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Sensor control circuit

Abstract

A control circuit for a sensor provided in a long member which can be inserted into a lumen to measure the flow velocity of a fluid in the lumen and a measurement device. The control circuit includes a drive circuit supplying a drive current to the sensor. A leakage current detection circuit detects a leakage current and performs an output corresponding to the detected leakage current. The leakage current detection circuit outputs a detection signal in response to detection of a leakage current exceeding a threshold value. A stop circuit stopping supply of the drive current to the sensor by the detection signal is further provided.

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References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
4015142	12/1976	Nagaoka	327/385	H01H 9/54
5139021	12/1991	Sekii et al.	N/A	N/A
6142958	12/1999	Ola et al.	N/A	N/A
6885210	12/2004	Suzuki	324/762.01	G01R 31/2621
2006/0129179	12/2005	Weber et al.	N/A	N/A
2009/0192413	12/2008	Sela	N/A	N/A
2014/0180141	12/2013	Millett	N/A	N/A
2014/0249386	12/2013	Caron et al.	N/A	N/A
2015/0105654	12/2014	Meyer	N/A	N/A
2015/0141854	12/2014	Eberle	N/A	N/A
2016/0262698	12/2015	Mahlin	N/A	N/A

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
202699093	12/2012	CN	N/A
55-065006	12/1979	JP	N/A
63-216534	12/1987	JP	N/A
2001-504249	12/2000	JP	N/A
2007-296354	12/2006	JP	N/A
2008-522717	12/2007	JP	N/A
2012-183239	12/2011	JP	N/A
2015-501184	12/2014	JP	N/A
97/27802	12/1996	WO	N/A
2014/100458	12/2013	WO	N/A
2016/009317	12/2014	WO	N/A
2015/059578	12/2014	WO	N/A

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Background/Summary

BACKGROUND OF THE INVENTION

(1) The present invention relates to a blood measurement device measuring the physical quantities relating to blood in a blood vessel.

(2) Moreover, the present invention relates to a control circuit for a sensor provided in a long member which can be inserted into a lumen to measure the flow velocity of a fluid in the lumen and a measurement device.

BACKGROUND ART

(3) As one of the indices for determining the course of treatment of a stenotic lesion in a coronary artery, the coronary flow reserve (CFR) is mentioned. The CFR is an index indicating the capability

to increase the coronary blood flow rate corresponding to an increase in the myocardial oxygen consumption and is determined based on a ratio of the coronary blood flow rate at the maximum congestion to the coronary blood flow rate at rest. A reduction in the CFR is considered to be the onset mechanism of the myocardial ischemia in view of the coronary circulation. Moreover, when the diameter of the coronary artery does not vary, the CFR is determined as a ratio of the maximum coronary artery blood flow velocity to the coronary artery blood flow velocity at rest because the coronary artery blood flow rate and the coronary artery blood flow velocity are linearly correlated with each other.

(4) The CFR is about 3.0 to 4.0 in a healthy sample but is less than 2.0 in significant stenosis with a diameter stenosis rate (% DS) of 75% or more. Moreover, it has been reported that the CFR reduces also in a minimum coronary artery disease even when the coronary artery is free from significant stenosis. Thus, the CFR is not merely used for the evaluation of the coronary artery diameter stenosis rate but used as a synthetic index of the coronary circulation including the coronary microcirculation.

(5) Patent Document 1 discloses a guide wire provided with a pressure sensor having a temperature sensing member in a tip portion. The pressure sensor is provided in a stainless steel outer tube having an opening portion. The temperature sensing member in the pressure sensor is exposed from the stainless steel outer tube through the opening portion. The temperature sensing member outputs signals corresponding to temperature changes accompanying mass flow rate changes of the blood flow contacting the temperature sensing member through the opening portion. Patent Document 1 describes that the CFR can be calculated only based on output signals of the temperature sensing member.

