Nov. 30, 1965 L. E. ROBERTS 3,221,294

CRIMPED ELECTRICAL CONNECTIONS

Filed May 3, 1963 3 Sheets-Sheet 1

Fig. 1

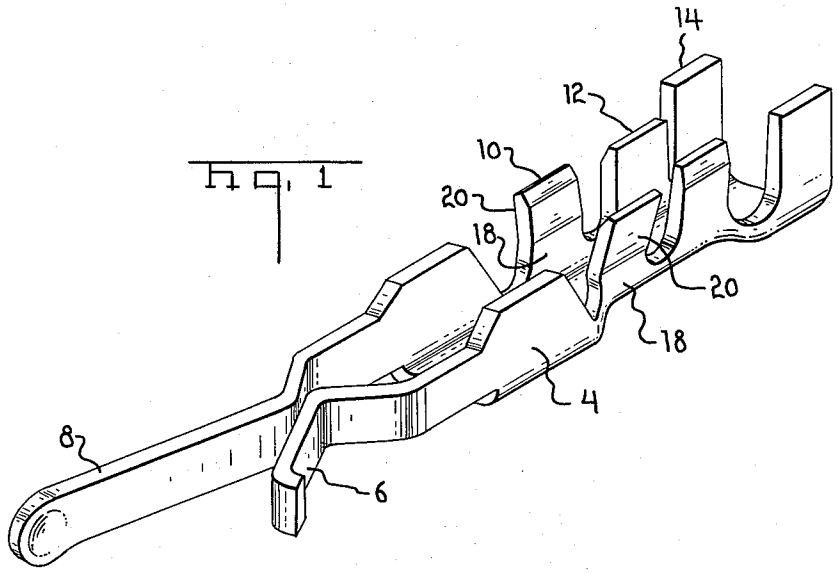
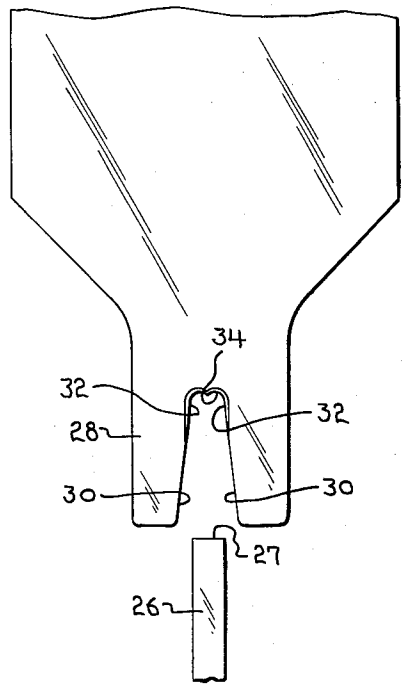


Fig. 2



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CRIMPED ELECTRICAL CONNECTIONS

