B. E. ELDRED.

LOW EXPANSION WIRE.

APPLICATION FILED DEC. 22, 1913.

1,140,136. Patented May 18, 1915.

Fig. 1.

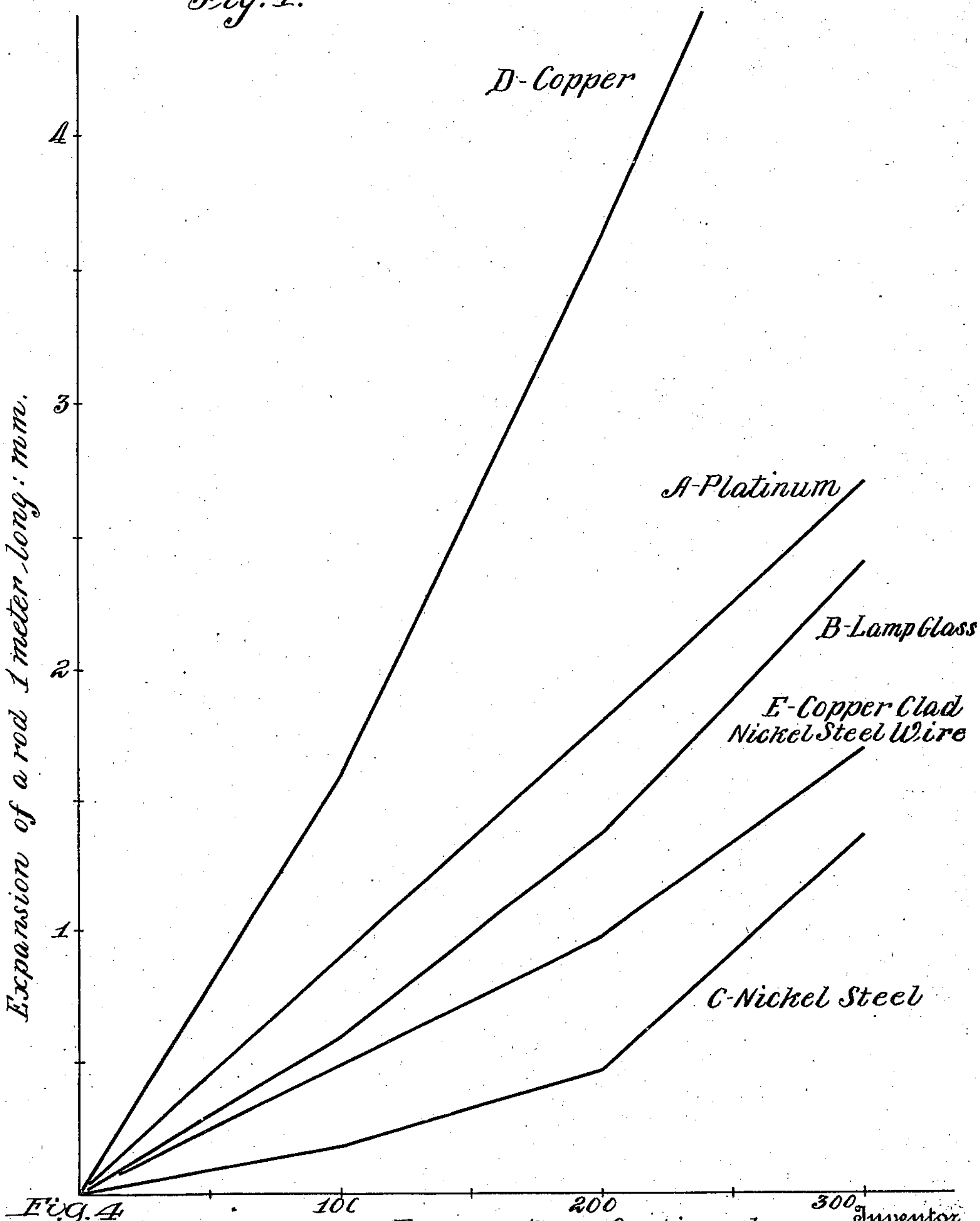

Fig. 4

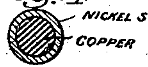

Fig. 2.

Fig. 3.

Witnesses

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LOW-EXPANSION WIRE.

1,140,136. Specification of Letters Patent. **Patented May 18, 1915.**

Application filed December 22, 1913. Serial No. 808,259.

To all whom it may concern:

Be it known that I, Byron E. Eldred, a citizen of the United States, residing at New York, in the county of New York and State of New York, have invented certain new and useful Improvements in Low-Expansion Wires, of which the following is a specification.

