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Triantafellow et al.

[11] **3,861,773**

[45] **Jan. 21, 1975**

[54] **WIRE TERMINAL FOR ALUMINUM WIRE**

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[73] Assignee: **General Electric Company**, New York, N.Y.

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[21] Appl. No.: **375,185**

[52] **U.S. Cl.** ..... **339/103 R**, 85/1 C, 339/116 R, 339/278 C

[51] **Int. Cl.** **H01r 13/58**

[58] **Field of Search** ..... 85/1 C; 339/101, 103 R, 339/114, 116, 164 R, 271, 278 C, 278 D, 269

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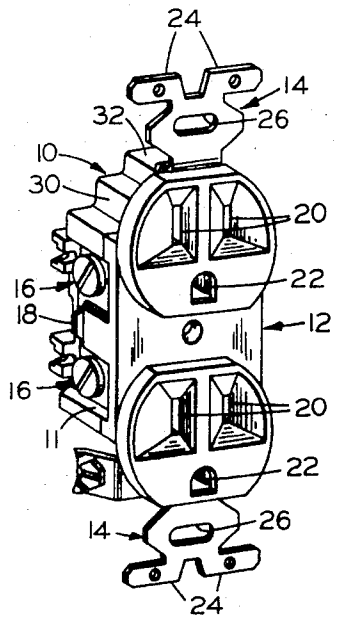
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Assistant Examiner—DeWalden W. Jones
Attorney, Agent, or Firm—Paul E. Rochford; P. L. Schlamp

[57] **ABSTRACT**

A wire terminal for aluminum wire includes a screw terminal having a metal plate of high conducitivy and a screw, the shank of which has a coefficient of expansion close to that of aluminum. It also includes wire restraining means adjacent to the screw terminal to minimize realignment of the wire after the screw pressure has been generated. The surfaces of the screw which contact the aluminum wire are of high lubricity to enhance the development of compressive pressure against wire held by the terminal.

