US007665890B2

(12) **United States Patent**
Culbertson et al.

(10) **Patent No.: US 7,665,890 B2**
(45) **Date of Patent: Feb. 23, 2010**

(54) **TEMPERATURE SENSOR ASSEMBLY AND METHOD OF MANUFACTURING THEREOF**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 201 days.

(21) Appl. No.: **11/767,362**

(22) Filed: **Jun. 22, 2007**

(65) **Prior Publication Data**

US 2008/0025372 A1 Jan. 31, 2008

Related U.S. Application Data

(60) Provisional application No. 60/815,620, filed on Jun. 22, 2006.

(51) **Int. Cl.**
G01K 1/00 (2006.01)

(52) **U.S. Cl.** **374/100**

(58) **Field of Classification Search** 374/185, 374/139, 126, 166, 100
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,934,786	A	1/1976	Kozak et al.
3,954,507	A	5/1976	Carter
3,963,316	A	6/1976	Williams
3,984,912	A	10/1976	Johnston et al.
3,994,552	A	11/1976	Selvin
4,039,244	A	8/1977	Leachy
4,066,325	A	1/1978	Pearce, Jr. et al.
4,072,394	A	2/1978	Waldron et al.
4,120,556	A	10/1978	Waldron et al.
4,129,351	A	12/1978	Sugimoto et al.
4,152,578	A	5/1979	Jacobs
4,206,958	A	6/1980	Hall et al.
4,223,968	A	9/1980	Kawabata et al.
4,252,397	A	2/1981	Eigenbrode et al.
4,258,974	A	3/1981	Kuo et al.
4,262,983	A	4/1981	Bogese, II
4,273,407	A	6/1981	Snuffer et al.
4,315,662	A	2/1982	Greenwood et al.
4,332,430	A	6/1982	Clark
4,343,523	A	8/1982	Cairns et al.
4,352,538	A	10/1982	Fowler
4,392,703	A	7/1983	Hall et al.
4,417,395	A	11/1983	Hall et al.

(Continued)

OTHER PUBLICATIONS

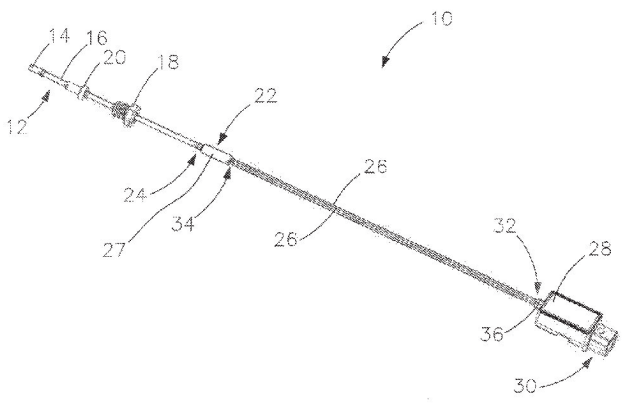
U.S. Appl. No. 11/767,373, filed Jun. 22, 2007, Frake, et al.

Primary Examiner—Andre J Allen
(74) *Attorney, Agent, or Firm*—Brinks Hofer Gilson & Lione

(57) **ABSTRACT**

A temperature sensor assembly and method of manufacturing thereof having a temperature probe, a mounting connector, a wire set, a transition component, a housing, and a circuit is provided. The temperature probe includes a probe body, a temperature sensor and at least one conductor configured for providing a temperature signal indicative of a temperature over the at least one conductor. The circuit is enclosed within the housing and configured for receiving the temperature signal from the temperature probe and generating the temperature characteristic in response to the received temperature signal.

25 Claims, 32 Drawing Sheets



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U.S. PATENT DOCUMENTS

4,431,252	A		2/1984	Cairns et al.
4,457,570	A		7/1984	Bogese, II
4,461,530	A		7/1984	Brush, Sr. et al.
4,470,100	A		9/1984	Rebaudo et al.
4,517,625	A		5/1985	Frink et al.
4,533,202	A		8/1985	Pohl
4,538,623	A		9/1985	Proctor et al.
4,556,265	A		12/1985	Cunningham
4,579,406	A		4/1986	Laursen et al.
4,581,478	A		4/1986	Pugh et al.
4,598,963	A		7/1986	White et al.
4,641,901	A		2/1987	Brennan et al.
4,695,112	A		9/1987	Maston et al.
4,707,657	A		11/1987	Boegh-Petersen
4,717,217	A		1/1988	Bogese, II
4,726,775	A		2/1988	Owen
4,833,402	A		5/1989	Boegh-Petersen
4,868,967	A		9/1989	Holt et al.
4,871,319	A		10/1989	Babow
4,871,326	A		10/1989	Coon
4,875,865	A		10/1989	Demlelr, Jr. et al.
4,894,906	A		1/1990	Huang
4,900,258	A		2/1990	Hnatuck et al.
4,912,772	A		3/1990	Beaudry, Jr. et al.
4,922,607	A		5/1990	Doan et al.
4,939,454	A		7/1990	Miner
4,985,000	A		1/1991	Tengler et al.
5,046,952	A		9/1991	Cohen et al.
5,070,597	A		12/1991	Holt et al.
5,171,166	A		12/1992	Sato et al.
5,188,536	A		2/1993	Ganthier et al.
5,200,574	A		4/1993	Cunningham et al.
5,214,243	A		5/1993	Johnson
5,215,471	A		6/1993	Reymond et al.
5,241,910	A		9/1993	Cunningham et al.
5,266,903	A		11/1993	Foster
5,302,934	A		4/1994	Hart et al.
5,364,186	A	*	11/1994	Wang et al. 374/126
5,369,225	A		11/1994	Natwig et al.
5,370,459	A	*	12/1994	Culbertson et al. 374/179
5,370,554	A		12/1994	Koyasu
5,393,932	A		2/1995	Young et al.
5,486,113	A		1/1996	Lundh
5,491,321	A		2/1996	Stuart et al.
5,533,901	A		7/1996	Hunt et al.
5,609,491	A		3/1997	Cooper et al.
5,618,109	A	*	4/1997	Culbertson 374/179
5,649,974	A		7/1997	Nelson et al.
5,676,694	A		10/1997	Boser et al.
5,728,149	A		3/1998	Laske et al.
5,730,607	A		3/1998	Darty
5,791,919	A		8/1998	Brisson et al.
5,795,196	A		8/1998	Hotea et al.
5,853,020	A		12/1998	Widner
5,857,259	A		1/1999	Johnston
5,865,631	A		2/1999	Berto et al.
5,878,851	A		3/1999	Carlson et al.
5,944,539	A		8/1999	Ernolf et al.
5,947,754	A		9/1999	Lin
5,954,759	A		9/1999	Swoyer et al.
5,982,253	A		11/1999	Perrin et al.
6,004,168	A		12/1999	Fuchs et al.
6,017,238	A		1/2000	Johnston
6,036,508	A		3/2000	Anderson et al.
6,055,725	A		5/2000	Berto et al.
6,126,494	A		10/2000	Fuchs et al.
6,135,829	A		10/2000	Johnston
6,171,150	B1		1/2001	Saito et al.
6,217,373	B1		4/2001	Johnston
6,230,406	B1		5/2001	Balfour et al.
6,261,137	B1		7/2001	Wilcox
6,283,778	B1		9/2001	Kupnicki et al.
6,312,280	B1		11/2001	Stevenson
D454,333	S		3/2002	Ikeda et al.
D454,335	S		3/2002	Okada
6,372,990	B1		4/2002	Saito et al.
6,384,335	B1		5/2002	Saito et al.
6,388,866	B1		5/2002	Rorvick et al.
6,428,332	B1		8/2002	Nakamura et al.
6,431,750	B1	*	8/2002	Haberbusch et al. 374/166
6,447,305	B1		9/2002	Roberts
6,491,530	B2		12/2002	Koide et al.
6,530,787	B2		3/2003	Harting et al.
6,533,615	B2		3/2003	Koide et al.
6,540,556	B1		4/2003	Fu
6,565,385	B1		5/2003	Anderson et al.
6,565,386	B1		5/2003	Yoneyama et al.
6,603,654	B2		8/2003	Rorvick et al.
6,617,939	B1		9/2003	Vermeersch
6,643,546	B2		11/2003	Mathis et al.
6,682,361	B2		1/2004	Zweigle
6,683,450	B2		1/2004	Rick et al.
D486,794	S		2/2004	Okamoto
6,772,505	B1		8/2004	Logan et al.
6,785,576	B2		8/2004	Verness
6,795,729	B1		9/2004	Breyen et al.
6,851,956	B2		2/2005	Saka et al.
6,906,541	B2		6/2005	Kimura
6,963,482	B2		11/2005	Breyen et al.
7,312,690	B1	*	12/2007	Geer ..... 338/22 R
2004/0002822	A1	*	1/2004	Keck 702/55
2004/0086215	A1	*	5/2004	Salerno et al. 385/12
2005/0069018	A1	*	3/2005	Hosler et al. 374/139

