Nov. 21, 1961 C. N. HOLTZAPPLE 3,009,503

IMPROVED TOOL FOR MAKING ELECTRICAL CONNECTIONS

Original Filed Feb. 1, 1949 2 Sheets-Sheet 1

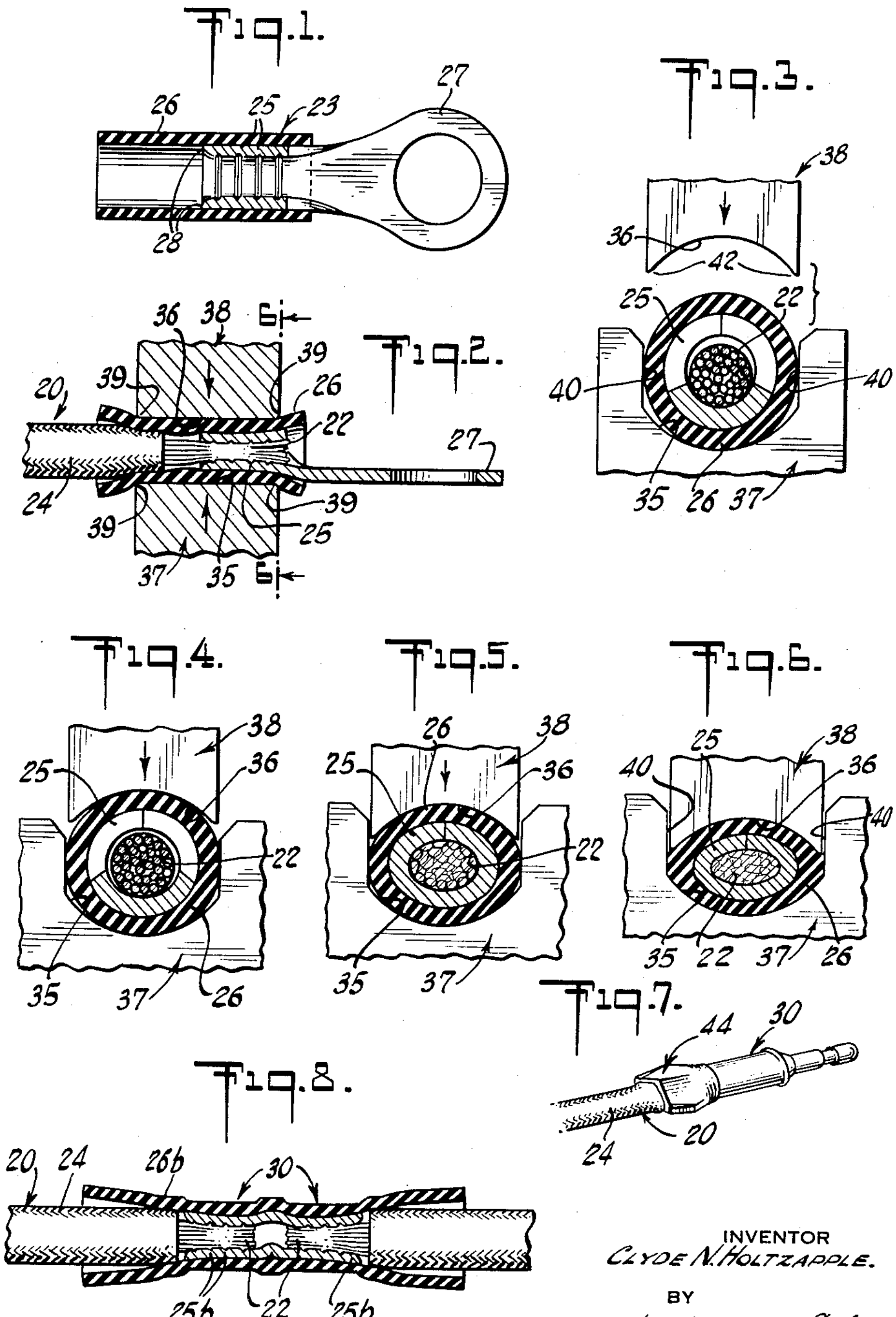

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Fig. 9.

