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ELECTRICAL CONNECTOR

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FIG. 1.

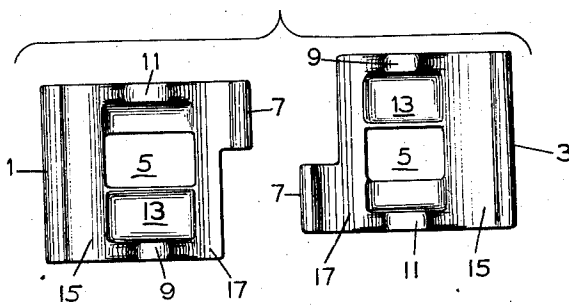


FIG. 2.

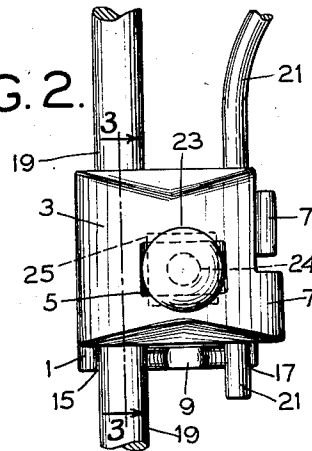
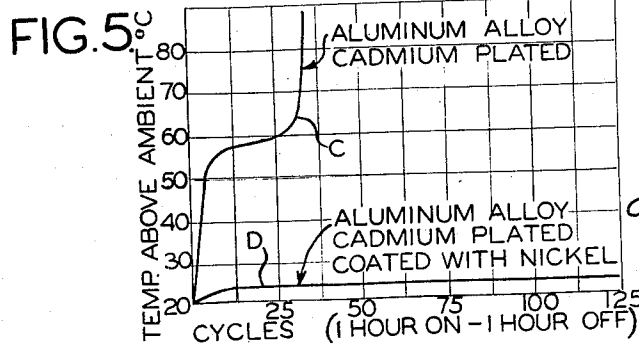
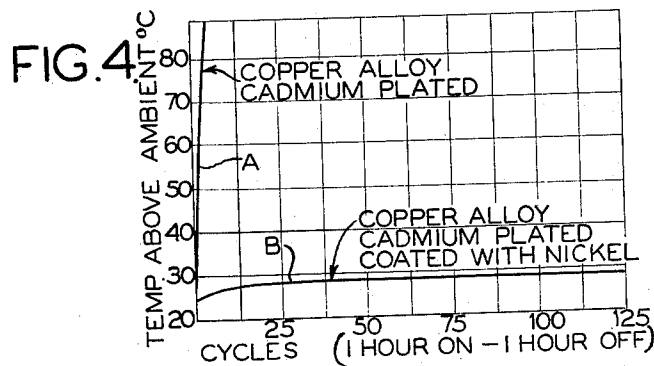
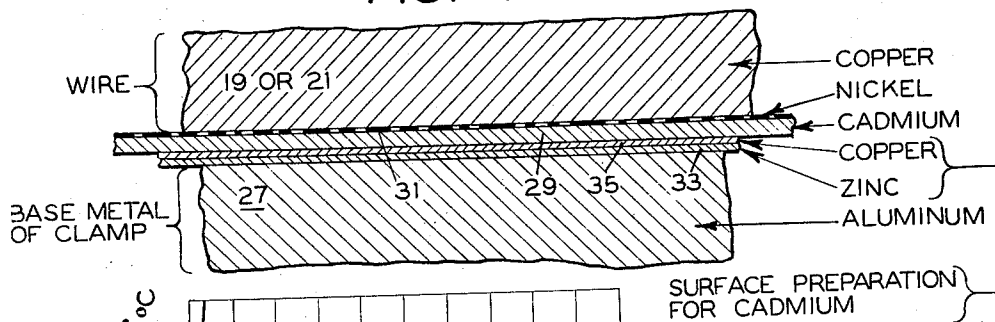


FIG. 3.