* cited by examiner

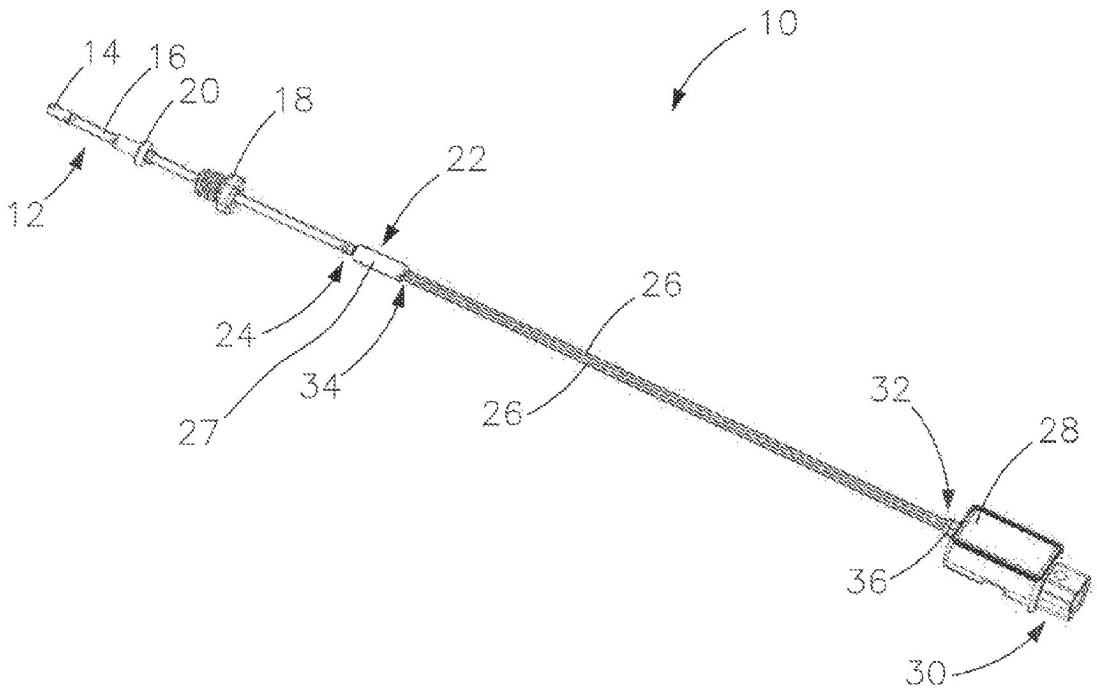


FIG. 1

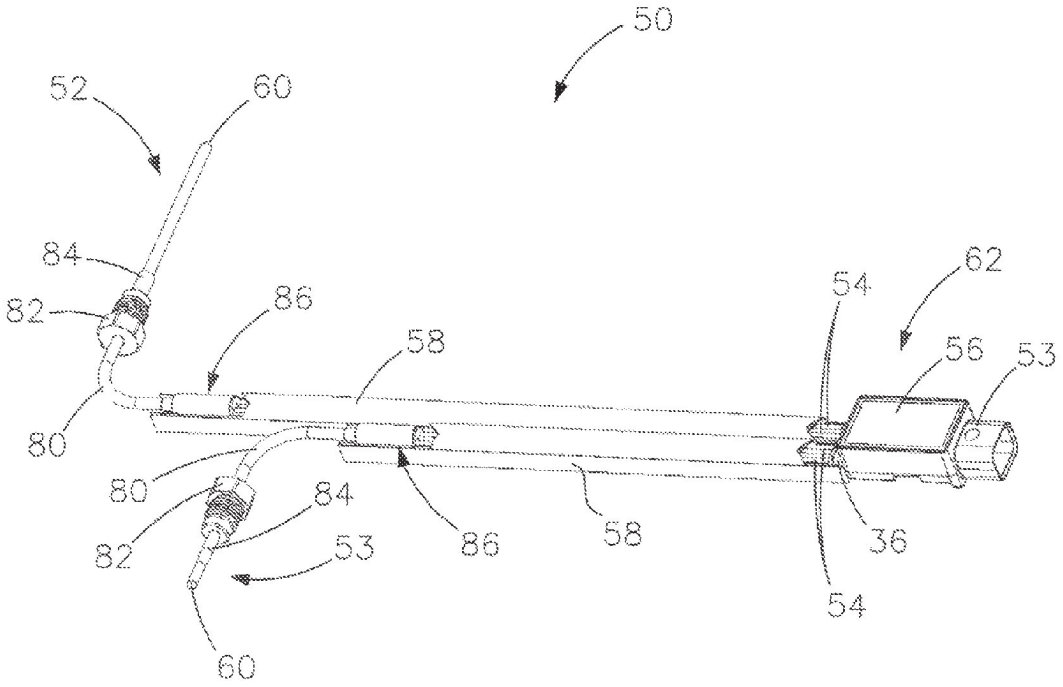


FIG. 2A

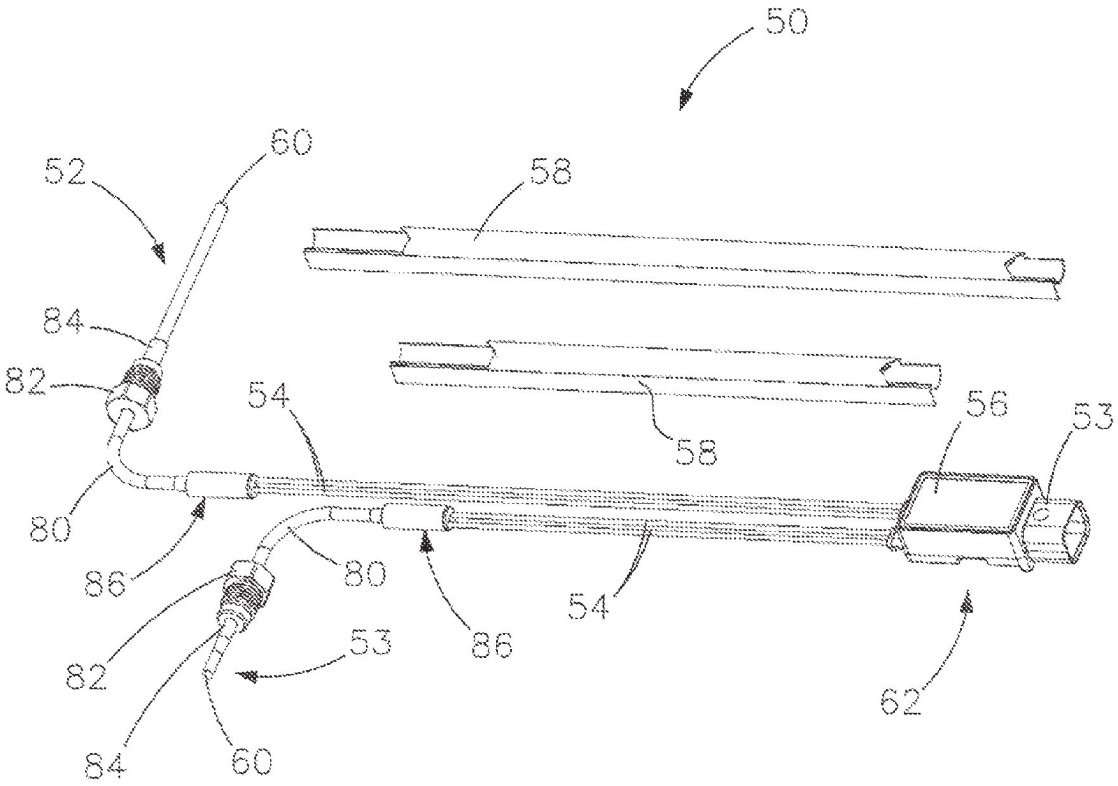


FIG. 2B

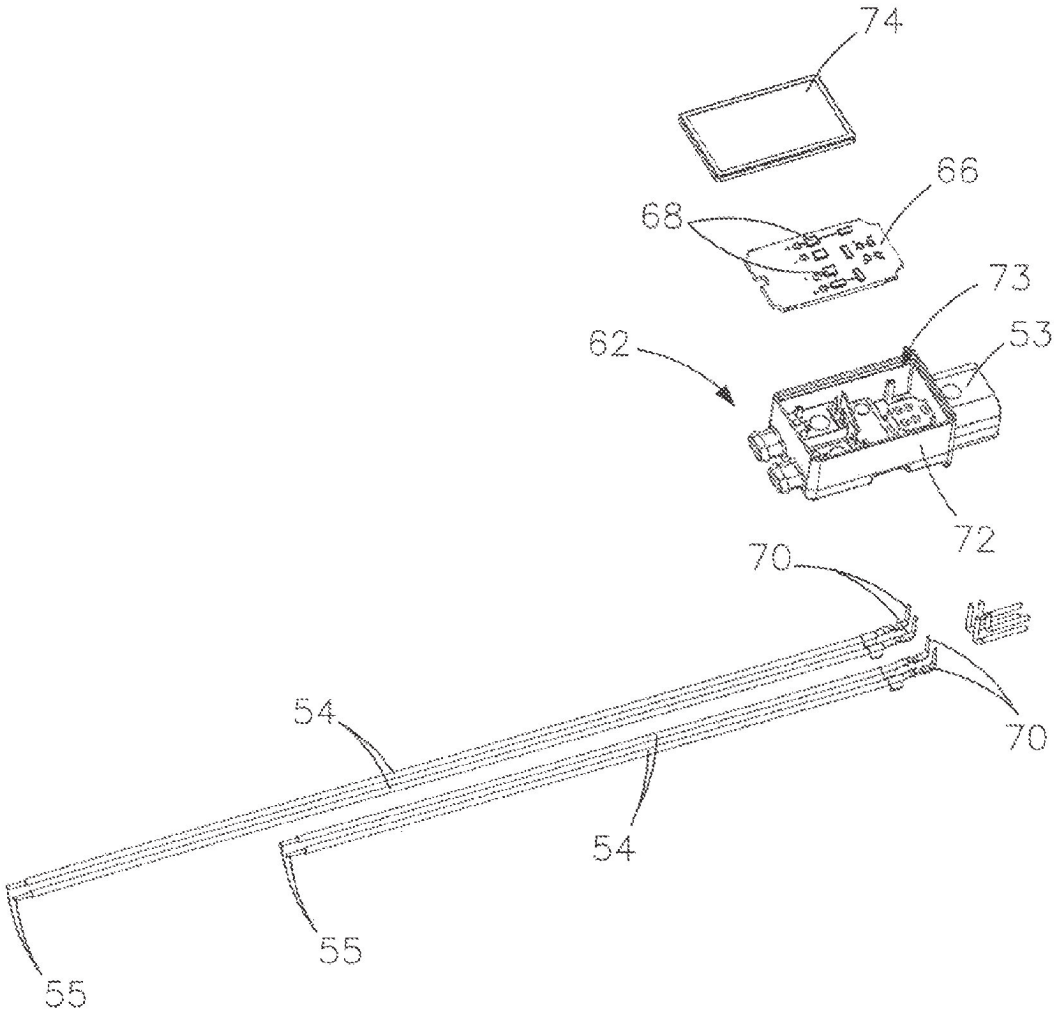


FIG. 3A

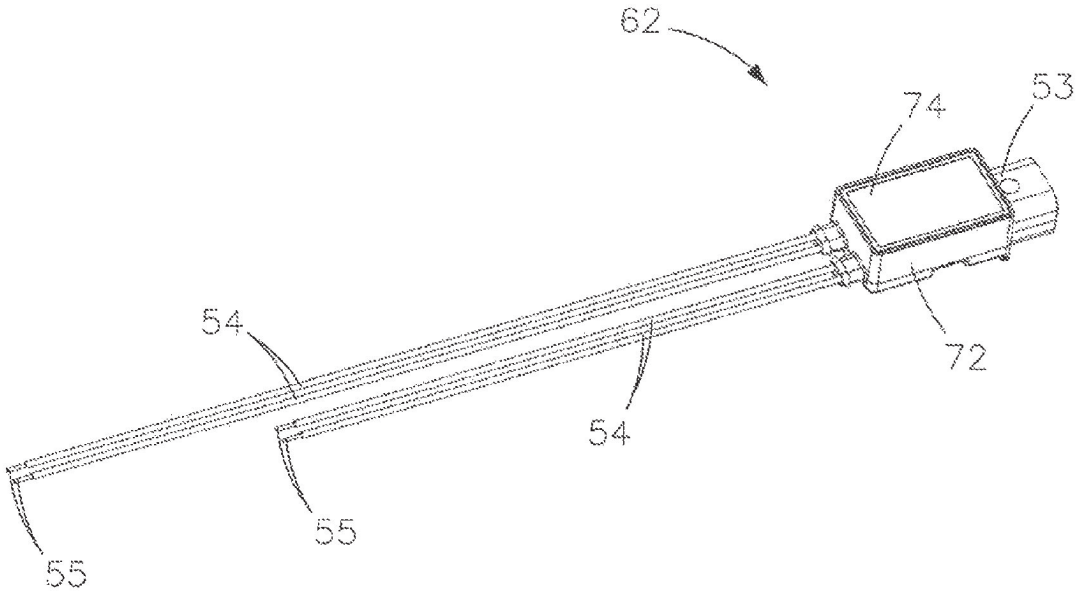


FIG. 3B

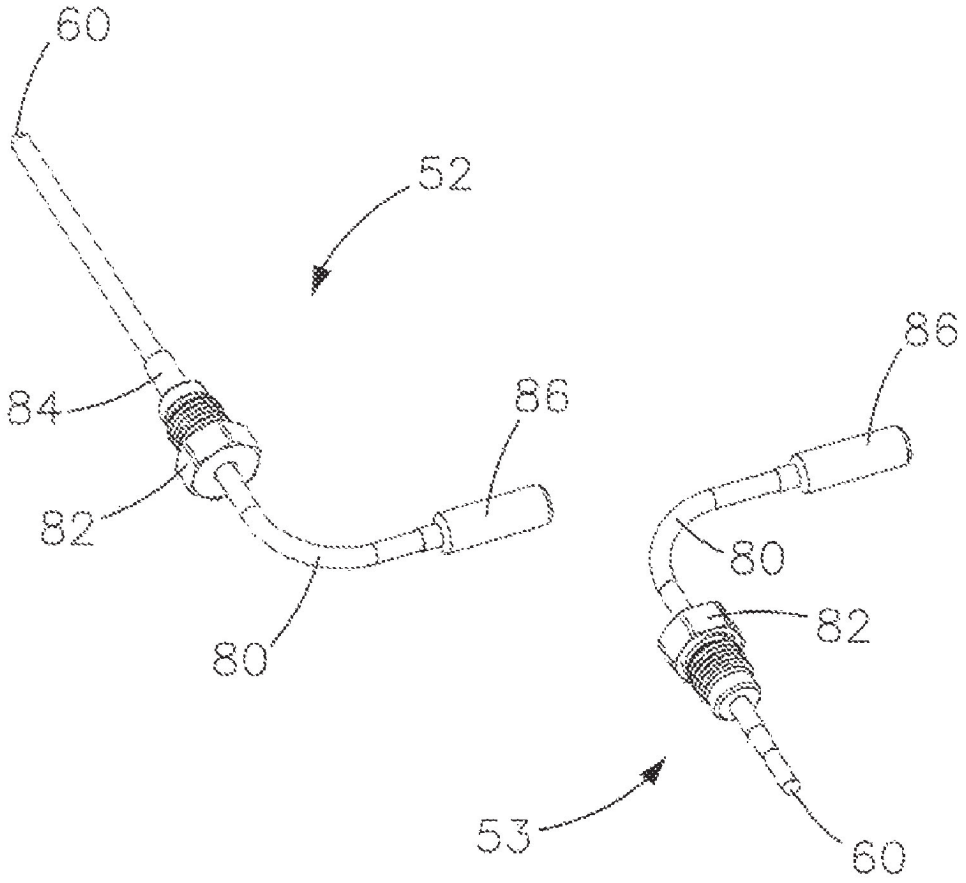


FIG. 4A

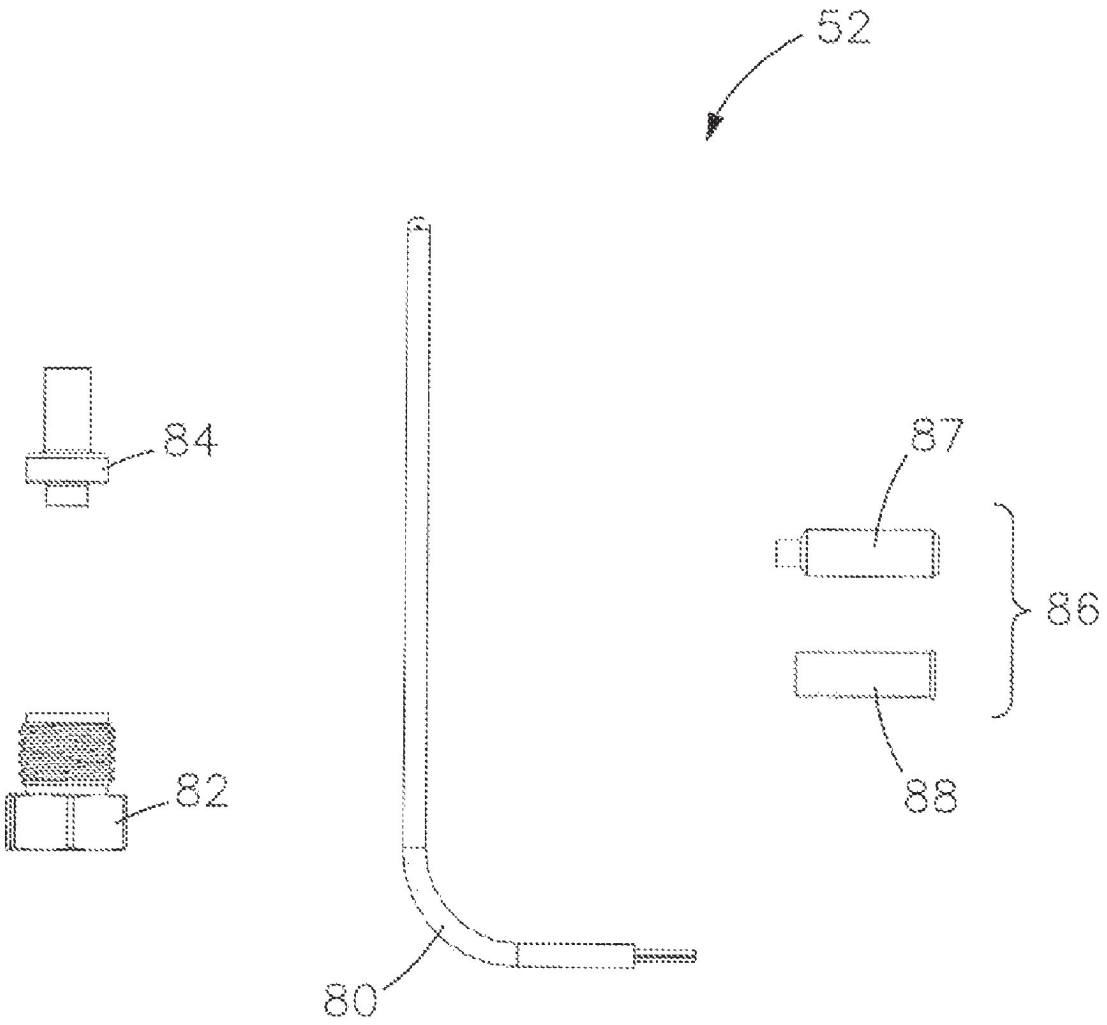


FIG. 4B

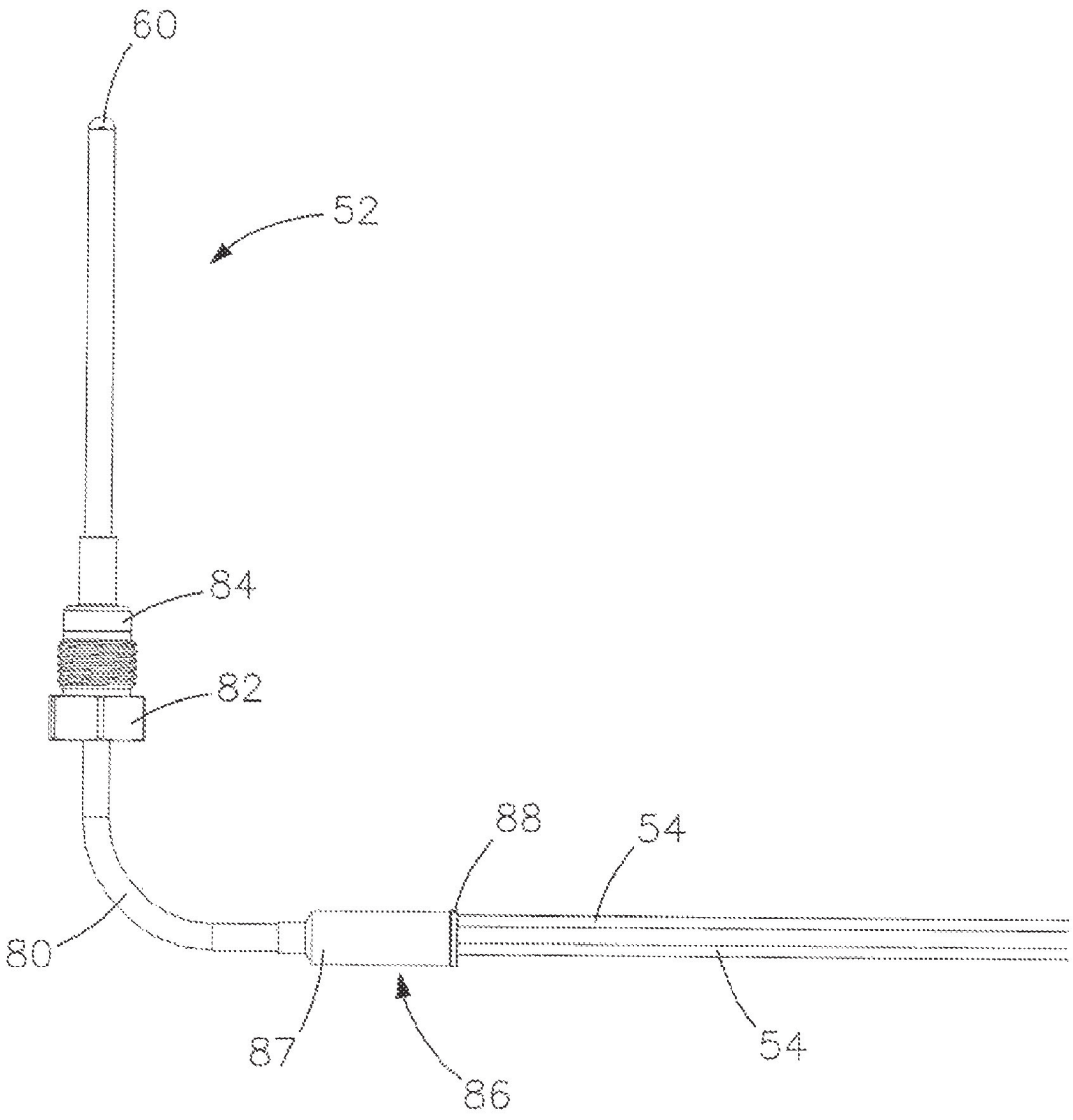


FIG. 4C

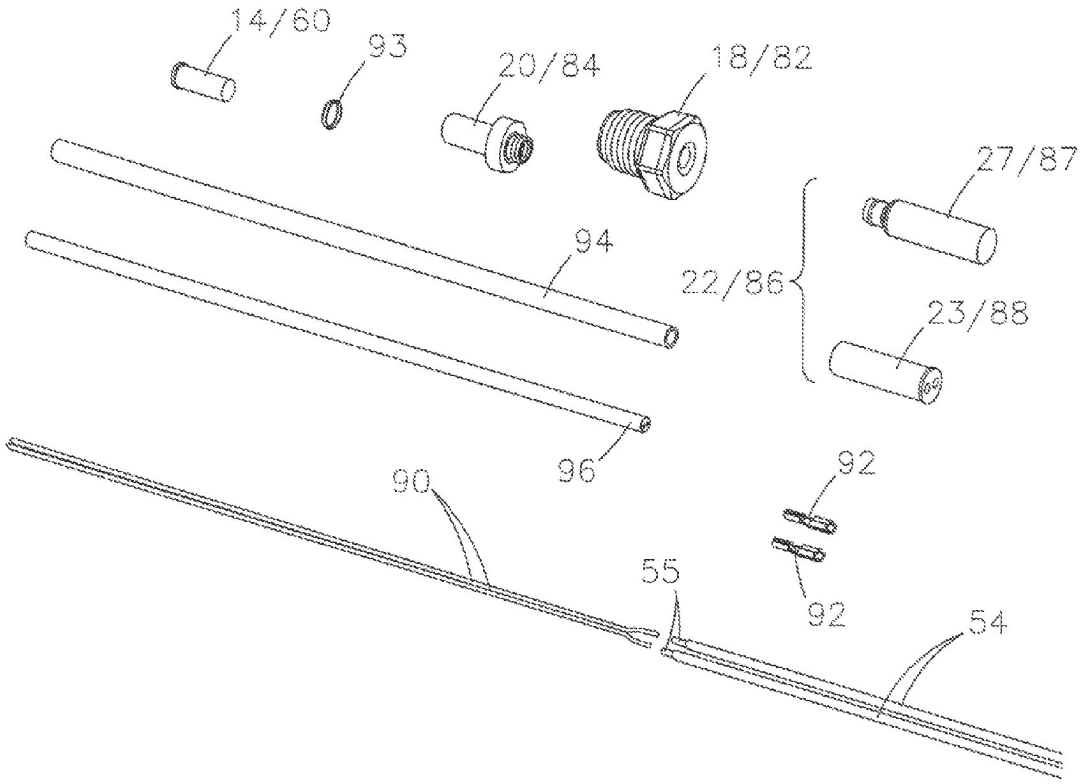


FIG. 5

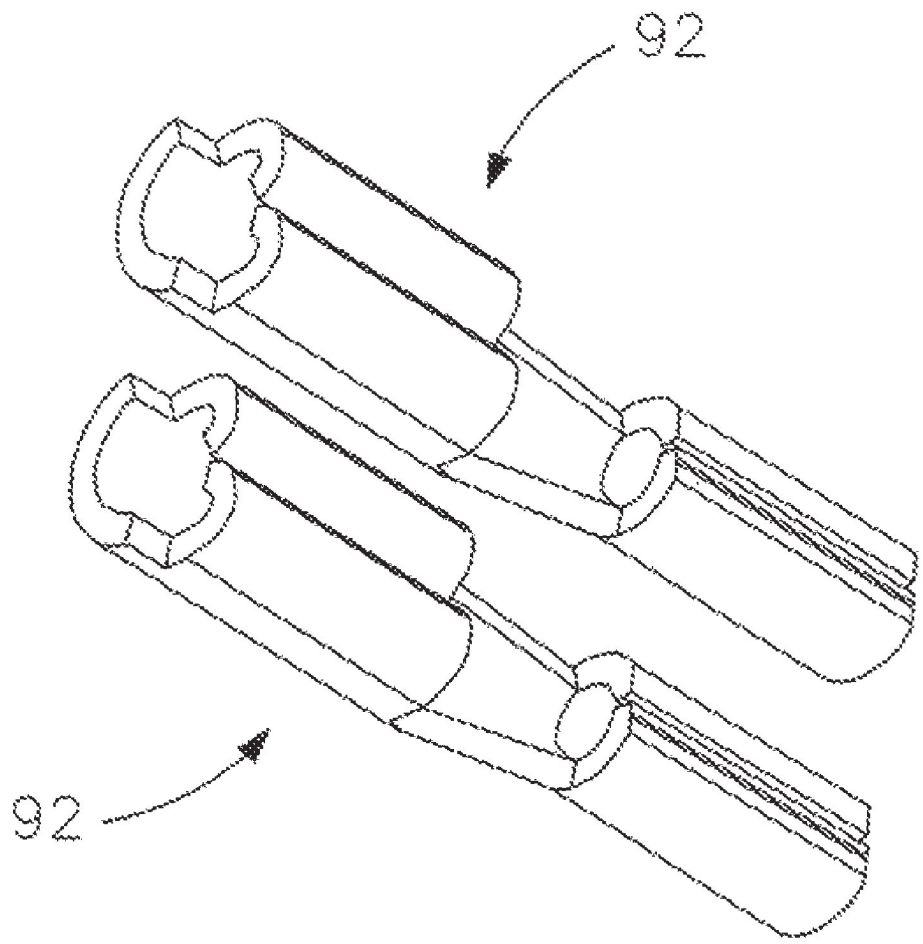


FIG. 6

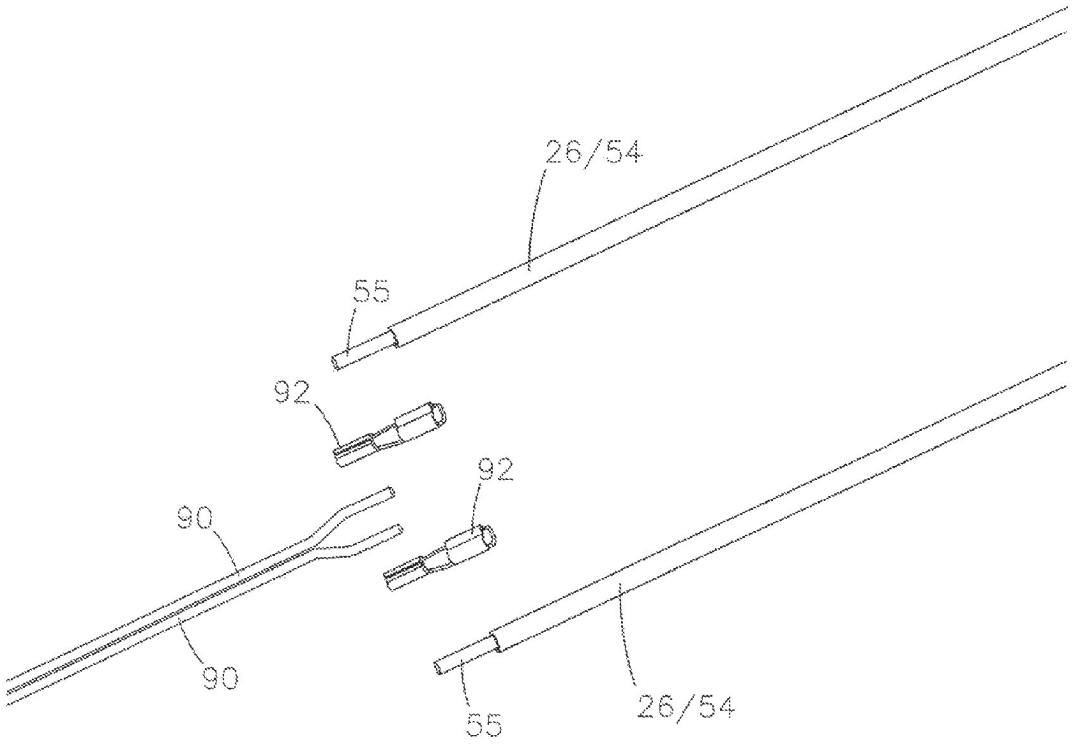


FIG. 7A

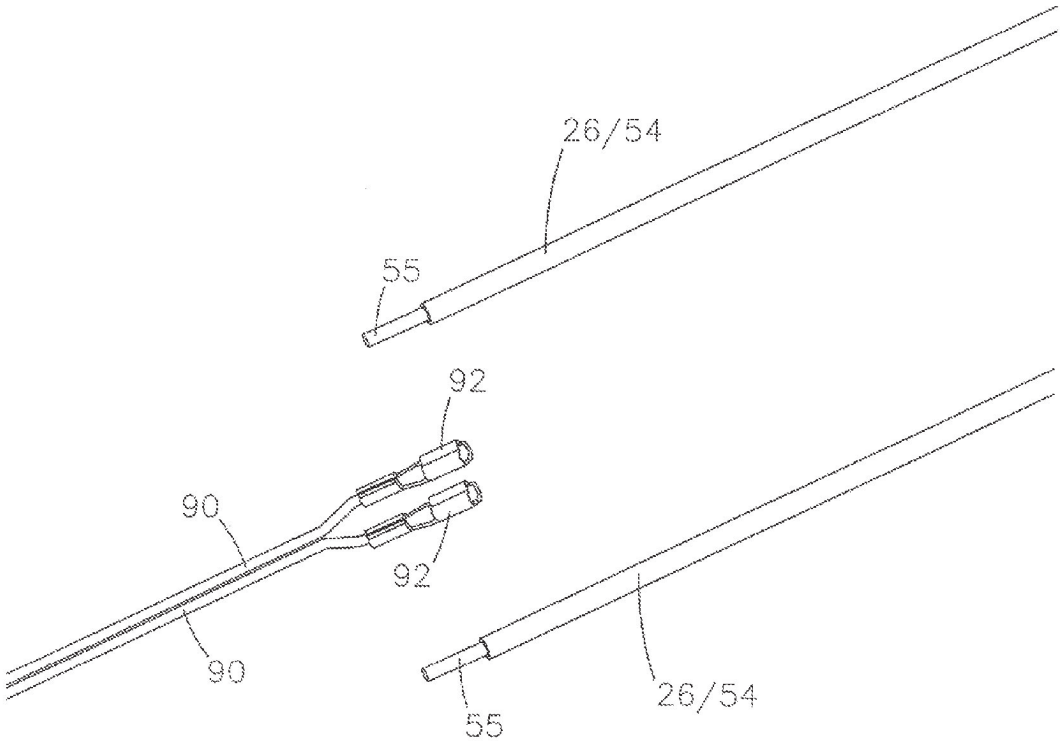


FIG. 7B

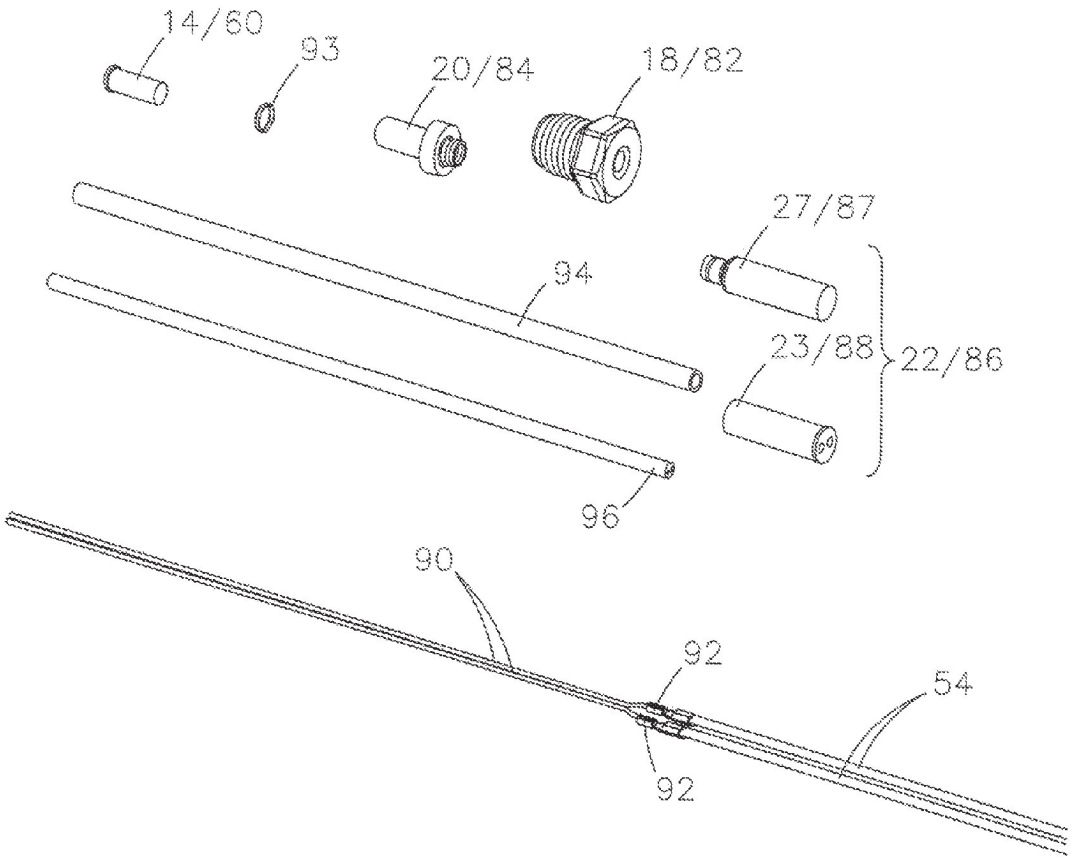


FIG. 7C

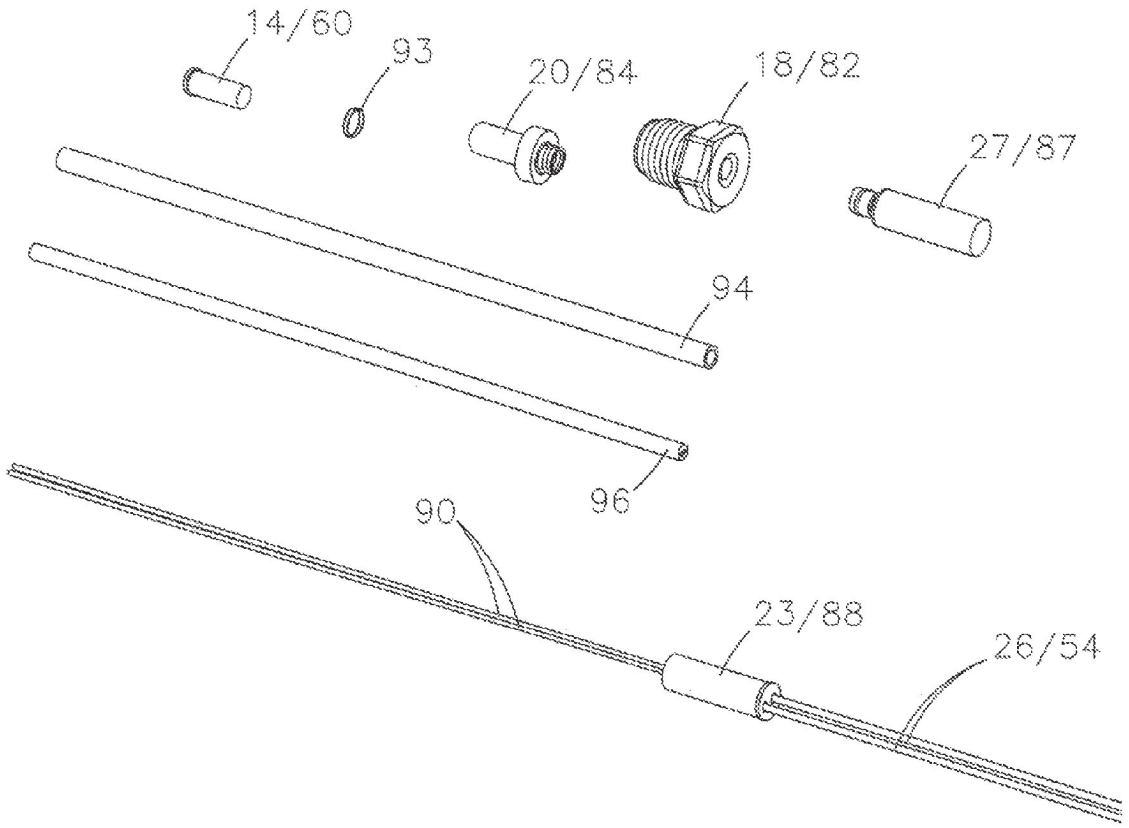


FIG. 7D

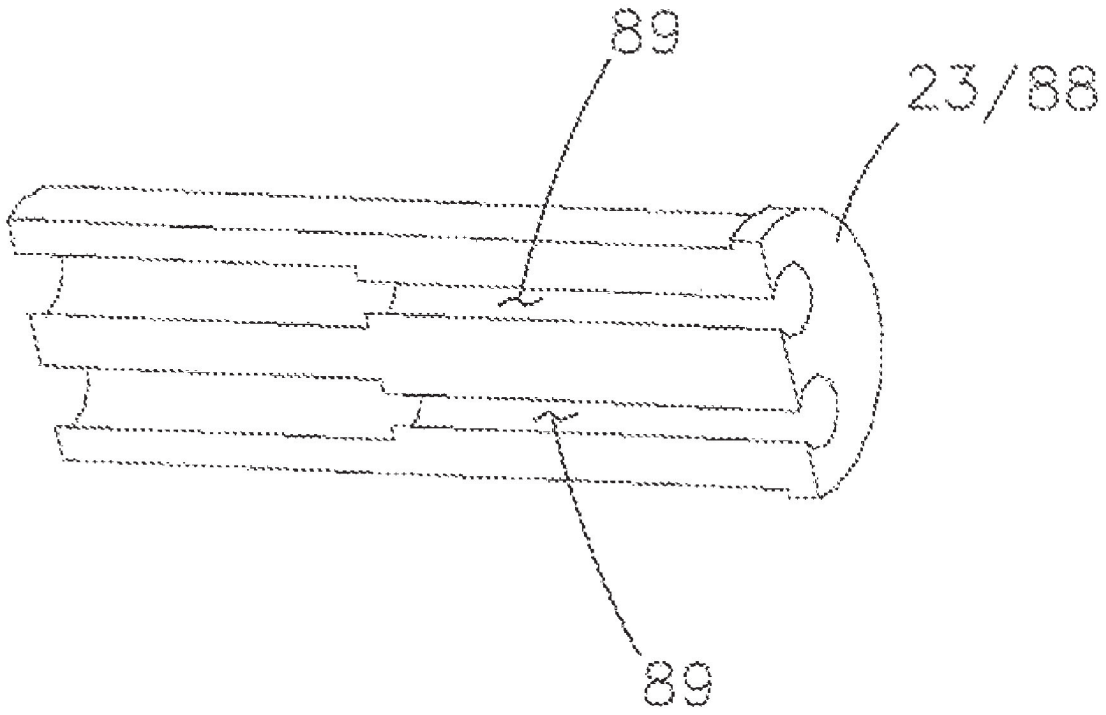