Filed May 3, 1963 3 Sheets-Sheet 2

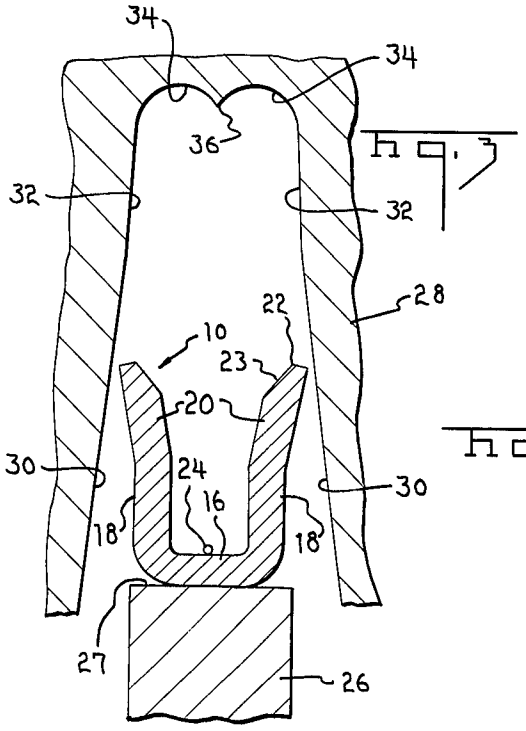

Fig. 3

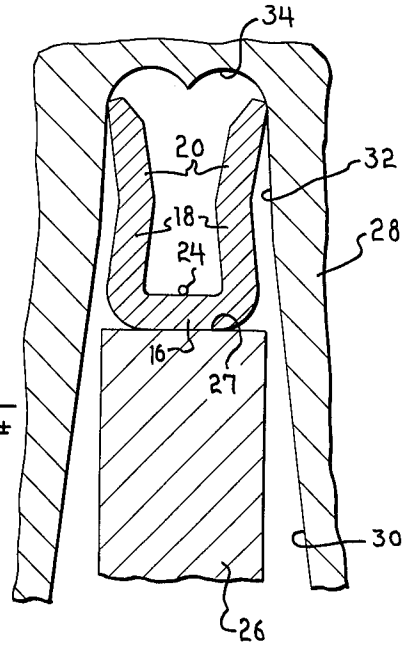

Fig. 4

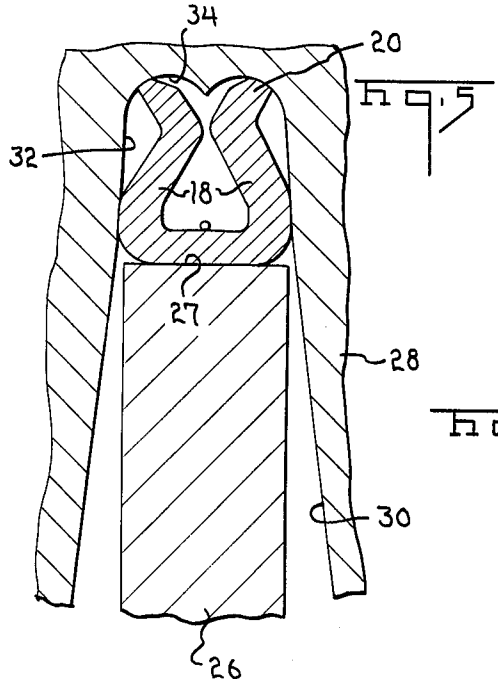

Fig. 5

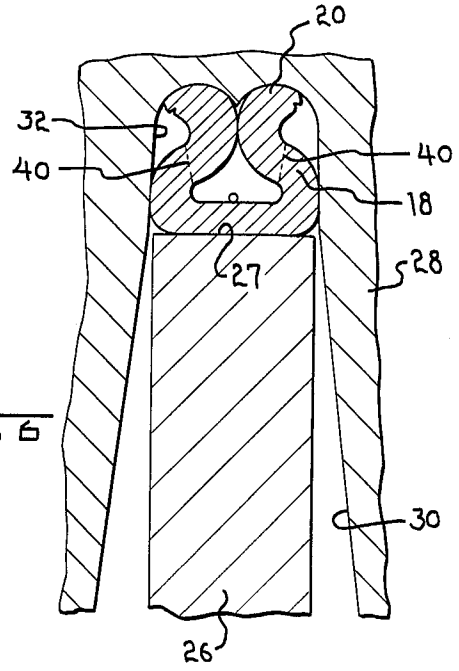

Fig. 6

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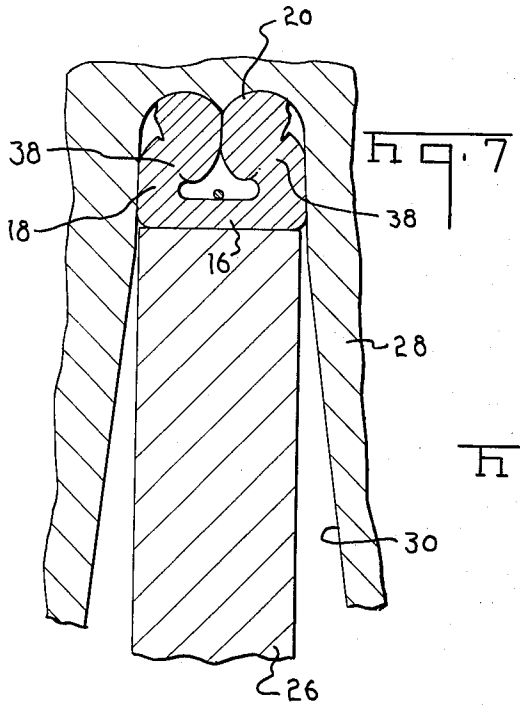

