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

(72) Inventors: **LIU, Richard Yufeng**; 3M Center, Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US).
BAETZOLD, John P.; 3M Center, Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US).

(74) Agent: **VIETZKE, Lance L.**, et al.; 3M Center, Office of Intellectual Property Counsel, Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US).

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Declarations under Rule 4.17:

- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))
- as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))

(54) Title: DATA AND POWER CABLES SUITABLE FOR IMMERSION COOLING

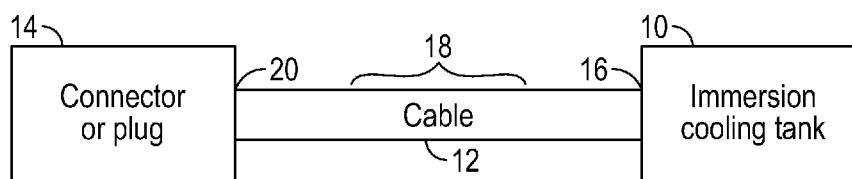


FIG. 1

(57) Abstract: A sealed cable assembly includes a jacket enclosing a plurality of insulated wires. Each insulated wire includes a bare wire covered by surrounding insulation, and a cable plug or connector is electrically connected with the bare wires. A sealant surrounds the insulated wires in an air gap between the jacket and the insulated wires in a location at or near the cable plug or connector, and the sealant fills the air gap at the location to prevent or reduce fluid loss through the cable in an immersion cooling system. The cable assembly can also be sealed at an in-between section away from the cable plug or connector. The cable assembly is wrapped with a weatherproof film or tape at the location of the sealing to further prevent or reduce fluid loss through the cable.

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- *in black and white; the international application as filed contained color or greyscale and is available for download from PATENTSCOPE*

DATA AND POWER CABLES SUITABLE FOR IMMERSION COOLING

BACKGROUND

5 Data centers use immersion cooling tanks to provide for cooling and temperature control of electronic components. Data and power cables external to the tanks connect with the electronic components in the tanks, and the fluid used for immersion cooling can leak from the tanks through the cables. Since the fluid is an expensive component for the data centers, it is advantageous to minimize or reduce the loss of such fluid. Accordingly, a need exists for data and power cables
10 better suited for immersion cooling.

SUMMARY

A sealed cable assembly includes a jacket enclosing a plurality of insulated wires and including an air gap between the jacket and the insulated wires. Each insulated wire includes a
15 bare wire covered by surrounding insulation. A sealant surrounds the insulated wires in the air gap between the jacket and the insulated wires in a location along the jacket, and the sealant fills the air gap at the location.

Another sealed cable assembly includes a jacket enclosing a plurality of insulated wires and including an air gap between the jacket and the insulated wires. Each insulated wire includes a
20 bare wire covered by surrounding insulation. A sealant surrounds the insulated wires in the air gap between the jacket and the insulated wires in a location at an in-between section of the jacket, and the sealant fills the air gap at the in-between section.

BRIEF DESCRIPTION OF THE DRAWINGS

25 The accompanying drawings are incorporated in and constitute a part of this specification and, together with the description, explain the advantages and principles of the invention. In the drawings,

FIG. 1 is a block diagram illustrating a cable used with an immersion cooling tank;

FIGS. 2A-2D illustrate a leak solution for sealing a power cable;

30 FIGS. 3A-3D illustrate a leak solution for sealing a data cable; and

FIGS. 4A-4D illustrate a leak solution for sealing an in-between section of a cable.

DETAILED DESCRIPTION

Embodiments include materials and design approaches which can prevent or reduce
35 cooling fluids from leaving immersion cooling tanks via cables which are inside the tanks and exit

the tanks to an external environment. Examples of cooling fluid include the NOVEC product and the FLUORINERT product, both from 3M Company.

FIG. 1 is a block diagram illustrating a cable 12 used with an immersion cooling tank or vessel 10. Tank 10 would contain electronic components in a data center, for example, with a cooling fluid in tank 10 used to cool or maintain temperature control of the electronic components. Cable 12 and other such cables are required to enter tank 10 at a hole or aperture 16 to provide power to the electronic components or provide for data transmission. Cable 12 includes a connector or plug 14 depending upon whether it is a power cable or a data cable. Cable 12 is mechanically coupled to tank 10 at aperture 16 and, since cable 12 enters tank 10, cable 12 is sealed to prevent or reduce the loss of fluid in tank 10 via cable 12. Cable 12 can be sealed in a location 20 at or near connector or plug 14, or sealed at an in-between section 18 in a location somewhere between the ends of cable 12, or sealed at both of these locations.