FIG. 7E

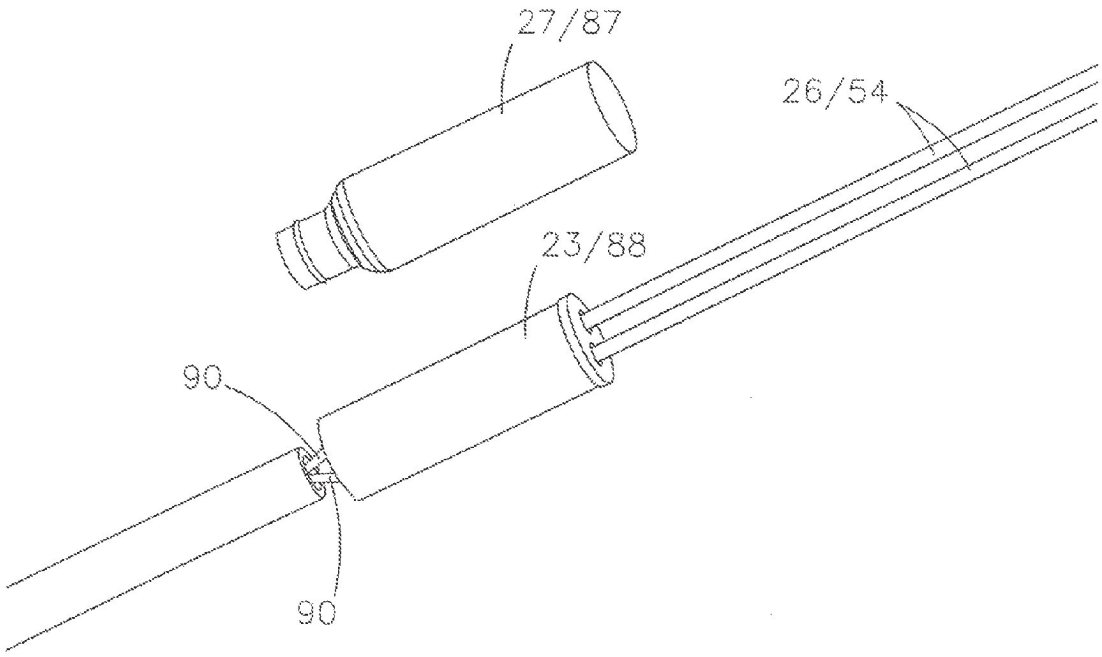


FIG. 7F

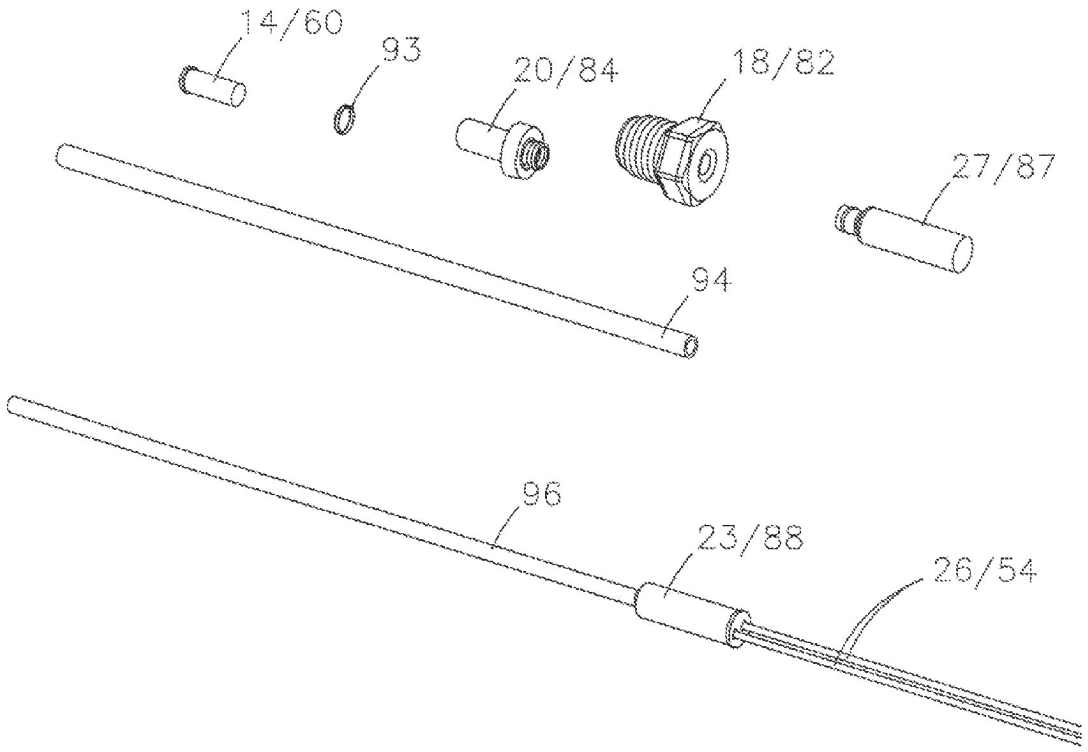


FIG. 7G

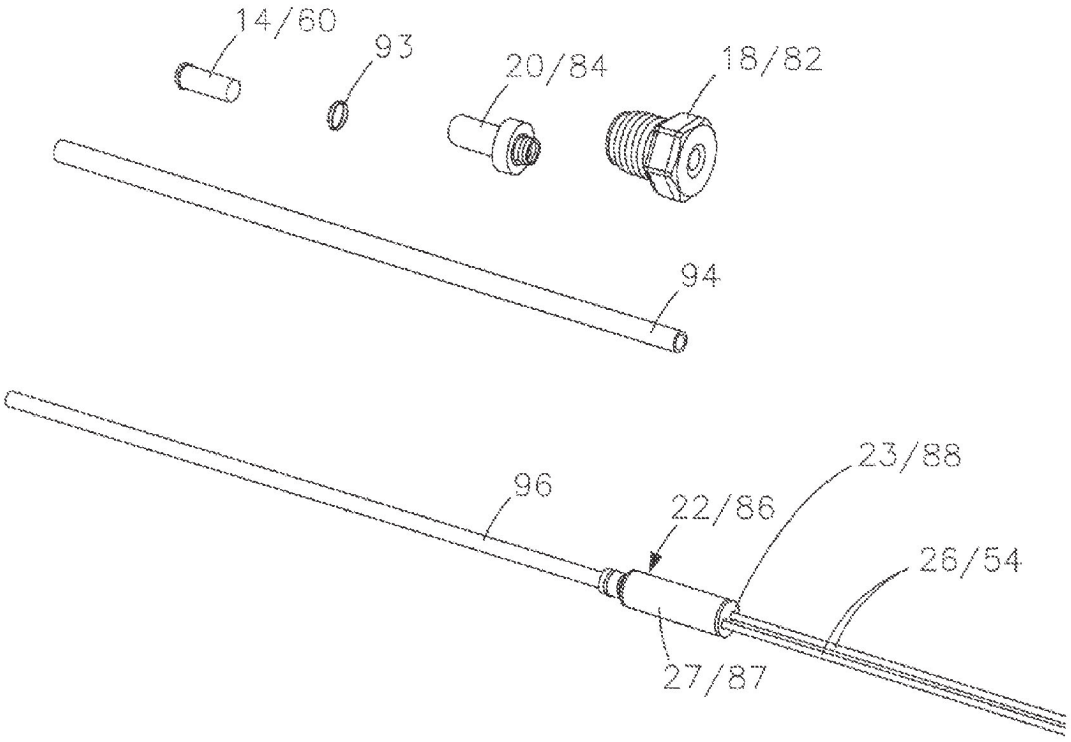


FIG. 7H

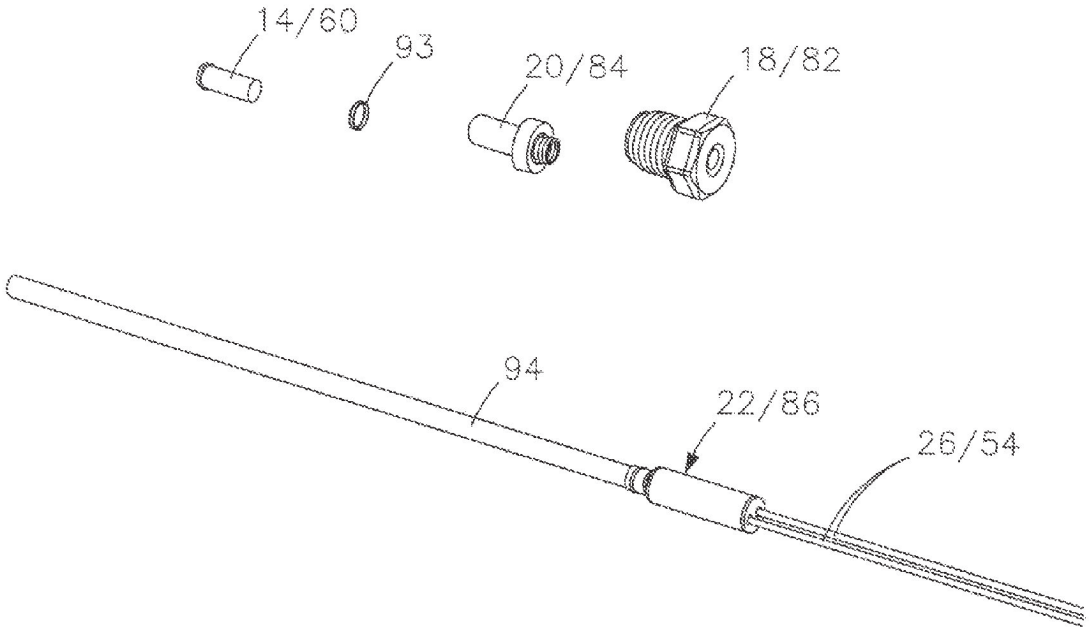


FIG. 7I

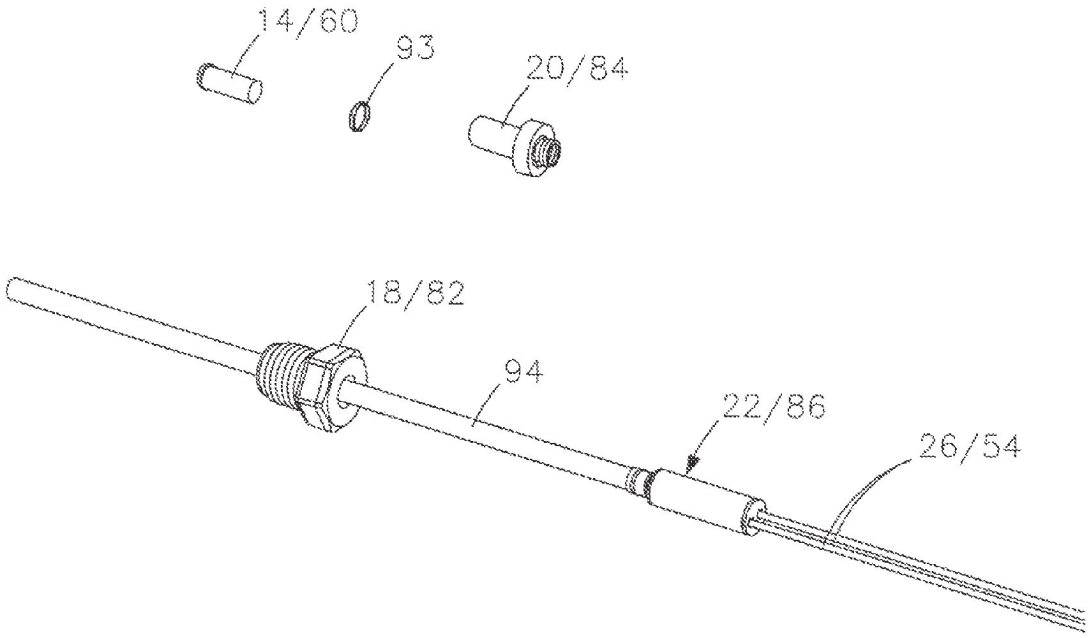


FIG. 7J

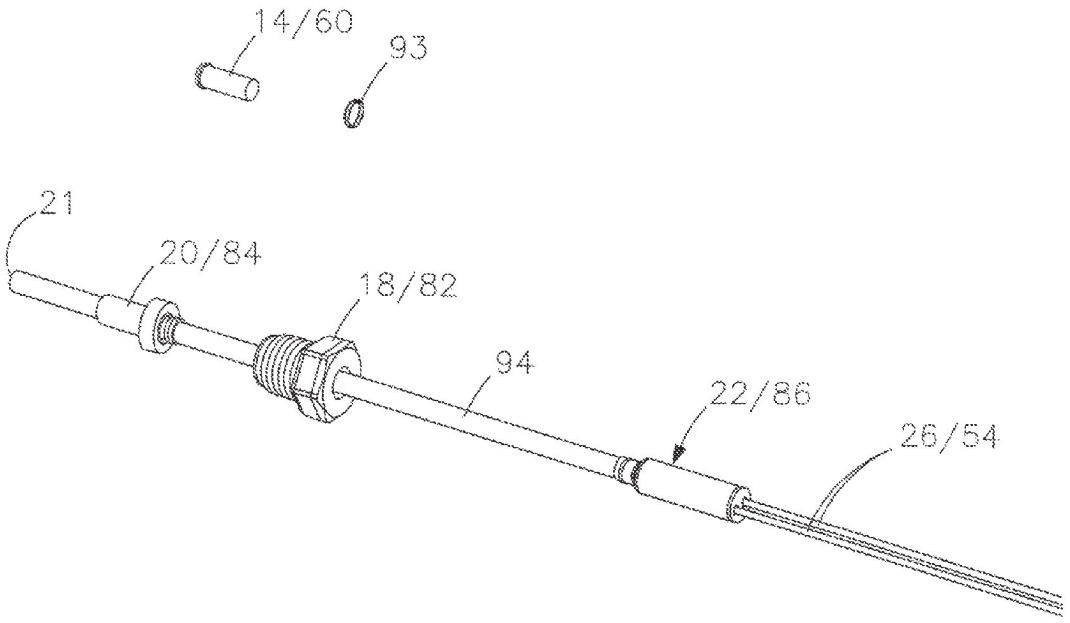


FIG. 7K

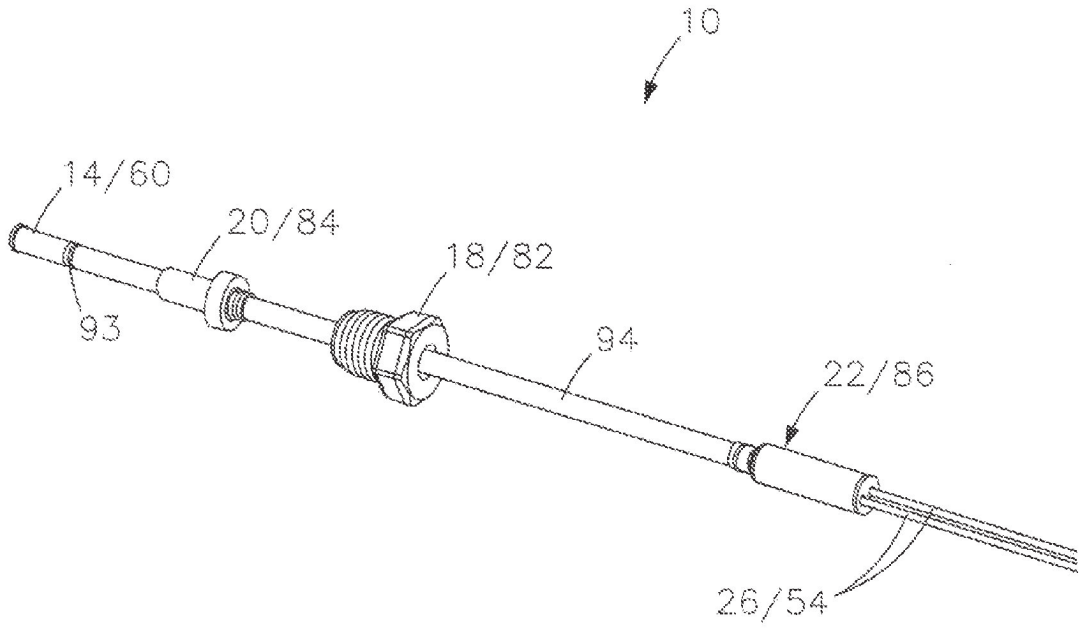


FIG. 7L

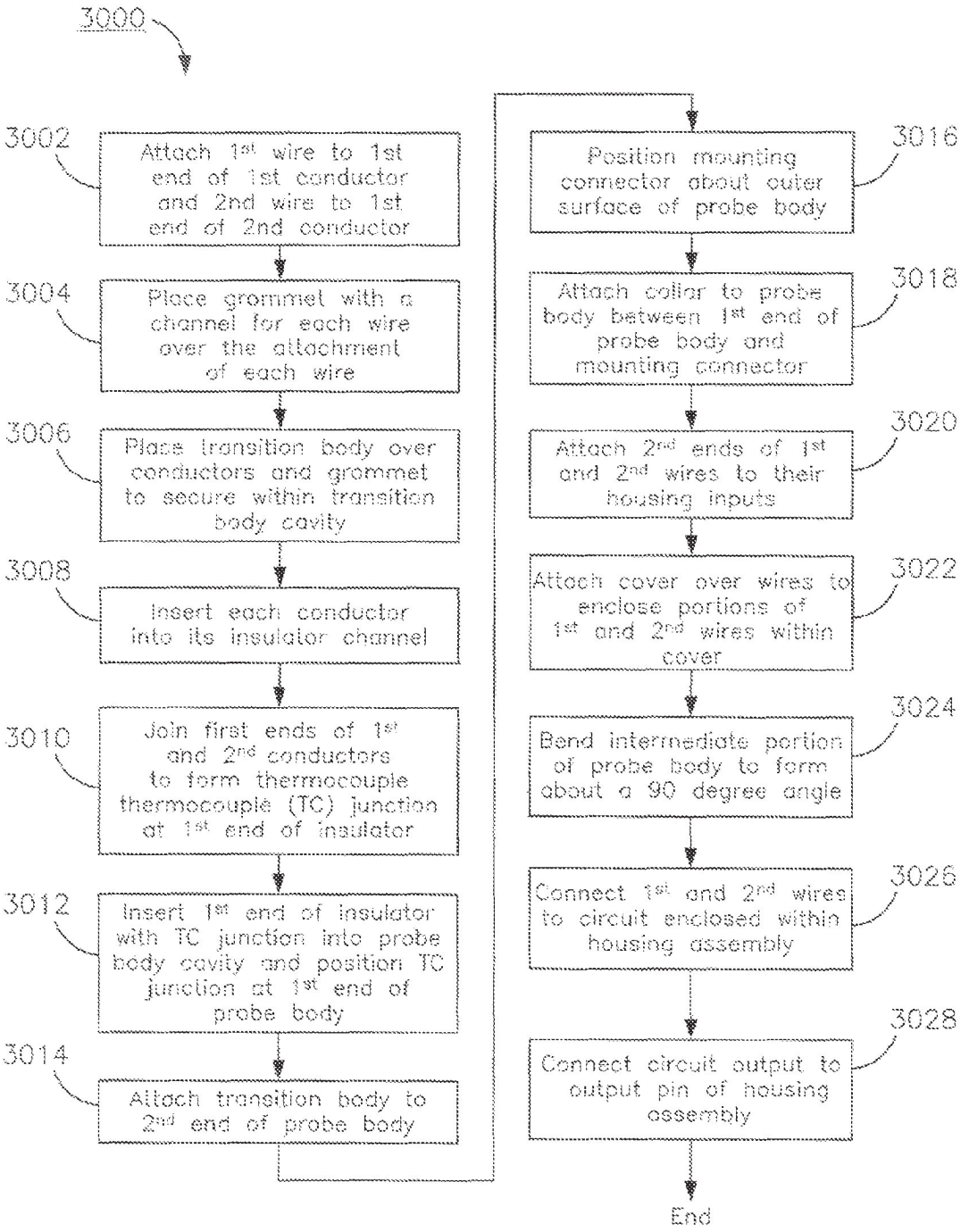

3000
3002
Attach 1st wire to 1st end of 1st conductor and 2nd wire to 1st end of 2nd conductor
3004
Place grommet with a channel for each wire over the attachment of each wire
3006
Place transition body over conductors and grommet to secure within transition body cavity
3008
Insert each conductor into its insulator channel
3010
Join first ends of 1st and 2nd conductors to form thermocouple thermocouple (TC) junction at 1st end of insulator
3012
Insert 1st end of insulator with TC junction into probe body cavity and position TC junction at 1st end of probe body
3014
Attach transition body to 2nd end of probe body
3016
Position mounting connector about outer surface of probe body
3018
Attach collar to probe body between 1st end of probe body and mounting connector
3020
Attach 2nd ends of 1st and 2nd wires to their housing inputs
3022
Attach cover over wires to enclose portions of 1st and 2nd wires within cover
3024
Bend intermediate portion of probe body to form about a 90 degree angle
3026
Connect 1st and 2nd wires to circuit enclosed within housing assembly
3028
Connect circuit output to output pin of housing assembly
End

