March 1, 1960 P. M. AMIGH ET AL 2,927,150

INSULATION PIERCING CRIMP

Filed Dec. 20, 1955 2 Sheets-Sheet 1

Fig. 1

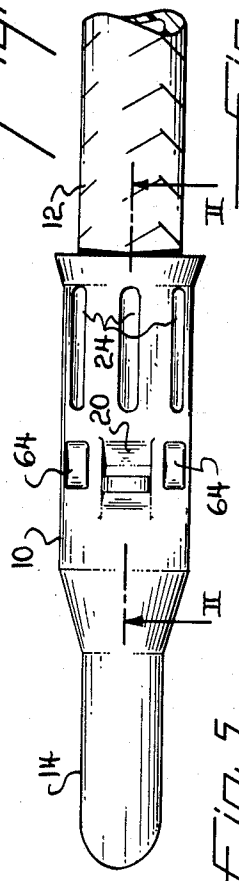


Fig. 2

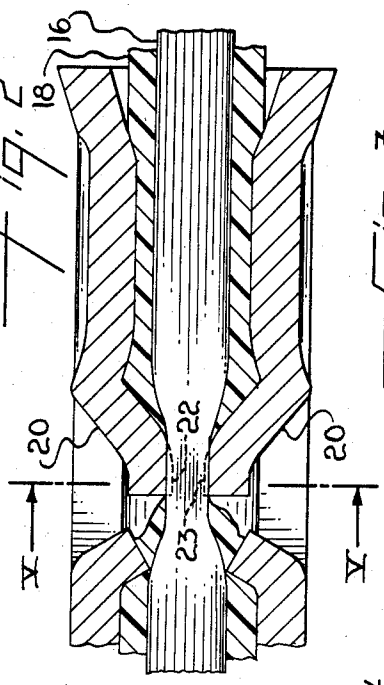


Fig. 3

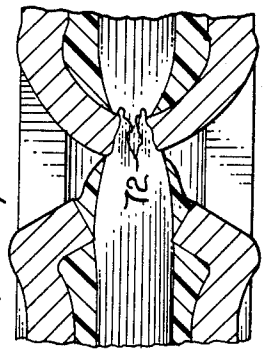


Fig. 4

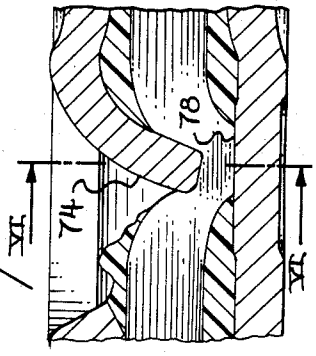


Fig. 5

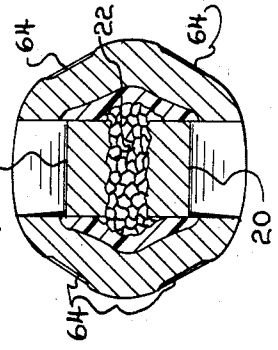


Fig. 6

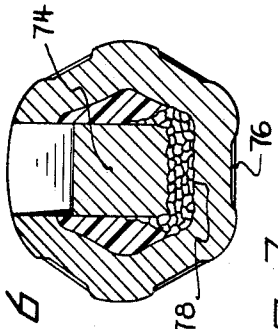


Fig. 7

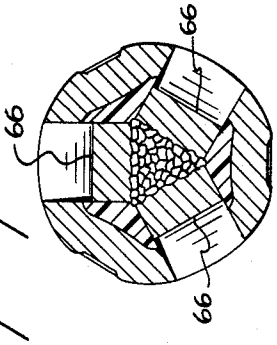
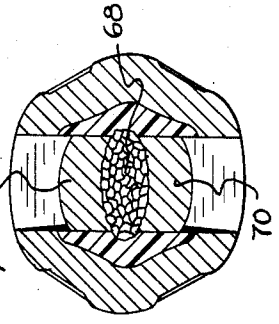


