Dec. 31, 1957 H. O. WOOLLEY, JR 2,818,363

ELECTRICAL CONNECTOR

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Fig. 3.

Step 1 — Apply adhesive lacquers to zinc-treated steel sleeve

Step 2 — Cure adhesive lacquer by heating at 320°F for twenty minutes

Step 3 — Cool the sleeve

Step 4 — Soak rigid nylon jacket in water

Step 5 — Force fit the Nylon jacket over sleeve

Step 6 — Dry the Nylon jacket and sleeve assembly

Step 7 — Place the assembly in high-frequency induction field for about 1/30 sec.

Step 8 — Chill assembly immediately in liquid bath

Step 9 — Assemble insulated sleeve on ferrule portion of connector and secure to make composite ferrule

Fig. 1.

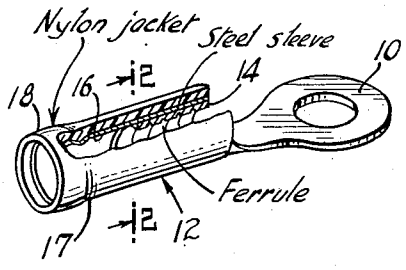
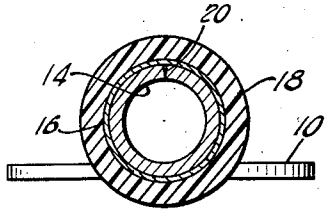


Fig. 2.



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ELECTRICAL CONNECTOR

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This invention relates to insulated electrical connectors or terminals of the type that are to be crimped onto electrical conductors. More particularly, this invention relates to an improved method of applying an insulating jacket to a metal ferrule or tube forming part of such a connector to provide an insulated electrical connector having improved characteristics.

The use of metallic connectors that are adapted to be crimped, i. e. pressure formed, rapidly and simply onto one or more electrical conductors, as by means of hand or power operated crimping tools, has grown considerably in recent years. Such connectors provide an excellent and durable electrical connection of stable, low contact resistance, generally superior to a comparable soldered joint. The so-called "solderless connector" typically includes a barrel portion into which the conductor is inserted, and which is deformable inwardly by the application of crimping pressure so as to firmly engage the conductor and to be cold-forged thereto. Such a connector may be formed in various ways, for example from extruded tube, or by drawing a seamless ferrule from an initially flat strip of copper or other malleable metal, or by stamping out a flat blank and rolling at least a part thereof into tubular shape with or without brazing or other reinforcement of its seam. Advantageously, the connector is insulated with a rigid plastic so tough that the insulated barrel portion or ferrule can be crimped under heavy pressure onto one or more electrical conductors without destroying or otherwise deteriorating the insulation effectiveness.

During a typical crimping operation, severe stresses are necessarily applied to both the ferrule and the conductor therein, in order to flow the ferrule and conductor together plastically to produce the desired connection. Because of these extreme pressures, it has been found desirable to position a close-fitting thin seamless sleeve, typically formed of copper, brass or bronze, around the ferrule or barrel portion prior to application of the crimping pressure.

It has recently become accepted as the best practice to cover the ferrule portion, i. e. the inner ferrule body and the surrounding seamless sleeve, with a layer of rigid plastic insulating material, in accordance with the teachings of Watts' Patent No. 2,410,321 and Broske's Patent No. 2,478,082. Advantageously, as set forth in the patent of R. C. Swengel No. 2,654,873, this layer of insulation is firmly bonded to the metal ferrule to overcome the tendency of localized high pressures of the crimping dies to displace the insulation.

Bonding of the plastic to the ferrule is at best a difficult problem; this is particularly true when using an insulating plastic such as nylon. Although fused nylon is known to be very adhesive, it had been found impossible to obtain a wholly acceptable bonded nylon insulated connector because the nylon thus fused proved brittle when crimped at low temperatures. It has been found, as disclosed in U. S. patent application Serial Number 418,919, filed by T. C. Freedom on March 26, 1954, that nylon can be satisfactorily bonded to metal by fusing a very thin layer of the nylon, the thinner the better.

