Nov. 2, 1954 J. R. KERCHNER ET AL 2,693,216

TOOL FOR ELECTRICAL CONNECTORS

Filed Oct. 11, 1951

Fig. 1.

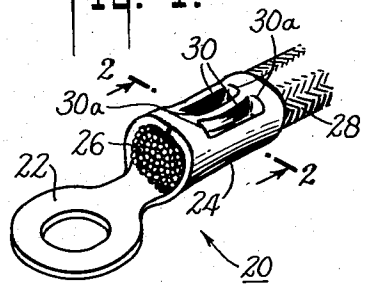


Fig. 2.

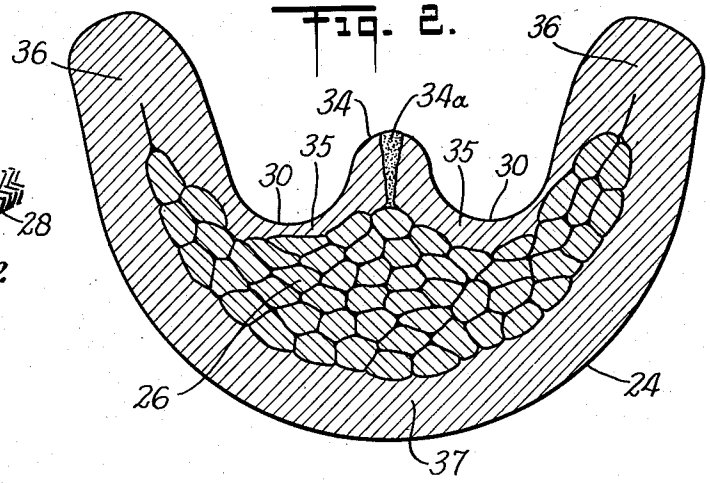


Fig. 3.

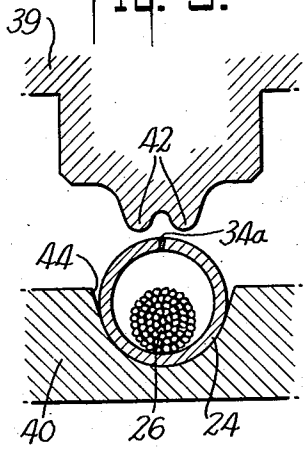


Fig. 4.

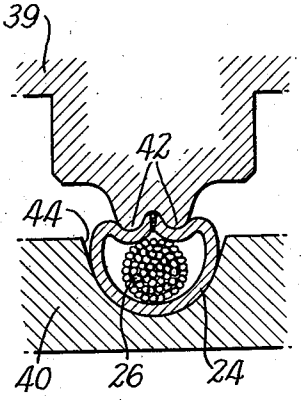


Fig. 5.

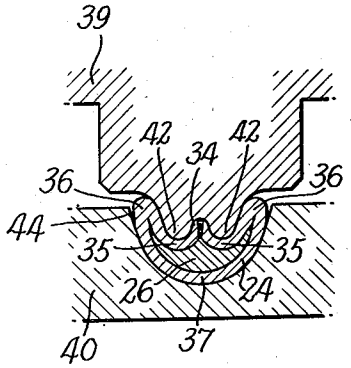
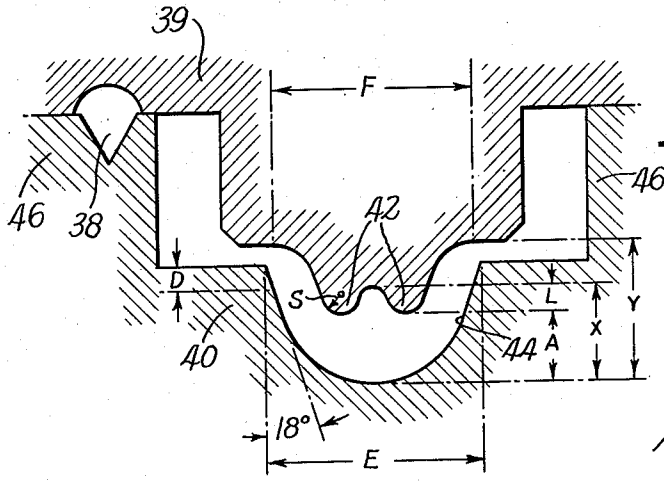


Fig. 6.