Fig. 7

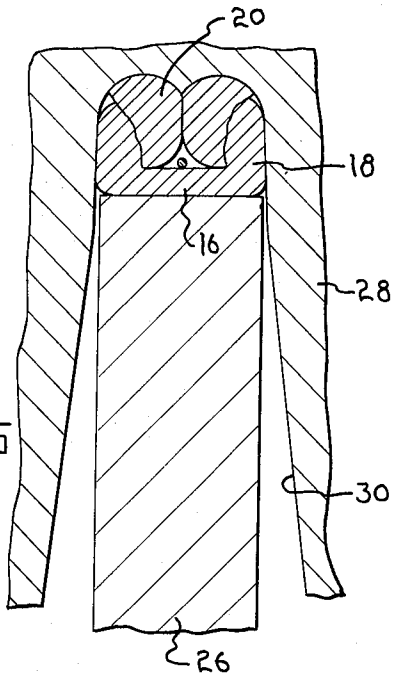

Fig. 8

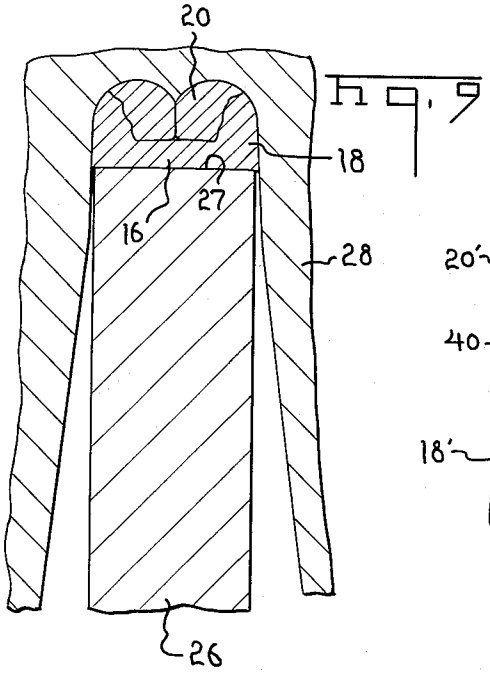

Fig. 9

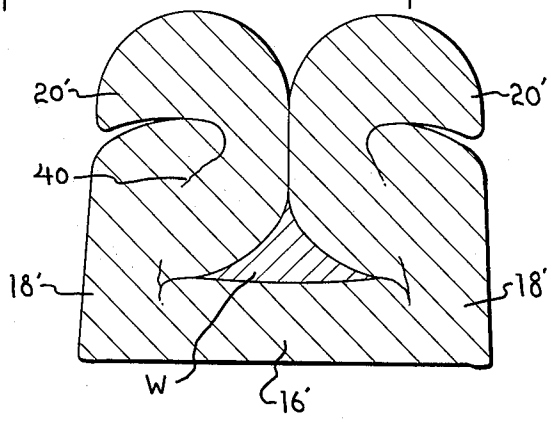

Fig. 10

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3,221,294

CRIMPED ELECTRICAL CONNECTIONS

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Filed May 3, 1963, Ser. No. 277,749
5 Claims. (Cl. 339—276)

This invention relates to crimped electrical connections of the type in which an initially channel-shaped section of a contact terminal is crimped onto a wire.