It is an object of the present invention to provide an improved such nylon-metal bonding. In accordance with one aspect of the present invention, there is provided a novel and advantageous method of securing a normally rigid tube of tough and stiffly-flexible insulating plastic to a metal sleeve such that the plastic jacket covers and tightly embraces the sleeve, and wherein the sleeve and the insulation jacket may be simply and positively assembled together to form a durable integral unit adapted to be fitted over a connector barrel; and whereby the insulating tube can transmit sufficient crimping pressure to the connector barrel from a crimping tool to crimp the barrel against a conducting wire by plastic flow in the metal without cracking or otherwise interfering with the electrical or mechanical effectiveness of the insulation. Other aspects, objects and advantages will be partly apparent from, and partly pointed out in, the following specification considered together with the accompanying drawings, in which:

Figure 1 is a perspective view partially broken away to show under layers of one type of connector constructed in accordance with the present invention;

Figure 2 is a cross-section view taken along line 2—2 of the connector ferrule of Figure 1; and

Figure 3 is a flow diagram in block form outlining process steps in the manufacture of a connector in accordance with the present invention.

One form of an insulated connector adapted for crimping onto one or more wires or other electrical conductors is shown in Figure 1. This connector includes a ring tongue **10** for attachment to a binding post, etc., and a composite, laminated ferrule generally indicated at **12** into which the conductors are to be inserted prior to the crimping operation. This ferrule **12** includes an interior portion **14**, serving as the wire barrel, and which is typically formed of copper, aluminum, iron or one of their alloys and integral with the tongue **10**. Surrounding and secured to the interior barrel portion **14**, is a metal sleeve **16** formed of very thin soft steel, which may serve among others the functions set forth in the Buchanan Patent No. 2,379,567. The exterior of the ferrule **12** comprises a plastic jacket **18** adhesively secured to the sleeve **16** and thus insulating it against short-circuit contacts. This jacket is advantageously formed of nylon but in a broader aspect of the invention may be of vinyl chloride slightly plasticized with a 2–5% vinyl acetate copolymerized therewith and/or a very small percentage of external plasticizer. In general, this plastic is a rigid, tough, high-polymer very high tensile strength and high melting point plastic, chemically stable and resistant to solvents.

Figure 2 shows this connector in cross-section taken along line 2—2 of Figure 1, and demonstrates in more detail the relationship between the elements comprising the barrel **12**. This view shows the seamless plastic jacket **18** disposed around and covering the seamless steel sleeve **16**, which in turn is positioned around the connector interior barrel portion **14**. The interior barrel portion **14** may with advantage have a brazed seam **20**, which runs the length of the barrel.

For the purposes of fully illustrating the invention and to point out the nature and principles thereof, certain specific examples of preferred structures and manufacturing processes are described below in detail. These examples, of course, are not to be taken as exhaustive and limiting the scope of the invention, but rather are to be considered as an aid to others skilled in the art so that they may be able so fully to understand the invention and its principles as to adapt the invention to a variety of forms each as may be best suited for a particular application.

Referring now to the flow diagram of Figure 3, a thin steel sleeve, zinc-plated or otherwise rust-proofed, its outside surface adapted for bonding with the insulation jacket, was first (step 1) treated with a thin layer of adhesive cement chosen with respect to the particular base and for adhesion by melted nylon. The steel sleeve was advantageously as thin as is consistent with a circumferential indent **17** (see Figure 1) capable of serving both to guide the wire into the barrel **14** and to secure the sleeve against axial removal. The length of the sleeve is such that the opposite end extends beyond the end of the barrel **14** so that it can be intented to secure the sleeve and ferrule together. It is an important advantage of steel that it may have sufficient stiffness and malleability for such indents although so thin that, when heated to a temperature above the melting point of nylon, its sensible heat will be sufficient to fuse only an extremely thin layer of nylon. For example, steel sleeves having thicknesses between .008 inch and .010 inch have been found to provide such advantages.

Although zinc-plating of the steel sleeve has been found to give superior results, other types of treatment will produce satisfactory results. For example, the surface of the steel sleeve may be passivated by a coating in accordance with the commercially-known "Cronak" process, wherein a zinc-chromium composition is formed on the steel surfaces or the steel sleeve may be treated in accordance with the commercially-known "Bonderizing" or "Parkerizing" processes. Instead of or on top of these metal treatments, the steel sleeve may be protected by a thin coat of resin, which may serve also as a cement.

