March 15, 1955 F. H. WELLS 2,704,358

ELECTRICAL CONNECTION AND METHOD

Filed Oct. 24, 1947 2 Sheets-Sheet 1

Fig. 1.

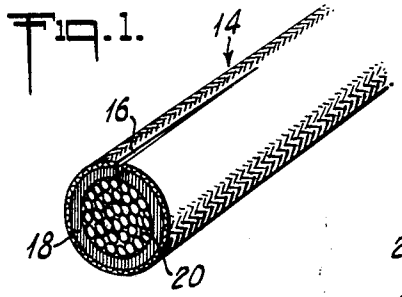



Fig. 2.

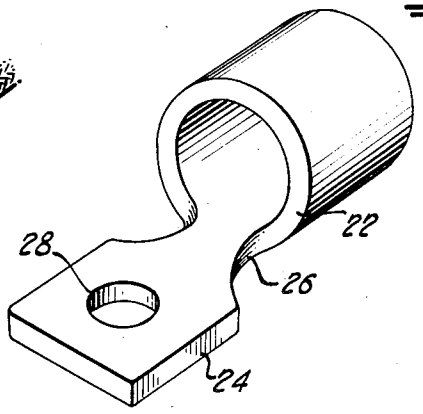



Fig. 3.

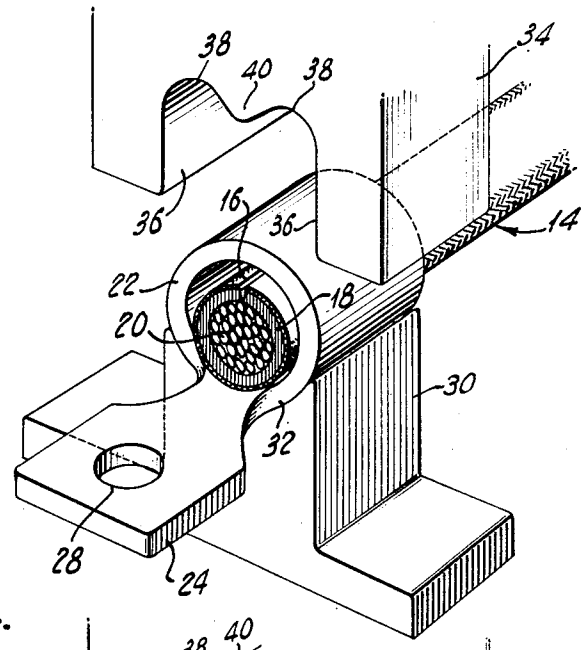



Fig. 4.

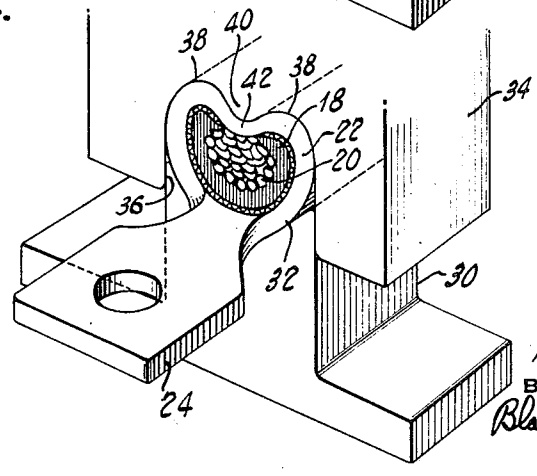
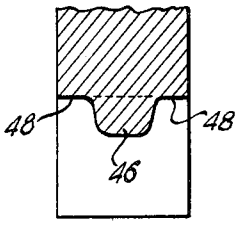



Fig. 5.




INVENTOR
FRANKLIN H. WELLS
BY
Blair, Curtis & Hayward
ATTORNEYS

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Fig. 6.

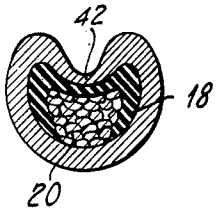



Fig. 7.

