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(71) Applicant: **3M INNOVATIVE PROPERTIES COMPANY** [US/US]; 3M Center, Post Office Box 33427, Saint Paul, MN 55133-3427 (US).

(72) Inventors: **CHIZANOV, Sergey, A.**; Krylatsky Hills Business Park, Krylatskaya St. 17, Building 3, 121614 Moscow (RU). **RODIONOV-KOZENKOV, Konstantin**; Krylatsky Hills Business Park, Krylatskaya St. 17, Building 3, 121614 Moscow (RU). **YUNYAZOV, Oleg, I.**; Krylatsky Hills Business Park, Krylatskaya St. 17, Building 3, 121614 Moscow (RU). **LARSON, Donald, K.**; 3M Center, Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US).

(74) Agents: **STORVICK, Kristofer, L.** et al.; 3M Center, Post Office Box 33427, Saint-Paul, MN 55133-3427 (US).

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(54) **Title**: CABLE ASSEMBLIES CAPABLE OF WITHSTANDING HIGH TEMPERATURE VARIATIONS

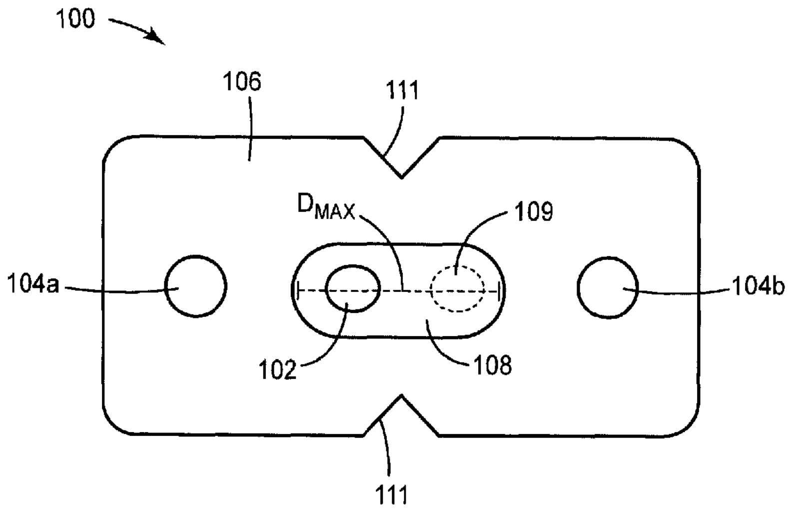

FIG. 1

(57) **Abstract**: Cable assemblies that may be used in environments that have extreme temperature variations, including very low, sub-zero temperatures are described. More particularly, jacketed cable assemblies having both fibers and strength members, with channels built between the fibers and the cable jacket are described.

WO 2015/193696 A1

CABLE ASSEMBLIES CAPABLE OF WITHSTANDING HIGH TEMPERATURE VARIATIONS

Field

The present description relates to cable assemblies that may be used in environments that have extreme temperature variations, including very low, sub-zero temperatures.

Background

Fiber re-enforced polymer (FRP) – type cables are known. Traditionally these cables include a fiber optic cable and polymer strength members within a common jacket. However, conventional FRP-type cables suffer signal degradation at very low temperatures, and thus have a relatively narrow operational temperature range. As such, conventional FRP-type cables cannot be used or at least qualified for outdoor applications in certain cold weather locations. The present description offers an improved cable that provides to the above-mentioned issues.

Summary

In one aspect, the present description relates to a cable assembly. The cable assembly includes an optical fiber, two strength members positioned on opposite sides of the optical fiber and a jacket that surrounds the two strength members and optical fiber. The optical fiber is surrounded by a channel formed within the jacket. The channel creates space between the optical fiber and the jacket. At cold temperatures, the optical fiber of the cable assembly is positioned closer to a first of the two strength members at a given point along the length of the cable assembly, and positioned closer to a second of the two strength members at a different point along the length of the cable assembly.

In another aspect, the present description relates to a cable assembly. The cable assembly includes an optical fiber, two strength members positioned on opposite sides of the optical fiber and a jacket that surrounds the two strength members and optical fiber. The optical fiber is surrounded by a channel formed within the jacket. The channel generally creates space between the optical fiber and the jacket, and the channel is filled with a filler material that surrounds the optical fiber.

Brief Description of the Drawings

Figure 1 is a cross-sectional view of a cable assembly according to the present description.

Figures 2a-2d are varying views of a cable assembly according to the present description.

Figure 3 is a top view of a cable assembly according to the present description.

Figure 4 is a cross-sectional view of a cable assembly according to the present description.

Figure 5 is a cross-sectional view of a cable assembly construction according to the present description.

Figure 6 is a cross-sectional view of a cable assembly construction according to the present description.

Figure 7 is a cross-sectional view of a cable assembly according to the present description.

Figure 8 is a cross-sectional view of a cable assembly construction according to the present description.

Figure 9 is a cross-sectional view of a cable assembly according to the present description.

The figures are not necessarily to scale. Like numbers used in the figures refer to like components. However, it will be understood that the use of a number to refer to a component in a given figure is not intended to limit the component in another figure labeled with the same number.

Detailed Description

In the following detailed description of the preferred embodiments, reference is made to the accompanying drawings, which illustrate specific embodiments in which the invention may be practiced. The illustrated embodiments are not intended to be exhaustive of all embodiments according to the invention. It is to be understood that other embodiments may be utilized and structural or logical changes may be made without departing from the scope of the present invention. The following detailed description, therefore, is not to be taken in a limiting sense, and the scope of the present invention is defined by the appended claims.

Unless otherwise indicated, all numbers expressing feature sizes, amounts, and physical properties used in the specification and claims are to be understood as being modified in all instances by the term "about." Accordingly, unless indicated to the contrary, the numerical parameters set forth in the foregoing specification and attached claims are approximations that can vary depending upon the desired properties sought to be obtained by those skilled in the art utilizing the teachings disclosed herein.

As used in this specification and the appended claims, the singular forms "a," "an," and "the" encompass embodiments having plural referents, unless the content clearly dictates otherwise. As used in this specification and the appended claims, the term "or" is generally employed in its sense including "and/or" unless the content clearly dictates otherwise.