10 Claims, 9 Drawing Figures



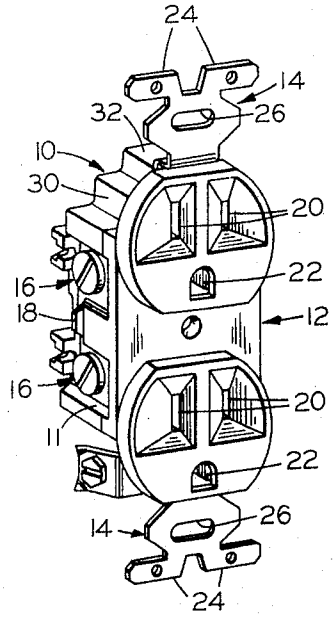


FIGURE 1

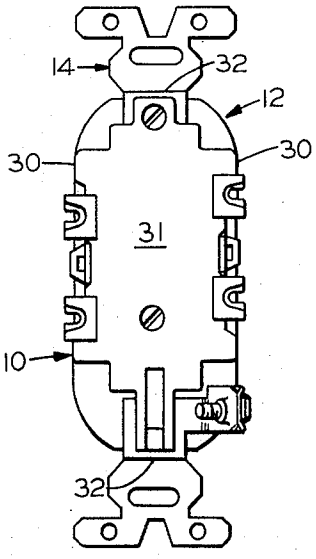


FIGURE 2

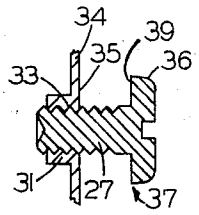


FIGURE 8

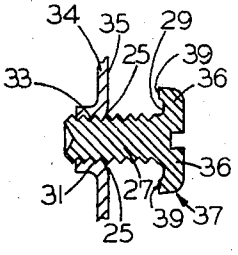


FIGURE 9

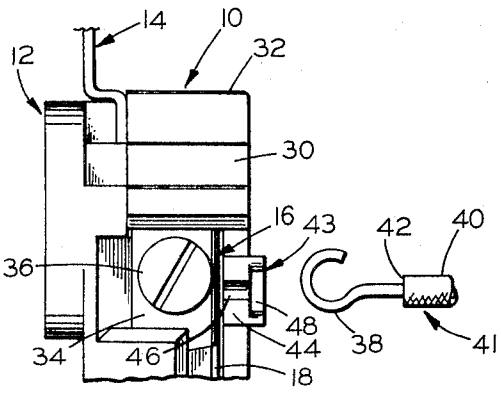


FIGURE 3

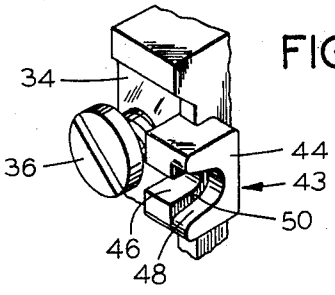


FIGURE 5

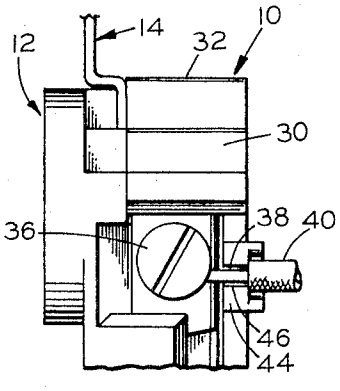


FIGURE 4

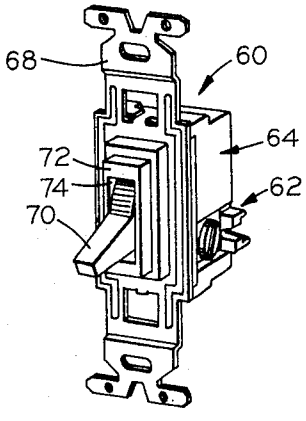


FIGURE 6

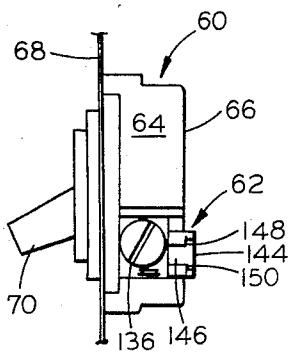


FIGURE 7

WIRE TERMINAL FOR ALUMINUM WIRE

BACKGROUND OF THE INVENTION

The present invention relates to terminal means for making reliable connections to aluminum wire. More specifically it relates to wire terminals useful in providing electrical contact with aluminum wire which terminals exhibit limited accompanying rise in temperature during current flow.

It is known that field problems exist in providing adequate electrical connection of aluminum wire to wiring devices. These problems are due largely to use of inadequate care in making the electrical connections and to certain inherent properties of aluminum conductors. Where the connection is inadequate the problems hinge largely on the tendency of heat to be generated at the surfaces at which aluminum conductors make contact with the metal of wiring devices. Some explanation of several factors involved in use of aluminum wire and particularly in termination of aluminum wire as well as one scheme for overcoming problems relating to use of aluminum wire with wiring devices are set out in U.S. Pat. No. 3,719,919.

One theory concerning heat generated at wiring device terminals to which aluminum wire is connected is that in making the connection of the aluminum wire to the wiring device, inadequate care is sometimes employed and the contact between the wire and the contact surfaces of the wiring device is not sufficiently firm to sustain conduction at low temperatures. Another theory is that the contact may be disturbed or loosened after being firmly made. Where such loose contacts result, heat is sometimes generated at the contact and the heat is produced partly because of the existence of an electrical resistance on the surface of the aluminum wire. The resistance is attributed in large part to the presence on the surface of the aluminum wire of an oxide layer which is the product of the reaction of the aluminum of the wire with oxygen in the air in contact with the wire. Where a connection is relatively loose a high current density flows through those restricted areas of the surface of the wire where electrical contact is made with surfaces of the terminal. Such high current density can produce localized heating particularly at the surface electrically resistant of the aluminum wire.

As the temperature of aluminum wire is increased the tendency toward this reaction between oxygen and aluminum metal is also increased. Further as the reaction increases the surface layer of aluminum oxide increases in thickness and the thicker layer causes generation of increased heat as current passes through the oxide layer to the metal of a screw contact. Because of this tendency, it is important that the temperature of the aluminum termination be limited. Where the temperature is limited, this limits the inducement toward forming a thicker layer of aluminum oxide on the aluminum wire where it contacts the metal of the screw terminal. It is known that where good contact of aluminum wire with contact metal is established and maintained there is relatively low increase in the temperature of either the wire or the contact over long periods of time and flow of current is not interrupted due to overheating or related causes.