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United States Patent Office 2,693,216 Patented Nov. 2, 1954

2,693,216

TOOL FOR ELECTRICAL CONNECTORS

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Application October 11, 1951, Serial No. 250,840

6 Claims. (Cl. 153—1)

This invention relates to tools for pressure crimping electrical connectors of the general type described in Patent No. 2,535,013 to Freedom.

In the electrical equipment industry and in other industries, it has been recognized that soldered electrical connections, which have been so widely used, have several disadvantages. Prominent among these disadvantages are the difficulties in making a great number of electrical connections which are inexpensive and yet uniform, and doing so rapidly yet while maintaining excellent mechanical strength and electrical characteristics. To overcome these and other difficulties of soldered connections, attention has been directed towards the so-called pressure welded or crimped connectors wherein an enveloping metal barrel or ferrule is squeezed tightly onto a bare wire conductor so that the wire and the barrel are firmly adherent after the crimping tool is removed.

While various forms of crimped connections have been proposed and used there have arisen certain difficulties and disadvantages in some forms of these connections also. For example, in some crimped connections a single indentation is made to combine the barrel and the conductor. This form of connection generally has poor mechanical strength and it is difficult even for a skilled operator to make successive crimps which are uniform. The double indent or W type crimp as described in the above-mentioned patent has proven superior in service, but the use of the present invention provides certain advantages thereover, as explained here and after.

In making a double indent crimp (wherein two closely adjacent projections or indentors are forced against a connector barrel which is supported in a generally conforming female die or nest), it has been considered necessary to use a different sized male die or set of two indenters with each barrel size one uses in order to obtain a satisfactory crimp for each of these various sizes. It is noted that it had been recognized that a given size nest could accommodate a specific size ferrule which was adapted for use with a limited range of wire sizes.

Thus, for the broad range of wire sizes and the necessary ferrules used in typical wiring systems, a multiplicity of male dies or indentors were required. This requirement is unsatisfactory in that either many separate tools are needed or else in a given tool or machine, the male dies would have to be changed frequently. Either of these contingencies is undesirable; in the first instance a considerable investment for tools is needed and in the second instance too much time is likely to be expended in changing dies. In either event, the tendency exists for the user to employ the incorrect dies in a given operation due to inadvertence or through inertia. It is noted that a fairly casual visual inspection of a crimp may fail to reveal that the desired structural configuration of the crimp has not been fully attained.

In general, the double indentors for a crimping tool are made to exacting specifications and are machined to close tolerances and exact curvatures, whereas the female dies or nests are considerably easier and less expensive to make. Thus, it is advantageous to minimize the amount of sets of indentors required for the usual ranges of wire sizes.

We have found by constructing a set of double indenters and nests for a W crimp according to certain predetermined shapes and proportions that the range of wire sizes over which the tools may be used while still attaining an effective crimp in the connection is substantially enhanced, so that a given set of two indenters approaches

universal applicability. We have also found that this improved construction tends to strengthen the indenters so that breakage thereof is minimized, and further that superior connections may be produced.

Before describing the invention in detail, the requisites of an effective crimp merit consideration in order that the features of the invention may be more fully understood and appreciated. In crimping a metal barrel onto a bare conductor or conductors, the final crimp should meet, and preferably exceed, the minimum pull-out or tensile strength values adopted by the various official standardization groups. Additionally, the torsion strength of the connection should be high lest the conductors become loose by twisting and bending actions. The corrosion resistance of the connection should also be high to avoid changes in the electrical characteristics of the connection; for example, a small change in the resistance of a high current carrying conductor system is reflected in excessive power losses and even overheating of the connection. In general, the existence of voids or air spaces in the crimped connection tends to impair the corrosion resistance of the connection and voids should be kept to a minimum. The external form of the connection should be symmetrical not only to avoid localized stresses but also so that standard size insulating sleeves, if desired, may be put on the connection without difficulty. Sharp flares or edges also are not desirable insofar as they tend to cut insulating sleeves and are also objectionable electrically in that they may cause voltage breakdown due to corona discharge. A further factor is that the barrel of the connection should not be sheared through or pierced. Since most barrels are tinned copper, ordinarily a visual test reveals that shearing has occurred if the contrasting color of the conductors is visible to the unaided eye.

By this invention the above mentioned advantages are attained while minimizing the factors which are regarded as objectionable in a good connection.

