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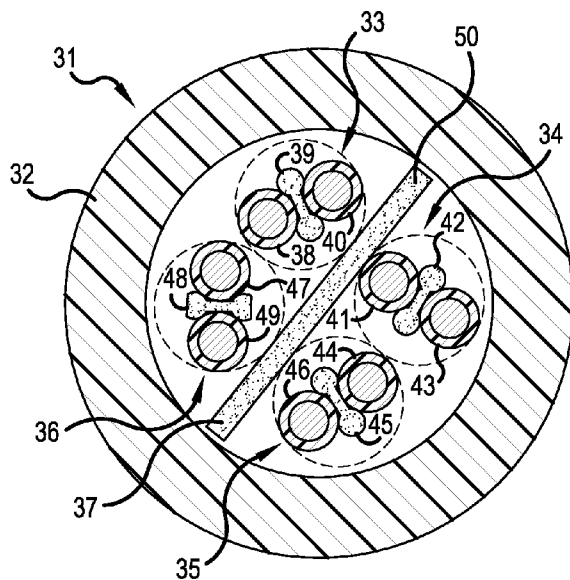


FIG. 4

(57) Abstract: A cable includes a first insulated conductor, a first dielectric tape and a second insulated conductor. The first insulated conductor is twisted with the second insulated conductor with the first dielectric tape residing between the first insulated conductor and the second insulated conductor to form a first twisted pair. The first dielectric tape has at least one strength member embedded therein. A separator may of the cable may also have at least one strength member embedded therein, and serve to separate twisted pairs from each other within the cable.

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HIGH STRENGTH COMMUNICATIONS CABLE SEPARATOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

5 [001] The present invention relates to a twisted pair cable for communication of high speed signals, such as a local area network (LAN) cable. More particularly, the present invention relates to a twisted pair cable having a high strength dielectric tape, which may be located between first and second insulated conductors of a twisted pair and/or to a high strength separator, which may separate at least a first twisted pair from at least a second twisted pair.

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2. Description of the Related Art

 [002] As shown in Figures 1 and 2, the Assignee's prior U.S. Patent No. 6,506,976 shows a LAN cable 1 having a jacket J surrounding first through fourth twisted pairs A, B, C, D which are spaced from each other by a separator 3. Each of the twisted
15 pairs A, B, C, D includes a first insulated conductor 5, a dielectric tape 7, and a second insulated conductor 9, wherein the first insulated conductor 5 is twisted with the second insulated conductor 9 with the dielectric tape 7 residing between the first insulated conductor 5 and the second insulated conductor 9.

 [003] As best seen in the close-up cross sectional view of the twisted pair A in
20 Figure 2, the width of the dielectric tape 7, which extends between opposing edges 11 and 13, is set to extend beyond the first and second insulated conductors 5 and 9. By this arrangement, the opposing edges 11 and 13 of the dielectric tape 7 circumscribe an area
15 15, around the twisted pairs A, B, C, D. The area 15 creates a spacing between the twisted pairs A, B, C, D and the separator 3 and between the twisted pairs A, B, C, D and
25 the jacket J. This spacing around the twisted pairs A, B, C, D can improve the electrical performance of the cable 1, such as by reducing crosstalk.

 [004] In typical cables of the background art, the first insulated conductor 5 would be formed by a first conductor 17 of about twenty-three gauge size, surrounded by a layer of a first dielectric insulating material 19 having a radial thickness greater than
30 seven mils, such as about tens mils or about eleven mils for a typical CAT 6 cable. Likewise, the second insulated conductor 9 would be formed by a second conductor 21 of

about twenty-three gauge size, surrounded by a layer of a second dielectric insulating material 23 having a same or similar radial thickness.

[005] Related prior art can be found in the following U.S. Patents 5,087,110; 6,222,130; 7,999,184; 8,798,419; 9,076,568 and 9,418,775, and the following U.S. Published Applications 2013/0014972; 2013/0161063; 2014/0262427 and 2015/0129277, with all of the above listed U.S. Patents and U.S. Published Applications being herein incorporated by reference.

SUMMARY OF THE INVENTION

[006] Although the cable of the background art performs well, Applicants have appreciated some drawbacks. Applicants have invented a twisted pair cable with new structural features, the object of which is to enhance one or more performance and/or manufacturing characteristics of a LAN cable, such as reducing insertion loss, matching impedance, reducing propagation delay and/or balancing delay skew between twisted pairs, and/or enhancing one or more mechanical characteristics of a LAN cable, such as improving flexibility, reducing weight, reducing cable diameter, reducing smoke emitted in the event of a fire, improving strength attributes of the cable, enabling faster production of the cable, or enabling less costly production of the cable.

[007] The tapes of the present invention have enhanced strength per unit volume and are particularly well suited to enable faster production of the cable, improving the strength of the cable, and allowing for a less bulky tape and smaller cable size.

[008] The invention is for a high-strength twisted pair isolator or separator and/or a bisector tape (depending upon the cable design of interest). The need for increased strength is more precisely described as a need for increased yield strength. There is a demand for increased throughput in production facilities; this translates into increasing manufacturing speeds, which puts increased stress on all components in the twisted-pair communications cable, such as the dielectric tape between insulated conductor and/or the separator between twisted pairs. This invention has several potential embodiments, but in one embodiment a reinforcing material with a greater tensile strength than the base polymer material of the tape or separator is embedded within the base polymer.

[009] The first two embodiments are 1) continuous fiber reinforcement in a flame-retardant polymer, and 2) discontinuous (short) fiber reinforcement in a flame-retardant polymer. The short-fiber reinforcement has advantages, since it could be produced in existing manufacturing equipment. The extrusion process would roughly align the short, discontinuous fibers in the lengthwise orientation, which would help increase the yield strength to the desired levels.

[010] Other embodiments include 3) a paper/hybrid separator tape. This potentially could be made of paper with a fire-retardant coating applied, or a blend of paper and microfibers (PET for example) along with a fire-retardant coating, 4) carbon-fiber reinforced separators, 5) carbon nano-tube reinforced separators, and 6) higher-strength polymers (with higher melt temperatures) used as elements embedded into another polymer to form a reinforced separator or dielectric tape.

[011] Besides the listed materials, any acicular material that could provide improved yield strength in the axial direction to the base polymer material could be substituted. Considerations other than improved tensile yield strength include the enhanced electrical impact of the separator on the cable performance, as well as improved smoke and/or burn results in a simulated fire test.

[012] Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[013] The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus, are not limits of the present invention, and wherein:

[014] Figure 1 is a cross sectional view of a twisted pair cable, in accordance with the prior art;

[015] Figure 2 is a close-up cross sectional view of a twisted pair in the cable of Figure 1;

[016] Figure 3 is a perspective view of a twisted pair cable, in accordance with a first embodiment of the present invention;

5 [017] Figure 4 is a cross sectional view of the twisted pair cable of Figure 3 taken along line IV--IV;

[018] Figure 5 is a close-up cross sectional view of a twisted pair from Figure 4;

[019] Figure 5A is a close up cross sectional view of a twisted pair similar to Figure 5, but illustrating that the dielectric tape may include a hollow air pocket;

10 [020] Figure 6 is a close-up cross sectional view of a twisted pair, having a dielectric tape with an alternative shape, in accordance with a second embodiment of the present invention;

[021] Figure 7 is a cross sectional view of a twisted pair cable employing twisted pairs in accordance with Figure 6;

15 [022] Figure 8 is a close-up cross sectional view of a twisted pair, having a dielectric tape with an alternative shape, in accordance with a third embodiment of the present invention;

[023] Figure 8A is a close-up cross sectional view of a twisted pair, having a dielectric tape with an alternative shape, in accordance with a fourth embodiment of the present invention;

20 [024] Figure 8B is a cross sectional view of a twisted pair cable employing twisted pairs in accordance with Figure 8A;

[025] Figure 9 is a perspective view of a twisted pair cable, in accordance with a fifth embodiment of the present of the present invention;

25 [026] Figure 10 is a cross sectional view of the twisted pair cable of Figure 9 taken along line X--X;

[027] Figure 11 is a close-up cross sectional view of a twisted pair from Figure 10;

30 [028] Figure 12 is a close-up cross sectional view of a twisted pair, having a dielectric tape with an alternative shape, in accordance with a sixth embodiment of the present invention;

[029] Figure 13 is a close-up cross sectional view of a twisted pair, having a dielectric tape with an alternative shape, in accordance with a seventh embodiment of the present invention;

5 [030] Figure 14 is a cross sectional view of a twisted pair cable employing twisted pairs in accordance with Figure 13;

[031] Figure 15 is a close-up cross sectional view of a twisted pair, having a dielectric tape with an alternative shape, in accordance with a eighth embodiment of the present invention;

10 [032] Figure 16 is a close-up cross sectional view of a twisted pair, having a dielectric tape with an alternative shape, in accordance with a ninth embodiment of the present invention;

[033] Figure 16A is a perspective view of a twisted pair similar to Figure 16, but having a dielectric tape embedded with continuous strength members;

15 [034] Figure 17 is a close-up cross sectional view of a twisted pair, having a dielectric tape with an alternative shape, in accordance with a tenth embodiment of the present invention;

[035] Figure 18 is a close-up cross sectional view of a twisted pair, having a dielectric tape with an alternative shape, in accordance with an eleventh embodiment of the present invention;

20 [036] Figure 19 is a close-up cross sectional view of a twisted pair, having a dielectric tape with an alternative configuration, in accordance with a twelfth embodiment of the present invention;

25 [037] Figures 20 and 20A are close-up cross sectional views of a twisted pair, having a dielectric tape with an alternative configuration, in accordance with a thirteenth embodiment of the present invention;

[038] Figure 20B is a perspective view of the twisted pair of Figure 20A, showing the interval of the closed-cell air pockets;

[039] Figure 21 is a perspective view of a twisted pair cable with a tape separator having embedded strength members and typical twisted pairs;

30 [040] Figure 22 is a cross sectional view of the twisted pair cable of Figure 21 taken along line XXII--XXII;

[041] Figure 23 is a perspective view of a twisted pair cable with a cross-web separator having embedded strength members and typical twisted pairs;

[042] Figure 24 is a cross sectional view of the twisted pair cable of Figure 23 taken along line XXIV--XXIV; and

5 [043] Figure 25 is a cross sectional view of a twisted pair cable with a coated paper separator.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

10 [044] The present invention now is described more fully hereinafter with reference to the accompanying drawings, in which embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art.

15 [045] It will be understood that when an element is referred to as being "on", "attached" to, "connected" to, "coupled" with, "contacting", etc., another element, it can be directly on, attached to, connected to, coupled with or contacting the other element or intervening elements may also be present. In contrast, when an element is referred to as being, for example, "directly on", "directly attached" to, "directly connected" to, "directly coupled" with or "directly contacting" another element, there are no intervening elements present. It will also be appreciated by those of skill in the art that references to a structure or feature that is disposed "adjacent" another feature may have portions that overlap or underlie the adjacent feature.

20 [046] Figure 3 is a perspective view of a twisted pair cable 31, in accordance with a first embodiment of the present invention. Figure 4 is a cross sectional view of the cable 31 taken along line IV--IV in Figure 3. The cable 31 includes a jacket 32 formed around and surrounding first, second, third and fourth twisted pairs 33, 34, 35 and 36, respectively. The jacket 32 may be formed of polyvinylchloride (PVC), low smoke zero halogen PVC, polyethylene (PE), fluorinated ethylene propylene (FEP), polyvinylidene fluoride (PVDF), ethylene chlorotrifluoroethylene (ECTFE), or other foamed or solid materials common to the cabling art.

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[047] A separator 37 within the jacket 32 resides between and separates the first and fourth twisted pairs 33 and 36 from the second and third twisted pairs 34 and 35. In Figures 3 and 4, the separator 37 is formed by a thin strip of dielectric material, having a thickness of about twenty mils or less, more preferably about eighteen mils or less, or about fifteen mils or less, such as about 10 mils. However, other sizes and shapes of separators 37 may be employed in combination with the present invention, such as plus-shaped or star-shaped separators, sometimes referred to as a flute, isolator, or cross-web. The separator 37 may be formed of any solid or foamed material common to the cabling art, such as a polyolefin or fluoropolymer, like fluorinated ethylene propylene (FEP) or polyvinylchloride (PVC).

[048] In accordance, with a first embodiment of the present invention, the separator 37 includes embedded strength members 50, best seen in the cross section of Figure 4. The strength members 50 may be short segments of acicular material, such as fibers formed of fire retardant material. Suitable materials could include aramid yarns, fiber glass, carbon fibers and carbon nanotubes. The embedded strength members 50 allow the thickness of the separator 37 to be reduced while the strength, e.g., the yield strength, of the separator 37 is maintained or even increased, as compared to a separator formed without strength members 50.

[049] As best seen in the cross sectional view of Figure 4, the first twisted pair 33 includes a first insulated conductor 38, a first dielectric tape 39, and a second insulated conductor 40. The first insulated conductor 38 is twisted with the second insulated conductor 40, in a helical fashion, with the first dielectric tape 39 residing between the first insulated conductor 38 and the second insulated conductor 40.

[050] The second twisted pair 34 includes a third insulated conductor 41, a second dielectric tape 42, and a fourth insulated conductor 43. The third insulated conductor 41 is twisted with the fourth insulated conductor 43, in a helical fashion, with the second dielectric tape 42 residing between the third insulated conductor 41 and the fourth insulated conductor 43.

[051] The third twisted pair 35 includes a fifth insulated conductor 44, a third dielectric tape 45, and a sixth insulated conductor 46. The fifth insulated conductor 44 is twisted with the sixth insulated conductor 46, in a helical fashion, with the third dielectric

tape 45 residing between the fifth insulated conductor 44 and the sixth insulated conductor 46.

[052] The fourth twisted pair 36 includes a seventh insulated conductor 47, a fourth dielectric tape 48, and an eighth insulated conductor 49. The seventh insulated conductor 47 is twisted with the eighth insulated conductor 49, in a helical fashion, with the fourth dielectric tape 48 residing between the seventh insulated conductor 47 and the eighth insulated conductor 49.

[053] Figure 5 is a close-up view of the first twisted pair 33, which is similarly constructed although not identically constructed (as will be detailed later in the specification) to the second, third and fourth twisted pairs 34, 35 and 36. Each of the first through eighth insulated conductors 38, 40, 41, 43, 44, 46, 47, 49 is formed by a conductor K surrounded by a layer of dielectric insulating material R, such as a polymer or foamed polymer, common to the cabling art like fluorinated ethylene propylene (FEP), polyethylene (PE) or polypropylene (PP). Further, the insulating material R may be formed by an enamel coating, or another nonconductive coating from a diverse art like motor armature windings. The conductor K may be solid or stranded, and may be formed of a conductive metal or alloy, such as copper. In one embodiment, the conductor K is a solid, copper wire of about twenty three gauge size.