FIGS. 2A-2D illustrate a leak solution for sealing a power cable. As shown in FIG. 2A, the power cable includes bare wires 24 each encased within an insulation 26 and collectively encased within a jacket 22. This leak solution for a power cable includes the following steps.

Step 1 – Strip insulation 26 to expose wires 24 (FIG. 2A).

Step 2 – Apply a liquid epoxy or other sealant to a jacket area 28 around the insulated wires and optionally around each individual wire insulation at an area 30 to fill air gaps and eliminate or reduce fluid leakage through the cable (FIG. 2B).

Step 3 – Before the epoxy from Step 2 is fully cured, electrically connect a power plug 32 to bare wires 24 and mechanically couple power plug 32 to jacket 22 in the final assembly, and optionally wrap the cable with additional weatherproof film or tape 34 at the location of mechanical coupling (FIG. 2C).

Step 4 – Optionally wrap the outer surface of the power cable at the plug, using a tape 36, to further eliminate or reduce fluid leakage through the cable (FIG. 2D).

These Steps 1-4 illustrated in FIGS. 2A-2D result in a cable assembly having a jacket enclosing a plurality of insulated wires with a sealant surrounding the insulated wires to fill and eliminate an air gap within the jacket around the wires in a location at or near the cable plug. The cable assembly optionally also includes a sealant surrounding a portion of each bare wire and overlapping with insulation where the bare wire is exposed to eliminate an air gap between the bare wire and the insulation surrounding the bare wire. A tape or film is wrapped around and surrounds the outer surface of the cable jacket in the location at or near the cable plug.

FIGS. 3A-3D illustrate a leak solution for sealing a data cable such as a coaxial cable or a fiber optical cable, or other data cables. As shown in FIGS. 3A and 3B, the data cable includes bare wires 44 each encased within an insulation 42 and collectively encased within a jacket 40.

The bare wires 44 can be, for example, metal wires for a coaxial cable or fiber optical wires for a fiber optical cable. This leak solution for a data cable includes the following steps.

Step 1 – Cut open the cable to expose the insulated wires (FIG. 3A).

Step 2 – Strip insulation 42 to expose bare wires 44 (FIG 3B).

5 Step 3 – Apply a liquid epoxy or other sealant to a jacket area 46 and optionally around each individual wire insulation at an area 48 to fill air gaps and eliminate or reduce fluid leakage through the cable (FIG. 3C).

10 Step 4 – Before the epoxy from Step 3 is fully cured, electrically connect a data link connector 50 to bare wires 44 and mechanically couple the data link connector 50 to jacket 40 in the final assembly, and optionally wrap the cable with additional weatherproof film or tape at the location of mechanical coupling (FIG. 3D).

15 These Steps 1-4 illustrated in FIGS. 3A-3D result in a cable assembly having a jacket enclosing a plurality of insulated wires with a sealant surrounding the insulated wires to fill and eliminate an air gap within the jacket around the wires in a location at or near the cable connector. The cable assembly optionally also includes a sealant surrounding a portion of each bare wire and overlapping with insulation where the bare wire is exposed to eliminate an air gap between the bare wire and the insulation surrounding the bare wire. Optionally, a tape or film is wrapped around and surrounds the outer surface of the cable jacket in the location at or near the cable connector.

20 FIGS. 4A-4D illustrate a leak solution for sealing an in-between section of a cable. This leak solution for an in-between section of a cable 60 (FIG. 4A) includes the following steps.

Step 1 – Peel away the cable jacket or skin to expose insulated wires 62 (FIG. 4B).

Step 2 – Apply a liquid epoxy or other sealant 64 to insulated wires 62 and allow the epoxy or sealant to cure (FIG. 4C).

25 Step 3 – Wrap the in-between section of the exposed insulated wires covered with the cured epoxy with a tape (FIG. 4D).

30 These Steps 1-3 illustrated in FIGS. 4A-4D result in a cable assembly having a jacket enclosing a plurality of insulated wires with a sealant surrounding the insulated wires to fill and eliminate an air gap within the jacket around the wires at an in-between section of the cable jacket. Optionally, a tape or film is wrapped around and surrounds the outer surface of the cable jacket at the in-between section.

35 Although the Steps illustrated in FIGS. 2A-2D, 3A-3D, and 4A-4D are shown as modifications to existing cables, these same or similar modification can be made to cables upon initial manufacture or assembly of them in order to seal the cables at or near connectors or plugs for the cables, or at an in-between section of the cables, or at both of these locations. The sealant in the modified cables fills and thus eliminates air gaps within the cable jackets and insulated wires

in order to prevent or reduce fluid loss through the cables in immersion cooling systems. The sealants and tapes used for the modification are typically flexible and heat resistant such that the modified cables are still flexible and heat-resistant. Sealing the bare wires is optional in that the insulated wires are typically coated with the insulation, which can result in no air gap between the bare wire and the insulation surrounding the bare wire. Sealing the bare wires can provide another level of protection against loss of fluid as can sealing the cables in multiple locations.