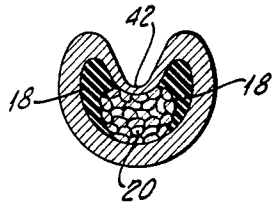



Fig. 8.

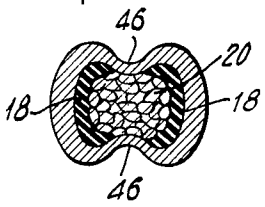



Fig. 9

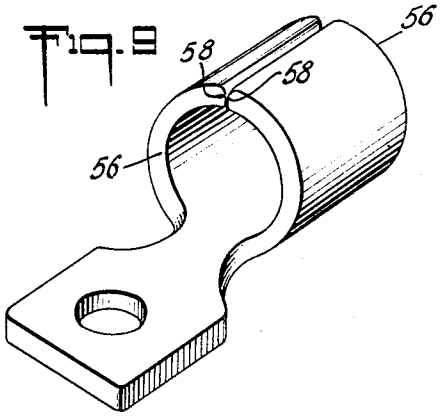



Fig. 10

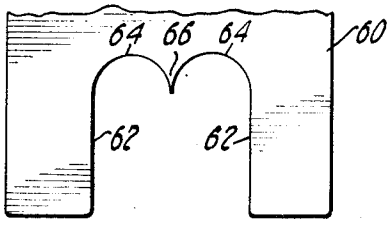



Fig. 12.

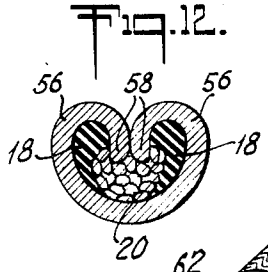
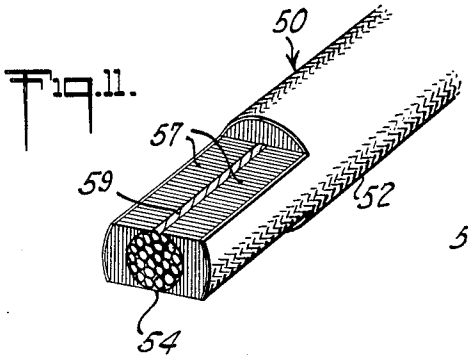



Fig. 11.



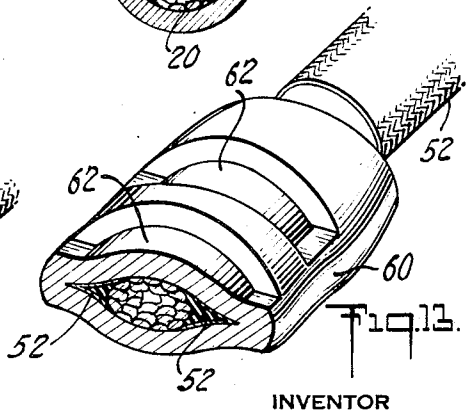




Fig. 13.

INVENTOR
FRANKLIN H. WELLS
BY
Blair, Curtis & Hayward
ATTORNEYS

United States Patent Office 2,704,358 Patented Mar. 15, 1955



2,704,358

# ELECTRICAL CONNECTION AND METHOD

Franklin H. Wells, Harrisburg, Pa., assignor to Aircraft-Marine Products Inc., Harrisburg, Pa.

Application October 24, 1947, Serial No. 781,826

7 Claims. (Cl. 339—223)

This invention relates to electrical connections comprising electrical conductors with connectors attached thereon, and to methods of forming same.