The preferred adhesive cement is a partially polymerized resorcinol-formaldehyde condensation resin dissolved in aqueous ethanol. After application of this adhesive, the sleeve was placed (step 2) in an oven at a temperature of 320° F. for a period of about 20 minutes, in order to dry and partly cure the adhesive resin.

After the coated sleeve was cured and cooled (step 3), a rigid nylon (Dupont FM 3003) jacket, preformed as extruded tubing or injection molded, was softened by soaking it in water (step 4) for a short period, and was then forced onto the steel sleeve (step 5). The inner diameter of the nylon jacket was selected so that it gives a tight fit but does not remove the adhesive resin layer.

The resultant assembly was then thoroughly dried (step 6) and then (step 7) passed axially through a high frequency (for example 1.4 megacycles) alternating magnetic field provided by the coil of an induction heating unit. The time in the field was about $\frac{1}{30}$ second, in this case attained by dropping the assembly from a position of rest just above the coil, the drop path terminating (step 8) in a cooling bath of water disposed beneath the coil. The axial length of the coil was about 6 inches to give the transit time of about $\frac{1}{30}$ second. If a stronger induction coil is used so as to require less time, the assembly may be released farther above the coil so that it falls more rapidly through it, or a shorter coil may be used. If longer time is required, the assembly may pass through the coil on a conveyor or on an inclined slide.

While the assembly passes through the induction coil, part of the magnetic field energy therein is converted to heat by the steel sleeve so as momentarily to raise the temperature of the steel sleeve above the melting point of the nylon jacket; the intensity of the field and duration of exposure to it was adjusted so that the heating stopped as soon as possible after the fusion temperature is passed. Heat imparted from the steel sleeve to the nylon jacket after the heating stopped caused the nylon to just barely begin to melt, and the heat was withdrawn and the assembly chilled in the water bath before fusion extended beyond the immediate surface film adjacent the steel sleeve.

The use of steel as the sleeve material is of advantage in this respect, since it heats very quickly in the high frequency field permitting an extremely short heating and chilling cycle. The free falling through the magnetic field makes possible accurate timing with respect to the heating cycle.

After cooling, the steel sleeve and nylon jacket bonded thereto was fitted over a connector barrel (as shown in Figure 1) to provide a durably bonded, corrosion-resistant, insulated connector (step 9); and its end portion was crimped to secure it in position.

Experiments have shown that the fusion bond formed between the nylon jacket and the steel sleeve, in accordance with the process outlined above, is extremely tough and durable and affords especially good crimping characteristics in practical usage. Connectors insulated in the above manner can satisfactorily be crimped at very low temperatures, and maintain their bond for long periods of time under extremely adverse conditions.

Although the above method of insulating connectors or terminals has unique advantages when employed with nylon, it has been found that this method may be used with insulating materials other than nylon. For example, a rigid insulating jacket formed from extruded rigid vinyl plastic tubing may be fitted over the steel sleeve and bonded to the outer surfaces thereof in accordance with the above process to produce a superior insulated connector.

It has been found advantageous, when using nylon for insulating purposes in accordance with the present invention, to soak the nylon insulating jacket in water for a short while prior to fitting the jacket over the steel sleeve. This soaking of the nylon, which can readily be done by immersing the jacket in a bath of water containing a dye to impart a distinguishing color to the nylon, should be continued until a substantial amount of moisture has diffused into the mass of nylon. The diffused moisture in this case serves to slightly plasticize the nylon, thus minimizing the tendency of the nylon to crack or disintegrate when it is pushed over the steel sleeve, for example by a power-operated machine designed to assemble the component parts rapidly and automatically.

Prior to passing the sleeve assembly through the magnetic induction field, however, it is important that the diffused moisture be completely removed from the nylon jacket. It has been found desirable, in this regard, to first remove any water adhering to the nylon surfaces, e. g. by centrifuging, and then evaporate the absorbed moisture from the mass of nylon, for example by placing the assembly in an atmosphere of low humidity and particularly by exposing it to a stream of dry air for at least 24 hours or until substantially all of the moisture has been removed.

