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Haywood

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(54) **ELECTRICAL INTERCONNECT FOR PRESSURE SENSOR IN A PROCESS VARIABLE TRANSMITTER**

(71) Applicant: **Rosemount Inc.**, Chanhassen, MN (US)

(72) Inventor: **Nicholas John Haywood**, Chanhassen, MN (US)

(73) Assignee: **Rosemount Inc.**, Chanhassen, MN (US)

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G01L 19/00 (2006.01)
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CPC ***G01L 19/0084*** (2013.01); ***G01L 9/0041*** (2013.01); ***G01L 9/0075*** (2013.01); ***G01L 19/0069*** (2013.01)

(58) **Field of Classification Search**
CPC G01L 19/0084
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See application file for complete search history.

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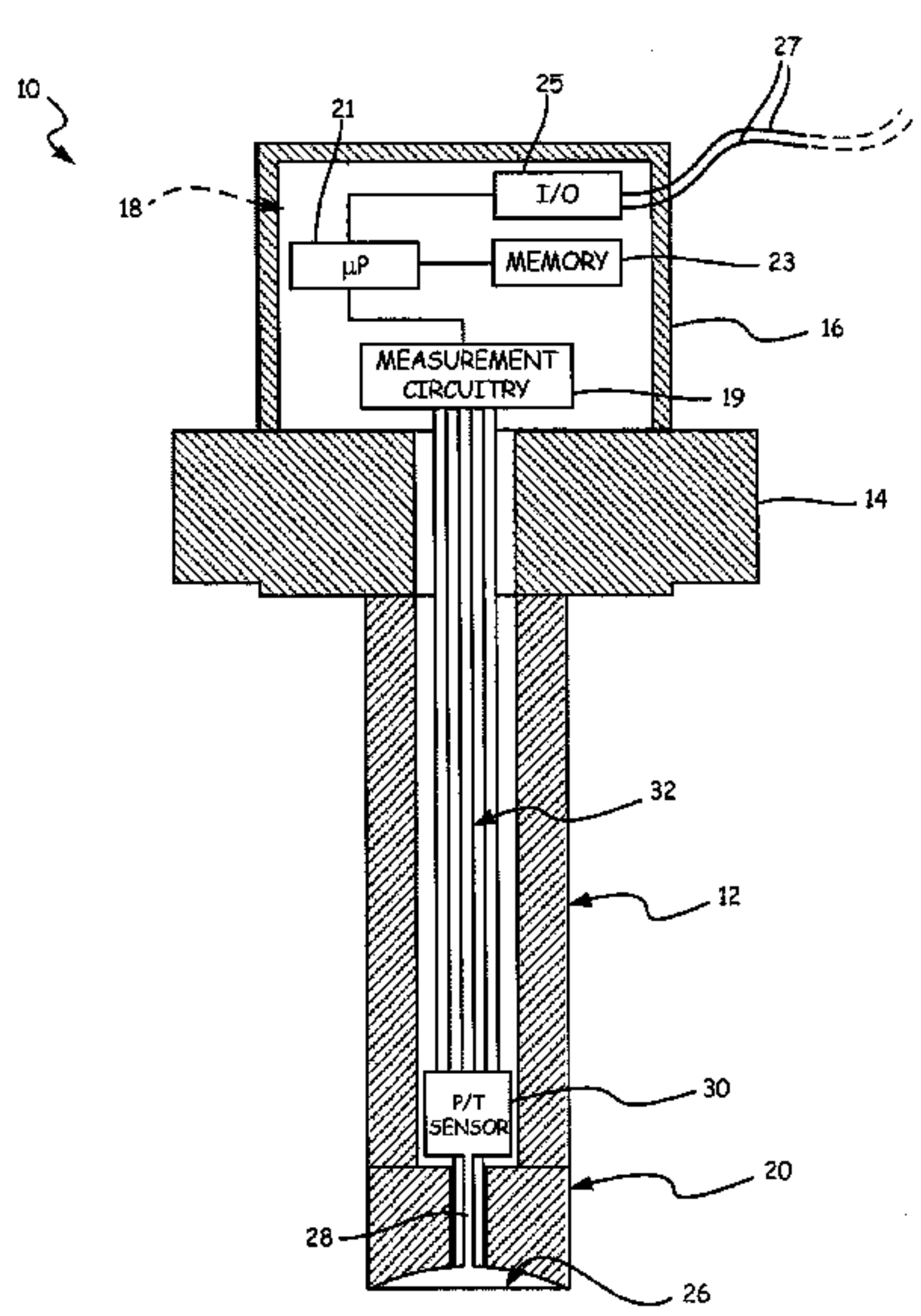
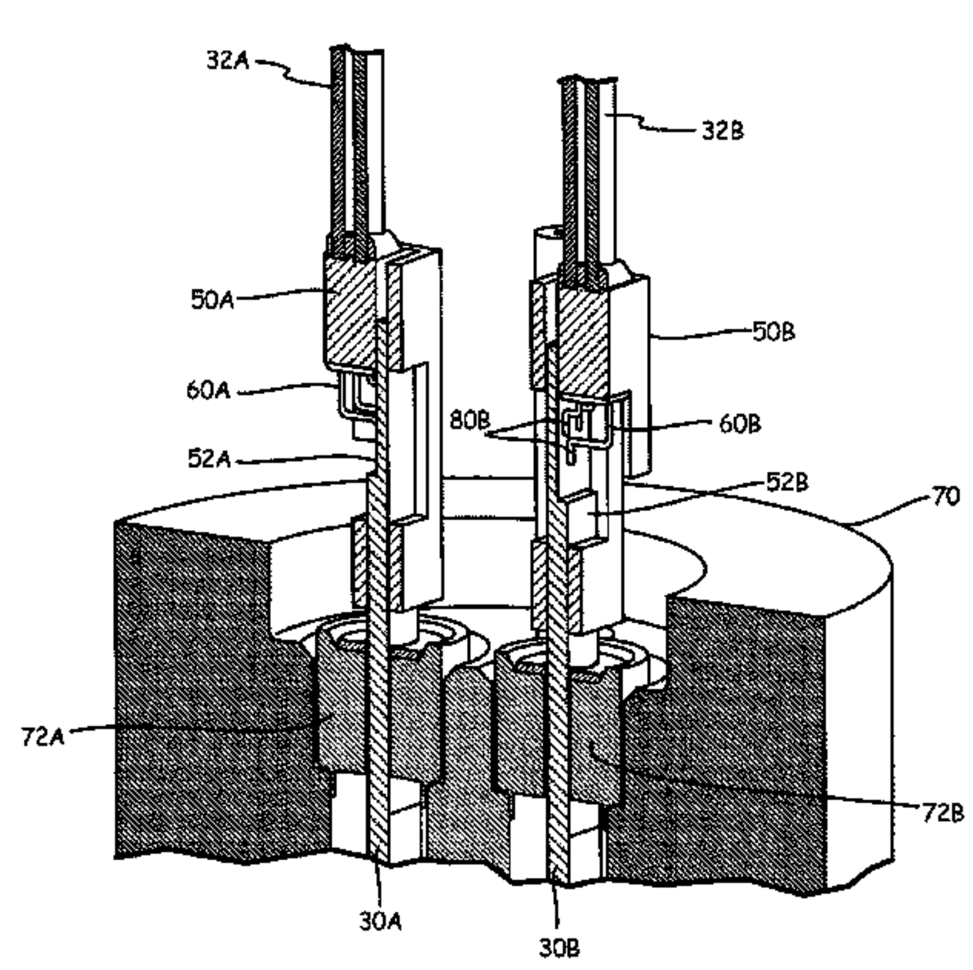
Primary Examiner — John Fitzgerald
(74) *Attorney, Agent, or Firm* — Westman, Champlin & Koehler, P.A.