FIG. 8

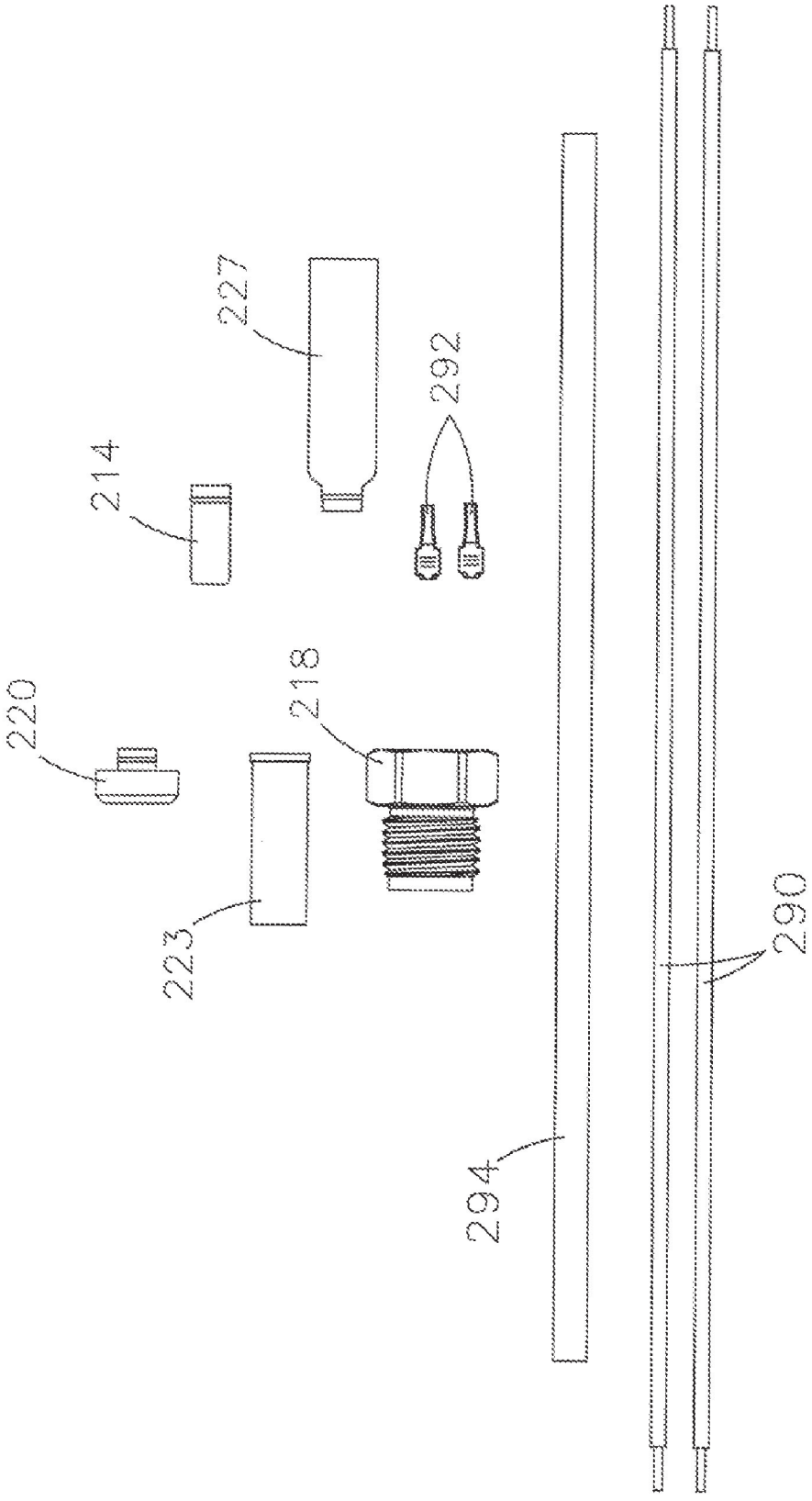


FIG. 9

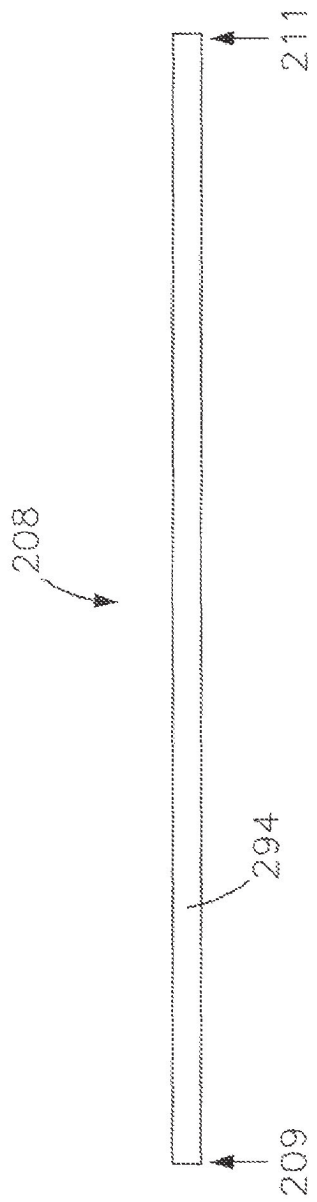


FIG. 10A

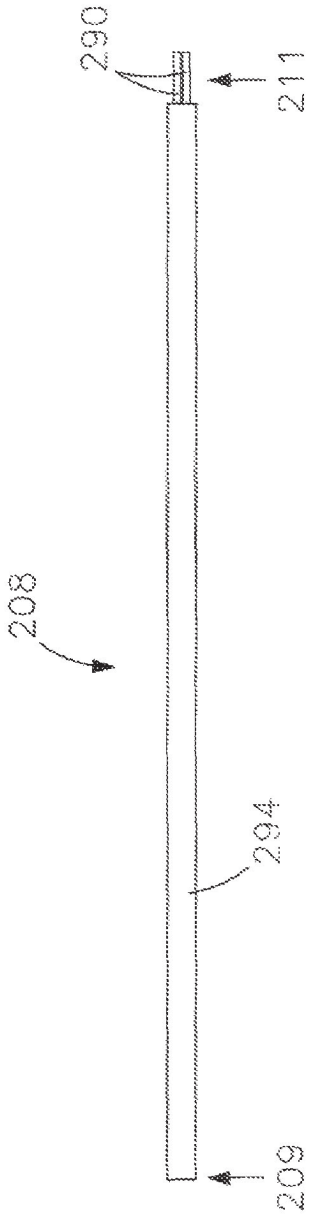


FIG. 10B

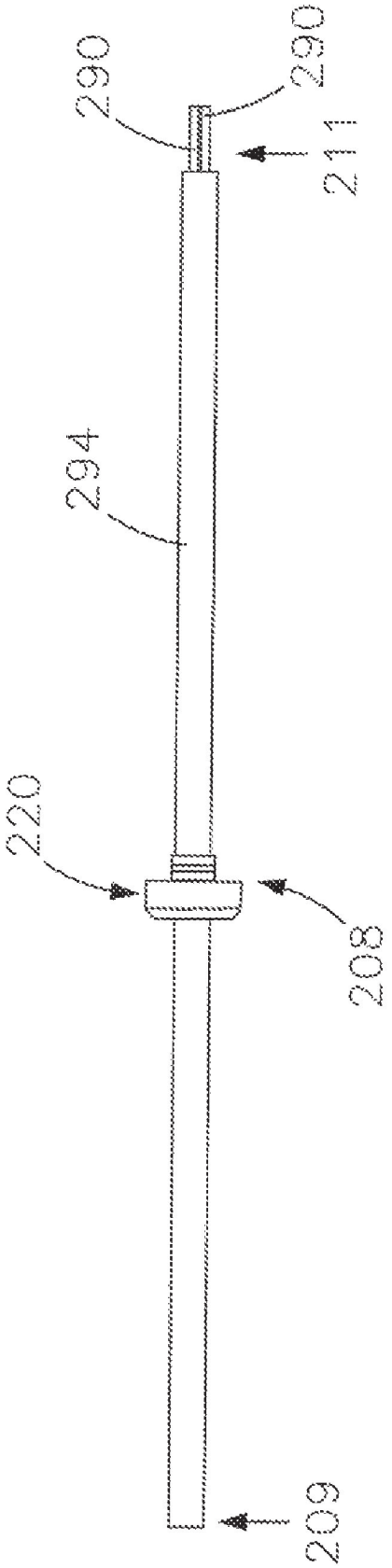


FIG. 10C

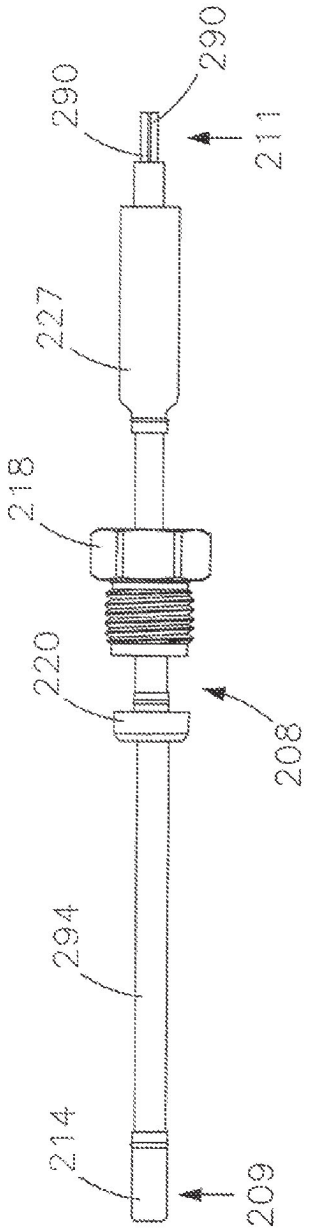


FIG. 10D

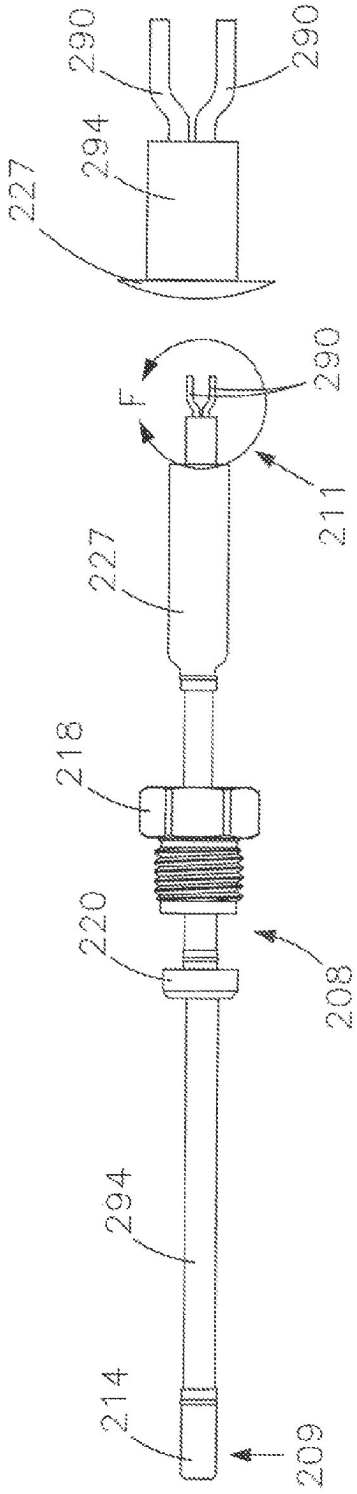


FIG. 10E

FIG. 10F

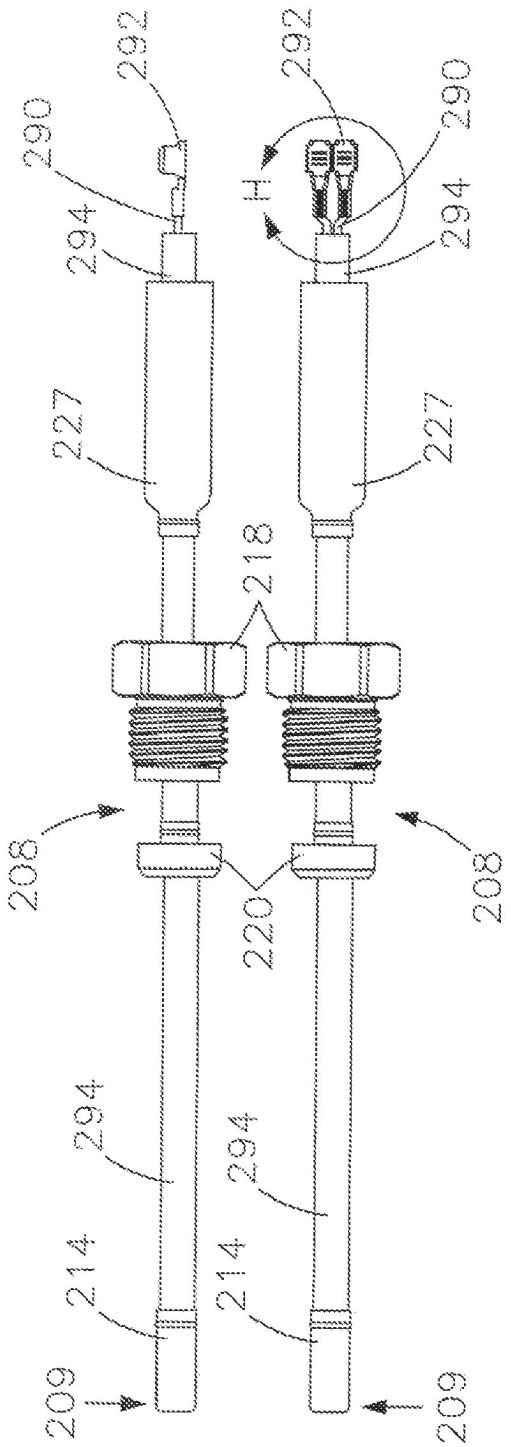


FIG. 10G

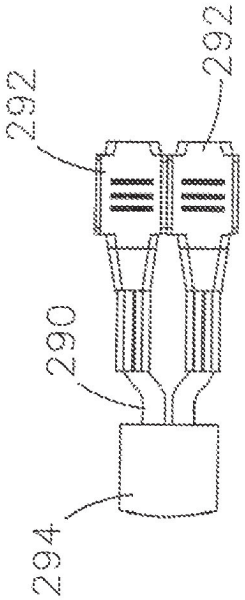


FIG. 10H

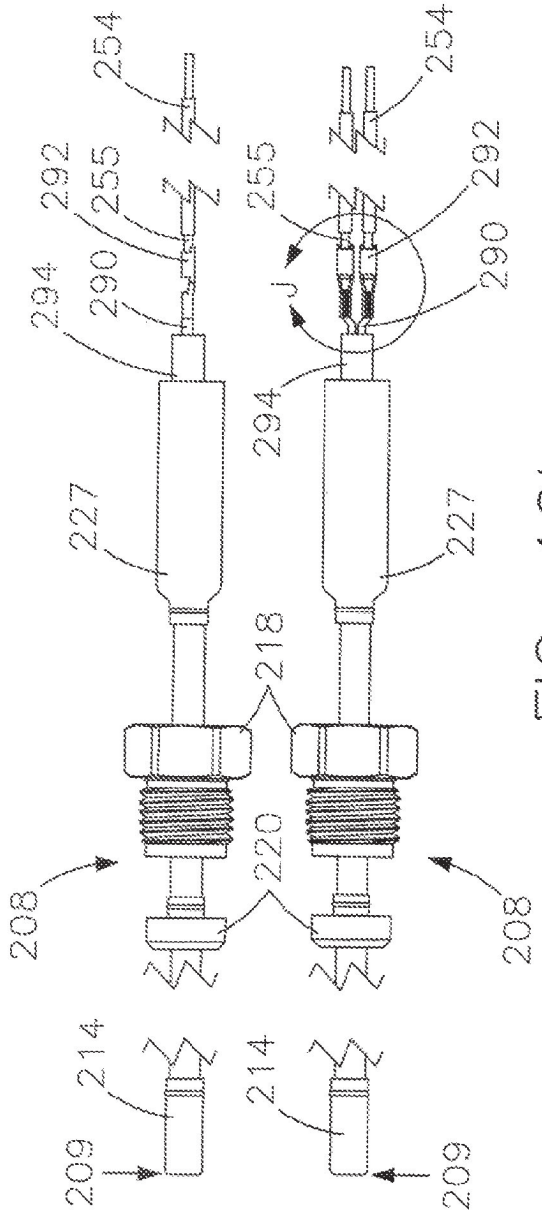


FIG. 10I

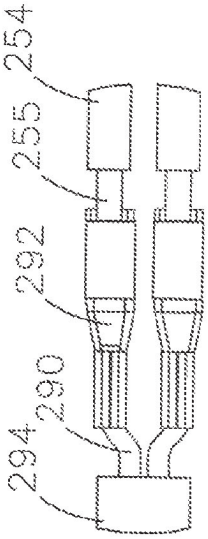


FIG. 10J

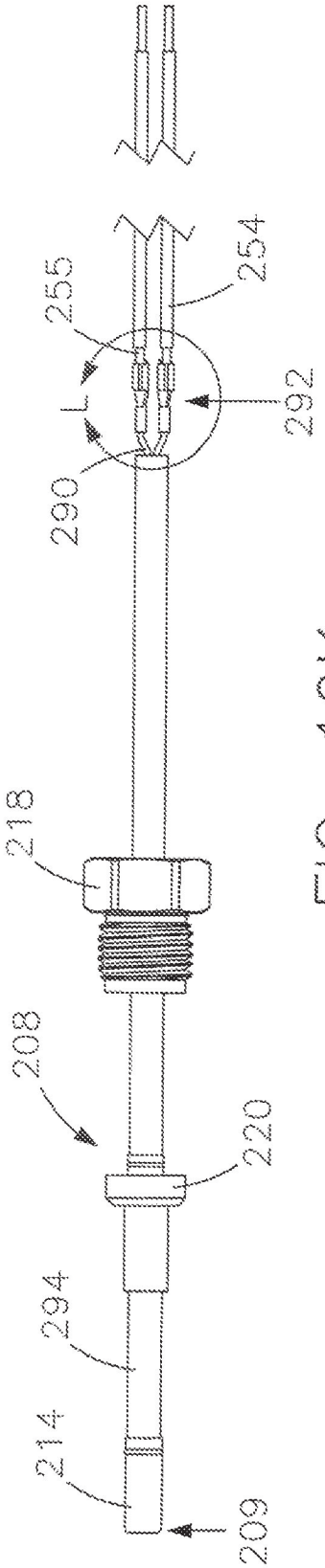


FIG. 10K

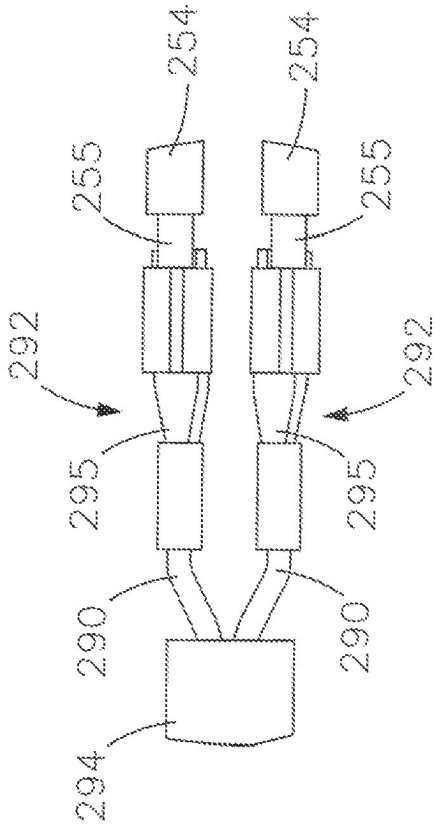


FIG. 10L

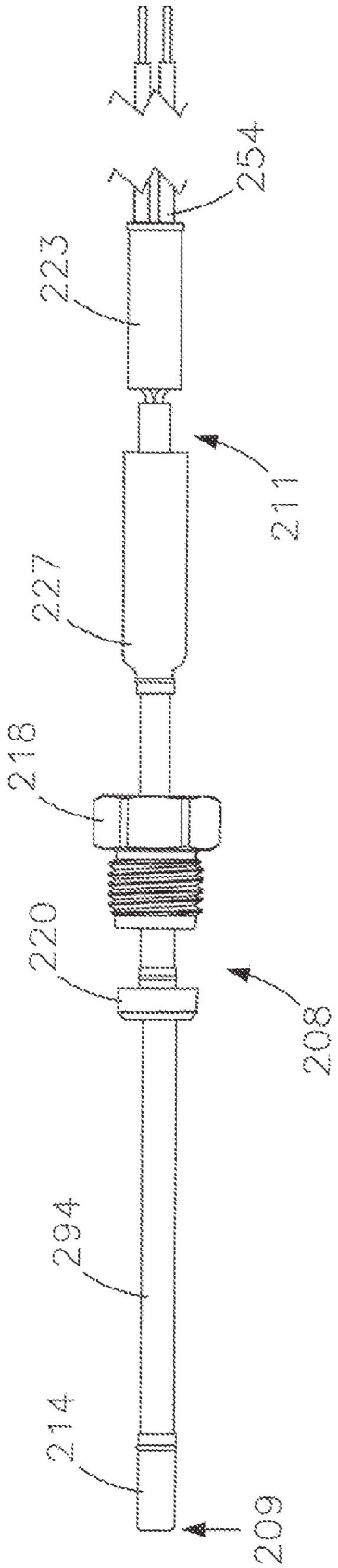


FIG. 10M

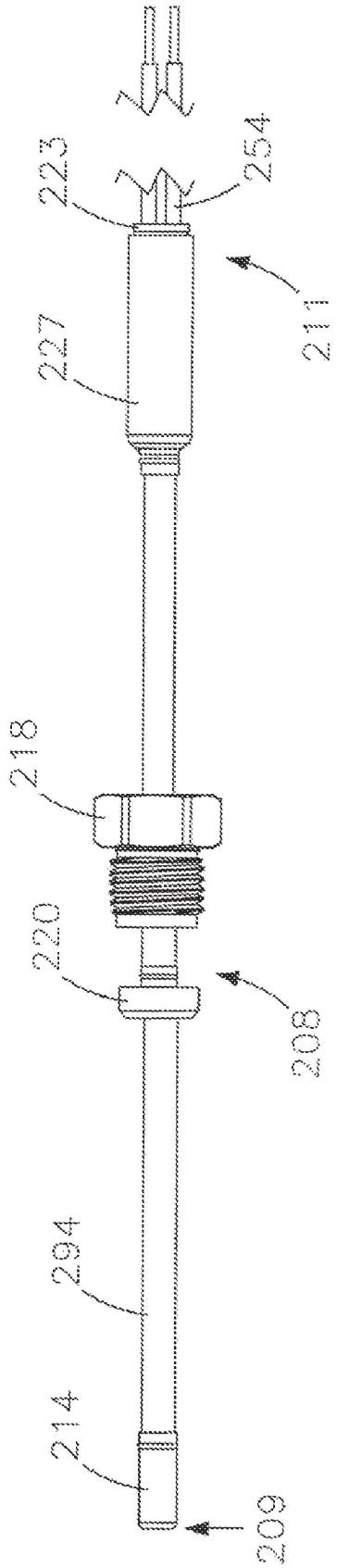


FIG. 10N

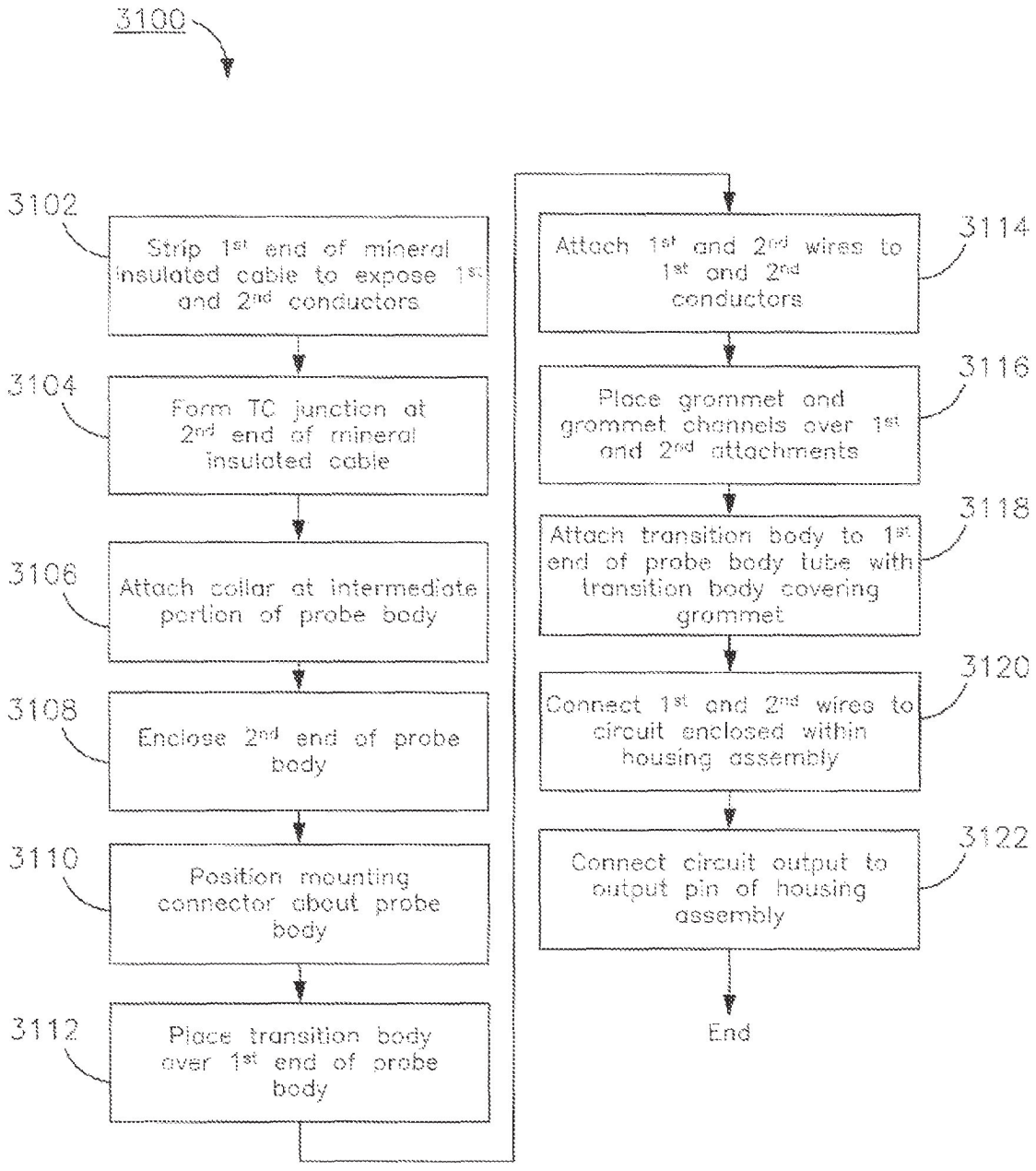

3100
3102
Strip 1st end of mineral insulated cable to expose 1st and 2nd conductors
3104
Form TC junction at 2nd end of mineral insulated cable
3106
Attach collar at intermediate portion of probe body
3108
Enclose 2nd end of probe body
3110
Position mounting connector about probe body
3112
Place transition body over 1st end of probe body
3114
Attach 1st and 2nd wires to 1st and 2nd conductors
3116
Place grommet and grommet channels over 1st and 2nd attachments
3118
Attach transition body to 1st end of probe body tube with transition body covering grommet
3120
Connect 1st and 2nd wires to circuit enclosed within housing assembly
3122
Connect circuit output to output pin of housing assembly
End

FIG. 11

TEMPERATURE SENSOR ASSEMBLY AND METHOD OF MANUFACTURING THEREOF

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 60/815,620, filed on Jun. 22, 2006. The disclosure of the above provisional application is incorporated herein by reference in its entirety.

FIELD

The present disclosure relates to sensors and, more specifically, to temperature sensor assemblies having one or more temperature sensors and the method of manufacturing such temperature sensor assemblies.

BACKGROUND

The statements in this section merely provide background information related to the present disclosure and may not constitute prior art.

Sensors are used in a wide variety of operational environments to monitor operating and environmental characteristics. These sensors can include temperature, pressure, velocity, position, motion, current, voltage, and impedance sensors, by way of example. They are placed in or associated with the operational environment being monitored and are designed for generating an electrical signal or having an electrical characteristic such as an impedance, voltage or current that varies in response to the changes in values as the monitored operating or environment characteristic changes.

Temperature sensing probes include numerous components, such as, for example, a temperature sensing element, various wiring, resistors, diodes, and switches, among others. Generally, the temperature sensing probe is subjected to harsh environments that easily can damage the components of the temperature sensing probe. Furthermore, the temperature sensing probe is subject to mechanical stress due to vibration from surrounding machinery. To reduce the potential for damage to the probe from environmental and mechanical stress, various packaging schemes have been implemented to protect the measuring circuitry of the probe. However, such packaging schemes and the methods that are used for manufacturing often result in premature failure or a reduction in performance of the temperature sensing probe.

SUMMARY

The present disclosure generally includes temperature sensor assemblies and methods of manufacturing temperature sensor assemblies that are capable of improved performance in harsh temperature sensing environments and that are cost effective to manufacture.

According to one aspect, a temperature sensor assembly including a temperature probe, a mounting connector, a wire set, a transition component, a housing and a circuit, the temperature probe includes a probe body, a temperature sensor and at least one conductor configured for providing a temperature signal indicative of a temperature over the at least one conductor, the mounting connector is adapted for securing the probe body to a mounting assembly, the wire set having at least one wire corresponding to each of the at least one conductors, each wire having a first end and a second end, the transition component adapted for coupling each of the at least one conductors to a first end of the at least one wire of the wire set, the housing having an input for receiving a second end of the wires of the wire set and an output for coupling to a temperature measurement system and providing a temperature characteristic, and the a circuit enclosed within the housing and configured for receiving the temperature signal from the temperature probe and generating the temperature characteristic in response to the received temperature signal.

According to another aspect, a temperature sensor assembly including a first temperature sensor probe, a second temperature sensor probe, and an adaptor circuit assembly, the first sensor probe having a first temperature sensor and one or more first conductors coupled to the first temperature sensor and configured for providing a first temperature signal indicative of a first temperature; the second sensor probe having a second temperature sensor and one or more second conductors coupled to the second temperature sensor and configured for providing a second temperature signal indicative of a second temperature, and the adaptor circuit assembly fixedly coupled directly to one or more of the conductors of the first temperature sensor probe and one or more of the conductors of the second temperature sensor probe and having a first input for receiving the first temperature signal and a second input for receiving the second temperature signal, and an output for coupling to a temperature measurement system and providing a first temperature characteristic and a second temperature characteristic, and a circuit configured for receiving the first temperature signal and generating the first temperature characteristic in response to the first temperature signal and receiving the second temperature signal and generating the second temperature characteristic in response to the second temperature signal.