Fig. 8



INVENTOR.
Rossiter R. Potter and
Paul M. Amigh

BY

Curtis, Morris & Safford

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Fig. 9

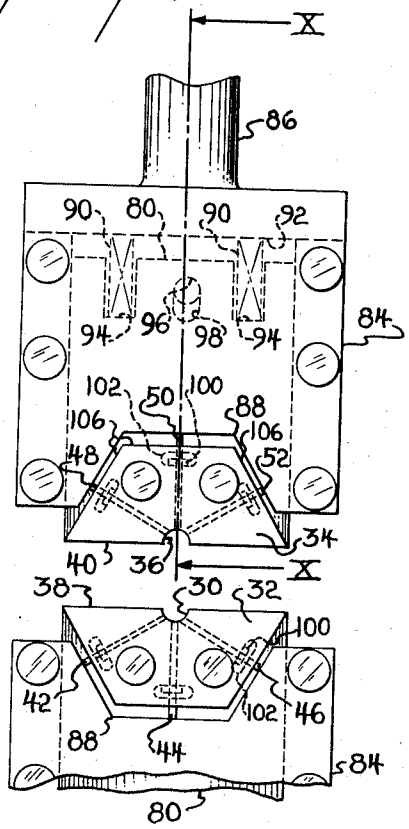


Fig. 10

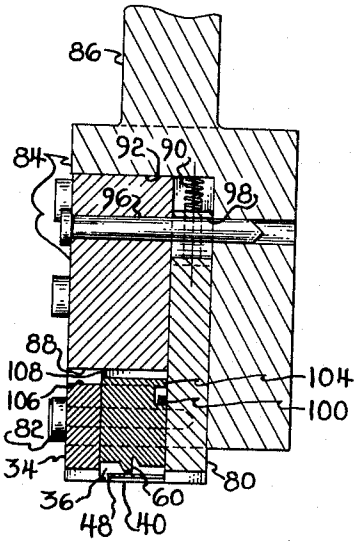


Fig. 11

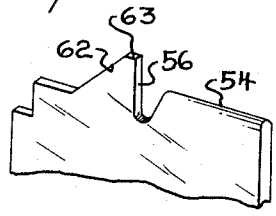


Fig. 13

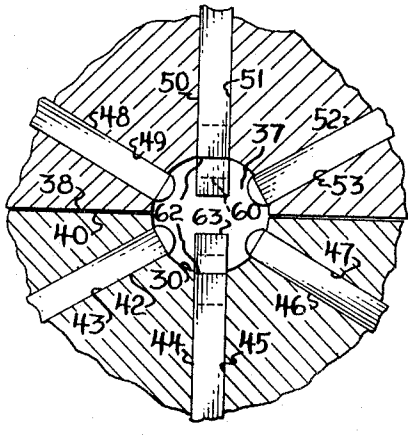
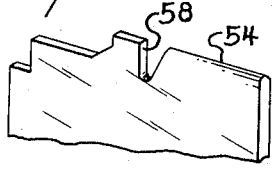


Fig. 12



INVENTOR.
Rossiter R. Potter and
Paul M. Amigh

BY

Smith, Morris & Safford

United States Patent Office

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INSULATION PIERCING CRIMP

Paul M. Amigh, Marysville, and Rossiter R. Potter, Harrisburg, Pa., assignors to Aircraft-Marine Products, Inc., Harrisburg, Pa.

Application December 20, 1955, Serial No. 554,176

3 Claims. (Cl. 174—74)

This invention relates to methods and apparatus for making solderless electrical connections and, more particularly, to the method and apparatus for effecting an electrical connection between a connector and the metallic core of an insulated conductor through the insulation covering thereof.

In the art of making solderless connections with insulated conductors, it heretofore has been the practice to dispose a conductor in an open ferrule connector which then is closed or crimped, the base of the ferrule having one or more preformed insulation piercing spears or prongs struck up therefrom so as to pierce the insulation and part the strands of the conductor during the crimping operation. The connections thus produced, however, at best provide a joint of relatively high electrical resistance and low mechanical strength which has operated to limit the field of use of the principle of insulation piercing in electrical connectors.