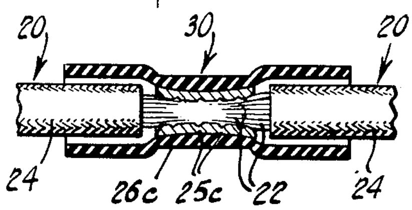


Fig. 10.

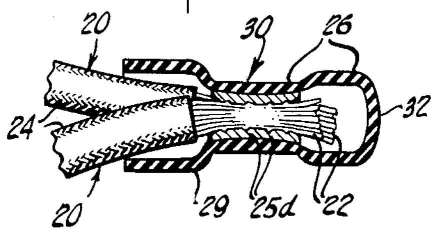


Fig. 11.

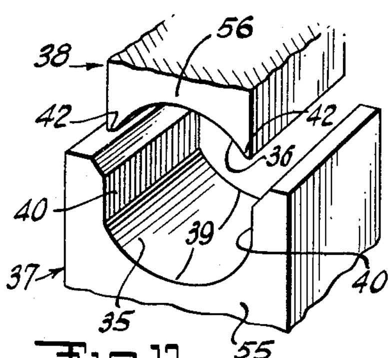


Fig. 12.

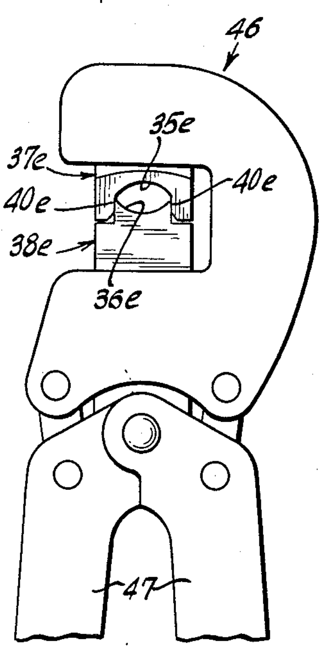
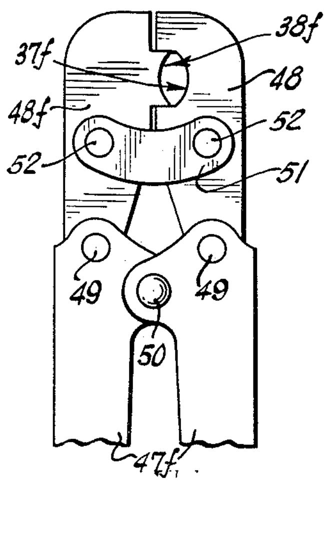


Fig. 13.



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IMPROVED TOOL FOR MAKING ELECTRICAL CONNECTIONS

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Original application Feb. 1, 1949, Ser. No. 73,946. Divided and this application Oct. 11, 1956, Ser. No. 616,909
2 Claims. (Cl. 153—1)

This invention relates to crimped electrical connections and more particularly to improved tools for the formation thereof. This application is a division of application No. 73,946, filed February 1, 1949, and now Patent No. 2,802,257, issued August 13, 1956.

In the formation of electrical connections it has been customary to enclose a wire-end in an electrically conducting metal ferrule to which a terminal lug or some other conducting member is or can be connected, or to enclose a plurality of wire ends in such a ferrule. In the recent past, it has been proven advantageous as shown in the patent of William S. Watts, No. 2,410,321, to enclose such a connector-ferrule in a sleeve or cylindrical shell of plastic insulating material, whereupon opposite sides of the assembly are pressed laterally toward each other and the metal ferrule is pressed into electrically conducting and mechanically strong connection with the conductor or conductors therein. The areas so compressed have been of various extents and have been in some cases directly opposite each other, e.g., as represented by the tool of the Carlson Patent No. 2,359,083, and in other cases staggered, as shown in the Macy application Serial No. 580,841, filed March 3, 1945, now Patent No. 2,639,754.

