

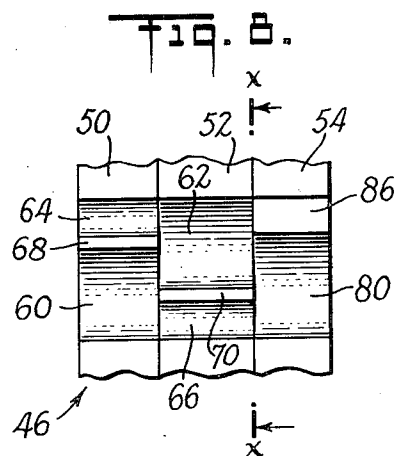
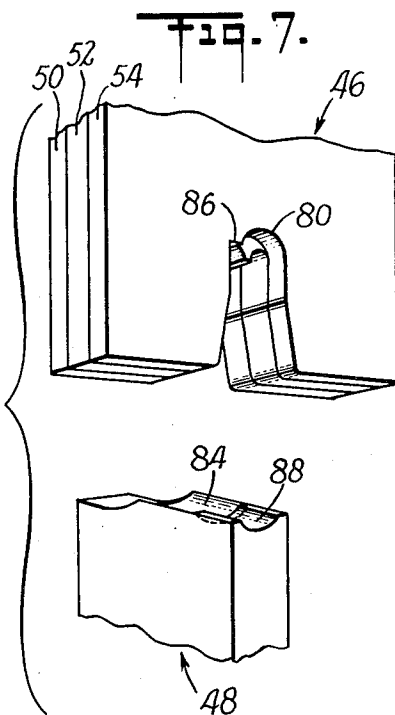
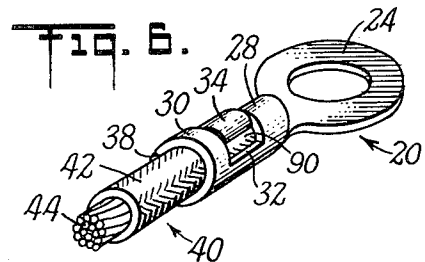
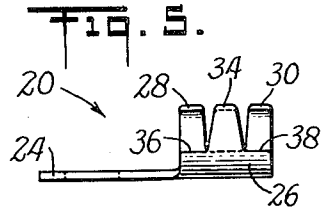
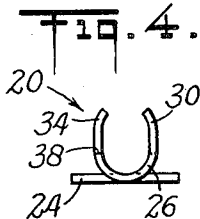
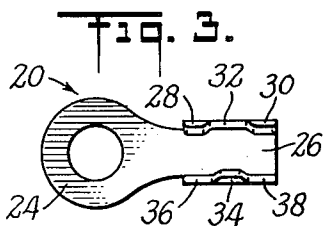
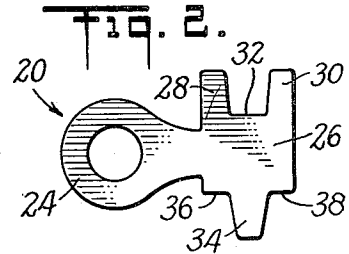
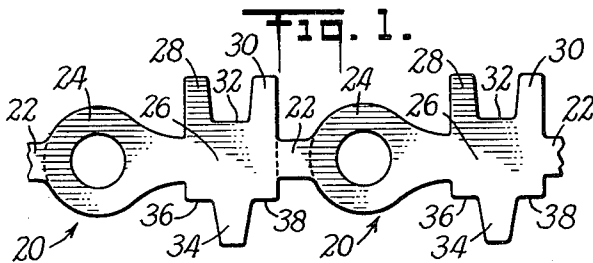
Sept. 4, 1951