As indicated, where inadequate contact is established between an aluminum conductor and a contact metal, heating at the aluminum metal surface results in increased oxide formation and such increases would in turn cause an increase in the tendency towards heat production at the surface of the aluminum wire. This increased heat production can in turn lead to further oxidation at the surface and formation of a thicker layer of oxide at the surface of the aluminum wire where such oxidation took place.

For devices of conventional construction this phenomenon is accelerated where current is interrupted periodically so that the heating is cyclic in natrue. Studies have shown that inadequate contact of aluminum wire made at screw terminals may be due to the irregular form of the wire between the screw head and terminal plate. Due to any irregular shape, actual contact may be made at high points on the wire. Further, chaffing of the surface of the wire at such high points may occur if differential expansion and contraction of the wire occurs with reference to elements of the screw terminal. Such chaffing can disrupt the wire surface and induce additional heating or the formation of hot spots at such high points where such contact occurs between wire surface and screw terminal.

OBJECTS OF THE INVENTION

One object of the present invention is to provide means for terminating aluminum wire which is characterized by low heat production when electric current is flowing.

Another object is to provide a low cost termination for aluminum wire.

A further object is to provide a highly reliable termination for aluminum wire employing screw means to apply electrical contact pressure to the aluminum wire.

A further object is to provide a highly reliable termination for aluminum wire which is resistant to thermal cycling phenomena.

Other objects and advantages of the present invention will be in part apparent from and in part pointed out in the description which follows.

SUMMARY OF THE INVENTION

One way in which objects of the invention can be carried out is by the use of a screw terminal including a metal plate or terminal base member of relatively high conductivity, at least equivalent to that of surface tinned 70–30 brass, and a headed screw threaded into the plate, the coefficient of expansion of the shank of the screw being close to that of aluminum metal, and at least as high as that of 70–30 brass. The underside of the head of the screw is lubricated or is otherwise made highly lubricious to permit the head of the screw to be advanced with facility toward the plate of high conductivity and to compress an aluminum conductor between the head of the screw and plate with a compressive force greater than that achieved for a given torque or turning force applied to unlubricated screw heads. Means for restraining movement of the wire between the screw head and plate are also provided to limit movement of the wire and particularly movement about the axis of the screw once the wire is secured in place.

As is well known the common designation 70–30 brass refers to a brass having 70 parts copper and 30 parts zinc.

BRIEF DESCRIPTION OF THE DRAWING

The manner in which the invention may be carried

into effect will be understood more clearly by reference to the accompanying drawing in which:

FIG. 1 is a perspective view of a receptacle incorporating features of the present invention.

FIG. 2 is a rear elevation of the device of FIG. 1.

FIG. 3 is a detail of a side elevation of the device shown in FIG. 1 illustrating the wiring terminal of the device with a wire poised for attachment at the screw terminal illustrated.

FIG. 4 is an illustration of the detail as shown in FIG. 3 with the wire in place at the screw terminal.

FIG. 5 is a detail in perspective of the screw terminal and wire restraining element as seen from the back of the device.

FIG. 6 is a perspective view of a switch incorporating features of the present invention.

FIG. 7 is a side elevation of the device illustrated in FIG. 6.

FIG. 8 is a crossectional view through a wire terminal.

FIG. 9 is a similar view through a wire terminal having a screw head of different configuration.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, a conventional duplex electrical receptacle is shown having an insulating body **10**, an insulating cover **12**, and a mounting strap **14** positioned therebetween.

Cover **12** has pairs of blade ports **20** and a grounding port **22** arranged in the conventional positions for insertion of power blades and grounding blades.

Strap **14** has pairs of "plaster ears" **24** and screw openings **26** for insertion of screws to mount the device into a wall receptacle box or the like.

Insulated housing **10** has side walls **30** and end walls **32.** A pair of screw terminals **16** separated by a conducting metal breakoff tab **18** are positioned in conforming openings **11** in the side wall **30** of insulating housing **10.** Screw terminal **16** is made up of a conducting metal plate or terminal base member **34,** and a headed metal screw **36** threaded into plate **34** through a threaded opening not seen therein but seen in the sectional views of FIGS. **8** and **9.**

The above description of a screw terminal is that of a conventional screw terminal. Screw motion is used in a conventional screw terminal to generate an electrical contact pressure against the wire which is placed between the underside of the screw head and the plate through which the screw is threaded.