Connection assemblies covered with plastic insulation before compression onto electrical conductors and compressed in this fashion have not been completely "foolproof," and their use accordingly has been somewhat restricted. I have found that defects which occasionally develop in such pressure-crimped electrical connections, principally the weakening of the insulating sleeve as to dielectric breakdown, are due to localized extrusion or squeezing out of the plastic material of the insulating sleeves during the crimping operation, or to penetration of the insulation by projections or sharp edges on the ferrule or the crimping tool.

I have found further that if the improved crimping tool provided with a smoothly curved, laterally confined pressure-applying surface which is large enough and free from major irregularities and from sharp corners and projections throughout its extent, the squeezing-out action in the plastic is greatly reduced because surrounding material resists the plastic flow at each point under compression and thus leaves each point confined so as to transmit a maximum pressure inward toward the center of the connection.

I have found that the reliability of the insulation on the resulting connection is further increased, permitting application of greater crimping force without serious impairment of the insulation, if the walls at the longitudinal edges of the die surfaces over which the insulation extends recede from the die surfaces so abruptly as substantially to avoid their obliquely pressing against plastic extruded from under the die during crimping.

With the foregoing and other considerations in view, the invention has for an object the provision of an improved crimping tool which gives an electrical connection which is strong, durable, and of lasting high conductivity, which is effectively insulated against unintentional electrical contact and which further can be reliably formed with extreme ease and economy.

Another object is the provision of a tool which is simple of construction, which can be operated with ease, and which will reduce the distortion of insulation due to the crimping operation and obtain a high degree of insulation over the entire area of the crimp.

A further object is the provision of a crimping tool which will not damage the insulating sleeve during the crimping operation.

Other objects will in part become apparent from and will in part be pointed out in the following specification and the accompanying drawings, wherein I show and describe preferred embodiments of my invention. It is to be understood that these are not intended to be exhaustive nor limiting of the invention but, on the contrary, are given principally 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 accompanying drawings:

FIGURE 1 is a view in axial section of an electrical connector of the type having an insulating sleeve permanently secured on its ferrule;

FIGURE 2 is a sectional view on an axial plane perpendicular to that of FIGURE 1, of a connection made with the connector as shown in FIGURE 1 by compression onto an electrical conductor, or wire, with a tool made in accordance with this invention;

FIGURES 3 through 6 show diagrammatically, the successive stages in the compression of a connection assembly, FIGURE 6 being the final stage shown also in FIGURE 2, FIGURES 3 to 6 being on an enlarged scale partly in section taken at the line 6—6 in FIGURE 2;

FIGURE 7 is an isometric representation of a second embodiment of an electrical connection provided by a tool which is made in accordance with the present invention;

FIGURES 8 through 10 are axially-sectioned views on an axial section corresponding to that of FIGURE 2 but showing further embodiments of electrical connections provided by tools which are made in accordance with the present invention;

FIGURE 11 is an isometric view of die blocks of the type shown in FIGURES 2 through 6;

FIGURES 12 and 13 show two types of hand-operated tools having compression dies similar to those shown in FIGURE 11; and

As exemplified in FIGURE 2, disposed between crimping dies **37** and **38** there is provided an electrical connection comprising an electrical conductor **20** which in the present instance is in the form of an insulated wire, the end portion of which is exposed as at **22** and the main portion of which carries permanent insulation **24**, and an electrical connector of the type shown in FIGURE 1. The exposed portion of the wire **22** is assembled within the connector-ferrule **23**. Copper, especially soft copper, is well suited as the material for such a connector ferrule, since it will yield readily to pressure transmitted through an outer plastic sleeve **26**, but harder metals can be used in connections crimped in accordance with this invention.

The terminal connector shown in FIGURES 1 and 2 may be of a usual type e.g., formed by stamping or rolling to a cylindrical ferrule **25** one end of a sheet metal blank; leaving it integrally attached to a tongue portion **27**. If thus made from flat strips, all sharp edges should be removed, e.g., by tumbling or otherwise polishing. Seamless tubing or drawn seamless sleeves or thimbles are advantageous for this purpose because the drawing process lends itself well to production of a smooth ferrule free from sharp edges and projections. Or, one may use a combination of a ferrule made from flat stock and a thin seamless drawn sleeve e.g., as set forth in the application of Robert C. Swengel, Serial No. 523,004, filed February 19, 1944, and subsequently abandoned. The ferrule 25, and in this case the adjacent end of the insulation 24 on the wire, are enclosed in a sleeve 26 of insulating material such, for example, as one of the common insulating plastics, of which ethyl cellulose, polyethylene, vinylite (e.g., a copolymer of 97% vinyl chloride with 3% vinyl acetate), nylon, and vinylidene chloride polymers (Saran) are examples. The plastic is slightly plasticized (e.g., with known plasticizers) if necessary to give it the property of coldmolding in the dies without fracture.

