L. & H. L. BRADLEY.

RESISTANCE DEVICE.

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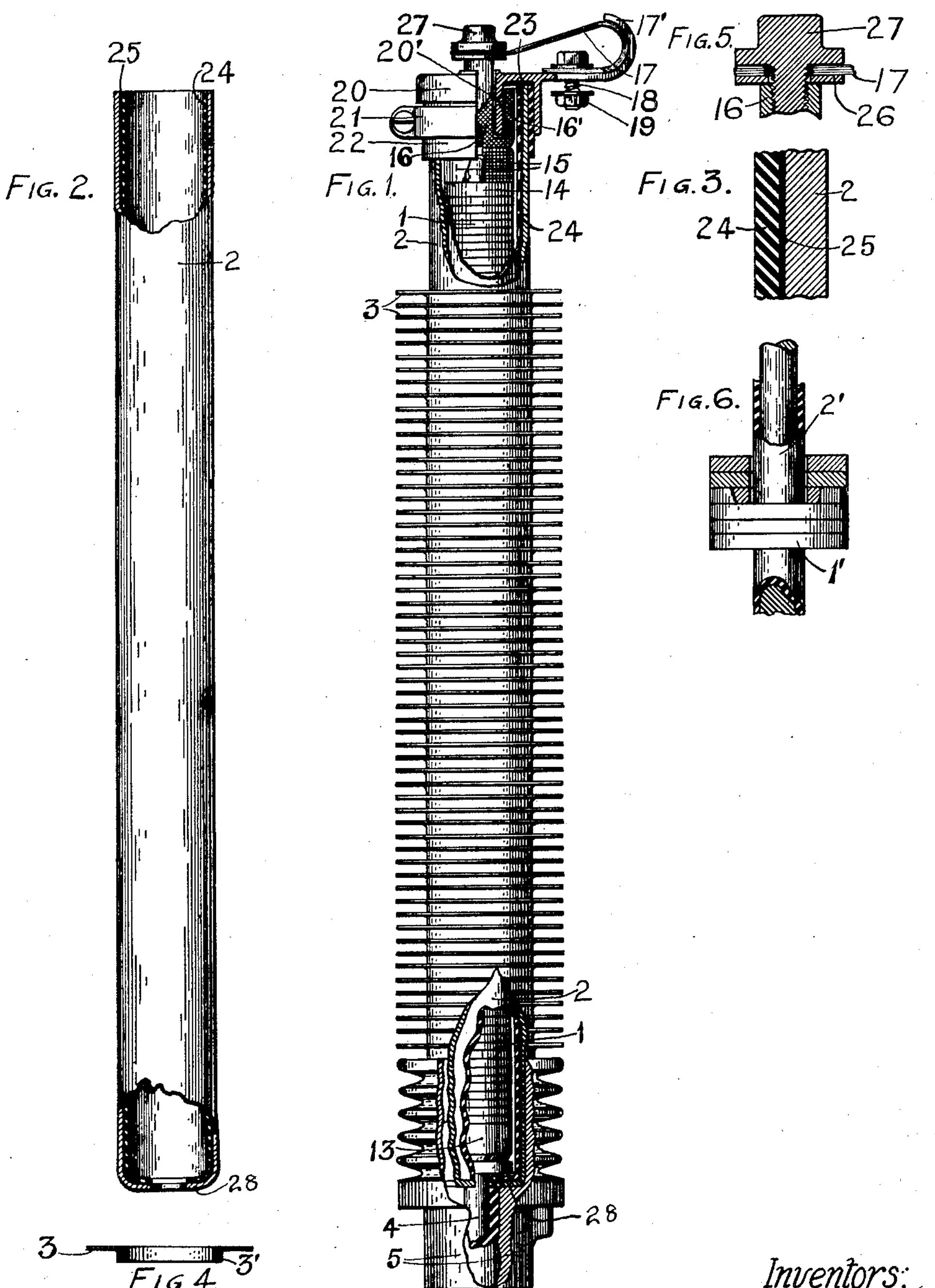
1,054,902. Patented Mar. 4, 1913.



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UNITED STATES PATENT OFFICE.

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RESISTANCE DEVICE.

1,054,902. Specification of Letters Patent. Patented Mar. 4, 1913.

Application filed December 14, 1908. Serial No. 467,352.