[054] In one embodiment, the insulating material R may have a radial thickness of about seven mils or less, more preferably about five mils or less. This radial thickness of the insulating layer R is at least 20% less than the standard insulation layer thickness of a conductor in a typical equivalent twisted pair wire, more preferably at least 25% to 30% less. Typically, such a thin insulation layer R would not be possible due to the incorrect impedance obtained when the conductors K of the first and second insulated conductors 38 and 40 become so closely spaced during the twisting operation due to the thinner insulating layers R. Typically, such thin insulation layers were not practiced in the background art, because there was no appreciation of a solution to the mechanical and performance problems. By the present invention, the interposed first dielectric tape 39 eases the mechanical stresses during twisting so that the thinner insulating layer R is undamaged and also spaces the conductors K apart so that a proper impedance may be obtained, e.g., one hundred ohms.

[055] As best seen in Figure 5, the first dielectric tape 39 has a first width which extends approximately perpendicular to an extension length of the first dielectric tape 39 from a first edge 51 of the first dielectric tape 39 to an opposing second edge 53 of the first dielectric tape 39. The first width is less than a diameter of the first insulated conductor 38 plus a diameter of the second insulated conductor 40 plus a thickness of the first dielectric tape 39, wherein the thickness is measured by the spacing created between the first and second insulated conductors 38 and 40. A typical spacing might be between four to twelve mils, such as about eight mils or about ten mils. By this arrangement, the twists of the first twisted pair 33 occupy a space within the dashed line 55, which is circumscribed by the helical twisting of the first and second insulated conductors 38 and 40. In this arrangement, the first through eighth insulated conductors 38, 40, 41, 43, 44, 46, 47 and 49 may contact each other if adjacent and also may contact the inner wall of the jacket 32.

[056] In Figure 5, the dielectric tape 39 is formed as a single unitary structure (e.g., the dielectric tape does not include multiple pieces attached together or layered). Figure 5A illustrates that the solid dielectric tape 39 of Figure 5 may be replaced with a dielectric tape 39A having a hollow core filled with a gas, like air (with a dielectric constant of 1.0) or a foamed insulation material (with a dielectric constant approaching 1.0). By filling the hollow core with a gas or material with a lower dielectric constant than a material used to form said first dielectric tape 39 or 39A, the overall dielectric constant of the first dielectric tape 39A may be reduced. The hollow core may extend the entire length of the dielectric tape 39A, resulting in a “straw-like” structure. Alternatively, support structures may be formed at intervals along the length of the dielectric tape 39A to form closed-cell air pockets, each having a short length, such as 1/2 inch, one inch, two inches, etc. Alternatively, one or more support structures may be formed within the hollow core, which extend along the length of the dielectric tape 39A and connect between the lateral walls of the hollow core to resist crushing of the hollow core during the twisting of the first twisted pair 33A. Although the other embodiments of the dielectric tapes of the present invention are illustrated with solid cores, hollow cores, as described in connection with Figure 5A, may be employed in any or all of the other

dielectric tapes. The first twisted pair 33A depicted in Figure 5A may be substituted into the place of the first twisted pair 33 depicted in Figure 4.

[057] The material forming the dielectric tape 39/39A is preferably embedded with randomly spaced strength members 50, such as the short segments of acicular material used to form the separator 37, as detailed above. In the case of the dielectric tapes 39, 42, 45 and 48 and the separator 37, the fibers or materials used to form the acicular material may be randomly oriented within the balls or pellets of polymer loaded into the extruder. As the pellets are melted within the extruder the acicular materials are randomly directed relative to each other. However, as the melt is extruded through the die opening to form the dielectric tape 39, 42, 45 or 48 or the separator 37, the acicular materials will naturally, generally align in the extrusion direction, e.g., along the length of cable.

[058] The general alignment of the acicular materials is best seen in Figures 3, 20B, and 23. The general alignment improves the strength of the dielectric tape and the separator in the longitudinal direction, i.e., the direction of the length of the cable. Further, the general alignment of the acicular material in the longitudinal direction improves the flexibility of the cable, e.g., the ability to curve/bend and route the cable during installation.

[059] As best seen in Figure 3, the first through fourth twisted pairs 33, 34, 35 and 36 may be stranded together in the direction 57 (see the arrow in Figure 3) to form a stranded core. In one embodiment, the core strand direction 57 is opposite to the pair twist directions of the first through fourth twisted pairs 33, 34, 35 and 36. However, this is not a necessary feature, as the strand direction 57 may also be the same as the pair twist directions.

[060] In preferred embodiments, the strand length of the core strand is about five inches or less, more preferably about three inches or less. In a more preferred embodiment, the core strand length is purposefully varied, or modulates, from an average strand length along a length of the cable 31. Core strand modulation can assist in the reduction of alien crosstalk. For example, the core strand length could modulate between two inches and four inches along the length of the cable 31, with an average value of three inches.

[061] The first twist length w (See Figure 3) of the first twisted pair 33 is preferably set to a short length, such as between approximately 0.22 inches and approximately 0.38 inches. The second twist length x of the second twisted pair 34 is different from the first twist length w and is between approximately 0.22 inches and approximately 0.38 inches. For example, the first twist length w may be set to approximately 0.26 inches and the second twist length x may be set to approximately 0.33 inches.

[062] In one embodiment, the first twist length w purposefully modulates from a first average value, such as 0.26 inches. For example, the first twist length could purposefully vary between 0.24 and 0.28 inches along the length of the cable. Likewise, the second twist length could purposefully modulate from a second average value, such as 0.33 inches. For example, the second twist length could purposefully vary between 0.31 and 0.35 inches along the length of the cable.

[063] The third twisted pair 35 would have a third twist length y and the fourth twisted pair 36 would have a fourth twist length of z . In one embodiment, the third twist length y is different from the first, second and fourth twist lengths w , x and z , while the fourth twist length z is different from the first, second and third twist lengths w , x and y . Of course, the third and fourth twisted pairs 35 and 36 could employ a similar twist length modulation, as described in conjunction with the first and second twisted pairs 33 and 34.

[064] Figure 6 is a close-up cross sectional view of a twisted pair 60, having a dielectric tape 61 with an alternative shape, in accordance with a second embodiment of the present invention. The dielectric tape 61 has a width which extends approximately perpendicular to an extension length of the twisted pair 60 from a first edge 62 of the dielectric tape 61 to an opposing second edge 63 of the dielectric tape 61. The width, in the embodiment of Figure 6, is equal to or less than the diameter of the first insulated conductor 38. Less material is used to form the dielectric tape 61 in the embodiment of Figure 6. This presents advantages in reducing the amount of consumable material in the case of a fire, and in reducing the amount of smoke emitted from the cable 31 in the case of a fire. This structure may also reduce the weight and outer diameter of the cable and improve the flexibility of the cable.

[065] As seen in Figure 6, the dielectric tape 61 has a cross sectional shape in a direction perpendicular to an extension length of the twisted pair 60, which presents a first recessed portion 64 for seating the first insulated conductor 38 and a second recessed portion 65 for seating the second insulated conductor 40.

5 **[066]** The cross sectional shapes of the dielectric tapes 39 and 61 in Figures 5 and 6 are mirror symmetrical. However, it is not necessary that the shape be mirror symmetrical in order to achieve many of the advantages of the present invention. Further, the first and second recessed portions 64 and 65 of the dielectric tape 61 in Figure 6 are semi-circular in shape. However, it is not necessary that the first and second
10 recessed portions 64 and 65 be semi-circular. In fact, the recesses in the dielectric tape 39 of Figure 5 for receiving the first and second insulated conductors 38 and 40 are not semi-circular in shape. Also, the first and second recessed portions 64 and 65 may include serrations to create pockets of air adjacent to the seated portions of the first and second insulated conductors 38 and 40.

15 **[067]** Figure 7 is a cross sectional view of a twisted pair cable 66 employing the first twisted pair 60 of Figure 6. The twisted pair cable 66 also includes similarly configured second, third and fourth twisted pairs 67, 68 and 69. The twists of the first, second, third and fourth twisted pairs 60, 67, 68 and 69 occupy respective spaces within the dashed lines 55 (See Figure 6). In this arrangement, the first through eighth insulated
20 conductors 38, 40, 41, 43, 44, 46, 47 and 49 may contact each other and also may contact the inner wall of the jacket 32.

[068] The dielectric tapes 61 may be formed of a same or similar material in a same or similar manner, as described in connection with the dielectric tapes depicted in Figures 3-5A.

25 **[069]** Figure 8 is a close-up cross sectional view of a twisted pair 70, having a dielectric tape 71 with an alternative shape, in accordance with a third embodiment of the present invention. The dielectric tape 71 has a width which extends approximately perpendicular to an extension length of the twisted pair 70 from a first edge 72 of the dielectric tape 71 to an opposing second edge 73 of the dielectric tape 71. The width, in
30 the embodiment of Figure 8, is equal to or less than the diameter of the first insulated conductor 38.

[070] The embodiment of Figure 8 illustrates that the dielectric tape 71 need not have recessed portions 64 and 65 (as shown in Figures 5 and 6) to seat the insulated conductors 38 and 40. Rather, the dielectric tape 71 may be formed as a generally flat member. The dielectric tape 71 will remain between the first and second insulated conductors 38 and 40 due to the frictional forces created during the twisting operation, when the twisted pair 70 is formed.

[071] The dielectric tapes 71 may be formed of a same or similar material in a same or similar manner, as described in connection with the dielectric tapes depicted in Figures 3-5A.

[072] Figure 8A is a close-up cross sectional view of a twisted pair 70A, having a dielectric tape 71A with an alternative shape, in accordance with a fourth embodiment of the present invention. The dielectric tape 71A has a width which extends approximately perpendicular to an extension length of the twisted pair 70A from a first edge 72A of the dielectric tape 71A to an opposing second edge 73A of the dielectric tape 71A. The width, in the embodiment of Figure 8A, is equal to or slightly less than (e.g., two to four mils less than) the diameter of the first insulated conductor 38 plus the diameter of the second insulated conductor 40 plus a thickness of the dielectric tape 71A.

[073] The embodiment of Figure 8A illustrates that the dielectric tape 71A may be a generally flat member having a width which is approximately equal the diameter of the first insulated conductor 38 plus the diameter of the second insulated conductor 40 plus a thickness of the dielectric tape 71A, such as about seventy-two mils plus or minus about three mils.

[074] Figure 8B is a cross sectional view of a twisted pair cable 76 employing the first twisted pair 70A of Figure 8A, in accordance with a preferred embodiment of the present invention. The twisted pair cable 76 also includes similarly configured second, third and fourth twisted pairs 77, 78 and 79. The twists of the first, second, third and fourth twisted pairs 70A, 77, 78 and 79 occupy respective spaces within the dashed lines 55 (See Figure 8A). In this arrangement, the first through eighth insulated conductors 38, 40, 41, 43, 44, 46, 47 and 49 may contact a plus-shaped separator 37A (sometimes referred to as an isolator, a flute or a crossweb) and also may contact inner ends of projections or fins 32A on the inner wall of the jacket 32. Figure 8B shows twelve

projections 32A, however more or fewer projections may be included, with the goal being to hold the core of twisted pairs 70A, 77, 78 and 79 in the center of the cable 76 while creating air pockets around the perimeter of the core of twisted pairs.

[075] The dielectric tapes 71A and the plus-shaped separator 37A may be formed of a same or similar material in a same or similar manner, as described in connection with the dielectric tapes and separator 37 depicted in Figures 3-5A.

[076] Figure 9 is a perspective view of a twisted pair cable 81, in accordance with a fifth embodiment of the present invention. Figure 10 is a cross sectional view of the cable 81 taken along line X--X in Figure 9. The cable 81 includes a jacket 82 formed around and surrounding first, second, third and fourth twisted pairs 83, 84, 85 and 86, respectively.

[077] The fifth embodiment of the invention, as illustrated in Figures 9 and 10, does not include a separator 37 or 37A. However, pair separators (sometimes referred to as tapes, isolators, flutes or crosswebs) may optionally be included, if desired.

[078] As best seen in the cross sectional view of Figure 10, the first twisted pair 83 includes a first insulated conductor 88, a first dielectric tape 89, and a second insulated conductor 90. The first insulated conductor 88 is twisted with the second insulated conductor 90, in a helical fashion, with the first dielectric tape 89 residing between the first insulated conductor 88 and the second insulated conductor 90.

[079] The second twisted pair 84 includes a third insulated conductor 91, a second dielectric tape 92, and a fourth insulated conductor 93. The third insulated conductor 91 is twisted with the fourth insulated conductor 93, in a helical fashion, with the second dielectric tape 92 residing between the third insulated conductor 91 and the fourth insulated conductor 93.

[080] The third twisted pair 85 includes a fifth insulated conductor 94, a third dielectric tape 95, and a sixth insulated conductor 96. The fifth insulated conductor 94 is twisted with the sixth insulated conductor 96, in a helical fashion, with the third dielectric tape 95 residing between the fifth insulated conductor 94 and the sixth insulated conductor 96.

[081] The fourth twisted pair 86 includes a seventh insulated conductor 97, a fourth dielectric tape 98, and an eighth insulated conductor 99. The seventh insulated

conductor 97 is twisted with the eighth insulated conductor 99, in a helical fashion, with the fourth dielectric tape 98 residing between the seventh insulated conductor 97 and the eighth insulated conductor 99.

[082] Figure 11 is a close-up view of the first twisted pair 83, which is similarly constructed to the second, third and fourth twisted pairs 84, 85 and 86. Like the first embodiment of Figures 3-5, each of the first through eighth insulated conductors 88, 90, 91, 93, 94, 96, 97 and 99 is formed by a conductor K surrounded by a layer of dielectric insulating material R. Also, the insulating material R may have a radial thickness of about seven mils or less, more preferably about five mils or less.

[083] Also, the first, second, third and fourth dielectric tapes 89, 92, 95 and 98 may be formed of a same or similar material in a same or similar manner, as described in connection with the dielectric tapes depicted in Figures 3-5A.

[084] As best seen in Figure 11, the first dielectric tape 89 has a first width which extends approximately perpendicular to an extension length of the first twisted pair 83 from a first edge 101 of the first dielectric tape 89 to a second edge 103 of the first dielectric tape 89. The first width is greater than a diameter of the first insulated conductor 88 plus a diameter of the second insulated conductor 90 plus a thickness of the first dielectric tape 89, wherein the thickness is measured by the spacing created between the first and second insulated conductors 88 and 90. A typical spacing might be between four to twelve mils, such as about eight mils or about ten mils. By this arrangement, the twists of the first twisted pair 83 occupy a space within the dashed line 105, which is circumscribed by the helical twisting of the first and second edges 101 and 103 of the first dielectric tape 89. In this arrangement, the first through eighth insulated conductors 88, 90, 91, 93, 94, 96, 97 and 99 do not contact each other and also do not contact the inner wall of the jacket 82. Rather, a small air pocket 107 is maintained around the outer perimeter of the dielectric insulating material R. Hence, the first insulated conductor 88 would be spaced from the inner wall of the jacket 82 by a first minimum distance, where the first minimum distance could be fixed in the range of one to twenty mils, such as two mils or four mils. Moreover, the first insulated conductor 88 would be spaced from any other insulated conductor of another twisted pair 84, 85 or 86 of the cable 81 by a second minimum distance. The second minimum distance would equal twice the first minimum

distance, because the small air pocket 107 of the first twisted pair 83 would be added to the small air pocket 107 of the other twisted pair 84, 85 or 86.