The Patent No. 2,410,321, issued to William S. Watts, shows a plastic ferrule-insulating sleeve extended over the permanent insulation of an electrical conductor and crimped on said permanent insulation with a crimp presenting roughly the shape of a hexagonal prism or the frustrum of a hexagonal pyramid. The Carlson Patent No. 2,359,083 presents the pair of angular die surfaces which produce such a crimp of hexagonal cross-section.

The tool of the present invention is more perfectly adapted to the crimping of a plastic sleeve and, through it, an enclosed metal ferrule and at least one electrical wire or other conductor, with sufficient force to flow the metal and give a physically strong electrical connection of lasting high conductivity—this being done without seriously impairing the plastic insulation or seriously weakening its dielectric strength. Such improved tools are also advantageously used for crimping metal ferrules or sleeves without a surrounding plastic sleeve.

The assembly, in a band, or zone, of the ferrule 25, advantageously coextensive with the ferrule, is compressed in such a fashion that the ferrule 25 and the wire 22 are compacted into a joint which is approximately elliptical in cross-section and which provides a strong and permanent electrical connection. I have found advantage in forming to elliptical cross sections about 65% as thick as they are wide. Widths can be, however, from 1⅓ to 2 times the thickness for various applications. As will be seen from FIGURE 6, the metal of the ferrule 25 is pressed tightly onto the exposed portion of the conductor 22 by the dies 37 and 38 of the crimping tool of the present invention and the whole metallic assembly is effectively compacted into a more or less solid mass of metal. Compression of the metal components into a solid mass is advantageous, although lesser compression, which leaves some voids between the conductors, is satisfactory for many purposes for which this invention can be used.

With the use of this invention, the ferrule 25 remains strong and unbroken as also does the plastic sleeve 26. Similarly, the insulating material of the sleeve 26 is evenly distributed without any punctures or dangerously thin or weakened portions or other actual or potential weakness.

In the formation of electrical connections with a tool made in accordance with the invention, as shown in FIGS. 1–6, the conductor 20 has its exposed end 22 thrust into the ferrule 25. So far as the basic aspects of such connections are concerned, the ferrule may be extended over the insulation 24 on the wire 22 as in FIGURE 2, and for this, the outer end of the ferrule may even be of enlarged diameter to accept thicker wire insulation 24. Further, the conductor 20 may be any electrically conductive element adapted to be inserted into the ferrule 25.

The compacting or crimping of the assembly is done with die surfaces 35 and 36 which provide opposed smoothly curved cylindrical surfaces (i.e., the surface generated by a straight line, known as the "generatrix" moving along a smooth curve, known as the "directrix," while maintained parallel to a given axis) which are confined by side walls 40 during the crimping operation. Small deformations or deviations from true arcuate surfaces are permissible and are not excluded here. The pressure imposed by these surfaces 35 and 36 is transmitted through the sleeve 26 to the ferrule 25 and compacts the assembly, as shown in FIGURES 3 through 6, into a compacted electrical connection. The smooth continuity of these surfaces from side to side not only assures against substantial weakening of the insulation sleeve 26 but assures a proper transmission of pressure through it to the ferrule 25. Because of the especially uniform transmission of pressure to the ferrule by the crimping tool of the present invention, ferrules may be made of harder or thinner metal and a wider range of plastics, including somewhat softer plastics, can be used without danger of breakage, and likewise, ferrules with an unsecured butt seam can be effectively compressed without danger of opening at the seam. In referring to "smooth" continuity, "smoothly curved" or "smooth" contours it is to be understood that it is freedom from projections and abrupt corners and not surface texture which is in question. The surfaces 35 and 36 of the dies 37 and 38 may be smooth and burnished, but there is advantage in a rougher surface, e.g., as produced by acid etching or sand blasting the die faces.