Spatially related terms, including but not limited to, "proximate," "distal," "lower," "upper," "beneath," "below," "above," and "on top," if used herein, are utilized for ease of description to describe spatial relationships of an element(s) to another. Such spatially related terms encompass different orientations of the device in use or operation in addition to the particular orientations depicted in the figures and described herein. For example, if an object depicted in the figures is turned over or flipped over, portions previously described as below or beneath other elements would then be above those other elements. The terms "proximate" and "distal" are used to identify the two ends of elongate electrodes in an array. A typical array according to the present disclosure is a one-dimensional array of parallel elongate electrodes each having a long axis, wherein the electrodes are arranged in approximately a line that is approximately perpendicular to the long axis of the elongate electrodes. For such a typical array, according to their use in the present application, the "proximate" ends of all of the elongate electrodes are arranged along a first edge of the array and the "distal" ends of all of the elongate electrodes are arranged along a second edge of the array that is opposite the first edge.

As used herein, when an element, component or layer for example is described as forming a "coincident interface" with, or being "on," "connected to," "coupled with," "stacked on" or "in contact with" another element, component or layer, it can be directly on, directly connected to, directly coupled with, directly stacked on, in direct contact with, or intervening elements, components or layers may be on, connected, coupled or in contact with the particular element, component or layer, for example. When an element, component or layer for example is referred to as being "directly on," "directly connected to," "directly coupled with," or "directly in contact with" another element, there are no intervening elements, components or layers for example.

As noted in the Background section, conventional FRP-type cables suffer signal degradation at very low temperatures, and thus cannot be qualified for use in regions with harsh winter climates. As an example, in at least one country, outdoor cables must be qualified to a temperature range of between -60°C and +85°C. However, conventional FRP-type cables have been well known to suffer signal degradation at temperatures below -30°C or -40°C. This is at least in part because of the strain placed on the optical fiber in traditional

FRP cables due to the differences in the coefficient of thermal expansion of the glass optical fiber and the polymeric jacket which directly surrounds and attaches to the optical fiber. The inventions described herein offer solutions that overcome this issue, as will be explained in greater detail.

Figure 1 provides a cross-sectional view of a cable assembly 100 according to the present description. Cable assembly 100 includes an optical fiber 102. The optical fiber can be a conventional optical fiber having a conventional coated fiber diameter of 250 μm or 900 μm. Two strength members 104a and 104b are positioned on opposite sides of the optical fiber 102. Although not shown herein, a second optical fiber may also be positioned immediately adjacent optical fiber 102. Such a construction is illustrated with duplex optical fibers in commonly owned and assigned PCT Publication No. WO 2013/048890. Strength members are intended to provide axial strength along the length of the cable assembly 100. Strength members 104a, 104b can be formed from conventional strength member materials such as polymer, carbon fiber reinforced polymer rods, metal rods or wires, and/or aramid fibers. Alternatively, strength members can be made up of glass or fiber reinforced polymer rods. Jacket 106 surrounds the two strength members and the optical fiber(s). In one particular construction, the cable assembly 100 is a hybrid cable, such as that described in commonly owned and assigned U.S. Provisional Application No. 61/871493, the relevant portions of which are hereby incorporated by reference. For example, the strength members 104a and 104b may comprise metallic wires, such as stainless steel wires, and the optical fiber(s) 102 may be a communication lines. In certain embodiments, where strength members 104a and 104b are metallic wires, the wires may act as power lines. In one aspect, the jacket 106 of the cable assembly is formed from a polymer material, such as polyethylene. In another aspect, jacket 106 is formed from a UV stabilized polyethylene material. Other suitable assembly jacket materials include polyvinyl chloride (PVC), neoprene and polyurethane.

Looking again to Figure 1, optical fiber 102 is surrounded by a channel 108 that is formed within the jacket 106. The channel generally creates space between the optical fiber 102 and the jacket 106. The channel is sized such that there is space around the optical fiber even at the lowest portion of the temperature range so that the contraction of the jacket material does not bind the optical fiber which could cause unwanted localized stresses on the optical fiber which could in turn result in the undesirable attenuation of the optical signals carried by the optical fiber. At cold temperatures, the optical fiber is positioned closer to a first of the two strength members because as the cable contracts in cold weather, the optical fiber is allowed to bend within the channel without strain being placed on the optical fiber (see, in Figure 1, the proximity of fiber 102 to strength member 104a vs. strength member 104b), at a given point along the length of the cable assembly. However, where a cross-section of the cable assembly is taken at a different point along its length, the optical fiber 102 will be positioned closer to a second of the two strength members (see, e.g., point 109 proximate to strength member 104b). Cable assembly 100 additionally includes a notch or notches 111 positioned above and below the channel to enable one to more easily extract fiber from the channel at a drop location.

One appropriate shape for the channel 108 is a racetrack shape, as illustrated in Figure 1. However, any other number of channel shapes may be appropriate. For example, the channel 108 could be oval-shaped or rectangular. Where a racetrack shape is utilized, the channel can be oriented such that the greatest cross-sectional diameter, D_{MAX}, of the racetrack runs generally laterally between the strength members (as illustrated in Figure 1, between strength member 104a and 104b). Alternatively, as illustrated in Figure 7, the greatest cross-sectional diameter, D_{MAX}, can be in a direction that runs generally vertically between notches 711. Of importance is that the channel be large enough to allow the optical fiber freedom of motion in each direction surrounding the fiber, such that the fiber can be, but need not be in contact with any wall of the channel.

In one construction, the position of the channel oscillates in relation to the first and second members along the length of the cable assembly. Such a construction is illustrated in Figures 2a-2d. Figure 2a provides a top view of a cable assembly 200, and Figures 2b-2d provide cross-sectional views of the cable assemblies at three points along the length of the cable assembly (points L1, L2 and L3). As is clear in Figure 2b, channel 208 is positioned closer to strength member 204a than it is to be strength member 204b at position L1. However, the position oscillates along the length of the cable assembly, such that at position L2, the channel 208 (and optical fiber 202 within channel) is positioned closer to strength member 204b than to strength member 204a. The relationship changes once again at position L3. The oscillating nature of the channel ensures that optical fiber 202 must also oscillate, and avoid being positioned in a rigid straight shape. This allows for flexion of the cable at cold weather temperatures without incredible strain created by the differential in coefficient of thermal expansion between the fiber and jacket.