[085] As in the first embodiment of Figures 3-5, the first through fourth twisted pairs 83, 84, 85 and 86 may be stranded together in the direction 109 (see the arrow in figure 9) to form a stranded core. In one embodiment, the core strand direction 109 is opposite to the pair twist directions of the first through fourth twisted pairs 83, 84, 85 and 86. However, this is not a necessary feature. The core strand length and pair twist lengths w, x, y and z may be tight, as described in conjunction with Figures 3-5, and may optionally be modulated.

[086] As best seen in the cross sectional view of Figure 11, the first dielectric tape 89 includes first and second recesses 111 and 113 to seat the first and second insulated conductors 88 and 90. The first and second recesses 111 and 113 may assist in properly positioning the three parts 88, 89 and 90 of the first twisted pair 83 during a manufacturing process, and may also assist in keeping the three parts 88, 89 and 90 of the first twisted pair 83 in place during use of the cable 81 (e.g., pulling of the cable through conduits or ductwork). However, many advantages of the invention may be achieved without the recesses 111 and 113, as will be seen in Figure 12.

[087] Figure 12 is a close-up cross sectional view of a twisted pair 120, having a dielectric tape 121 with an alternative shape, in accordance with a sixth embodiment of the present invention. The dielectric tape 121 has a width which extends approximately perpendicular to an extension length of the twisted pair 120 from a first edge 122 of the dielectric tape 121 to a second edge 123 of the dielectric tape 121. Like the embodiment of Figures 9-11, the width of the dielectric tape 121 is greater than the diameter of the first insulated conductor 88 plus the diameter of the second insulated conductor 90 plus a thickness of the first dielectric tape 121. The dielectric tape 121 may be formed as a generally flat member. The dielectric tape 121 will remain between the first and second insulated conductors 88 and 90 due to the frictional forces created during the twisting operation, when the twisted pair 120 is formed.

[088] The dielectric tape 121 may be formed of a same or similar material in a same or similar manner, as described in connection with the dielectric tapes depicted in Figures 3-5A.

[089] Figure 13 is a close-up cross sectional view of a twisted pair 130, having a dielectric tape 131 with an alternative shape, in accordance with a seventh embodiment of the present invention. The dielectric tape 131 has a width which extends approximately perpendicular to an extension length of the twisted pair 130 from a first edge 132 of the dielectric tape 131 to a second edge 133 of the dielectric tape 131. The dielectric tape 131 has a cross sectional shape in a direction perpendicular to an extension length of the twisted pair 130, which presents a first recessed portion 135 for seating the first insulated conductor 88 and a second recessed portion 136 for seating the second insulated conductor 90.

[090] The first edge 132 of the first dielectric tape 131 in Figure 13 will circumscribe an area 105 around the first twisted pair 130, which includes the small air gaps 107. However, the width of the first dielectric tape 131 is only slightly more than one-half the width of the dielectric tape 89 in the embodiment of Figures 9-11. Figure 14 illustrates a cable 140 with a jacket 141, wherein the first twisted pair 130 is stranded with three other similarly-configured twisted pairs, namely a second twisted pair 142, a third twisted pair 143 and a fourth twisted pair 144.

[091] The dielectric tapes 131 may be formed of a same or similar material in a same or similar manner, as described in connection with the dielectric tapes depicted in Figures 3-5A.

[092] Some of the advantages of the seventh embodiment of Figures 13 and 14 over the fifth embodiment of Figures 9-11 are that the material cost, and the weight of the cable 140 can be reduced. Yet, the seventh embodiment of Figures 13 and 14 will still create the small air gaps 107, primarily due to the tight twist lengths of the first through fourth twisted pairs 130, 142, 143 and 144.

[093] Figure 15 is a close-up cross sectional view of a twisted pair 150, having a dielectric tape 151 with an alternative shape, in accordance with a eighth embodiment of the present invention. The eighth embodiment is identical to the seventh embodiment of Figures 13 and 14, except that the dielectric tape 151 does not have recessed seats 135 and 136 to seat the first and second insulated conductors 88 and 90. Rather, the dielectric tape 151 has a substantially rectangular cross sectional shape. The dielectric tape 151 will remain between the first and second insulated conductors 88 and 90 due to the

frictional forces created during the twisting operation, when the twisted pair 150 is formed.

[094] The dielectric tapes 151 may be formed of a same or similar material in a same or similar manner, as described in connection with the dielectric tapes depicted in
5 Figures 3-5A.

[095] Figure 16 is a close-up cross sectional view of a twisted pair 160A, having a dielectric tape 161A with an alternative shape, in accordance with a ninth embodiment of the present invention. The ninth embodiment includes a first insulated conductor 88, a first dielectric tape 161A, and a second insulated conductor 90. The first insulated
10 conductor 88 is twisted with the second insulated conductor 90 with the first dielectric tape 161A residing between the first insulated conductor 88 and the second insulated conductor 90 to form the twisted pair 160A. The dielectric tape 161A has a width which extends approximately perpendicular to an extension length of the twisted pair 160A from a first edge 162 of the dielectric tape 161A to an opposing second edge 163 of the
15 dielectric tape 161A. The width, in the embodiment of Figure 16, is equal to or less than the diameter of the first insulated conductor 88.

[096] The embodiment of Figure 16 is similar in most regards to the embodiment of Figure 8, but illustrates that the dielectric tape 161A may include a plurality of ridges 164A and valleys 165A on at least a first side of the first dielectric tape
20 161A facing to the first insulated conductor 88. In a preferred embodiment, the first dielectric tape 161A includes a plurality of ridges 164A and valleys 165A on both the first side of the first dielectric tape 161A facing to the first insulated conductor 88 and on a second side of the first dielectric tape 161A facing to the second insulated conductor 90.

[097] The dielectric tape 161A may be formed of a same or similar material in a same or similar manner, as described in connection with the dielectric tapes depicted in
25 Figures 3-5A. Alternatively, and as illustrated in Figure 16A, the dielectric tape 161A' may be formed of a polymer (as listed in conjunction with Figures 3-5A) with embedded continuous strands or strengthen members 275, which extend from one end of the cable to an opposite end of the cable. Figure 16A is a perspective view and two strengthen
30 members 275 have been illustrated as extending away from the rear end of the dielectric tape 161A', so as to demonstrate the continuous nature of the strengthen members along

the entire length of the dielectric tape 161A. In practice, the strength members 275 would be cut flush with the end of the dielectric tape 161A.

[0098] The insulation layers R of the first and second insulated conductors 88 and 90 engage the ridges 164A, so that the valleys 165A introduces air immediately adjacent to the insulation layers R of the first and second insulated conductors 88 and 90. Air has a dielectric constant of approximately 1.0, and the introduction of air close to the insulation layers R improves the overall dielectric constant of the first dielectric tape 161A, e.g., reduces the overall dielectric constant of the first dielectric tape 161A.

[0099] In Figure 16, the plurality of ridges 164A are shaped in the form of angled peaks, and the plurality of valleys 165A are shaped in the form of angled valleys. The actual shapes of the ridges and/or valleys are not critical. Rather, an important aspect is the introduction of air into the first and second surfaces of the first dielectric tape 161A, which contact the first and second insulated conductors 88 and 90.

[0100] Figure 17 is a close-up cross sectional view of a twisted pair 160B, having a dielectric tape 161B with an alternative shape, in accordance with a tenth embodiment of the present invention. The tenth embodiment is the same as the ninth embodiment, except that the plurality of ridges 164B are shaped in the form of rectangular protrusions, and the plurality of valleys 165B are shaped in the form of rectangular recesses.

[0101] The dielectric tape 161B may be formed of a same or similar material in a same or similar manner, as described in connection with the dielectric tapes depicted in Figures 3-5A.

[0102] Figure 18 is a close-up cross sectional view of a twisted pair 160C, having a dielectric tape 161C with an alternative shape, in accordance with an eleventh embodiment of the present invention. The eleventh embodiment is the same as the ninth and tenth embodiments, except that the plurality of ridges 164C are shaped in the form of curved protrusions, and the plurality of valleys 165C are shaped in the form of curved recesses.

[0103] The dielectric tape 161C may be formed of a same or similar material in a same or similar manner, as described in connection with the dielectric tapes depicted in Figures 3-5A.

[0104] Figure 19 is a close-up cross sectional view of a twisted pair 160D, having a dielectric tape 161D with an alternative configuration, in accordance with a twelfth embodiment of the present invention. The twelfth embodiment is the same as the ninth embodiment, in that the plurality of ridges 164D are shaped in the form of angled peaks, and the plurality of valleys 165D are shaped in the form of angled valleys. However, in the twelfth embodiment, the first dielectric tape 161D is formed of at least two different materials. A first side 168 of the first dielectric tape 161D, facing to the first insulated conductor 88, and a second side 167 of the first dielectric tape 161D, facing to the second insulated conductor 90, are formed of a first dielectric material. A mid-portion 166 of the first dielectric tape 161D is formed of a second dielectric material. A first dielectric constant of the first material is different from a second dielectric constant of the second material. In a preferred embodiment, the second dielectric constant is lower than the first dielectric constant. The second material improves the overall dielectric constant of the first dielectric tape 161D, e.g., reduces the overall dielectric constant of the first dielectric tape 161D.

[0105] The first dielectric material may be formed of a same or similar material, as described in connection with the dielectric tapes depicted in Figures 3-5A. The second dielectric materials may be formed of a material with a lower dielectric constant than the first material, such as a highly foamed polymer.

[0106] Figures 20 and 20A are close-up cross sectional views of a twisted pair 160E, having a dielectric tape 161E with an alternative configuration, in accordance with a thirteenth embodiment of the present invention. The thirteenth embodiment is the same as the twelfth embodiment, in that the plurality of ridges 164E are shaped in the form of angled peaks, and the plurality of valleys 165E are shaped in the form of angled valleys. However, in the thirteenth embodiment, the construction of the first dielectric tape 161E is different. In Figure 20, the first side 168 of the first dielectric tape 161E, facing to the first insulated conductor 88 is attached to the second side 167 of the first dielectric tape 161E, facing to the second insulated conductor 90 along the first edge 162 and along the second edge 164.

[0107] Like the embodiment depicted in, and described in relation to Figure 5A, the first dielectric tape 161E has a hollow core which may possess a gas (See Figure

20A), like air 166A (with a dielectric constant of about 1.0) or, as depicted in Figure 20, a foamed insulation material 166 (with a dielectric constant approaching 1.0, e.g., like 1.3 or 1.2). Again, the material 166 would have a lower dielectric constant than a material used to form the remaining portions of the first dielectric tape 161E. By filling the
5 hollow core with a gas or material with a lower dielectric constant than a material used to form the remaining portions of the first dielectric tape 161E, the overall dielectric constant of the first dielectric tape 161E may be reduced.

[0108] The first dielectric material may be formed of a same or similar material, as described in connection with the dielectric tapes depicted in Figures 3-5A. The
10 attachment portions between the first and second sides 168 and 167 of the first dielectric tape 161E along the first edge 162 and along the second edge 164 each include the embedded acicular material, e.g., the high strength fibers. The reinforced strength materials residing entirely around the perimeter of the lower dielectric material will protect the stability of the dielectric tape during high speed production. In other words,
15 the dielectric tape will not tend to tear apart, separate or delaminate at the weaker, lower dielectric layer.

[0109] Further, the impact and pressure induced between the dielectric tape and insulation layers R of the first and second insulated conductors 88 and 90 by the twisting operation during cable manufacturing will be better tolerated by the high strength
20 material, which is less susceptible to crushing. The lower dielectric material, e.g., the highly foamed material, which can crush more easily, will be protected in the middle of the dielectric tape 161E.

[0110] The hollow core or the lower dielectric material in the middle may extend the entire length of the dielectric tape 161E, resulting in a “straw-like” structure.
25 Alternatively, support structures may be formed at intervals IN1, IN2, IN3, ... along the length of the dielectric tape 161E to form closed-cell air pockets or closed-cell lower dielectric material pockets, each having a short length, such as 1/2 inch, one inch, two inches, etc., as graphically shown, not to scale, in Figure 20B. Alternatively, one or more support structures may be formed within the hollow core, which extend along the length
30 of the dielectric tape 161E and connect between the first and second sides 168 and 167 of

the hollow core to resist crushing of the hollow core during the twisting of the twisted pair 160E.

[0111] In cables of the background art, different twist lengths were applied to each of the four twisted pairs. The different twist lengths had the benefit of reducing crosstalk between adjacent pairs within the cable. However, employing different twist lengths also created drawbacks, such as delay skew (e.g., it takes more time for a signal to travel to the far end of the cable on a relatively tighter twisted pair, as compared to a relatively longer twisted pair in the same cable). Differing twist lengths can also cause relative differences between the twisted pairs in such performance characteristics as attenuation and impedance.

[0112] In the background art, the insulation layers R were varied in thickness and/or material composition to compensate for the differences. For example, the insulation layers R of the insulated conductors 91 and 93 in the tighter twisted pair 84 (in Figure 9) could be formed of a material with a different dielectric constant than the insulation layers R of the insulated conductors 94 and 96 in the longer twisted pair 85 (in Figure 9). Also, air could be introduced into the insulation layers R to foam the insulation layers R. The foaming could be set at different levels for one or more of the twisted pairs, depending upon their twist length.

[0113] Such measures of the background art helped to offset the different performance characteristics induced by the different twist lengths of the twisted pairs. However, there was an added cost in that the insulated conductors used in different twisted pairs of the same cable had to be manufactured differently. This created a need for inventorying different types of insulated conductors and added more complexity in the manufacturing process.

[0114] In accordance with one embodiment of the present invention, the insulated conductors 38, 40, 41, 43, 44, 46, 47 and 49 of each of the twisted pairs 33, 34, 35 and 36 in the cable 31 may be made structurally identical (noting that certain non-structural features, like colors, stripe patterns or printed indicia may be employed to merely identify the insulated conductors from each other). In embodiments of the present invention, the dielectric tape structures can be used to mitigate the performance differences, which arise when different twist lengths are employed in the twisted pairs. Moreover, the insulated

conductors 38, 40, 41, 43, 44, 46, 47 and 49 may be made structurally identical and also be identical in appearance. In embodiments of the present invention, the color of, or indicia on, the first through fourth dielectric tapes 39, 42, 45 and 48 could be used to distinguish between the first through fourth twisted pairs 33, 34, 35 and 36 of the cable 31, when the cable 31 is terminated and a connector is attached thereto.

[0115] For example, the dielectric tape of one twisted pair of a given cable may be different in shape, size or material content as compared to the dielectric tape of another twisted pair in the same cable. In Figure 4, the first dielectric tape 39 of the first twisted pair 33 has a first thickness, which sets a spacing distance between the first insulated conductor 38 and the second insulated conductor 40. In the third twisted pair 35, the third dielectric tape 45 has a second thickness, which sets a spacing distance between the fifth insulated conductor 44 and the sixth insulated conductor 46. The second thickness is different from the first thickness, which also means that the shape of the first dielectric tape 39 is different than the shape of the third dielectric tape 45.