According to yet another aspect, a method for manufacturing a thermocouple sensor assembly includes attaching a first wire to a first end of a first conductor, attaching a second wire to a first end of a second conductor, placing a grommet having a first channel over the attachment of the first wire to the first conductor and having a second channel over the attachment of the second wire to the second conductor, placing a transition body over the first and second conductors and about the grommet for securing the grommet and attachments within a cavity of the transition body, joining a first end of the first conductor to a first end of the second conductor to form a thermocouple junction at a second end of the conductors, attaching the transition body to a second end of the probe body, positioning a mounting connector about the outer surface of the probe body between the first end and the second end of the probe body, attaching a collar to an intermediate outer surface of the probe body between the first end of the probe body and the mounting connector, attaching a second end of the first wire to a circuit board, and attaching a second end of the second wire to the circuit board.

According to still another aspect, a method for manufacturing a thermocouple sensor assembly includes stripping a first end of a mineral insulated cable to expose a first conductor and a second conductor, forming a thermocouple junction at a second end of the mineral insulated cable, attaching a collar about an intermediate portion of the probe body, enclosing the second end of the probe body, positioning a mounting connector about an outer surface of the probe body between the first end of the probe body and the collar, placing a transition body over the first end of the probe body, attaching a first wire to the exposed first conductor and the second wire to the exposed second conductor, placing a grommet having a first channel over the attachment of the first wire to the first conductor and having a second channel over the attachment of the second wire to the second conductor, attaching the transition body in a position proximate to the

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first end of the probe body with the transition body substantially covering the grommet, attaching a second end of the first wire to a circuit board, and attaching a second end of the second wire to the circuit board.

Further aspects of the present disclosure will be in part apparent and in part pointed out below. It should be understood that various aspects of the disclosure may be implemented individually or in combination with one another. It should also be understood that the detailed description and drawings, while indicating certain exemplary embodiments, are intended for purposes of illustration only and should not be construed as limiting the scope of the disclosure.

DRAWINGS

The drawings described herein are for illustration purposes only and are not intended to limit the scope of the present disclosure in any way.

FIG. **1** is a perspective view of a temperature sensor assembly having a single temperature probe and constructed in accordance with the principles of the present disclosure;

FIG. **2**A is a perspective view of a temperature sensor assembly having dual temperature probes and lead covers constructed in accordance with the principles of the present disclosure;

FIG. **2**B is a partially exploded perspective view of the temperature sensor assembly having dual temperature probes of FIG. **2**A in accordance with the principles of the present disclosure;

FIG. **3**A is an exploded perspective view of an adaptor circuit assembly and lead wires for a temperature sensor assembly constructed in accordance with the principles of the present disclosure;

FIG. **3**B is a perspective view of the adaptor circuit assembly and connected lead wires of FIG. **3**A in accordance with the principles of the present disclosure;

FIG. **4**A is a perspective view of temperature sensor probes constructed in accordance with the principles of the present disclosure;

FIG. **4**B is a side exploded view of one of the temperature sensor probes of FIG. **4**A constructed in accordance with the principles of the present disclosure;

FIG. **4**C is a side view of one of the temperature sensor probes of FIG. **4**A constructed in accordance with the principles of the present disclosure;

FIG. **5** is an exploded perspective view of various components, also referred to as a "kit," for assembly of a temperature probe in accordance with the principles of the present disclosure;

FIG. **6** is an enlarged perspective view of an electrical connector for a temperature probe transition component constructed in accordance with the principles of the present disclosure;

FIGS. **7**A to **7**L are sequential assembly perspective views illustrating one method of assembling a temperature probe in accordance with the principles of the present disclosure;

FIG. **8** is a flow chart illustrating a method of assembling a temperature sensor in accordance with the principles of the present disclosure;

FIG. **9** is an exploded side view of various components, also referred to as a "kit," for assembly of a temperature probe according to another form of the present disclosure;

FIGS. **10**A-**10**N are sequential assembly side views of the various components and a method of assembling the temperature probe of FIG. **9** in accordance with the principles of the present disclosure; and

FIG. **11** is a flow chart illustrating a method of assembling another form of a temperature sensor assembly in accordance with the principles of the present disclosure.