A common type of crimped electrical connection between a terminal and a wire is made by providing a channel-shaped or open-U ferrule on the terminal, positioning the wire between the sidewalls of the ferrule, and curling these sidewalls towards each other and downwardly towards the web of the ferrule. This type of crimped connection has received a wide acceptance in the art for the reason that the open-U type ferrule can be easily formed by conventional die stamping and forming methods and it therefore lends itself to inexpensive manufacturing techniques. An additional advantage of this type of connection is that the wire can be positioned in the channel-shaped ferrule with relative ease.

The previously known methods of crimping open-U type ferrules are intended for usage where the wire size and the ferrule size are reasonably closely matched so that when the sidewalls of the channel-shaped section are curled towards each other and towards the web of the open-U type ferrule, they will be formed around, and will tightly embrace, the wire. This known method of crimping open-U type ferrules also requires that the hardness or formability of the metal stock from which the terminal is manufactured be such that the curling operation on the sidewalls can be effectively carried out; in other words, if the metal of the channel-shaped section were unduly stiff and hard, it would be impractical, if not impossible, to curl the sidewalls to form the crimp.

There are circumstances where it is desirable to form the contract terminal of an extremely hard and stiff stock metal in order to obtain the properties (e.g. stiffness and tensile strength) of such hard metals in the contact portion of the contact terminal. There are also circumstances where it is desirable to crimp a contact terminal having an open-U type ferrule onto a wire which has an extremely small diameter relative to the size of the ferrule; this situation arises, for example, where a contact terminal of a given relatively large size must be used in order to mate the terminal with a complementary contact terminal although an extremely small wire must be crimped onto the terminal. Where either of the foregoing conditions arise, the known method of crimping open-U type ferrules is not entirely satisfactory.

It is an object of the present invention to provide an improved crimped connection between an open-U type ferrule and a wire. A further object is to provide a crimped connection between an open-U type ferrule and a wire which has an extremely small diameter relative to the cross sectional dimensions of the ferrule. A further object is to provide a crimped connection, and a method of crimping, for open-U type ferrules which is amenable to usage with extremely hard and therefore non-formable metals. A still further object of the invention is to provide a crimped electrical connection and method for open-U type ferrules which permits a wide variation in the size of the wire for a fixed ferrule size.

These and other objects of the invention are achieved in a prefered embodiment in which the wire is positioned on the web and between the sidewalls of the ferrule. A compressive force is applied to each of the sidewalls at their upper edges. Since the sidewalls are relatively thin, with relation to their height, they behave in the same

manner as a compressively loaded column and buckle. The compressive loading and the buckling of the sidewalls is controlled in a manner such that they buckle inwardly and towards each other until their opposed sides come into engagement with each other along a line extending parallel to the axis of the ferrule. Thereafter, compressive loading is continued and the external surfaces of the sidewalls are supported and confined in a manner which results in a displacement of the upper portions of the sidewalls relatively towards the ferrule web. Under some circumstances, the sidewalls will be fractured along shear planes in the sidewalls extending parallel to the ferrule axis. Under other circumstances, the upper portions of the sidewalls will be displaced relatively downwardly towards the web although these upper portions will not be fractured during such displacement. Fracture of the sidewalls will occur or not depending upon the size of the wire, the relative hardness (and therefore the ductility) of the connector ferrule, and the thickness of the metal stock from which the ferrule is made.

In the final crimped connection the displaced sections of the sidewalls are contained between lower portions of the sidewalls which are adjacent to the web. The displaced sections additionally have their upper ends curled over the portions of the sidewalls which are adjacent to the web so that the parts are all tightly compacted and held together with the wire disposed between the opposed sides of the displaced sidewall sections. The invention thus avoids the extreme degree of curling of the sidewalls, which would be imposed with very hard metal and permits the crimping of extremely fine wires to the contact terminal by virtue of the fact that most of the area within the ferrule is occupied by the severed sections of the sidewalls.

In the drawing:

FIGURE 1 is a plan view of one form of contact terminal having an open-U type ferrule which is adapted to be crimped in accordance with the principles of the invention.