J. C. MACY
CRIMPING DIE

2,567,155

Original Filed June 27, 1946

2 Sheets-Sheet 1



INVENTOR
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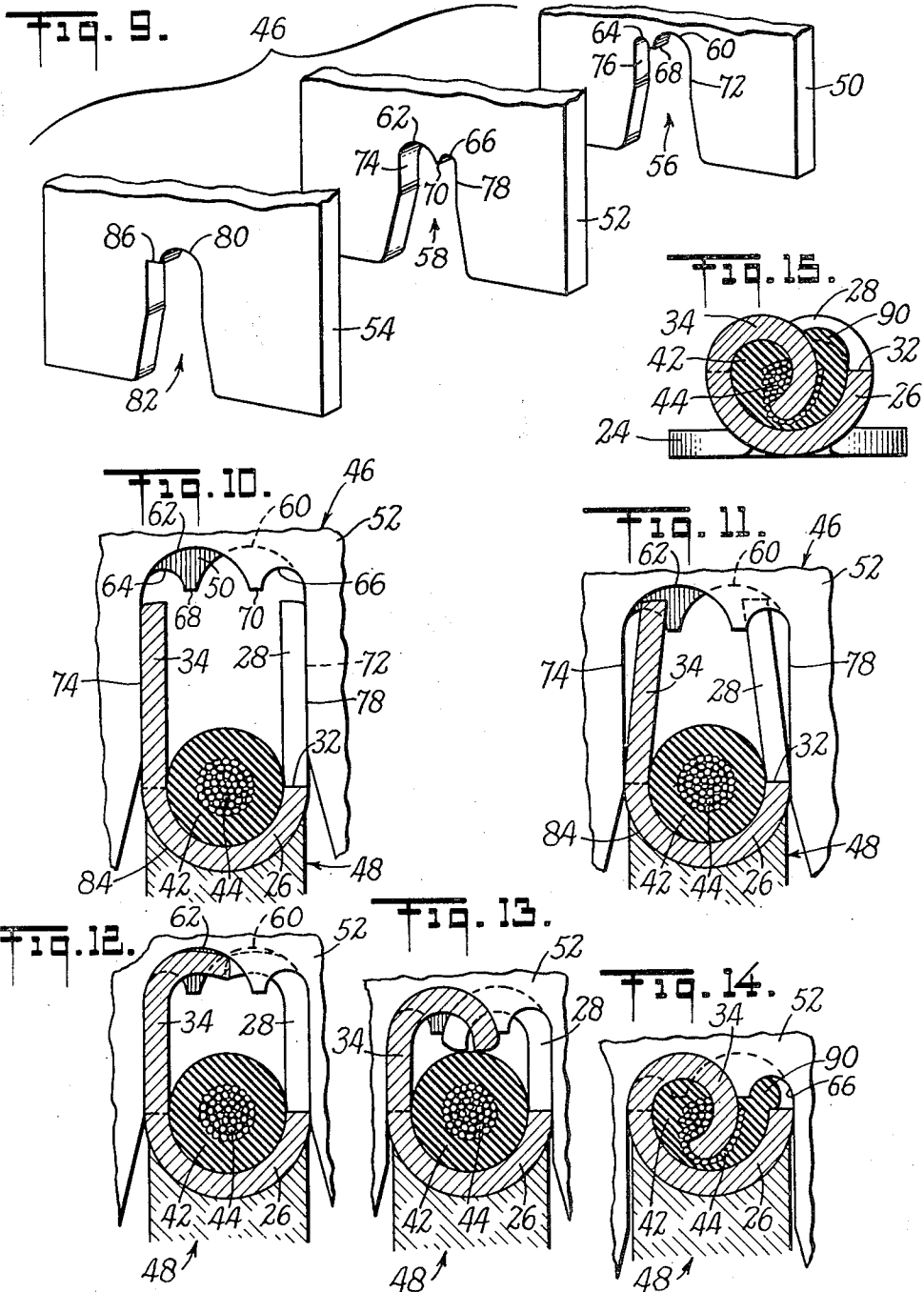
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UNITED STATES PATENT OFFICE

2,567,155

CRIMPING DIE

James C. Macy, Westfield, N. J., assignor to Aircraft-Marine Products, Inc., Harrisburg, Pa., a corporation of New Jersey

Original application June 27, 1946, Serial No. 679,630. Divided and this application February 21, 1948, Serial No. 10,021. In Canada June 19, 1947

2 Claims. (Cl. 153—1)

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This invention relates to apparatus for crimping an electrical connector onto an insulated electrical conductor and more particularly to inter-engaging dies for crimping a U-section electrical connector having offset opposite ears onto an insulated electrical conductor.

Crimping dies have, heretofore, been restricted to effectively securing an electrical connector onto an insulated wire after the insulation has been stripped from the wire over the area of attachment. This procedure while resulting in a connection of permanence and good metal to metal engagement between the wire and connector, nevertheless possesses several drawbacks. Principal among these are the restrictions on mass production due to the added step of stripping insulation from the wire and the fact that the exposed connection is subject to corrosive attack thereby affecting the electrical conductivity of the connection. Hence, it has long been recognized that crimping dies would be desirable that directly attached a connector to a wire unstripped of insulation.

According to my invention, apparatus in the form of crimping dies are provided which will securely attach a connector or terminal to an insulated wire. The connector normally includes a ferrule portion in which the wire is received. The ferrule portion generally has two or more laterally extending ears. The crimping dies comprise two dies which move relatively toward and away from each other and which define in their closed position substantially the final configuration of the connection. In operation the ferrule portion of the connector is placed in one of the dies while they are in an open position and the portion of the insulated wire to which the connector is to be attached is placed in overlying relation thereto. The dies are then closed to effect the crimping operation. As this happens, they cooperate to curl the lateral ears on the ferrule portion to a radius smaller than that of the exterior of the wire and at the same time forced into or around the wire. At least one of the ears, as a result of the dies, pierces the insulation and intimately engages the bare wire in the case of a solid conductor and intimately engages a strand wire by being forced in between the strands if such is the case. The remainder of the ferrule is crimped tightly against the wire and aids in holding the ears in position.