In the production of all types of electrical equipment, it has been found advantageous to make electrical wiring connections by attaching to the wires or other electrical conductors, connectors which are adapted in turn to make efficient electrical and mechanical connection with electrically conductive elements of the equipment, as distinguished from methods wherein the wires are connected directly to said elements with or without soldering. Where the wires are insulated, that portion of the insulation at the point where the connector is to be attached has had to be removed before attachment except in the case of special terminals having prongs adapted to pierce the insulation and make contact with the central wire. Stripping of insulation is disadvantageous not only in that costly working time is consumed and special apparatus required, but also in that it frequently results in severing some of the strands of the ordinary stranded conductor wire.

Accordingly, it is among the objects of this invention to provide an efficient method of conductively attaching an electrical connector to an insulated wire without removing the insulation from said wire. It is also an object of this invention to provide such a method which does not depend upon an edge of the connector to cut through the insulation.

Another object is provision of a method of forming electrical connections which is economical and which utilizes connector blanks and crimping devices of simple and readily available type. A further object is that of providing connections which afford good electrical conduction which is maintained despite subjection to severe physical stress and exposure to corrosive atmospheres and sprays, etc. Other objects will be in part obvious and in part pointed out hereinafter.

In this specification and the accompanying drawings I have shown and described a preferred embodiment of my invention and suggested various modifications thereof; but it is to be understood that these are not intended to be exhaustive nor limiting of the invention, but, on the contrary, are given for purposes of illustration in order that others skilled in the art may fully understand the invention and the principles thereof and the manner of applying it in various forms, each as may be best suited to the conditions of a particular use.

In the drawings,

Figure 1 is an isometric view of an end of an insulated wire the insulation of which has been slit;

Figure 2 is an isometric view of a typical connector which may be used in the practice of this invention;

Figure 3 is an isometric view of a pair of typical crimping dies which may be used in the practice of this invention, with a connector and wire in place in the dies before crimping;

Figure 4 is an isometric view of the dies in closed position on the crimped connector;

Figure 5 is a vertical axial section through a modified form of die which may be used in the practice of this invention;

Figure 6 is a transverse section through a crimped connection wherein the insulation is slit along the lower side of the wire;

Figure 7 is a transverse section through a crimped connection wherein the insulation is slit along both upper and lower sides of the wire;



Figure 8 is a transverse section through a crimped connection wherein the insulation is slit along both upper and lower sides of the wire and where the ferrule of the connector has been indented both at the top and bottom;

Figure 9 is an isometric view of another typical connector which may be used in the practice of this invention;

Figure 10 is an elevational view of another form of crimping die which may be used in the practice of this invention;

Figure 11 is an isometric view of an end of a length of wire from which portions of the insulation have been removed;

Figure 12 is a transverse section through a connector assembly formed by crimping a connector of the type shown in Figure 9 on the end of a wire prepared as shown in Figure 11 with a die such as shown in Figure 10; and

Figure 13 is an isometric view of a connector assembly comprising a connector of the type shown in Figure 2 crimped onto a conductor which has been prepared as illustrated in Figure 11, in accordance with another method within the scope of my invention; for simplicity, the tongue portion of the connector has been broken away.

The first step of forming an electrical connection in accordance with the present invention, comprises breaking into, but not stripping, the insulation in the area where the connection is to be made. In the example illustrated in Figures 1 to 10 this is by the forming of a longitudinal slit **16** in the insulation **18** on the wire **14**, as shown in Figure 1.

While in Figure 1 and throughout the several figures of the drawings the connector is shown applied to an end of the wire, the connectors may suitably be applied at any other point along the length of the wire.

Slit **16** may be formed manually, for example, with an ordinary knife, or it may be formed by a machine, e. g. one adapted to stab the wire from opposite sides with slitting knives or chisels, or to pass the wire between rotating knife disks; or the slitting knife may be incorporated in the crimping die. Slit **16** preferably extends completely through the insulation, although it satisfactorily may be shallower provided it extends deeply enough into the insulation to weaken appreciably that portion of the insulation where the slit is made so that it will start a tear under the stress of crimping and thus expose the wire before the crimping is completed. The length of slit **16** is approximately equal to, or advantageously somewhat less than, the length of the ferrule of the connector which is to be applied. It is an advantage of the invention that it provides for locking the insulation and the central conductor together, as well as to the connector, so that they support one another against tensile and bending stresses. This locking is most effective when the slit ends well within the crimped portion of the ferrule.