An illustrative sheathed conductor **41** may be connected to such a screw terminal by first removing a portion of an insulating sheath **40** to expose conductor **38.** Then wire **38** is curved to conform generally to the compression area of the underside of head **36** of the screw. Such an insulated wire **41** is shown to the right of the screw terminal in FIG. **3** in position preparatory to attachment of the wire to the screw terminal **16** and curved to conform generally to the area of the underside of screw head **36.**

While wire **38** is shown with a very uniform and symetrical curve formed at its end to lie flat in a single plane, it will be understood that in actual field practice, the curve will most often be irregular both in the shape of the curve and in having high points at those portions of the exposed wire where the curve does not lie in a plane but protrudes out in random fashion based on how an electrician performs the task of cutting the wire, exposing the end **38** and forming the loop in the wire end **38.**

The insulating sheath **40** is insulation conventionally found on such wire and may be polyvinyl chloride or other insulating thermoplastic, extruded directly over the metal wire **38** and forming a solid coating thereon. Removal of a portion of the insulation at the wire end **38** may leave a shoulder **42** at which the diameter of the wire is reduced from that of the outer surface of the insulated wire **41** to that of the outer surface of the metal conductor **38** itself. Removal may also leave scratches or shaved surfaces, not shown, along the outer surface of wire end **38.**

A distinctive feature of the wire terminal **16** of this invention is that it has a different combination of elements than are employed in conventional wire terminals. Furthermore, wire terminal **16** is constructed so that wire connected to the terminal cooperates with a wire restraining means **43** which can be formed, as illustrated, integrally with the side **30** of the insulating housing. This wire restraining means comprises in effect, part of the wire termination of this invention and may be formed equally well as a channeled portion or extension of plate **34.**

As is evident from FIG. **3,** and more particularly from FIG. **5,** the wire restraining means **43** can include a wire channel **46** into which a metal wire such as **38** is fitted as the attachment of the wire to the screw terminal is performed. Other alternative forms of wire restraining means may be employed to restrict particularly pivotal movement of an attached wire about the axis of screw **36.** The restraining means can also include an insulation channel **48** into which the end of the insulating sheath **40** may be fitted to bring the wire insulation shoulder **42** into abutting engagement with a shoulder **50** within the restraining means **43.**

The illustrated wire restraining means is one form of such means and the use of other forms of such means in combination with other elements of the wire terminal taught herein is contemplated. Also the use of such means on wiring devices other than wall receptacles is contemplated.

Thus in FIGS. **6** and **7** a switch **60** equipped with a wire terminal **62** as taught herein is shown. The terminal **62** is located in a side wall **64** of an insulating housing **66** of the switch. The switch also includes a conventional metal mounting bracket **68,** a trigger **70** of a toggle mechanism not shown and an insulating collar **72** about a trigger opening **74** and trigger **70.**

The contact is made up of elements numbered to correspond to elements of FIG. **5** and having functions as described for similarly numbered elements of FIG. **5.**

Another difference between the wire terminal of the present invention and conventional wire terminals involves the presence on the underside of the head of the screw and optionally on threads of the wire terminal of a lubricant which facilitates the generation of greater compressive force on the wire for a given torque applied to the screw. In other words one factor which has been found to be important in the establishment of proper contact between the aluminum wire and a conductive metal surface, such as the surfaces of a wire terminal illustrated in the Figures, is the provision of a lubricated surface on the underside of the screwhead of the terminal so that the operation of the screw is more efficient in delivering compressive force per unit of

torque applied than is the case when the lubricant is absent.

The lubricant must be on the underside of the screw-head of the terminal and can be on the threads in the terminal plate or can be on the threads of the terminal screw or on both. A convenient way of depositing lubricant on both the threads and underside of the head of the screw is by dipping the screw in a solution or emulsion of a lubricant in a solvent, either organic or aqueous, and by then evaporating the solvent so as to leave a deposit of the lubricant on the screw. Such deposit leaves lubricant on all exposed surfaces of the screw and thus both on the underside of the screw head and on the screw threads.