In such connections electrical continuity between the conductor and the body of the connector body is accomplished by virtue of the core strands pressing against the sides of the insulation piercing spear. In this type of electrical connection, the quality and characteristics of the joint depend primarily on the amount of pressure forcing the contacting surfaces together and in part on the area of contact. Accordingly, the high resistance usually encountered in insulation piercing connectors heretofore designed may be traced to insufficient contact pressure being maintained between the surfaces in contact. This relatively low contact pressure is assignable to two primary causes. First, the energy maintaining the conductor strands pressed against the insulation piercing spear is stored in the insulation material surrounding the conductor core, which insulation, being under constant pressure from the confining and crimped connector ferrule, tends to relax and be extruded out of the crimped area. Secondly, as the connector ferrule usually is simply wrapped around the conductor, leaving an open seam, the inherent resiliency of the metal produces springback tendencies which are augmented by the reaction stresses set up in compressing the insulation and conductor core and result in relaxation of the insulation material. Increase in operating temperature in use further tends to cause the insulation to relax, all of which results in a decrease in contact pressure and a rise in contact resistance.

It is, therefore, an object of the present invention to provide an improvement in electrical connections with insulated conductors, and a simplified, yet effective, method of producing such connections.

Another object is to provide in the insulation piercing connector art, a connection, and a method for producing it, having a sustainable high contact pressure.

Still another object of the invention is to provide a method and apparatus for crimping a connector to an insulated wire wherein the conductor metallic core is directly pressed between opposed portions of the metallic ferrule thus avoiding reliance on the conductor insulation to sustain the contact pressure in use.

A further object is to provide a method and apparatus for effecting an insulation piercing crimp utilizing a seamless or closed ferrule reducing to a minimum preforming of the connector prior to application and forming of the ferrule during the crimping operation.

A still further object is to provide in an insulation piercing connector utilizing a seamless or closed ferrule a method and apparatus for applying the connector with minimum distortion of the ferrule in cross-section over the crimped length.

Other objects and attainments of the present invention will become apparent to those skilled in the art upon a reading of the following detailed description when taken in conjunction with the drawings in which there are shown and described several embodiments of the invention; it is to be understood, however, that these embodiments are not intended to be exhaustive nor limiting of the invention but 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 practical use so that they may modify it in various forms, each as may be best suited to the conditions of a particular use.

In the drawings:

Figure 1 is a plan view of a metallic ferrule crimped onto the end of an insulated conductor in accordance with the present invention;

Figure 2 is an enlarged fragmentary sectional view taken along lines **2—2** of Figure 1;

Figures 3 and 4 are views similar to Figure 2 illustrating slightly modified connections formed in accordance with the basic principles of the present invention;

Figure 5 is a sectional view taken along lines **5—5** of Figure 2;

Figure 6 is a sectional view taken along lines **6—6** of Figure 4;

Figures 7 and 8 are sectional views similar to Figures 5 and 6 illustrating further modified forms of the connection;

Figure 9 is a fragmentary front view of the crimping dies for effecting the connections generally illustrated in Figures 1 through 8;

Figure 10 is a sectional view taken at lines **10—10** of Figure 9;

Figures 11 and 12 are fragmentary perspective views of the forming and severing blades employed in connection with the dies shown in Figures 9 and 10; and

Figure 13 is an enlarged fragmentary sectional view taken at lines **13—13** of Figure 10 for the purpose of illustrating the cooperation of the blades shown in Figures 11 and 12 with the dies of Figures 9 and 10.

With reference to Figures 1 and 2, in accordance with one embodiment of the invention, a ferrule **10** is crimped onto the end of an insulated conductor **12** and serves to couple electrically and mechanically the conductor with a pin or plug member **14** formed as an integral extension of ferrule **10**. It is to be understood, however, that member **14** may take any form suitable for a particular use, such as a wire ring or spade terminal, or may be a ferrule duplicate of ferrule **14** thereby to serve as a means for spicing a pair of conductors. Conductor **12** may consist of a multiple strand metallic core **16** surrounded by a concentric covering **18** of a suitable insulating material. In general, the principles of the present invention are applicable in connection with conductors having any of the common types of insulation, for example, good electrical connections have been made utilizing a conductor covered with a primary serving

of a vinyl-base plastic material and an outer serving of cotton braiding.