It is an object of my invention to provide crimping dies for attaching an electrical connector to an insulated wire without the necessity

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of stripping the insulation from the wire at the point at which the connector is to be attached.

It is another object of my invention to provide crimping dies for this purpose which will result in connections being effected more efficiently and economically than by an apparatus which has heretofore been available.

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 practical use so that they may modify and adapt it in various forms, each as may be best suited to the conditions of a particular use.

In the drawings:

Figure 1 is a top plan view (enlarged) of a connected strip of terminal blanks;

Figure 2 is a top plan view of a single separated blank;

Figure 3 is a top plan view of a blank with partially pre-formed ferrule;

Figure 4 is an end view of the blank with partially pre-formed ferrule;

Figure 5 is a side view of the blank with partially pre-formed ferrule;

Figure 6 is a perspective view of the completed terminal applied to an insulated conductor;

Figure 7 is a perspective view of a set of dies embodying the invention and for applying a terminal to a conductor;

Figure 8 is a view (enlarged) looking into the upper of the two dies shown in Figure 7;

Figure 9 is an exploded fragmentary view of the die plates which together constitute the upper die;

Figure 10 is a cross-sectional view taken on the plane $x-x$ of Fig. 8, through a connector and insulated conductor and die set in the initial stage of the installation onto the conductor;

Figures 11, 12 and 13 are views similar to Figure 10, but showing successively later stages of the die operation;

Figure 14 is a view similar to Figure 10, showing the final stage of the die operation; and,

Figure 15 is a sectional view through the completely crimped connector and conductor after they are released from the die.

Similar reference characters refer to similar

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parts throughout the various views of the drawings.

Figure 1 shows a series of connected terminal blanks 20 attached head to tail in the flat form in which they leave the blanking dies. The terminals may be blanked from a variety of materials; I have found that the physical properties of half-hard brass, 70-30 commercial or cartridge brass, are suitable for this purpose. Quarter-hard electrical copper can be used if desired and even fully annealed pure copper can be used if the dies are designed so as to keep the compressive stress on the ears sufficiently low that the ends are bent before other parts of the ears buckle under the stress. I have found that sheet metal carrying a film of insulating sheet material bonded or deposited on one of its faces can be used with success, as more fully set forth in Patent No. 2,476,429. The insulating sheet materials may be the same as those used in tubing form in the applications of Frank J. Sowa, Serial No. 505,087, filed October 6, 1943, now Patent No. 2,551,299 issued May 1, 1951, and William S. Watts, Serial No. 514,216, filed December 14, 1943, now Patent No. 2,410,321 issued October 29, 1946, and may be cemented to the metal by adhesives such as are set forth in the application of Robert C. Swengel, Serial No. 523,004, filed February 19, 1944.

In general the thickness, stiffness and ductility of the metal will all affect the curvature of the die which is required for a given curl of the ferrule-forming ears and a given piercing of the wire thereby; and where a particular material which is desirable for other reasons is found to be too hard or too soft for complete forming in the die set of the present invention, the desired result can often be obtained by partially pre-forming the ears and then completing the formation by a die-set of the present invention, for example, as shown in the drawings.

To facilitate separation of individual blanks 20 from the continuous strip, while the end terminal and adjacent blank remain in the same plane, a connecting piece 22 is provided which is punched out before the finished terminal is removed. In some embodiments of the invention the intervening piece 22 can be omitted with the advantage of eliminating production of scrap material at the site of the crimping operation. In such case the strip is ordinarily fed to the die at a level offset from that of the lower die; and the blank 20 is moved to the level of the die by the shearing operation. If desired the ears 28 and 34 may be bent up to a U (see Figure 4) by forcing the blank at the same time through a flared mouth die.

Although it is an advantage of the present invention that it lends itself well to magazine feed application, the connected strip is not essential to the present invention, which also includes single blanks as shown in Figure 2. The blank as shown comprises a connecting portion 24 and a ferrule portion 26 from one side of which extend ears 28 and 30 slightly tapering and longer than they are wide. These ears are separated along ferrule edge 32 sufficiently to receive an opposite ear 34 between them when the blank is applied onto a wire. A single slightly tapering, longer-than-wide ear 34 extends from the other side of the blank leaving ferrule edges 36 and 38 on opposite sides thereof.