(6) Patent Document 2 discloses a guide wire assembly having sensors, such as a pressure sensor and a flow rate sensor. The guide wire assembly has a tubular shaft, and a sensor element is provided in an end portion on the distal side of the shaft. A core wire is inserted into and passed through the inside of the shaft. A tip portion of the core wire is inserted into the sensor element. The sensors are mounted in the core wire portion positioned in the sensor element. To the sensor, a cable for, for example, transmitting and receiving signals between the sensor and external devices is connected. The cable is inserted into and passed through the inside of the shaft along the core wire.

(7) When measuring the blood pressure and the like in a blood vessel by the sensor, the guide wire assembly is inserted into the blood vessel with the sensor element as the head. The sensor element is caused to advance in the blood vessel by propulsive force applied to an end portion on the proximal side of the shaft. When the rotational force around the axis line is applied to the end portion on the proximal side in the shaft, the rotational force is transmitted to the sensor element through the shaft. Thus, the sensor element is turned around the axis line.

CITATION LIST

Patent Literature

(8) Patent Document 1: Japanese Unexamined Patent Application Publication (Translation of PCT Application) No. 2001-504249 Patent Document 2: Japanese Unexamined Patent Application Publication (Translation of PCT Application) No. 2007-296354

SUMMARY OF THE INVENTION

(9) The guide wire having the sensors described above has been demanded to be reduced in the size and the diameter so as to be able to be inserted into a small-diameter coronary artery. The guide wire assembly disclosed in Patent Document 2 requires space which the cable is inserted into and passed through together with the core wire in the shaft. However, it is limited to increase the outer diameter of the shaft because the outer diameter of the shaft is set so as to be able to be inserted into a blood vessel. Therefore, when the space which the cable is inserted into and passed through together with the core wire is secured in the shaft having a predetermined outer diameter, the thickness (thickness) of a peripheral surface portion in the shaft needs to be reduced.

(10) When the thickness of the shaft decreases, the bending rigidity of the shaft decreases. When the shaft with low bending rigidity advances the inside of a blood vessel, the shaft is easily curved by the resistance, such as frictional force, with the blood vessel. Thus, there is a possibility that propulsion properties of the sensor element in the blood vessel may be impaired. When the thickness of the shaft is small, the rotational force given to the end portion on the proximal side of the shaft is easily displaced into a state where the peripheral surface portion of the shaft is twisted. Therefore, there is also a possibility that the transmission properties of the rotational force may decrease.

(11) The present invention has been made in view of the above-described circumstances. It is an object of the present invention to provide a blood measurement device having high bending rigidity and having excellent propulsion properties and rotational force transmission properties in a blood vessel.

(12) It is another object of the present invention to provide a safe control circuit for a small sensor measuring the flow velocity of a fluid in a lumen.

(13) (1) A blood measurement device according to the present invention has a tubular shaft having flexibility, a tubular connection portion positioned coaxially with the distal end of the shaft and having an inner diameter larger than the inner diameter of the shaft, a passage communicating the inside and the outside of the connection portion, a tubular tip guide portion having flexibility coaxially connected to the distal end of the connection portion, a core material having flexibility fitted into the connection portion and extending to the distal end in the internal space of the tip guide portion to be connected to the tip guide portion, a measurement element positioned in the internal space of the tip guide portion and measuring the physical quantity of blood, and a signal wire which is extended from the measurement element to be inserted into and passed through the internal space of the shaft through the passage.

(14) In the blood measurement device, the bending rigidity of the tip guide portion is secured by the core material. Moreover, the thickness (thickness) of the peripheral surface portion in the shaft can be reduced, and therefore the bending rigidity of the shaft can be secured by the thickness of the circumferential surface portion of the shaft. Furthermore, the propulsive force and the rotational force to be applied to the shaft can be efficiently transmitted to the tip guide portion by the thickness of the peripheral surface portion of the shaft. Moreover, even in the state where the core material is supported by the connection portion, the signal wire is inserted into and passed through the inside of the connection portion through the passage.

(15) (2) Preferably, the connection portion is integrally formed in the distal end of the shaft.