In another construction, the channel contains ridges formed within the channel that divert the optical fiber in the direction of either the first strength member or the second strength member along the length of the cable assembly. Such a construction is illustrated in

Figure 3. Figure 3 provides a top view of a cable assembly 300 according to the present description. Here, the channel 308 contains ridges (e.g. 309a, 309b and 309c) that are formed within the channel 308 that divert the optical fiber 302 in the direction of the first strength member 304a or second strength member 304b along the length of the cable assembly. In an exemplary embodiment the ridges alternate between the left and the right side of the channel as shown in Figure 3. For example, ridges 309a and 309c work to divert optical fiber 302 in the direction of strength member 304a, while ridge 309b works to divert optical fiber 302 in the direction of opposing strength member 304b. The ridges may generally be made of the same material as the cable jacket, and in fact understood as an extension of the jacket. The construction in Figure 3 differs in part from that shown in Figures 2a-2d in that the channel does not have a constant cross-sectional width. However, in some embodiments, the ridges may be formed in a sinusoidal shape spaced periodically along the length of the cable assembly, such that the width of an open portion of the channel 308 is constant along the length of the cable assembly. In such a case, the channel itself will more closely resemble that shown as channel 208 in Figure 2. The ridges in either construction can aid in the controlled bending of the optical fiber as the length of the cable assembly decreases at cold temperature.

In another embodiment, the cable assemblies discussed herein may include a pull string. Such a construction is illustrated in Figure 4. Figure 4 provides a cable assembly 400 having a channel 408. Inside the channel is positioned not only a fiber 402, but also a pull string 410. Pull string 410 runs generally parallel to the optical fiber 402 along the length of the cable assembly. The pull string can be utilized to tear open the jacket 406 by pulling the pull string upward along the length of the assembly through the thinned region formed by the notches. Once the pull string creates a slit in jacket 406, the optical fiber 402 can be released from jacket and routed to a connection point. In one embodiment, pull string 410 may be a water swell yarn.

In another aspect, the present description relates to a cable assembly construction that includes any of the aforementioned cable assemblies, as well as at least a second cable assembly. Such a construction is illustrated in Figure 5. Cable assembly construction 500 includes a cable assembly 505, which may be very similar to that provided in Figure 1. Cable assembly construction further includes a second cable assembly 512 that is positioned adjacent cable assembly 505. The second cable assembly 512 includes a second optical fiber 514, and two strength members 516a and 516b that are positioned on opposite sides of the second optical fiber 514. The common jacket 506 that surrounds the cable assembly 505 also surrounds second cable assembly 512. Additionally, jacket 506 has an indentation 507 that is positioned between the cable assembly 505 and second cable assembly 512. This indentation allows an installer to furcate the cable assembly construction and route the two different cable assemblies to different locations. As further shown in Figure 5, at least two more cable assemblies may be positioned adjacent to both or either cable assembly 505 and cable assembly 512 and positioned within common jacket 506, with an indentation positioned between each adjacent assembly. In fact, at least four more cable assemblies (for a total of six cable assemblies), each cable capable of furcation from an adjacent assembly and routing to a separate location, may be present in a common jacket.

In an alternative embodiment, illustrated in Figure 6, cable assembly construction 600 includes a cable assembly 605, again very similar to that provided in Figure 1 or assembly 505 in Figure 5. Again, cable assembly construction further includes a second cable unit 612 that is positioned adjacent cable assembly 605 and disposed within a common outer jacket. However, in this specific embodiment, second cable assembly does not include optical fiber surrounded by strength members. Instead, second cable unit includes a pair of copper wires, 616a and 616b. This construction allows for the routing of both communication and power in a common construction. In certain embodiments, as is illustrated in both constructions 500 and 600, the indentation 507 or 607 may be formed on both the top side and bottom side of the cable.

In yet another embodiment, illustrated in Figure 8, a cable assembly of the current description may further include a messenger or support wire. The construction provides a cable assembly 805 as described previously herein. The construction further includes a support wire 818 that is positioned on the opposite side of one of the strength members 804b from the channel 808. The support wire is enclosed, like the cable assembly, by jacket 806. As previously described, cable constructions having multiple cable assemblies can include indentations 807 formed in the jacket between the support wires 818 and the cable assembly 805 to allow easy separation of the cable assembly from the support wire. Construction 800 is sometimes referred to as a "messenger wire" construction. The construction allows aerial pole to pole cable mounting. The addition of the steel support wire 818 creates the ability to place the strain and tension from mounting on this element, and provides strain relief to the cable assembly 805 (including the optical fiber therein).

A different aspect of the present description is illustrated in Figure 9. Figure 9 provides a drop cable assembly 900. For purposes of this description, a drop cable or drop cable assembly (as present in either Figure 9 or any of the other embodiments shown) should be understood as a cable or assembly that connects an end user to a distribution cable. Drop cable assembly 900 includes an optical fiber 922 and two strength members 924a, 924b positioned on opposite sides of the optical fiber. In addition, the drop cable assembly includes a jacket 926 that surround the two strength members 924a, 924b and optical fiber 922. A channel 928 surrounds the optical fiber 922 and creates space between the optical fiber and the jacket 926. In this embodiment, the channel 928 is filled with a filler material 930 that surrounds the optical fiber. In one particular embodiment, the filler material may be a gel, such as a standard cable water block gel, e.g., a thixotropic gel.

The cable assemblies containing channels described herein may be manufactured by appropriate methods known in the industry. Generally, the jacket is extruded such that it is in intimate contact with the strength members and forms a channel around the optical fiber.

The embodiments described herein, uniquely address the low temperature signal degradation of conventional FRP cables by allowing for accommodation of the surplus length of the optical fiber that is generally created due to lower CTE (i.e. less shrinkage) of the optical fiber as compared to the CTE of the polymeric jacket material when ambient temperature drops to extreme temperatures (i.e., below -30 or -40 degrees C), and by providing protective materials around the fiber that are suitably soft at cold temperature to allow the optical fiber to flex or bend within the channel at cold temperatures.