The end of the wire, having been thus prepared by breaking, at least partially through the insulation, is inserted into the ferrule **22** of an electrical connector. The connector illustrated, which is shown most clearly in Figure 2, comprises a tubular ferrule **22** and a tongue **24** which is connected to ferrule **22** by a neck **26** which may be of any usual or special form or omitted altogether. As shown, tongue **24** is provided with a hole **28** for connecting to other electrical components, as by bolting or otherwise. Such connectors may be suitably fabricated, for example, by stamping in one piece from sheet metal wherein ferrule **22** is formed of opposed tabs which are rolled upwardly until their ends meet and are brazed to form a peripherally continuous tube, or the ferrule may be deep drawn from the copper strip from which the tongue is stamped.

The end of wire **18** is inserted in ferrule **22** in such manner that the end of the wire projects slightly beyond the end of the ferrule adjacent tongue **24**, as shown in Figure 3.

The ratio of the outside diameter of the wire to the inside diameter of the ferrule may be, as shown, of the order of 3:4; it is an advantage of this invention, how-

ever, that the same connector may be employed on wires of a substantial range of sizes, the excess cross-sectional area of the wire being disposed of, at least in part, by compressive extrusion of the resilient or plastic insulating material.

The connector and wire when thus assembled are placed between a pair of crimping dies of the type shown in Figure 3. The lower die includes an upstanding rectangular column **30** whose width approximately equals the diameter of ferrule **22** and whose length may be approximately equal to, but advantageously is slightly less than, the length of ferrule **22**. The upper face **32** of column **30**, which constitutes the lower die face, is shown as a cylindriform trough whose contours are approximately fitted to those of ferrule **22**. The form of the die face however can be widely varied, e. g., from flat, or even convex, to a W or M form.

The upper die comprises a block **34** having a recess in the lower side thereof, said recess having opposed parallel side faces **36** which terminate in an end face formed to an M-shape, with parallel troughs **38** and a ridge **40** extending between troughs **38** along the center line of the die. The width between the side faces **36** is slightly greater than the outside diameter of ferrule **22** and approximately equal to the width of column **30** so that side faces **36** fit over ferrule **22** and column **30**. Troughs **38** are approximately cylindriform and substantially tangential to side faces **36**, and each has a radius approximately one-half of the outside radius of ferrule **22** although it may be appreciably more or less. The upper and lower dies may be mounted on the ram and table, respectively, of any standard or special press or may be formed on opposite jaws of a pliers-like hand tool. While the lower die has been shown as the male, and the upper die as the female. these may be reversed.

During closure of the dies, ridge **40** contacts ferrule **22** along the top thereof and turns it inwardly from both sides to form a longitudinal indentation **42** in ferrule **22**. The inward projection resulting from this indentation in turn strikes insulation **18** along slit **16** and wedges apart the insulation along the slit and contacts the conductive core **20** of the wire.

During this first phase of the crimping the cross-sectional area within ferrule **22** is reduced to equal substantially the cross-sectional area of wire **14** with its insulation; while the shape of wire **14** is deformed and the relative positions of the strands of conductor **20** and insulation **18** are changed with but slight, if any, reduction in cross-sectional area of wire **14**; past this point, as the dies continue to close, ferrule **22** and its contents are compacted so that each of the strands of conductor **20** are deformed to fill the interstices and form a substantially solid metallic section which contacts ferrule **22** throughout substantially its entire internal surface between the parted edges of insulation **18**. At the same time there is a cold flow of the metal in the ferrule whereby the wall is first thickened and then the ferrule is extruded to greater length. Although such flow relieves stresses in the metal, the interior of the ferrule is maintained at considerable pressure by the compressed resilient insulation, to give positive engagement of the conductor with the interior of the ferrule.