FIGURE 2 is a frontal view of a crimping die and anvil for forming a crimped connection in accordance with the invention.

FIGURES 3–9 are fragmentary views illustrating the manner in which the sidewalls are deformed and fractured during the formation of a crimped connection in accordance with the invention.

FIGURE 10 is a cross-sectional view of a crimped connection in accordance with the invention in which the wire has a relatively larger cross section than in the embodiment of FIGURES 3–9.

FIGURE 1 shows a type of contact terminal which is more fully described in my co-pending application Serial Number 183,542, filed March 29, 1962, and now abandoned. This type of contact terminal has an intermediate channel-shaped section **4** from which a pair of arms **6** and **8** extend, these arms being formed in a manner such that contact terminals of this type are matable with identical terminals as fully explained in my above-mentioned co-pending application. Rearwardly of the channel-shaped section **4**, there are provided a series of three separate channel-shaped sections **10**, **12**, **14**. The channel-shaped section **10** constitutes a ferrule forming portion which is adapted to be crimped onto a wire core. The channel-shaped section **12** is intended for crimping onto the insulation of the wire and the section **14** functions as a stabilizing device for retaining the contact against undue lateral movement after the contact has been inserted into an insulating block. My above-mentioned co-pending application shows the ferrule portion **10** as being crimped onto the wire in the manner known to the prior art, that is by curling of the sidewalls relatively towards each other and

towards the web while the section **12** is shown as being conventionally crimped onto the insulation of the wire. In the description which follows immediately below however, the ferrule portion **10** is crimped onto an extremely fine wire in accordance with the principles of the present invention and the insulation crimp **12** is not utilized.

As shown in FIGURE 3, the ferrule portion **10** comprises a web **16** having sidewalls extending upwardly from its longitudinal sides. The portions of the sidewalls **18** which are adjacent to the web **16** extend substantially parallel to each other and normally of the plane of the web **16** while the sidewall portions **20** which are remote from the web diverge slightly. The cross-sectional shape of ferrule portion **10** differs from that shown in application, Serial Number 183,542, particularly with regard to the divergent remote sidewall sections **20**. Advantageously, the upper edges **22** of the sidewalls are slightly chamfered on their inner sides as shown at **23**. A fine wire **24** to which the ferrule is to be crimped is positioned between the sidewalls and on the web. FIGURE 3 shows the approximate size of the wire with relation to the size of the ferrule where the invention is being practiced for purposes of forming a crimped connection between an extremely small wire (e.g. A.W.G. 40) and a ferrule which is grossly oversized with relation to the wire.

The crimped connection is formed with an anvil **26** and a crimping die **28** movable towards and away from the anvil. This anvil and die will ordinarily be mounted in a conventional bench press or a hand tool. Anvil **26** has an upper surface **27** on which the web of the ferrule is supported during crimping. The anvil is adapted to be received within a recess in the die **28** as the parts move relatively towards each other. This recess in the crimping die has inwardly convergent forming surfaces **30** which merge with forming surfaces **32** adjacent to the upper end of the recess. The surfaces **32** converge silghtly and in turn merge with semi-circular curved surfaces **34** on each side of the center line of the recess. These curved surfaces **34** are symmetrical about the center line and intersect each other to form a central cusp **36**.

When it is desired to form a crimped connection, the wire ferrule is positioned on the anvil surface **27** and the wire is positioned on the web **16** and between the sidewalls as shown in FIGURE 3. The crimping die **28** is thereafter moved relatively towards the anvil **26** until the surface portions **30** of the die recess engage the outside edges of the upper sidewall portions **20**. As the crimping die moves relatively downwardly from the position of FIGURE 3 to the position of FIGURE 4, the surface portions **30** and later the surface portions **32** of the die recess bend the sidewalls towards each other. The sidewalls each bend as a unit during this point of the crimping cycle until the remote sidewall portions **20** extend substantially parallel to each other and the adjacent sidewall portions **18** extend slightly convergently towards each other. As the crimping die moves further downwardly, the surfaces **34** engage the upper ends of remote sidewall portions **20** and further bend the sidewalls inwardly until the remote sidewall portions are slightly divergent as shown in FIGURE 5 and the sidewall edges bear against the center portions of the surfaces **34**.