To effect the electrical connection with core **16**, ferrule **10** is provided with a plurality of peripherally aligned rectangular, or angular, tangs or tabs **20** severed from ferrule **10** so as to have a free end contact portion **22** that extends through insulation **18** to contact in intimate engagement with core **16**. Preferably, electrical contact by ferrule **10** with core **16** is had over relatively wide surfaces substantially transverse to the longitudinal axis of the conductor core and at a plurality of opposed points so that the conductor core may be tightly compressed between relatively rigid metal portions under high pressures. More particularly, it is desired that the tabs **20** of ferrule **10** in contact with the core be at diametric points about the periphery of the conductor so as to mutually assist each other in maintaining any contact pressures originally imposed on the core thus to avoid placing any reliance on the insulating material to hold the core strands against the insulation piercing portions of the ferrule. To this end, the generally rectangular tangs or tabs **20** are severed from opposite sides of ferrule **10** with the leading and free end edges **23** of contact portions **22** being substantially transverse to the longitudinal axis of the conductor so that upon turning the tabs inwardly about a transverse bending axis, the conductor core may be compressed between opposed metal surfaces as shown in Figure 5.

Longitudinally displaced from tabs **20** along ferrule **10** are a series of indentations **24** which serve to increase the mechanical strength of the connection by firmly grasping the insulation in a manner to be more particularly described.

The connection shown in Figures 1 and 2 may conveniently be effected by automatic or semi-automatic crimping machines well-known generally in the art, which machines conventionally include a press bed and a ram movable toward and away from the bed to complete a crimping cycle, the ram being driven by a power source either electrical or mechanical in nature as desired. A cooperating die set including upper and lower forming die members or blocks affixed to the ram and bed respectively of the machine serve to operate on the ferrule according to the design of the operating die faces for producing the end result desired.

To achieve the specific connection of the present invention, forming die member **32**, Figures 9 and 10, the lower member of a die set, is provided with an elongated recess **30** contoured to receive ferrule **10** in position to be crimped. The die set also includes an upper forming die member **34** adapted to be moved by the machine ram in the crimping stroke toward die member **32**, die member **34** also having in its operative face a recess **36** in alignment with recess **30** for forming a ferrule-confining cavity **37** when opposed faces **38** and **40** respectively of the die blocks abut.

Any method of presenting the ferrules to be shaped in proper crimping position between the die set will suffice. For example, the connectors may be fed one at a time from a hopper into the crimping region as an automatic operation of the machine, or the connectors may be manually positioned as desired. With the end portion of an insulated conductor assembled within the ferrule and therewith disposed within recess **30** of forming die **32**, the initial phase of the crimping operation is completed when the die set is closed, at which time surfaces **38** and **40** of the respective die blocks are in abutting relation thereby confining the ferrule within the similarly contoured cavity **37**.

For effecting the desired forming and severing operations on ferrule **10** a plurality of forming blades **42**, **44** and **46** and **48**, **50**, **52** in die blocks **32** and **34** respectively are slidably movable in a like number of radiating slots **43**, **45** and **47**, and **49**, **51** and **53**, in the associated die blocks.

As will be discussed in detail the forming blades are adapted to be driven under high pressure into cavity **37** in a second phase of crimping machine operation, which is preferably initiated subsequent to the bottoming of die **34** with respect to die **32** forming cavity **37**.

Each of the forming blades, Figures 11 and 12, have at their leading side that is projectable in cavity **37**, an elongated multiple die face arranged lengthwise relative to cavity **37**, which die face includes a generally rounded and elongated die **54** for effecting the indentations **24**. There being a combined total of six blades and dies **54**, for example, a like manner of elongated indentations **24** will be produced, longitudinally oriented and preferably equally spaced about the periphery of ferrule **10** as shown in the embodiment of Figure 1.

At least one and preferably a pair of forming blades, such as blades **44** and **50**, in diametric positions in the respective die blocks are provided with severing and curling dies **56**, Figure 11, which are so shaped as to strike tangs or tabs **20** from the body of ferrule **10** and turn them inwardly towards core **16** through insulation **18**. On the remaining blades **42**, **46**, **48** and **52**, a holding or supporting die **58**, Figure 12, in peripheral alignment with severing die **56**, is provided for a purpose to be described hereinafter.