It is preferred to use a solid lubricant which will adhere well to the screw surface during handling. Also it is preferred that the melting point of the lubricant be high enough so that melting of the lubricant, which may be a wax, does not occur during normal assembly, storage or use of the screw terminal.

Pre-cleaned brass screws which have been surface tinned or surface coated with other thin layers of metal may be plated with lubricant in this way as well as uncoated brass or aluminum screws.

It has been found possible where the underside of the heads of brass terminal screws as well as the threads of the screws are lubricated as indicated above and are threaded into brass terminal plates to use a torque on the screw of 6 inch pounds to establish a compressive force on the wire sufficient to insure effective electrical contact between the wire terminal and an aluminum wire. At the same time, it has been found possible to reduce the increase in heating at the interface between the wire terminal and aluminum wire which, as described above, is found to be a source of resistance heating during power flow and which can give rise to excessive heating of the wire terminal and adjacent wiring device if the wire terminal does not maintain sufficiently good electrical contact.

For conventional wire terminals Underwriters' Laboratories requires two full screw thread turns in the terminal plate. Terminals as taught herein for use with aluminum wire can be made with the conventional two threads in the threaded screw hole of the terminal plate such as **34** of FIG. **3.** Because of the lubricated surface of the screw of the terminal taught herein, it is feasible to strip threaded aperture by application of excessive torque on a screw such as **36.** Terminals of brass metal which have at least two screw thread turns in the terminal plate and which can withstand at least 16 inch pounds of torque are preferred embodiments of the present invention as they provide surprisingly effective terminals for connection of aluminum wire, yet may be formed at low cost on conventional equipment. For those terminals on which it is desirable to use higher torque a thicker plate or larger number of threads should be employed in the threaded screw hole of the terminal plate or some similar compensating steps to strengthen the terminal should be carried out.

Terminals having thicker plates and/or larger numbers of threads should also be used where the screw and/or terminal plate is of a softer metal of high conductivity such as aluminum.

The preferred form of lubricant is a wax form or other form which does not easily liquify and run or spread over adjacent surfaces. It is preferred to employ particularly a wax form which adheres to a metal surface where it is deposited and does not run or spread as for example onto the terminal plate surface itself where electrical contact may be made under pressure with the wire pressed against the terminal plate by the screw.

Some lubricants, as for example liquid hydrocarbon lubricants, should be avoided as well as other lubricants such as those detergents containing lubricants which can form an insulating layer on the surfaces of the terminal. It has ben observed that use of such liquid insulating lubricants increases the heating at a screw terminal to which aluminum wire is connected and increases the likelihood of failure of the terminal to function within the performance standards established by Underwriters' Laboratory.

It is also preferred to employ a terminal plate of relatively high electrical conductivity in the screw terminal of this invention. The alloys of copper commonly known as copper-iron and having a combination of high conductivity and good physical properties, as well as brasses having higher copper content than the conventional 70–30 brass have been found most satisfactory. These include 80–20 brass.

The theoretical mechanism by which the improvements made possible by the present invention occur is not fully understood. No specially formed surfaces have been found necessary as required in U.S. Pat. No. 3,719,919 to provide a special means to penetrate or fracture a surface oxide of aluminum. In fact, quite the contrary, it has been found that the surfaces of the terminal of this invention which bear against the aluminum wire surface can be quite flat and planar and need not be specifically formed into ridges or other special geometric forms. A form of a terminal screw **37** and a portion of a corresponding terminal plate **34** are shown in section in FIG. **8.** It will be noted that the underside **39** of the head **36** of screw **37** is illustrated as essentially flat or planar and that the confronting face **35** of plate **34** is also illustrated to be essentially flat or planar. This is a somewhat idealized representation and the confronting surfaces which compress the wire need not be perfectly flat. For example, at least part of the metal removed from the plate **34** in forming a threaded opening in the plate is extruded out of the plane of the plate and constitutes extrusion **31.** Extrusion of metal may produce a slight funnel-like depression **25** in the face **35** of a plate such as **34** as illustrated in FIG. **9.** This thickness added by the extrusion makes possible the inclusion of two full threads of desired pitch in the threaded opening **33** in plate **34.** The threaded shank of screw **37** can thus bite on two full threads in threaded opening **33** in developing compressive force on a wire between underside **39** of screw **37** and the confronting surface **35** of plate **34.**