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2,858,520

ELECTRICAL CONNECTOR

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5 Claims. (Cl. 339—241)

This invention relates to electrical connectors, and more specifically, to connector clamps for electrically connecting wire conductors.

This application is a continuation-in-part of my copending United States patent application Serial No. 390,880, filed November 9, 1953, now abandoned, for Electrical Connector.

Among the several objects of the invention may be noted the provision of an electrical connector clamp which, when forming a connection between conductors, will not overheat in response to cycling of heavy load currents in the conductors; the provision of a connector of the class described which, due to its characteristic of continuous cool operation under load cycling conditions, will not have its clamping parts creep or relax their initial contact pressures as installed; the provision of a connector clamp of the class described which resists both atmospheric and galvanic corrosive action between it and the conductor being clamped; the provision of a connector clamp of the class described which, due to its permanent maintenance of noncorroded and properly pressured (unrelaxed) contact areas, prevents the increase with aging of contact resistance; the provision of a connector clamp of the class described which is economical to produce; and the provision of a method for making electrical connectors resistant to corrosion and overheating in response to load cycling conditions. Other objects and features will be in part apparent and in part pointed out hereinafter.

The invention accordingly comprises the methods, constructions and products hereinafter described, the scope of the invention being indicated in the following claims.

In the accompanying drawings, in which several of various possible embodiments of the invention are illustrated,

Fig. 1 is an exploded view of two typical connector parts treated in accordance with the invention;

Fig. 2 is an assembled plan view of the connector parts of Fig. 1 shown joining two conductors and forming a connector clamp;

Fig. 3 is a greatly enlarged fragmentary section taken on line 3—3 of Fig. 2 and schematically shows coatings for the connector parts applied according to the invention;

Fig. 4 is a graph based upon tests showing comparative temperature rises of typical copper alloy connector clamps, one being made according to the prior art and the other according to the present invention; and,

Fig. 5 is a graph based upon tests showing comparative temperature rises of typical aluminum-alloy connector clamps, one being made according to the prior art and the other according to the present invention.

Corresponding reference characters indicate corresponding parts throughout the several views of the drawings.

The invention has its primary use on so-called connector clamps for electrically connecting load distribution wires, although it will be apparent from the following

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description that the invention is applicable to any type of connector for connecting electrically conducting parts. The connector clamps to which the invention has most important application are in general used in industrial, outdoor, and marine applications, all of which are often subjected to corrosive atmospheres. Moreover, the electrical circuits of which the connected wires form parts often have substantial cyclic variations in loads which, particularly in the case of heavily loaded circuits, brings about a condition in prior connectors known as heat cycling. That is to say, there are current-induced temperature rises in the connector clamps as heretofore constructed. If the cycling is rapid enough, one temperature rise in a connector fails to dissipate before the next is applied, resulting in a steady increase in temperature to a point where creep or permanent deformation takes place in the clamp material. If and when cooling then occurs, the original contact pressures between the clamp and the conductor are lost, with a resulting increase in contact resistance.

This phenomenon is observed even if complete cooling occurs between cycles. In service, the overload or heating period may be long enough to induce creep before the current is reduced sufficiently to allow cooling, with resultant loss of contact pressure. As contact pressure is progressively lost, contact resistance is increased. Therefore, any cooling that might result from decreased currents (radiating surfaces remaining the same, with reduced heat input) during minimum demand periods is progressively offset by increased resistance (I²R effect). The rapidity of the cycling is not a cause of this failure but would accelerate it, provided the heating portion is of sufficient duration to allow the metals to creep.

Moreover, the clamps are called upon to connect various types of wires such as copper, aluminum, or ferrous or iron-containing material such as steel, etc., and it is not always feasible to have the body material of a given connector clamp the same as the wires which it connects. Therefore, under various circumstances corrosive galvanic current is likely to be generated, which current the present invention inhibits.