While I have shown connecting tongue portion 24 apertured for use with a binding post, it is to be understood that this portion of the terminal

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may be given any desired form, or omitted entirely, as its specific characteristics are immaterial herein.

The flat terminal blank 20 is pre-formed to give its ferrule portion 26 a U-shaped cross section, as shown in Figures 3, 4 and 5, so that ears 28, 30 and 34 extend upwardly in parallel relation from the plane of connecting portion 24. The bottom of ferrule 26 may be rounded as shown in Figure 4. The tips of the ears 28, 30 and 34 may advantageously be pre-bent to a desired curvature while still in the flat blank as shown in Figure 1 or 2. Thus there is formed a receptacle for a portion, usually but not necessarily the end portion, of a wire generally indicated at 40 (Figure 6). This terminal may be used with insulated (unstripped) or bare wire; but since its greatest advantage is realized in use on insulated wire, Figure 6 shows a wire provided with insulation 42 and a multi-stranded core 44.

With wire 40 positioned in the partially pre-formed ferrule portion 26, the assembly is ready to be operated upon by the installation dies 46 and 48 (see Figure 7).

Dies 46 and 48 may conveniently be mounted upon or integral with the opposed jaws of a pair of pliers (not shown) or may be installed in a press or any other suitable mechanism capable of forcing the dies together with sufficient pressure to attach the terminal to the wire. Upper die 46 (see Figure 7) may conveniently be made of three die plates 50, 52 and 54 (see Figure 9) secured together in any suitable manner, as by rivets.

Each of die plates 50 and 52 is channeled as at 56 and 58 in such a manner as to provide rounded die faces 60 and 62 tangent at one side with edges 72 and 74, respectively, and terminating abruptly at the opposite side in ridges 68 and 70, respectively. Beyond the ridges 68 and 70 are clearance grooves or slots 64 and 66. The shape of these clearance slots 64 and 66 is not critical, while the shape of die slots 60 and 62 needs to be accurately formed for purposes to be described.

Die plate 54 may, for some applications, be slotted similarly to plate 50; thereby giving 3-prong contact with the wire core 44; but in the present embodiment this third die plate 54 has its die face 80 shaped to wrap ear 30 around the wire without piercing the conductor. If desired it may be designed to embrace without piercing the insulation sheath. (See Figure 6.) Thus, as seen in Figure 6, ear 30 forms an insulation support while ears 28 and 34 pierce the insulation and make contact with conductor core 44. To this end the radius of curvature of die face 80 at the base of die channel 82 is slightly greater than the radius of curvature of rounded die faces 60 and 62 and is approximately equal to the radius of curvature of die surface 84 in lower die 48. Ferrule portion 26 and ear 30 are thus given a final shape which is substantially cylindrical.

No clearance slot, corresponding to slots 64 and 66, is necessary where there is no insulation piercing and accordingly the remainder of the bottom of channel 82 takes the form of a flat shelf 86. Where the insulation piercing ears are sufficiently narrow no recesses (such as 64 and 66) or other special provision need be made for extruded insulation beside the ears which pierce the insulation; but ordinarily I find it an advantage to provide such relief.

The composite thickness of die plates 50, 52 and 54 is substantially equal to the length of die

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surface 84 in lower die 48. A die extension 88 in the lower die acts as a nest to support wire 40 adjacent the wire portion which is enveloped by the connector. This nest projects forwardly of the front face of plate 54 (see Figure 7).

The thickness of die plate 52 is slightly greater than the thickness of die plates 50 and 54 for a reason now to be explained. Plates 50 and 54 act on ears 28 and 30 on one side of the connector. Plate 52 acts on single ear 34 on the other side of the connector. There is advantage in making the total downward die forces somewhere near equal on the two sides of the connector so that the connector will not twist nor rotate within the die. This is achieved in the case illustrated in the drawings by having the width of single ear 34 greater than the width, but less than the combined widths, of ears 28 and 30. In the present embodiment die plate 52 is about twenty percent wider than either die plate 50 or 54; plates 50 and 54 are given equal widths.

In one die which has given commercial satisfaction the three plates 50, 52 and 54 are of hardened tool steel. The plates 50 and 54 have thicknesses of .078 in., whereas plate 52 has a thickness of .094 in. In this same die the radius of curvature of arcuate die surfaces 60 and 62 is .046 in., whereas the radius of curvature of arcuate slot 80 is .055 in. The radius of curvature of arcuate die surfaces 64 and 66 is .018 in. In all three die plates the width between the parallel side walls (as in plate 50 between faces 72 and 76) is .136 in. The lower die 48 also is made of hardened tool steel and has an over-all width of .133 in. The radius of curvature of surface 84 is .070 in. and the radius of curvature of surface 88 is .050 in.