The crossectional configuration of screw **37** as illustrated in FIG. **8** is also somewhat idealized in showing a fully flat or planar underside **39** of screw **37.** In production of wire terminals of this invention, there is no need to make the underside of the screw head as flat as illustrated in FIG. **8.** What is important is that the underside not have a form which increases the friction between the screw head and the wire against which it bears as the head compresses the wire during the turning of the screw. This contact of the underside **39** of the screw with a wire loop under the screw head is in fact one of the largest potential sources of friction in the wire terminal. It is by reducing this friction, together

with the use of the other measures as disclosed herein, that it is feasible to establish effective electrical contact with aluminum wire pursuant to this invention. Reduction of friction at the threaded surfaces of the wire terminal is also beneficial in ensuring development of good electrical contact with aluminum wire employing the wire terminal of this invention. Such reduction of friction at the threaded surfaces is preferred where it is an addition to the reduction at the underside of the screw head.

Also while it is necessary to avoid deforming or forming or shaping an underside **39** of head **36** of a screw such as **37** where such shaping significantly increases the friction developed at the underside **39** as the screw is turned, it is nevertheless feasible to shape the underside **39** without significant increase in turning friction and such shaping may in fact be beneficial to development of good electrical contact. Thus shaping of generally radial configuration such as that taught in U.S. Pat. No. 3,719,919 is generally detrimental if applied to the underside of a screw. However a shaping of generally circular or annular configuration can be beneficial in avoiding sliding or extrusion of the wire from under the screw head, particularly where the screw head underside is well lubricated. Such shaping may also be beneficial in increasing the deformation of the wire which takes place as the screw is turned into place without appreciable increase in friction.

A screw which has an inner annular channel formed on its underside close to the screw shank is illustrated in FIG. **9.** The channel **29** is on underside **39** of screw **36.** It is illustrated in section and has a generally annular or circular configuration. Use of screws with a deformed undersurface where the configuration of the deformation is generally circular or annular is preferred where the character of the deformation can aid in holding a wire more firmly in place beneath the screw head. By a deformed undersurface or a deformation of an undersurface as used herein is meant a surface which is given a configuration which is not flat or planar as the surface **39** of FIG. **8.** It is not clear to what extent any breaking or penetration of an oxide layer or a wire surface occurs in carrying out the present invention. However it is known that in conventional field installations, the application of as little as 6 inch pounds of torque to a brass base wire terminal as taught herein having an 8–32 thread, does result in such compressing of a Number 10 aluminum wire as to produce in each case a reliable electrical connection to the aluminum wire such that 20 amperes of power can flow between wire and terminal with acceptably low heat rise.

The performance of wire terminals provided pursuant to this invention has been found to be dependent on the manner in which terminal elements are combined in accordance with this invention. Thus where greater contact pressure is developed from use of preferred lubricants, a lower conductivity material may be employed in the terminal plate and with acceptable heat rise of the terminal. By acceptable heat rise is meant a rise in terminal temperature above ambient temperature to an operating temperature of less than 150°C at steady state operation. A terminal with 70–30 brass can operate within this acceptable heat rise range and in fact, can operate close to a 100°C temperature where the screw of the terminal has a coefficient of thermal expansion close to that of aluminum; where the underside of the head and the threads have been well lubricated with a preferred lubricant; where good screw pressure is developed by application of at least 6 inch pounds torque to the screw; where the terminal plate is free of insulating surface layers as of lubricant; and where high mechanical pressure has been established between the aluminum wire and the brass terminal plate as a result of the use of the foregoing combination of terminal elements. Where lower contact pressure is achieved or where another factor is not optimized, higher conductivity metal such as 80–20 brass or copper-iron alloy can be employed as the metal of the terminal plate.

Another problem described in U.S. Pat. No. 3,719,919 as relevant to good terminations for aluminum wire is that concerned with a differential expansion of the aluminum of the wire and of other metals of the terminal to which the aluminum wire is connected.