(57) **ABSTRACT**

A process fluid pressure sensor assembly includes a pressure sensor configured to sense a pressure of a process fluid. The assembly includes a pressure sensor body formed of an insulating material. The pressure sensor includes a plurality of electrical contact pads which couple to a pressure sensing element of the body of the pressure sensor. An interconnect body is configured to fit over an end of the pressure sensor body. A plurality of electrical connectors carried in the interconnect body are in electrical contact with the plurality of electrical contact pads. A wiring harness attaches to the interconnect body and includes a plurality of wires which are electrically connected to the plurality of electrical connectors.

18 Claims, 7 Drawing Sheets





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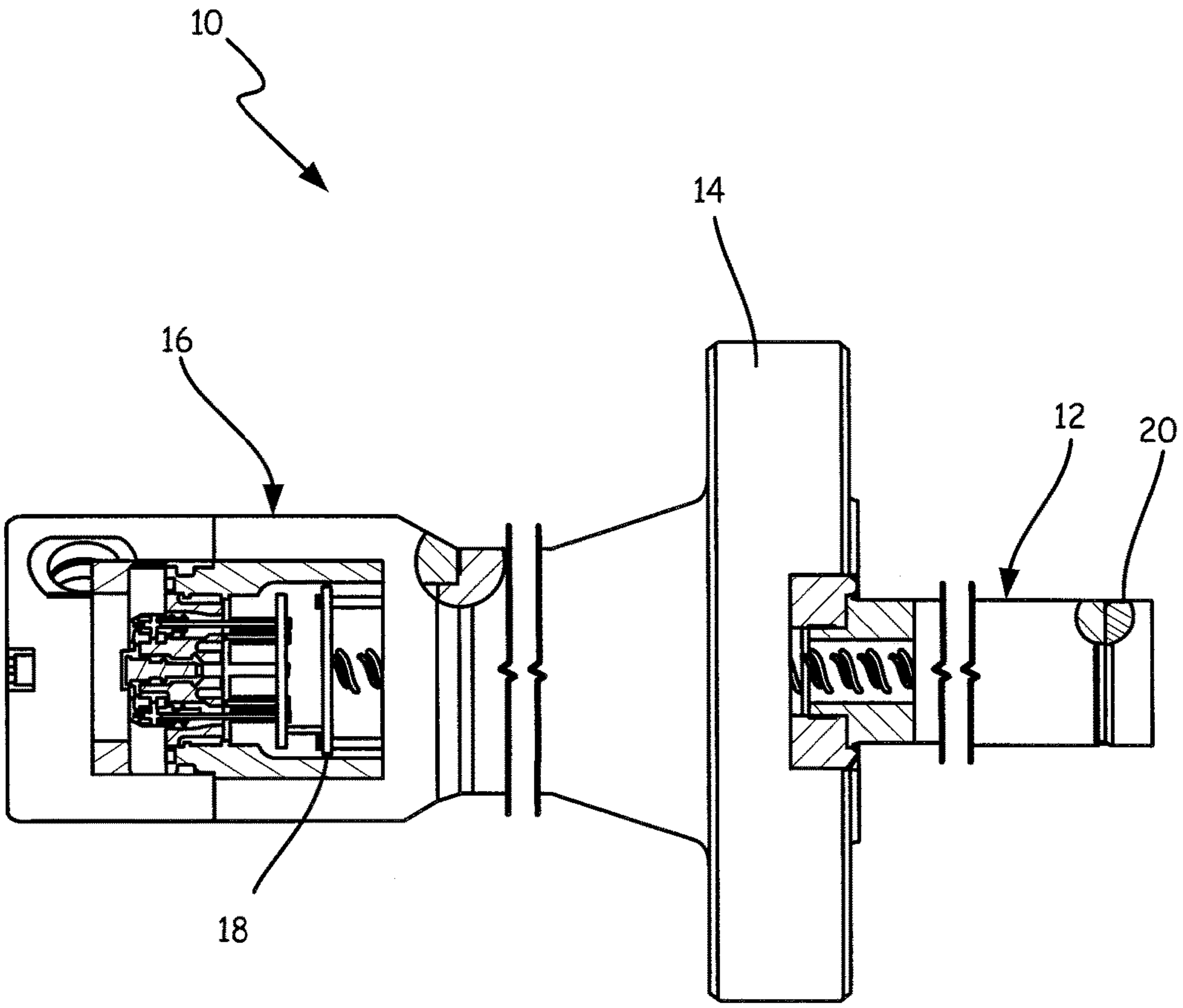
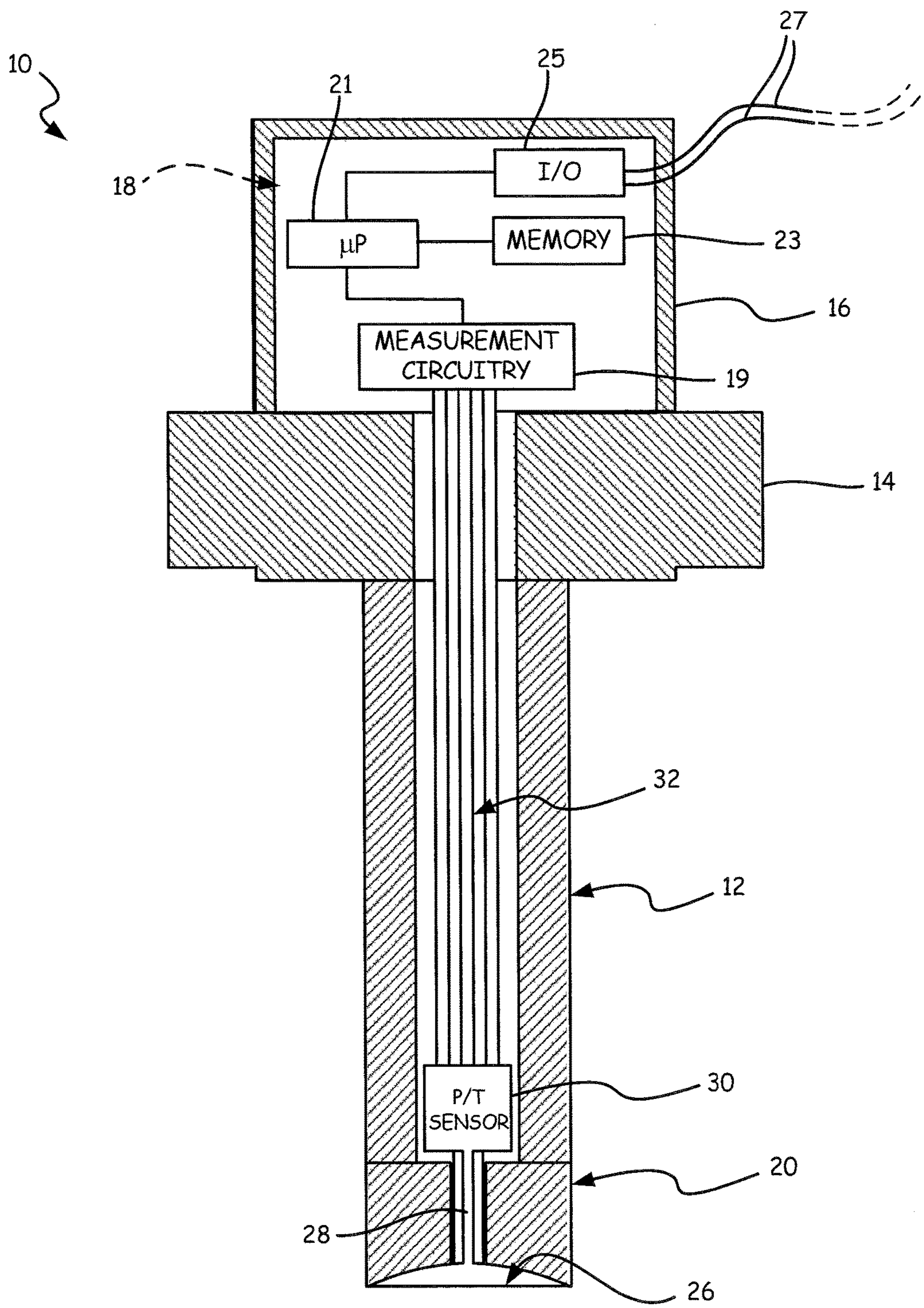