To all whom it may concern:

Be it known that we, LYNDE BRADLEY and HARRY L. BRADLEY, citizens of the United States of America, and residents of Muskegon, county of Muskegon, and State of Michigan, have invented a new and useful Improvement in Resistance Devices, of which the following is a specification.

Our invention pertains to resistance units. It relates particularly to that class of variable-resistance units wherein a resistance component of variable resistance value is used, the resistor being composed of a number of carbonaceous plates so arranged as to be compressed and released in order to bring about the desired changes in the electrical resistance of the path through the resistor.

The mechanism for compressing and releasing the resistor forms no part of the present invention, a suitable mechanism being shown for instance in Patent No. 821,697, May 29, 1906, for an electrical current controller. A method of and means for exerting and relieving the pressure on a column of disks is clearly indicated in that patent. Since our present invention relates to the variable-resistance unit, rather than to any means for compressing the resistor thereof, it is obvious that the variable-resistance unit of our present invention may be made in any form and may be used with any type of compressor.

A difficulty in the use of compressible variable resistance units heretofore has been lack of durability and constancy in the resistor. The best available compressible resistor heretofore known has been a column of amorphous carbon disks, but such disks thus used deteriorate. Under ordinary service through long periods of time a disintegration of the carbon disks begins at the middle of the disks, or at the axis of the column and grows outwardly, thus indicating that the disintegration is mechanical or allotropic rather than chemical, there being no chemical changes in the constituency of the material so far as we have been able to determine, and not due to combustion or oxidation, since it occurs at a place where oxygen exists in very limited quantities, or is entirely absent.

Our improvement over the prior art in such resistors and resistance units lies in the provision of an improved resistor, an improved container or retainer for the resistor, and in the improved resistance unit resulting upon the assembling of those improved parts with other improved auxiliary parts to form a complete resistance unit.

The container for the variable resistance medium and the process by which it is made are made the subject matter of another application, Serial No. 535,223, filed December 27, 1909, the present application relating particularly to the resistance element *per se* and the complete resistor unit.

In the drawings, Figure 1 shows an assembled resistance unit of a type selected for specific illustration herein, the device being shown partly in section; Fig. 2 shows the tubular container forming a structural part of the variable-resistance device of Fig. 1, the wall of the container being shown in part in section; Fig. 3 shows a portion of the wall of the container of Fig. 2, in section, on an enlarged scale; Fig. 4 shows sectional view of one of the heat-radiating ribs of Fig. 1; Fig. 5 shows a detail of the upper terminal of the device of Fig. 1; and Fig. 6 shows a modified detail for devices of the general type of Fig. 1.

The assembled unit selected as a specific type of variable-resistance unit for the purpose of this application is illustrated in Fig. 1. It comprises a resistor 1, within a containing chamber 2 which is a metal tube properly lined. Surrounding the tube 2 are the radiating ribs 3. At the bottom the tube 2 is restricted so as to form a shoulder 28. This shoulder, as illustrated in Figs. 1 and 2, is made by drawing or spinning the metal of the tube toward the center line of the tube, and serves partially to close the end of the tube to form a seat for the copper-headed stud 4, which has its head within the tube and its shaft projecting through the opening in the bottom thereof. Upon the stud 4 the lower cap 5 is held by the nut 6 and its washer 7, the stud being insulated from the cap and tube by insulating washers and bushings. The nut 12 is provided to clamp a leading-in conductor. The radiating ribs 3 are cut in annular form from sheet metal and the central lip is shaped up in a shaping press by stretching the metal. These are forced upon the outside of the tube 2, the central lip 3′ forming a spacing member acting to determine the distance between ribs and to maintain the alinement of the ribs. Upon the head of the stud 4 rests a copper-plated graphite cylinder 13, the upper face being left unplated, and upon this part and within the container 2 are piled the resistance disks 1, which as a whole make up the resistance element of the resistance unit. At the top of the series of resistance disks, a terminal is provided. A graphite disk 14 is placed in contact with the top resistance disk; upon the disk 14 is a copper-plated graphite cylinder 15, the under face being left unplated, which is attached to terminal plug 16. The terminal plug 16 preferably is of aluminum to avoid excessive weight which would tend to compress the resistor 1. The floating terminal plug 16 is connected electrically through the flexible copper conductor 17 to the bolt 18 and nut 19, which are adapted to clamp the other leading-in conductor. Top cap 20 is clamped at 21, holding insulating bushing 22 in place and being further insulated by insulating washer 23. The tube 2 is lined with an insulating lining 24 attached to the wall of the tube by the layer of cement 25, the cement 25 being also an insulator, preferably.

