grains. Thus it will be seen that these contacts have for each ampere of current carrying capacity for which the contacts are designed, of the order of 50 grains on the working surface.

Fine grain tungsten contacts of the prior art when electrolytically conditioned in accordance with the present invention, are found to show an improvement of thirty per cent. or more in starting characteristics over the same contacts not electrolytically conditioned. They are also capable of satisfactory operation at engine speeds of from 200 to 300 revolutions per minute greater than the same contacts not electrolytically conditioned. After 1176 hours of operation, these contacts show a surface contact resistance measured in terms of millivolt drop of less than thirty per cent. of that of similar contacts not electrolytically conditioned which had been in operation only 600 hours.

Since certain changes may be made in the contacts and in the processes of manufacture described above without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described and all statement of the scope of the invention which as a matter of language might be said to fall therebetween.

Having described my invention, what I claim as new and desire to secure by Letters Patent is:

1. An electrical make-and-break contact having a tungsten face substantially freed from material in the grain boundary condition by subjecting the tungsten face as an anode to the passage of current in an electrolyte including one or more of the hydroxide, carbonate and tungstate compounds of the alkali metals.
2. An electrical make-and-break contact having a tungsten face substantially freed from material in the grain boundary condition by a heat treatment to insure a grain growth resulting in a grain count of less than 1,000 grains per square millimeter on the tungsten face and an electrolytic treatment in an electrolyte adapted to reduce the material in the grain boundary condition and produce a hard, smooth working surface when the tungsten face of said contact is subjected as an anode to the passage of electric current in the electrolyte.
3. An electrical make-and-break contact having a face comprising a single tungsten crystal electrolytically conditioned in an electrolyte adapted to reduce the amount of materials deleterious to efficient operation and produce a hard, smooth working surface when said face is subjected as an anode to the passage of current in the electrolyte.
4. An electrical make-and-break contact having a tungsten face with a grain count of less than 1,000 grains per square millimeter on the working surface and substantially freed from material in the grain boundary condition and other materials deleterious to efficient operation by subjecting the tungsten face as an anode to the passage of electric current in an electrolyte adapted to reduce the amount of such materials and produce a hard, smooth working surface.
5. An electrical make-and-break contact having a tungsten face substantially freed from material in the grain boundary condition by a heat treatment to insure a grain growth resulting in a grain count of the order of twenty-five grains per square millimeter on the working surface and an electrolytic treatment in an electrolyte adapted to reduce the material in the grain boundary condition and produce a hard, smooth working surface when the tungsten face of said contact is subjected as an anode to the passage of electric current in the electrolyte.
6. An electrical make-and-break contact having a hard, smooth face of tungsten substantially freed from material in the grain boundary condition by subjecting the tungsten face as an anode to the passage of electric current in an electrolyte adapted to reduce the amount of such material and produce a hard, smooth working surface.
7. An electrical make-and-break contact of tungsten having a grain count of less than 1,000 grains per square millimeter on the working surface, said working surface being a hard, smooth tungsten face substantially freed from material in the grain boundary condition by subjecting the tungsten face as an anode to the passage of electric current in an electrolyte adapted to reduce the amount of such material and produce a hard-smooth working surface.
8. An electrical make-and-break contact having a hard, smooth tungsten face with a grain count of the order of twenty-five grains per square millimeter on the working surface, said working surface being electrolytically conditioned by subjecting the tungsten face as an anode to the passage of electric current in an electrolyte adapted to reduce the amount of material in the grain boundary condition and produce a hard, smooth working face.
9. The method of making electrical make-and-break contacts of tungsten comprising electrolytically conditioning the working surfaces of the tungsten contacts by subjecting the working surfaces thereof as anodes to the passage of electric current in an electrolyte adapted to reduce the amount of material in the grain boundary condition and other materials deleterious to efficient operation and produce hard, smooth working surfaces.
10. The method of making electrical make-and-break contacts of tungsten comprising electrolytically conditioning the working surfaces of the contacts after attachment to supports by subjecting the mounted working surfaces as anodes to the passage of electric current in an electrolyte adapted to reduce the amount of material in the grain boundary condition and other materials deleterious to efficient operation and produce hard, smooth working surfaces.
11. The method of making electrical make-and-break contacts of tungsten, comprising electrolytically conditioning the working surfaces of the tungsten contacts by subjecting them as anodes to the passage of electric current in an electrolyte including one or more of any of the hydroxide, carbonate and tungstate compounds adapted to reduce the amount of material in the grain boundary condition and other materials deleterious to efficient operation and produce hard, smooth working surfaces.
12. The method of making electrical make-and-break contacts of tungsten, comprising electrolytically conditioning the working surfaces of the contacts by subjecting them as anodes to the passage of electric current in a solution containing sodium hydroxide, sodium tungstate and water.
13. The method of manufacturing electrical make-and-break contacts of tungsten, comprising heat treating the contact material to insure a grain growth resulting in a grain count of less than 1,000 grains per square millimeter in a face adapted to form the working surface of a completed contact to decrease material in the grain boundary condition, and electrolytically conditioning the working surfaces of the contacts by subjecting the working surfaces as anodes to the passage of electric current in an electrolyte adapted to reduce the amount of material in the grain boundary condition and other materials deleterious to efficient operation and produce hard, smooth working surfaces.
14. The method of manufacturing electrical make-and-break contacts of tungsten, comprising heating the contact material under non-oxidizing conditions to a temperature slightly less than its fusion temperature, maintaining said temperature for a period of time, allowing the material to cool to a predetermined temperature at which it will not be seriously oxidized upon exposure to the air, forming contacts therefrom and electrolytically conditioning the working surfaces of said contacts by subjecting the working surfaces as anodes to the passage of electric current in an electrolyte adapted to reduce the amount of material in the grain boundary condition and other materials deleterious to efficient operation and produce hard, smooth working surfaces.
15. The method of manufacturing electrical make-and-break contacts of tungsten comprising