CLAIMS

1. A cable assembly, comprising:

an optical fiber,

two strength members positioned on opposite sides of the optical fiber; and

a jacket that surrounds the two strength members and optical fiber, wherein the optical fiber is further surrounded by a channel formed within the jacket, the channel generally creating space between the optical fiber and the jacket, wherein the optical fiber is positioned closer to a first of the two strength members at a given point along the length of the cable assembly, and positioned closer to a second of the two strength members at a different point along the length of the cable assembly.

2. The cable assembly of claim 1, wherein the strength members comprise polymer rods.

3. The cable assembly of claim 1, wherein the strength members comprise aramid fiber strength members.

4. The cable assembly of claim 1, wherein the strength members comprise glass re-enforced polymer rods.

5. The cable assembly of claim 1, wherein the strength members comprise carbon fiber reinforced polymer rods.

6. The cable assembly of claim 1, wherein the cable assembly comprises a hybrid cable.

7. The cable assembly of claim 6, wherein the strength member comprise metallic wires and the optical fiber comprises a communication line.

8. The cable assembly of claim 7, wherein the metallic wires comprise stainless steel.

9. The cable assembly of claim 7, wherein the metallic wires comprise power lines.

10. The cable assembly of claim 1, further comprising a second optical fiber also positioned within the channel formed in the jacket.

11. The cable assembly of claim 1, wherein the position of the channel oscillates in relation to the first and second strength members along the length of the cable assembly.

12. The cable assembly of claim 1, wherein the channel contains ridges formed within the channel that divert the optical fiber in the direction of either the first strength member or the second strength member along the length of the cable assembly.

13. The cable assembly of claim 12, wherein the ridges are formed in a sinusoidal shape, such that the width of an open portion of the channel is constant along the length of the cable assembly.

14. The cable assembly of claim 1, wherein the jacket is formed from a UV stabilized polyethylene material.

15. The cable assembly of claim 1, further comprising a pull string that is positioned within the channel and runs generally parallel to the optical fiber, wherein the jacket may be opened by pulling the pull string.

16. A cable assembly construction, comprising:

the cable assembly of claim 1, and

a second cable assembly positioned adjacent to the cable assembly, wherein the second cable assembly comprises a second optical fiber and two second strength members positioned on opposite sides of the second optical fiber, and wherein the jacket of the cable assembly of claim 1 further surround the second cable assembly, the jacket having an indentation disposed between the cable assembly and second cable assembly that allow an installer to furcate the cable assembly construction and route the cable assembly and second cable assembly to different locations.

17. The cable assembly construction of claim 16, further comprising at least four more cable assemblies positioned adjacent to one another and positioned within the jacket, wherein an indentation is disposed between each of the adjacent assemblies.

18. A cable assembly construction, comprising:

the cable assembly of claim 1, and

a second cable assembly comprising a pair of copper wires wherein the jacket of the cable assembly of claim 1 further surrounds the second cable assembly, the jacket having an indentation disposed between the cable assembly and second cable assembly that allows an installer to furcate the cable assembly construction and route the cable assembly and second cable assembly to different locations.

19. The cable assembly of claim 1, further comprising a notch formed on both the top side and bottom side of the cable.

20. The cable assembly of claim 1, wherein the cross-section of the channel is racetrack shaped.

21. The cable assembly of claim 20, wherein the greatest cross-sectional diameter of the racetrack runs generally laterally between the strength members.

22. The cable assembly of claim 19, wherein the greatest cross-sectional diameter of the racetrack runs generally vertically between the indentations.

23. The cable assembly of claim 1, wherein the cross-section of the channel is oval shaped.

24. The cable assembly of claim 1, wherein the cross-section of the channel is rectangular.

25. A cable assembly construction, comprising:

the cable assembly of claim 1, and

a support wire positioned on an opposite side of one of the strength members from the channel, the support wire being enclosed within the jacket.

26. The cable assembly construction of claim 25, wherein indentations are formed in the jacket between the support wires and the cable assembly.

27. A drop cable assembly, comprising:

an optical fiber,

two strength members positioned on opposite sides of the optical fiber; and

a jacket that surrounds the two strength members and optical fiber, wherein the optical fiber is further surrounded by a channel formed within the jacket, the channel generally creating space between the optical fiber and the jacket, wherein the channel is filled with a filler material that surrounds the optical fiber.