The resistance medium, or resistor, which in the device of Fig. 1 is the column of disks 1, is held by a metallic retainer, but is insulated from the metal. The insulating material used in connection with the retainer must possess great heat-resisting properties, must not crumble, flake off or loosen under changes in temperature, and also must be proof against undue deterioration by mechanical wear, as there will be more or less sliding of the resistor against the insulating wall in the processes of compression and release of the resistor. With resistance disks of the type hereinafter described, this insulating medium or lining upon the containing wall must endure without undue injury a temperature of approximately 2000 degrees F. or more. The function of the tube or retainer is to retain the resistor in position for compression. It is obvious that other than tubular forms of retainers may be employed. Another obvious way of retaining the plates in their columnar relation is to form the plates with open centers and to string them like beads upon a single rod, the surface of which has been treated previously with a heat-resisting material similar to that employed on the inner surface of the tube. This is illustrated at 2′ in Fig. 6, the resistor being in the form of annular plates 1′ strung upon and surrounding the retaining rod 2′. The retainer rod 2′ of Fig. 6 may be constructed of a metal rod surfaced with a refractory composition attached to the rod by a layer of cement or vitreous enamel.

The resistor in the resistance unit is composed of elements which have been described as disks 1. These are graphite disks which in themselves would be of little value as a resistor, as they possess high conductivity and a low contact resistance. However, they are surrounded or surfaced with a coating or treatment of carbonized coal tar which possesses a comparatively high conductivity and also a higher contact resistance, which can be greatly varied by pressure. Thus there is produced a resistance element of graphite surfaced with carbon, *i. e.*, consisting of a body of carbon in its form of graphite, surfaced with carbon in its amorphous form, the carbon skin being the true variable resistance medium and the graphite being merely a suitable conducting support. At the top and bottom of the column of disks are suitable electrodes, or contact parts, for making the electrical connections. A desirable form of electrode is a copper-plated block of graphite having one face left unplated whereby an integral electrode is obtained having a copper face for contact with the metallic leading-in conductor and a graphite face for contact with the resistor proper.

The resistance disks described have the following characteristics: They possess a high contact resistance which, when subjected to pressure, may be reduced to less than 1% of its initial value. They maintain this property of variable contact resistance indefinitely; they endure extremely high temperatures, as high as 2000 degrees F., for an indefinite period when kept isolated from air or oxygen; they are so hard and strong that there is no appreciable wear, and the breakage is negligible with disks of reasonable thickness.

In resistors of the prior art, using amorphous carbon disks, there is a deterioration as has been pointed out, apparently due to the change of the allotropic state of the carbon. This change may be rapid or slow, according to the severity of the duty imposed upon the disks. We have found that by using graphite treated as herein described, this deterioration does not occur, and disks may be subjected to very heavy current-carrying duty without appreciable change throughout long periods of time.

In making the resistor elements of my invention, I use graphite in any suitable state and cut or otherwise form it by any suitable method into the desired shape, which is preferably that of a disk. I have found the following process, which I recite in detail, to be well adapted to the manufacture of my disks: The disks or plates are cut or sawed from rods of artificial graphite and then are ground so that the flat faces are parallel. The plates then are placed in a tray and properly supported so that the flat faces will not make contact with each other. This is done in order that the flat faces all may have free, full and equal access to the solution in which they are to be placed. Then they are immersed in a tank containing coal tar thinned by a "light oil" of the same nature as the tar. The refined coal tar and light oil which we use are obtained as follows: In the processes of making gas from coal, there is produced a "crude coal tar," which, when refined, yields "refined coal tar," "light oil" and other substances. It is the "refined coal tar" and "light oil" thus obtained that we use as a bath in preparing our improved resistance element and our improved resistor. The consistency of the tar and oil bath may be varied as desired. The heavier the bath used, the higher will be the resistance of the resulting resistor. During the first few minutes of immersion the thinning oil enters the plates and leaves a coating of thick tar remaining on the surface, but by the end of about fifteen minutes this sticky coat has been dissolved. After immersion for a sufficient length of time, the disks and the tar mixture are placed in a centrifugal separator, and if necessary more of the tar mixture is added to insure complete immersion of the disks in the separator. The surplus tar mixture is thrown from the disks centrifugally. The disks then are brushed to remove still further the adhering tar mixture. They are then placed in an oven and kept at 66 degrees C. for about twenty-four hours and again are brushed. This gives them a polish and a smooth surface and tends to prevent sticking together during further baking. They are then packed in sheet iron tubes, placed in an oven and baked at constantly increasing temperatures,—ten hours at 100 degrees C., ten hours at 150 degrees C., ten hours at 200 degrees C., ten hours at 300 degrees C. They are then allowed to cool and are placed in a cast iron retort and are raised to 800 degrees C., which causes a complete carbonization of the tar mixture remaining on and in the disks. Upon cooling they are ready for use. If, upon inspection, the resistance of any disk should be found too high for the service required, the resistance is lowered by grinding the surface of the disk slightly, thus removing a portion of the high-resistance coating which the disk acquires by its tar treatment. If the resistance of any disk is not high enough, the disk may be subjected to the treatment repeatedly. In this way the range of the resultant resistor may be made to lie between limiting resistances comparatively high or comparatively low. Adopting a musical analogy, the range of the resistor thus may be placed in any selected register.