With dies 46 and 48 in open position (see Figure 10) ferrule portion 26 is placed between the dies so that ears 28, 30 and 34 extend upwardly from die 48 into the channels in die 46. Wire 40 may be disposed on the portion 26 between the ears 28, 30 and 34 either before or after the blank is placed between the dies. Advantageously the radius of curvature in the bottom of ferrule portion 26 (see Figures 4 and 10) exceeds the exterior radius of curvature of the wire by an amount on the order of .005 in. to .015 in., although the bottom die may even be flat, especially where uninsulated wire is being used.

The two dies 46 and 48 are forced together, and as they near one another, ear 34 enters channel 58 (see Figure 11) in die plate 52. At the same time ears 28 and 30 enter similar channels 56 and 82 respectively in plates 50 and 54 and the ears respectively engage the rounded surfaces of the die faces 62, 60 and 80, being bent or curled thereby inwardly toward one another. Initially the ears may not curl over from their outer ends but instead may continue substantially straight, the opposing ears being bent or cantilevered from an area closer to the ferrule body 26. An early stage of this bending is shown in Figure 11. Upon further closing, however, the ears collapse farther up into substantially full contact and conformity with the rounded dies over most of their length (see Figure 12). Further closing of the dies given the effect shown in Figure 13 with each of the ears 28 and 34 piercing the insulation sheath at an angle so nearly normal to the surface of the insulation as to assure the piercing and avoid deflecting the ends of the ears. The ear 30, on the contrary, strikes the insulation at a deflecting angle so that ear

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30 wraps tightly around the wire but without piercing the insulation. The final closing drives each piercing ear through and into good contacting relationship with the stranded wire core 44; and at the same time it compresses the metal of the ears and wipes the metal at the outer surfaces of the bent portions, with the result that stresses in the metal are equalized by plastic flow and tendency to spring-back or unwrapping of the ears is minimized and may be substantially eliminated. This final position of the dies is shown in Figure 14.

The extent to which the condition pictured in Figure 11 may be present depends principally upon the material of the ferrule and the speed of die closing; softer materials tend to conform more fully and readily to the shapes of the dies and slower closing of the dies tends to result in more even bending of the die ears. It is often advantageous to pre-bend in the blank the tips of the ears, which otherwise may remain straight, as shown in Figures 12 and 13. Such pre-bending is shown for example in Figures 3, 4 and 5.

As dies 46 and 48 are forced together, the ears are formed more and more, the metal thereof being drawn and swaged somewhat along the edge to produce sharp leading edges at the ends of the ears. Under certain circumstances, it may be desirable to swage the ear tips in the blank before it is applied to the wire to give a sharper edge for breaking into the insulation, particularly where fabric or tough synthetic materials are used.

The dies 46 and 48 are not merely curling dies, but serve also to produce a plastic flow in the metal by which a permanent pressure contact is assured. The initial action in the stages between Figure 10 and Figure 13 is mainly a mere bending of the ears; their resistance to such bending is not great and, therefore, the ears are not pressed very hard against the die faces and the friction is not high. The bending of the metal of course puts the outer surface under tension, and there is some working and burnishing by the surface of the die which relieves to some extent this tensile stress and rounds off the outer corner of the tip with advantages set forth below. When the stage shown in Figure 13 is reached, however, the further movement of the die is opposed not only by the resistance to bending but even more by the resistance of the wire to entry of the ear. This greatly increases the friction of the metal against the die and thus increases the burnishing or drawing of the surface metal by the die, with the result that the curl is given a permanent set and is not a mere elastic bend. As the ear penetrates more deeply the resistance increases and there is added to this action an actual endwise compression of the metal with plastic flow therein, which further equalizes stresses to prevent spring-back. This action is controlled to some extent by the surface character and radius of curvature of the die faces, and of course by the ductility of the metal of the blanks. With all but the most ductile metals, it is desirable that the die faces should not be polished and lubricated for maximum slip, but should be purposely designed for higher friction to assure some drawing or burnishing of the surface metal.

When the dies are finally closed, as shown in Figure 14, the materials of the terminal and wire are substantially confined within the die so that the final pressure can cause coining of the metal and a compacting of the wire and ear to-

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gether. At this stage the ferrule 26 is substantially cylindrical in form with the ears curled within the same geometric cylinder as the ferrule.

In the present embodiment the ferrule is shaped to this over-all cylindrical form by the action of die faces 60, 62 and 80 on ferrule ears 28, 34 and 30; these die faces are curved to about the same radius as the pre-formed portion of the ferrule. In the illustrative form the radius of curvature of die face 80 is about twenty percent longer than the radius of curvature of faces 60 and 62, and slightly less than the radius of curvature of the face 84. The cylindrical form however, is not essential to the invention; and in some cases it is advantageous to use a spiral curvature on the die face instead of arcuate.