The characteristics of the invention are brought out in the drawings wherein:

Fig. 1 is a perspective view of an electrical connection crimped by dies made in accordance with one embodiment of the invention;

Fig. 2 is an enlarged sectional view taken transversely through the connection of Fig. 1 and along the line 2—2 thereof;

Figs. 3, 4 and 5 are sectional elevations taken through a pair of crimping dies made according to this invention and these figures show a ferrule and conductor within the dies in progressive stages of crimping;

Fig. 6 is an enlarged view showing the outlines of the dies of Figures 3–5.

In Fig. 1 an electrical connector is generally indicated at **20** showing a ring contact portion **22** and the ferrule portion **24**. The ferrule portion **24** is crimped over the bare conductor ends **26** of insulated wire **28**. Substantially parallel indents or grooves **30** are shown in ferrule **24** as extending therein for the greater portion of the ferrule length and terminating a short distance (e. g. 1/16") from the respective ends of the ferrule. Ends **30***a* of the indents **30** are shown as sloping gradually upwardly from the greatest depth of the indent to the terminus of the indent.

Fig. 2 shows the characteristic W configuration of the cross-section of the crimp in Fig. 1 wherein the top of the central hump **34** is below the level of the top of the side horns **36**. The conductors **26** are shown as coined and extruded within the deformed ferrule **24**. Thin side-walled sections **35** of ferrule **24** extend downwardly from the centrally, depressed hump **34** having seam **34***a*. Folded and cold-worked beads or horns **36** extend along the outer edges of the crimp while the bottom **37** of the crimp conforms to the shape of the nest (see Fig. 3).

In Fig. 3 is shown the indenters **42** of the male die **39** as they approach the ferrule **24** as it lies in nest **44** of the female die **40**. In this view the ferrule size shown is that of the smallest ferrule which may be satisfactorily used within the range of the male die. Figs. 4 and 5 depict partial and then completed crimping and emphasize the distortion achieved in cold working and flowing the ferrule **24** and conductors **26** to a cohesive mass.

Fig. 6 shows the construction of a specific size nest 44 and indenters 42 in terms of dimensions which are:

E=the maximum width of the nest
F=the maximum width of the indentor set
D=the depth below the upper surface of the nest of the center of the radius of curvature of the greater portion of the nest
S=the radius of curvature of the curved surfaces on the male die such as the ends of the indentors
L=the overall height of the indentors
A=the distance from the bottom of each indentor to the bottom of the nest when the crimping dies are fully closed. This dimension largely determines the final cross-sectional area of the crimped connection.

Referring to Figs. 2 and 6 it is to be noted that when the crimping is completed, the top of the central hump **34** is considerably below the tops of the side horns **36**. In other words, as Fig. 6 brings out, the distance X is less than the distance Y. Thus, as crimping pressure is exerted on the ferrule and conductor, the central top portions of the ferrule and barrel are "coined" and metal flows away from the central hump towards the outer areas of the connection. We have found that by this arrangement, the indenters over a variety of barrel and wire sizes produce an improved distribution of the metal of the ferrule at the thin side-walled sections **35** and in the horns **36**.

An additional feature of this invention is that the configuration of the outer surface of each indentor is so curved (or has a small straight portion) that it is substantially parallel to the straight portion of the adjacent parts of the nest cavity (see Fig. 6). This relationship of substantial parallelism is maintained for the smallest size barrel for which a given indenting die is adapted. We prefer to maintain the slope of the straight portion of the nest at about 18° from the vertical for the parallel relationship and to decrease this slope for the larger wire sizes and ferrules within the given range, thus sacrificing parallelism somewhat. We also elongate the straight portion of the nest (dimension D) substantially beyond the proportions indicated by Freedom.

In designing for an optimum W crimp, we have found it desirable to construct the male dies and cooperating female nest so that the dimensions thereof yield a final cross-sectional area of the crimp which is about ⅔ of the original cross-sectional area of the metal in the ferrule and the conductor or conductors. In other words, extrusion of the metal takes place longitudinally so that about ⅓ of the original gross metal area is squeezed away from the crimp.