While it is advantageous in certain instances that both side walls 40 be provided by the same die surface as exemplified, a construction wherein one side wall is on one die and another side wall is on another die, as shown in FIG. 7 of the Carlson Patent No. 2,359,083 and 2,359,084, for example, may readily be employed without departing from the invention in its broader aspects.

Directing attention to FIGURE 3, it is seen that a single pair of dies 37 and 38 include a U-shaped, concave die 37 which has a recessed working portion including straight parallel sides 40 connected by a smooth, arcuate crimping surface 35. The distance between the sides 40 form the chordal width of the arcuate surface 35. As noted in FIGURE 3, this chordal width is approximately equal to the width of the connector sleeve 26. The second die 38 comprises an indenting die which projects into the recessed portion of the first die. The indenting die has a width slightly less than the width of the sides 40 of the first die. The connecting portion 36 of the second die also comprises a smooth, arcuate crimping surface forming a concave section which is in opposition to the concave section of the die 37. The concave, arcuate surface of the second die 38 has a radius which is equal to the radius of the crimping surface of the die 37.

In accordance with the invention in certain of its more specific aspects, the shape of the die surfaces 35 and 36 is that of arcuate surface whose directrix (i.e. the curve presented by a cross section taken laterally) is a smooth curve. The directrix which has been discovered to be best for purposes of this invention in its most efficient aspects is one which has a radius of curvature at the center approximately equal to that of the periphery of the plastic sleeve 26 of the connection assembly to be crimped by the surfaces and its radius of curvature increasing toward the ends or side portions, so that, when the dies are moved together (FIGURES 3 through 6), they first contact the sleeve 26 with their central arcuate portions fitting the sleeve and applying pressure over a substantial central area of the sleeve. As the initial pressure flattens the connector to elliptical form, it meets and fits smoothly against the concave die faces 35 and 36 over a broadening area. Ordinarily, it is not necessary to have the radius of the central portion of the trough provided by these surfaces exactly fit the sleeve 26, because the initial pressure is relatively low. It is enough that it so closely approximates that of the sleeve as to fit it after initial flattening and before severe compression. Thus, the contact of the die surfaces with the sleeve is substantially uniform, and the initial pressure of the die surfaces on the sleeve is substantially uniform, so as to substantially avoid concentration of pressure which might damage the sleeve. In the form shown in the drawings, the die surfaces **35** and **36** have arcuate directrices whose radii are an average of the radii discussed above, a simplification which I have proven to be satisfactory. Specifically, in an advantageous case the ratio of the width of the die cavity to radius of curvature is 1.7. Other cases generally lie between 1.5 and 1.8.

The longitudinal dimension or length of the die surfaces **35** and **36** measured from end to end in the direction perpendicular to the plane presented in FIGURE 3, is advantageously not less than one quarter of an inch in extent, although shorter lengths as small as one-eighth of an inch can be used in special cases, and down to, but not less than, four times the average radial thickness of the insulating sleeve in the crimped band. Advantageously also, the length of the die surfaces, and consequently of the crimped band formed thereby, is not less than the length of the metal ferrule to be crimped. The lateral dimension or width of the die surfaces, that is the horizontal dimension of the area confined by the die surfaces between the side walls **40** as shown in FIGURE 3, is approximately the diameter of the connector assembly prior to crimping, although it should ordinarily be enough greater than this diameter to provide clearance for easy insertion of the connector assembly into the die.

In the operation shown in FIGURE 2, note that the crimping die surfaces **35** and **36** extend to the rear, i.e. away from the terminal tongue portion **27**, beyond the enclosed metal ferrule **25**. This is satisfactory, as long as the following requirement of the peripheral edge **28** of the metal ferrule **25** is met.

