Dec. 13, 1966 P. F. VAN DYKE 3,291,895

COAXIAL CABLE CONNECTORS

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Fig. 1.

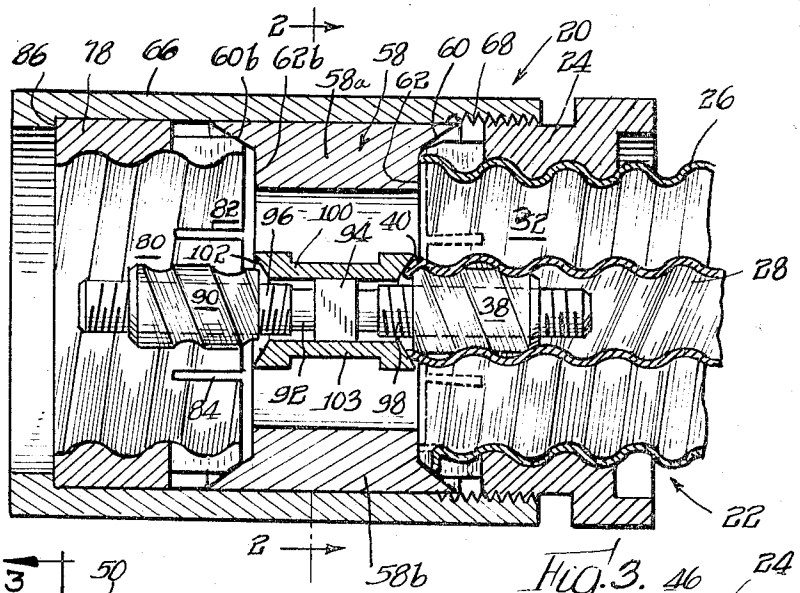


Fig. 2.

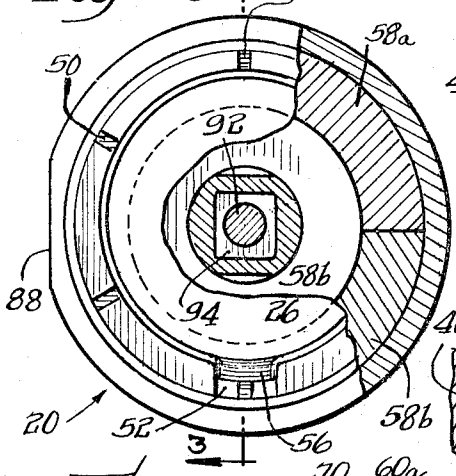


Fig. 7a

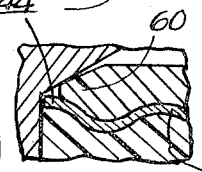


Fig. 7b

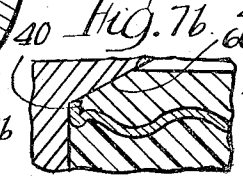


Fig. 3.

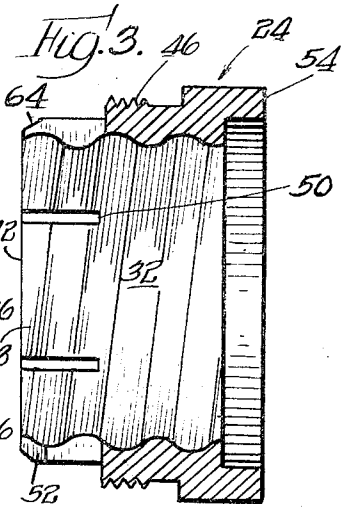


Fig. 4.

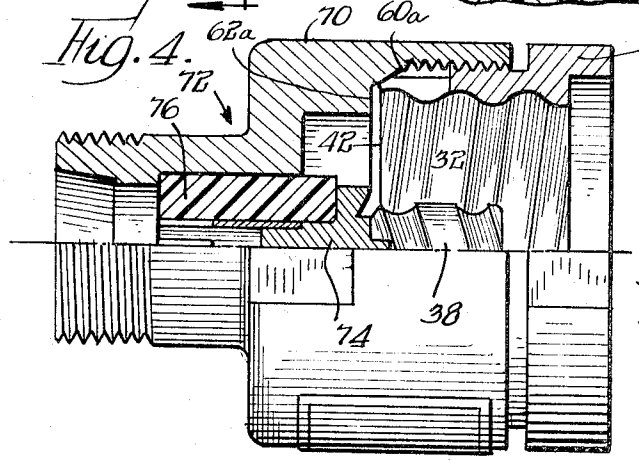
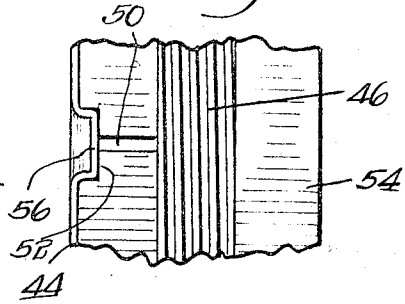


Fig. 5.