Attempts have been made heretofore to improve both copper, aluminum and other connector clamps by coating or plating them with hot-flowed tin, cadmium plating and the like. A plated cadmium coat has been found to be the most satisfactory from the anticorrosive standpoint. While these coatings have improved the anticorrosive and resistance characteristics of the clamps, they have been found in service unexpectedly to build up excessively high temperatures in response to heat cycling under cycling electrical loads.

For example, in Fig. 4 the line A shows, in the case of one prior-art type of copper-alloy, cadmium-coated connector clamp, the temperature rise above ambient temperature in ° C. in response to one-hour on-off cycling of load current. By contrast, line B shows how the same connector clamp is caused by means of the invention to operate under the said conditions with a markedly smaller temperature rise. While the ambient temperature is variable in any given installation, the ambient temperature for Fig. 4 may be taken as 26° C. The same is true as to Fig. 5.

In Fig. 5, line C again shows, in the case of a prior-art type of aluminum-alloy, cadmium-coated connector clamp of a different design than the copper-alloy connectors mentioned above, the temperature rise above ambient temperature in ° C. in response to one-hour on-off cycling of load current. By contrast, line D shows how the same connector clamp is caused by means of the invention to operate under the said conditions with a markedly smaller temperature rise.

As a result, the clamps made according to the invention and operating according to curves B and D in Figs. 4 and 5, respectively, avoid the former relaxation of contact pressure that occurred upon cooling of the connector clamps after the stated formerly excessive temperature rises.

Briefly, the invention consists in applying to the anti-corrosive cadmium coating of connector clamps made of copper, copper alloy, aluminum, aluminum alloy, iron, iron alloy, etc. an additional coating which has the effect of preventing the stated temperature rise under load cycling conditions. Various additional or second coating materials may be used and are listed below. Among these are nickel, silver and tin.

It is preferable that the additional coating be thinly enough applied so that it has a porous characteristic providing what may be called openings or windows in a thin lattice of nickel, silver, tin or the equivalent, through which the cadmium can obtain effective electrical contact with the wire being clamped, and thus inhibit galvanic corrosion which would occur by the use of a thicker second coating of nickel, silver, tin or the equivalent. Thus it is preferred that the additional porous or lattice-like coating be electroplated to a thickness in the range of approximately .000010 to .000100 inch, with .000030 inch preferred. It may be mentioned that techniques exist for making thickness measurements of such thin coatings, whether nonporous, porous, or latticed. One technique involves optics, and measurements of time and temperature during treatment with a reagent. Such a coating is sufficiently thin to provide the desired (window-in-lattice) type of porosity for the contact surface of the connector, thus providing what may be referred to as cathodic protection, obtained by reason of the contact of the cadmium with the clamped wire through the lattice of nickel, silver, tin or the equivalent resulting from the thin porous coat. This contact in effect inhibits the electromotive potential that, in the absence of porosity or too thick an outer coating even if porous, might build up between the outer coating and the wire, as for example, in the case of an outer coating of nickel engaging an aluminum wire.

It will be understood that the purpose of the cadmium coating is to afford protection against atmospheric corrosion, and therefore it should not itself have the porosity of the outer coating. Therefore, the cadmium coating preferably should be .000500 inch thick, with a possible range of .000200 to .001000 inch or more thick. However, the upper limit on the thickness of the cadmium coating is determined primarily by cost. It may be remarked that from an abstract viewpoint, most plated coatings, regardless of how thickly applied, have a few pores, but above certain thicknesses these are so extremely small as to be of no practical importance so far as is concerned the ability of the cadmium to resist atmospheric corrosion. But if the outer coating is too thick, the exceedingly few pores that might exist would not be of an amount nor of a form allowing the underlying cadmium to gain any effective electrical contact access to the clamped wire. In other words, the openings of a sufficiently thin and porous outer coat are in the nature of flat window-like openings in a lattice-like structure through which the cadmium and the clamped wire can meet, whereas whatever exceedingly few pores may exist in a thick outer coat would be in the nature of isolated tubes (if there is any porosity at all). Such tubular pores, particularly if few in number, are incapable of providing through them the desired electrical contact between the cadmium and the clamped wire. Thus in the lattice-like thin-coat case, any electromotive potential that the outer coat might have with the wire would be short-circuited by the cadmium-wire contact obtained, whereas in the thick-coat case such short-circuiting could not be obtained, and whatever electromotive potential

might exist between the outer coating and the wire would cause rapid cathodic corrosion.