Both the inner metal ferrule **25** and the compressing die surfaces **35** and **36** may advantageously be slightly rounded at their longitudinally extreme edges **28** and **39**, respectively, i.e., to a slight radius, about .005 to .020 inch being considered appropriate for this radius. If either edge **28** of the metal ferrule, such as sometimes is the case with the edge adjacent the tongue portion, is not enclosed between the die surfaces during crimping, such an edge need not be rounded off. However, if very sharp metal edges engage the plastic in the area in which it is compressed, such edges may cause a serious reduction in the dielectric strength of the plastic sleeve.

While it is ordinarily more convenient to leave the ends of the dies open so that some longitudinal extrusion of the plastic is permitted, a further improvement, and a still further increase in the range of plastic materials which can be used, results from extending the die (or an end member cooperating with the die) inward over the end of the ferrule **25** and having the insulation sleeve **26** substantially abut this overhanging portion of the die, so that endwise extrusion is confined.

It should be noticed that the areas of metal which bear on the plastic sleeve with the full pressure of the crimping operation have no chamfered or gradually rounded edges which would press obliquely on the plastic extruded from beneath the dies during crimping. As mentioned previously, I have found that the walls at the unenclosed, or longitudinally extreme edges **39**, FIGURES 2 and 11, of the die surfaces **35** and **36** may advantageously recede sharply from these plastic-engaging surfaces to get the best crimping characteristics, and ferrule edges **28** which engage the area of plastic crimped may also advantageously recede sharply. These edges should have only the slight radius discussed in the second preceding paragraph. Enclosed or side edges **42** of the die surface **36** would best be so perfectly fitted that the crimping surface **36** forms a smooth curve with the side walls **40** and thus with the opposed crimping surface **35**. In practice, these edges are not left sharp, but are slightly blunted or rounded to prevent their being easily damaged. There is, however, advantage if the die is made of a high-stiffness, fatigue-resistant metal like beryllium bronze, in sharpening these die edges to a feather edge which can flex when they pass beyond the point where the die cavity curves inward. This will give some lateral compression and thereby also facilitates removal of the crimped connection from the die.

In FIGURE 7 we have an electrical connection, of the terminal plug type, in which both a hexagonal insulation-gripping crimp, shown generally at **44**, and the subject crimp (i.e., made with a tool embodying the present invention) shown generally at **30**, are used, each for the purpose to which it is best suited. The hexagonal-section crimp **44** is used to compress the extended plastic sleeve **26** onto the insulation **24** of an electrical conductor **20**, and the crimp **30**, as shown in detail in FIGURES 2 through 6, is used to compress the metal ferrule and wire into a joint without damaging the surrounding plastic sleeve. Both of these crimps **30** and **44** can advantageously be applied simultaneously by a single pair of dies, or by adjoining dies operated as a unit.

FIGURES 8, 9 and 10 show three additional connections in which the insulation sleeves **26** substantially enclose the entire areas of the metallic components. These embodiments have the common function of connecting two or more insulated electrical conductors or wires **20** by compressing previously insulated connector ferrules **25** onto the bared or exposed ends **22** of the wires in the manner shown in FIGURES 3–6, and shown generally here as **30**. These are frequently referred to as Butt (FIGURE 8), Parallel (FIGURE 9), and End or Acorn (FIGURE 10) -connectors.

In FIGURE 8 wire ends **22** are brought end-to-end within an elongated metal ferrule **25*b*** previously enclosed in a plastic sleeve **26*b*** as described, and the assembly is crimped at **30** twice, that is, adjacent the exposed or bared portion **22** of each wire **20**. The subject crimp shown in FIGURES 2–6 could be used for compressing a sleeve on wire-insulation, though the hexagonally shaped crimp (FIGURE 8) has been preferred for such purposes.

The connection shown in FIGURE 9 is quite similar to the butt connection shown in FIGURE 8. Here, however, the two bared conductors **22** are side by side in lhe metal ferrule **25*c*** which, of course, may be shorter than the ferrule used in a butt connection, and the assembly **30** crimped with cylindrically-surfaced dies as shown in FIGURE 3.

The end or "Acorn" connection shown in FIGURE 10 is preferred for many applications. Here the wires are laid side by side as in FIGURE 9. The plastic sleeves **26*d*** on such connections are closed at one end **32** and are usually expanded as at **29**, to incorporate the insulation of both wires **24**.

