ELECTRICAL CONNECTOR AND METHOD OF MANUFACTURE

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This invention is related to electrical connectors of the type which are used, in the form of a continuous strip of connectors, in machines which pressure-crimp the connectors individually onto wire conductors or the like. In preferred form, the subject connector is adapted to connect a lead wire to electrical elements with precision to embody them as useful components for electrical circuits (e.g., resistors, reactors, and capacitors).

Connectors in strip form have recently come into wide use as a consequence of inventions of V. E. Carlson (Patent No. 2,396,913) and W. S. Watts (application No. 514,214, filed December 14, 1943) and successive developments of their associates of F. L. Pierce, J. C. Macy, and myself. In those cases where the connectors are to be used for permanently joining two or more conducting members, such strip generally comprises pairs of rolled-up laterally-opposed portions of sheet metal which form either cylindrical ferrules or channels, with an integral connection from the base of each channel to the next connector in the strip.

In such strip as known before the present invention, portions of the stock were stripped away to leave such joining portions of substantially lesser transverse extent than the adjoining parts of the connectors. In a copending application of F. L. Pierce there is shown a strip having successive terminals partially sheared from one another without waste and the joining portions weakened to facilitate final severing by tearing or shearing in automatic applicator machines with greatly increased life of shear blades and thus reducing cost of servicing such machines. This also avoided the necessity for precision die structures such as had been used to stamp out connecting portions of the strip prior to or during the pressure-crimping operation.

In my copending application, Serial No. 119,220, filed October 3, 1949, now Patent No. 2,659,871 granted November 17, 1953, I disclose and claim continuous strips of electrical connector structures which can be indexed or moved to one another without waste and the joining portions weakened to facilitate final severing by tearing or shearing in automatic applicator machines with greatly increased life of shear blades and thus reducing cost of servicing such machines. This also avoided the necessity for precision die structures such as had been used to stamp out connecting portions of the strip prior to or during the pressure-crimping operation.

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strip without the protrusion of any burrs, such as may be acquired during the severing of connectors from the strip.

I accomplish these as well as other objects through the use of novel joining areas between the connectors in the strip. These areas are longitudinally of small dimension, and, laterally, they are substantially thinner than the sheet metal which comprises the connectors. In combination with this small joining area, this invention in preferred form utilizes a recessed area in the inner surface of the connector strip adjacent each such joining area. Other novel features in combination particularly adapt my invention to certain specific applications.

The aforesaid and other objects will in part be pointed out in and will in part become apparent from the following specification and claims, taken in conjunction with the accompanying drawings.

In the drawings:

Figure 1 is an isometric view of upper die structures, a strip of sheet metal stock as it is formed into a continuous strip of connectors by such die structures, and lower die structures as are used in conjunction with the upper structures;

Figure 2 is a longitudinal, vertical, sectional view of the elements shown in Figure 1, with the die structures brought together against the strip;

Figure 3 is an isometric view of a strip of connectors embodying this invention;

Figure 4 is an isometric view of a single connector as might be severed from a strip as shown in Figure 4;

Figure 5 is a side elevational view of a strip as is shown in Figure 2, partially broken away to present an axial cross-section of this strip;

Figure 6 is an end elevation of a connector as is shown in Figure 3;

Figure 7 is a side view of the strip of connectors, electrical element, lead wire, and their assembly apparatus, the latter shown partially in cross-section;

Figure 8 is a right end elevational view of certain elements in Figure 7;

Figure 9 is a cross-section taken at the line 9—9 in Figure 7;

Figure 10 is a side elevation of a precision electrical circuit component, partially broken away and presented in axial cross section;

Figure 11 is an isometric view of an end connection of the component shown in Figure 10;

Figure 12 is a cross section taken at the line 12—12 in Figure 10.

Referring to Figure 1, a strip of sheet metal 20 is shown disposed between an upper set of die structures 22 and a lower set of die structures 24, this strip 20 being successively worked, cut, and otherwise repeatedly reformed at various stages in the opposed die structures 22 and 24.

The lower die structures 24 include a generally flat surfaced anvil 26, a laminating block 28 having a dihedral surface 29, and a "U-ing" or bending block 30 having a curved cylindrical surface 32. For forming the preferred connector strip 46, two small peening forms 33 are on opposite sides of the surface 36 of the anvil 26, which peening forms 33 are used to peen the connector strip 46 in the area 36. The anvil 26, the bending block 30, and the peening forms 33 are shown in Figure 10 at the sectional view 32.