Another distinction between the improved wire terminal as taught herein, and that of some other conventional devices, is that in the combination of elements employed the screw of this wire terminal must have a coefficient of thermal expansion which closely approximates that of the aluminum wire to be held under the screw of the wire terminal. By closely approximates is meant that the thermal coefficient of expansion of the screw shank is at least as high as that of 70–30 brass. Terminals including screws formed of material having such coefficient of thermal expansion have been shown to operate reliably in accordance with the present invention even though the coefficient of thermal expansion of brasses such as 70–30 brass does not precisely match that of the aluminum wire held by the terminal. This close approximation of coefficients of thermal expansion as between screw shank and aluminum wire is particularly important with regard to the uses of the device which involves intermittent flow of electricity through the wire and terminal. When current flow is intermittent the heating is also intermittent. There is a tendency during intermittent heating for a cyclic expansion and contraction of the various elements of the terminal along with the heating and cooling of the terminal. Depending on the respective coefficients of thermal expansion of the respective elements, this can result in a relative increase of pressure on the wire during the heating cycle followed by a relaxation of pressure on the wire during the cooling period and can produce effects as described in the U.S. Pat. No. 3,719,919.

Pursuant to the present invention, however, a closer approximation of thermal coefficient of expansion as between screw and aluminum of the wire is provided and this lower differential in thermal coefficients is provided in combination with a greater compressive force between the screw and plate elements of the screw terminal and motion restraining means.

Screws formed of conventional 70–30 brass or of such brass which has been surface tinned or otherwise surface coated with a conductive metal layer have been found to function satisfactorily in screw terminals as provided pursuant to this invention, i.e., where they are used in combination with surface lubrication and other elements as described above.

Another phenomenon referred to in the U.S. Pat. No. 3,719,919 as relevant to forming successful terminations for aluminum wire is described as cold flow or creep. This creep is a slow distortion of the wire or a slow dimensional change which occurs while there is a

sustained pressure on the wire over a period of time. The terminals provided pursuant to this invention do not suffer adverse effects based on the expected cold flow or creep and are accordingly resistant to problems relating to the expected cold flow or creep.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. A wiring terminal for aluminum wire which comprises:

a. a metal base member having an electrical conductivity at least equivalent to that of surface tinner 70–30 brass,

b. a threaded opening in said plate,

c. a headed screw threaded into said threaded opening to generate a compressive force on a wire placed between the head of said screw and the confronting surface of said plate on application of a torque to said screw,

d. the shank of said screw having a coefficient of thermal expansion close to that of aluminum and at least as high as that of 70–30 brass,

e. the undersurface of the screw head of said wire terminal being lubricated to substantially increase the compressive force generated by application of a given torque,

f. and means to restrain pivoting of a wire about the axis of said screw after it is compressed in place.

2. The wiring terminal of claim **1** wherein the metal plate is 80–20 brass.

3. The wiring terminal of claim **1** wherein the screw is a 70–30 brass screw.

4. The wiring terminal of claim **1** wherein at least some of the threads of the wire terminal are lubricated.

5. The wiring terminal of claim **1** wherein the lubricant is a wax.

6. The wiring terminal of claim **1** wherein the lubricant is a wax having a melting point higher than the normal operating temperature of the terminal.

7. The wiring terminal of claim **1** wherein the restraining means is an element including a wire receiving channel proximate the terminal.

8. A wiring device having a wire terminal which comprises:

a. an insulating housing enclosing current carrying components of said wiring device and a wire terminal exposed at one surface of said insulating housing,

b. said wire terminal comprising a screw threaded into a terminal plate, the plate being connected to other current carrying components of said device,

c. and a wire restraining means proximate the screw of said terminal to minimize pivoting of a wire connected to said terminal about the screw axis,

d. said terminal plate having a conductivity equivalent at least to the electrical conductivity of tin coated 70–30 brass,

e. said screw having a thermal coefficient of expansion at least as high as that of 70–30 brass,

f. and the underside of the head of said screw of said terminal being lubricated to substantially increase the compressive force developed by said terminal when a torque is applied to the screw of said screw terminal.

9. The wiring device of claim **8** in which the plate and screw are of 70–30 brass.

10. The wiring device of claim **8** in which the lubricant is a wax of relatively high melting point.

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