FIG. 1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I/O
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P/T SENSOR
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28
26

FIG. 2

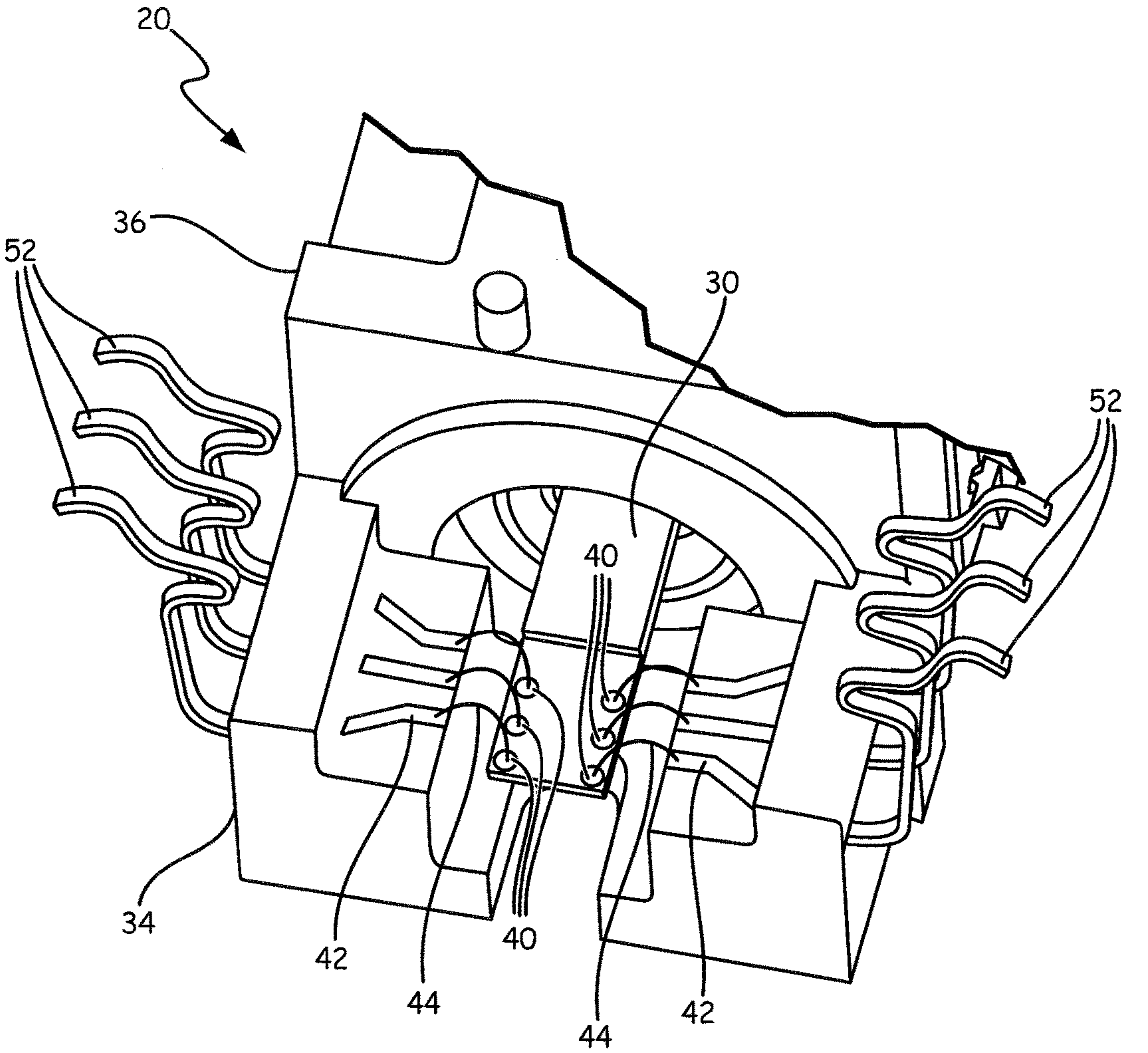

FIG. 3
(PRIOR ART)