Cooperating with these surfaces are upper die structures 22 which include a lance 38 and a "U-ing" or curvature punch 40. A strip of sheet metal 20 indexed intermittently (from right to left in the drawings) between the repeatedly closed sets of die structures 22 and 24 is cut and bent from its original flat stock form 42 into partially folded portion, comprised of two surfaces joining at an angle, which will be referred to as a dihedral 44, and then bent further to form a continuous strip 46 of generally cylindroidform, U-shaped structures which comprise, individually, electrical connectors 48.

Referring to Figures 1 and 2, the lance 38, in forming the dihedral 44, severs it at its trailing edge 50 from the flat stock 20, but for the vertex 52 of the dihedral 44 which is offset from said flat stock 20 and partially severed therefrom. This particular forming operation thus serves the functions of forming the individual connector blanks 43, bending them generally into the form of a dihedral 44 as an intermediate step in their slitting from the continuous strip, leaving a joining area 54 of small cross-section, and, by virtue of first providing an offset 55 in the strip and said flat stock 42 and partially severing said blanks 43 as they are further shaped to form connectors 48, providing a recessed area 56 in the strip 46 adjacent the joining areas 54.

The nature of this recess 56 and joining area 54 is best seen in Figure 2 taken in conjunction with Figure 5 and with Figures 3, 4 and 6, which latter figures present this area 54 after subsequent shearing. It is to be noted that the joining area is of relatively small cross-section, and, preferably, does not extend laterally into contact with either surface of the strip. Among the advantages accruing from this latter feature is the fact that the dimensions of each individual connector are well pre-established by the placement of said joining area 54; these connectors 48 are thereby adapted to be accurately severed from the strip without the use of sharp cutting means, but rather with the mere imposition of a lateral force between the end connector 48a and the strip 46 (Figures 3 and 5).

This shearing process is best seen in Figure 7, wherein the strip 46a, here in an inverted position, is seen disposed between an upper guiding and supporting member 58 and a lower supporting member 60. A third member, in practice one of two cooperating die structures, referred to herein as the upper crimping die 62, is abutted against the bottom (here turned upward) of the end connector 48c of the strip 46a, and the upper crimping die 62 and the strip supporting members 58 and 60 are driven transversely (vertically) relative to one another, and the end connector is thus slid or wiped off the supported strip 46c. In effect, the supported strip provides the "shaping edge" for this severing action—i.e., the connectors shear against one another. In the lateral movement of the end connector 48c relative to the strip 46a the vertical end edges 67 of the side walls 68 of the end connector 48c slide along those 67a of adjacent connector in the strip 46a, thus advantageously limiting the motion of the end connector to a laterally shearing one and causing joining area 54 to be cleanly sheared rather than partially bent and torn off. The performance previously described provides further assurance in that if by any chance this shearing should produce any burr it would be within this recess and within the thickness of the connector 48c as well as of that in the adjacent connector in the strip 46a.

Subsequent application of the end connector 48c to a fragile electrical element 64 and a lead wire 66 is seen in Figures 7 and 8 taken together. Referring to Figure 7, after being severed from the strip 46a the end connector 48c is held between the upper crimping die 62 and a lower crimping die 74, by virtue of sliding frictional engagement of the side wails 72 of the connector 48c with the longitudinal end edges 79 of the connector 48c.

In application to an electrical element and a lead wire, as is shown in Figure 8, the severed end connector 48c is disposed between the crimping dies 62 and 72, with a fragile electrical circuit element 64 and a lead wire disposed opposite the end edges 70 of the connector 48c. Subsequent bringing together of the dies 62 and 72 encloses and compressively engages the electrical element 64 in the connector 48c and securely grips the lead wire between the end edges 70 of the connector.

The previously discussed recessed areas 56 in the strip 46, or 46a, provide recessed end edges 76 in the severed connector 48c. In the connection 80 (Figure 10), seen partially in cross-section in the opposite-end connection
80a, these recessed edges 76 accommodate any burr which might conceivably be produced during the shearing of the connector from its strip, and thus preclude the cutting of the fragile wires 82 of the electrical element 64a.

The formation of the recessed edges 76 also serves to avoid the scratch even through the wires 82 might impose damaging shear strength of the fragile wires 82 when the connections 80a are crimped thereon.