This invention relates especially to leading-in wires for lamps, although this invention may be applied also to other uses, and it includes as a new article of manufacture a composite wire or sheet having a core or layer of a low-expansion metal or alloy firmly united to a layer of high-expansion metal of high conductivity, the relative thickness of such layers and the relative expansions of the metals thereof being so correlated that the composite wire or sheet as a whole shall have a compounded regular rate of expansion, such rate of expansion being below and advantageously materially below, that of platinum or ordinary glass; that is, materially below an average rate of expansion of 0.0000089 or 0.0000090 for each centigrade degree of change in temperature through the sealing-in range and below, say, from about 300° to normal temperature; such composite wire advantageously having a core of nickel-steel of proper low expansion and an external sheath or layer of copper or silver; all as more fully hereinafter described and as claimed.

The invention also includes a method of producing wire and a wire as fully disclosed and claimed hereinafter.

In the manufacture of incandescent lamps it has heretofore been the practice to use platinum leading-in wires for conveying the current from an exterior source to the filament within the lamp bulb. Platinum has been employed for this purpose because of certain characteristics which render it particularly suited for the purpose and which have been heretofore regarded as practically indispensable in a leading-in wire. Among these characteristics may be mentioned (1) its relatively low coefficient of expansion, which is nearer than that of any other pure, high melting metal to the coefficient of expansion of glass; (2) its peculiar superficial affinity for molten glass whereby its surface is actually wetted by molten glass; and (3) its unoxidizability, which insures the maintenance of a clean metallic surface throughout the heating operations involved in making lamp seals.

The thermal coefficient of expansion and contraction of platinum is generally stated to be from about 0.0000089 to 0.0000091 for each centigrade degree change in temperature. Curve A in the accompanying drawing shows graphically the rate of thermal expansion of platinum, abscissæ representing temperatures in degrees centigrade, while ordinates represent in millimeters the corresponding increases in length of a rod 1 meter long at 0° C. The thermal coefficient of glass is always somewhat below that of platinum, and with many types of glass it is very much below that of platinum. Glass can be produced however having at temperatures, say, below 100° C. an expansion as high as 0.0000081, rising to 0.0000087 to 0.0000088 at temperatures around 300° C. A union can therefore be formed with platinum at the softening point of such glass which will in most cases persist. The tendency of the platinum, which contracts more than the glass on cooling, to shrink away from the glass, is resisted by the mechanical strength of the union formed with the softened glass. In the cooled lamp the layers of glass next the wire are however under tension and this may produce cracks and air leaks. Much, however, depends on the thickness of the wire; thin wire being safer in this respect than thick.

All high melting metals other than platinum have a still greater thermal rate of expansion and consequently it has not been feasible to employ such metals alone as leading-in wires, for the obvious reason that the tensile stresses between such wires and the glass would be so great as to destroy the seal. Furthermore, the tendency of metals, such as iron, to oxidize readily especially under the high temperature conditions obtaining in lamp manufacture has rendered it practically impossible to keep the surface of such leading-in wires clean. With most metals, porous oxid layers are formed and the formation of an air-tight joint with the glass has been prevented. Further, since platinum leading-in wires in practice must be made exceedingly thin, both for the sake of economy and to reduce the strain in the metal-glass union, the conductivity is not good. Platinum is a relatively poor conductor. In my application No. 790,467 I have disclosed and claimed a compound wire having a platinum surface, a low-expansion nickel steel core and an intermediate linking layer of copper or silver, the wire as a whole having an expansion below that of platinum; and in my application No. 656,987 I have claimed such a wire in connection with a glass article in which it is sealed. This type of leading-in wire has proved eminently satisfactory in practice; but it is to be noted that it involves the use of a platinum surfaced leading-in wire. It has been considered necessary to have platinum in contact with glass in order to secure a perfectly satisfactory union or seal between the wire and the glass. The present invention is directed to an improvement over the leading-in wire specifically claimed in the said applications, whereby the use of the expensive platinum sheath may be done away with if certain conditions, hereinafter to be more fully described, are carefully observed.