Returning to the crimping dies, FIGURE 11 shows clearly the spatial relationships between the two die surfaces, **35** and **36**, the side walls **40**, and their supporting structure **38** and **37**. The side walls are so spaced that a connection assembly can be inserted between them easily. These side walls **40**, of course, may be in any operational relationship with the die surfaces **35** and **36** which enables said side walls to laterally confine the die surfaces and an enclosed connection assembly during the crimping operation. Most advantageously the side walls **40** are integral as shown with one die portion **37** or **38** but one side wall may be integral with each die as in the Carlson patent cited above, or both side walls may be on a third die member with the concave dies operating in its groove or bore, or each side wall may be on a separate die member. The surfaces **35** and **36** meet end walls **55** and **56** with the previously discussed slight radius at the edges **39**.

In crimping with dies of the form shown in FIGURE 11, the side edges **42** of the upper die **38** usually leave thin longitudinal lines in the crimped surface, and the side walls **40** leave flat sides in small portions of the otherwise smoothly curved crimped area. I have found that such minor discrepancies do not materially detract from the generally elliptically-shaped confined crimp.

Pressure-crimping dies constructed in accordance with the invention may be embodied in a wide variety of crimping tools. In FIGURE 12, the die **37e** provides the surface **35e** between walls **40e**. The channel formed by the walls **40e** receives die surface **36e** which is located on a projection of die **38e** which fits snugly between the walls **40e**. The die **37e** is dependent from a head **46**, and the die **38e** is carried on a toggle linkage as shown and is slidable within this head to operate the die **38e** with parallel action for moving the dies **37e** and **38e** relatively to each other in order to provide the crimping cycle as shown in FIGURES 3 through 6. The tool linkage enables this cycle to be performed by means of closing the handles **47** together.

Another form of construction is shown in FIGURE 13. Here the die **37f** is located on a jaw **48**, and the die **38f** is located on a similar jaw **48f**; the jaws **48** and **48f** being pivoted at **49** on lever arms **47f** which are mutually pivoted at **50**. A link **51** connects the jaws at pivot points **52** to complete a linking which enables approximately parallel action of the jaws.

A particularly gentle and uniformly distributed pressure may be applied when rubber or other resiliently fluid cushion is provided on the pressure-crimping surfaces. In this manner the sleeve **26** to be crimped is protected, and a softer plastic insulating sleeve can be used, if desired. Particularly effective results are secured when the rubber is concentrated away from the center lines of the recesses.

I claim:

1. A tool for crimping ferrule-type electrical connectors onto conductors including: a pair of jaws, means for urging said jaws toward and away from each other, a single pair of cooperable dies, one of said dies disposed on each of said jaws, the first die comprised of a U-shaped, recessed working portion having straight parallel sides connected by a section at the bottom of said sides having a smooth, arcuate crimping surface joining said sides and facing concave upwardly, the distance between the sides or the chordal width of said arcuate surface being substantially equal to the width of the connector, the second die projecting into the first die and having straight sides having a width slightly less than the distance between the sides of the first die, and a connecting portion joining the sides at the bottom of said sides and having a smooth, arcuate crimping surfaces joining said sides and facing concave downwardly, said concave arcuate surface having a radius equal to the radius of the first crimping surface with the arcuate crimping surfaces opposed to each other.

2. The device of claim 1 wherein the ratio of said distance between said sides to the radius of curvature of said crimping surfaces is approximately 1.7 to 1.8.

References Cited in the file of this patent

UNITED STATES PATENTS

308,087	McDonald	Nov. 18, 1884
2,359,083	Carlson	Sept. 26, 1944
2,359,084	Carlson	Sept. 26, 1944
2,639,754	Macy	May 26, 1953

FOREIGN PATENTS

359,800	France	Apr. 4, 1906

OTHER REFERENCES

Reprint of an article entitled "Solderless-Type Wire Terminals," by T. C. Freedom, in the May 1949 issue of Electrical Manufacturing, copyrighted 1949, by the Gage Pub. Co.