Thus the invention is constituted by a connector with a sufficiently thick substantially nonporous coating of cadmium to prevent atmospheric corrosion, and a sufficiently thin and porous outer coating to provide porosity of the window-in-lattice type adapted to prevent temperature rise but at the same time to allow the cadmium coating to attain contact with a clamped wire, so as to inhibit the galvanic corrosion that might be expected otherwise from the outer coating. Taking as an example the case of a connector clamp on an aluminum wire, the clamp having a first cadmium coat and a second nickel coat applied according to the invention, the resulting advantages are:

- (1) Adequate protection afforded by the cadmium coat against atmospheric corrosion of the connector;
- (2) Adequate prevention by the nickel coating of undesirable cyclic heating caused by the cadmium coat;
- (3) Prevention by reason of the adequate porosity of the lattice-like nickel or like coat of undesirable cathodic corrosion between the nickel and the aluminum wire, such as would otherwise be caused by the nickel coat if it were sufficiently thick.

Referring now more particularly to Fig. 1, there are shown at numerals 1 and 3 connector clamp jaws made according to the invention. These have openings 5 for alignment and the reception of a clamp bolt 24 (Fig. 2). Side ears 7 and end ears 9 are for the usual side and end alignment purposes. Inside lugs 11 are adapted to be received in inside sockets 13 respectively. Cooperative grooves 15 are for the reception upon assembly of one wire 19, and cooperative grooves 17 for the reception of another wire 21.

In Fig. 2 the jaws are shown assembled and clamping a line wire 19 (held in the grooves 15) and a branch wire 21 (held in the grooves 17). The clamp bolt passes through the openings 5. It has a head 23 and tightening nut 25. It will be understood that the connector clamp thus described is one of many and various shapes or forms that might be used for the purpose, and the invention is not limited to the particular shape. The particular shape shown is only by way of example.

Referring to Fig. 3, the base metal 27 of the electrical connectors of the invention, to which the primary cadmium coating 29 and the additional thin coating 31 are applied, may be composed of any of the common materials for the purpose, such as copper, copper alloy, aluminum, aluminum alloy, or ferrous material such as iron or iron alloy, et cetera. Among the metals which have been found suitable for use as thin coatings 31 on the cadmium-coated base metal may be mentioned nickel, tin, zinc, silver, chromium, iron and binary tin-zinc. Binary tin-zinc is an alloy of tin and zinc.

In general, conventional methods are used in applying the basic cadmium coating 29 and thin coating 31 to the base metal. Where aluminum or an aluminum alloy is used as a base metal 27, for example, the metal is first subjected to a mild alkaline cleaning followed by a rinse. The metal then undergoes an acid pickling process, after which it is given two more rinses. This is followed by treatment with a solution of sodium zincate, which results in the deposition of a thin layer of zinc 33 on the base metal. After two additional rinses, the base metal is plated with a thin layer of copper 35 (or nickel) to protect the zinc film in an alkaline plating solution. The basic cadmium coating 29 is then conventionally plated onto the base metal and the thin coating 31 of nickel or one of the other suitable metals previously mentioned is applied to the cadmium-coated base metal. It will be understood by those skilled in the art that when copper is employed as the base metal 27, the zinc layer 33, resulting from the sodium zincate treatment, and the copper or nickel layer 35 may be omitted.