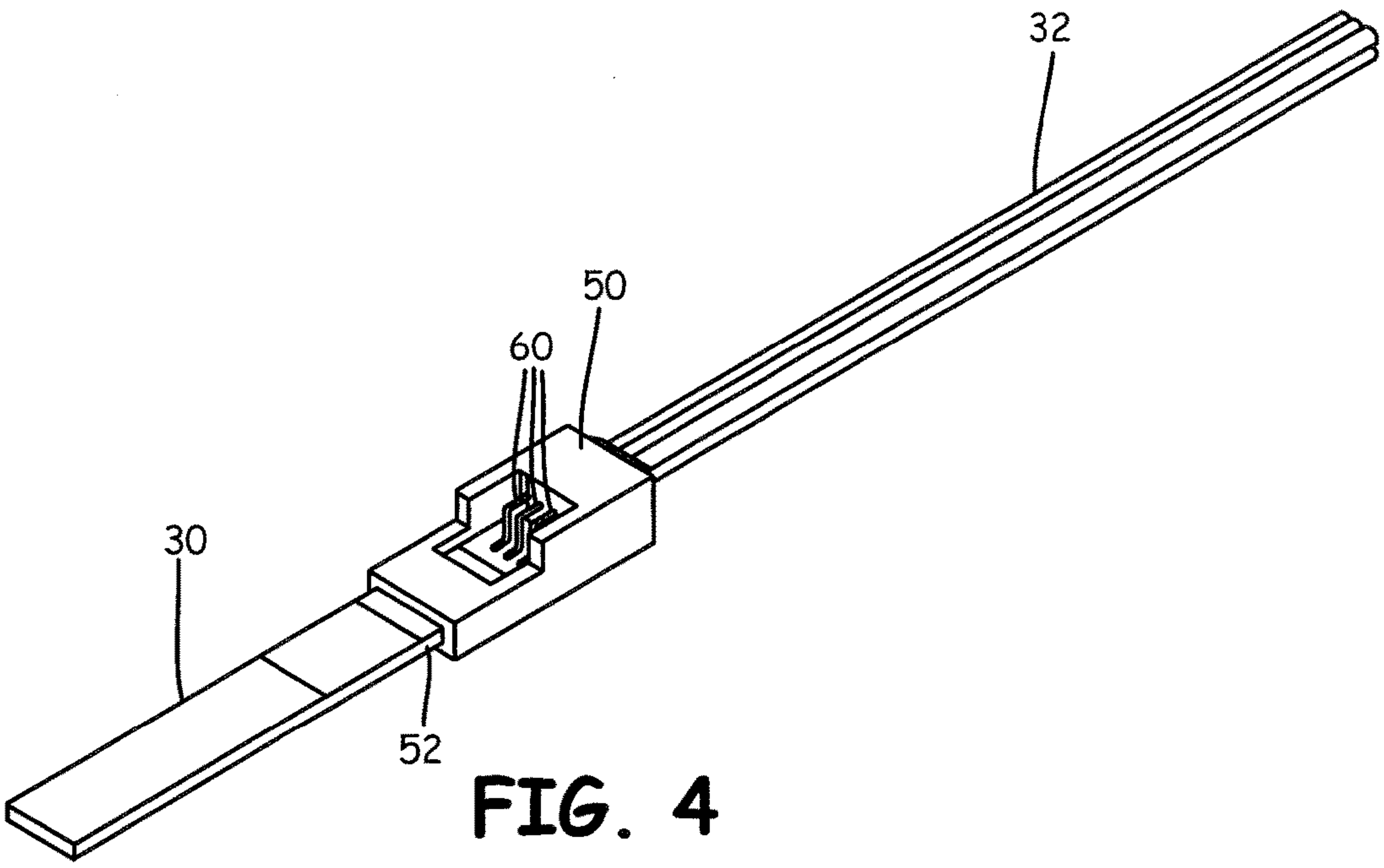

FIG. 4

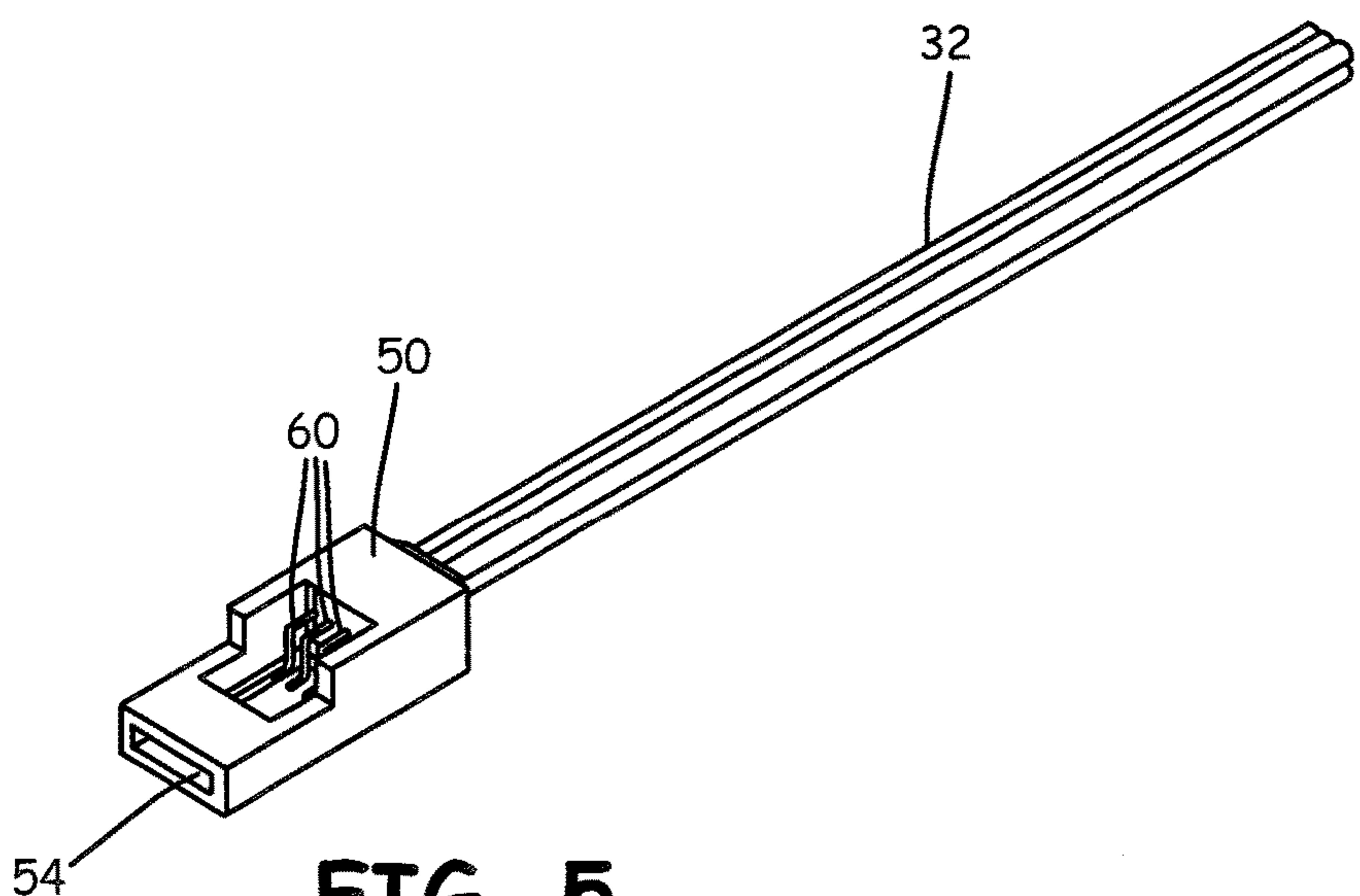

FIG. 5

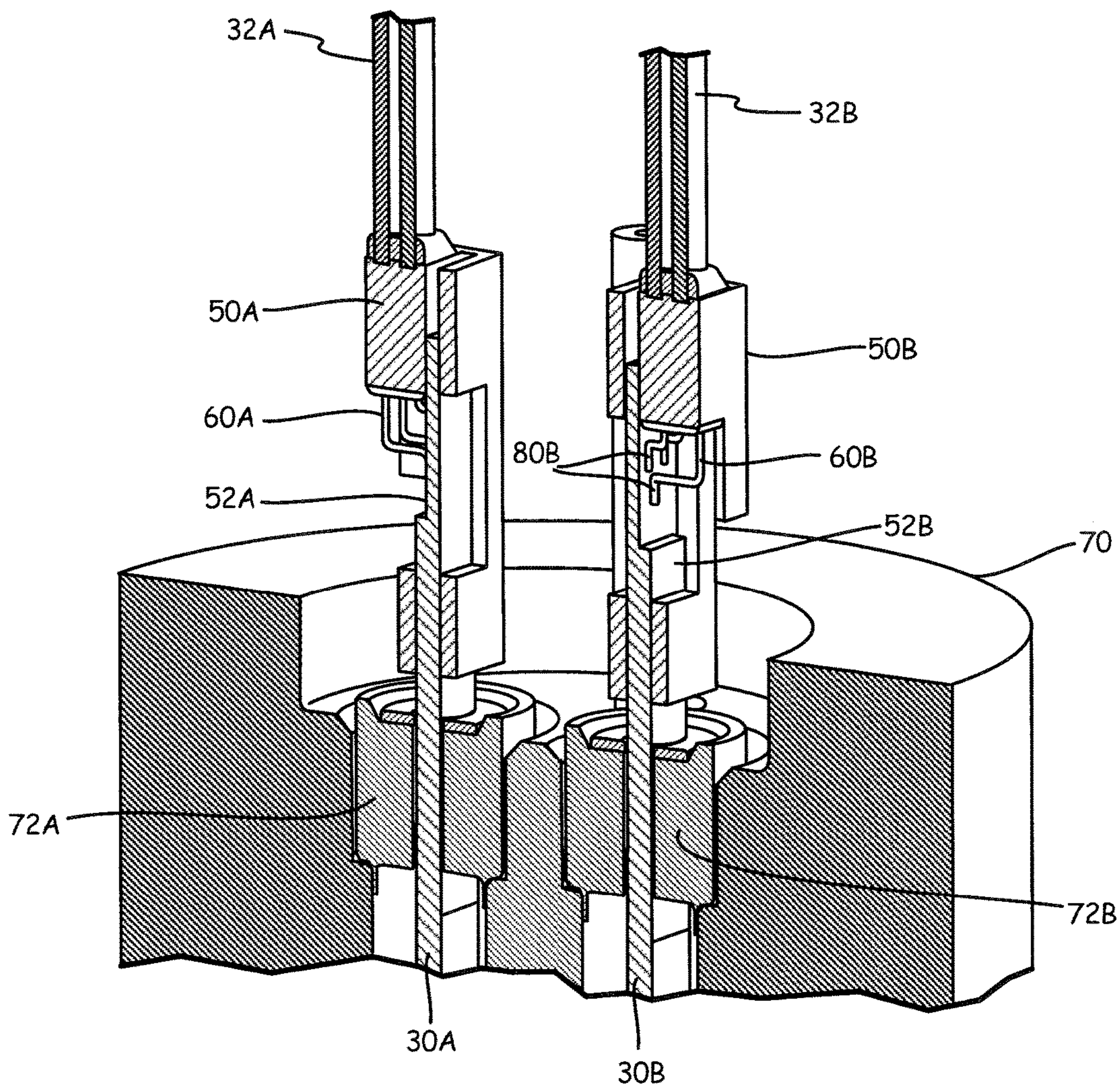

FIG. 6

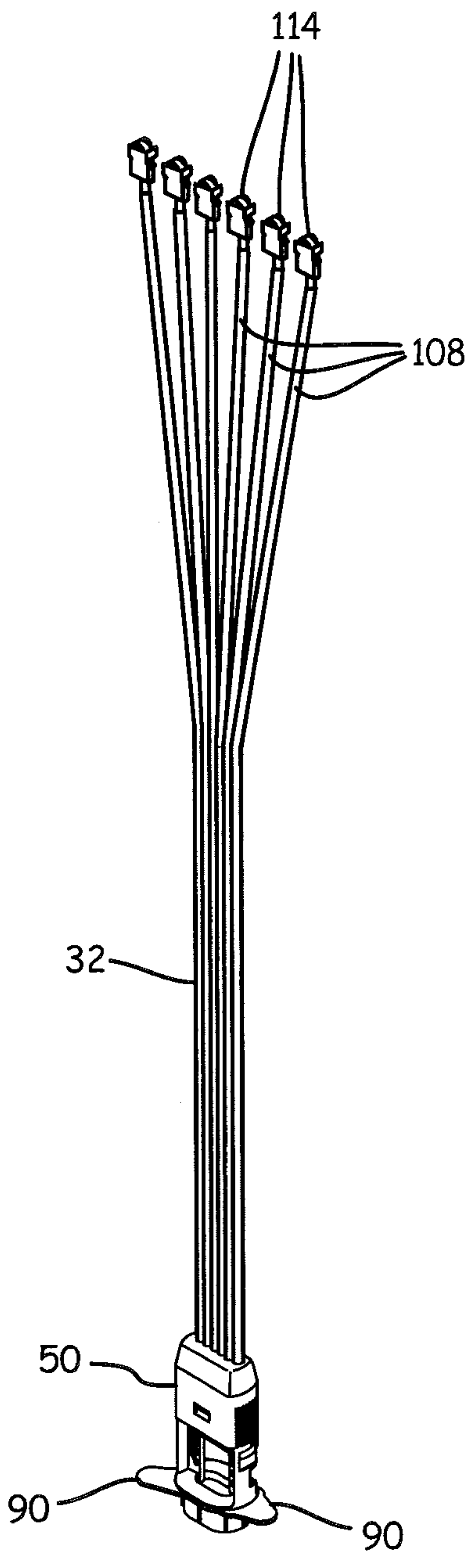

FIG. 7

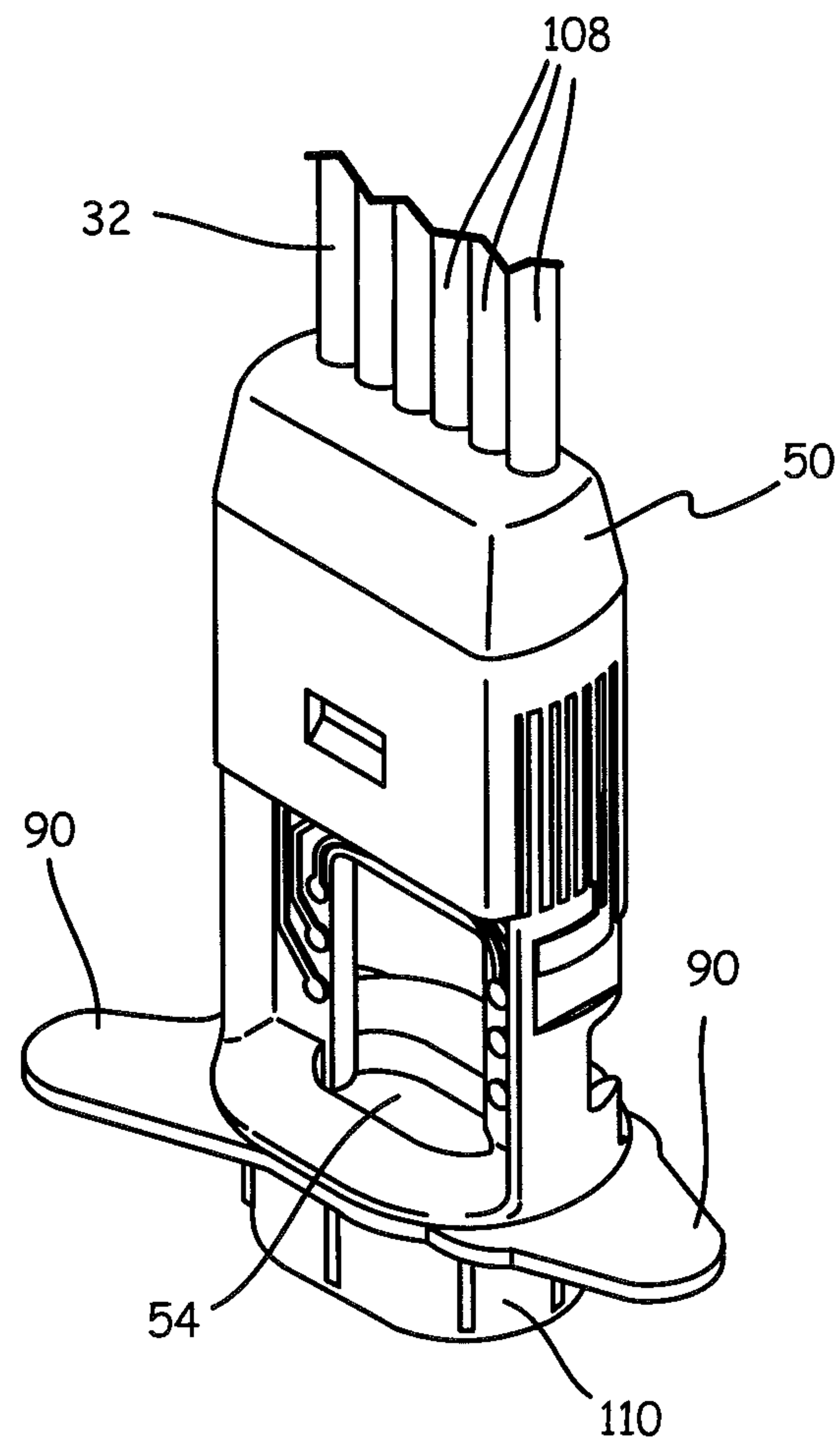

FIG. 8

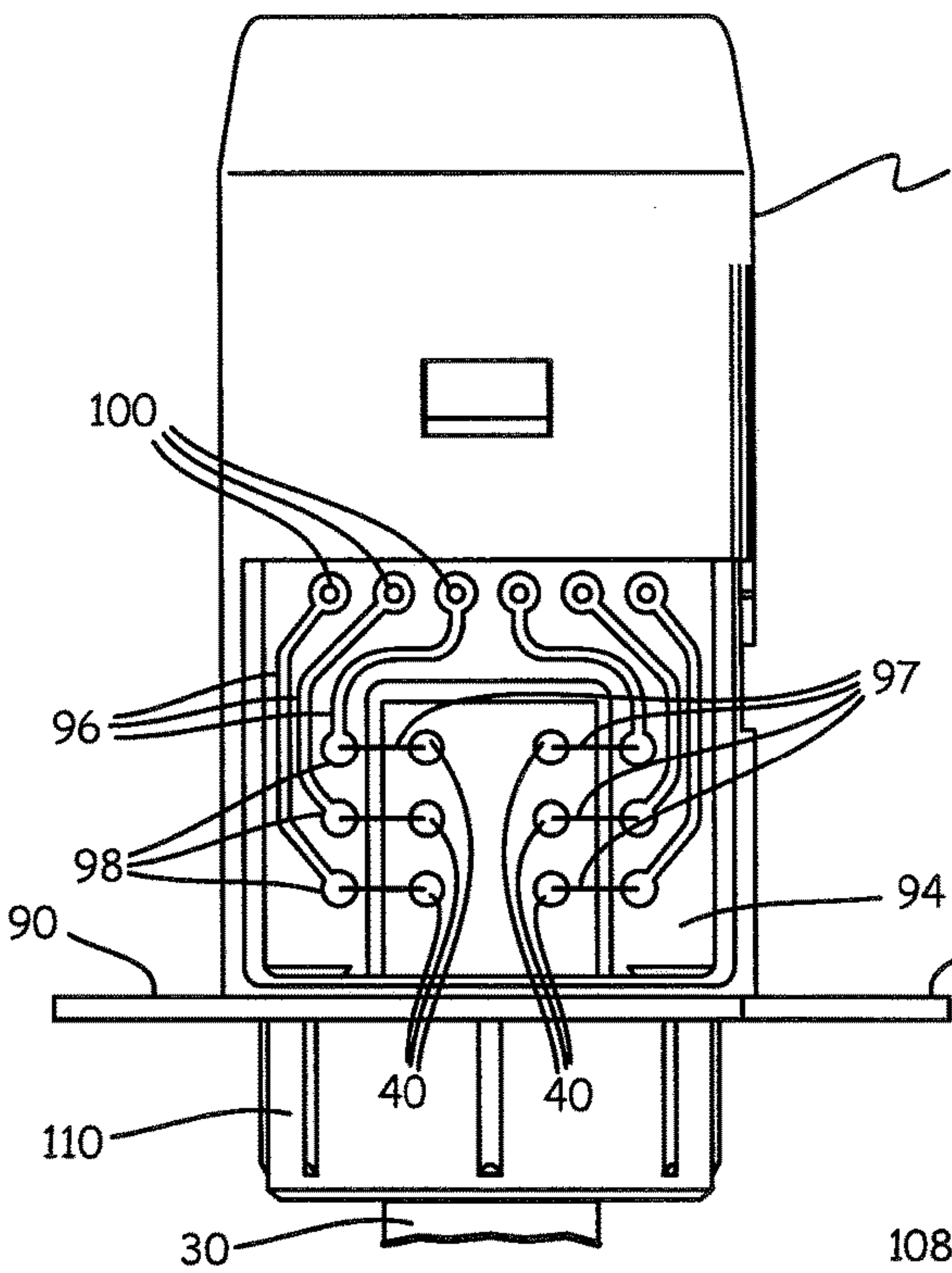
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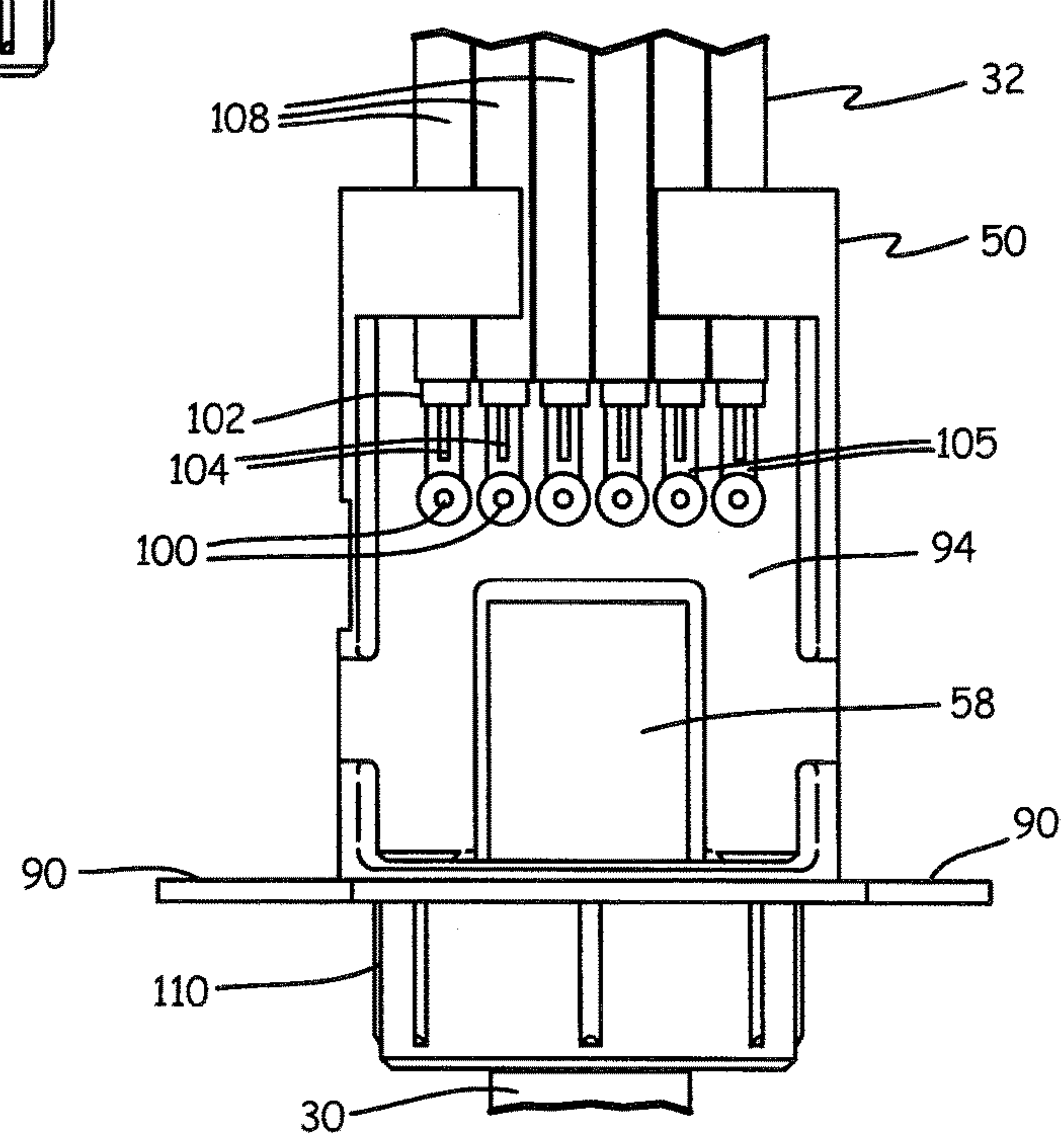
FIG. 9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102
104
105
100
94
58
90
90
110
30

FIG. 10

ELECTRICAL INTERCONNECT FOR PRESSURE SENSOR IN A PROCESS VARIABLE TRANSMITTER

BACKGROUND

Industrial process control systems are used to monitor and control industrial processes of the type used to produce or transfer fluids or the like. In such systems, it is typically important to measure "process variables" such as temperatures, pressures, flow rates, and others. Process control transmitters measure such process variables and transmit information related to the measured process variable back to a central location such as a central control room.

One type of process variable transmitter is a pressure transmitter which measures process fluid pressure and provides an output related to the measured pressure. This output may be a pressure, a flow rate, a level of a process fluid, or other process variable that can be derived from the measured pressure. The pressure transmitter is configured to transmit information related to the measured pressure back to the central control room or other location. Transmission is typically provided over a two-wire process control loop, however, other communication techniques may be used including wireless transmission.

Generally, the process pressure is coupled to the process variable transmitter through some type of process coupling. In many instances, a pressure sensor of the transmitter is fluidically coupled to the process fluid either through an isolation fluid or by direct contact with the process fluid. The pressure of the process fluid causes a physical deformation to the pressure sensor which generates an associated electrical change in the pressure sensor such as capacitance or resistance.