The ability afforded by the foregoing process of producing disks or plates of variant resistances is advantageous in that it permits the manufacture of resistance units adapted for use in circuits of widely different electrical pressures. It is also advantageous in that it permits of a gradation in the resistances of the several disks in the same resistance unit. Such a gradation is sometimes desirable because in resistance units where the column is designed to be held in a vertical position the weight of the upper disks slightly compresses the lower disks and reduces the resistances of the lower ones. The lower disks therefore may be selected of a higher resistance, and the degree of compression resulting from the weight of the superposed disks will bring this resistance down to a point where the total resistance of the resistor will be distributed equally throughout its length. Similarly, the gradation of the disks with respect to their resistances may be so made that the disks at the top of the column may have a lower contact resistance per lineal unit than those at the bottom for the purpose of maintaining a uniform temperature along the vertical column of the resistor, this being desirable in that it tends to maintain a constant temperature throughout the length of the tube, the upper portions of the tube naturally tending to be somewhat hotter than the lower, by the rising of the convection currents. The method of graduating the lineal resistance of the resistor above referred to may be accomplished by varying the thickness of the disks or plates as well as by grading their inherent contact resistance, thus accomplishing the result by providing a varying number of contact resistances per lineal unit of column. When this gradation of resistances along the length of the column is employed, it is advantageous to have some means of designating the order of resistance of the disks in order to facilitate the assembling of the unit and the re-assembling thereof in case the unit is taken apart. This in the case of the disks of varying thickness is automatically provided. In the case of disks of uniform thickness, the disks may be marked or designated in any desired manner.

The life of a carbonaceous resistor under heat is prolonged by excluding air or oxygen from it, and in the device of Fig. 1 specific means has been provided to prolong the life of the resistor in this manner. The lower end of the tube is sealed, as shown by the insulating washers and bushing. The top cap 20 seals the upper end of the tube except for the required clearance around the neck of the floating electrode or terminal block 16. A considerable degree of isolation for the main cavity of the container is secured by permitting only a tortuous path connecting that cavity with the clearance at the neck of the float 16. This is attained by casting an internal downwardlyprojecting annular flange 20′ upon the cap 20, and providing a coöperating upwardly-extending annular flange 16′ upon the floating terminal. The deep flange 20′ thus lies within a snug annular groove, and circulation of air and other gases is greatly impeded, if not altogether stopped. The length of the path connecting the cavity with the outer air may be greatly increased above that shown in the drawings, by providing a number of interleaving tongues. The neck of the floating terminal 16 is required to carry large currents of electricity, yet this neck purposely is made small. This is done in order that a necessary clearance to provide for the sliding of the neck may not result in too great an opening for the escape or admission of air or gases; also in order that sufficient room around the neck may be provided for the interleaving flanges above described. The small size of the neck imposes a severe requirement in providing for the connection of the flexible jumper 17. The specific design found to give the best results is shown in section in Fig. 5. In this design, the screw-threaded locking bolt 27 is enlarged at the lower face of its head to secure a large contact surface with the jumper 17, and that face is integral with the metal of the head and body of the screw, thus forming a conductor of low resistance into the neck of the floating terminal 16. A washer 26 provides a backing for jumper 17 under pressure of screw-stud 27, but this under surface is not made integral with the part 16 nor is the upper end of the neck of that part enlarged to secure greater surface of contact, because then the part would not pass through the opening inside the flange 20′. The cap 20 is cast, and the protecting extension 17′ is bent upward and around the flexible jumper 17 to protect that part from accidental injury.