The following are exemplary materials to seal cables using the Steps and assemblies described above.

Sealants include the following: 3M SCOTCH-WELD Structural DP100 Plus Epoxy Adhesive product (3M Company); SCOTCH Advanced Formula Super Glue product (3M Company); 3M Super Strength Adhesive product (3M Company); SCOTCH Maximum Strength Adhesive product (3M Company); and 3M SCOTCH-WELD EC 2216 Epoxy Adhesive product (3M Company). Other sealants that are flexible as cured, heat-resistant, and fluid-proof can also be used for the cable sealing. Other sealant chemistries that are also useful in this application include polyester, polyurethane, PVC, polyacrylates, polyamide, polyimide, or combination thereof. The curing process for the sealant could be selected from thermal curing, UV curing, electron beam curing, gamma radiation curing, moisture curing, or chemical curing.

Tapes or films include 3M Weatherproofing Film Wrap product (3M Company). Other tapes or films that are flexible, heat-resistant, and fluid-proof can also be used for the cable sealing. Such films or tapes can be selected from polyester film/tapes, polyurethane film/tapes, PVC film/tapes, acrylic film/tapes, or combination thereof.

EXAMPLES

Cables were sealed and tested by immersion in perfluorochemical fluid. Weight loss and extraction tests were performed. These Examples are merely for illustrative purposes only and are not meant to be limiting on the scope of the appended claims. All parts, percentages, ratios, etc. in the examples and the rest of the specification are by weight, unless noted otherwise. The following abbreviations are used herein: cm = centimeters; g = gram; °C = degrees centigrade; min= minute.

Materials

Material	Abbreviation	Description
Perfluorochemical fluid	F1	“3M FLUORINERT Electronic Liquid FC-40” obtained from 3M Company, St. Paul, MN
Perfluorochemical fluid	F2	“3M Performance Fluid PF 5060” obtained from 3M Company
Bottle with Cap		VWR Clear Wide Mouth Bottle with cap (4 ounce) Part # 10862-344 obtained from VWR International, Radnor, PA.
Power Cable - Consisting of an outer jacket which protects 3 wires with insulation around each wire		Item# 1FD87B obtained from W. W. Grainger, Inc Lake Forest, IL
Epoxy Adhesive/Sealant	S1	“3M SCOTCH-WELD Epoxy Adhesive DP100 Plus” obtained from 3M Company
Epoxy Adhesive/Sealant	S2	“3M SCOTCH-WELD Epoxy Adhesive DP125 Gray obtained from 3M Company

Test Methods

5 Extraction Test:

To determine the compatibility of the adhesives/sealants with perfluorochemical fluid, soxhlet extraction tests were run. The method as described in the publication “Design Considerations Relating to Non-Thermal Aspects of Passive 2-Phase Immersion Cooling”, 27th IEEE SEMI-THERM Symposium, section 3.2 was used. The soxhlet extraction test was run with the perfluorinated fluid F2. The amount of adhesive/sealant extracted by the fluid = me% (percent extracted mass). The amount of fluid absorbed by the adhesive/sealant = ma% (percent mass adsorbed fluid). Results are shown in Table 1.

Table 1. Soxhlet Extraction Results for Adhesives/Sealants

Adhesive/Sealant	Fluid	Tc (deg C)	Time (hours)	me%	ma%
S1	F2	56	67	0.26	0.1
S2	F2	56	48	0.15	-0.2*

*negative number = no fluid absorbed

15 Weight Loss Test / Example Preparation:

The power cable consisted of an outer jacket which surrounded 3 individual wires. The wires each had an insulation layer around them. The gap area was defined as the region between the outer cable surface and the insulation of the individual wires. The gap seal was defined as the sealant applied to the gap. The wire area was defined as the region between the individual wire insulation and the bare wire. The wire seal was defined as the sealant applied to the region between the bare wire and wire insulation.

Description of preparation for cable leak test – gap seal and wire seal:

A 15 cm long portion of the power cable was cut for each Example (both ends of the cable were cut with a wire cutter). At one end of the power cable, the outer jacket was removed with the wire cutter. This exposed about 2 cm of insulated individual wires. Then the same tool was used to remove the insulation on the 3 individual wires. This exposed about 1.5 cm of bare wire.

Examples (E1-E8):

In each Example, an adhesive/sealant was applied to either 1) the gap area to fill the region between the cable and wire insulation, or 2) both the gap area and the wire area. See Table 2 for the configurations tested. The sealed cables for each Example configuration were left to fully cure at room temperature for at least 180 minutes to achieve sufficient solidification.