In the illustrated embodiment of the crimping dies, die **56** is shown to be an integral extension of die blades **44** or **50** and substantially triangular in shape for presenting a substantially planar face **60** inclined inwardly toward the axis of the cavity **37**, and hence, the axis of ferrule **10** and inserted lead **12**. The side edges **62** of die face **60** are relatively abrupt and sharp to cooperate with a sharp and transverse leading edge **63** of the die thus to be capable of severing the metal ferrule **10** on being urged inwardly under pressure into cavity **37**.

In general, in the art of making cold-forged solderless connections it has been found that optimum electrical characteristics are achieved when the metallic core of the conductor is compressed within the encompassing terminating connector to a degree sufficient to produce a voidless cross-section of metal in the crimped area. Further, the compression should be accomplished at pressures sufficient to extrude the metal comprising the metallic core from its original cross-sectional area to a final area significantly less than the original area, a reduction of 20% being typical for a gas tight crimp. On pressing the opposed tabs **20** together at their end portions to the extent necessary to produce a voidless cross-section of metal, it has been found that such pressure concentration proves at least adequate to eliminate completely insulation from between the contact surfaces **22** of the tabs and the underlying conductor core. The insulation piercing action thus occurs as a result of imposing high pressures along lateral lines, at least as defined by the leading free edges of the tabs, on opposite sides of the conductor, the action being effective to pierce such insulating materials as are in common use and depending in nature, i.e., whether a severing, extruding, or both, upon the type insulation to be parted.

It will be appreciated that the extent to which tabs **20** are bent radially inwardly and the tab width depend upon the width of die face **60** and the length and angle this face makes with respect to the longitudinal axis of the cavity **37**, and further, the extent to which the die **56** is projected into cavity **37**. The length and width of the tab and the angle at which it is turned inwardly determine, of course, the area of contact made with the metallic core **16** at free end portion **22**. To obtain optimum electrical characteristics in the contact the width of the tab should be approximately as wide as the conductor core in its compressed condition thereby trapping and essentially surrounding the strands of the conductor as illustrated in Figure 5. As a minimum, the tab width should not be so diminished that the strands of the conductor core may be appreciably extruded around the tab

side edges during crimping although some slight mushrooming effect, as shown, of the conductor is desirable for stabilizing the tab against lateral movement in response to sidewise pulls on the conductor. Conversely, the tabs should not be so wide as to weaken significantly the ferrule mechanically, it being understood that the number of tabs and the width thereof are designed to retain adequate structural strength for the particular use involved.

Where only a pair of piercing tabs are to be used it is especially desirable that the side walls of the ferrule in peripheral alignment with the tabs be supported, or preferably slightly indented, during the crimping operation to permit sufficiently high pressures at the exact piercing station for effective severing and extruding or both. To furnish lateral support for the ferrule side walls, supporting dies **58** on forming blades **42**, **46**, **48** and **52** have operating faces dimensioned to produce indentations **64**, Figures 1 and 5, which cover as much of the ferrule side walls between the tabs as is practical. Indentations **64** advantageously absorb the lateral pressure of the conductor core during crimping thus assuring that the metal of the conductor and the insulation are extruded longitudinally, rather than laterally, while maintaining the side walls of the ferrule within their original configuration.

For many applications the mechanical strength of the connection afforded by tabs **20** and indentations **64** will be sufficient. It is preferred, however, that the electrical contact area at tab portions **22** be isolated when stresses of significant magnitude are expected to be applied in normal use to conductor **12**. The mechanical strength added to the joint by indentations **24** also serves to isolate the electrical contact area, the characteristics, such as the size, shape and the number of indentations **24** depending upon the conditions of a particular use. In general, however, the indentations should be as deep as possible without significantly damaging or rupturing the underlying insulation, and as long and narrow as possible for minimizing distortion of the original configuration of the ferrule without acting as a piercing instrument relative to the insulation.