[0116] In one embodiment, the difference between the second thickness and the first thickness is at least 1 mil. For example, the first dielectric tape 39 could have a thickness of about 10 mils, whereas the third dielectric tape 45 could have a thickness of about 8 mils. Such a change in thickness and shape will affect the respective performance characteristics of the first twisted pair 33 and the third twisted pair 35, such as their respective attenuation, impedance, delay skew, etc.

[0117] Also in Figure 4, the first dielectric tape 39 of the first twisted pair 33 has a first width, which extends approximately perpendicular to an extension length of said cable 31 from its first edge 51 to its second edge 53 (See Figure 5). In the fourth twisted pair 36, the fourth dielectric tape 48 has a second width, which extends approximately perpendicular to the extension length of said cable 31 from its corresponding first edge 51 to its corresponding second edge 53. The second width is different from the first width. For example, the second width may be several mils shorter than the first width, such as about 2 to 12 mils shorter, e.g., about 5 mils shorter. Again, the respective differences in width will serve to create differences in performance characteristics, which can be adjusted and used to offset for the performance differences created by the different twist lengths.

[0118] Also in Figure 4, the first dielectric tape 39 of the first twisted pair 33 is formed of a first material having a first dielectric constant. In the second twisted pair 34, the second dielectric tape 42 is formed of a second material having a second dielectric constant. The second dielectric constant is different from the first dielectric constant due to the embedding of a greater number of high strength members, i.e., acicular material (as illustrated by the greater number of end sections of the acicular material visible in the cross section of the second dielectric tape 42 as compared to the first dielectric tape 39). The dielectric constants can also be made different by employing a different base polymer for different tapes and/or due to a different foaming percentage between different tapes using a same base polymer. The dielectric constants can also be made different between dielectric tapes by changing the size or material content of the high strength members in one dielectric tape relative to another dielectric tape. The statement "wherein a number, size or material content of plural first segments of acicular material in a first dielectric tape is different than a number, size or material content of plural second segments of acicular material in a second dielectric tape," is meant to encompass the situation wherein the numbers are the same, the sizes are the same and only the materials are different. Likewise, the statement would encompass the situation wherein the sizes are the same, but the numbers are different and the materials are different.

[0119] For example, the second dielectric constant could differ from the first dielectric constant by about 0.1 to about 0.8, e.g., the first dielectric constant might be 1.2, whereas the second dielectric constant is 1.4, thus illustrating a difference of 0.2 in dielectric constant between the two materials. Again, the respective differences in material will serve to create differences in performance characteristics, which can be adjusted and used to offset for the performance differences created by the different twist lengths. Of course, the differences between the dielectric tapes can also be employed as a supplemental measure in conjunction with differences in insulation layers on the insulated conductors to provide an additional ability to compensate for performance differences between the twisted pairs.

[0120] The cables 31, 66, 81 and 140 of the present invention may be manufactured using standard twisting equipment, such as a double twist twinning machine, known in the art of twisted pair cable making. An additional spool would be

added to feed the dielectric tape into the twisting machine between the insulated conductors of the twisted pair.

[0121] Although, the cables illustrated in the drawing figures have included four twisted pairs, it should be appreciated that the present invention is not limited to cables having only four twisted pairs. Cables having other numbers of twisted pairs, such as one twisted pair, two twisted pairs or even twenty-five twisted pairs, could benefit from the structures disclosed in the present invention. Further, although the drawing figures have illustrated that each of the twisted pairs within the cable have a dielectric tape, it would be possible for less than all of the twisted pairs to have the dielectric tape. For example, the first through third twisted pairs could include a dielectric tape, while the fourth twisted pair could be formed without a dielectric tape. Further, although the drawing figures have illustrated an unshielded cable, it is within the scope of the appended claims that the cable could include a shielding layer and/or a core wrap between the core of twisted pairs and the inner wall of the outermost jacket. Further, although some drawing figures have illustrated a jacket having a smooth inner wall, it is within the scope of the present invention that in all embodiments the inner wall of the jacket could include fins or projections (as illustrated in Figure 8B) for creating air pockets around the perimeter of the core of twisted pairs. Further, all embodiments of the present invention may include a separator (e.g., tape, isolator, flute, crossweb).

[0122] The high strength material, e.g., embedded acicular material, may also be employed for a separator 37 or 37A (e.g., tape, isolator, flute, crossweb) in a cable wherein the twisted pairs are formed without a dielectric tape disposed between the insulated conductors. For example, Figure 21 is a perspective view of a twisted pair cable 231. Figure 22 is a cross sectional view of the cable 231 taken along line XXII--XXII in Figure 21. The cable 231 includes a jacket 232 with six fins 293 and six recesses 295 (similar to the twelve fins 32A and twelve recesses of the jacket 32 of Figure 8B). The jacket 232 is formed around and surrounding first, second, third and fourth twisted pairs 233, 234, 235 and 236, respectively.

[0123] A separator 37 is formed the same as described in relation to Figures 3 and 4, i.e., the separator 37 includes embedded strength members, best seen in the cross

section of Figure 22. The separator 37 is formed as a single unitary structure (e.g., the separator 37 does not include multiple pieces attached together or layered).

[0124] As best seen in the cross sectional view of Figure 22, the first twisted pair 233 includes a first insulated conductor 238 and a second insulated conductor 240. The first insulated conductor 238 is twisted with the second insulated conductor 240, in a helical fashion. The second twisted pair 234 includes a third insulated conductor 241 and a fourth insulated conductor 243. The third insulated conductor 241 is twisted with the fourth insulated conductor 243, in a helical fashion. The third twisted pair 235 includes a fifth insulated conductor 244 and a sixth insulated conductor 246. The fifth insulated conductor 244 is twisted with the sixth insulated conductor 246, in a helical fashion. The fourth twisted pair 236 includes a seventh insulated conductor 247 and an eighth insulated conductor 249. The seventh insulated conductor 247 is twisted with the eighth insulated conductor 249, in a helical fashion.

[0125] The twist lengths w, x, y and z and core twist 57 may be set or modulated as described in conjunction with Figures 3 and 4. Figures 21 and 22 also illustrate a shielding layer 297. The shielding layer 297 may be formed of a bi-layered material, such as Mylar and aluminum foil. However, other types of shielding materials may be used. In the depicted embodiment, the shielding layer 297 is overlapped at area 299 and may optionally be adhered to itself at area 299.

[0126] Figure 23 is a perspective view of a twisted pair cable 231A. Figure 24 is a cross sectional view of the cable 231 taken along line XXIV--XXIV in Figure 23. The cable 231A includes a jacket 232A with twelve fins 293A and twelve recesses 295A (the same as the twelve fins 32A and twelve recesses of the jacket 32 of Figure 8B). The jacket 232A is formed around and surrounding the first, second, third and fourth twisted pairs 233, 234, 235 and 236. The first, second, third and fourth twisted pairs 233, 234, 235 and 236 may be formed identically to the twisted pairs of Figures 21 and 22.

[0127] A separator 37A is formed the same as described in relation to Figure 8B, i.e., the separator 37A is a cross web and includes embedded strength members, best seen in the cross section of Figure 24. Figures 23 and 24 also illustrate an alternative shielding layer 297A. The shielding layer 297A may be formed of a bi-layered material, such as Mylar and aluminum foil. However, other types of shielding materials may be used. In

the depicted embodiment, the shielding layer 297A is spirally or helically wrapped around the cable core and overlapped at areas 299A and may optionally be adhered to itself at areas 299A.

[0128] Figure 25 is a cross sectional view of a twisted pair cable with a coated paper separator 37B. The paper/hybrid separator tape 37B is made of a paper layer 287 with a fire-retardant coating 289 applied to both sides of the paper layer 287. The paper layer 287 may optionally be formed of a blend of paper and microfibers, PET for example.

[0129] The strength data based upon a model of a dielectric tape having a width (from the first edge 72A to the second edge 73A in Figure 8A) of about 171 mils and a thickness (from the side in contact with the first insulated conductor 38 to the side in contact with the second insulated conductor 40) of about 10 mils, has been computed. The present production machinery running at top speed for forming a cable with a twisted pair cable employing a dielectric tape 71A between the first and second insulated conductor 38 and 40 requires a yield strength of about 2000 psi for the dielectric tape 71A in order to avoid damage to the dielectric tape 71A. A dielectric tape 71A without embedded strength members in the dimensions of about 171 mils in width and about 10 mils in thickness has a yield strength of about 1,700 psi. The dielectric tape 71A with the embedded strengthen members, in accordance with the present invention, will exceed 2,000 psi in yield strength, so that the manufacturing machinery can produce cables with bisector tapes at full speed. In accordance with preferred embodiments of the present invention, the dielectric tape will exhibit a psi yield strengthen of about 2,300 psi.

[0130] The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are to be included within the scope of the following claims.

We Claim:

1. A cable comprising:

5 a first insulated conductor, a first dielectric tape, and a second insulated conductor, wherein said first insulated conductor is twisted with said second insulated conductor with said first dielectric tape residing between said first insulated conductor and said second insulated conductor to form a first twisted pair; and

a jacket formed around said first twisted pair, wherein said first dielectric tape has at least one strength member embedded therein.

10

2. The cable according to claim 1, wherein said at least one strength member is formed of plural segments of acicular material embedded within said first dielectric tape.

15 3. The cable according to claim 2, wherein said acicular material includes fibers formed of fire retardant material.

4. The cable according to claim 2, wherein said acicular material includes at least one of plural aramid yarns, plural fiber glass strands, plural carbon fibers and plural carbon nanotubes.

20

5. The cable according to claim 1, wherein said at least one strength member is formed of a member embedded within said first dielectric tape which extends along the entire length of the cable.

25 6. The cable according to claim 1, wherein said first dielectric tape is formed as a single unitary structure which does not include multiple pieces attached together or layered.

30 7. The cable according to claim 1, wherein said first dielectric tape includes a hollow core partitioned into closed-cell pockets along a length of said first dielectric tape.

8. The cable according to claim 7, wherein said closed-cell pockets are filled with air.

9. The cable according to claim 7, wherein said closed-cell pockets are filled with a dielectric material having a lower dielectric constant than the material of said first dielectric tape surrounding said closed-cell pockets.

10. The cable according to claim 1, further comprising:

a third insulated conductor, a second dielectric tape, and a fourth insulated conductor, wherein said third insulated conductor is twisted with said fourth insulated conductor with said second dielectric tape residing between said third insulated conductor and said fourth insulated conductor to form a second twisted pair, and wherein said jacket is also formed around said second twisted pair, and wherein said second dielectric tape has at least one strength member embedded therein.

11. The cable according to claim 10, wherein said at least one strength member of said first dielectric tape is formed of plural first segments of acicular material embedded within said first dielectric tape, wherein said at least one strength member of said second dielectric tape is formed of plural second segments of acicular material embedded within said second dielectric tape.

12. The cable according to claim 11, wherein said first dielectric tape is different in shape, size or material content as compared to said second dielectric tape.

13. The cable according to claim 12, wherein a number, size or material content of said plural first segments of acicular material is different than a number, size or material content of said plural second segments of acicular material.

14. The cable according to claim 1, wherein said first dielectric tape is formed of at least two different materials, and wherein said first and second sides of said first dielectric tape are formed of a first material, and wherein a mid-portion of said first

dielectric tape is formed of a second material, and wherein a first dielectric constant of said first material is different from a second dielectric constant of said second material.

15. The cable according to claim 14, wherein the dielectric constant of said first material is greater than a dielectric constant of said second material.

16. The cable according to claim 14, wherein said at least one strength member is formed of plural segments of acicular material embedded within said first material of said first dielectric tape.

17. A cable comprising:

a first insulated conductor, a first dielectric tape, and a second insulated conductor, wherein said first insulated conductor is twisted with said second insulated conductor with said first dielectric tape residing between said first insulated conductor and said second insulated conductor to form a first twisted pair;

a third insulated conductor, a second dielectric tape, and a fourth insulated conductor, wherein said third insulated conductor is twisted with said fourth insulated conductor with said second dielectric tape residing between said third insulated conductor and said fourth insulated conductor to form a second twisted pair;

a jacket formed around said first and second twisted pairs, wherein said first dielectric tape has at least one first strength member embedded therein, and wherein said second dielectric tape has at least one second strength member embedded therein; and

a separator disposed within said jacket and separating said first twisted pair from said second twisted pair, wherein said separator includes at least one third strength member embedded therein.

18. A cable comprising:

a first insulated conductor and a second insulated conductor, wherein said first insulated conductor is twisted with said second insulated conductor to form a first twisted pair;

a third insulated conductor and a fourth insulated conductor, wherein said third insulated conductor is twisted with said fourth insulated conductor to form a second twisted pair;

a jacket formed around said first and second twisted pairs; and

5 a separator disposed within said jacket and separating said first twisted pair from said second twisted pair, wherein said separator includes plural segments of acicular material embedded within said separator.

10 19. The cable according to claim 18, wherein said separator is formed as a single unitary structure which does not include multiple pieces attached together or layered, and wherein said acicular material includes fibers formed of fire retardant material.

15 20. The cable according to claim 18, wherein said acicular material includes at least one of plural aramid yarns, plural fiber glass strands, plural carbon fibers and plural carbon nanotubes.