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Fig. 6.

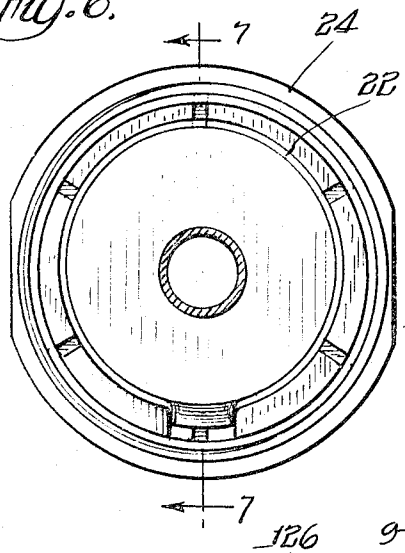


Fig. 7.

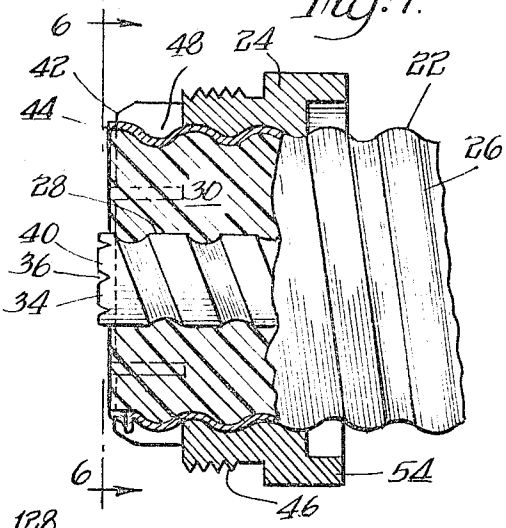


Fig. 8.

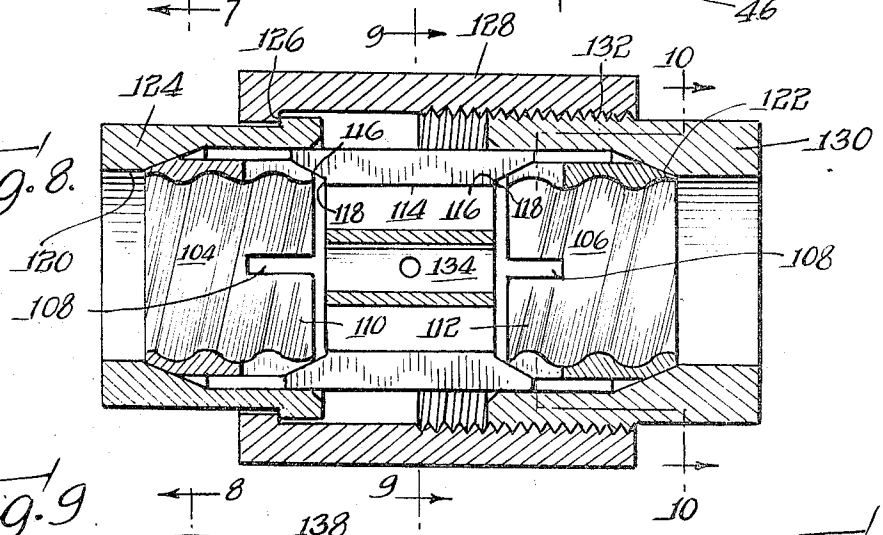


Fig. 9

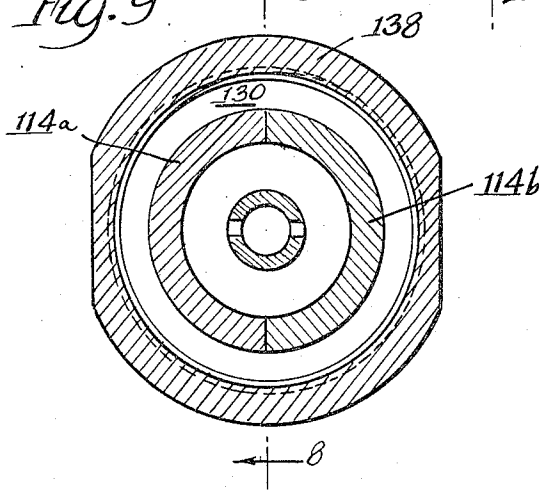
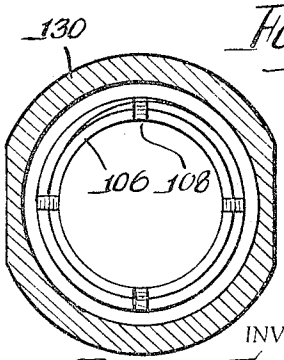


Fig. 10.