To create an enclosed space for the weight loss testing, a bottle with cap was used. A drill press was used to create a hole (the same diameter as the power cable) in the center of the cap of the bottle. Two samples were made and tested for each Example configuration. The average of the two results are reported in the Table 2.

The bottle was first weighed by an analytical balance (wt1). Then about 90g of F1 fluid was poured in the bottle and was weighed (wt2). After that, the sealed power cable for each Example configuration was put through the bottle opening, followed by applying the same adhesive/sealant to the inside of the cap thread and around the hole of the cap. Then quickly the cap was screwed on top of the bottle with F1 fluid inside to create an air tight seal. The exact depth of the power cable was adjusted to ensure that the end of the cable was 1 centimeter from the bottom of the bottle and fully submerged inside the liquid.

Examples configurations that were used in the Weight Loss Tests:

1) The sealed wire or gap area are outside of the bottle, i.e. labeled as “Gap and “Wire” area outside bottle” in Table 2.

2) The sealed wire or gap area are inside of the bottle, i.e. labeled as “Gap and Wire area inside bottle” in Table 2.

Then, the bottle was left for 24 hours at room temperature to fully cure.

After the sealant was fully cured, the whole assembly was weighed on an analytical balance (wt3). Then the whole assembly was put in an oven set at 50C and removed at pre-determined time (T) to be weighed, (wt[T]). The following equations were used to determine weight loss:

Initial Weight of Fluorochemical: $wt4 = wt2 - wt1$

Weight Loss% at Time (T): $Wt\ Loss\% (T) = (wt[T] - wt3) / wt4 \times 100\%$

Comparative Example (CE1):

A Comparative Example was made and tested using the same protocols described above except that the jacket and wire were not removed, and no sealant was applied. The cap thread and the space between the cable and the cap around the drilled hole were sealed with sealant S1.

5

Results:

Table 2

Example	Sealant/ Adhesive	Test Time (hours)	Seal Configurations				wt% Loss (24 hours)
			Gap Seal	Wire Seal	Gap and Wire area outside bottle	Gap and Wire area inside bottle	
CE1	none	24	No	No	n/a	n/a	12.5%
E1	S1	24	Yes	No	Yes	No	9.2%
E2	S1	24	Yes	No	No	Yes	8.3%
E3	S1	24	Yes	Yes	Yes	No	0.0%
E4	S1	24	Yes	Yes	No	Yes	0.6%
E5	S2	24	Yes	No	Yes	No	8.6%
E6	S2	24	Yes	No	No	Yes	7.6%
E7	S2	24	Yes	Yes	Yes	No	1.4%
E8	S2	24	Yes	Yes	No	Yes	0.9%

The invention claimed is:

1. A sealed cable assembly, comprising:
a jacket enclosing a plurality of insulated wires and including an air gap between the
5 jacket and the insulated wires, wherein the insulated wires each comprise a bare wire covered by a
surrounding insulation; and
a sealant surrounding the insulated wires in the air gap between the jacket and the
insulated wires in a location along the jacket, wherein the sealant fills the air gap at the location.
- 10 2. The cable assembly of claim 1, further comprising another sealant surrounding a portion of
each bare wire and overlapping with the insulation where the bare wire is exposed.
3. The cable assembly of claim 1, wherein the cable has at least one plug or connector on at
least one end of the cable connected to at least one of the bare wires.
- 15 4. The cable assembly of claim 3, wherein the sealant is present on at least one wire inside or
near the plug or connector.
5. The cable assembly of claim 3, wherein the sealant is present as part of a space between
20 the insulated wires inside or near the plug or connector.
6. The cable assembly of claim 5, wherein the sealant fills the space between the insulated
wires inside or near the plug or connector.
- 25 7. The cable assembly of claim 1, further comprising a tape or film wrapped around and
surrounding an outer surface of the jacket in the location at or near the cable plug.
8. The cable assembly of claim 1, wherein the sealant comprises an epoxy.
- 30 9. The cable assembly of claim 2, wherein the another sealant comprises another epoxy.
10. The cable assembly of claim 4, wherein the sealant is a cured epoxy.
11. The cable assembly of claim 10, wherein the sealant comprises an epoxy-containing
35 liquid.

12. The cable assembly of claim 1, wherein the cable assembly comprises a coaxial cable for data transmission.

13. The cable assembly of claim 1, wherein the cable assembly comprises a fiber optical cable for data transmission.

14. The cable assembly of claim 1, wherein the cable assembly comprises an electrical cable for power supply.

15. The cable assembly of any of claims 1-14, wherein the cable assembly is mechanically coupled with an immersion cooling tank at an aperture in the tank.