In experimenting with leading-in wires of the general type of said prior applications, that is, with leading-in wires having a regulated coefficient of expansion below that of the glass into which they are to be sealed, I have discovered that if the coefficient of expansion of the wire be carried sufficiently far below that of the glass employed at temperatures involved in the sealing operation to cause absolute contact by compressive forces, it is not necessary to employ platinum for contacting with the glass, as has heretofore been generally considered indispensable. Under the conditions just mentioned, the glass during the cooling down from the sealing-in temperature exerts a strong positive pinch or compression on the sealed-in wire, this compression causing the glass to be in extremely intimate contact with the surface of the leading-in wire, with the result that a tight seal is formed, amply sufficient to maintain the requisite degree of vacuum in the lamp bulb at all times. When the glass is hot, it is, of course, quite plastic and can shrink into absolute conformity with the wire surface. By choosing a high melting, low expansion alloy, such as certain alloys of nickel and iron, a leading-in wire can be made to have a rate of expansion as much less than that of the particular glass in question as may be desired. These nickel-iron alloys have a lower expansion than either iron or nickel alone. Although such alloys are of course more or less oxidizable, the formation of oxid to a reasonable extent on a surface of the wire during the formation of the seal does not interfere with the production of an air-tight union with the glass, this being due to the fact that the surface of the joint is so tightly compressed by the surrounding glass during the sealing-in operation as to cause a perfect joint. It is of course feasible also to perform the sealing-in operation in an inert atmosphere of hydrogen, nitrogen or the like if it is deemed desirable to prevent oxidation altogether, in which event such a strong compression of the glass on the wire is not required.

In the accompanying illustration in Figure 1 I have plotted the expansions of various materials as curves. Fig. 2 shows diagrammatically a compound wire having a nickel-steel core and a copper sheath. Fig. 3 illustrates a composite sheet having a layer of nickel-steel united to a copper layer. Fig. 4 illustrates a modification comprising an annular sheath of nickel-steel, surrounding a central body of copper.

While it is possible to obtain good seals with leading-in wires of nickel-iron alloys, such alloys when used alone have certain drawbacks, among which may be mentioned particularly their irregular rate of expansion through the range of temperatures involved in making lamp seals. This irregularity is well illustrated by curve C, from which it appears that the expansion curve for nickel-steel alloys of the low expansion types here in consideration is rather irregular and is by no means rectilinear between temperatures of 0° and 325° C., the latter temperature being approximately the highest temperature involved in making lamp seals, that is, about the temperature at which lampglass sets to its hardened state from its softened or plastic condition. The particular nickel-steel alloy corresponding to the curve contains about 38 per cent. nickel. Curve B shows the rate of expansion of a typical American lamp glass. In making wire for lamp purposes, I have found it advantageous, therefore, to provide a low expansion nickel-iron alloy core with a sheath of another high melting metal whose rate of expansion, although much higher than that of glass or of the core, is nevertheless substantially uniform over the range of temperatures in question. In this way, the irregular expansion curve of the nickel-iron alloy may be forced, so to speak, to assume much greater uniformity. That is, the compound wire, as a whole, has a compounded rate of expansion materially more uniform than that of the nickel-iron alloy, although somewhat less uniform of course than the high expansion sheath. By selecting a nickel-iron alloy of sufficiently low thermal expansion and combining a core of this alloy with a regulating sheath of high expansion metal of the proper relative dimensions, the compound leading-in wire as a whole may be given any combined or average coefficient of expansion desired, which may be as much less than that of the particular type of glass to be used as may be desired. Various high melting metals, excluding platinum, may be employed to give this forced or regulated rate of expansion through the range of temperatures involved in lamp making to the compound leading-in wire. For most purposes however, I find a regulating sheath of copper to be most satisfactory and this is especially desirable for leading-in wires, on account of the high conductivity of copper. Curve D represents the rate of expansion of copper; and it is to be noted that this rate, though relatively rather high, is much more nearly uniform than that for nickel-steel. Such copper sheath may be united to the nickel-iron core integrally as by a weld-union produced in accordance with the process described in the United States patent to Monnot 853,716. Better results however may be attained in another method of weld-uniting hereinafter more specifically described. Where the sheath and core are weld united in this manner, the regulating effect of the copper sheath in straightening the expansion curve of the wire as a whole and forcing it to approach rectilinearity is most effective. Curve E shows the rate of expansion of a copper-clad nickel-steel wire such as that just described, and illustrates clearly how the copper sheath renders the expansion rate of the compound wire as a whole much more uniform than that of nickel-steel alone.

While the integral union between the copper sheath and its supporting core is a distinct advantage for the reasons specified, I do not desire to be limited to the use of such a bimetallic wire. A union effected by soldering or hammering, hot swaging, etc., may be used but is more liable to be defective and such defects may only be disclosed when the finished lamp is tested. Since however a leading-in wire under the present invention may be made so as to be strongly compressed by the glass into which it is sealed, during the sealing-in operation the weld union between core and sheath is not absolutely indispensable, although it is much to be preferred.