28. The drop cable assembly of claim 27, wherein the filler material comprises a gel.

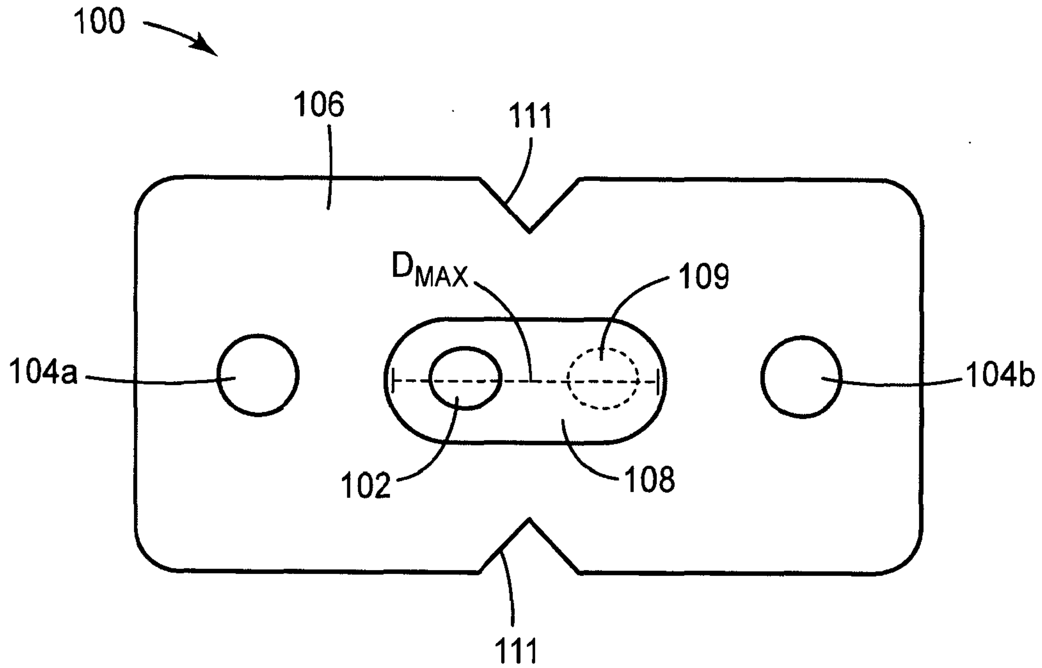

FIG. 1

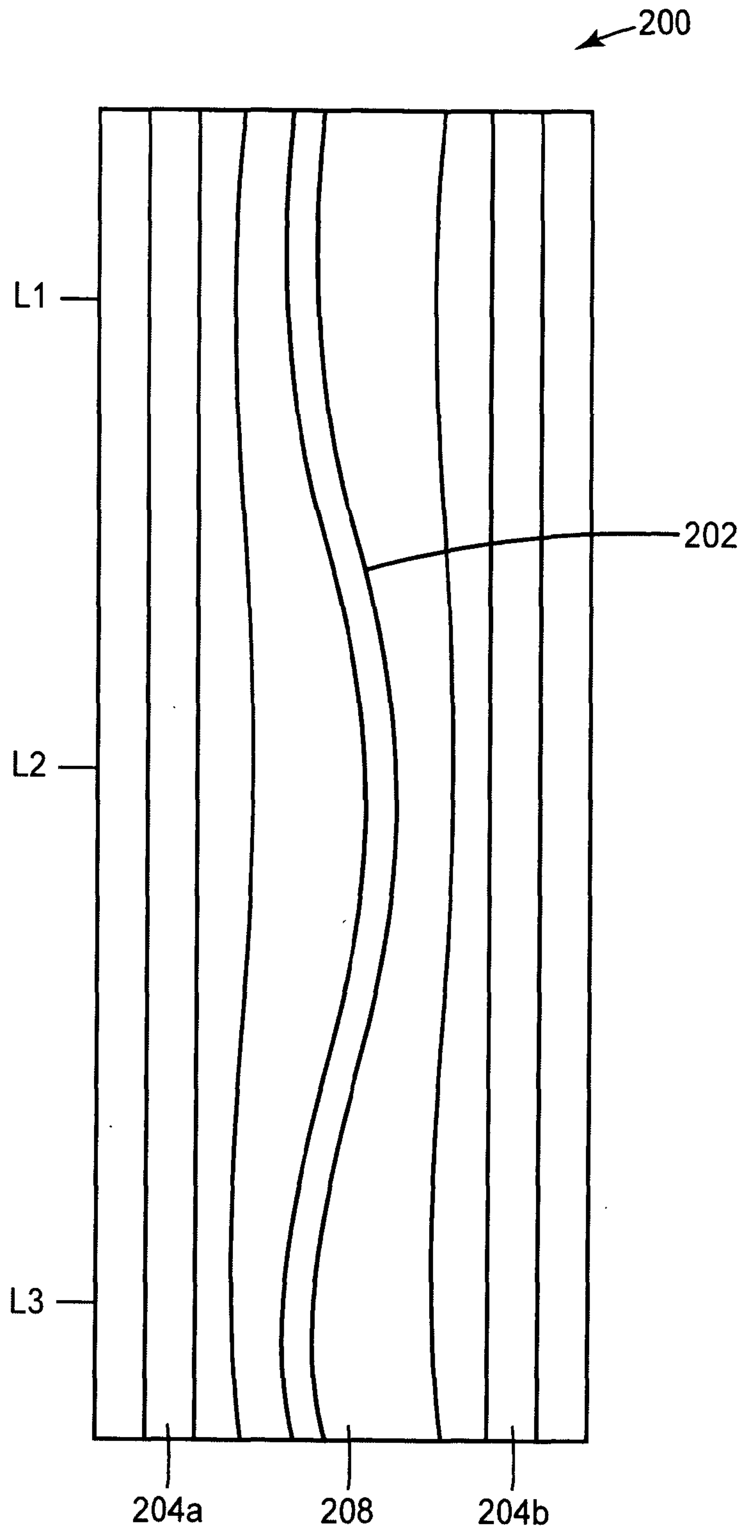

FIG. 2A

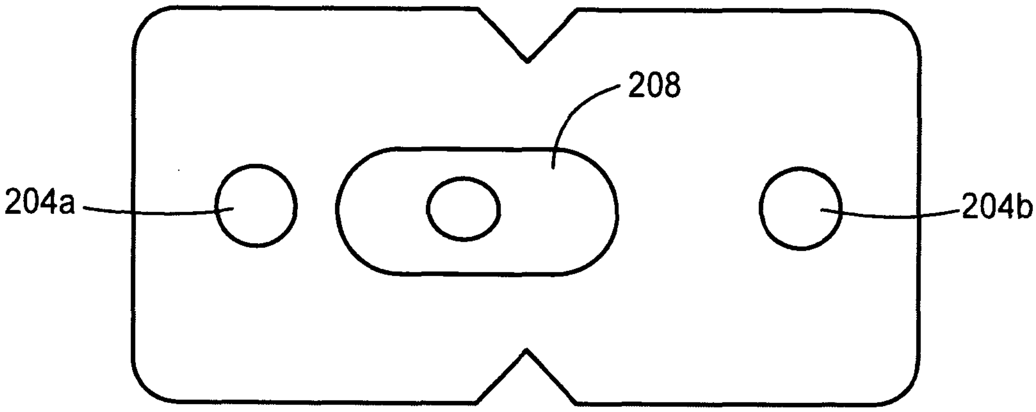

FIG. 2B

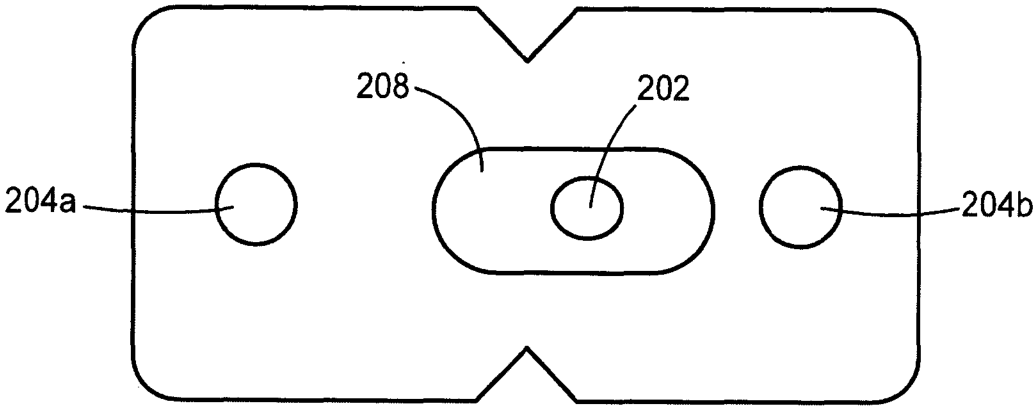

FIG. 2C

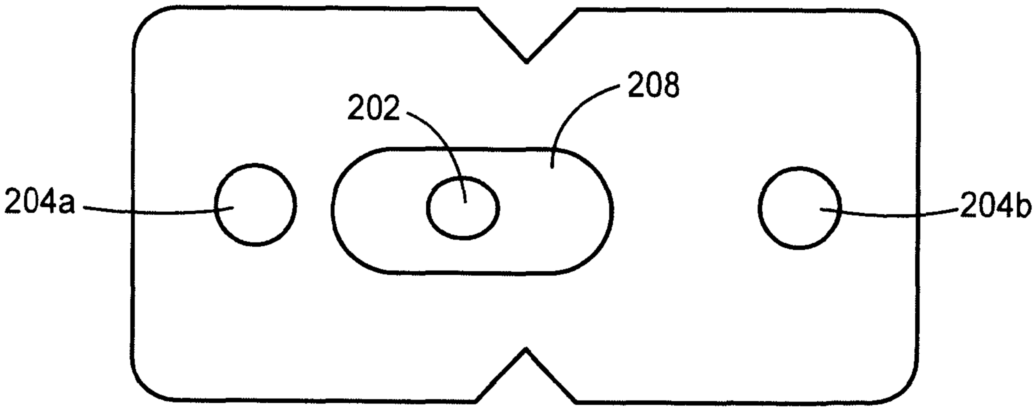

FIG. 2D

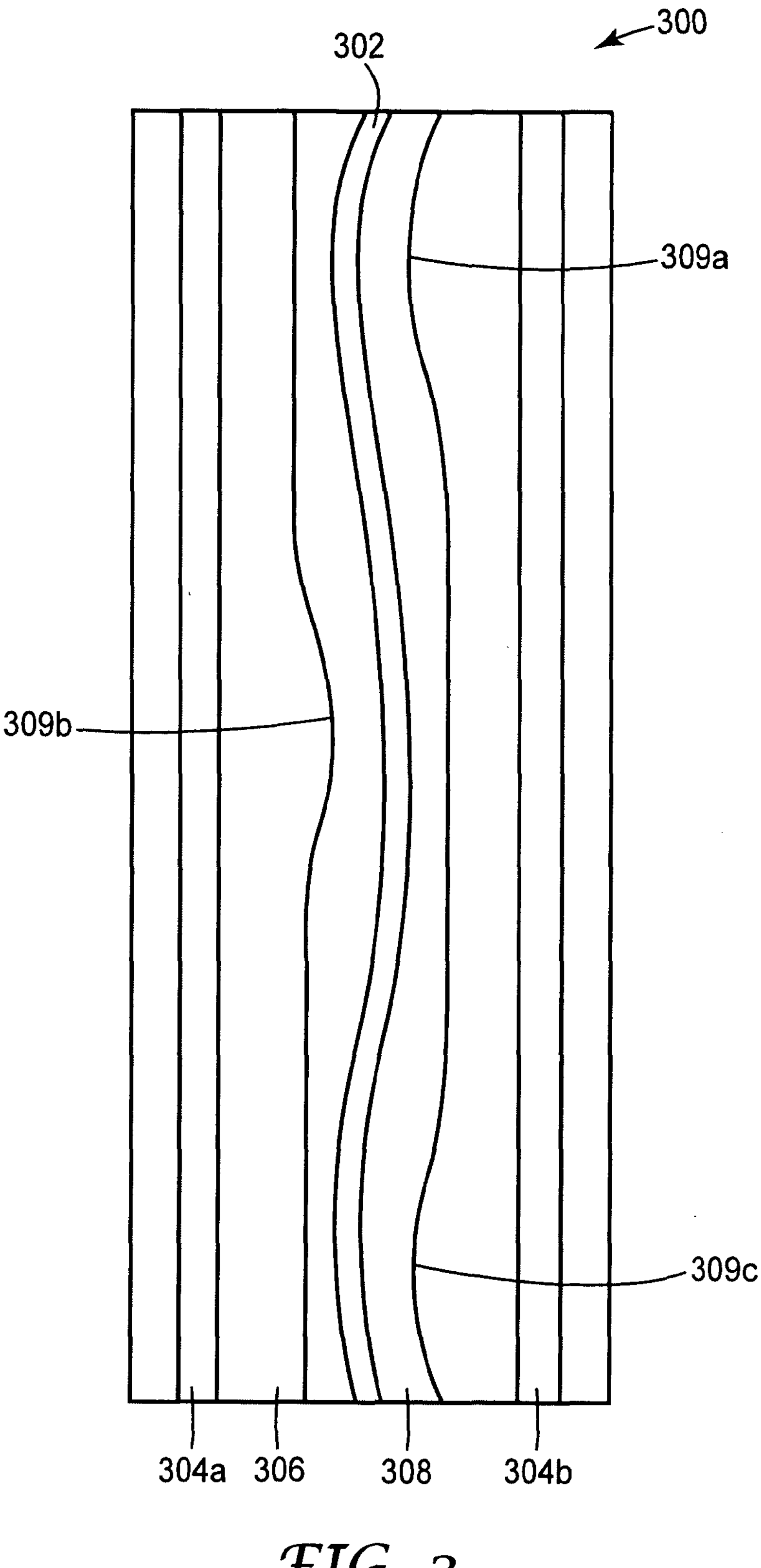

FIG. 3

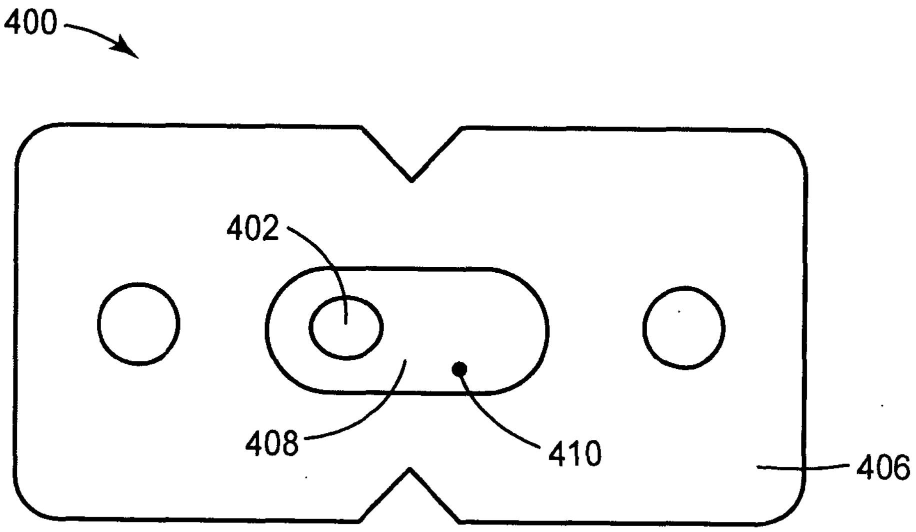

FIG. 4

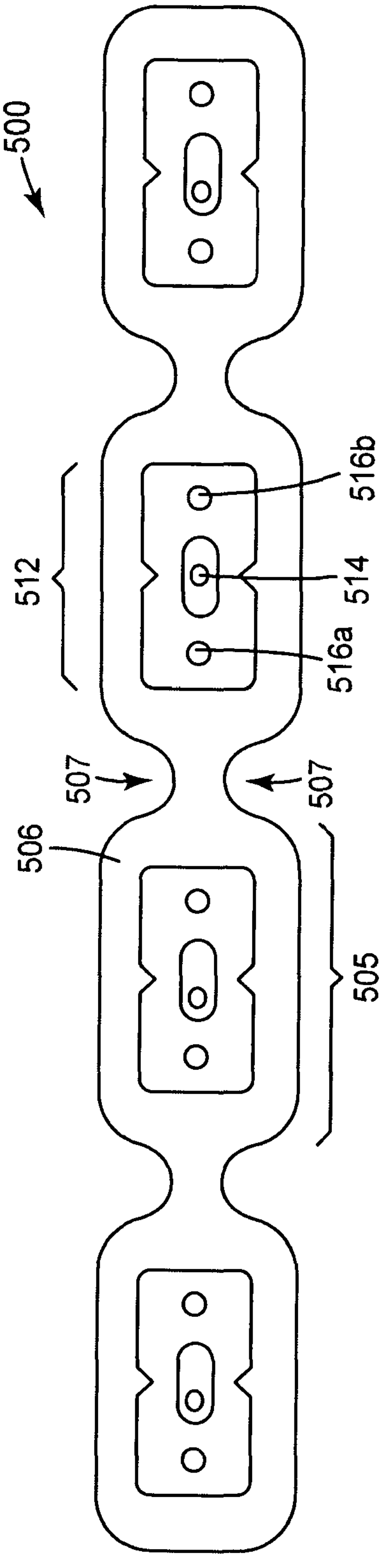
500
512
516b
514
516a
507
507
506
505

FIG. 5

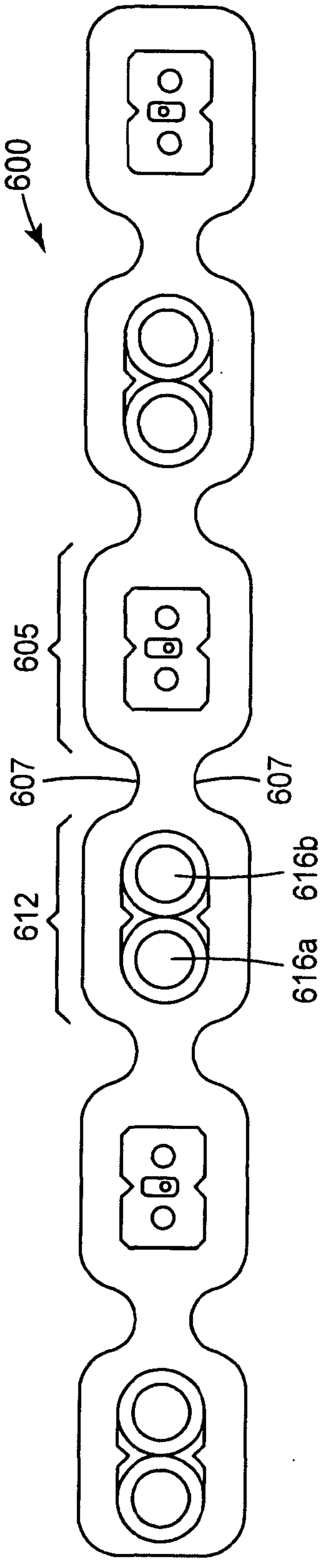
600
605
607
607
612
616b
616a

FIG. 6