At this stage, the sidewalls will be under a substantially vertical compressive load (as viewed in the drawing) which will be applied on the outside edge portions of the upper ends of the sidewalls, that is beside the chamfered portions **23**. The sidewalls do not bend about their lower ends beyond the position of FIGURE 5 for the reason that they are being compressed by a vertical load without a substantial horizontal component. The sidewalls buckle after the stage shown in FIGURE 5 has been reached until the cross section of the ferrule is as shown in FIGURE 6 with opposed internal surfaces of the remote sidewall portions bearing against each other and with the external surfaces of the adjacent sidewall portions bearing against the surfaces **32** of the die recess. The compressive loading which causes the buckling also causes an increase in the thickness of the metal stock as is indicated in FIGURE 6. After the die has moved relative to the anvil to the position shown in FIGURE 6, the cusp of the forming surface of the die will be disposed between the opposed surfaces of sidewall portions **20** and the upper edges of these sidewall portions will have been deformed to conform to the curvature of the surfaces **34** of the die.

After the cross section of the ferrule has been deformed as shown in FIGURE 6, it is apparent that an extremely rigid system will have been established because of the confinement of the sidewalls by die surfaces **32**. It follows that further downward movement of the crimping die from the position of this figure will be resisted by the buckled and confined ferrule and will result in the imposition of extremely high stresses in the planes generally indicated at **40** which extend substantially parallel to, or slightly obliquely of, the direction of movement of the crimping die and approximately between the remote and adjacent portions of the sidewalls. The extremely high stress concentration in the planes **40** causes the sidewalls to fail in shear as shown at **38** (FIGURE 7) along fracture planes which approximately separate the remote and adjacent portions of the sidewalls. The two remote sidewall portions are then displaced downwardly as shown in FIGURE 8 until they move against the surface of the web **16** on each side of the wire. The term "displaced" as used above is intended to imply that the remote sidewall portions are moved as units downwardly against the surface of the web **16**. These remote sidewall portions do not lose their identity during the process. The upper longitudinal edges of the remote portions **20** will assume a surface configuration corresponding to the curvature of the surfaces **34**. The final increment of downward movement of the crimping die relative to the anvil compacts the severed remote sidewall portions between the remaining integral sidewall portions **18** and compresses the entire system until the opposed sides of the remote portions **20** compressively confine the wire against the web surface **16**.

The finished crimped connection has been found to possess a high degree of stability against relaxation for the reason that the severed sidewall sections **20** are rigidly held between the adjacent sidewall sections **18** and the wire, in turn, is held between the sides of the remote sections **20**. FIGURE 9 clearly shows that the cross-sectional area of the wire is extremely small as compared to the cross-sectional area of the entire crimped connection however, because of the high degree of compacting the wire is tightly held in the crimp.

It will be noted from FIGURES 8 and 9 that a substantially triangular opening extends centrally through the crimp which is defined by the sides of the sidewall portions **20** and by the web and that the wire is deformed until it assumes a cross-sectional shape corresponding to this triangular opening. It has been found that this triangular cross-section is ordinarily obtained although its size will vary when the wire size is changed; that is the larger the wire, the larger the triangular space.

FIGURES 3–9 assume that the wire was centrally positioned by the operator on the web and remained so located during the crimping process. In practice, the wire will not always be centered by the operator however, as the severed remote sidewall portions move through the positions of FIGURES 7–9, they will push the wire rightwardly or leftwardly until it is centered during the final stages of the crimping operation.