In addition to straightening out and rendering more nearly uniform the expansion rate of the leading-in wire, the copper sheath has the additional function of materially increasing its conductivity. Nickel-iron alloys have a conductivity relatively low as compared with copper. This second function of the copper sheath is therefore an extremely important and advantageous one. In this compound wire the copper gives conductivity and the nickel-steel strength and low expansion; and, in a way, the wire may be regarded as a reinforced, low-expansion copper wire.

Instead of using copper for the sheath, either silver or gold may be employed, both metals being good conductors and the rates of expansion of both of these metals being much more uniform than that of nickel-iron alloys, although considerably higher than that of glass or of platinum. Nickel, iron, or any other high melting metal having a relatively high but sufficiently uniform coefficient of expansion may also be used for the sheath under some conditions. The highly conductive metals of the copper class, copper gold and silver are however better. The nickel-steel of the core is not highly conductive and pure metals of the iron class are not much better. Use of metals of the copper class as one layer is, therefore, much more advantageous.

With glass having a coefficient of expansion of, say, 0.0000087 from common temperatures up to 300° C., it is advantageous to employ a leading-in wire having an average coefficient of expansion lying between 0.0000060 and 0.0000075 within the same range of temperature. With a leading-in wire of this description the pressure existing between the wire and glass in the seal is sufficient to insure a permanently tight joint; and at the same time, this pressure is not so great as to require the use of thicker or more massive lamp stems than are ordinarily employed in present practice. By increasing the size of the lamp stem its strength (to withstand stress) may be correspondingly increased, permitting the use of leading-in wires having much lower coefficients of expansion than that above mentioned; and under some circumstances this may be desirable. Of course where glasses of lower expansion coefficients are to be used, the leading-in wire should have a correspondingly lower coefficient of expansion. In this connection, it is to be understood that by suitably varying the proportions of nickel and iron in a nickel-iron alloy, an alloy having practically any desired average rate of expansion is obtainable, the upper limits being those of the individual metals while the lower limit may be carried down very low and may be made substantially zero for temperatures not over 100° C.

In a typical embodiment of the present invention in its most advantageous form, I may use a nickel-iron alloy containing, say, 38 per cent. nickel and having an average coefficient of expansion up to 100° C. of about 0.0000025. A billet of this alloy may be provided by any suitable method with an outer layer or sheath of copper. This layer may then be turned down in a lathe to the exact thickness required to correct the expansion curve of the nickel-iron alloy and to give the requisite degree of uniformity in the rate of expansion in the complete leading-in wire. The billet may then be drawn or swaged to wire and annealed. In practice, the billet or rod of nickel-iron alloy may be 0.892 inches in diameter, and after the copper layer is attached thereto, the assemblage may be turned down to a cylinder of 1 inch diameter. In the finished wire resulting from drawing down the billet, the total diameter may be, say, .008 to .015 inch in diameter, the thickness of the copper layer being advantageously about 0.00005 inch. The foregoing dimensions are to be understood to be illustrative only and as capable of considerable variation.

In producing the article, I find it advantageous to use a vertical bar or core of low expansion nickel steel alloy with a surrounding layer of molten copper in a carbon or graphite mold, causing the molten copper to solidify and weld-unite to the core. By this process (which is more specifically described in my application No. 539,245, filed Jan. 21, 1910), not only is a firm and permanent weld secured, but the article gives a wire which unites better with glass than does a copper-surfaced wire secured in other ways.

As further explaining curves B, C and E of the drawing illustrating the above embodiment of the invention, the following data are useful.

Average coefficients of expansion.

Curve B. Glass—	
Up to 100° C.	0.0000081
Up to 300° C.	0.0000087
Curve C. Nickel-steel (38 per cent. Ni.)—	
Up to 100° C.	0.0000027
Up to 200° C.	0.0000030
Curve E. Compound lamp wire (copper-clad nickel-steel wire)—	
Up to 200° C.	0.0000057
Up to 300° C.	0.0000063

It is to be understood, of course, that the important temperature is that at which the glass sets from its plastic condition. This temperature varies somewhat according to the nature of the glass and in general is above 300° C.