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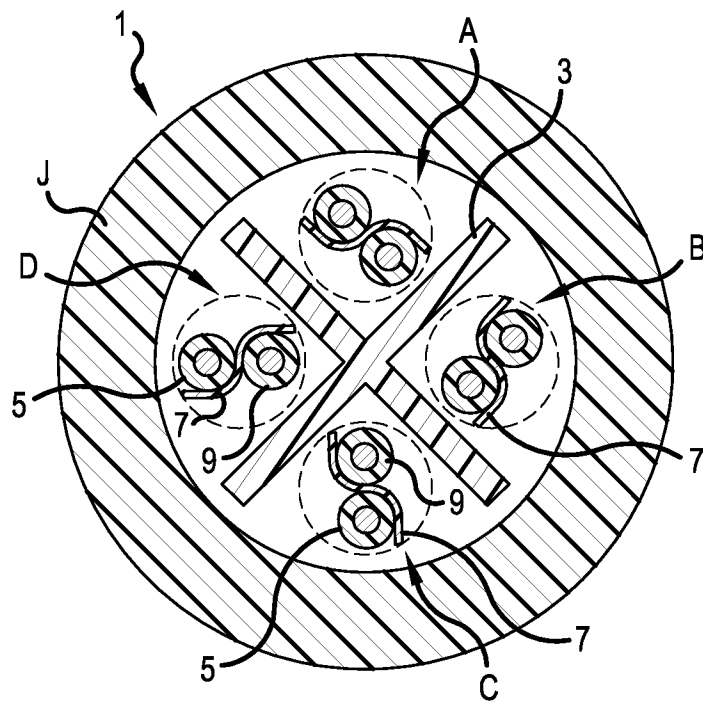


FIG. 1
PRIOR ART

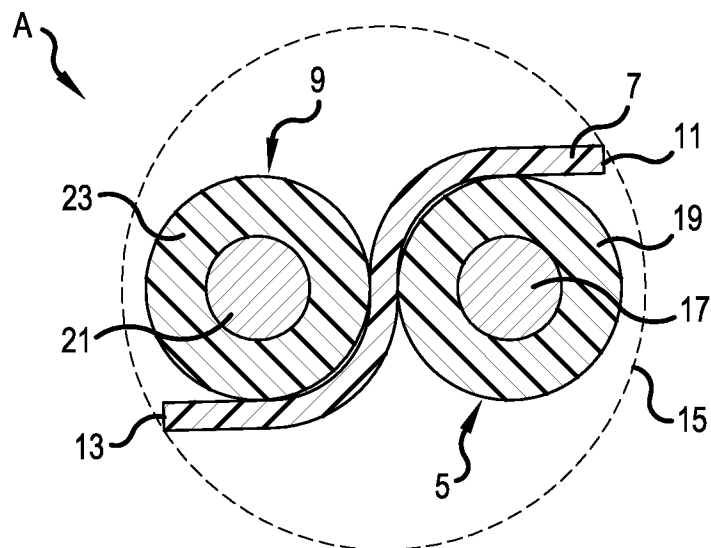


FIG. 2
PRIOR ART

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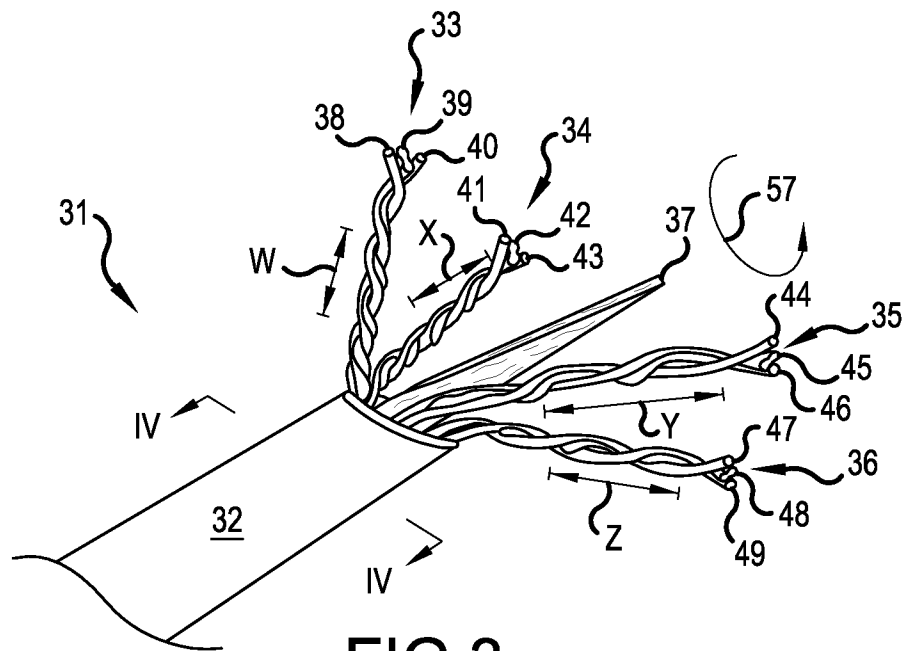


FIG.3

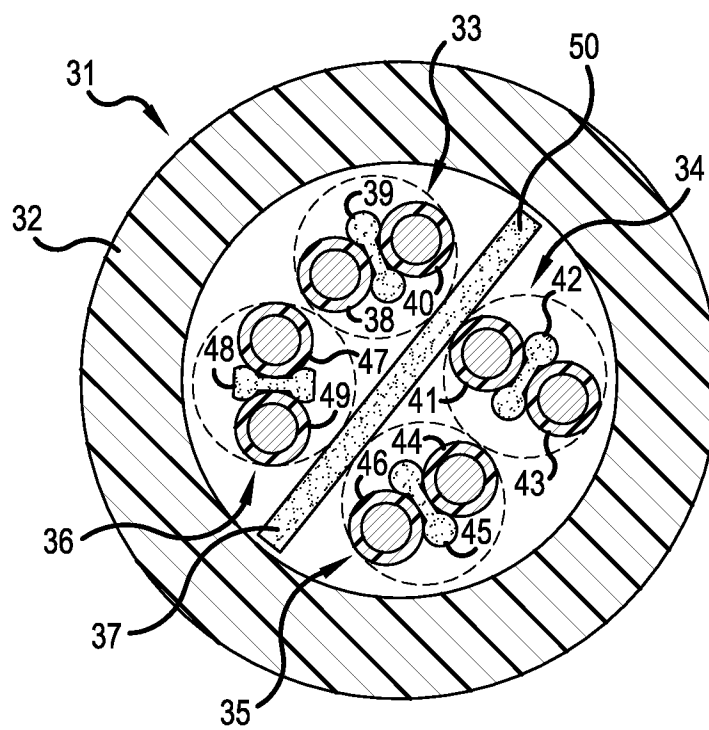


FIG.4

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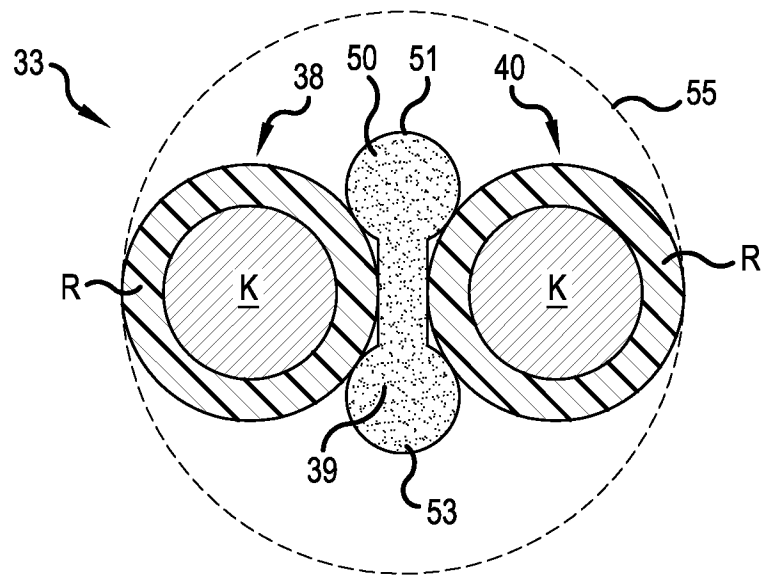


FIG. 5

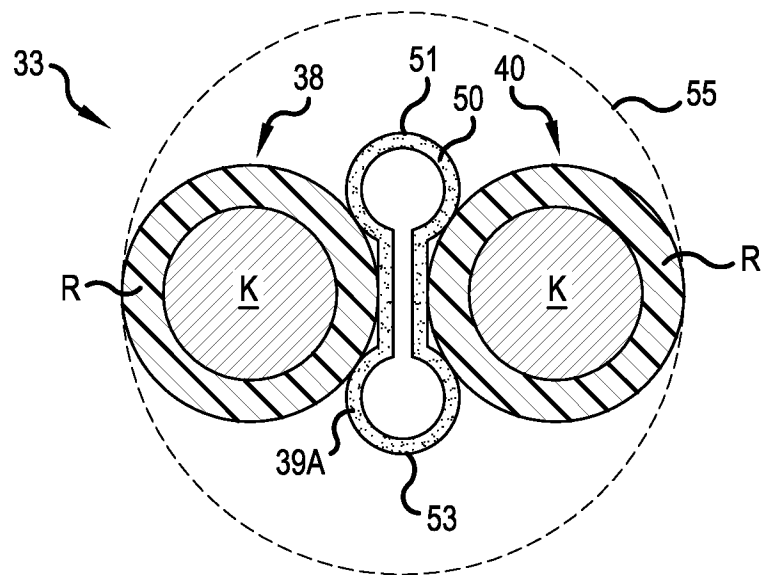


FIG. 5A

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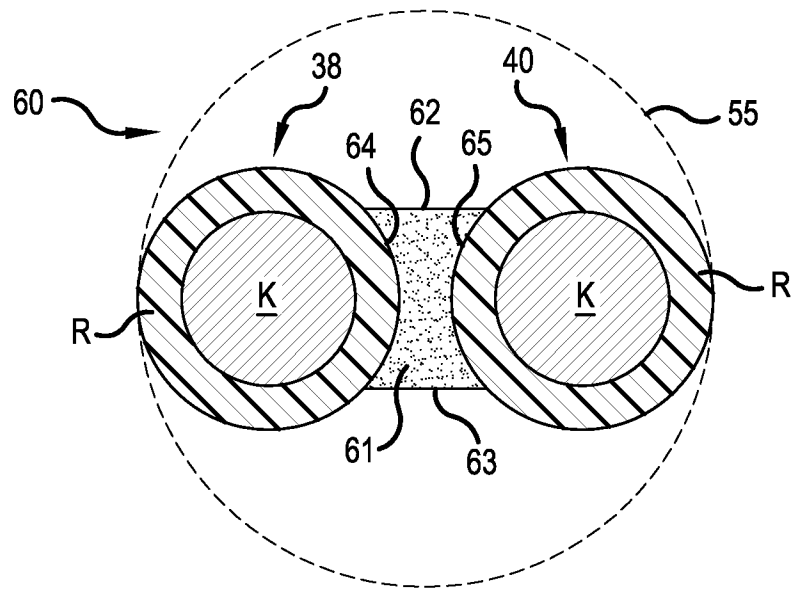


FIG.6

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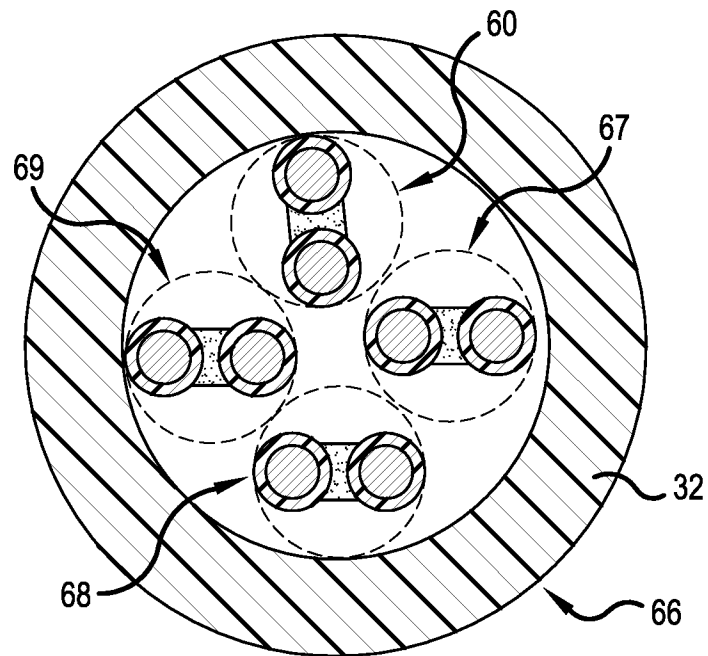


FIG. 7

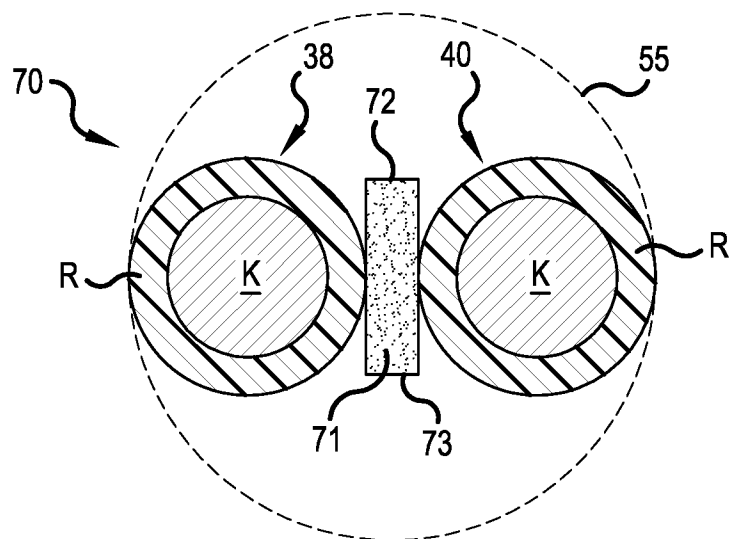


FIG. 8

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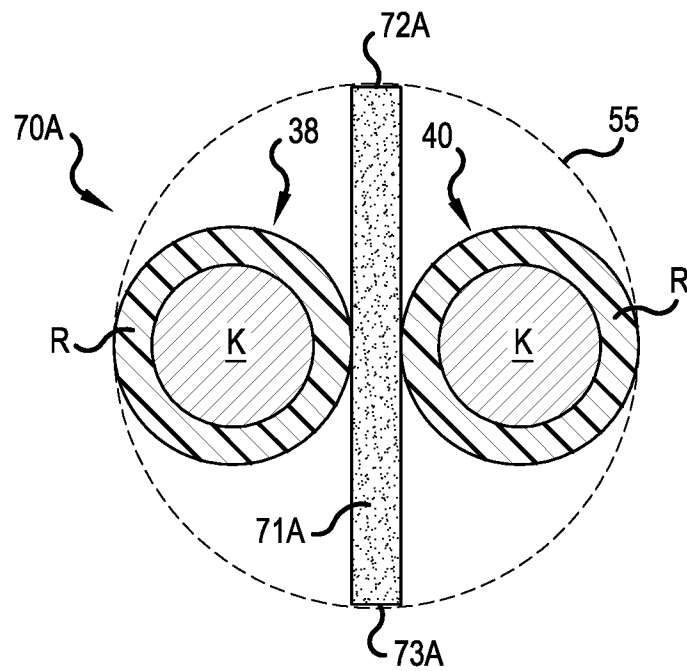