The principles of the invention are also applicable to the crimping of open-U type ferrules where the wire has a cross-sectional area which is more closely matched to the size of the ferrule. FIGURE 10 shows a cross-section of a crimped connection in accordance with the invention where a relatively larger wire is involved. In this embodiment, it can be seen that the remote portions **20'** of the sidewalls were displaced towards the web along the

shear planes 40' so that remote portions are, as in the previously described embodiment, contained between the opposed faces of the adjacent portions 18'. The embodiment of FIGURE 10, however, differs from the previously described embodiment of the invention in that fracturing did not take place along the shear planes 40' although it is apparent that there was a substantial displacement of the remote portions of the sidewalls along these planes. Fracture did not take place in the embodiment of FIGURE 10 for the reason that the relatively large wire W' became compressed between the opposed faces of the remote portions 20' and prevented further downward displacement of the remote portions before complete shearing has taken place. It is thus apparent that shearing along the planes 40 or 40' may or may not take place depending upon the size of the wire relative to the size of the ferrule and the hardness or ductility of the metal.

It will be noted that the upper ends of the adjacent sidewall portions 18' in FIGURE 10 are inwardly directed towards each other and overlie the lower portions of the remote sidewall portions 20'. This configuration is probably a result of the presence of the relatively large wire W' during movement of the remote sidewall portions towards the web 16'. The large wire deflects the remote sidewall portions during their downward displacement so that the upper ends of the adjacent sidewall portions can be bent relatively towards each other.

It will be apparent from the drawing that in both embodiments, the remote sidewall portions and the adjacent sidewall portions extend generally normally from the plane of the web 16 and that these remote sidewall portions and adjacent portions extend generally parallel to each other.

A salient advantage of the invention is that it permits a relatively large channel-shaped ferrule to be crimped onto an extremely small wire since a substantial portion of a crimp cross-section is occupied by the severed sidewall sections 20. An additional feature of the invention is that it does not require an extremely high degree of bending of the ferrule but rather relies upon limited bending of the ferrule sidewalls coupled with the fracturing step illustrated in FIGURE 7 and the utilization of the fractured or displaced portions of the sidewall to confine the wire. This feature of the invention permits the crimping of ferrules made of extremely hard materials which would not be capable of being bent and formed in accordance with previously known methods of crimping.

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

I claim:

1. A crimped electrical connection between a wire and a ferrule portion of a terminal, said ferrule portion having been substantially U-shaped in cross-section and having comprised a web with upstanding sidewalls on two opposite sides thereof prior to crimping, each of said sidewalls having comprised an adjacent portion and a remote portion with respect to said web, said remote portions having been displaced as units during crimping towards said web and being at least partially telescopically disposed between the opposed faces of said adjacent portions, the planes of said remote portions in said crimped connection extending beside the planes of said adjacent portions and the planes of said remote and adjacent portions extending substantially normally of the plane of said web, said wire being confined by the opposed faces of said remote portions and said web.

2. A crimped electrical connection as set forth in claim 1 wherein said ferrule portion is of a material susceptible to fracture, said remote portions have been fractured from said adjacent portions during crimping.

3. A crimped electrical connection as set forth in claim 1 wherein said remote portions are integral with said adjacent portions.

4. The method of forming a crimped electrical connection between a wire and an open-U type ferrule having a web and upstanding sidewalls on two opposite sides thereof, said method comprising the steps of positioning said wire on said web, applying a compressive load to said sidewalls at their upper ends and thereby buckling said sidewalls until the opposed faces of said sidewalls are in engagement with each other at their upper ends, supporting the external surfaces of said sidewalls at their lower ends adjacent to said web, increasing said compressive load thereby to displace the portions of said sidewalls which are remote from said web as units towards said web until said remote sidewall portions are partially contained between the portions of said sidewalls which are adjacent to said web and are on opposite sides of said wire, said remote and adjacent sidewall portions extending generally normally of said web after displacement of said remote sidewall portion, and compressing the upper ends of said remote sidewall portions against said adjacent sidewall portions.

5. The method as set forth in claim 4 wherein said ferrule is of a material susceptible to fracture, said method including the step of fully severing said remote sidewall portions from said adjacent sidewall portions during displacement towards said web.

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JOSEPH D. SEERS, *Primary Examiner.*