In a modified form of the invention, I may use a wire comprising an annular sheath of nickel-iron alloy or other suitable high-melting ferrous alloy surrounding a central body of copper, but for most purposes the reverse arrangement is better. I may also use a leading-in wire having more than two layers of metal. For example, the wire may have a core of a high-melting ferrous alloy, a sheath of copper, and an exterior layer or coating of silver or gold incasing the compound core of the ferrous alloy and copper. It is to be understood therefore that the term "core" as herein employed may refer not merely to a single core of a single metal or alloy, but may refer also to a composite core such as has just been described. The present invention includes a two-layer wire, the core being one layer and the sheath another; but either layer may be composite. It is also to be noted that a wire may be made with a high-melting alloy either coating or centrally coring a body of nickel-steel. The coefficient of expansion of such alloy is not likely, as a rule, to be as uniform as that of copper, for example; but it is only necessary that its expansion be sufficiently uniform to exert a substantial corrective effect on that of the nickel-steel and thus to force a more nearly uniform rate of expansion in the finished wire.

In referring to nickel-iron alloys, it is to be understood that this term covers all alloys containing nickel and iron which are suitable for present purposes by reason of their low expansion as compared with either nickel or iron alone and is used as synonymous with the term "nickel-steel".

By reason of the high compressive strains between glass and the like, and a metallic conductor sealed therein, which may be obtained according to the present invention, seals of this character are in many instances superior to those obtained by using leading-in wires of solid platinum. The tensile stresses between platinum and glass, due to the considerably higher rate of expansion and contraction of the platinum, may be entirely eliminated by the present invention, as has been clearly pointed out. On this account, it is now possible to substitute for platinum, which is so expensive and which is not wholly satisfactory, leading-in conductors having base metal or alloy surfaces; or having cores of base metals or alloys provided with external sheaths, of silver, gold or other non-platinum metal, much cheaper than platinum itself, the wire as a whole also being a better conductor than platinum and better suited to modern high capacity lamps.

While the expansion curves shown in the drawings represent data obtained by careful experiments, it is to be understood that such data are always subject to more or less experimental error, especially where, as in the present instance, heat measurements are involved. The curves are therefore to be considered as merely indicative of the probable comparative conduct of the materials in question, and of typical examples examined, and not as absolutely accurate.

While, as stated, I may use other combinations of metals, the best embodiment of the invention comprises a copper-coated nickel steel. The copper not only has the function of correcting the curve of expansion but the greater further advantage of given a relatively high conductivity to the composite wire. Gold-surfaced and silver-surfaced wires are good conductors and less oxidizable; but the copper-surfaced wires on the whole I deem the best suited for my present purposes. Other low-expanding alloys and metals may be used in lieu of nickel steel, but the latter is best. The use of alloys of metals melting at low temperatures such as lead, tin, antimony, etc., is of course precluded by the heat necessary in sealing wire through glass.

While advantageously the expansion of the wire is as above pointed out, less than that of platinum or of the glass with which it is to be used, yet in another aspect the present invention may be said to include a method of reducing the expansion of highly conductive metals by uniting them with alloys of low expansion to produce a compounded reduced expansion; in the provision of a highly conductive wire of reduced expansion.

What I claim is:—

1. A composite low expansion wire comprising a core of nickel steel and an external copper sheath welded thereto, said wire as a whole having less expansion than platinum.

2. A composite low expansion wire comprising a core of nickel steel and an external sheath of a metal of the copper class welded thereto, said wire as a whole having less expansion than platinum.

3. As a new article of manufacture, a copper surfaced wire having a rate of expansion as a whole below that of platinum.

4. As a new article of manufacture, a composite wire having a surface of base metal and having a rate of expansion as a whole below that of platinum.

5. As a new article of manufacture, a wire having a surface of metal of the copper class and a rate of expansion as a whole below that of platinum.

6. A 2-layer composite wire, one such layer being of low-expansion nickel steel and the other layer of high-expansion high-melting metal, the wire as a whole having an expansion less than that of platinum.

7. As a lamp wire, reinforced copper surface wire, said reinforcement consisting of an interior layer of low expansion nickel-iron alloy.

8. As a lamp wire, a composite wire composed of a layer of copper and another layer of low expansion nickel-steel in sufficient amount to reduce the total expansion sufficiently to secure a seal with lamp glass.

9. A leading-in wire comprising an outer sheath of high-melting, high-conductive material united to a core of nickel-steel having an average coefficient of expansion distinctly below that of the sheath, the core being under compression by the sheath at all temperatures to which the wire is subjected in lamp-making use.

In testimony whereof, I affix my signature in the presence of two subscribing witnesses.

BYRON E. ELDRED.

Witnesses:
Ned J. Whelan,
W. S. Howell.