16. A sealed cable assembly, comprising:

a jacket enclosing a plurality of insulated wires and including an air gap between the jacket and the insulated wires, wherein the insulated wires each comprise a bare wire covered by a surrounding insulation; and

a sealant surrounding the insulated wires in the air gap between the jacket and the insulated wires in a location at an in-between section of the jacket, wherein the sealant fills the air gap at the in-between section.

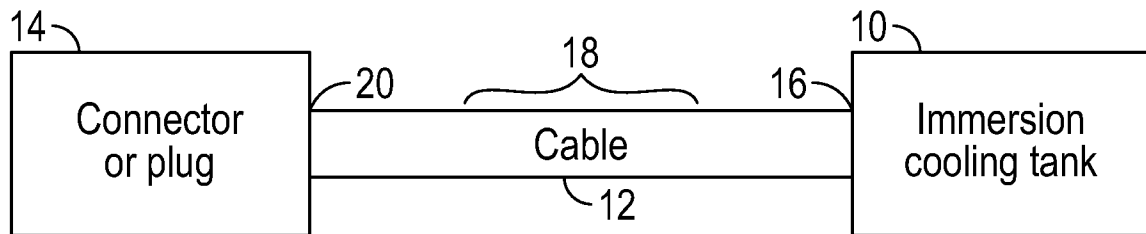
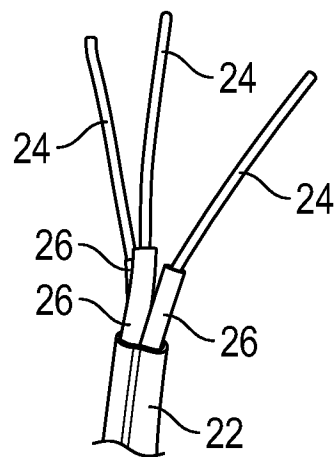
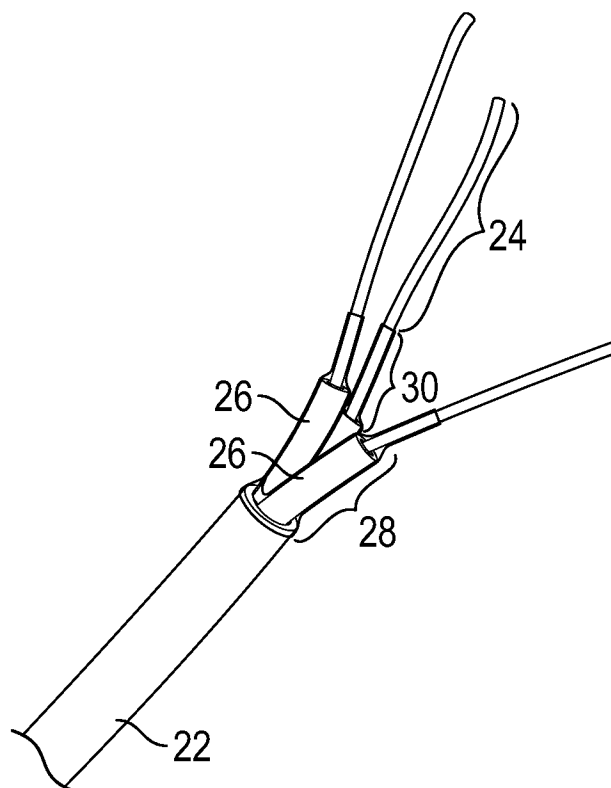
17. The cable assembly of claim 16, further comprising a tape or film wrapped around and surrounding an outer surface of the jacket at the in-between section.

18. The cable assembly of claim 16, wherein the sealant comprises an epoxy.

19. The cable assembly of claim 16, wherein the cable assembly comprises a power cable.

20. The cable assembly of claim 16, wherein the cable assembly comprises a data cable.

21. The cable assembly of any of claims 16-20, wherein the cable assembly is mechanically coupled with an immersion cooling tank at an aperture in the tank.