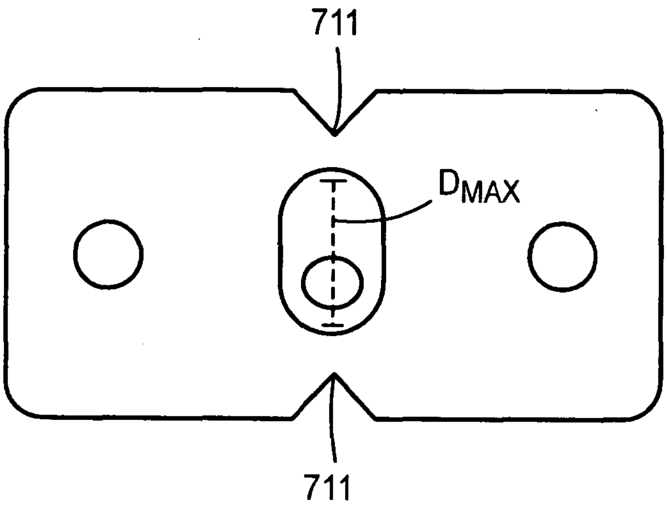

FIG. 7

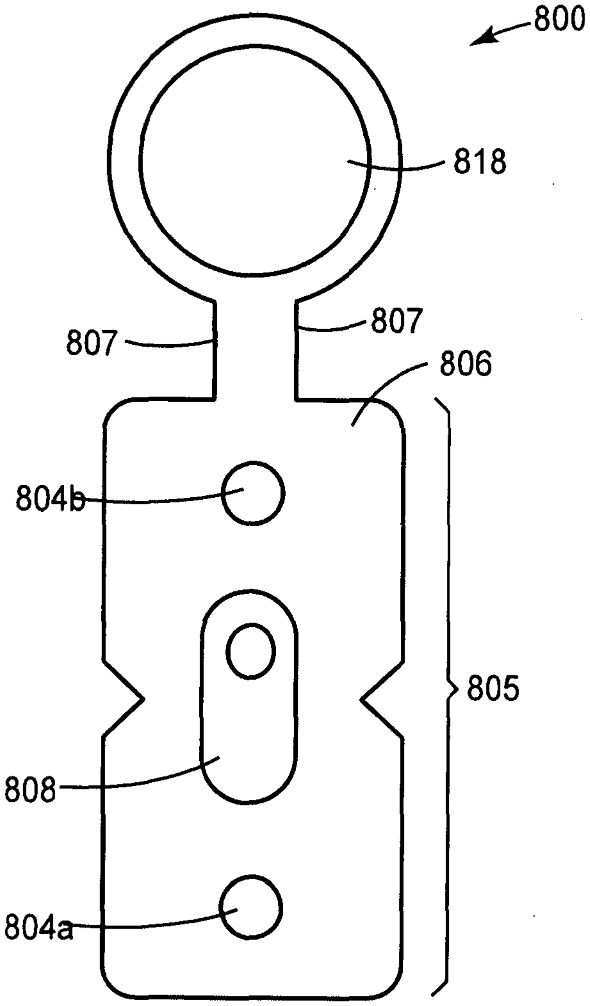

FIG. 8

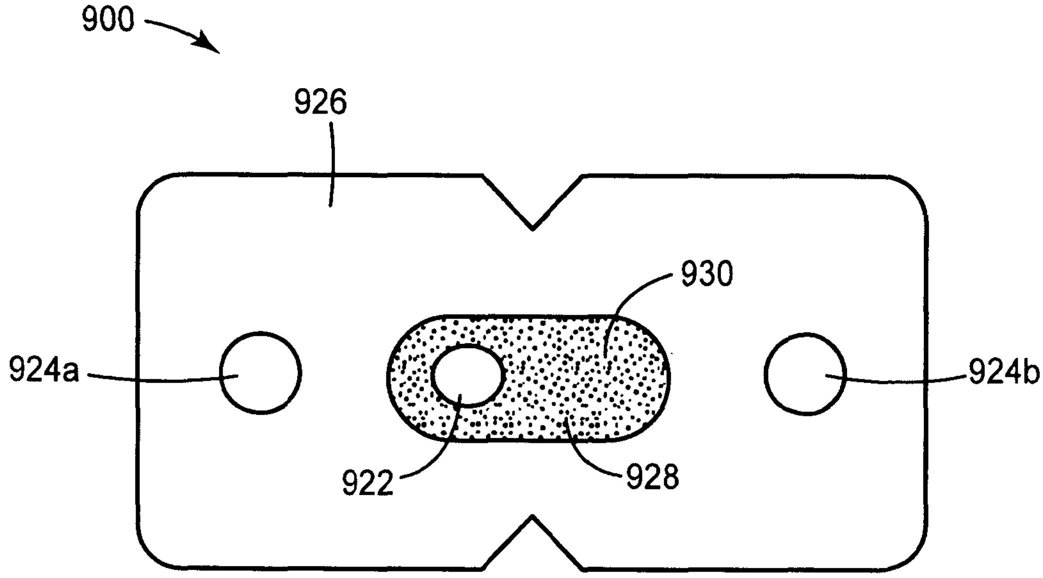

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB 2014/001717

A. CLASSIFICATION OF SUBJECT MATTER

H01B 11/22 *(2006.01)*
G02B 6/44 *(2006.01)*

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 7/00-11/22, G02B 6/00, 6/44

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

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

RUPAT, PatSearch (RUPTO internal), Espacenet, USPTO, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	JP S5931906 