Where nickel is used as a thin coating 31 for the

cadmium-coated base metal, a plating solution with a pH of approximately 5.5 should be employed in order to avoid attack on the base metal by the acid nickel solution prior to the production of a protective deposit of nickel. This pH value can be obtained by using a "high sulfate bath," i. e., one containing nickel sulfate and sodium sulfate, and adjusting the pH after the bath components have completely dissolved by the addition of sodium hydroxide, if the pH is too low, or sulfuric acid if the pH is too high. If desired, the outer coating may be applied according to the process known in the art as a flash coating, but the invention is not to be taken as limited to such a coating in the sense that flash coating merely means a rapid deposition of the coating, whether thick or thin. In the sense that a flash coating is a convenient manner of obtaining a thin porous coat, the term defines an appropriate coating method.

Thus, the invention provides electrical connectors having the stated improved properties of both galvanic and corrosion protection; prevention of excessive overheating in response to load cycling conditions; prevention of the build-up of high electrical contact resistance; and a convenient method for making such electrical connectors. In addition, the invention is applicable to all types of electrical connectors insofar as their shapes and mechanical clamping means are concerned.

It will be understood that, wherever base metals are referred to herein by their elemental designations, alloys thereof are included. Thus the terms aluminum, copper and iron used for designating the base material of the connector includes aluminum alloys, copper alloys and iron alloys.

In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

As various changes could be made in the above methods and products without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. An electrical connector clamp for connecting electric wires, comprising jaws composed of electrically conductive metal, opposed parts on said jaws being adapted to cooperate with said wires, clamping means cooperating with said jaws adapted to force said jaws against the wires at said parts with substantial pressure, a relatively thick nonporous layer of cadmium on and covering said parts and adapted to prevent atmospheric corrosion, and an additional relatively thin and substantially porous layer of metal on the outside of said cadmium layer selected from the group consisting of nickel, tin, zinc, silver, chromium, iron and binary tin-zinc, adapted to minimize cyclic heating of the clamp due to said substantially nonporous cadmium layer, the porosity of said thin coating exposing parts of said nonporous cadmium layer for direct contact thereof under said pressure with the surfaces of said wires, whereby galvanic action is prevented between said porous layer and the wire surfaces.

2. A connector clamp for connecting electric wires composed of metal selected from the group consisting of copper, aluminum and iron, comprising jaws composed of electrically conductive metal also selected from

the group consisting of copper, aluminum and iron, opposed parts on said jaws being adapted to cooperate with any of said wires, clamping means cooperating with said jaws adapted to force said jaws against the wires at said parts with substantial pressure, a substantially nonporous coating of cadmium on and covering said parts adapted to prevent atmospheric corrosion and an additional substantially porous coating of metal on the outside of said cadmium coating selected from the group consisting of nickel, tin, zinc, silver, chromium, iron and binary tin-zinc, adapted to minimize cyclic heating of the clamp due to said substantially nonporous cadmium coating, the porosity of said porous coating exposing parts of said nonporous cadmium coating for direct contact thereof under said pressure with the surfaces of said wires, whereby any galvanic action is prevented that might occur between said porous layer and a wire surface.

3. An electrical connector clamp for electrically connecting wires composed of material selected from the group consisting of copper, aluminum and iron, comprising base metal jaws composed of material also selected from the group consisting of aluminum, copper and iron, said jaws having opposed parts adapted to cooperate with said wires, clamping means adapted to force said jaws together with said opposed parts in tight pressure engagement with the wires, a relatively heavy electroplated substantially nonporous coating of cadmium on said parts and an additional exposed relatively light and substantially thin porous coating of electroplated metal on the outside of said cadmium coating selected from the group consisting of nickel, tin, zinc, silver, chromium, iron and binary tin-zinc, the porosity of said thin coating being sufficient that under pressure of said clamping means the surface of said electroplated nonporous layer will be forced into engagement with the wire surfaces through the porous openings in said thin electroplated coating.

4. An electrical connector clamp made according to claim 3, wherein the electroplated thickness of said porous coating is in the range of from .00001 to .0001 inch.

5. An electrical connector clamp made according to claim 3, wherein the electroplated thickness of said cadmium coating is not less than approximately .0002 inch thick and the thickness of said porous coating is in the range of from .00001 to .0001 inch.

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