heat treating the tungsten to minimize material in the grain boundary condition by structural reorganization, and electrolytically conditioning the working surfaces of the contacts by subjecting the working surfaces as anodes to the passage of electric current in an electrolyte adapted to reduce the amount of material in the grain boundary condition and other materials deleterious to efficient operation and produce hard, smooth working surfaces.

16. A method of manufacturing electrical make-and-break contacts of tungsten, comprising heat treating the contact material to insure a grain growth resulting in a grain count of the order of about twenty-five grains per square millimeter in a face adapted to form the working surface of a completed contact to decrease material in the grain boundary condition, and electrolytically conditioning the working surface of the contact by subjecting the working surface as an anode to the passage of electric current in an electrolyte adapted to reduce the amount of material in the grain boundary condition and other materials deleterious to efficient operation and produce a hard, smooth working surface.

17. The method of making electrical make-and-break contacts which comprises heating wrought tungsten under non-oxidizing conditions to a temperature slightly less than its fusing point, maintaining said temperature for a period of time, and then allowing the material to cool rapidly to a predetermined temperature

at which it will not be seriously oxidized upon exposure to the air to insure a grain of growth resulting in a grain count of less than 1,000 grains per square millimeter in a face adapted to form the working surface of a completed contact and electrolytically conditioning the working surface of each contact by subjecting the working surface as an anode to the passage of electric current in an electrolyte adapted to reduce the amount of material in the grain boundary condition and other materials deleterious to efficient operation and produce a hard, smooth working surface.

18. The method of making electrical make-and-break contacts which comprises heating wrought tungsten under non-oxidizing conditions to a temperature slightly less than its fusing point, maintaining said temperature for a period of time, and then allowing the material to cool rapidly to a predetermined temperature at which it will not be seriously oxidized upon exposure to the air to insure a grain growth resulting in a grain count of the order of twenty-five grains per square millimeter in a face adapted to form the working surface of a completed contact and electrolytically conditioning the working surface of each contact by subjecting the working surface as an anode to the passage of electric current in an electrolyte adapted to reduce the amount of material in the grain boundary condition and other materials deleterious to efficient operation and produce a hard, smooth working surface.

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