In Figure 5 is shown in axial section a preferred form of the upper die shown in Figures 3 and 4. In the die of Figure 5, boss **46**, which is longitudinally centered in the die, does not extend the full length of the die, leaving at either end a semi-cylindrical portion **48**. The use of this die results in indenting only a central portion of the ferrule **22**; the wire **14** is deformed only along that portion adjacent the indentation and not along that portion immediately adjacent the ends of the ferrule. This gives the connector assembly a high pull-out resistance and high fatigue resistance against transverse bending. Also since the insulation **18** on wire **14** is separated only along that portion of the wire adjacent the center of ferrule **22** and not along that portion of the wire at either end of the ferrule, the conductor **20** is well sealed against corrosion.

Figure 6 is a transverse section through a connector assembly in which a connector blank of the type previously described is crimped by means of dies, such as those described above, onto a wire which has been prepared as described, the wire, however, being oriented in the ferrule **22** with the slit **16** through its insulation adjacent the bottom, i. e., facing away from the point at which the indentation is made. In crimping, indentation **42** contacts the wire on the side opposite the slit and drives the wire through the slit into compressive engagement with the base.

In either this type of crimp, or that wherein the indentation is made on the slit side of the wire, the wire preferably should be so oriented that the slit in the insulation is within approximately 15° of the axial plane bisecting indentation; this, however, affords a sufficient tolerance that the wire may be rapidly inserted manually or by automatic mechanism under production conditions without extraordinary expense. Advantageously, however, the slit will be made in the same operation as the insertion into the ferrule and the ferrule is crimped in the same location so that the knife or chisel which makes the slit establishes the orientation plane to which the crimp location is related.

In Figure 7 is shown a similar view of a connector assembly wherein the same connector blank and die are used, but where the wire is slit along both top and bottom, the two slits being 180° apart. As shown this results in a crimped connection in which the ferrule contacts the conductor along both top and bottom. Such a connection has a very great area of contact and a high current capacity.

In Figure 8 is shown a similar view of a connector assembly wherein a connector blank of the type heretofore described is applied to a wire slit along both top and bottom as just described, but wherein both upper and lower crimping dies are ridged in similar form as the upper dies shown in Figures 3 and 4 or in Figure 5 so that the ferrule of the connector is indented at both top and bottom and contacts the conductor along both indentations. Three or more indentations may be made as shown, for example, in Patent No. 2,034,090 to Harry A. Douglas, and the insulation slit at one or more or all of the indentations.

In Figure 11 is shown an end of an insulated wire **50**, wherefrom portions of the insulation **52** at either side of said wire have been removed along a short distance from said end. Such removal may suitably be accomplished by abrasion, as with a standard, coarse, highspeed grinding wheel. The removal is preferably to such depth, as shown, that the conductive core **54** of the wire is just bared, as at **59**, along the center of the flattened face **57** formed by such removal. The grinder in such case is provided with stops to limit the grinding to the thickness of the insulation so that wire core will not be substantially weakened or reduced in cross-section. This operation may thus be performed rapidly and without hazard of injury to the conductor **54**. This method of preparing the wire for crimping may be used in lieu of slitting in any of the types of connector assembly described above, and of course, may be used on one or more sides of the wire.

Since a portion of the insulation has been removed from the wire, less of the internal sectional area of the crimped connection is occupied by the remaining insulation, and the breach between the parted edges of the insulation becomes wider to allow greater area of contact between the conductor and the internal surface of the ferrule.

In Figure 9 is shown a modified form of connector blank which may be used in the practice of this invention. It is similar in all respects to the blank shown in Figure 2, except that the edges **58** of the opposed tabs **56** which meet in a butt joint along the top of the cylindrical ferrule are not brazed or otherwise made peripherally continuous. The blank shown in Figure 9 may be applied on a slit wire, as shown in Figure 1, with the slit aligned with or opposite to the butt joint, or on a wire from which portions of the insulation have been removed, as shown in Figure 11, in which case the orientation of the wire in the ferrule is not essential.