While we have outlined in this specification with considerable detail the structural features and process of manufacture which we have found to be successful, we do not wish to be limited in our claims to the exact details specified, as it is obvious that changes might be made within the skill of one versed in the arts without departing from the spirit of our invention.

While we have referred in the specification and the following claims to a "column" of disks, we do not wish to be confined by this expression to a vertical pile, as, obviously, the axis of the mass of disks may be disposed vertically, horizontally, or in any intermediate position.

What we claim as new and desire to secure by United States Letters Patent is:

1. The combination of a variable resistance medium surrounding a core of high conductivity, said resistance medium being formed and supported upon the surface and within the pores near the surface of said core.

2. The combination of a porous core of high conductivity and a surface coating of carbonized coal tar.

3. The combination of a graphite core of high conductivity and a surface coating of carbonized coal tar.

4. A resistance unit comprising a column of graphite plates, each having contact surfaces of amorphous carbon.

5. A graphite resistance element having an amorphous carbonized surface.

6. The process of making an electrical resistor which comprises forming graphite to the desired shape and coating the surface with carbonaceous material.

7. The process of making an electrical resistor which comprises forming a conductor to the desired shape and treating the conductor with a carbonaceous material, and subsequently heating said carbonaceous material to produce a contact surface of relatively high resistance.

8. The process of making an electrical resistor which comprises forming graphite to the desired shape and coating the surface with a carbonaceous material, and subsequently carbonizing said carbonaceous material.

9. The process of making an electrical resistor which comprises forming graphite to the desired shape and coating the surface with coal tar, and subsequently carbonizing said coal tar at high temperatures.

10. In a resistance unit, a resistor consisting of a column of graphite disks, each disk being surfaced with a carbonized substance.

11. A resistance unit, comprising a column of porous disks, each having a surface coating of carbonized coal tar.

12. As a resistance element: a graphite body having a carbonized surface.

13. A resistor comprising a number of compressible disks arranged upon each other in a vertical column and subject to reduction of resistance by compression, said disks being of varying degrees of resistance and arranged with the disks of higher resistance at the bottom of the column.

14. A resistor comprising a number of compressible separate contact elements arranged upon each other in a vertical column and subject to reduction of contact resistance by compression, said disks being of varying degrees of contact resistance and arranged with elements of higher contact resistance at the bottom of the column.

15. In a resistance unit, a container consisting of a metal tube lined with a refractory compound attached to the tube with a cement which becomes plastic with heat; and a resistor within said container consisting of a series of conducting disks, each surfaced with a substance having a high con-

tact resistance variable by pressure, the disks varying among themselves and the disks of the higher resistances being arranged at the bottom of the resistor.

16. In a resistance unit, a container consisting of a vertical tube and a resistor within said tube consisting of a series of conducting disks, each surfaced with a substance having a high contact resistance variable by pressure, the disks varying among themselves, and the disks of the higher resistance being arranged at the bottom of the resistor.

17. In a resistance unit, a vertical container; and a resistor within said container consisting of a series of graphite disks, each surfaced with a substance having a high contact resistance variable by pressure, the disks varying among themselves, and the disks of the higher resistances being arranged at the bottom of the resistor.

18. In a variable compressible resistance unit, a vertical series of resistance sub-units of graduated resistances, graduated in resistance with the sub-units of higher resistance at the bottom.

19. In a resistance unit, a chamber; a pressible resistor within said chamber; a floating electrode for said resistor and projecting through one end of said chamber; and a seal for said chamber comprising interleaving annular flanges upon the inner surface of the end of said chamber and upon the contiguous face of said floating electrode.

20. In a resistance unit, a containing chamber; a fixed closure therefor; a compressible resistor within said chamber; a movable electrode for said resistor; a stud upon said movable electrode and projecting through said first closure; and interleaving annular flanges surrounding said stud and upon said closure and said electrode whereby a tortuous path is provided between the cavity of said chamber and the outer air.