**FIG. 1****FIG. 2A****FIG. 2B**

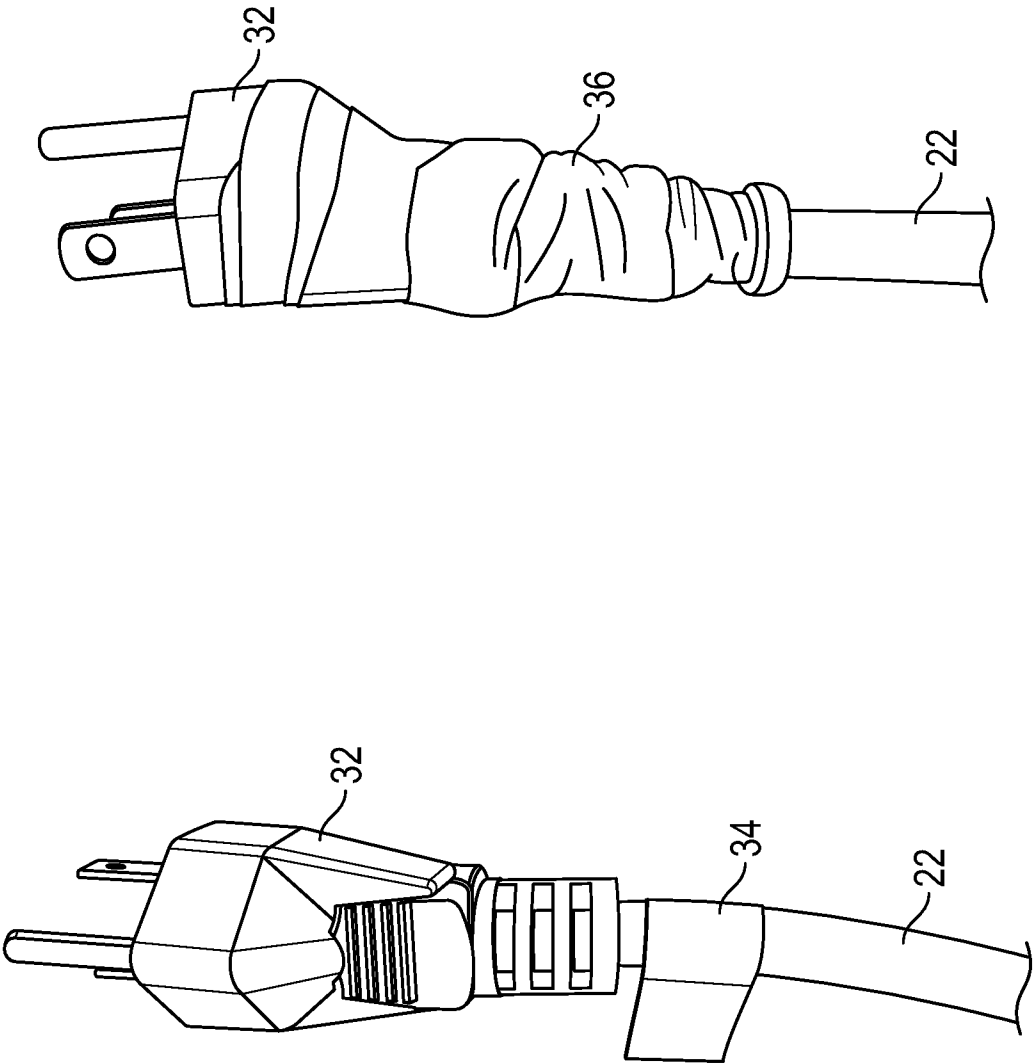


FIG. 2D

FIG. 2C

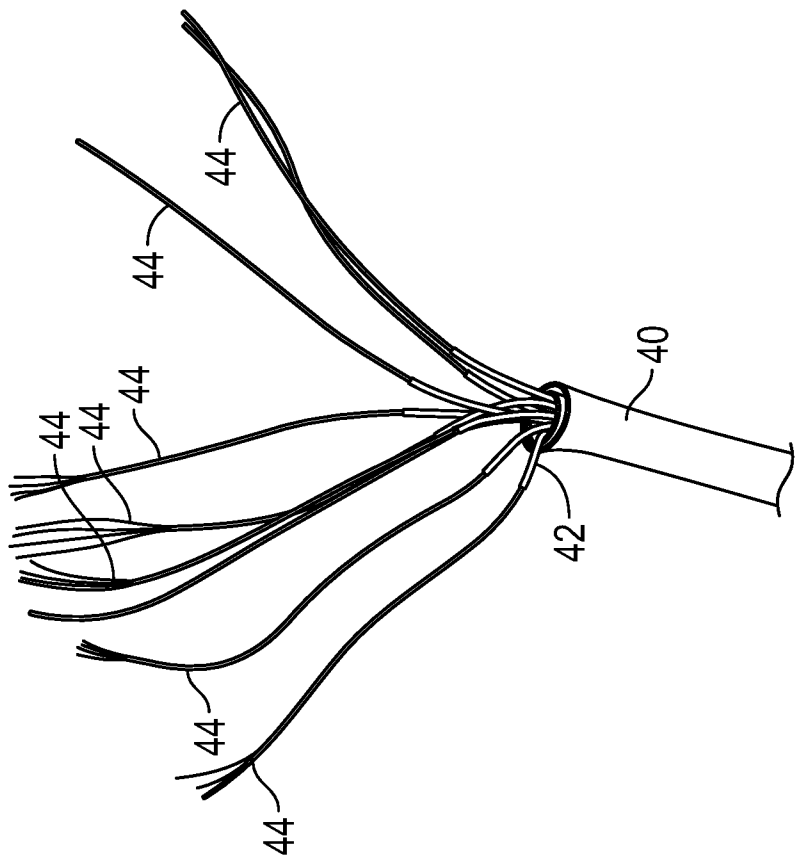


FIG. 3B

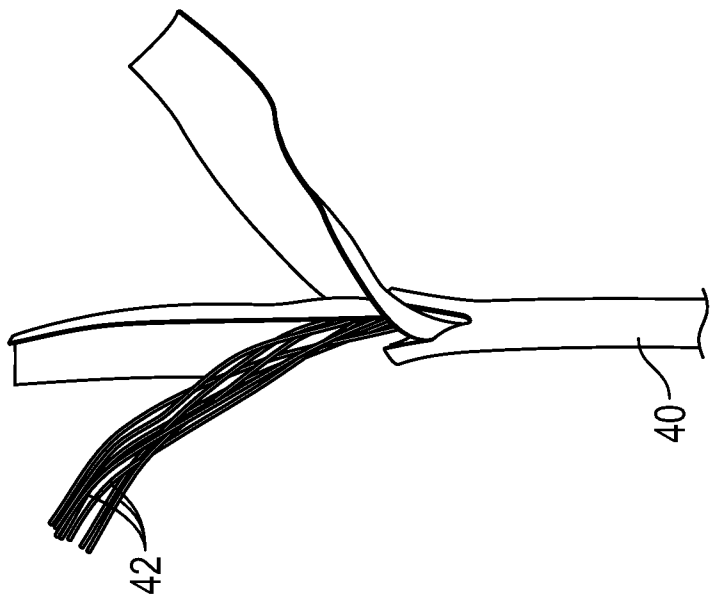


FIG. 3A

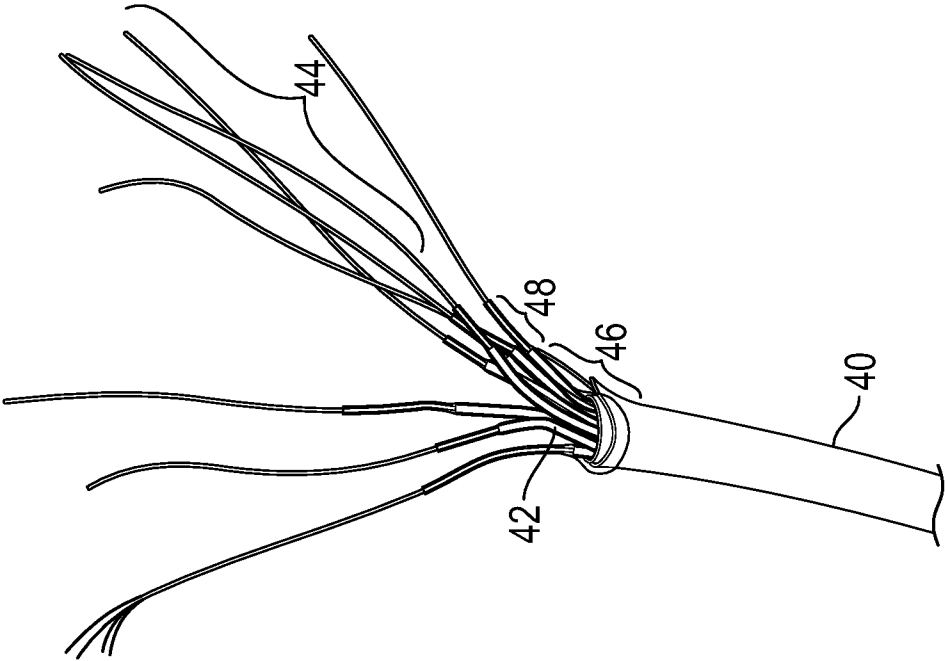


FIG. 3C

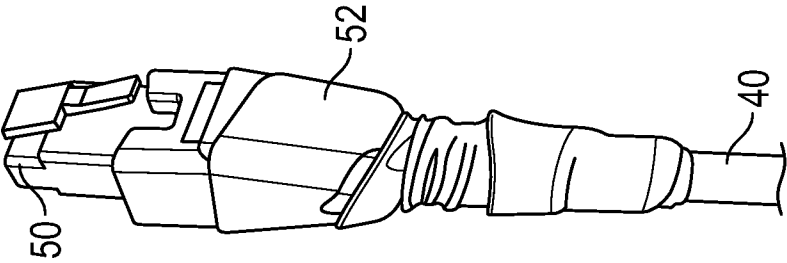


FIG. 3D

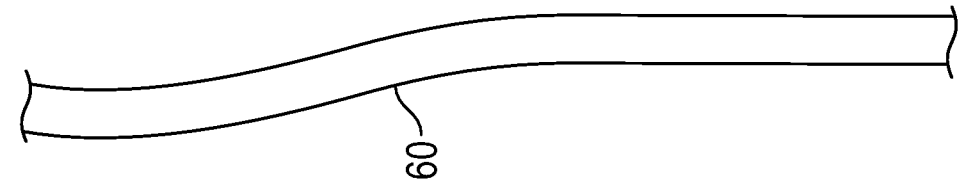


FIG. 4A

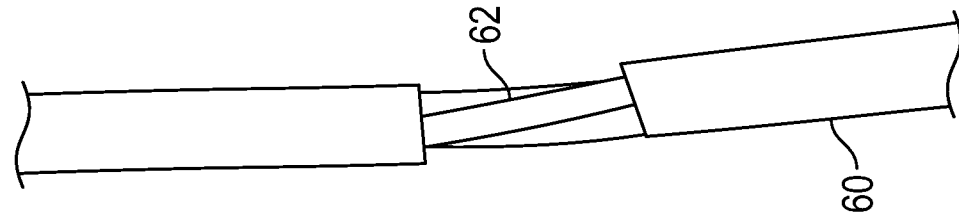


FIG. 4B

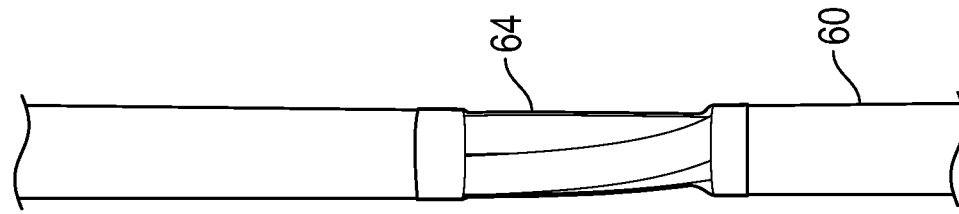


FIG. 4C

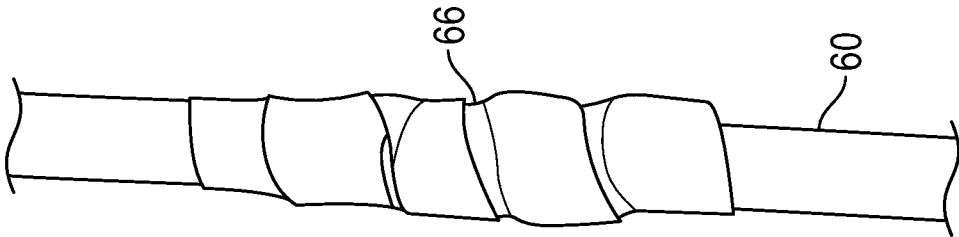


FIG. 4D

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2020/050712**A. CLASSIFICATION OF SUBJECT MATTER****H01B 7/42(2006.01)i, H01B 11/18(2006.01)i, H01B 9/00(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 