Suitably, the crimping of the terminal shown in Figure 9 onto either of said types of wire may be accomplished in a pair of dies, the lower of which is similar to the lower of the dies shown in Figures 3 and 4, and the upper of which is shaped as shown in Figure 10. Said upper die comprises a block **60** having in its lower side a recess formed of opposed parallel side faces **62** which merge into an upper face formed to an M-shape, with parallel cylindriform troughs **64** which meet along the center line of the die in a comparatively sharp ridge **66**. Troughs **64** are tangential to said faces **62**, and their

radius is such that they are substantially mutually tangential along the center line of the die. When crimping is accomplished, ridge **66** contacts the ferrule of the connector along the seam formed by edges **58** and turns it inwardly. As closure of the dies continues, at one point tabs **56** will be bent so as to conform to the contour of troughs **64**. Past this point, as closure continues, tabs **56** curl around troughs **64**, contact wire **50** along exposed portion **55** of conductor **54** and are driven into the bundle of strands forming said conductor, as shown in Figure 12. At the same time the metal of the ferrule is thickened by compression at the inturned ends and at the sides and to a lesser extent even at the top in the troughs **64**.

If, as shown in Figure 11, the strands of conductor **54** are spirally twisted to an appreciable extent, the edges **58** may not pass between the strands but will force the uppermost strands downwardly to displace the remaining strands aside and upwardly within the ferrule. If the strands of conductor **54** are not twisted, or are twisted but slightly, edges **58** will part some strands and pass between them. In the latter type of crimping, less crimping force is required. In the former type, more force is required, but, due to the rearrangement of the relative positions of the strands, a connector assembly having an extremely high pull-out resistance is formed. In either case the resulting connector assembly has very high contact area, since a substantial portion of the end of each tab **56** is in contact with the strands of conductor **20**.

If the insulation of wire **50** has been removed at both top and bottom, as in the wire shown in Figure 11, conductor **20** will be driven into compressive engagement with the internal surface of the ferrule at the bottom thereof, as shown in Figure 12. This is seldom important, however, since the high current carrying capacity afforded by contact of the ends of tabs **56** with the conductor **20** will be sufficient, so that removal of insulation from either the top or the bottom of the wire may be suitably dispensed with. In crimping, the tabs **56** will continue to slide around the troughs **64** until they reach approximately the position shown. Past that point, the resistance to further penetration creates sufficient back pressure that friction between tabs **56** and troughs **64** becomes great enough to prevent further sliding. As the dies complete their downward movement, the sides of the ferrule and the down-turned edge portions are compressed and thickened; and the wire within the ferrule is compacted, and to some extent extruded, in the manner hereinbefore described.

In lieu of the type of connector shown in Figure 9, a connector having an open, U-shaped ferrule of the type shown and described in the copending application of James C. Macy, Serial No. 717,842, filed December 23, 1946, may be used. This results in a crimped connection closely resembling that of Figure 2, except that, as pointed out in said copending application, since the ends of the connector tabs in crimping follow approximately arcuate courses, their ends **58** separate within the conductor, to divide the core into three approximately equally sized bundles of strands.

In Figure 13 is shown a connector assembly crimped in an alternative manner within the scope of my invention. In the particular assembly shown, the conductor **50** has been prepared as shown in Figure 11, and the ferrule **60** of the connector has been crimped in place on the conductor by forming on one side of the ferrule a pair of longitudinally spaced transversely extending flattened portions **62**. Such a crimp may preferably be made by using a pair of dies of the type shown in Patent No. 2,379,567 to Stephen N. Buchanan.