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Fig. 11.

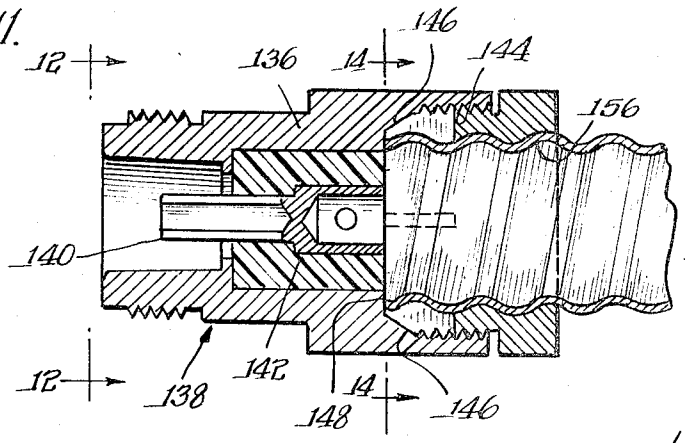


Fig. 12.

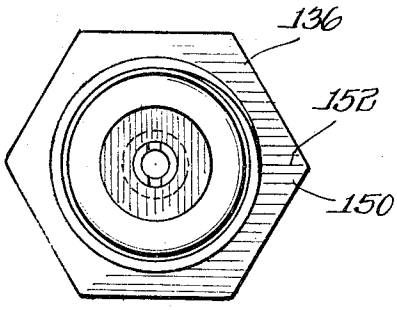


Fig. 13.

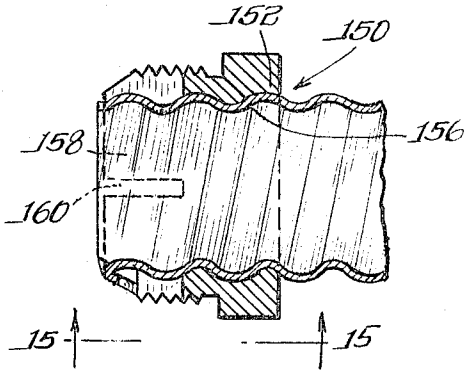


Fig. 14.

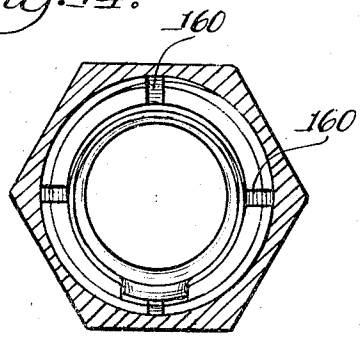
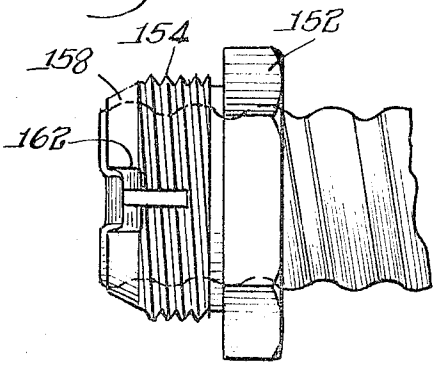


Fig. 15.



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COAXIAL CABLE CONNECTORS

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Filed May 5, 1964, Ser. No. 364,940
13 Claims. (Cl. 174—88)

This invention relates to connectors for coaxial cable, and more specifically to connectors for cables of the low-dielectric-constant type employing an outer conductor in the form of a more or less solid tube, and even more particularly of the type in which the outer conductor is helically corrugated.

There have in recent years become available various forms of coaxial cable having electrical properties, particularly dielectric constant, approaching that of so-called "air dielectric" rigid coaxial lines, while having flexibility and other convenience characteristics generally associated with solid-dielectric cables. In general, these low-loss high-frequency cables employ in the interelectrode region a suitable plastic (polyethylene being frequently used for the purpose) in a non-solid disposition producing occupation of a more or less large part of the dielectric region by air or gas, while at the same time maintaining the proper positioning of the inner and outer conductors. In more expensive and refined constructions, the insulating material may be in the form of a helical cord or tape preserving the spacing, while a much less expensive form of this general type of cable uses a foamed or cellular plastic dielectric.

The most desirable forms of these cables employ substantially solid impervious outer conductors of reasonable thickness, preferably helically corrugated for flexibility. One limitation or drawback which has appeared as the cables themselves have become available in quantities and at costs rendering them otherwise competitive with older types of cable has been the relative lack of simplicity of the coaxial cable connectors suitable for use with these new cables. The full utilization of the electrical characteristics of low-dielectric-loss cables requires that the connectors be of high precision as regards freedom from noise, maintenance of constancy of characteristic impedance, and similar characteristics matching those of the cable itself. At the same time, it is obviously undesirable that the connectors be of high complexity and cost, as compared with the connectors which have been developed over a period of numerous decades for solid-dielectric cables. In general, the constructions used for solid-dielectric cable, and particularly the types used for the popular types of cable employing mesh and similar outer conductors, are unsuitable for use with the new types of cable.

It is of course an additional requirement for any fully suitable connector construction that it be capable of simple installation on the end of the cable, without the necessity of precision measurements, etc., or special tools not available in the field. Again, of course, this must be accomplished without either impairing the precision of the overall assembly, or adding largely to the cost.

It is the object of the present invention to provide a cable connector construction which fully meets all of the requirements just discussed. This object has been accomplished in a manner to be described in connection with the embodiments of the invention shown in the drawing. The general teachings of the invention are applicable to a large variety of types of connectors. As is well known, a large variety of cable connectors are generally made for use with any given type of cable, varying widely as to details of terminal or mating construction, electrical (impedance matching or transformation, etc.) and mechanical (male or female, panel-mounting, swivel, etc.).

The present invention is useful with any type of such connector, these differences being of little consequence as regards the joint between the cable and the connector itself. However, an exception lies in the case of the splice connector, where other aspects of the present invention are of peculiar utility.

Both the general and the specific nature of the manner in which the present invention has solved the problems of providing such connectors are best understood from the description of the embodiments illustrated in the drawing.

In the drawing:

FIGURE 1 is a view in longitudinal section of a coaxial splice connector made in accordance with the invention, fragmentarily illustrating the conductors of the end of a cable thereto attached;

FIGURE 2 is a view partially in section taken along the line **2—2** of FIGURE 1 and partially broken away to show in elevation a clamping member made in accordance with the invention;

FIGURE 3 is a longitudinal sectional view of the clamping member of FIGURE 2 taken along the line **3—3** of that figure;

FIGURE 4 is a view partly in elevation and partly in longitudinal section showing a reducing coupler or connector employing a construction partially the same as that of FIGURE 1;

FIGURE 5 is a fragmentary detail view in bottom elevation showing the manner in which the cable outer conductor and the clamping member are rotationally locked in the embodiments thus far mentioned;

FIGURE 6 is a view in end elevation illustrating a step in the installing of a connector upon a cable;

FIGURE 7 is a view in longitudinal section taken along the line **7—7** of FIGURE 6;

FIGURE 7*a* is a more or less schematic enlarged view illustrating the location of the parts prior to completion of the assembly by tightening;

FIGURE 7*b* is a view similar to FIGURE 7*a* but showing (more or less schematically) the manner in which the mechanical and electrical connections are accurately formed by the final tightening in assembly;

FIGURE 8 is a view in longitudinal section of another splice connector embodiment of the invention;

FIGURE 9 is a transverse sectional view taken along the line **9—9** of FIGURE 8;

FIGURE 10 is a tranverse sectional view taken along the offset line **10—10** of FIGURE 8;

FIGURE 11 is a longitudinal sectional view of a further connector embodying the invention;

FIGURE 12 is an end view in elevation of the connector of FIGURE 11;

FIGURE 13 is a longitudinal sectional view of a clamping member constituting a part of the embodiment of FIGURES 11 and 12;

FIGURE 14 is a transverse sectional view taken along the line **14—14** of FIGURE 11; and

FIGURE 15 is a view in elevation of the clamping member as assembled with the end of a cable (center conductor omitted for clarity of illustration).

In FIGURE 1 there is shown a coaxial splice connector **20** employed for joining a coaxial cable **22** with another identical cable (omitted from the illustration to permit readiness of recognition of cable parts and connector parts).

The end of the cable is surrounded by a clamping nut **24** on the outer conductor **26** of the cable. The inner conductor **28** is insulatedly supported in the outer conductor by the dielectric **30** (shown only in FIGURE 7), such as foam polyethylene. Both the inner and outer conductors **26** and **28** are in this instance in the form of helically corrugated tubes. It will readily be

recognized by those skilled in the art that this hollow or tubular center-conductor construction is normally associated with cables of relatively large diameter, and in fact the particular embodiment illustrated is a splice for 1⅝ inch 50 ohm foam cable. The nut **24** is internally threaded or grooved helically at **32** to form a mating thread with the helically corrugated outer conductor **26**, formed by longitudinal welding of a copper or aluminum strip, followed by corrugation.

Details of the construction illustrated in FIGURE 1 are best understood by consideration of certain of the structural parts and the steps in the assembly, as illustrated in certain of the other FIGURES.

As may be seen in FIGURE 7, the end of the cable is prepared by cutting back the outer conductor and the dielectric to expose a very short length of the center conductor. This is readily done with, for example, a hack-saw and a knife. Extreme accuracy is not an absolute requirement, but this extension may be made very highly accurate by making the cut to expose a slightly greater length and then cutting off the inner conductor itself. V-shaped notches **36** are cut in this extension of the inner conductor, and a plug **38**, externally threaded to match the internal corrugations of the inner conductor **28**, is threadedly inserted in the end thereof. The tabs **40** formed by the mentioned notching are bent over against the end of the plug **38**.

The clamping nut **24**, now to be described further, is threaded onto the end of the outer conductor **26** to the point where its front edge **42** leaves exposed an extremely small end portion **44** (of the order of 1/32 of an inch) of the tip of the outer conductor.

The clamping nut **24** has a longitudinally central externally threaded portion **46** of substantial thickness, and terminates at its front end in a clamping portion **48** of substantially less thickness. The clamping portion **48** has longitudinal slits **50** distributed entirely around it, thus more or less dividing this clamping portion into tines or prongs which may be bent inwardly with reasonable force. A recess **52** is formed on the extreme end at one point on the circumference by a relatively wide slot or mouth at the outer termination of one of the slits **50**.

With the threading on of the nut **24** to the point just mentioned, i.e., with the small exposure of the end **44** of the outer conductor, the outer conductor is deformed at the recess **52** in such a manner as to seat the deformed portion in the recess, and thus lock the nut in position. This may be done, for example, by means of a pliers, with the back jaw against the rear end **54** of the nut, and the front jaw bending the outer conductor into the recess to form a detent or lip **56** engaged in the recess. As will hereinafter become clear, this interlock is not required to be of great strength and permanency, or to withstand the stresses and twistings to which the cable assembly will be exposed in later use. Accordingly, it is not necessary that this operation be performed with great force or highly unusual care, nor is it necessary that there be any soldering or other permanent reinforcement of the locking.

This lock is of a temporary use in the making of the installation, and produces an assembly at the cable end which is adapted for highly precise control of the exact disposition of all of the parts in the later completion of assembly. The screw action of the nut produces simple adjustment of the exposed length of outer conductor to a degree of precision which cannot be obtained readily by other means. The simple locking, by the same token, need not even guard against all possibility of "play," since any small freedom between the parts for rotation represents a minuscule longitudinal error.

With the simple manner of obtaining precision in the length of the exposed portion **44** at the tip of the outer conductor understood, the further construction and manner of functioning of the embodiment of FIGURE 1 may be described and understood. The front end **42** of the nut **24** registers with an annular ring **58** (split in two parts **58***a* and **58***b* for purposes later to be discussed). The ring **58** has on the periphery of its facing end a bevelled female camming surface **60**, radially inward of which is an annular transverse surface **62**. The outer portion of the front edge **42** of the clamping nut **24** is bevelled at **64** (best seen in the exaggerated magnified view of FIGURE 7*a*) which is at a slightly smaller angle with respect to the axis than the bevel or camming surface **60**. The splice connector **20** has a body **66** which is internally threaded at **68** to mate with the externally threaded portion **46** of the nut **24**.

The further portions of the splice connector **20** of FIGURE 1, and their mode of operation, will more easily be understood by first considering another embodiment, that of FIGURE 4. It will be observed that the right-hand portion of the device there illustrated corresponds closely to the portion of the device of FIGURE 1 thus far described. The body **70** of the connector of FIGURE 4 has a terminal portion **72** which will be recognized as a size-reducing transformer or coupling joining the cable (not illustrated in this figure) to one of smaller diameter. It will be understood that the inner and outer cable conductors are here omitted, and it will be seen that the center conductor terminal **74** is somewhat different from that illustrated in FIGURE 1 (to be later described), being supported by an insulator **76**. However, it will also be seen that except for these differences, which are not highly material to the present invention, the structure is in many respects identical with that of the portion of FIGURE 1 thus far described, the same clamping nut **24** and the installation on the cable illustrated in FIGURES 6 and 7 being employed, and the body **70** having a bevelled female camming surface **60***a* and an annular transverse surface **62***a* corresponding in all respects to those previously described in connection with the ring **58**.

The operation of these parts, and the purpose served by the exact positioning of the tip **44**, locked by the deformation previously discussed, may be understood from the illustrations of FIGURES 7*a* and 7*b*. FIGURE 7*a* shows the condition of parts just before the final tightening operation, i.e., as the tip **44** of the outer conductor is about to strike the surface **62***a* and the end **42** of the nut is striking the camming surface **60***a*. (It will be understood that this illustration might equally well use the reference characters **60** and **62**.) As the tightening continues to the fully tightened condition of FIGURE 7*b*, the end **44** is jammed against the surface **62***a* and the tines or prongs formed by the slits **50** are all bent inward slightly to grasp the outer conductor extremely firmly, but not to an extent to deform it substantially and thus create any discontinuity in the characteristic impedance. At the same time, the jamming of the end **44** against the surface **62***a* occurs just to the right degree to deform the soft metal of the outer conductor (aluminum or copper, preferably) to essentially fill the gap between the extreme tip of the nut and the involved surfaces of the body **70**, the bevel **64** terminating at least approximately in abutment against the surface **60***a*, thus providing complete mechanical and electrical contact, while at the same time so exactly controlling the reproducibility of the relative positions that the secure electrical contact is achieved (over a fairly wide range of maximum manual tightness) without any unpredictable flow or bending.

Thus without any undue care or effort, any reasonably competent field personnel can install the connector in the manner described, and obtain a joint which is mechanically and electrically very closely equivalent to that obtained by use of the measuring instruments and working tools of a machine-shop. It will be observed that this may readily be done by one man without use of any vise or jig.

Returning now to FIGURE 1, it will be seen that the connector there illustrated has a second clamping nut

78, again internally threaded at 80 to receive an identical cable end, and having a clamping portion 82 formed by slits 84, the other details of the clamping portion, and the manner of installation of the cable, being identical to that previously described. The nut 78 abuts against a shoulder 86 on the interior of the body 66. The nut 24 is formed with flats 88 to permit gripping by a wrench, and similar provision (not illustrated) is made on the body 66. The ring 58 is of course "floating" or self-centering, being free with respect to the body 66, so that the tightening operation applies identical pressures in making the joints of the two cables with the ring 58, which has at its opposite face camming and transverse surfaces 60*b* and 62*b* corresponding exactly with those at 60 and 62.

It may be observed that the purpose or necessity of the rotational locking accomplished by simple slight deformation of the outer conductor is slightly different in the cases of the connectors of FIGURE 1 and of FIGURE 4. In the case of the connector of FIGURE 4, relative rotation between the clamping nut 24 and the bevelled cam surface 60*a* is inherent, and it is impossible to avoid it. With such a construction, the tightening of the body 70 onto the nut 24 may (and in general will) cause relative rotation between the outer conductor and the nut 24, in the absence of some rotational locking provision, thus changing the length of the exposed portion 44 to a degree which is dependent on such uncontrollable variables as the conditions of the various surfaces, including the cut-off edge of the outer conductor itself. Although the latter is of course filed to remove sharp remnants, the desired fine control of the resultant jammed metal joint cannot be achieved without rotational locking.

There is thus introduced either a noisy and unreliable outer conductor contact or the upsetting of the exact pattern or geometry of the interior required for proper electrical operation, both as regards impedance and breakdown voltage; an excessive length of extending end will of course be sharply bent or torn, resulting in arcing and breakdown at the joint at voltages far below the capability of the cable or the connector.

In the case of connectors like that of FIGURE 4, the locking provision is accordingly essentially indispensable in obtaining a good joint by one man without a jig or special clamp. In the case of FIGURE 1, however, it would be theoretically possible to obtain satisfactory results without the locking provision by careful control of friction in the connector parts, but as a practical matter it will be seen that it would add greatly to the cost to attempt to assure completely negligible friction between the body 66 and the nut 78 and between the body 66 and the ring 58, while maintaining a close fit throughout.

For purposes of completeness, the structure associated with the inner conductor of FIGURE 1 should be described. There is provided a plug 90 externally the same as the plug 38, but the plugs 38 and 90 are threaded internally in opposite directions or senses to receive the ends of a turnbuckle screw 92. The screw 92 has a square central drive portion 94 and oppositely threaded end portions 96 and 98. A collar 100 has an aperture for self-centering driving of the screw, and bevelled clamping ends 102 engaging the tabs 40 on the center conductors.

For overall installation of the splice, the body 66 is placed over the cable to be connected from the left-hand end, and the two nuts 24 and 78 are installed as previously described, along with the plugs 38 and 90. The screw 92 is then started in the two plugs 38 and 90 and the collar is then tightened by use of the flat 103 thereon until the inner conductor structure is firmly clamped and fixed. Thereupon the two halves 58*a* and 58*b* of the ring 58 are put in place, and the body 66 is then brought over the assembly and the parts are tightened as previously described. It may be noted in this connection that the resilience of a foam dielectric plays a substantial part. This resilient yielding permits ready insertion of the ring 58 although the center conductor assembly has been fully "laced up" and also permits the slight deformation of the end of the outer conductor, previously described, without creating the likelihood of flow of the dielectric into the critical region of connection of the outer conductor of the cable to the outer conducting portion of the connector.

FIGURES 8 through 10 show a modified form of splice connector. Here again there are a pair of clamping nuts 104 and 106 on respective ends of the cables to be joined (not shown). Slits 108 are used in forming the respective clamping regions 110 and 112 and a split ring 114, formed of segments 114*a* and 114*b*, is again provided, with its ends bearing camming surfaces 116 and annular transverse surfaces 118, generally similar to those previously described. However, in the present case, the outer ends 120 and 122 of the nuts 104 and 106 are differently formed and driven. The outer end 120 of the nut 104 abuts a collar 124 which is in sliding shouldered engagement at 126 with a body or shell 128. The outer end 122 of the nut 106 is engaged by a collar 130 which is in external threaded engagement at 132 with the body or shell 128. The outer ends of the nuts are tapered or bevelled to correspond with similar tapers or bevels on the collars 124 and 130.

Both the clamping nuts 104 and 106 and the ring 114 are thus separated from the body 128 by the collars 124 and 130, which thus serve as intermediate bearings. With this construction, it will be observed that it is not excessively difficult to assure that no rotational motion on the exterior is transferred to either of the nuts or the ring on the interior. Accordingly, with this construction, the provision of a rotational lock such as previously described may be omitted if desired.

It might be noted that in this instance the center conductor provision is merely a tube 134 into which the center conductors of the cable ends (not illustrated) may be secured. This embodiment is of course designed for cables of smaller size than those previously described, although it will be understood that the principles of construction involved are actually more or less independent of cable size.

FIGURES 11 through 15 show still another embodiment. Here the body 136 is illustrated with another typical kind of terminal portion 138, in this instance having a center conductor terminal 140 supported by an insulator 142. The body 136 is again internally threaded at 144 and provided with a bevelled cam surface 146 and annular seat or transverse surface 148. Again there is a clamping nut 150, in this instance provided with a hexagonal head 152, forward of which the nut is externally threaded at 154. Again an internal thread 156 is provided to match the exterior of the helically corrugated outer conductor, and the clamping portion 158 is rendered readily deformable by provision of the slits 160.

In this instance, the transverse dimensions of the entire assembly for the relatively small cable size involved are such that the radial extension permitted by a mere end recess such as shown in FIGURE 5 and earlier described would not be of sufficient thickness. That is to say, when the tip of the outer conductor is deformed radially outwardly sufficiently to lock the nut against rotation, it is then in such position that this lip or extension strikes the bevel cam 146 and prevents proper and reliable seating or "jamming" action at the extreme end of the circumference of the outer conductor. This problem is solved by altering the recess so that it also includes a groove 162 on the outer surface into which the bent-out portion of the outer conductor is readily driven by the cam surface, so that the deformation-type lock does not interfere with the proper seating action.

It will be obvious to persons skilled in the art that the embodiments herein illustrated and described are all closely similar, representing basically only one form of practice of the broad teachings of the invention. A multitude of variants will readily be apparent from mere under-

standing of the description above, while an even greater number of specific details of manners of practicing the invention will be devised after study of the basic principles and mode of operation. Accordingly, the scope of the patent protection to be afforded the invention should not be limited in any manner by the particular embodiments herein discussed, but should extend to all practice of the teachings of the invention as described in the appended claims, and equivalents thereof.