Referring again to Figure 7, it is seen that the connector 48c has a longitudinal dimension (length from left to right in Figure 7) great enough to permit the connector to grip a substantial length of the electrical element 64a. This entire area is substantially uniformly compressed onto the element 64a so that the element is securely gripped with a good electrical contact but without excessive pressure of the connector 48c on the fragile wires 82 (because of distribution of the gripping force over an area sufficient to prevent the damaging of these wires).

Further, it is distinctly advantageous to have this longitudinal dimension great enough to provide a secure grip on a lead wire 65a between the end edges 70 of the connector 48d even though this lead wire 65a does not extend to the inner edge 84 of the connector (note the connection 80a, Figure 10, also Figure 11). The inner edge 84 is thus relieved from great pressure, and this produces a longitudinal gradient of pressure on the electrical element 64a which helps to protect it against damage, and this also avoids any danger of driving the cut end of the lead wire into the electrical element 64a in the critical area which determines its active length. The length of the connector 48 also determines the leverage which the lead wire 66 can exert tending to pry open the connection, although ordinarily the rigidity of the connection is so much greater than the bending strength of the wire that this leverage is not a controlling factor. Yet another function served by the length of the connector 48 is the strengthening against flexure of the connections 80, 80a, which in turn enhances the electrical and mechanical stability of these connections.

It is to be noted that, in the preferred embodiment shown in the drawings, the strip of connector 66 extends the general appearance of a channel and, more particularly, one with a rounded bottom. In certain applications, such as that described herein, this rounded contour of the bottom of the connectors is distinctly advantageous in order that the connectors can receive and snugly fit round fragile electrical elements without damaging them during crimping. The radius of curvature of the bottom inner surface of the connectors, or of the channel comprising a strip of connectors, is in present practice, slightly less than the outer radius of curvature of a round electrical element to be gripped therein. The reason for this is that the forces on the connector as it is driven along the side walls 72 and into the lower crimping die 74 tend to spread its bottom as said connector is driven around and about said element. It is to be understood, of course, that strips with other than rounded bottoms can be successfully used, with appropriate male and female crimping means, but it unnecessarily complicates the problem, when the element to be engaged is round, if the electrical elements to be used in the manufacture of circuit components were of a shape other than round, or if they were not fragile but were themselves sturdy structures, the cross-sectional shape of the connectors could be made within broad limits providing that the generally channel-like form is adhered to.

With the round, fragile, electrical element to be connected in an embodiment of this invention and a lead wire gripped between the longitudinal end edges (i.e., the longitudinally directed, laterally extreme end edges) of the connector or channel, the lateral inner peripheral dimension (i.e., from one such edge transversely at the inner surface to the other end edge along a section normal to the axis) must be such that secure compressive gripping of the lead wire can be acquired while the entire closed element is held with adequate but not destructive pressure; and that such adequate gripping pressure is reached after the lead wire has been gripped between the edges 70 but before it has been weakened beyond the requirements of its use. When the crimping dies are at the end of their movement, the wire 66 should be substantially deformed to the edges 70 so that it is keyed against rotation and against axial pull-out. (Note Figure 11 and 12.) In order that the element 64 will not be scratched by the connector as it being forced around the element during assembly (which could result in breakage of the fragile wires when the connector therefor is improperly used) and any such metal or other foreign material beyond its yield point and thus given a "permanent" character to secure the lead wire and element) this peripheral dimension plus the diameter of the lead wire should be considerably greater than the compressed circumference of the electrical element used. With the dimensional relationships of connector, channel, and lead wire as shown in the accompanying drawings, this inner periphery is approximately four times the lateral width of the rounded bottom portion of the inner surface of the connector measured at an altitude equal to one half said width above the bottom of the interior.