Often the stranded conductors are given a rope-like twist during manufacture; for such conductors the ferrule ears may be skewed, by means of skewed die faces, so as to present the ears with their leading edges parallel to the direction of the twisted strands and hence to enter easily between strands without cutting the conducting wires. If, however, the ends are not driven too far into the wire, advantage can be taken of this twist to give good contact by virtue of strands of the wire being engaged over the end of the ear and pulled tight against it, at the same time such strand being pulled so as to bear tightly against any other ear which may have pushed it aside in penetrating the wire. As noted above, the end edges of the ears are sharpened as the ears are curled, thus facilitating the entrance of the ears into the strands.

Where the applied ferrule has more insulation piercing ears on one side than on the other, there is advantage, as pointed out, in making the lesser number of ears broader than those of greater number so that nearly equal forces are imposed on the opposite edges of the ferrule for piercing the wire and curling the ears. However, it is not essential to balance these forces, and a good connection can be made with all ears, or only a single ear, on one side, the other side being held against rotation by an abutment in the die.

Where the wire has but a single strand the ears cannot pierce the wire, but can be wrapped thereabout so as to clamp it firmly; and in this case by using the proper curvature on the die faces, having regard to the material and thickness used for the ears, the ends of the ears may be made to scrape the periphery of the wire as it curls around it. The radii of curvature of the several die surfaces may be chosen so that any or all of the ears may have the described wedging or clamping characteristics, as desired. Thus, with either a stranded or solid wire, the alternate connector ears on opposite sides of the ferrule portion may be made to press the wire respectively to the right and to the left, giving it an undulatory effect which further increases the pull-out strength of the connector and improves the electrical contact. The result will be somewhat similar to that of a pencil caught between the hooked, interdigitated fingers of each hand with the two hands pulling on the pencil from opposite directions. This results in an excellent and permanent contact and one which, to the best of my knowledge, is new.

It is not essential that the ears be staggered on opposite sides; but if ears are opposite to one another each must pierce the wire on its own side of a plane between them and this requires a narrower arc and ordinarily a shorter radius of

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curvature than is shown in Figures 6 to 15. As an alternative, however, still within the scope of the present invention, one of such opposed ears may be designed to pierce the wire much as in the case illustrated by Figures 6-15 and the other, a shorter ear, may be curled in against the first to close fully the ferrule around the wire, but not itself piercing the wire. In this case the ridge 68 or 70 would be shorter and the grooves 64 and 66 would be of greater radius.

The particular point at which the ear penetrates the wire is not critical, although there is advantage in the point as shown. If the point is moved closer to the base of the ear, the end of the ear should enter at a slope such that it moves slightly away from its base before it curls back toward it; and/or the end of the ear should be sharp on its outer edge and relieved on its inner edge to carry it sufficiently toward or beyond the axis of the central conductor core to assure contact engagement. If the point of piercing is moved further from the base of the ear it may be necessary to use a sufficiently longer ear that it will be curled beyond 180° when it comes into contact with the wire, so that it is at a suitable angle for puncture, advantageously approximately radially.

The length of the ears on the terminal relative to the cross-sectional periphery of the die surfaces engaged thereby and relative to the radii of the insulation and the central core of the wire is important. The ears should be long enough to travel along the die surfaces 60, 62, etc., until turned back upon themselves, advantageously approximately 180°, more or less, before striking the insulation; and then to have enough remaining length in the ears and/or the edges of the ferrule body portion 26 to push the end, after piercing the insulation, fully into engagement with the central conductor.

If the ears are too long, they will curl beyond the 180° before contacting insulation, and when the insulation is contacted, the ear will be curled under so that instead of meeting the insulation with its sharp edge nearly radially of the wire, it meets the insulation circumference to circumference, with the result that further pressure serves only to double the ear under and against itself without ever piercing the insulation. If the ear is too short it may never reach the central conductor core, or may not sufficiently engage it. With ordinary stranded wire the ear should pass through and somewhat beyond the conductor core, as in Figures 14 and 15. With single strand wire substantially the same length and curvature may be used, the end of the ear striking the conductor core on a secant sufficiently far from the center so that it scrapes the surface of the core and deflects it to one side; as the end passes on, the resistance of the insulation against the end plus the lateral pressure of the wire against the side of the ear beyond the end tends to increase the curl and cause it to follow the surface of the core, embracing it in a tight curl. In this latter case it is desirable to use a somewhat longer ear to embrace the central core as fully as possible.

It is advantageous to have the curling die so formed that the ear is supported by the die almost up to the point where it actually pierces the insulation. When insulation piercing finally occurs, however, the tip of the sharpened ear should have passed beyond the die ridge by an amount at least one-half the radius of the wire, and advantageously somewhat more.