Regarding the range of wire sizes for which a given male die constructed according to this invention is satisfactory, we find that a given size set of two indenters will accommodate wire sizes from 16–8 AWG, that the next larger size is suitable for 6–2 AWG wire and the still larger size is useful in crimping conductors from 1/0 through 4/0 AWG wire. The above ranges are illustrative of the flexibility of a male die constructed as described above; thus, one male die in the smaller wire sizes is suitable for crimping nine different sizes of wire, which vary from about 2600 circular mils in area to about 16,400—an area range of over 6 to 1. In crimping different sized wires with the same indenter set the ferrules (and of course the female dies) would preferably be changed so that 16–14 AWG wires are used in one size ferrule, 12–10 AWG wires are used in a still larger ferrule and the 8 AWG wire is accommodated in the largest ferrule of this range.

As pointed out heretofore, it is desirable to avoid excessive voids in the crimped connection. We have found that this may be minimized in the horn section of the crimp by maintaining the distance between the outer edges of each indenter and the adjacent surface of the nest substantially the same over the range of ferrules used. With given range for a specific size tool, the substantially parallel relationship described above will be maintained, preferably by flattening the mouth of the nests so that the slope thereof is about 18° from the vertical. But in the wider diameter ferrule as the radius of curvature of the nest increases, the straight portion of the nest is brought upwards more abruptly to compensate for the greater width of the nest, e. g. the slope from the vertical may be about 16° or 14° or even less. By this arrangement the thickness of the horn section of the

crimped connection is maintained over a variety of sizes at about 100% of the original uncrimped wall thickness of the ferrule.

It is a further feature of this invention that it permits the use not only of thinner walled ferrules than have heretofore been thought possible but that it is feasible to use shorter barrels while maintaining a mechanically strong and electrically sound connection. This feature is of considerable interest due not only to the high cost of conductive metals such as copper, aluminum and tin but also because of their relative scarcity.

By following the teachings of this invention, satisfactory connections may be made using various forms of conductors. Thus, the conductor metal may vary in nature as well as the shape of the conductor; soft copper, hardened conductors, aluminum, etc., whether solid, round, square, oval or stranded may be used. With solid rather than stranded conductors, it is sometimes found advisable to deform the conductor before crimping the connection. This may be done, for example, by presqueezing it to a generally oval shape in cooperating cavities as are shown in Fig. 6. With oval conductors, these should be positioned in the barrel within the nest so that the smaller or minor axis of the conductor is perpendicular to the bottom of the nest.

As pointed out above, in the optimum sizes very superior connections may be made. For example, with a 4/0 size aircraft cable having a tensile strength of approximately 5500 pounds, a single indent type crimp yields a connection having a tensile strength of approximately 20% of the cable strength. On the other hand a W crimp on this same cable made according to this invention exhibited a strength of about 45% of the cable strength. The advantages of this increased strength in terms of safety where the safety of human lives and expensive equipment depend on performance are self-evident.

Having now particularly shown and described the invention what is claimed is:

1. Apparatus for producing laterally spaced longitudinal indentations in a wire-surround-ferrule which comprises a female die member having a nest cavity adapted to accommodate and receive the ferrule longitudinally therein, said nest cavity having on each side below the mouth thereof a pair of substantially straight forming sections extending upwardly and inclined outwardly at a small angle to the vertical, a first motion-limiting means connected to said female nest die member, a male die member, and a second cooperating motion-limiting means connected to said male die member and adapted to cooperate with the first motion-limiting means when said die members are in the closed die position to limit the motion of said die members toward each other, said male die member having a pair of laterally spaced longitudinal indenters projecting downwardly and including therebetween a longitudinal hollow, said indenters being adapted to enter said nest cavity in spaced relation thereto with said indenters extending longitudinally of said nest cavity and with said indenters being offset laterally to opposite sides of the center line of said nest cavity to indent the ferrule along opposite sides of its axis, said hollow included between said indenters extending upwardly therebetween a significant distance so that said indenters and said hollow define in outline a smooth W configuration with the top of said hollow between said indenters being a substantial distance below the outer upper ends of said W configuration, whereby, in closing, the top of said hollow moves down into said nest cavity a significant distance below the upper limits of said straight forming sections of the nest cavity before said first and second motion-limiting means cooperate with each other in the closed die position to limit the motion of said die members toward each other.