In crimping, the element 64 is initially of diameter slightly greater than the said lateral width of the bottom portion of the connector and hence does not immediately bottom therein; but as the end edges 70 of the connector are bent inward in the die the edge is slightly increased and the element is pushed in toward the bottom. The lead wire is then gripped between the longitudinal end edges of the connector as the electrical element is enclosed thereby; and the connector is then finally compressed against the wire until, finally, inelastic radial extrusion and compression of the connector sets walls thereof in a form to maintain a strong but well distributed gripping pressure on the enclosed element. A general expression for the width of the strip of sheet metal stock from which these preferred forms of connectors are made has been found to be pi times the sum of the outside diameter of the electrical element plus the thickness of the sheet metal stock minus the lead wire diameter, and 3 to 25 percent of the remainder added thereto to allow for compressive "setting." Although the 25% addition will ordinarily be more than necessary (and even larger excess can be used in extreme cases) it is permissible in my invention by reason of the crimping die set shown in Figure 1. As the pressure on the ferrule increases in the dies its frictional resistance against the die face increases to such extent as to preclude the wire, the compression tends to be relieved by thickening and extrusion of the metal in the zone where the surfaces of the male and female dies meet. Unless lead wires in the form of wider, more or less flat, strips of metal were used, the connector itself would have an inner lateral peripheral greater than three times the width of the curved bottom inner surface thereof, said width being taken at a point one-half the width above the bottom of said inner surface.

Various advantages accrue from having the side edges of the connector face-to-face in the strip and lying in the same plane. As previously discussed, this construction gives sliding support to the end connector as it is moved laterally across the strip for shearing and holds the alignment of the connector so that it is properly oriented in the crimping die. Of great interest is the fact that this alignment of the side walls of the connectors, in the strip, enables the size of the crimping die 74 to be reduced and permits crimping of the connectors onto fragile electrical elements with much less danger of damage by reducing the necessary clearance between said elements and the die surfaces. Advantageously, this clearance is only slightly greater than the thickness of the connector metal, but sufficient so that it does not bind on the core. This small clearance of the side of the element
can be filled in by thickening of the connector by compression during crimping. These features permit much greater and more precise location of the connector. Furthermore, this essentially cylindrical shape of the connectors obviates the risk of having relatively inwardly disposed portions of the side walls making contact, with high unit pressure, with the electrical element as it is enclosed by the connector during crimping.

A yet further advantage gained in the use of strips comprised of such aligned cylindrical connectors is the fact that the strip can bend in only one direction. The joining areas between connectors are strong enough to permit the strip being handled, that is, loaded onto applicator machines in the form of rolls of strip and the end of the strip fed through guiding and indexing mechanisms in the machines, the butting relationship of the connectors in the strip enables them to behave as if they were rigid members when subjected to columnar loading, greatly facilitating their being accurately fed in an automatic applicator. Furthermore, this strip is wound onto reels with easily achieved neatness, as it bends in only one direction and resists twisting. In order to gain these and other advantages a new means of providing an abutment for indexing members in feeding the strip in the machine, is herein provided.

In my previously referred to copending application Serial No. 119,220 I disclose and claim various embodiments of lateral deformations in the side walls of strip-form connectors. A specific embodiment of this broad idea is claimed herein because its novel advantages closely relates to the other features of the present invention. This novel indexing abutment in the embodiment shown is comprised of a lateral deformation of the side wall of the connector in the form of an indentation extending into the side wall from the outer surface thereof. Referring to Figure 1, the upper set of die structures is seen to include a pair of notching punches 89 which are so disposed, in this case, that they strike the strip of sheet metal 20 while it is still in flat stock form 42 and produce indentations 86 which, after subsequent formation of the connectors 48, reside in the side walls thereof. These indentations 86 are so formed that a laterally disposed abutment 87 is available for engagement by indexing means. An alternative structure preferable for some applications would be the placing of this indent on the inner bottom surface of the strip of connectors so that, although indexing must then be done from the inner side of the strip, the indent could also serve the functions of partially pre-sheeting the connectors one from another and recessing the area to be sheared.

The thickness of the sheet metal stock out of which the connectors are to be made is, of course, dependent on such things as the diameter of the lead wire to be subsequently gripped between the longitudinal end edges of the connector, the hardness, elastic limit, and other characteristics of this sheet metal stock, the nature of the electrical element, or, possibly, electrical conductor to be gripped therein as well as other variables, such as the size and shape of the crimping dies, which could be adapted to meet specific connector-stock thickness requirements. With quarter or half-hard brass as stock, an electrical element whose circumference is .380 inch, a stock thickness of .023 to .029 inch has been found to be quite satisfactory for use with a soft copper lead wire whose diameter is slightly greater than this thickness. Such brass connectors have a yield point low enough to permit compressive flow of the metal therein during crimping and to thus allow a permanent "set" to be given to the connector. Connectors, and in particular, the ability of the strip of sheet metal 20 to be securely grip the lead wire and electrical element gripped therein. If the sheet metal used is harder, it could be, accordingly, of less thickness.