As thus made, the connection provides electrical contact at end edges **22** of the tabs **20** with the conductor core along diametrically opposed surfaces between which the conductor core may be compressed under high pressures to achieve insulation piercing and retainable high contact pressures over effective surfaces of contact. From Figure 5 it can be seen that the major portion of the conductor perimeter is in contact with metal portions of the ferrule. To increase still further the proportional contact area and to provide a system which can be subjected to higher crimping pressures, it is preferred that three mutually opposed insulation piercing tabs be struck from the ferrule, Figure 7. In this embodiment, of course, the width of the tabs should be designed so as not to mutually interfere during the crimping operation.

In another embodiment, for a two tab system, the face **60** of shearing dies **56** may be made with a slight transverse concavity thereby to impart a like contour to contact surfaces **68** of tab end portions **70** as shown in Figure 8. The concave configuration obviously reduces the tendency of the conductor core strands to extrude laterally and escape contact with the contact surfaces of the tabs during crimping while an advantageously high linear proportion of the core perimeter is contacted by the tabs.

Additional mechanical strength and rigidity may be imparted to the tab structure by curling the tab portions, as they are moved radially inwardly towards the conductor core, as compared with the flat bend form described in connection with Figures 1 and 2. By having the operating face **60** of severing die **56** gradually curved, not shown, relative to its length, as illustrated by the contour of the tabs in Figure 3, during the crimping

operation leading edges **72** of the tabs are caused to part the conductor insulation and engage the metal core. Further inward curling of the tabs causes edges **72** to slide along, as well as into, the conductor core thereby to effect a grooving action along opposite sides of the conductor core. During this grooving action the high pressures involved in crimping results in both extrusion of the conductor core metal and coining or burnishing of the relatively sharp edges **72** to the rounded configuration indicated in Figure 3. There is thus assured a good clean electrical contact and complete removal of insulation from within the contact area. In addition, metal of the conductor is disposed axially behind the leading edges **72** of the tabs. Consequently, metal of the conductor core must first be deformed before any tensile stresses imposed on the conductor, either to the right or left of the conductor axis in Figure 3, can result in relative movement of the conductor and ferrule. Furthermore, relative to a pull on the conductor to the right in Figure 3, a camming action arises at the free end of the tabs which tends to draw the tabs further inwardly and more tightly against the conductor core thereby substantially increasing the resistance of the conductor to mechanical displacement from the ferrule.

The principles discussed in connection with the embodiment of Figure 3 may be applied in instances where it is desired to employ only a single insulation piercing tab, as shown in the embodiment illustrated in Figures 4 and 6. As shown, application of sufficient pressure between the free end portion of tab **74** and diametric supporting indentation **76** has caused extrusion of insulation from under the tab and from between the core and side wall **78** of the ferrule opposite indentation **76**. The degree of pressure required, and the length of tab **74** to be struck and other like considerations depend, of course, on the characteristics of the insulation such as thickness, toughness, etc.

As alluded to above, in the crimping operation die blocks **32** and **34** are first closed to define cavity **37** whereupon the forming blades are driven into the cavity to operate on and effect the connection between the assembled ferrule and conductor. To accomplish these operations in the sequence desired, in the illustrated embodiment, die blocks **32** and **34** take the form of a split hexagonal block, the block halves being associated with the press bed and ram respectively of the crimping machine, not shown. Each die block, for example, block **34** is rigidly affixed as by bolts **82** to a carrier plate **80** slidably mounted in a die block holder **84** which is rigidly connected to the press ram **86**, or the press bed as the case may be. Each of the die block holders **84** is provided with a semihexagonal recess **88** which corresponds in dimensions to its associated die block **34** for receiving the block in a close fit. The die blocks are urged or biased out of the associated recesses **88** by virtue of normally compressed springs **90** which act between the base **92** of the die block holder and a bearing surface **94** on the die block carrying plate **80**. A pin **96** in die block holder **84** cooperating with slot **98** in the carrying plate **80** limits the extent of movement of the die block relative to the recess therefor. The forming blades, for example, blades **48**, **50** and **52** in die block **34** are freely slidable in their respective slots **49**, **51** and **53**, but are restrained from dropping altogether out of the slots by means of flat stop keys **100** received in recesses **102** in die block **34**, the recesses being closed by the inside face of carrying plate **80** as best illustrated in Figure 10. Each of the forming blades are provided with a notch **104** along one side edge of a length sufficient to permit free movement of the blade to the extent desired. The blade receiving slots in the die blocks radiate from cavity **37** to each face **106** respectively of the hexagonal die block combination, the forming blades having lengths such that when the rear ends **108** thereof are flush with faces **106**,