One particularly challenging environment for pressure measurement is applications which have a very high working pressure. One such application is the subsea environment. In such applications, the static pressure to which the process equipment is exposed can be quite high. Further, the process variable sensor may be exposed to a very broad range of temperatures. In such applications, various industry standard form factors are used for configuring the process variable transmitter. One typical configuration includes a pressure sensor positioned at a distal end of a probe. Transmitter electronics are carried in an electronics housing which is spaced apart from the probe. Electrical connectors extend from the electronics housing and couple to a pressure sensor carried in the probe. In many instances, it is difficult to reliably electrically connect to a process variable sensor carried at the distal end of the probe. Such connections may be difficult to achieve and may also be prone to failure. Further, in such configurations, size constraints may also present a challenge.

SUMMARY

A process fluid pressure sensor assembly includes a pressure sensor configured to sense a pressure of a process fluid. The assembly includes a pressure sensor body formed of an insulating material. The pressure sensor includes a plurality of electrical contact pads which couple to a pressure sensing element of the body of the pressure sensor. An interconnect body is configured to fit over an end of the pressure sensor body. A plurality of electrical connectors carried in the interconnect body are in electrical contact with the plurality of electrical contact pads. A wiring harness

attaches to the interconnect body and includes a plurality of wires which are electrically connected to the plurality of electrical connectors.

This Summary and the Abstract are provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. The Summary and the Abstract are not intended to identify key features or essential features of the claimed subject matter, nor are they intended to be used as an aid in determining the scope of the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side view of a process variable transmitter suitable for use in subsea oil and gas applications.

FIG. **2** is a simplified diagram of the transmitter of FIG. **1**.

FIG. **3** is a perspective view showing a prior art technique for electrically connecting two a process variable sensor.

FIG. **4** is a perspective view showing an electrical interconnect body coupled to a process variable sensor.

FIG. **5** is a perspective view of the electrical interconnect body of FIG. **4**.

FIG. **6** is a perspective cross-sectional view showing two process variable sensors coupled to two respective electrical interconnect bodies.

FIG. **7** is a perspective view of another example electrical interconnect.

FIG. **8** is an enlarged perspective view of an electrical interconnect body shown in FIG. **7**.

FIG. **9** is a top plan view of the electrical interconnect body of FIG. **8**.

FIG. **10** is a bottom plan view of the electrical interconnect body of FIG. **8**.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

FIG. **1** is a partial cut away perspective view of one standard configuration of a process variable transmitter **10** for use in a subsea environment. Transmitter **10** can be used to sense process variables and transmit information related to a sensed process variable to another location. Example process variables which may be measured and transmitted included pressure and temperature. Transmitter **10** includes an elongate probe **12** and an electronics housing **16**. A pipe flange **14** is configured for mounting the transmitter **10** to a process vessel such as a process pipe. The probe **12** is inserted into an opening in a pipe wall and used to position a process variable sensor **30** (not shown in FIG. **1**) proximate process fluid in the process vessel. The process variable sensor **30** is carried in a sensor assembly **20** and may couple to the process fluid directly or through an isolation diaphragm. Interconnect wiring **32** extends from the process variable sensor **30** in the sensor assembly **20** to transmitter electronics **18** carried in the electronics housing **16**. The probe **12** may typically vary in length from 0 to more than 13 inches depending upon the particular application. In order to provide accurate measurement, the process variable sensor **30** is typically positioned at the distal end of the probe **12**. This reduces the amount of isolation fluid required and improves the accuracy in the sensed process variable. Further, in order to increase the life span and accuracy of the transmitter electronics **18**, electronics **18** are typically spaced apart from the pipe flange **14** such that the electronics **18** may be maintained at a temperature which is less than or equal to 85° C. by sea water cooling of the housing **16**. This may create a separation distance of more than 15 inches between the electrical connections on the process variable sensor **30** and the transmitter electronics **18**.

In addition to being able to accommodate spacing variations between the process variable sensor **30** and the transmitter electronics **18**, the electrical interconnect **32** to the sensor **30** should also be capable of operating over a broad range of temperatures, for example −46° C. to 204° C. As the electrical connection to the process variable sensor **30** occurs at the far distal end of the probe **12**, the electrical connection experiences the full temperature range of the process fluid. Further, the electrical connection to the process variable sensor **30** may be required to be made in a very limited area. For example, the distal end of the probe **12** may have a diameter which is less than 1.25 inch. In addition, electrical noise or stray capacitance in the electrical connection between the transmitter electronics **18** and the process variable sensor **30** should be minimized in order to obtain accurate process variable measurements.

FIG. **2** is a simplified diagram showing process variable transmitter **10** including a process variable sensor **30**. Electrical interconnect wiring harness **32** includes a plurality of wires and extends between the process variable sensor **30** and the transmitter electronics **18**. In FIG. **2**, the process variable sensor **30** is illustrated as a pressure and temperature sensor. Sensor **30** couples to the process fluid through an isolation diaphragm **26** and a capillary tube **28**. An isolation fill fluid is carried in the space formed by capillary **28** and isolation diaphragm **26** to convey an applied pressure by the process fluid to the process variable sensor **30**.

As illustrated in FIG. **2**, transmitter electronics **18** includes measurement circuitry **19** coupled to sensor **30**. For example, circuitry **19** can be configured to convert an output from a temperature sensor and an output from a pressure sensor into digital values which are provided to a microprocessor **21**. Microprocessor **21** operates in accordance with instructions stored in a memory **23** and communicates using I/O circuitry **25**. I/O circuitry can communicate over any appropriate communication medium including a two-wire process control loop **27**. In some configurations, I/O circuitry **25** is also used to provide power to transmitter electronics **18** using power received from loop **27**. Wireless communication may also be employed.

FIG. **3** is a partial perspective view showing an electrical connection made to process variable sensor **30** using a prior art technique. In FIG. **3**, sensor assembly **20** includes a sensor lead frame body **36** having a lead frame body extension **34**. A proximal end of sensor **30** carries electrical pads **40**. Wire bonds **44** are used to electrically connect the pads **40** to extension traces **42** carried on extension **34**. Extension traces **42** connect to extension leads **52**. Electrical wires may be coupled to extension leads **52** and used to connect the process variable sensor **30** to transmitter electronics **18**.

FIGS. **4** and **5** are perspective views showing an interconnect body **50** and a wiring harness **32** in accordance with one example embodiment. In FIG. **4**, a proximal end **52** of sensor **30** is inserted into an interconnect body through an opening **54** (see FIG. **5**). Electrical connectors **60** are electrically coupled to individual wires in wiring harness **32** and contact bond pads **40** on the proximal end **52** of sensor **30** which are illustrated in FIG. **3**. The proximal end **52** of sensor body **30** may be secured in opening **54** through a friction fit or other attachment technique. For example, an adhesive may be used or the like. Bonding to the sensor **30** may be achieved using a high temperature adhesive such as Delomonopox® AD223 available by Delo Industrial Adhesives, LLC.

FIG. **6** is a cutaway perspective view showing two process variable sensors **30**A and **30**B carried in a sensor capsule **70**. In FIG. **6**, pressure resistant sensor mounts **72**A and **72**B are used to mount respective sensors **30**A and **30**B. Interconnects **50**A and **50**B electrically connect wiring harness **32**A, **32**B to respective proximal ends **52**A, **52**B of sensors **30**A, **30**B. As illustrated with respect to interconnect **50**B, electrical conductors **60**B include attachment feet **80**B. Feet **80**B are configured to contact the pads **40** shown in FIG. **3** of sensor **30**B. The connection may be through a spring loading of the feet **80**B and may also include bonding such as through soldering, resistance welding, etc., of the electrical connection.

In the configuration illustrated in FIGS. **4-6**, the interconnect body **50** and electrical connections may be coupled to the sensor **30** after the sensor **30** is mounted in the sensor capsule **70**. Further, the individual wires in the wiring harness are configured as coaxial wires using coaxial conductors as an electrical shield. This reduces the amount of electrical wiring which is unshielded and thereby reduces interference from electrical noise sources as well as stray capacitance in the sensor signal. Further, the wire bonds **44** shown in FIG. **3** are eliminated. The size of the connector may be reduced as the six wires are attached in a two row staggered pattern.