FIG. 8A

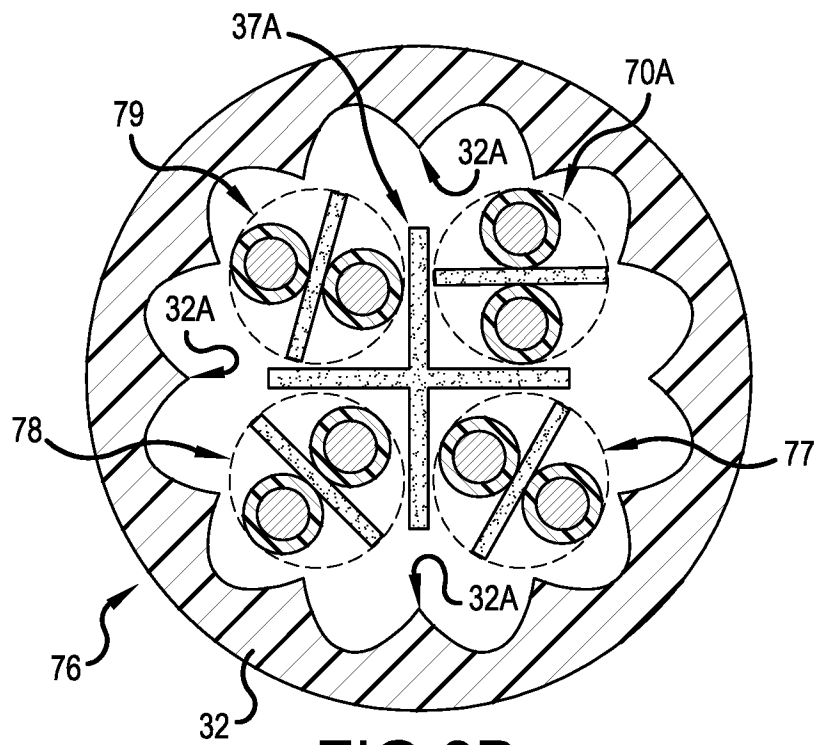


FIG. 8B

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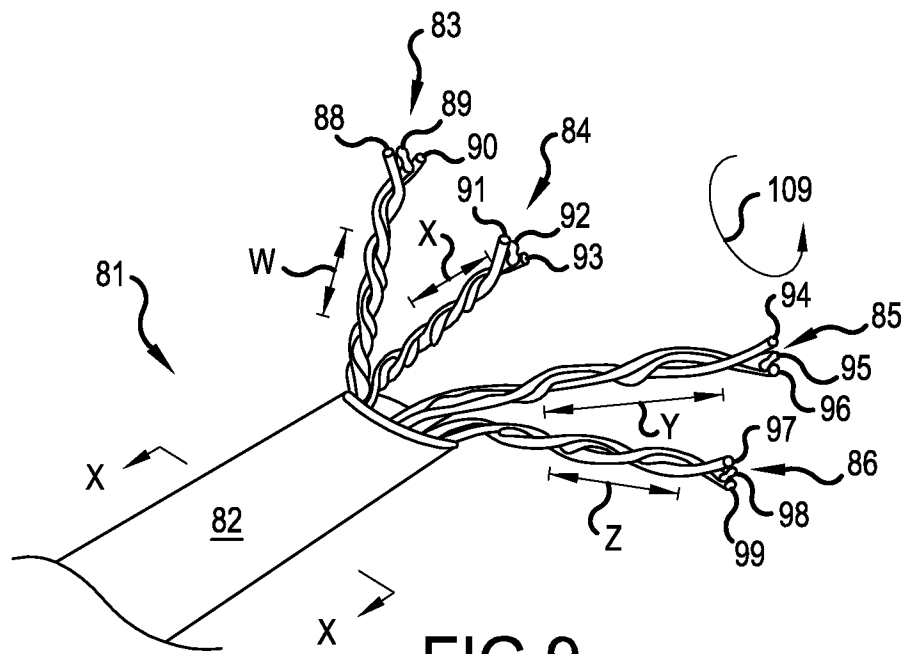


FIG. 9

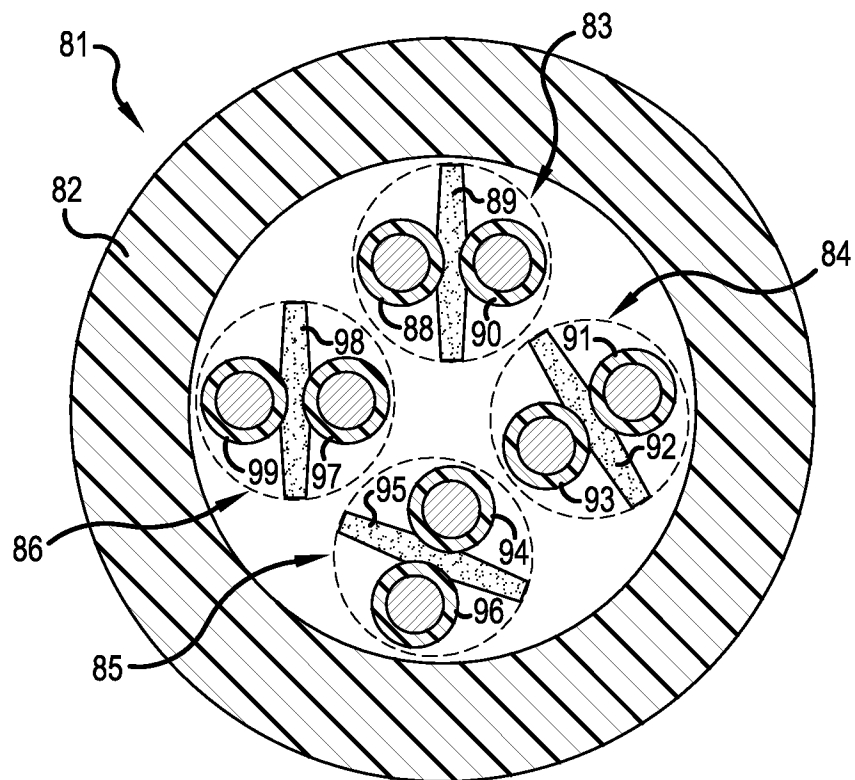


FIG. 10

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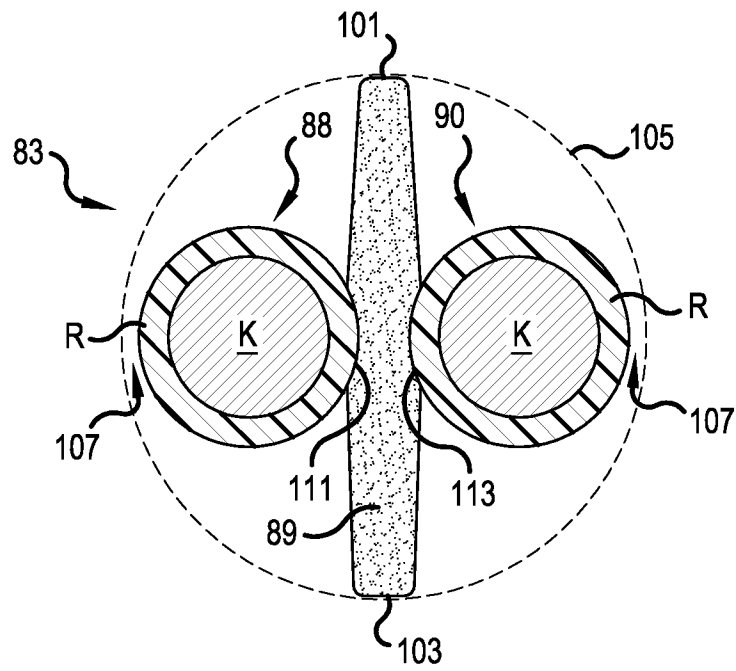


FIG.11

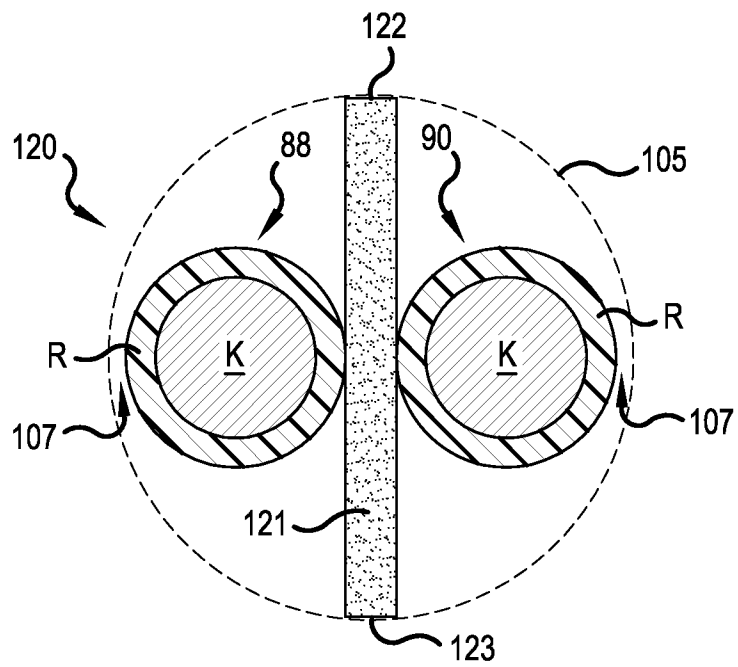


FIG.12

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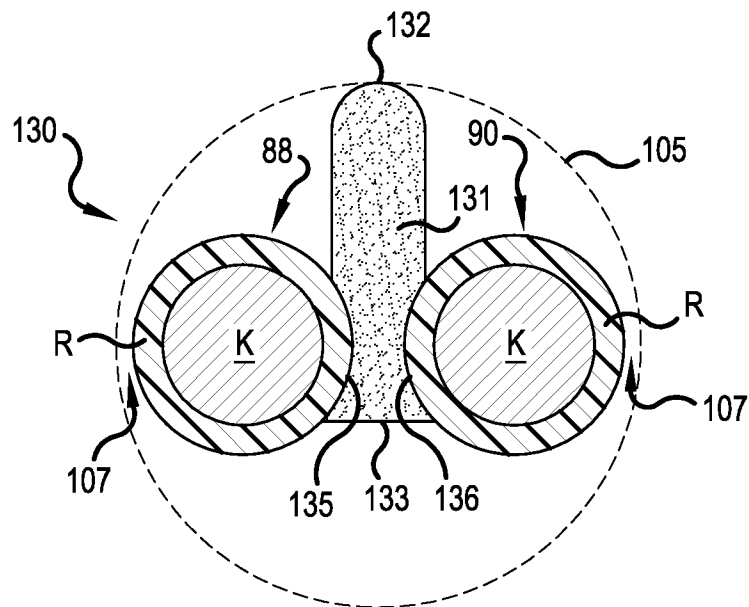


FIG. 13

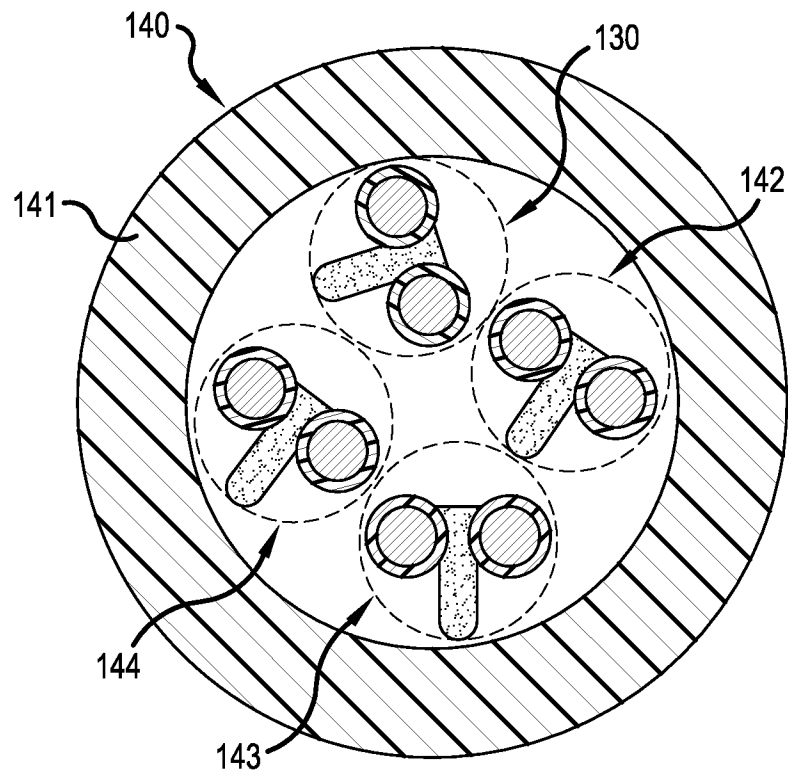


FIG. 14

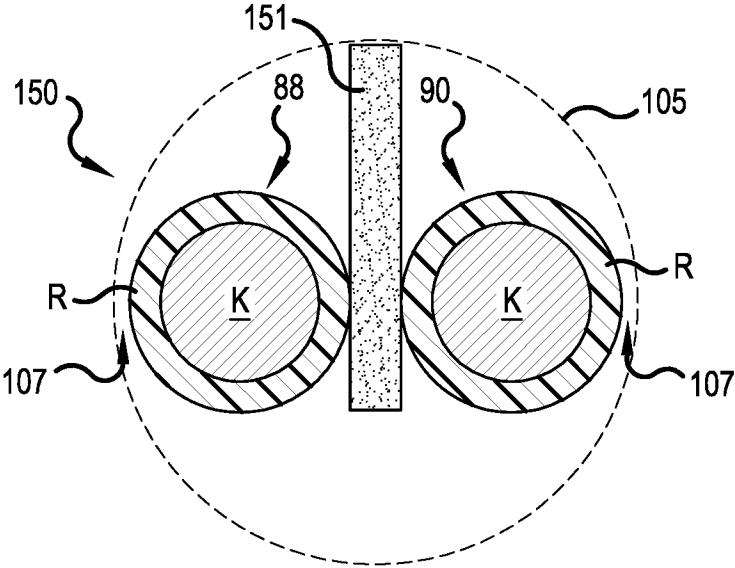


FIG.15

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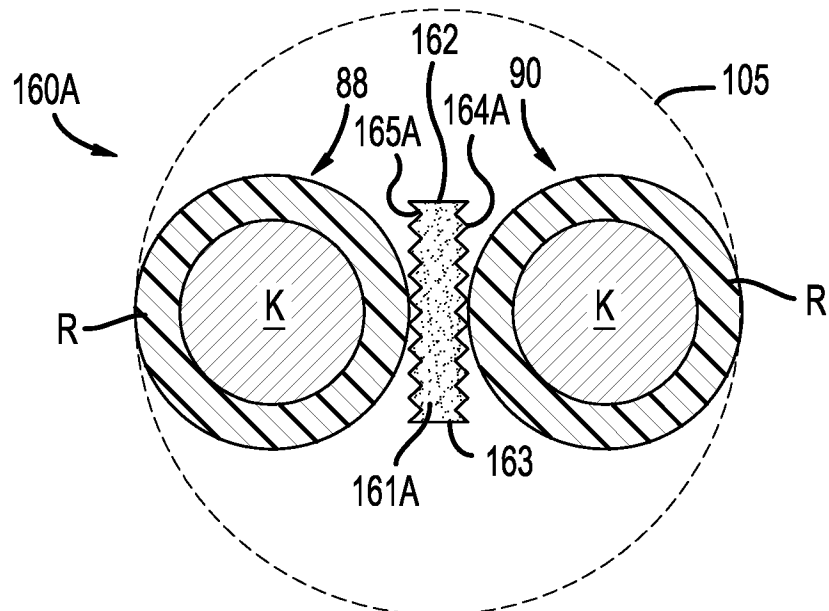