It should be understood that throughout the drawings, corresponding reference numerals indicate like or corresponding parts and features.

DETAILED DESCRIPTION

The following description is merely exemplary in nature and is not intended to limit the present disclosure or the disclosure's applications or uses.

Referring to FIG. **1**, a temperature sensor assembly according to the present disclosure is illustrated and generally indicated by reference numeral **10**. The temperature sensor assembly **10** generally includes a temperature probe **12**, which includes a tip cap **14** (preferably a metal alloy) at one end of a probe body **16** (preferably mineral insulated (MI) cable). A mounting connector **18** is secured to the probe body **16**, and a collar **20** is positioned between the tip cap **14** and the mounting connector **18**. A transition component **22** covers a second end **24** of the probe body **16** and comprises a transition body **27** encapsulating a grommet **23** (not shown in FIG. **1**; see FIG. **5**). The grommet has two channels that enclose connectors that terminate conductors of the temperature probe **12** to lead wires **26**. The specific details of the grommet, its channels, the connectors, and the conductors are illustrated and described in greater detail below.

A housing **28** receives the lead wires **26** and includes an output portion **30** for coupling to a temperature measurement system and providing a temperature characteristic. A circuit assembly (not shown) is enclosed within the housing **28** and is configured for receiving the temperature signal from the temperature probe **12** and generating a temperature characteristic in response to the received temperature signal.

The temperature probe **12** can include a mineral insulated (MI) cable **16** having one or more conductors contained therein or can be a conductor surrounded by a conductor such as a compressed powder. The MI cable can include one or two resistance heating elements or conductors embedded in highly compressed magnesium oxide covered by a copper or an Alloy 825 stainless steel sheath, by way of example. The specification of the MI cable **16** is based, at least in part, on the application requirements and associated conductivity, resistance and sheath material.

The mounting connector **18** is adapted for securing the temperature probe **12** to a mounting assembly in an operating environment. Such an arrangement can be as simple as a hanger or can include a nut, flange, rotatable connector, or other device. For example, in some embodiments, the mounting connector **18** includes a sealing ring or collar **20** for placing the temperature sensor within a temperature sensing environment that is then sealed by the mounting connector **18**. In one embodiment, the mounting connector **18** can be a powder metal high strength nut (in the form of a hex nut or other geometry). In such embodiments, the power metal nut can provide for cost effectively securing the temperature probe **12** in a hostile or enclosed environment, such as within an engine, power plant, fluid flow, or chemical process, by way of example.

The lead wires **26** include one or more wires that correspond to one or more of the conductors within the temperature probe **12**. Each lead wire **26** includes a first end **32** and a second end **34** and can be stranded or solid wires, among others. The transition component **22** is adapted for coupling or aiding in the coupling each of the conductors to an end of lead wire **26**, as described in greater detail below.

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The housing **28** also includes an input portion **36** for receiving an end of the lead wires **26**. The output portion **30** of the housing **28** couples to a temperature measurement system and provides one or more temperature characteristics. A circuit assembly (not shown) is enclosed within the housing **28** and is configured for receiving the temperature signal from one or more temperature probes **12** (and/or temperature sensors) and generating temperature characteristics in response to the received temperature signals.

The temperature sensor can be any type of sensor including a thermocouple, a thermistor, or resistance temperature detector. In one example, the sensor is a thermocouple that can be formed by coupling the conductors (ungrounded thermocouple) or coupling to the probe body (grounded thermocouple). The temperature signal typically can include a voltage level generated by the thermocouple. In such an example embodiment, a cold junction compensation circuit can be implemented within the probe assembly or within the circuit or housing **28**. The generated temperature characteristic can be any characteristic desired and practical for providing information as a function of the temperature signal and as required or desired by the application. For instance, this can include a resistance value, a frequency, a digital pulse stream, a current, an impedance, or a voltage.

The circuit assembly receives the one or more temperature signals from one or more sensors and/or temperature probes **12** and can generate an output signal or characteristic in response to the signals. These output characteristics can include a ratiometric analog voltage signal (RAVS), a pulse width modulated signal, a variable frequency signal, a variable output impedance, a variable voltage signal, and a variable current signal, by way of example.

In some embodiments, the circuit assembly can be configured for generating a digital signal including the temperature characteristic, wherein the circuit and the housing are each adapted for coupling to an connected component, network, instrument or controller, such as an engine control module. For example, they can be adapted for communication over any well known digital or analog communication facility including a wired or wireless connection. Additionally, by way of example but not intended to be limited thereto, this can include communication protocols such as a controller area network (CAN). CAN is just one example of a well known and widely used communication protocol that can be implemented by the circuit and the housing. Additionally, proprietary interfaces and communications protocols can also be implemented. The circuit assembly and further details of the housing are described in greater detail in copending application titled "Sensor Adaptor Circuit Housing Assembly and Method of Manufacturing Thereof," filed concurrently herewith on Jun. 22, 2007, which is commonly assigned with the present application and the contents of which are incorporated herein by reference in their entirety.

Referring now to FIGS. **2**A and **2**B, another form of a temperature sensor assembly constructed in accordance with the principles of the present disclosure is illustrated and generally indicated by reference numeral **50**. In this form, the lead wires **54** are contained within protective lead covers **58**, and the tip caps **60** are in an opposed relationship to sense the temperature of two different areas. Accordingly, the temperature sensor assembly **50** includes a first sensor probe **52**, a second sensor probe **53**, and an adaptor circuit assembly **62**. Each sensor probe **52**, **53** can include a probe body, such as a cable **80**, containing a temperature sensor (not shown) and one or more conductors coupled to the temperature sensor. Each sensor probe **52**, **53** is configured for providing one or more temperature signals indicative of a temperature about an exterior portion of the sensor probe **52**, **53**. The adaptor circuit assembly **62** includes inputs for receiving the temperature signals and an output **53** for coupling to a temperature measurement system and providing one or more temperature characteristics responsive to the received temperature signals. A circuit is enclosed within the housing **56** and is configured with electronic circuit components and software such as computer executable instructions for receiving the temperature signals and generating the temperature characteristics in response to one or more temperature signals.

As shown in FIG. **2**B, the lead covers **58** can be removed in some embodiments as this cover is optional. The lead covers **58** can cover all or only a portion of the leads between the temperature probes **12** and housing **56**. With reference to FIG. **2**A, the lead covers **58** are shown extending from the housing **56**, past the transition components **86**, and to an area near the collars **84**.

As shown in FIGS. **3**A and **3**B, an adaptor circuit assembly **62** is assembled from dual lead wires **54** that lead to connectors **70**, which pass through the housing base **72** and into a cavity **73** formed in the housing base **72**. The connectors **70** are in electrical contact with the circuit board **66** and its circuit components **68** in order to provide the temperature signals as previously set forth. Also, the cavity **73** is enclosed by a cover **74**, which may be a potting compound in another form of the present disclosure or used with a potting compound in yet another form, thus protecting and/or sealing the cavity and the electronics therein.

Referring now to FIGS. **4**A to **4**C, the two sensor probes **52** and **53** are illustrated, along with their various components and assembly thereof, prior to attachment to the lead wires **54**. The sensor probes **52**, **53** are preferably constructed with cables **80** or constructed sensor tubes having intermediate bends of about 90 degrees from the tip cap **60** to the transition component **86**. The components of the sensor probes **52**, **53** include the cable **80**, preferably MI and having about a 90 degree bend, a mounting connector **82**, a collar **84**, and a transition component **86**, the transition component **86** comprising a transition body **87** and a grommet **88**. The lead wires **54** are coupled through the transition component **86** for connection to the housing (not shown), which is described in greater detail below.

Turning now to FIG. **5**, various components of the temperature sensor assembly **50** are illustrated and described with reference to the sequential assembly thereof. The sensor probes **52**, **53** as shown in FIGS. **4**A to **4**C, by way of example, can be assembled from a selection of components as shown in one exemplary embodiment of an unassembled "kit" in FIG. **5**. The "kit" of FIG. **5** includes conductors **90**, connectors **92**, lead wires **54** having leads **55**, an insulator **96**, a tube **94**, a transition component **22**/**86** comprising a transition body **27**/**87** and a grommet **23**/**88**, a mounting connector **18**, a collar **20**/**84**, a tip cap **14**/**60**, and a tip disc **93**. The assembly of these components, which may comprise a "kit", will be described below.

FIG. **6** illustrates one embodiment of connectors **92** that provide for the crimping termination of the temperature probe conductors **90** and the crimping of the sensor leads **55** to a second opposing end of each connector **92**. As shown in FIG. **6**, the connectors **92** may have a straight configuration to provide for an in-line crimp between the leads **55** and the conductors **90**. The connectors **92**, when assembled, each reside within their own channel within the grommet **88** enclosed within the transition component **86**. In some embodiments, the connector **92** is composed of a metal that can be welded, so that a conductor **90** and/or a wire **54** can be

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welded to the connector **92** following compressive engagement with the connector **92** such as through crimping.

Referring now to FIGS. **7**A to **7**L and to the flow chart of FIG. **8**, various exemplary embodiments of temperature sensor assembly parts of a kit such as the kit of FIG. **5**, and methods of manufacturing and assembling temperature sensor assemblies are illustrated.

FIG. **7**A illustrates the unassembled relationship of the formed sensor conductors **90** to the connectors **92** and the connectors **92** to the lead wires **26/54**. FIG. **7**B illustrates the relationship of the sensor conductors **90** after being crimped to the connectors **92** showing how the forming step maintains a physical separation between each of the connectors **92**. FIG. **7**C illustrates the assembly of the sensor conductors **90**, the connectors **92**, and the lead wires **26/54** after the lead wires **26/54** are crimped to a second end of each connector **92**. The other components for the temperature sensor assembly **10**, **50** are also illustrated in their unassembled state as another embodiment of sensor kit components. These components include an insulator **96**, a tube **94**, a transition component **22/86** comprising a transition body **27/87** and a grommet **23/88**, a mounting connector **18**, a collar **20/84**, a tip cap **14/60**, and a tip disc **93**. In the paragraphs that follow, a description is given as to how each of these components may be added to the assembly.

FIG. **7**D illustrates the assembly after attaching the conductors **90** to the wires **54**, via the connectors **92**, and placing the attached portions within individual channels of the grommet **23/88**, further maintaining a physical separation of the connectors **92** from each other. In other embodiments, the conductors **90** can be welded or otherwise directly attached to the wires **26/54** and those attachments can be enclosed within the channels of the grommet **23/88**. As one exemplary embodiment. FIG. **7**E provides cross-sectional details of the grommet **23/88** illustrating the individual channels **89** within the grommet **23/88** for maintaining the physical separation of the connectors **92**. As shown, the channels **89** can have a step nature having two portions each coupled in series and each having a different diameter or channel width.

FIG. **7**F further illustrates an embodiment of a temperature sensor having two sensor conductors **92** attached to connectors (not shown) and wires **26/54** attached to the connectors **92**, with the attachments placed within the stepped channels **89** of the grommet **23/88**. The conductors **90** of FIG. **7**F are each formed so as to extend in an outward direction from a longitudinal axis, which may help facilitate crimping of the conductors **90** to the connectors **92**.

FIG. **7**G illustrates the assembly of an insulator **96** over sensor conductors **90**. The probe may comprise a tube **94** or sheath that can be assembled on the insulator **96** in an embodiment where a curved MI cable **80** is not used for the probe body. FIG. **7**H illustrates the transition body **27/87** being assembled over the grommet **23/88** and an end of the insulator **96**.

FIG. **7**I illustrates the assembly of FIGS. **7**G and **7**H having the tube **94** positioned over the insulator **96**. The transition body **27/87** may be attached to the metal body of the tube **94**, such as by welding.

FIG. **7**J illustrates the mounting connector **18/82** being rotatably positioned about the body of the probe, which is the tube **94** in this example and FIG. **7**K shows the collar **20/84** being positioned between the sensing end **21** of the probe and the mounting connector **18/82**. The collar **20/84** is attached to the probe body (tube **94**), such as by welding or other means. The collar **20/84** is preferably attached to the surface of the probe body or tube **94** to form an airtight seal in some embodiments. The mounting connector **18/82** and collar **20/84** are each adapted for mounting the temperature probe **12/52** to a mounting surface, such as by screwing the mounting connector **18/82** into a threaded hole and sealing the collar **20/84** and mounting connector **18/82** against the mounting surface, by way of example.

FIG. **7**L shows the placement of a tip cap **14/60** and/or a tip disc **93** that can be attached, such as through welding, to the end of the metal probe tube **94** or MI cable to enclose the temperature sensor. In some embodiments, the end of the MI tube **94** or the probe body can be left open and not sealed.

This process is also described in FIG. **8** as one exemplary embodiment of a manufacturing assembly operation. The process **3000** includes a step **3002** of attaching a first wire to a first end of a first conductor and attaching a second wire to a first end of a second conductor, another step **3004** of placing a grommet having a first channel over the attachment of the first wire to the first conductor and having a second channel over the attachment of the second wire to the second conductor, another step **3006** of placing a transition body over the first and second conductors and about the grommet for securing the grommet and attachments within a cavity of the transition body, another step **3008** of inserting each conductor into a channel of an insulator, another step **3010** of joining the first end of the first conductor to the first end of the second conductor to form a thermocouple junction at a first end of the insulator, another step **3014** of attaching the transition body to a second end of a probe body, another step **3016** of positioning a mounting connector about the outer surface of the probe body between a first end and the second end of the probe body, and another step **3018** of attaching a collar to the outer surface of the probe body between the first end of the probe body and the mounting connector. The process **3000** can also include a step **3020** of attaching a second end of the first wire to an input of a housing and attaching a second end of the second wire to an input of the housing. This step **3020** may also include attaching a second end of the first wire to a circuit board; and attaching a second end of the second wire to the circuit board.

In other embodiments, the process **3000** can include a step **3022** of attaching a cover over the wire, or a portion of the wires. For example, the cover could extend from the transition body or probe to an input of the housing, enclosing a portion of the first and second wires within the cover between the transition body and the housing. In yet other embodiments, the process **3000** can include a step **3024** of bending an intermediate portion of the probe body between the transition body and the mounting connector to form an angle, such as a 90 degree angle.

The process **3000** can also include a step **3026** of connecting the first wire and the second wire to a circuit enclosed within a housing assembly having an input for receiving a second end of the wires, the circuit being configured for receiving a temperature signal from the temperature sensor, for example a thermocouple, and generating the temperature characteristic in response to the received temperature signal. Further, the process **3000** may include a step **3028** of connecting an output of the circuit to an output pin of the housing assembly configured for providing the generated temperature characteristic to a temperature measurement system coupled to the output pin.

Referring now to FIG. **9**, FIGS. **10**A to **10**N, and to the flow chart of FIG. **11**, various embodiments of temperature sensor assembly parts (or a kit as shown in FIG. **9**) and the methods of manufacturing and assembling temperature sensor assemblies (as shown in FIGS. **10**A to **10**N) are illustrated, which will now be described. The "kit" of FIG. **9** includes conductors **290**, connectors **292**, a MI cable **294**, a transition body **227**, a grommet **223**, a mounting connector **218**, a collar **220**,

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and a tip cap **214**. The assembly of these components, which may comprise a "kit", will be described below.

As shown in FIG. **11**, another example of a process **3100** of assembling a temperature sensor assembly is illustrated. The process **3100** starts with a MI cable **294** as shown in FIG. **10**A, which has an end stripped to expose a first conductor **290** and a second conductor **290** as shown in FIG. **10**B. Thus, the process **3100** includes a step **3102** of stripping a first end of a MI cable **294** to expose first and second conductors **290** The process **3100** also includes a step **3104** of forming a thermocouple junction or other temperature sensor or sensing element at a second end **209** of the mineral insulated cable **294**. In FIG. **10**C, a collar **220** is attached about an intermediate portion **208** of the probe body (MI cable **294** in this example). Thus, the process **3100** also includes a step **3106** of attaching the collar **220** about the probe body (MI cable **294**). An end of the probe body can also be closed as discussed above and shown by way of example as an attached tip cap **214** or disc (as shown in FIG. **10**D) or by other means as described above. Thus, the process **3100** may include a step **3108** of enclosing the second end **209** of the probe body. The process **3100** also includes a step **3110** of positioning a mounting connector **218** about an outer surface of the probe body (MI cable **294**) between the first end **211** of the probe body and the collar **220** as shown in FIG. **10**D, and a step **3112** of placing a transition body **227** over the first end **211** of the probe body. The conductors **290** can be formed for crimping or attaching as shown in FIGS. **10**E-**10**F, wherein the conductors **290** are bent so as to oriented in an outward direction from the longitudinal axis of the MI cable **294**.