21. In a resistance unit, a containing chamber; a fixed closure therefor; a compressible resistor within said chamber; a movable electrode for said resistor; a stud upon said movable electrode and projecting through said fixed closure; an internal flange upon said fixed closure and surrounding said stud, and a flange upon said movable electrode and surrounding the flange of said fixed closure.

22. In a resistance unit, a terminal comprising a cylindrical stud; and screw-threaded into the end of said stud and occupying a major portion of the gross cross-sectional area of said stud; a head for said screw having an enlarged under surface for contact; and a flexible ribbon conductor clamped between said surface for contact and a washer supported upon the end of said stud.

23. A resistor comprising a number of resistance elements arranged vertically, the resistance value per unit of length of resistor being greater near the bottom of the column than near the top.

24. A compressible resistor, comprising a number of resistance elements having contact resistance variable by pressure and arranged vertically, the resistance value per unit of length of resistor being greater near the bottom of the column than near the top.

25. In a resistance unit, a compressible resistor consisting of separate resistance elements, each having a core of high conductivity and a surface coating of relatively low conductivity.

26. The process of making an electrical resistor element comprising forming a conductor to the desired shape, treating the surface with fluid carbonaceous material, and carbonizing said material.

27. The process of preparing resistant material, consisting in impregnating substantially pure graphite in its solid form with a stable, refractory substance of lower electrical conductivity than the graphite.

28. The process of preparing resistant material, consisting in impregnating a block of graphite with a material yielding a stable, refractory substance of lower electrical conductivity than the graphite, and then converting said material into said stable, refractory substance.

29. The process of preparing resistant material, consisting in first impregnating a block of graphite with a material yielding a stable, refractory substance of lower electrical conductivity than the graphite, and then subjecting the impregnated graphite to heat.

30. The process of preparing resistant material, consisting in first impregnating a block of graphite with a mixture comprising a suitable fluid medium and a material yielding a stable, refractory substance of lower electrical conductivity than the graphite, then raising the impregnated graphite to a temperature sufficient to convert said material into said stable, refractory substance.

31. The process of preparing resistant material, consisting in first impregnating a block of graphite with a mixture comprising a suitable fluid medium, and a substance yielding a stable, refractory residue of lower electrical conductivity than the graphite and then subjecting the impregnated graphite to heat.

32. The process of preparing resistant material, consisting in first soaking a block of graphite in a solution comprising a suitable solvent and a carbonaceous substance of lower electrical conductivity than the graphite to introduce said solution into the pores or interstices of said graphite, then raising

the soaked graphite to a temperature sufficient to volatilize the solvent and to carbonize the substance introduced therein.

33. The process of preparing resistant material, said process consisting in first dissolving tar in a suitable solvent, then soaking a block of substantially pure graphite in the solution, and then subjecting the soaked graphite to a temperature sufficient to convert the impregnating material into a stable, refractory substance of lower electrical conductivity than the unimpregnated graphite.

34. As a new article of manufacture, the herein described product consisting of a solid, porous block of substantially pure, uncemented carbon, impregnated with a substance of lower electrical conductivity and characterized by increased weight and lower electrical conductivity as compared with untreated carbon.

35. As a new article of manufacture, the herein described product consisting of a block of substantially pure graphite in solid form, impregnated with a substance of lower electrical conductivity than the graphite and characterized by a lower electrical conductivity as compared with untreated graphite.

36. As a new article of manufacture, the herein described product, consisting of a block of substantially pure graphite in solid form, impregnated with a stable, refractory substance and characterized by increased weight and lower electrical conductivity as compared with untreated graphite.

37. As a new article of manufacture, the herein described product, consisting of a block of substantially pure graphite in solid form, impregnated with a substance of lower electrical conductivity than the graphite and characterized by increased weight and lower electrical conductivity, as compared with untreated graphite.

38. As a new article of manufacture, the herein described product, consisting of a block of substantially pure graphite in solid form, impregnated with a stable, refractory substance of lower electrical conductivity than the graphite and characterized by increased weight and lower electrical conductivity as compared with untreated graphite.

39. As a new article of manufacture, the herein described product, consisting of a block of substantially pure graphite in solid form, impregnated with carbon and characterized by increased weight and lower electrical conductivity as compared with untreated graphite.

Signed by us at Muskegon, county of Muskegon and State of Michigan, in the presence of two witnesses.

LYNDE BRADLEY.
HARRY L. BRADLEY.

Witnesses:
JOHN VANDERWERP,
JOSIE VANDERWERP.