Removal of the moisture prior to heating the assembly by passing it through the magnetic induction field not only prevents blistering of the fused nylon and consequent weakening of the bond, but also causes the jacket to shrink slightly onto the steel sleeve and thus more tightly grip the sleeve in accordance with the invention of F. J. Sowa set forth and claimed in U. S. patent application Serial No. 254,516, filed October 1, 1951. This also substantially improves the ultimate adhesive bond. In general, plasticizers for the particular plastic of the jacket may be used in this way.

In accordance with another aspect of the present invention, the nylon jacket, after fusion bonding to the metal sleeve, is again slightly plasticized, advantageously before (but may be after) the sleeve assembly is fitted onto the connector barrel. Although various plasticizers may be so employed, it has been found that for nylon specifically, water is most advantageous in minimizing the tendency of bonded nylon to crack during the application of the severe crimping pressures encountered under low temperature conditions. For this purpose, the sleeve

with the nylon jacket fusion-bonded thereto may be soaked in a humid atmosphere or in water for a moderate period, for example two hours in water. The sleeve assembly may then be spun dry and assembled to the connector barrel. If desired, the assembled connector may be soaked, e. g. for four or more hours, and then again spun dry, to insure that moisture diffuses throughout a sufficient portion of the nylon insulation.

The moisture so placed in the nylon jacket should be retained as it is most important at the time the connector is crimped onto its conductor. To insure this moisture retention, it has been found advantageous to package the completed connectors in moisture-proof containers adapted to keep the moisture within the container for a substantial period of time and yet arranged so that the closure seal may readily be opened to take the connectors out for use. Preferably, the connectors are removed from the container only in lots sufficiently small to be used up before the absorbed moisture is lost.

It should be understood that the specific examples given hereinabove are illustrative of preferred embodiments of the invention, and that other arrangements within the scope of the invention are feasible. For example, an adhesive bond between a nylon jacket and the steel sleeve may be obtained without using a cementing lacquer, it being possible by induction heating to fuse a very thin layer of the nylon directly onto the steel or a metal plating or passivating surface thereon and it will adhere thereto. From the foregoing description, it will be apparent that a secure and stable bond between the insulating jacket and the steel sleeve is obtained by magnetically-induced fusion of the plastic insulating and/or cementing material. This bond is easily, simply and rapidly produced in accordance with the above process; and is resistant to corrosion and sufficiently strong to resist crushing and cracking and circumferential or axial displacement and consequent diminution of the insulation at the point of crimping, even when very great forces are applied for compressive forging of the insulated ferrule onto the wire. Production efficiencies not previously available with solderless connectors of this general type are, furthermore, made possible in accordance with the process above described.

What is claimed is:

1. The method of making a nylon insulated electrical connector of the type which includes a metal ferrule capable of being cold forged onto an electrical conductor, including the steps of (1) forming a steel sleeve adapted to surround the metal ferrule, (2) applying adhesive lacquer to the steel sleeve, (3) curing the adhesive lacquer (4) inserting a nylon sleeve tightly onto the steel sleeve (5) placing the assembly in a high frequency induction field only long enough to melt the inter-face between the steel sleeve and the nylon sleeve, leaving the nylon sleeve in a solid state (6) chilling the assembly to bind the nylon sleeve to the steel sleeve and (7) positioning the assembly over the ferrule to form an insulated connector.

2. The method of making a nylon insulated electrical connector of the type which includes a metal ferrule capable of being cold forged onto an electrical conductor including the steps of (1) forming a steel sleeve adapted to surround the metal ferrule (2) inserting the steel sleeve into a nylon sleeve to form an assembly, (3) introducing the assembly into a high frequency induction field to raise the temperature of the steel sleeve, (4) when the steel gets hot enough to melt the interface of the steel and nylon, removing the assembly from the high frequency field and cooling it, to provide a bond between the nylon and the steel and (5) telescoping the assembly over the ferrule.

3. The method set forth in claim 2 including the step of zinc plating the steel sleeve.

4. The method set forth in claim 2 wherein the assembly is introduced into the high frequency field by dropping it through the field.

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