The processes **3100** further includes a step **3114** of attaching the conductors **290** to exposed wire leads **255** of wires **254**. The conductors **290** could be connected directly to the leads **255** of the wires **254**, or they may be attached by crimping, welding, soldering, other mechanical coupling, or any other suitable coupling as is know to those skilled in the art. This step **3114** can include forming an end of each conductor **290** for crimping, and as described above, this can include stripping the end of the conductor **290** to expose a conducting portion, bending or shaping the conducting portion to a desired position or shape, and otherwise preparing the conducting portion for compression and/or welding, soldering, or coupling as is known to those skilled in the art. In some embodiments, connectors **292** can be welded, soldered or otherwise coupled to the end of one of the conductors **290**. With reference to FIGS. **10**G-**10**H, the conductors **290** are mechanically crimped to the connectors **292**. With reference to FIGS. **10**I-**10**J, the lead ends **255** of the lead wires **254** are also mechanically crimped to the connectors **292**. While crimping the mechanical coupling may be sufficient in some embodiments, in other embodiments the crimped coupling between the conductor **290**, the wire **254**, and the connector **292** can also be welded or soldered. For example, with reference to FIGS. **10**K-**10**L, welding or soldering material may be added to the connector **292** at a portion **295**, or to any other suitable portion of the connector **292**. The welding described herein can include any type or method of welding known or developed in the art. In these embodiments, the combination of mechanical coupling via a crimped connector **292** and a welding of the connector **292** to the conductor **290** and/or to the wire **254** can provide benefits. For example, the combination can provide for improved conductivity, a stronger bond, and decrease failures of this attachment and coupling.

The process **3100** also includes a step **3116** of placing a grommet **223** having one or more channels (not shown) over the attachments of the wires **254** to the conductors **290**, as shown in FIG. **10**M. The process **3100** further includes a step **3118** of sliding the transition body **227** over the grommet **223** and attaching the transition body **227**, for example by welding, to an end of the probe body with the transition body **227** substantially covering the grommet **223** as shown in FIG. **10**N. As described in regard to FIGS. **3**A and **3**B above, the process **3100** can also include a step **3120** of attaching a second end of the first wire to a circuit board and step **3122** of attaching a second end of the second wire to the circuit board.

Additionally, as described in the example above with regard to FIG. **3**, in some embodiments the method of manufacturing can also include connecting the first wire **54** and the second wire **54** to a circuit enclosed within a housing **28** of an adaptor circuit assembly **62** having an input for receiving a second end of the wires **54**. As noted above the circuit can be configured with electronic components **68** and circuits, memory, a processor, and computer executable instructions configured for receiving one or more temperature signals from temperature sensors, such as a thermocouple, thermistor, or RTD, and generating one or more temperature characteristics in response to the received temperature signals. The method can also include connecting an output **53** of the circuit to an output connector or pin of the adaptor circuit assembly **62** configured for providing the generated temperature characteristic to a temperature measurement system coupled to the output connector.

As known to those skilled in the art, each of the processes described herein can be repeated to produce one or more probes. After such probes are manufactured, one or more, for example, two probes can be connected to a common circuit for receiving a plurality of temperature signals. In such embodiments, the sensor adaptor circuit can be configured for generating and providing one or more temperature characteristics at the output. Each temperature characteristic can be based on one or more of the temperature signals depending on the desired application and operational environment for the temperature sensor assembly.

Various benefits are provided by one or more embodiments of the temperature sensor assemblies and methods of manufacturing such temperature sensor assemblies as generally described in this disclosure. One or more of these embodiments can provide for a high compaction construction, an assembly that is high vibration and shock resistance and therefore provides a longer useful life. The temperature sensor assemblies described herein are capable of use in a wide variety of temperature applications including temperature of flames and temperatures of greater than 900 degree Celsius and have been shown to perform well up to temperatures of 1200 degree Celsius through the use of Alloy 600 in the construction. The design and method of construction provides for utilizing either a moderate duty lead wire or up to an extra heavy duty lead wire which is the source of many faults and failures for temperature sensor assemblies. Similarly, the assemblies of the present disclosure can be utilized in a wide variety of temperature sensing applications including low temperature applications such as coolant, brake fluid, inlet air, sea water, and oil temperature.

In some embodiments more than one temperature probe **12** can be included in the temperature sensor assembly **10** or more than one temperature sensor can be included in one or more temperature probes **12**. In such cases, one or more of the temperature probes **12** or sensors can provide separate temperature signals to the circuit associated with one or more measured or sensed temperatures. In one such embodiment, the assembly includes a second wire set corresponding to a set of second conductors **90**, and a second transition component **22** for coupling each of the second conductors **90** to at least one of the wires **26** of the second wire set. In these cases, the

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housing **28** will include a second input **36** for receiving the second wire set **26**. The circuit is adapted to receive the second temperature signals and generate a second temperature characteristic indicative of the temperature about the exterior of the second temperature probe **12**.

In one embodiment, the temperature probe **12** is assembled from a mineral insulated cable having conductors, a metal body, and insulating material. In other embodiments, the temperature probe **12** can be manufactured to include the conductors **90** and the body **16**. In some embodiments, a collar **20** is positioned about an exterior surface of the probe body **16** and adapted for engaging the fitting to secure the temperature probe **12** to the mounting assembly **18**. The collar **20** is attached, such as by welding, to the exterior surface of the probe body **16**. The collar **20** can be attached to the exterior surface of the probe body **16** by any known or future method including laser welding, spin welding, electronic beam welding, resistance welding, and ultrasonic welding, by way of example.

In some embodiments, the transition component **22** includes a grommet **23** and a transition body **27**. The grommet **23** can include one or more internal cavities **89** each dimensioned for receiving an end of one of the conductors **90** and for receiving an end **34** of at least one of the at least one wire **26** of the wire set, and the transition body **27** having a cavity substantially enclosing the grommet **23** and being welded to the probe body **16**. Each of the internal cavities **89** of the grommet **23** can also be configured to include a first portion and a second portion coupled and positioned in series with the first portion. The second portion can have a cavity width greater than or less than a cavity width of the first portion.

In some embodiments, the conductors **90/290** are directly connected to the wires **26/54/254** by welding or soldering or other known forms of directly connecting conductors **90/290**. In other embodiments, an electrical connector **92/292** is utilized to couple the conductors **90/290** to the wires **26/54/254**. For example, one electrical connector **92/292** can include a first end compressively engaging a conductor **90/290** and/or a second end compressively engaging a wire **26/54/254**. This can be a crimp compression engagement or similar coupling. In such cases, the electrical connector **92/292** can be positioned within one of the internal cavities **89** of the grommet **23/223**, when provided. In some embodiment, the compressive engagement can be supplemented with a welding or soldering. In such cases, the electrical connector **92/292** is preferably composed of a weldable material, such as an alloy **42** material, by way of example. In other embodiments, the transition component **22/86/222** may couple the conductors **90/290** to the wires **26/54/2554** by maintaining a mechanical communication between the wire leads **55/255** and the conductors **90/290**.

In some embodiments, the probe body **16** is formed from a metal tube **94/294**. This can aid in the manufacturing process and help reduce costs. In such embodiments, one end **209** of the metal tube **94/294** can be closed about the temperature sensor by crimping, welding, roll forming and/or swaging an end **209** of the metal tube **94/294**. In other embodiments, a tip cap **14/60/214** or disc **93** can be positioned proximate the end **209** of the metal tube **94/294** including the temperature sensor, and can be welded, brazed, or otherwise bonded to the end **209** of the metal tube **94/294** to close the end **209** of the metal tube **94/294** and to seal it for temperature sensing applications.

As noted above, the probe body **16/80** can be formed, bent or otherwise arranged for mounting on the desired temperature sensing application. For example, the probe body **16/80** can be bent or formed to have any required angle, and as shown in the examples of some of the figures, has an intermediate portion having an angled portion positioning the first end of the probe body **80** at about 90 degrees from the second end of the probe body **80**.

In some embodiments, a cover **58** covering all or a portion of the wire set **54** from the transition portion **22** or probe body **16** to the housing input **36** can be provided to provide an aesthetic or practical benefit to the temperature sensor assembly. For example, in some cases the temperature sensor assembly **10**, **50** may be placed in a high heat environment where it may be desirable for the cover **58** to be adapted with heat shielding or deflecting material. In other embodiments, it may be desired to protect the leads **55** due to moving parts or a likelihood that the leads **55** may be snagged or pulled in the operating environment.

Each of the sensor probes **12/52/53/212** can include a wire set having one or more wires **26/54/254** and a transition component **22/86/222** coupled to an end of the probe body **16/80/94/294**. A grommet **23/88/223** having one or more channels **89** adapted for receiving one or more of the conductors **90/290** and one or more of the wires **26/54/254** provides, at least in part, a transition between the probe assembly and the wire set. The grommet **23/88/223** can also be configured to enclose the coupling of each wire **26/54/254** to each conductor **90/290**.

In some embodiments, each sensor probe **12/52/212** can include a collar **20/84/220** attached to the exterior of the probe body **16/80/94/294** and a connector **18/82/218** rotatably coupled to the probe body **16/80/94/294** that is configured to engage the collar **20/84/220** and to secure the temperature probe **12/52/212** to a first mounting assembly within the operating environment.

In some embodiments, the leads from the sensor probes **12/52/212** are directly connected to the adaptor circuit assembly **62** such that the assembly is an integrated unit, e.g., the probes **12/52/212** are not unpluggable. In such embodiments, the first lead is fixedly coupled to the circuit and the second lead is fixedly coupled to the circuit. Such fixedly coupling preferably includes a coupling mechanism that does not enable the unplugging or otherwise detachment of the wire **26/54/254** from the adaptor circuit assembly **62** or adaptor circuit housing **28**.

The adaptor circuit assembly **62** includes a housing **28** that can be assembled from two or more portions, can be integrated portions, or can be an integrated or unitary body. In some cases, the wire leads **26/54/254** can be retained by the housing **28** itself such as an integral portion of the molded assembly.

When describing elements or features and/or embodiments thereof, the articles "a", "an", "the" and "said" are intended to mean that there are one or more of the elements or features. The terms "comprising", "including", and "having" are intended to be inclusive and mean that there may be additional elements or features beyond those specifically described.

Those skilled in the art will recognize that various changes can be made to the exemplary embodiments and implementations described above without departing from the scope of the disclosure. Accordingly, all matter contained in the above description or shown in the accompanying drawings should be interpreted as illustrative and not in a limiting sense.

It is further to be understood that the processes or steps described herein are not to be construed as necessarily requiring their performance in the particular order discussed or illustrated. It is also to be understood that each process or step can be repeated more than once and that additional or alter-

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native processes or steps may be employed and still be within the scope of the present disclosure.

What is claimed is:

1. A temperature sensor assembly comprising:

at least one temperature probe having a probe body and a temperature sensor and at least one conductor configured to provide a temperature signal indicative of a temperature over the at least one conductor;

a mounting connector configured to secure the probe body to a mounting assembly;

a wire set having at least one wire corresponding to the at least one conductor, the at least one wire having a first end and a second end, the first end of the at least one wire being coupled to the at least one conductor at a coupled portion;

a transition component surrounding the coupled portion of the at least one conductor and the least one wire of the wire set;

a housing having an input configured to receive the second end of the at least one wire of the wire set and an output for coupling to a temperature measurement system and providing a temperature characteristic; and

a circuit enclosed within the housing, the circuit being configured to receive the temperature signal from the temperature probe and generate the temperature characteristic in response to the received temperature signal,

wherein the temperature probe is external to the housing.

2. The assembly of claim **1** wherein the temperature probe includes a probe body defining a cavity therein, the temperature sensor being positioned within the cavity and the at least one conductor being positioned within the cavity.

3. The assembly of claim **1** wherein the temperature probe includes a mineral insulated cable including the at least one conductor, the probe body and an insulating material.

4. The assembly of claim **1** wherein the temperature sensor is a thermocouple and wherein the temperature signal includes a voltage level generated by the thermocouple and wherein the circuit includes a cold junction compensation circuit and wherein the temperature characteristic is a resistance value.

5. The assembly of claim **4** wherein the temperature probe includes a mineral insulated cable having the at least one conductor contained therein, wherein the at least one conductor is two conductors, the two conductors being coupled to form a thermocouple junction of the thermocouple.

6. The assembly of claim **1** wherein the circuit is configured to generate a signal including the temperature characteristic, the signal selected from the group consisting of a ratiometric analog voltage signal (RAVS), a pulse width modulated signal, a variable frequency signal, a variable output impedance, a variable voltage signal, and a variable current signal.

7. The assembly of claim **1** wherein the circuit is configured to generate a digital signal including the temperature characteristic and wherein the assembly is adapted to connect to a component in communication with one of a controller area network (CAN), an instrument, an engine control module, and a digital communication facility.

8. The assembly of claim **1** wherein the temperature probe having a probe body and a temperature sensor and at least one conductor is a first temperature probe having a first probe body, a first temperature measuring device and at least one first conductor, the assembly further comprising a second temperature probe having a second probe body and a second temperature measuring device and at least one second conductor configured to provide a second temperature signal indicative of a second temperature about an exterior of the second temperature probe.

9. The assembly of claim **8**, further comprising:

a second wire set having at least one second wire corresponding to each of the at least one second conductors, the at least one second wire being coupled to the at least one second conductor at a second coupled portion; and

a second transition component surrounding the second coupled portion of the at least one second conductor and the at least one second wire;

wherein the housing includes a second input the second wire set and wherein the circuit is configured to receive the second temperature signal and generate a second temperature characteristic indicative of the temperature about the exterior of the second temperature probe, and wherein the output is configured to provide the second temperature characteristic.

10. The assembly of claim **1** wherein the mounting connector includes a powdered metal fitting having threads configured to screw the fitting into a threaded mounting assembly.

11. The assembly of claim **10** wherein the probe body is a metal, the assembly further comprising a collar positioned about an exterior surface of the probe body, the collar being configured to engage the fitting to secure the temperature probe to the mounting assembly.

12. The assembly of claim **11** wherein the collar is attached to the exterior surface of the probe body by a method selected from the group consisting of laser welding, spin welding, electronic beam welding, resistance welding, and ultrasonic welding.

13. The assembly of claim **1** wherein the transition component includes a grommet and a transition body, the grommet including at least one internal cavity dimensioned for receiving an end of one of the at least one conductor and for receiving the first end of the at least one wire of the wire set, and the transition body having a cavity substantially enclosing the grommet and being welded to the probe body.

14. The assembly of claim **13** wherein the at least one internal cavity of the grommet includes a first portion and a second portion coupled in series with the first portion, the second portion having a cavity width greater than a cavity width of the first portion.

15. The assembly of claim **13**, further comprising at least one electrical connector coupling the at least one conductor to the at least one wire at the coupled portion.

16. The assembly of claim **15** wherein the at least one electrical connector includes a first end compressively engaging the at least one conductor and a second end compressively engaging the at least one wire, the at least one electrical connector being positioned within the at least one internal cavity of the grommet.

17. The assembly of claim **16** wherein the at least one conductor is laser welded to the first end of the at least one electrical connector and the at least one wire is laser welded to the second end of the at least one electrical connector.

18. The assembly of claim **15** wherein the at least one electrical connector comprises a weldable metal.

19. A temperature sensor assembly comprising:

a first temperature sensor probe having a first temperature sensor and a pair of first conductors coupled to the first temperature sensor, the pair of first conductors being configured to provide a first temperature signal indicative of a first temperature;

a second temperature sensor probe having a second temperature sensor and a pair of second conductors coupled to the second temperature sensor, the pair of second conductors being configured to provide a second temperature signal indicative of a second temperature;

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an adaptor circuit assembly fixedly coupled directly to the pair of first conductors and the pair of second conductors, the adapter circuit assembly having a first input configured to receive the first temperature signal and a second input configured to receive the second temperature signal, the adapter circuit assembly having an output for coupling to a temperature measurement system, the output being configured to provide a first temperature characteristic and a second temperature characteristic, the adapter circuit assembly having a circuit configured to receive the first temperature signal and generate the first temperature characteristic in response to the first temperature signal, the circuit being further configured to receive the second temperature signal and generate the second temperature characteristic in response to the second temperature signal.

20. The assembly of claim **1** wherein the temperature probe has a tip cap positioned proximate to the temperature sensor, the tip cap being welded about a first end of the probe body to enclose the temperature sensor within the probe body.

21. The assembly of claim **1**, further comprising a cover covering at least a portion of the wire set.

22. The temperature sensor assembly of claim **19** wherein the first temperature sensor probe includes a first wire set having a pair of first wires, each first wire being coupled to a first conductor of the pair of first conductors to form a first coupling, and wherein the first temperature sensor probe further includes a first transition component coupled to an end of the first temperature sensor probe and having a first grommet with two channels, the channels each receiving one of the first conductors and one of the first wires, the first grommet enclosing the first couplings, and wherein the second temperature sensor probe includes a second wire set having a pair of second wires, each second wire being coupled to a second conductor of the pair of second conductors to form a second coupling, wherein the second temperature sensor probe further includes a second transition component coupled to an end of the second temperature sensor probe and having a second grommet with two channels, the channels each receiving one of the second conductors and one of the second wires, the second grommet enclosing the second couplings.

23. The temperature sensor assembly of claim **19** wherein the first sensor probe includes a first collar attached to the exterior of the first temperature sensor probe, a first connector rotatably coupled to the first temperature sensor probe and configured to engage the first collar and to secure the first temperature probe to a mounting assembly, and the second sensor probe includes a second collar attached to the exterior of the second temperature sensor probe, a second connector rotatably coupled to the second temperature sensor probe and configured to engage the second collar and to secure the second temperature probe to a mounting assembly.

24. The temperature sensor assembly of claim **19**, further comprising a first lead for directly connecting the first probe to the adaptor circuit assembly and a second lead for directly connecting the second probe to the adaptor circuit assembly, the adapter circuit assembly further including a housing having integrated portions for fixedly retaining the first and second leads.

25. The temperature sensor assembly of claim **24** wherein the housing is a unitary housing and wherein the housing is molded about the first and second leads.

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