Figure 10, the blade dies 54, 56 and 58 project to the desired degree in cavity 37.

As thus constructed, in the open position of the apparatus, Figure 9, die blocks 32 and 34 are projected out of recesses 88 with the forming blades resting or idling in their associated slots. On movement of the press ram towards the press bed the die block holders 84 move relatively towards one another to cause the die blocks 32 and 34 to close, forming and closing cavity 37 about the ferrule to be crimped. Further movement of die block holders 84 seats recesses 88 about the hexagonal faces of the die blocks. As a result, the surfaces of recesses 88 are forcefully brought to bear against the rear ends of the forming blades, driving them inwardly along their associated slots, and causing the die faces thereof to project within cavity 37 operating on the ferrule 10 as has been described. On upward or opening movement of the ram, the die blocks are biased by springs 90 out of the recesses permitting the forming blades again to idle within the die block slots, thus completing the cycle of crimping operation.

Changes in construction will occur to those skilled in the art and various apparently different modifications and embodiments may be made without departing from the scope of the invention. The matter set forth in the foregoing description and accompanying drawings is offered by way of illustration only. The actual scope of the invention is intended to be defined in the following claims when viewed in their proper perspective against the prior art.

We claim:

1. In an electrical connection with an insulated electrical conductor, a substantially cylindrical metallic ferrule receiving an insulated section of the conductor, at least a pair of opposed tab portions intermediate the length of said ferrule having substantially transverse free end edges relative to the longitudinal axis of the conductor core, the length of said edges being approximately equal to the original diameter of said core, said tab portions being turned inwardly with said edges penetrating the conductor insulation and compressing said core along opposed lines of contact, said opposed lines lying in the same transverse plane relative to the longitudinal axis of the ferrule.

2. In an electrical connection with an insulated electrical conductor, a substantially cylindrical metallic ferrule receiving an insulated section of the conductor, at least a pair of opposed tab portions intermediate the length of said ferrule having substantially transverse free end edges relative to the longitudinal axis of the conductor core, said tab portions being turned inwardly with said edges penetrating the conductor insulation and compressing said core along opposed lines of contact, said tab portions being transversely bowed at said edges with an inward concavity so as substantially to encompass said core along said lines of contact, said opposed lines lying in the same transverse plane relative to the longitudinal axis of the ferrule.

3. In an electrical connection with an insulated electrical conductor, a substantially cylindrical metallic ferrule receiving an insulated section of the conductor, at least three circumferentially spaced tab portions in said ferrule having substantially transverse free end edges relative to the longitudinal axis of the conductor core and substantially encompassing said core, said tab portions being turned inwardly with said edges penetrating the conductor insulation and compressing said core along lines of contact substantially encompassing said core, said opposed lines lying in the same transverse plane relative to the longitudinal axis of the ferrule.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,927,150 March 1, 1960

Paul M. Amigh et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

In the grant, lines 2 and 3, for "assignors to Aircraft-Marine Products, Inc., of Harrisburg, Pennsylvania," read -- assignors to AMP Incorporated, a corporation of New Jersey, --; line 12, for "Aircraft-Marine Products, Inc., its successors" read -- AMP Incorporated, its successors --; in the heading to the printed specification, lines 4 and 5, for "assignors to Aircraft-Marine Products, Inc., Harrisburg, Pa." read -- assignors to AMP Incorporated, a corporation of New Jersey --.

Signed and sealed this 27th day of September 1960.

(SEAL)
Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents

UNITED STATES PATENT OFFICE

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Signed and sealed this 27th day of September 1960.

(SEAL)
Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents