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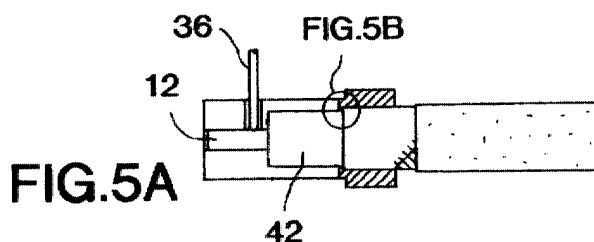
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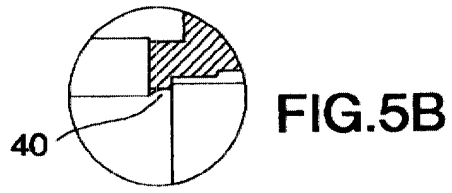
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(54) **Coaxial cable and process and apparatus for forming**

(57) A method of forming an end of a coaxial cable to prevent the dielectric from receding within the outer conductor is disclosed, together with a cable formed by the method and an apparatus for carrying the method out. The cable comprises a central wire conductor (12), a dielectric (14) formed of several layers of PTFE tape, and an outer conductor (16) of metal braid. The outer conductor is cut away to expose a substantial length of the dielectric. A shroud (20) is slid over the outer conductor. The shroud carries a spacer lip (26) that abuts the end of the outer conductor, while leaving a gap (28)

between the lip and the exposed dielectric. The end of the cable is then inserted into a blind bore (32) in a heated tool (30). The blind bore fits snugly around the exposed dielectric, but is appreciably shorter. The tool is forced onto the cable, compressing the dielectric, until the tool meets the spacer lip. The heat of the tool fuses the layers of the PTFE together, and allows the PTFE to flow, forming a bead (40) in the gap inside the spacer lip. The bead engages the end of the outer conductor, preventing the dielectric from receding within the conductor.





Description

FIELD OF THE INVENTION

[0001] The invention relates to a method of forming the ends of a coaxial cable, and especially to a method of securing together the ends of the outer conducting layer and the inner dielectric layer.

BACKGROUND OF THE INVENTION

[0002] A coaxial cable consists essentially of a center conductor, typically metal wire, a dielectric spacer, an outer conductor, typically of metal braid, and a protective jacket. The dielectric spacer may be made of unsintered or partially sintered polytetrafluoroethylene (PTFE). The PTFE is commonly either extruded onto the center conductor or in the form of a tape wrapped around the center conductor, typically in 3 to 10 layers wrapped helically. All such unsintered or partially sintered PTFE dielectrics will be referred to hereinafter as "expanded PTFE" (ePTFE).

[0003] For many applications, flexible high performance microwave cables are required to operate through large temperature extremes, particularly in spaceflight. Because of power, multipaction, return loss (impedance mismatch), and phase matching concerns, it is important that cable and connector component locations remain stable and unchanged relative to each other. Any change in dimensions or dielectric constant can severely impact the microwave properties of the cable assembly. Due to the variety of materials used to manufacture these cable assemblies, it was impossible to guarantee no movement of the various layers of materials within the cable under extreme temperature changes. The movement primarily results from the large difference between the coefficients of thermal expansion of the ePTFE dielectric and the metallic conductors. With coaxial cable manufactured using ePTFE tape as the dielectric, in particular, there is a tendency for the dielectric to recede at the cable ends under repeated cycles of high and low temperature. The result is a gap between the dielectric of the cable and a dielectric block forming part of a connector on the end of the cable. The sudden change in dielectric constant at the ends of the gap severely disrupts microwave transmission along the cable.

BRIEF SUMMARY OF THE INVENTION

[0004] To prevent this potentially catastrophic problem, the dielectric must be mechanically captivated to the rest of the cable. Until now, there has been no simple method to do this without severe degradation of the high frequency electrical performance. The present invention proposes to sinter the different PTFE layers together at the end of the cable, so that they cannot move relative to one another, and to form the outer layer with a bead that engages the end of the metal braid, so that the PT-

FE cannot recede inside the braid.

[0005] According to one aspect of the invention, there is provided a method of forming an end of a coaxial cable. The cable comprises center and outer conductors separated by a dielectric. The dielectric is exposed beyond the end of the outer conductor. The exposed dielectric is compressed axially, while confining it radially. The dielectric is permitted to expand radially at a region adjacent to the end of the outer conductor so as to form a bead having an external diameter greater than the internal diameter of the outer conductor.

[0006] According to another aspect of the invention, there is provided a coaxial cable comprising center and outer conductors separated by a dielectric, wherein at least one end of the dielectric projects lengthwise beyond the corresponding end of the outer conductor and is formed with an encircling bead that projects radially adjacent the end of the outer conductor sufficiently to prevent the dielectric receding within the outer conductor.

[0007] The step of permitting the dielectric to expand may comprise defining a gap between two axially-separated components and permitting the dielectric to expand into the said gap. The width of the gap may be determined by a spacer, and the bead is then preferably formed radially inside the spacer, with free space remaining between the formed bead and the spacer. One of the two said axially-separated components may be the outer conductor of the cable, and one of them may be a member that confines the exposed dielectric radially. The latter member may be a heated tool if the dielectric is thermoplastic.

[0008] According to a further aspect of the invention, there is provided apparatus for shaping an end of a coaxial cable, comprising: a shroud of refractory material dimensioned to fit over the outer conductor of the cable, and having at one end a spacer lip dimensioned to abut the end of the outer conductor while defining a radial clearance from the outer surface of the dielectric of the cable; and a heated tool having a blind bore dimensioned to fit snugly over the dielectric of the cable and dimensioned to abut the spacer lip of the shroud.

[0009] The dielectric may be thermoplastic, especially PTFE, and may be heated sufficiently to soften it. If the dielectric is wound from tape or otherwise formed in layers, it is preferably heated sufficiently to fuse the layers in the exposed dielectric into a solid mass.

[0010] The bead may be shaped after it is formed to reduce the effect of any change in impedance at the transition between fused and unfused layers of the dielectric. Preferably, the effect of the transition with the shaped bead is less than, and is preferably no greater than half, the effect of a similar transition in impedance with no bead at all.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Figure 1 is a side view, partly in section, of a

cable, shroud, and sintering head ready for forming of one end of the cable.

[0012] Figure 2 is a view similar to Figure 1, showing the shroud in position on the cable.

[0013] Figure 3 is a view similar to Figure 2, showing the sintering head engaging the end of the cable.

[0014] Figure 4A is a view similar to Figure 3, showing a later stage of the forming process

[0015] Figure 4B is an enlarged view of the detail within the circle marked "Fig. 4B" in Figure 4A.

[0016] Figure 5A is a view similar to Figure 4A, showing a final stage of the forming process.

[0017] Figure 5B is an enlarged view of the detail within the circle marked "Fig. 5B" in Figure 5A.

[0018] Figure 6A is a view similar to Figure 5A, showing the formed cable removed from the sintering head.

[0019] Figure 6B is an enlarged view of the detail within the circle marked "Fig. 6B" in Figure 6A.

[0020] Figure 7 is a view in longitudinal section of a coaxial cable connector fitted onto a cable formed as shown in Figures 1 to 6.

[0021] Figure 8 is an enlarged view of the detail within the circle marked "Fig. 8" in Figure 7.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

[0022] Referring to the accompanying drawings, and initially to Figure 1, one form of coaxial cable for the transmission of microwave signals is indicated generally by the reference numeral 10. The cable 10 consists essentially of a center conductor 12 of metal wire, a dielectric spacer 14 of several layers of helically wound or extruded ePTFE tape, an outer conductor 16 of metal braid, and a protective jacket 18. In a first step of the forming process according to the invention, each layer is cut back to provide a clean end square to the length of the cable, and to expose a length of the layer within it. In particular, the braid 16 is stripped back to expose a substantial length of the ePTFE.

[0023] Referring now also to Figure 2, in a second step of the process a ceramic shroud indicated generally by the reference numeral 20 is slid over the prepared end of the cable 10. As is shown in Figure 2, the main body of the shroud 20 consists of a cylindrical tube 22 that fits easily over the exposed braid 16. As is shown in more detail in Figure 4B, at the trailing end of the shroud is a shoulder 24 that fits more closely over the exposed braid 16, to ensure accurate centering of the shroud on the cable. Beyond the shoulder 24 is a lip 26 that extends radially inward far enough to overlap the braid 16. The lip 26 does not extend far enough to contact the exposed dielectric 14, but rather leaves a substantial radial gap 28. The radial width of the gap 28 is normally at least 2% of the diameter of the braid 16. The shroud 20 is positioned so that the lip 28 abuts the cut end of the braid 16.

[0024] Referring now also to Fig. 3, a sintering head,

indicated generally by the reference numeral 30, consists largely of a cylindrical block of titanium with a heating element (not shown). The sintering head 30 has in one end a blind bore 32 that is of a suitable diameter to fit snugly over the exposed dielectric 14 of the cable 10. The depth of the bore 32 is approximately half the exposed length of the dielectric 14. The sintering head 30 also has an axial through bore 34, sufficiently wide to receive the center conductor 12 of the cable 10. A firing pin 36 is received in a radial bore in the sintering head 30, and can be advanced to a position where it clamps the center conductor 12, if the conductor is present in the bore 34. The sintering head 30 is preheated to a temperature of at least 375 °C (700 °F), and not more than 540 °C (1000 °F). As shown in Figure 3, the sintering head 30 is initially placed on the end of the cable 10 so that the cut end of the dielectric 14 abuts the bottom of the blind bore 32, and the tip of the center conductor 12 fits into the through bore 34.

[0025] Referring now to Figure 4A, the sintering head 30 is then forced onto the end of the cable 10, compressing the dielectric 14. During this step the cable 10 is gripped by at least one cable grip 35, which is set back at least 7 mm (0.25") from the exposed braid 16. The braid 16 fits over the dielectric 14 with sufficient tension to prevent the dielectric from being forced into the braid by the sintering head 30. The sintering head is advanced until it contacts the lip 26 of the shroud 20, as shown in Figure 4B. The gap 28 is now a closed, annular space, axially between the braid 16 and the sintering head 30, and radially between the dielectric 14 and the lip 26.

[0026] As shown in Figure 5A, the sintering head 30 is then clamped in place by tightening the firing pin 36 onto the center conductor 12. This also ensures good thermal contact between the sintering head 30 and the center conductor 12. Within the heated sintering head, the ePTFE forms a continuous mass 42. The ePTFE expands, filling the interior of the blind bore 34 within the sintering head. As the ePTFE presses against the surface of the blind bore, good heat transfer is ensured. The ePTFE then flows into the gap 28 to form a bead 40, shown in Figure 5B. The time for which the sintering head is left heated on the cable depends on the cable type, but is typically between 20 seconds and 3 minutes. As is shown in Figure 5B, the bead 28 does not fill the gap 28, but an air space is left outside it. This permits solder to flow completely around the circumference of the braid, so that a good solder fill can be obtained. The heat also erases any memory of previous shapes from the PTFE, ensuring that the bead will be permanent.

[0027] The whole assembly is then allowed to cool, and the titanium sintering head 30 and the ceramic shroud 20 are then removed from the cable. As is shown in Figure 6A, the sintered PTFE mass 42 shrinks, but the bead 40 is still large enough to lock on the end of the braid. The braid is not embedded within the sintered PTFE, but the bead is too wide to slip inside the braid. The bead 40 may be shaped, as shown in Figure 6B, by

providing a bevel 44 on the lip of the bore 32 in the sintering head 30, as shown in Figure 6A.

[0028] The sintering of the ePTFE does, of course, alter the dielectric constant. In particular, there is a fairly sudden change in dielectric constant between the sintered ePTFE 42 of the endpiece and the only partially sintered ePTFE 14 within the braid 16. That change occurs approximately at the level of the bead 40, and can be compensated for by shaping the bead and/or by shaping the inside of a metal cable connector where it fits over the bead. The transition between partially-sintered and unsintered ePTFE 14 within the braid 16 is sufficiently gradual not to cause a serious effect on microwave transmission. The sintered ePTFE 42 of the endpiece may also be shaped for optimal fitting, both mechanical and electrical, into a connector.

[0029] Referring now to Figures 7 and 8, a conventional coaxial cable connector, indicated generally by the reference numeral 50, is shown mounted on the end of the cable 10. A sleeve 52 of the connector 50 is mounted on the cable 10, covering the exposed portion of the braid 16 and the end of the jacket 18. The sleeve 52 is secured mechanically and electrically to the braid 16 by soldering. A collar 54, with an external screw thread, is captive behind a shoulder 56 on the sleeve 52. A metal connector pin 58 fits over the exposed end of the center conductor 12 of the cable 10, and forms the center pin of the connector 50. The pin 58 is captive behind a shoulder on an insulating sleeve 60, which is captive behind a shoulder on an internally screw-threaded sleeve 62, which is screwed onto the collar 54. An internally screw-threaded collar 64, which forms the outer connection component of the connector 50, is held captive, but free to rotate, on the sleeve 62 by means of a spring ring 64.