By tapering the ears either in thickness or width, or both, the advantage is secured that they tend to bend first near the end and then to bend progressively back from the end, thus giving a smooth curl. In general I have found that the use of a trapezoidal shape for the ears is the most satisfactory. The altitude of the trapezoid is greater than the lower base and the upper base usually should not be greatly less than the lower base. Thus the ear tapers some toward its tip but yet remains sufficiently strong throughout its length to follow well the curvature of the curling die and to pierce any insulation encountered.

As pointed out previously the precise shape of clearance slots 64 and 66 is not important so long as sufficient space is provided for extrusion of insulation, as at 90 in Figure 14. Strangely enough I have found that with a connector having two insulation piercing ears on each side of the ferrule portion, four ears in all, it does not seem to be necessary to provide space for extrusion of insulation. Perhaps the reason for this is that where the length of the ferrule portion is maintained the same for four ears as for three, each ear is sufficiently narrow that extrusion of insulation is so reduced at any one point as to be insignificant.

It will be observed in Figure 14 that a small mass of insulation 90 has been extruded into clearance slot 66; when the connector is removed from the die this mass returns plastically, as shown in Figure 15, to seal tightly the opening through which the ear passed. Thus the interior portions of the connection are sealed against entrance of foreign matter and a high quality electrical contact is maintained. This is an important feature of my invention and one which is wholly new in an electrical connector.

While I have shown ferrule 26 as provided with three ears, it is to be understood that the number of ears may be more or less, one advantage of three being that one ear may pierce the wire from each side so as to enter between the strands of the central core and/or to grasp the strands between the opposing ear ends, while a third is curled around and clamps the whole wire, providing effective insulation support which prevents flexing of the wire strands near the contact area.

From what has been said above, and in view of the accompanying drawings, it should now be understood that the curvature and configuration of the die faces is important. By this means, the long connector ears are bent to a definite curvature and at the same time pushed along the die sides to bring them edgewise against the wire. It is essential that the ear be directed at a suitable angle when it meets the insulated surface of the wire. Otherwise valuable benefits of the invention are lost. Ordinarily the end of the ear should be moving almost radially of the wire when it strikes the insulation so that no appreciable bending moment is imposed on the ear by the descending die ridge (68, 70); how far this direction can be varied depends mainly upon the thickness and resistance to piercing of the insulation encountered, the diameter and type of wire, and how sharp and strong is the edge of the ear. Except for rare cases the angle at which the ear meets the wire (that is, the angle made by the tangent to the curled ear at its end with the tangent to the outside of the insulation sheath at the point of piercing), should not vary more than thirty degrees on either side of the normal (that is, the perpendicular to the tangent at the point of contact). If the ear is curled back too far before engaging the insulation on the

wire, it will be deflected, denting the outside of the insulation somewhat, and doubling under but not piercing it. If it is not yet curled enough, it may be deflected the other way so as merely to wrap around the outside of the wire and never pierce the insulation. Between these extremes and a correct curvature, the ends may pierce the insulation but miss the central conductor core, or make only a light temporary contact which may be seriously affected by flexing the wire or by corrosion. Which of these conditions will result in any case depends upon the curvature of the dies and the material of the blanks, and, to a lesser extent the nature of the outer portion of the wire—both toughness and resiliency of the material and character of its outer surface.

The best results are secured when the ends are brought into contact with the insulation a few degrees on opposite sides of the vertical axial plane through the wire and with the ends almost, but advantageously not quite, radial. Such a condition is shown in Figure 13. It should be remembered, however, that the condition of the ends of the ears and the material and surface character of the insulation affect materially the extent to which one can safely depart from the radial form and movement of contact.

With the straight tip as shown in Figure 13, the contacting ends of the ears may be radial as shown, but their direction of movement is along secants of the central conductor core. With a relatively soft and resilient insulation this works well; and, in fact, the resistance of the insulation to the end of the ear tends to bend the straight end of the ear and thus assist it in finding the desired curl within the wire. The form of the end edge also assists in this, the sharper edge at the inner surface tending to bite into the insulation and deflect it under the rounded edge and thus adding to the bending movement by which this end is curled into or against the central conductor core. With tougher insulation material or a harder outer surface, the bending movement might become excessive so that the end would be bent under before it could pierce, or wrap itself around, the central conductor, or even before piercing the insulation. In such case it is desirable to change the curvature of the dies and/or the pre-forming of the ends of the ears so that the end of the ear is more nearly radial, and moving radially of the wire, at the moment of contact and is well supported by the die, and/or to sharpen the end edge for piercing the insulation or to shift the sharper edge somewhat toward the outer face so as to reduce its tendency to be deflected inwardly by the material through which it passes.