FIGS. **7**, **8**, **9** and **10** illustrate another example configuration of interconnect body **50**. In this configuration, the interconnect body **50** includes sensor opening **54** configured to receive sensor **30** as illustrated in FIGS. **9** and **10**. Interconnect body **50** includes mounting (or placement) tabs **90** for use when placing interconnect body over the proximal end **52** of sensor **30**. Tabs **90** can also be bonded to sensor capsule **70** shown in FIG. **6**.

In one configuration as illustrated in FIGS. **9** and **10**, electrical traces **96**, bond pads **98** and vias **100** are formed directly on interconnect body **50** through a deposition process such as laser direct structuring (LDS). However, other deposition processes may be implemented as well. For example, structuring interconnect body may include an optional interconnect circuit board **94** which carries electrical traces **96**. Traces **96** include bond pads **98** which are used for wire bonding to bond pads **40** of sensor **30** by wire bonds **97**. Traces **96** extend from pads **98** to vias **100** which connect to a bottom side of the circuit board **94** as illustrated in FIG. **10**. Outer electrical conductors **102** of wiring harness **32** provide an outer shield and need not be electrically connected to interconnect body **50**. In another example configuration, optional circuit board **94** may include a ground plane or the like whereby electrical connectors **102** of wiring harness **32** connect to electrical ground. A second electrical connector **104** of wiring harness **32** can be bonded to bonding pads **105** and electrically couple to a sense element at the distal end of sensor **30** through traces **96** and the connection to bond pads **40**. The individual cables **108** of harness **32** may be configured as coaxial cables having an inner conductor and a coaxial outer shield.

The sensor **30** is held securely within the sensor capsule **70** by sensor mount **72**. In one configuration, the sensor **30** is held securely in the sensor mount **72**. The interconnect body **50** is secured to the sensor capsule **70** whereby there is substantially no contact between the interconnect body **50** and the sensor **30** other than any electrical interconnect used to couple to the sensor **30**. This ensures that minimal stress is placed on the sensor **30**. A distal lip **110** of body **50** can provide a friction fit to the sensor capsule **70**. In another example embodiment, an adhesive or other bonding material, or a friction fit, is used to secure interconnect body **50** to the sensor **30**. As illustrated in FIG. **7**, proximal connectors **114** are used for electrically connecting cables **108** to electronics **18**. For example, connectors **114** may comprise miniature coaxial RF connectors. Wiring harness **32** can be formed of a ribbon cable having a desired length. This length may be the maximum length which may be necessitated for connecting the sensor **30** to the transmitter electronics **18**. The electrical traces **96** may be formed using any appropriate technique including laser direct structuring (LDS). Tabs **90** can be configured as stainless steel or other material and used for welding or otherwise bonding the interconnect **50** to the sensor capsule **70** shown in FIG. **6**. The body **50** may be formed using a plastic or the like through injection molding, for example. This laser direct structuring (LDS) is used to place electrical traces directly on a plastic connector body. The interconnect body **50** may be formed of any appropriate material including Liquid Crystal Polymer (LCP) or other high temperature plastic. The body **50** also provides a strain of relief to the wiring harness **32**. Preferably, the coaxial cables are constructed to withstand high temperature and are fabricated from appropriate materials such as PFA and nickel-plated copper. The attachment technique may be used to electrically connecting wires including crimping, soldering or welding. The connector **50** may contain a potting material to provide strain relief to the wiring harness **32**.

The sensor **30** may be in accordance with any desired sensing technology. In one specific configuration, the sensor **30** is formed of a body comprising insulating material and carries a pressure sensor and a temperature sensor therein. In a specific configuration, the body of sensor **30** is formed of a single crystal material and is in accordance with the sensor technology discussed in U.S. Pat. No. 6,089,097, issued Jul. 18, 2000 to Frick et al., entitled ELONGATE PRESSURE SENSOR FOR TRANSMITTER, commonly assigned herewith which is incorporated by reference in its entirety. In such a configuration, a cavity within the sensor body changes size as a function of the applied pressure. Capacitive plates provide a pressure sensing element and are mounted with respect to the cavity and have an electrical capacitance which changes as a function of cavity size. The capacitance can be measured and correlated to the applied pressure. Although six coaxial cables are specifically discussed above, the connections may also be made using unshielded wires. Further, the connections may be any combination of shield and unshielded wires. For example, unshielded electrical wires can be used for connecting to a temperature sensor for use in resistance measurement and coaxial cabling can be used to connect to a pressure sensor which has an electrical capacitance which changes in response to applied pressure. A metal mounting tab **90** may be included in the connector **50** for soldering or welding to the sensor **30**. Body **50** may include a potting compound to provide strain relief to wiring harness **32**.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.

What is claimed is:

1. A subsea process variable transmitter, comprising:

a transmitter housing;

measurement circuitry located in the transmitter housing configured to measure a pressure of the process fluid;

a flange configured to mount the transmitter housing to a subsea process system;

an elongate probe configured to extend from the flange into the subsea process system;

a process fluid pressure sensor assembly at a distal end of the probe, comprising:

a pressure sensor configured to sense a pressure of a process fluid comprising a pressure sensor body, the pressure sensor including a plurality of electrical contact pads which couple to a pressure sensing element of the pressure sensor;

an interconnect body which is separated from the elongate probe and fits over an end of the pressure sensor body;

a plurality of electrical connectors carried in the interconnect body electrically coupled to the plurality of electrical contact pads and which are in direct abutting contact with the plurality of electrical contact pads; and

a wiring harness attached to the interconnect body comprising a plurality of wires which are electrically connected to the plurality of electrical connectors, the wiring harness is configured to electrically connect the pressure sensor to the measurement circuitry in the transmitter housing.

2. The subsea process variable transmitter of claim **1** wherein at least one of the plurality of wires of the wiring harness comprises a coaxial cable.

3. The subsea process variable transmitter of claim **1** wherein the interconnect body includes an opening configured to receive a proximal end of the pressure sensor.

4. The subsea process variable transmitter of claim **1** wherein the pressure sensor includes a temperature sensing element electrically connected to the plurality of electrical contact pads.

5. The subsea process variable transmitter of claim **1** wherein the pressure sensor comprises an elongate body formed of a single crystal material.

6. The subsea process variable transmitter of claim **1** wherein a proximal end of the wiring harness includes a plurality of RF connectors configured to connect the plurality of electrical wires to transmitter electronics.

7. The subsea process variable transmitter of claim **1** wherein the interconnect body includes a distal lip configured to couple to a pressure sensor capsule which carries the pressure sensor.

8. The subsea process variable transmitter of claim **1** wherein the interconnect body includes a potting compounds configured to provide strain relief to the wiring harness.

9. The subsea process variable transmitter of claim **1** wherein the interconnect body includes at least one tab configured to be bonded to a sensor capsule which carries the pressure sensor.

10. The subsea process variable transmitter of claim **1** wherein the interconnect body is formed of a plastic.

11. The subsea process variable transmitter of claim **1** wherein the plurality of electrical connectors comprise traces which are deposited on the interconnect body.

12. The subsea process variable transmitter of claim **11** wherein the interconnect body includes a plurality of vias for connecting to the plurality of traces.

13. The subsea process variable transmitter of claim **1** wherein the plurality of electrical connectors comprise traces on a circuit board of the interconnect body.

14. The subsea process variable transmitter of claim **13** wherein the circuit board includes a plurality of vias for connecting to the plurality of traces.

15. The subsea process variable transmitter of claim **1** including a second pressure sensor connected to a second wiring harness by a second interconnect body.

16. The subsea process variable transmitter of claim **15** wherein the pressure sensor and the second pressure sensor are carried in a sensor capsule.

17. The subsea process variable transmitter of claim **1** wherein the plurality of electrical connectors include feet which are configured to electrically contact the electrical contact pads carried on the pressure sensor.

18. The subsea process variable transmitter of claim **17** wherein the feet are bonded to the electrical contact pads.

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