[0030] As may be seen from Figure 7, the bead 40, and therefore the transition from sintered dielectric 42 to only partially sintered dielectric 14, is aligned with the transition between the braid 16 and the connector sleeve 52. As is shown in Figure 8, the bead 40 is machined to a profile that compensates for the transitions in the other components, so as to afford as nearly as possible an unimpeded propagation of the microwave signals along the cable 10 and through the connector 50.

[0031] Although the invention has been described with reference to an exemplary embodiment thereof, it will be understood by those skilled in the art that various changes, omissions, and additions may be made thereto without departing from the spirit and scope of the invention as recited in the attached claims.

Claims

1. A method of forming an end of a coaxial cable, comprising the steps of:

providing a coaxial cable comprising center and outer conductors separated by a dielectric, with the dielectric exposed beyond the end of the outer conductor;

compressing the exposed dielectric axially, while confining it radially; and
 permitting the dielectric to expand radially at a region adjacent to the end of the outer conductor so as to form a bead having an external diameter greater than the internal diameter of the outer conductor.

2. A method according to claim 1, wherein the step of permitting the dielectric to expand comprises defining a gap between two axially-separated components and permitting the dielectric to expand into the said gap.

3. A method according to claim 2, wherein the width of the gap is determined by a spacer, and the bead is formed radially inside the spacer, with free space remaining between the formed bead and the spacer.

4. A method according to claim 2 or 3, wherein one of the two said components is the outer conductor of the cable.

5. A method according to claim 2, 3 or 4, wherein one of the two said components is a member that confines the exposed dielectric radially.

6. A method according to any one of claims 1 to 5, wherein the dielectric is thermoplastic, and which comprises heating the dielectric sufficiently to soften it.

7. A method according to claim 6, wherein the dielectric comprises PTFE.

8. A method according to claim 6 or 7, wherein the dielectric is formed in layers, and which comprises heating the dielectric sufficiently to fuse the layers in the exposed dielectric into a solid mass.

9. A method according to claim 8, which comprises shaping the bead to reduce the effect of any change in impedance at the transition between fused and unfused layers of the dielectric.

10. A method according to any one of claims 6 to 9, which comprises inserting the exposed dielectric into a blind bore in a heated tool, the walls of which bore serve both to compress the dielectric axially and to confine it radially.

11. A coaxial cable comprising center and outer conductors separated by a dielectric, wherein at least

one end of the dielectric projects axially beyond the corresponding end of the outer conductor and is formed with an encircling bead that projects radially adjacent the end of the outer conductor sufficiently to prevent the dielectric receding within the outer conductor. 5

12. A coaxial cable according to claim 11, wherein the bead has been formed by plastic flow of the dielectric. 10

13. A coaxial cable according to claim 12, wherein the dielectric is thermoplastic and the bead has been formed by hot flow of the dielectric while heated sufficiently to soften it. 15

14. A coaxial cable according to claim 13, wherein the dielectric is PTFE.

15. A coaxial cable according to claim 13 or 14, wherein the dielectric is formed of layers, and the layers are fused together where the dielectric projects beyond the end of the outer conductor. 20

16. A coaxial cable according to claim 15, wherein the bead is shaped to reduce the effect of any change in impedance at the transition between fused and unfused layers of the dielectric. 25