For a connection such as illustrated, I have found that the chordal distance across rounded die faces 60 and 62 should be equal or nearly equal to the diameter of core 44 plus one thickness of insulation sheath 42.

For a stranded wire it is feasible to drive the piercing ears well into and even through the bundle of strands, advantageously on opposite sides of the axis, respectively. For a solid wire or wire moving in a short pitch spiral, the rounded die should be so configured that its projected curve will send the ear, when the dies are substantially finally closed, tangentially past the solid wire with enough scraping and wiping action to assure good contact. The dies may then be closed hard to assure final high pressure contact.

Even after the insulation is pierced or entered

by the ears, the die curvature is still important. Depending upon the curvature of the die and its relation to the particular ferrule blank and wire used, the ear may penetrate an outer layer of strands, curling around into the wire, or it might curl around in the layer of insulation without ever contacting the wire. Different ears of a multi-ear terminal are sometimes advantageously given different curvatures, such as to enter the stranded wire at respectively different positions and thus assure contact even if the conductor core should be displaced from a truly central position in the wire. It is often advantageous also to give at least one of the ears a curvature such that it curls itself around a considerable number or all of the strands so as to clamp the stranded core and thus assure relatively high pressure contact of the strands against adjacent ears which pierce the core. In most cases, however, the contact secured by penetrating to and through the wire is adequate and the external pressure exerted on the insulation assures a good electrical contact.

When light, relatively weak or soft ferrule ears are used the speed at which the dies are closed has some bearing upon the resulting crimp. Thus, as in the case of a light staple for binding together papers, the ferrule ears have less tendency to buckle if the dies are closed at a relatively high speed. However, as pointed out, the ears tend to conform more accurately to the shapes of the curling dies when the closing velocities are not so high; and if by design of the dies and/or partial pre-forming of the blanks the buckling is directed outward, the ears will be supported by the die.

The location of the edges 32, 36 and 38 of the ferrule portion 26 is not critical, and in fact there are some advantages in extending these edges so that they contact the curled ear opposite when the ferrule is crimped onto the wire.

As already set forth in the copending application of Annis G. Asaff, Serial No. 551,141, filed August 25, 1944, now abandoned, the quality and security of the electrical connection made by this invention can be improved by treating the terminal blank and/or the wire with mercury.

From the foregoing it will be observed that electrical connectors, dies, and methods of making connections embodying my invention are well adapted to attain the ends and objects hereinbefore set forth and to be economically exploited since the separate features are well suited to common production methods and are subject to a variety of modifications as may be desirable in adapting the invention to different applications.

Many other and different embodiments may be made of the above invention and many changes may be made in the embodiments above set forth.

I claim:

1. Interengaging dies for crimping a U-section electrical connector having offset opposite ears onto an insulated electrical conductor with at least one ear piercing the insulation that comprises a first die having an elongated trough-like die face to accommodate therein the conductor and ferrule with the ears of the ferrule projecting outwardly generally tangentially of the trough-like die face, a second die having walls defining a recess to receive the first die and having

a plurality of face portions to act on the connector ears, said face portions being adjacent in a direction parallel to the long axis of the die face of said first die, said face portions all including curved trough-like ear curling portions of a diameter less than the width of the die face of the first die, axially adjacent ear curling portions being offset transversely of said recess, the ear curling portions of axially adjacent face portions blending substantially tangentially with opposite walls of said second die at one side, at least one of said face portions having a socket between the other side of the curling portion and the wall opposite to the one with which it substantially tangentially blends, said socket functioning to receive insulation during operation of the dies so that the resistance of the insulation to piercing by the curled ear is reduced.

2. Interengaging dies for crimping a U-section electrical connector having offset opposite ears onto an insulated electrical conductor with at least one ear piercing the insulation that comprises a first die having an elongated trough-like die face to accommodate therein the conductor and ferrule with the ears of the ferrule projecting outwardly generally tangentially of the trough-like die face, a second die having walls defining a recess to receive the first die and having a plurality of face portions to act on the connector ears, said face portions being adjacent in a direction parallel to the axis of the die face of said first die, said face portions all including curved trough-like ear curling portions of a diameter less than the width of the die face of the first die, axially adjacent ear curling portions being offset transversely of said recess, the ear curling portions of axially adjacent face portions blending substantially tangentially with opposite walls of said second die at one side, some of said face portions having a socket between the other side of the curling portion and the wall opposite to the one with which it substantially tangentially blends and at least one of said face portions presenting a flat surface between the other side of the curling portion and the wall opposite to the one with which it substantially tangentially blends, said sockets functioning to receive insulation during operation of the dies so that the resistance of the insulation to piercing by the curled ears is reduced.

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