What is claimed is:

1. A coaxial cable and connector assembly comprising:
(a) a coaxial cable having a helically corrugated outer conductor,
(b) an outer conductor connector comprising a member having an inwardly bevelled camming surface,
(c) a conducting clamping member on the end of the cable having internal helical threads engaging the corrugation of the outer conductor,
(d) the clamping member being longitudinally slitted about the entire circumference of its end and having a recess at one circumferential portion thereof, and the outer conductor being radially outwardly deformed at said circumferential portion of its end and engaging the recess for rotational interlocking,
(e) and a threaded tightening means acting upon the connector and the clamping member and tightened to join the clamping member against the camming surface and thus bending the end of the clamping member inwardly to clamp the outer conductor securely,
(f) the bevelled camming surface having a transverse annular surface immediately inward thereof, the end of the outer conductor being jammed against this transverse surface.

2. A coaxial splice connection comprising:
(a) a pair of cables each having a helically corrugated outer conductor,
(b) a conducting clamping member on the end of each of the cables having internal helical threads engaging the corrugations of the respective outer conductors,
(c) each clamping member having circumferentially distributed longitudinal slits in its end,
(d) a tubular conducting ring between the cables having its ends bevelled to form female camming surfaces and having transverse annular surfaces radially inwardly adjacent to the camming surfaces,
(e) and threaded tightening means acting upon both clamping members to drive them toward each other clamping the respective clamping members against the respective camming surfaces and the ends of the outer conductors against the respective transverse surfaces.

3. The splice connection of claim 2 wherein the ring is confined for longitudinal motion solely by the clamping members.

4. The splice connection of claim 2 wherein the ring is split to permit access to the inner conductor .

5. The splice connection of claim 2 wherein each outer conductor is radially deformed at one circumferential portion thereof to engage the clamping member for rotational interlocking.

6. The splice of claim 2 having:
(f) said clamping members being substantially identical rings,
(g) the tightening means including threaded members abutting against each of the rings in the direction to drive them together.

7. A coaxial splice connection comprising:
(a) a pair of cables each having a tubular outer conductor,
(b) a conducting clamping member on the end of each of the cables,
(c) each clamping member having circumferentially distributed longitudinal slits in its end,
(d) a tubular conducting ring between the cables having its ends bevelled to form female camming surfaces and having transverse annular surfaces radially inwardly adjacent to the camming surfaces,
(e) and threaded tightening means acting upon both clamping members to drive them toward each other clamping the respective clamping members against the respective camming surfaces and the ends of the outer conductors against the respective transverse surfaces.

8. The splice connection of claim 7 wherein the ring is confined for longitudinal motion solely by the clamping members.

9. The splice connection of claim 7 wherein the ring is split to permit access to the inner conductor.

10. A coaxial cable connector for helically corrugated cable comprising:
(a) an annular clamping member having internal helical threads adapted to engage the outer conductor of a cable having helical corrugations along the entire length thereof for installation on the end of such a cable,
(b) the clamping member having longitudinal notches distributed about the forward end thereof and extending substantially rearwardly to weaken said end against inward bending stress,
(c) the extreme forward end having a recess adapted for rotational locking of the cable by deformation of the corresponding portion of the outer conductor into said recess,
(d) a mating member having a bevelled female camming surface in register with the end of the clamping member and a transverse annular surface immediately radially inward thereof,
(e) and threaded tightening means acting between said members,

so that the clamping member may be installed on the end of a cable with its forward end slightly exposing the outer conductor and locked into relative position on the cable by deformation of said outer conductor end, and thereupon forced against the camming surface to clamp the conductor securely, with its end jammed against the annular surface.

11. A coaxial splice connector comprising the connector of claim 10 characterized by
(f) the mating member having said bevelled camming surface and said transverse annular surface at each of opposite ends,
(g) one said clamping member being disposed at each of said ends.

12. The coaxial splice connector of claim 11 characterized by:
(j) the mating member being a split ring.

13. A coaxial cable connector for helically corrugated cable comprising:
(a) an annular clamping member having internal helical threads adapted to engage the outer conductor of a cable having helical corrugations along the entire length thereof for installation on the end of such a cable,
(b) the clamping member having longitudinal notches distributed about the forward end thereof and extending substantially rearwardly to weaken said end against inward bending stress,
(c) means for temporary rotational locking of the clamping member on the outer conductor,
(d) a mating member having a bevelled female camming surface in register with the end of the clamping member and a transverse annular surface immediately radially inward thereof,
(e) and threaded tightening means acting between said members,

so that the clamping member may be installed on the end of a cable with its forward end slightly exposing the outer

conductor and temporarily locked into accurate position on the cable, and thereupon forced against the camming surface to clamp the conductor securely, with its end jammed against the annular surface.

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