FIG.16

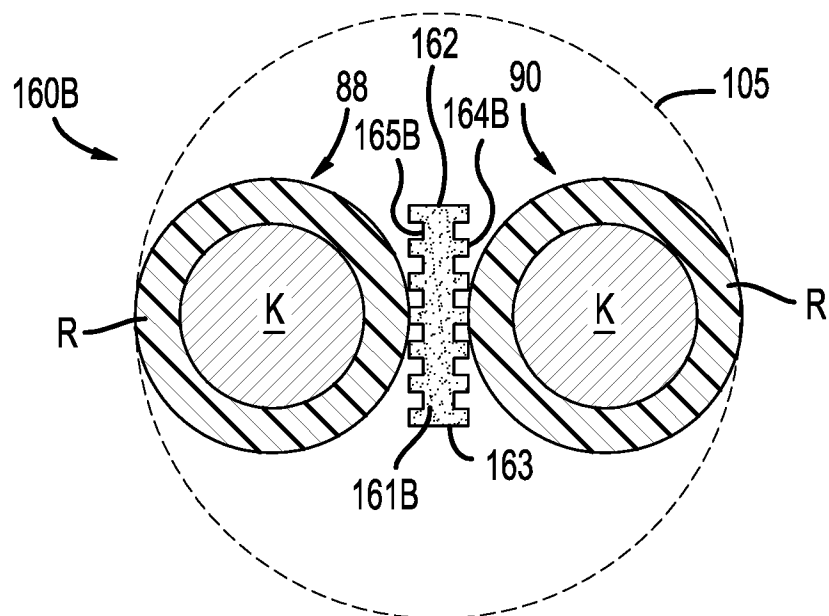


FIG.17

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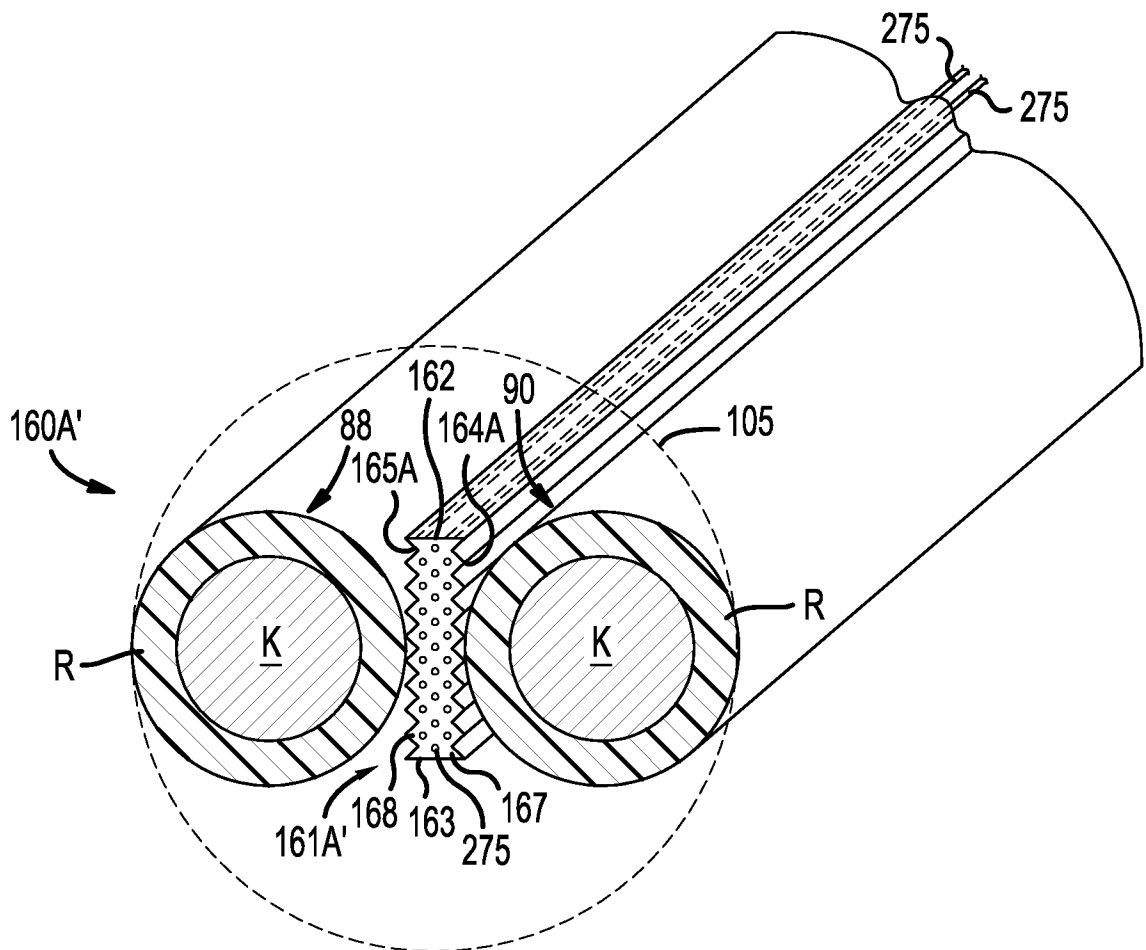


FIG.16A

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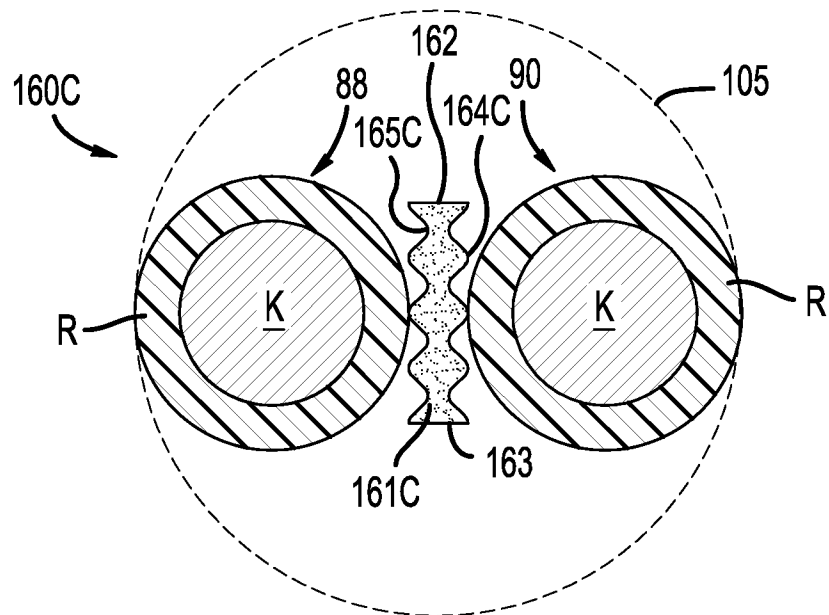


FIG.18

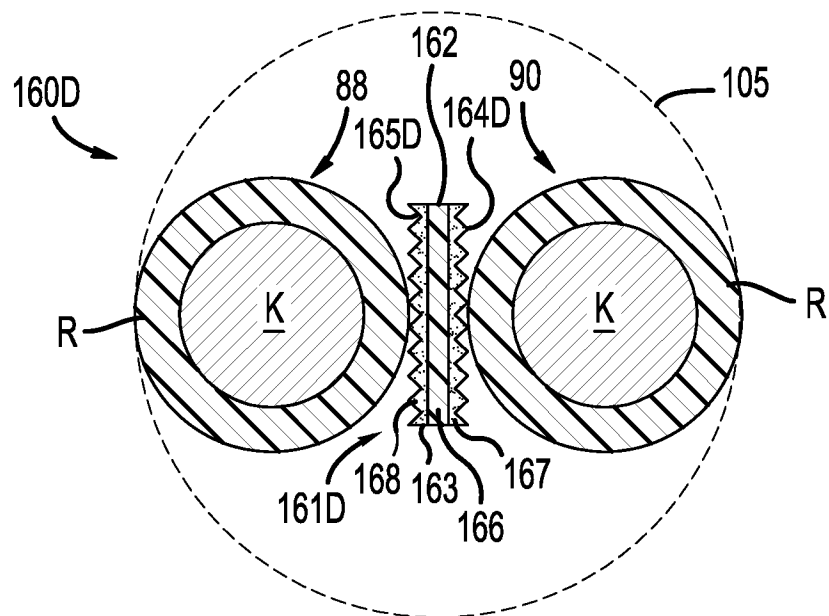


FIG.19

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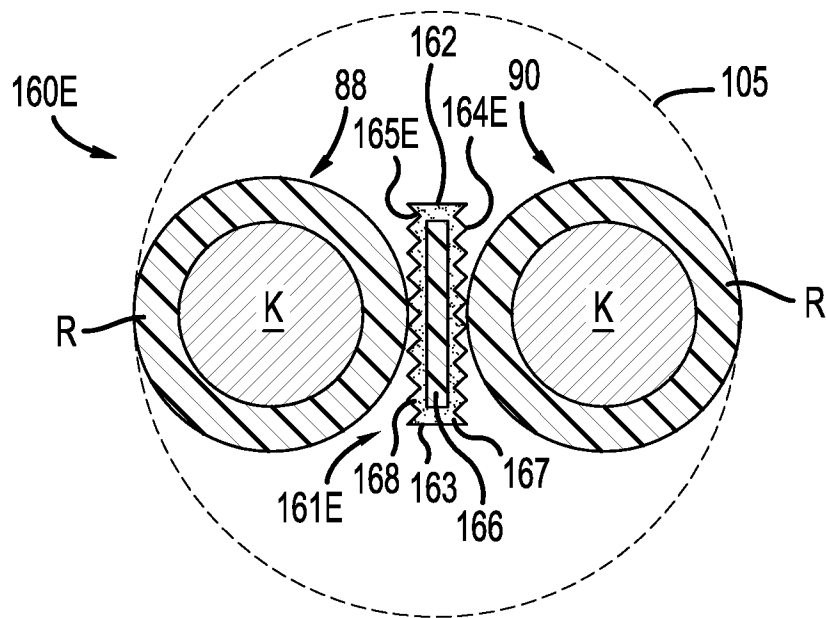


FIG.20

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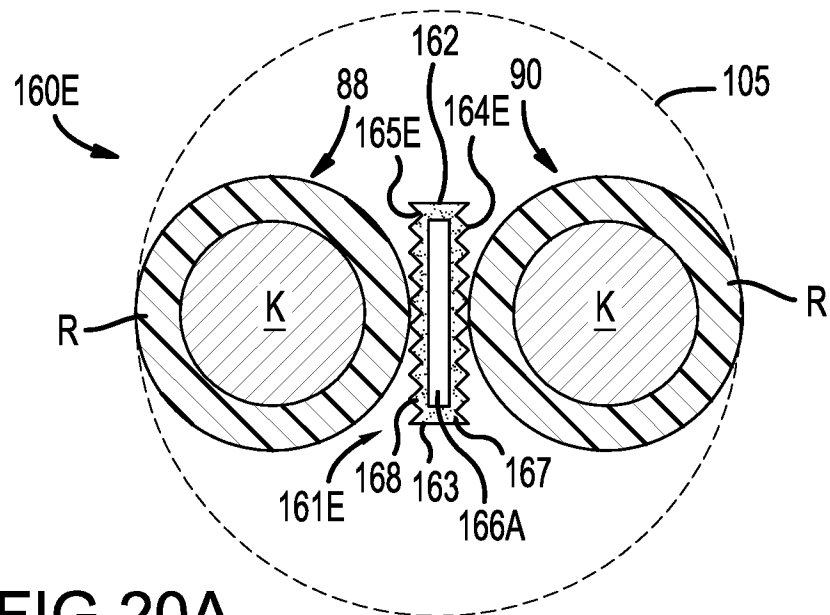