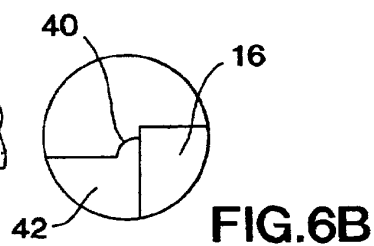
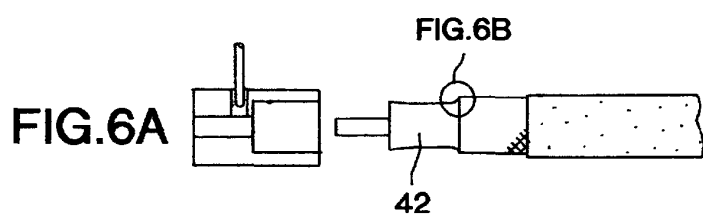
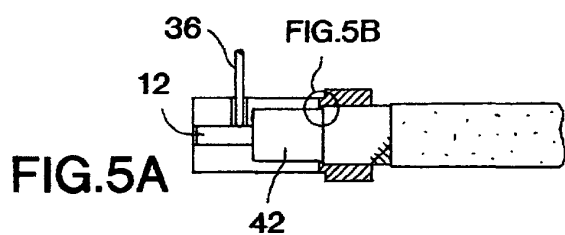
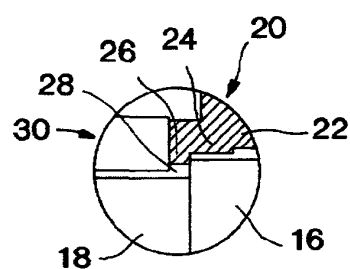
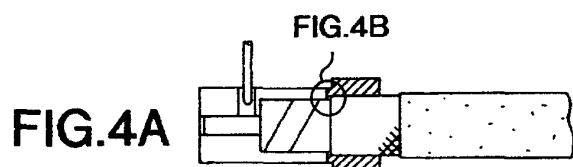
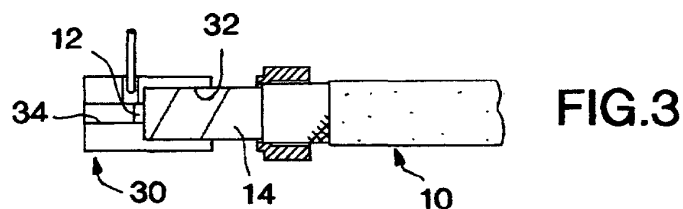
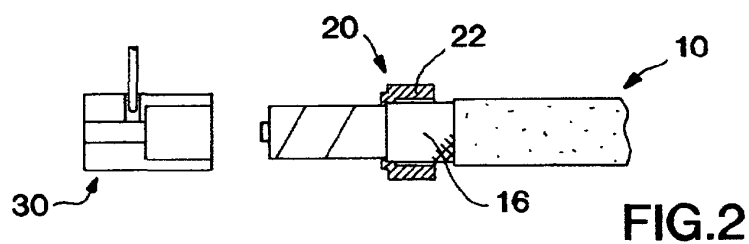
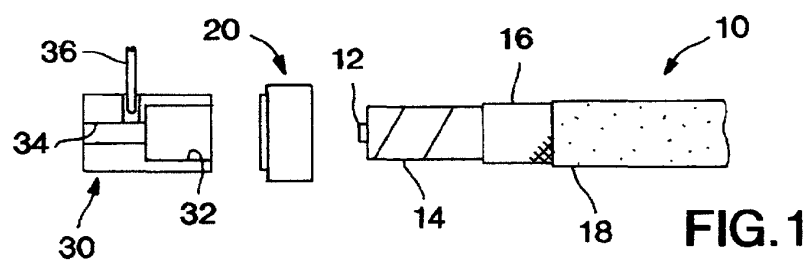
17. Apparatus for shaping an end of a coaxial cable, comprising: 30

a shroud of refractory material dimensioned to fit over the outer conductor of the cable, and having at one end a spacer lip dimensioned to abut the end of the outer conductor while defining a radial clearance from the outer surface of the dielectric of the cable; and 35
a heated tool having a blind bore dimensioned to fit snugly over the dielectric of the cable and dimensioned to abut the spacer lip of the shroud. 40