Related to the thickness of the sheet metal used in making the connectors is the problem of insuring the secure retention of the lead wire gripped between their longitudinal end edges. In order to insure that this wire is correctly engaged by these edges during the crimping operation (Fig. 1), the crimping operation is performed. Furthermore, these features permit much greater and more precise location of the connector. To obtain this end of the strip is cut and formed into a connector, the flanges 90 are to be seen disposed at the center of the longitudinal end edges 70 of the connector, and each is in part an extension of the outer surface of the connector. Although other types of wire-gripping and edge deformations may be used to enhance the security of the retention of the lead wire between the end edges of the connector, these flanges are particularly advantageous as they tend to "gather" the lead wire into the proper position between the end edges during crimping. Furthermore, the edge recesses 91, left by the metal being peened flanged to form the flanges 90, receive extruded portions of the lead wire during the final stage of the crimping operation, thus serving to "key" the wire into place (note Figures 10 and 11). The flanges themselves, in combination with extrusion of the lead wire, also serve to "key" the wire against subsequent rotation, as is shown in Figure 12. This gripping of the wire is thus made independent of the enclosed element, and enables the pressure on the wire and on the element to be varied independently, as previously discussed.

If thinner and harder material, e.g., steel, is used in the manufacture of connectors which are to be used as described above, it would be distinctly advantageous to so form the longitudinal end edges that they are effectively thick enough to grip and retain the lead wire. Corrugated edges, for instance, would not only be effectively thick enough, but would enhance a "keying" of the wire by permitting extrusion thereof between the corrugations.

The minimization of burrs at the severed ends of the connectors, the minimization of the maximum radial dimension of the connections formed therewith by gripping the lead wire in an opening in the wall of the connector, and the secure "keying" or rigid gripping of the lead wire—these and other features enhance the subsequent molding of plastic insulating material over the electrical components so formed. For instance, the lead wire is used, advantageously, as a support for the component during such molding—if it is not properly disposed, and securely held, in the component, it may preclude the component being adequately covered with insulation.

I claim:

1. A continuous strip of sheet metal electrical connectors of channel-like form, transverse slits extending inwardly from the opposed side edges of the strip to define adjacent and abutting end edges of a pair of individual connectors of said strip and further to define between the inward limits thereof a short intermediate connecting portion joining the adjacent connectors, said slits extending completely through the walls from surface to surface of said channel and being repeated at regular intervals along the length of said strip, each said connecting portion being partially severed inwardly from the opposed surfaces of said strip in continuity with said slits to leave a connecting area of metal significantly less in thickness than the thickness of the sheet metal, said said connectors being strong enough to be located within the sheet metal thickness so as to be offset relative to both the inside and outside surfaces of the channel to render the individual connectors easily separable from the strip without disturbance to the working surfaces of the connector.

2. A strip of connectors as defined in claim wherein—
said channel is generally cylindriform with a smoothly curved bottom wall and relatively straight side walls, the inside surface of said channel having a lateral peripheral dimension greater than three times the lateral separation of the side walls measured at a distance above the channel bottom equal to one-half said lateral separation.

3. A strip of connectors as defined in claim 1 wherein the outer surface of at least one side wall of said channel is formed inwardly to provide substantially a transverse surface relative to the longitudinal axis of said channel, the inside surface of the portions of said channel defined by said slits being cylindriform and continuous between said side edges.

4. A strip of connectors as defined in claim 1 wherein the end face of at least one side wall of each of the individual connectors in said strip is provided with an indentation intermediate the longitudinal end edges thereof, the outer surface of at least one side wall of each said connectors being formed to have a relatively thin extension in substantial transverse alignment with said indentation.

5. The method of making a continuous strip of channel-like electrical connectors including the steps of repeatedly shearing at regular intervals through a strip of sheet metal along transverse lines extending inwardly from the opposed side edges of the strip, the line of metal between the inward limits of the transversely opposed shear lines defining a short connecting portion joining adjacent connectors in the strip, repeatedly folding down the transversely opposed portions of the strip in advance of the transverse shear lines to form channel side walls, laterally offsetting the bottom portion, including the connecting portion, of the connector channel from the plane of the strip so as to sever partially through the connecting portion from both the inside and outside surfaces of the channel to leave a connecting area of metal approximately centered within and significantly less in thickness than the thickness of the sheet metal, and restoring the offset portions to flush condition relative to the formed connectors of the strip.

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