2. Apparatus for producing laterally spaced longitudinal indentations in a wire surrounding ferrule which comprises a female die member having a nest cavity adapted to accommodate and receive the ferrule longitudinally therein, said nest cavity having on each side below the mouth thereof a pair of substantially straight forming sections extending upwardly and inclined outwardly at a small angle to the vertical, a first motion-limiting means connected to said female nest die member, a male die member, and a second cooperating motion-limiting means connected to said male die member and adapted to cooperate with the first motion-limiting means when

said die members are in the closed die position to limit the motion of said die members toward each other, said male die member having a pair of laterally spaced longitudinal indenters projecting downwardly and including therebetween a longitudinal hollow, said indenters being adapted to enter said nest cavity in spaced relation thereto with said indenters extending longitudinally of said nest cavity and with said indenters being offset laterally to opposite sides of the center line of said nest cavity to indent the ferrule along opposite sides of its axis, said hollow included between said indenters extending upwardly therebetween a significant distance so that said indenters and said hollow define in outline a smooth W configuration with the outer surface of each indenter being substantially parallel to the respective adjacent straight forming section of said nest cavity and with the top of said hollow between said indenters being a substantial distance below the outer upper ends of said W configuration, whereby, in closing, the top of said hollow moves down into said nest cavity a significant distance below the upper limits of said straight forming sections of the nest cavity before said first and second motion-limiting means cooperate with each other in the closed die position to limit the motion of said die members toward each other.

3. Apparatus for producing laterally spaced longitudinal indentations in a wire-surrounding ferrule which comprises a female die member having a nest cavity adapted to accommodate and receive the ferrule longitudinally therein, said nest cavity having on each side below the mouth thereof a pair of substantially straight forming sections extending upwardly and inclined outwardly at a small angle to the vertical, a first stop element fixed with respect to said female nest die member, a male die member, and a second cooperating stop element fixed with respect to said male die member and adapted to contact the first stop element when said die members are in the closed die position, said male die member having a pair of laterally spaced longitudinal indenters projecting downwardly and including therebetween a longitudinal hollow, said indenters being adapted to enter said nest cavity in spaced relation thereto with said indenters extending longitudinally of said nest cavity and with said indenters being offset laterally to opposite sides of the center line of said nest cavity to indent the ferrule along opposite sides of its axis, said hollow included between said indenters extending upwardly therebetween a significant distance so that said indenters and said hollow define in outline a smooth W configuration with the outer surface of each indenter being substantially parallel to the respective adjacent substantially straight forming section of said nest cavity and with the tips of said indenters being defined in outline by smooth curves and the hollow between said indenters being defined in outline by a smooth curve having an effective radius of curvature less than the effective radius of curvature of the tips of said indenters.

4. Apparatus for producing laterally spaced longitudinal indentations in a wire-surrounding ferrule which comprises a female nest die member having a longitudinally extending female nest cavity adapted to accommodate

and receive the ferrule longitudinally therein, said nest cavity having on each side below the mouth thereof a pair of substantially straight forming sections extending upwardly and inclined outwardly at a small angle to the vertical, a first stop element fixed with respect to said female nest die member, a male die member, and a second cooperating stop element fixed with respect to said male die member and adapted to contact the first stop element when said die members are in the closed die position, said male die member having a pair of laterally spaced longitudinal indenters projecting downwardly and including therebetween a longitudinal hollow, said indenters being adapted to enter said nest cavity in spaced relation thereto with said indenters extending longitudinally of said nest cavity and with said indenters being offset laterally to opposite sides of the center line of said nest cavity to indent the ferrule along opposite sides of its axis, said hollow included between said indenters extending upwardly therebetween a significant distance so that said indenters and said hollow define in outline a smooth W configuration with the outer surface of each indenter being substantially parallel to the respective adjacent straight section of said nest cavity and with the top of said hollow between said indenters being a substantial distance below the outer upper ends of said W configuration, whereby, in closing, the top of said hollow moves down into said nest cavity a significant distance below the upper limits of said straight forming sections of the nest cavity before said first and second stop elements engage each other and stop said die members in the closed die position, and the extreme upper outer ends of said W configuration being flared outwardly beyond a parallel relationship with the respective adjacent straight forming sections of the nest cavity and said flaring ends of said W configuration being closely adjacent the upper limits of said substantially straight forming sections when said die members are in the closed die position, whereby said flaring ends of said W configuration control the extrusion of the ferrule upwardly along said straight forming sections of the nest cavity as said die members approach the closed die position.

5. Apparatus as claimed in claim 2 and wherein said small angle to the vertical is in the range from about 14° through about 18°.

6. Apparatus as claimed in claim 2 and wherein said small angle to the vertical is about 18°.

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