7/42; A61B 1/00; F28F 27/02; H01B 13/00; H01B 7/00; H01B 7/02; H01B 7/17; H01B 7/18; H01B 7/28; H02G 15/013; H05K 7/20; H01B 11/18; H01B 9/00

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: immersion cooling, cable, seal, epoxy, connector

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 102751020 B (JIANGSU YUANYANG CABLE CO., LTD.) 26 February 2014 See abstract, paragraph [0032], claim 1 and figure 1.	1, 2, 12-14, 16, 17, 19, 20
Y		3-11, 15, 18, 21
Y	EP 0594793 B1 (W.L. GORE & ASSOCIATES, INC.) 13 September 1995 See claim 1 and figures 1-5.	3-11, 18
Y	US 2017-0013744 A1 (DELL PRODUCTS, L.P.) 12 January 2017 See paragraphs [0075]-[0079] and figure 4.	15, 21
A	CN 105655017 A (WUHAN HONGLIAN WIRE & CABLE CO., LTD.) 08 June 2016 See abstract, claim 1 and figure 1.	1-21
A	US 2018-0026433 A1 (HEAT-LINE CORPORATION) 25 January 2018 See the whole document.	1-21

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

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Date of the actual completion of the international search

27 May 2020 (27.05.2020)

Date of mailing of the international search report

28 May 2020 (28.05.2020)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea



Facsimile No. +82-42-481-8578

Authorized officer

Kim, Yeonkyung

Telephone No. +82-42-481-3325



INTERNATIONAL SEARCH REPORT

Information on patent family members

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