FIG. 20A

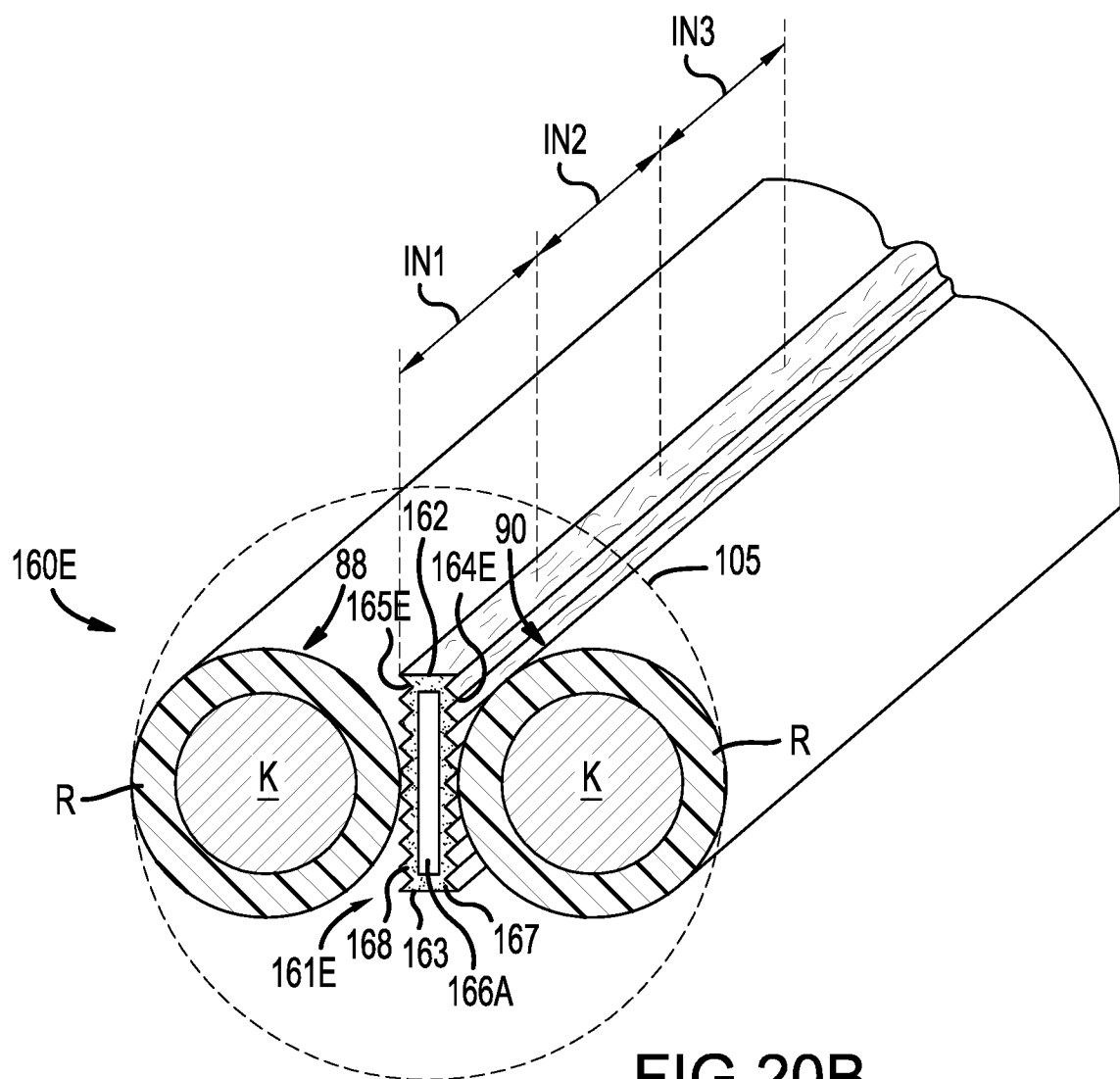
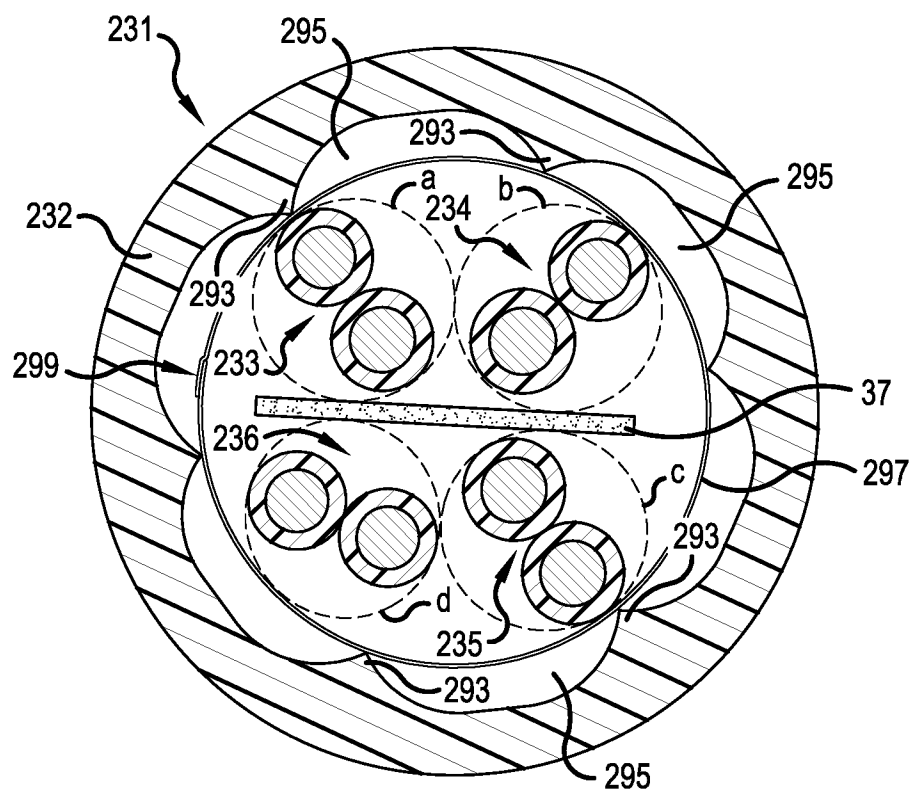
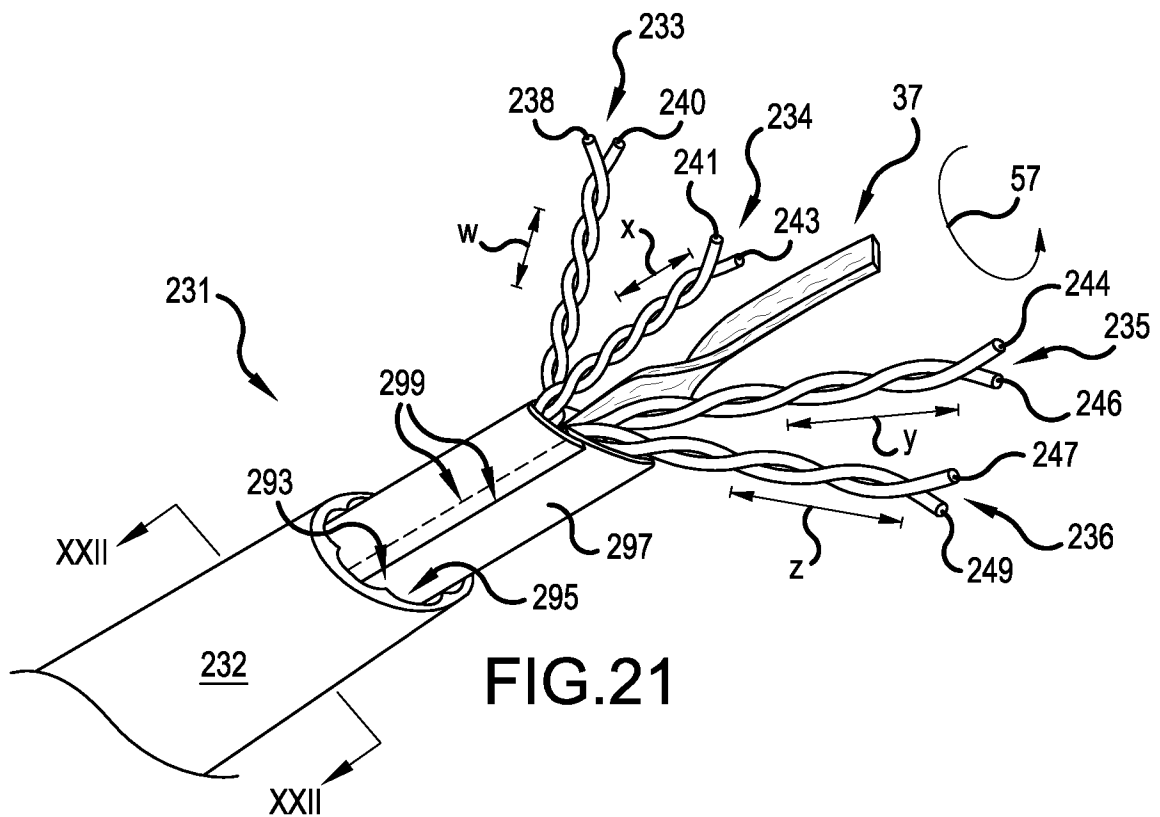
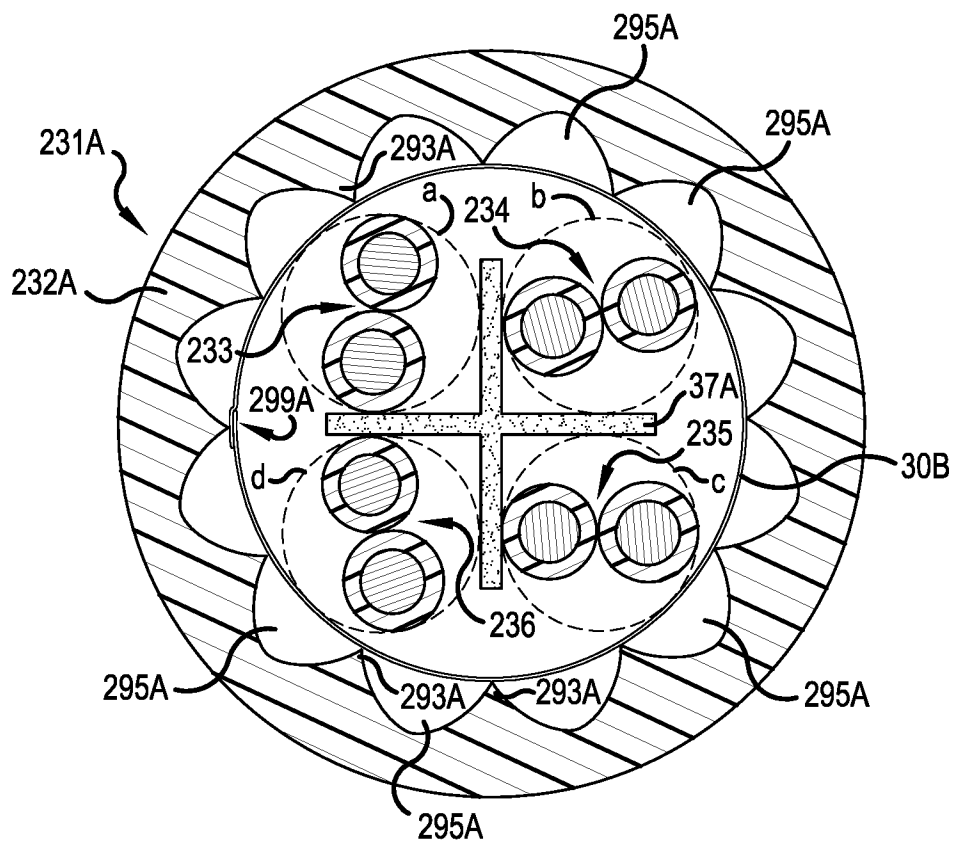
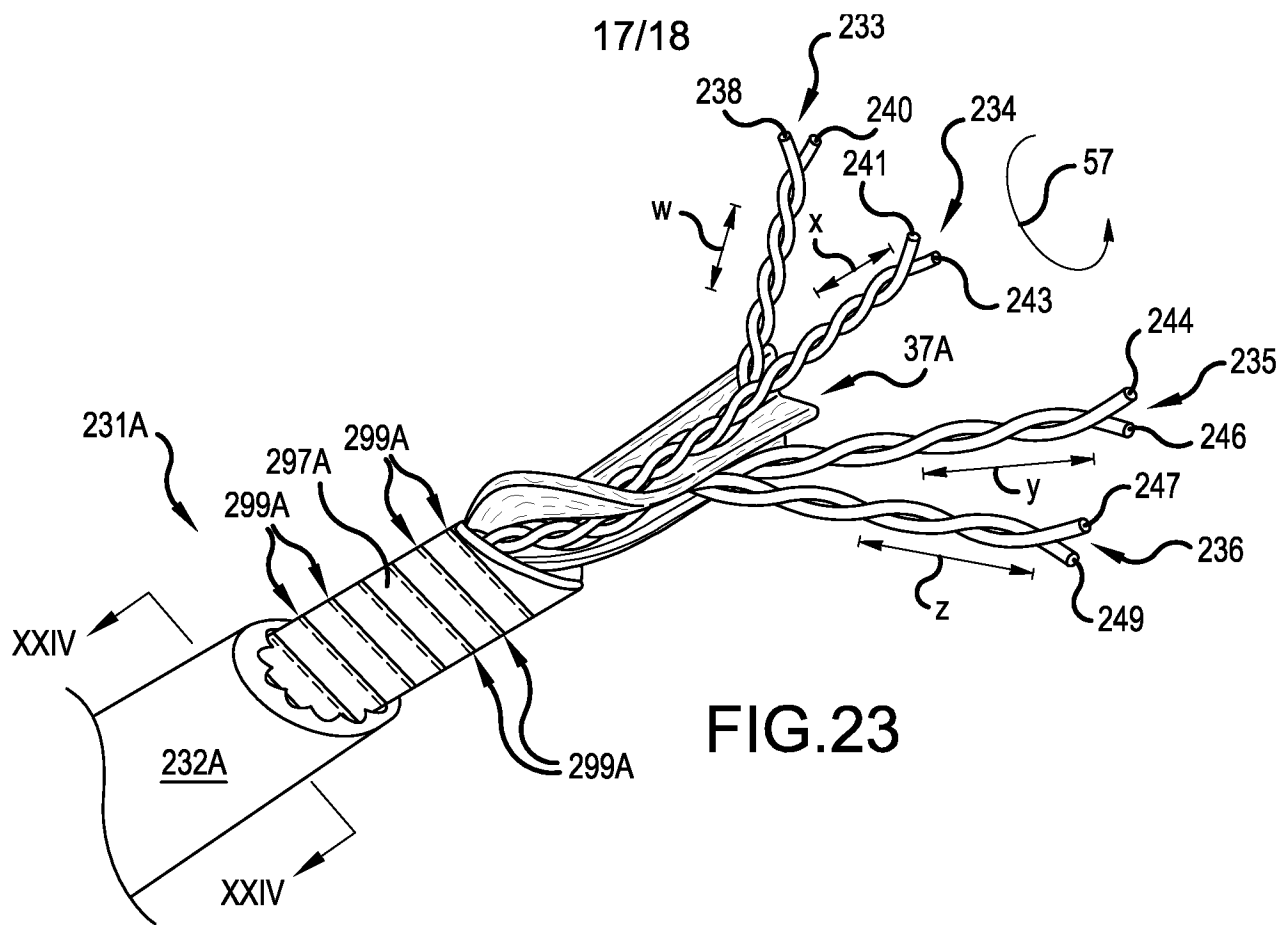


FIG. 20B

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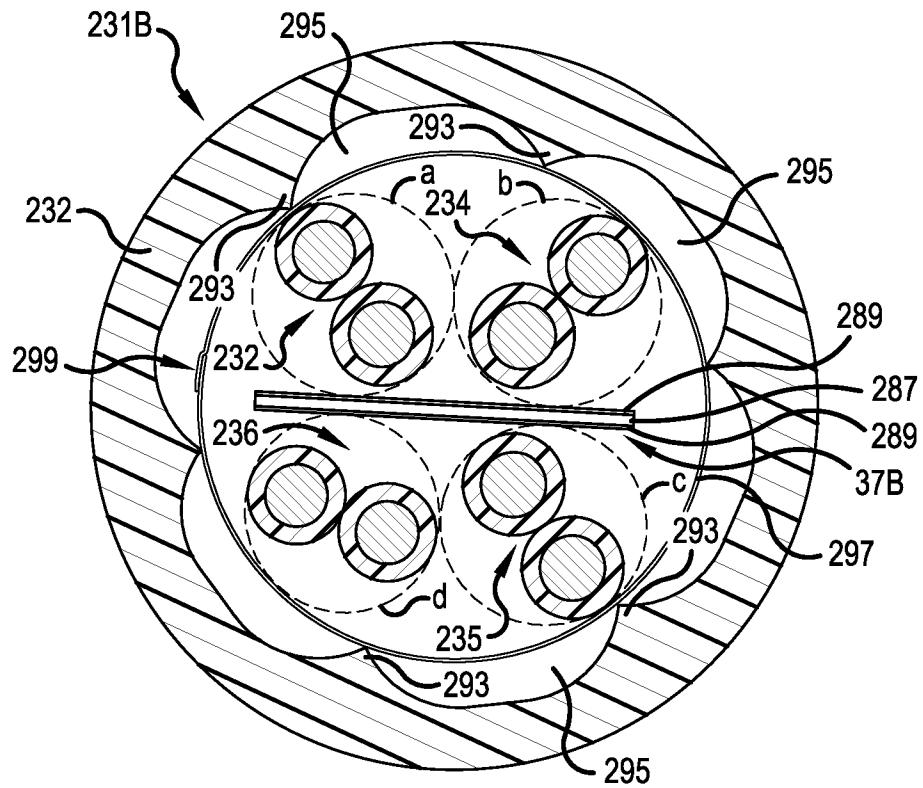


FIG.25

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/064044**A. CLASSIFICATION OF SUBJECT MATTER****H01B 11/02(2006.01)i, H01B 7/02(2006.01)i, H01B 3/08(2006.01)i, H01B 3/12(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01B 11/02; H01B 7/00; H01B 11/04; H01B 11/00; G02B 6/44; H01B 7/02; H01B 3/08; H01B 3/12

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: cable, strength, dielectric, tape, separator

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2014-0238721 A1 (COMMScope, INC. OF NORTH CAROLINA) 28 August 2014 See paragraph [50], claims 1-19 and figure 4.	1-20
Y	US 2013-0170800 A1 (CONSONNI et al.) 04 July 2013 See paragraph [73] and claim 16.	1-20
A	US 2003-0121695 A1 (WIEBELHAUS et al.) 03 July 2003 See claims 1-6 and figures 5-7.	1-20
A	US 2009-0304338 A1 (DAVIDSON et al.) 10 December 2009 See paragraphs [32]-[34] and figure 4.	1-20
A	US 2002-0118933 A1 (DIXON et al.) 29 August 2002 See paragraphs [23]-[26] and figures 1,2.	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

17 March 2017 (17.03.2017)

Date of mailing of the international search report

17 March 2017 (17.03.2017)

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2016/064044

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