A (NIPPON TELEGRAPH & TELEPHONE) 21.02.1984, abstract, fig. 1-5	1-5, 10-14 6-9, 15, 18-28 16, 17
Y	US 2012/0315004 A1 (JAMES A. REGISTER, III et al.) 13.12.2012, abstract, fig. 1-12	6-9
Y	JP H09261822 A (KAMIBAYASHI KAZUHIKO) 03.10.1997, abstract, fig. 1-3	15
Y	WO 2011/035547 A1 (YUAN BAOYI) 31.03.2011, abstract, fig. 1-4	18-24
Y	WO 2003/058105 A1 (PREFORMED LINE PRODUCTS CO) 17.07.2003, abstract	25-26

[X] Further documents are listed in the continuation of Box C.

[ ] See patent family annex.

* Special categories of cited documents:

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Date of the actual completion of the international search	Date of mailing of the international search report
09 February 2015 (09.02.2015)	19 February 2015 (19.02.2015)

Name and mailing address of the ISA/RU:
Federal Institute of Industrial Property,
Berezhkovskaya nab., 30-1, Moscow, G-59,
GSP-3, Russia, 125993
Facsimile No: (8-495) 531-63-18, (8-499) 243-33-37

Authorized officer

O. Schedrina

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB 2014/001717

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2008/051945 A2 (AFL TELECOMMUNICATIONS LLC et al.) 02.05.2008, abstract, paragraph 31	27-28