The interior of the ferrule in the area of the indentations **66** is driven into compressive contact with the conductive core of the wire and said core is compacted and extruded in the manner hereinbefore described; in the present method, some of the extrusive flow is from the portion of the wire opposite the indentations into that portion between the indentations, creating a protuberance in the latter area, which forms an excellent lock between and among the ferrule **60**, insulation **52** and conductive core **54**, affording extremely high resistance to tensile forces. While the method of preparing the wire as shown in Figure 11 is extremely well adapted for the type of crimp illustrated by Figure 13, another suitable method of preparing the wire is that of making one or more slits in the insulation **52**, the slits extending transversely of the wire and penetrating just through the insulation, or deeply enough therein to weaken it substantially and allow it to tear apart under the stress of crimping. Preferably, the slits are made adjacent the points where the indentations **62** are to be made, so that the interior wall of the ferrule at the indentation acts to wedge apart the insulation along the slit and allow the greatest area of contact between the ferrule and conductor core **54**. Only one, or three or more of such indentations **66** may suitably be made instead of the number shown.

In all of the above embodiments the costly operations necessary to accomplish wire stripping have been eliminated. The connector assemblies formed have excellent electrical characteristics and high strength against tensile pull and high resistance to fatigue and corrosion. There will thus be seen to have been provided methods and devices whereby the aforementioned and other desirable objects may be obtained.

I claim:

1. A method of connecting an insulated conductor which comprises providing a connector with a tubular ferrule, at least partially dividing the insulation longitudinally along a portion of said conductor leaving a significant part of the insulation on said portion, surrounding said portion with said ferrule, and indenting a portion of said ferrule along a longitudinal line to separate said insulation along the division and drive said ferrule and conductor into compressive engagement along a continuous unbroken portion of said ferrule.

2. The method of connecting an insulated conductor which comprises providing a connector with a tubular ferrule, slitting the insulation along an axial plane adjacent an end of said conductor, inserting said end into said ferrule, and indenting said ferrule substantially along said axial plane to force apart the insulation along the slit and drive said ferrule and said conductor into compressive engagement along a continuous unbroken portion of said ferrule.

3. The method of attaching to an insulated conductor a terminal connector having a tubular ferrule which comprises the successive steps of forming a longitudinal slit in the insulation adjacent an end of said conductor, inserting said end into said ferrule, and radially indenting a portion of said ferrule adjacent said slit to drive said indented portion through said slit into compressive engagement with said conductor, the indented area of said ferrule adjacent the portion in compressive engagement with said conductor being continuous and unbroken.

4. The method of attaching to an insulated conductor a terminal connector having a tubular ferrule which comprises the successive steps of forming a longitudinal slit in the insulation adjacent an end of said conductor, inserting said end into said ferrule, and radially indenting a portion of said ferrule so that the indented portion contacts the insulated wire on the side opposite the slitted portion and drives said conductor through said slit into compressive engagement with the unbroken side of said ferrule opposite the indented portion.

5. The method of attaching to an insulated conductor a terminal connector having a tubular ferrule which comprises the successive steps of forming a pair of longitudinal slits in opposite sides of said insulation adjacent an end of said conductor, inserting said end into said ferrule, and forming a pair of indentations in the portions of said ferrule adjacent said slits to drive the indented portions of said ferrule through said slits into compressive engagement with said conductor, at least one of said indentations extending along a longitudinal line along a continuous unbroken portion of said barrel.

6. The method of attaching a connector to an insulated conductor which comprises dividing the insulation along a portion of said conductor leaving a significant part of the insulation in place, forming a tubular metal ferrule, surrounding such divided portion of the insulation with the metal ferrule, and indenting said barrel along a continuous unbroken line driving it inwardly into said division until it is pressed against and deforms the conductor.

7. A connection on an insulated conductor, comprising a connector having a continuous tubular ferrule surrounding said conductor, said ferrule having a reentrant portion compressively engaging the insulation on said conductor, which insulation extends over said conductor for substantially the full length of said conductor within said ferrule but has a longitudinal breach through which

the conductor projects to make contact with said ferrule on the side of said ferrule opposite said reentrant portion.

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