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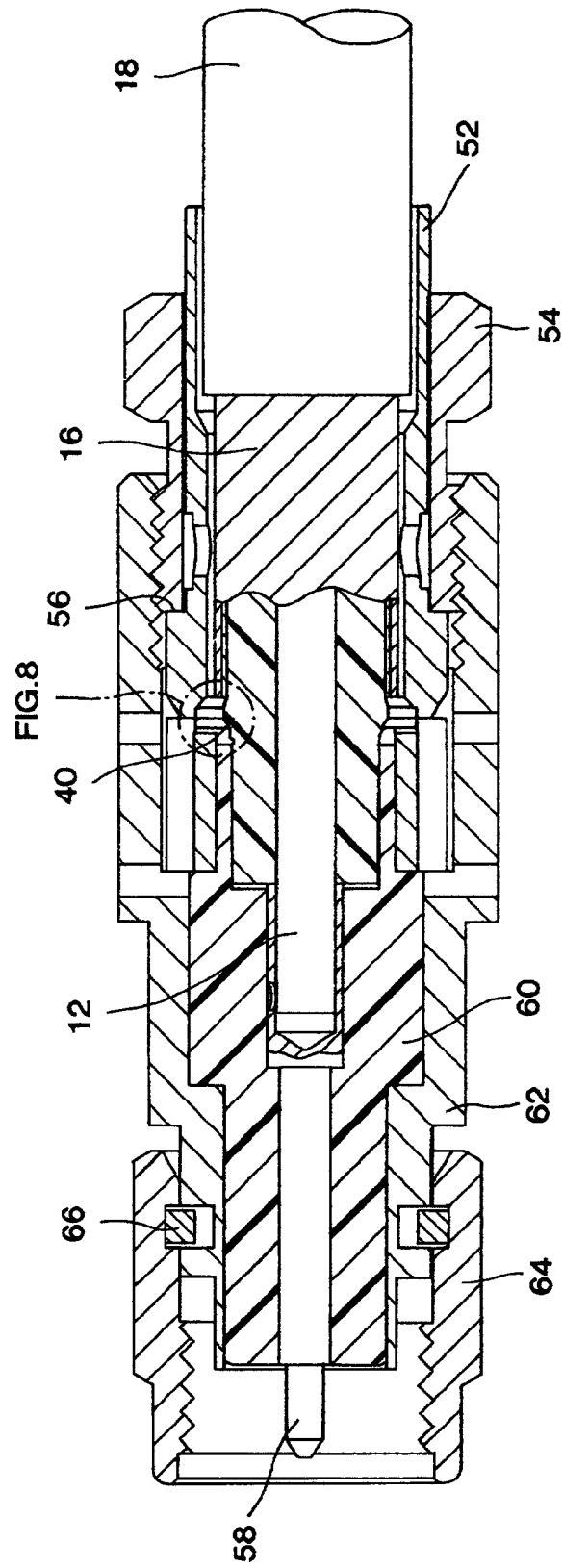


FIG. 7

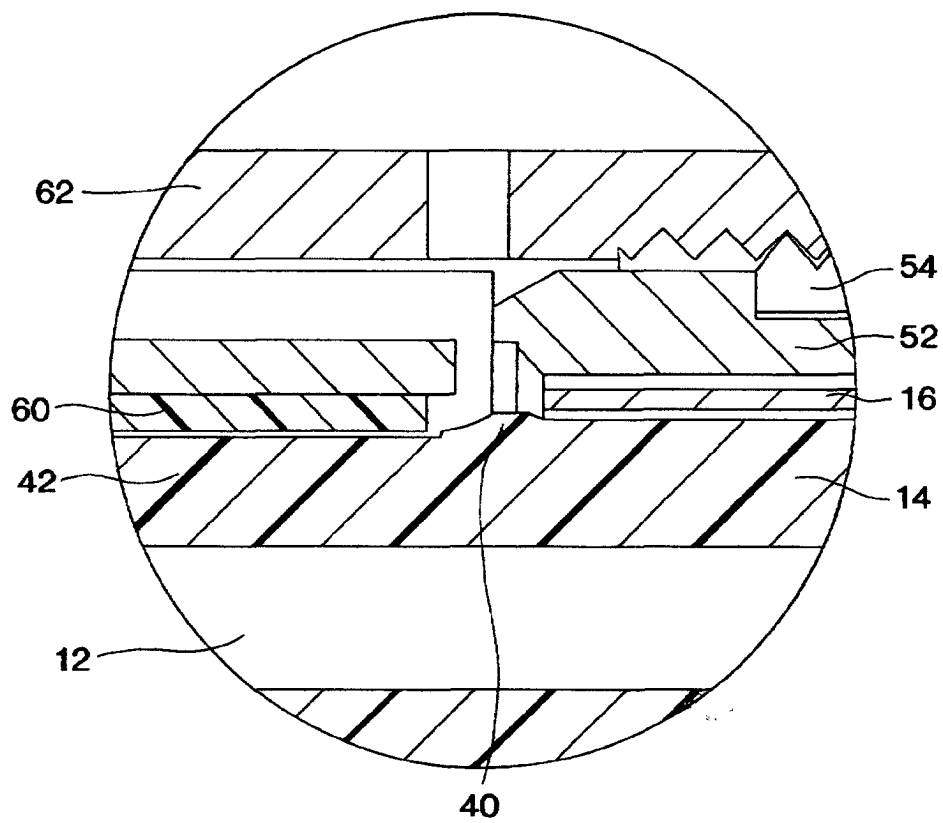


FIG.8



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 30 8800

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	US 3 437 960 A (ZIEGLER GEORGE WILLIAM JR) 8 April 1969 (1969-04-08) -----		H01R13/646
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
			H01R
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 3 May 2001	Examiner Lomme1, A
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 00 30 8800

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03-05-2001

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