(16) (3) Preferably, the passage is a slit extending in the axial direction in the connection portion.

(17) (4) Preferably, the passage is a groove extending in the axial direction in the proximal end of the core material.

(18) (5) Preferably, the outer diameter of the connection portion is smaller than the outer diameter of the proximal end of the shaft and the blood measurement device is further provided with a tubular cover member fitted onto the connection portion.

(19) A connection place between the connection portion and the core material is reinforced with a cover member.

(20) (6) Preferably, the proximal end of the core material is positioned between the proximal end and the distal end of the passage.

(21) The above-described configuration makes it difficult for the proximal end of the core material and the signal wire to contact each other.

(22) (7) Preferably, the connection portion has a tubular body portion coaxially connected to the distal end of the shaft and a tubular support portion which is positioned in the distal end in the body portion and into which the core material is fitted.

(23) (8) Preferably, the passage is a slit extending in the axial direction in the support portion.

(24) (9) Preferably, the passage is a groove extending in the axial direction in the proximal end of

the core material.

(25) (10) Preferably, the proximal end of the support portion is positioned between the proximal end and the distal end of the body portion.

(26) The above-described configuration makes it difficult for the proximal end and the signal wire of the shaft to contact each other.

(27) (11) Preferably, the inner diameter of the internal space of the shaft is smaller than the outer diameter of the proximal end of the core material.

(28) (12) Preferably, the tip guide portion has a coil body in which a wire is wound in a spiral shape and a tip member positioned in the distal end, in which the core material is connected to the tip member.

(29) According to the configuration, the tip guide portion has preferable bending rigidity.

(30) (13) Preferably, the measurement element measures the pressure of blood.

(31) (14) Preferably, the measurement element measures the flow velocity of blood.

(32) (15) A control circuit of the present invention is a control circuit for a sensor provided in a long member which can be inserted into a lumen to measure the physical quantity of a fluid in the lumen. The control circuit has a drive circuit supplying a drive current to the sensor and a leakage current detection circuit detecting a leakage current and performing an output corresponding to the detected leakage current.

(33) The sensor is inserted into the lumen with the long member. The sensor measures the flow velocity of a fluid flowing through the lumen at an arbitrary position of the lumen. In the measurement, the leakage current detection circuit detects a leakage current. By the detection of the leakage current, the drive of the sensor is stopped, the power supply is turned off, the leakage current is monitored, or a warning is issued, for example.

(34) (16) Preferably, the leakage current detection circuit outputs a detection signal in response to the detection of a leakage current exceeding a threshold value, and a stop circuit stopping the supply of the drive current to the sensor by the detection signal may be further provided in the control circuit of the present invention.

(35) When the leakage current exceeding a threshold value is generated, the current supply to the sensor from the drive circuit is automatically stopped, so that the leakage of a current into a fluid is stopped.

(36) (17) Preferably, the control circuit of the present invention may further have a function switch turning on/off an input of the detection signal from the leakage current detection circuit to the stop circuit.

(37) When it is not appropriate to stop the drive of the sensor, the drive of the sensor can be maintained or resumed by turning off the function switch.

(38) (18) Preferably, the leakage current detection circuit may have at least either one of a first detection circuit detecting a value corresponding to a difference between a predetermined current and a feedback current from the sensor as a leakage current and a second detection circuit detecting a current between the fluid and a ground as a leakage current. The predetermined current is a current corresponding to the drive current of the sensor or a constant current.

(39) The first detection circuit detects the value corresponding to the difference between the predetermined current and the feedback current as a leakage current. More specifically, the first detection circuit detects a current leaking from the sensor. The second detection circuit detects a current between the fluid and the ground as a leakage current. More specifically, the second detection circuit detects not only a leakage current from the sensor but a leakage current from the entire long member to the fluid.

(40) (19) Preferably, the drive circuit has a constant current circuit supplying a constant current to the flow velocity meter and the first detection circuit has a first shunt resistor converting the feedback current from the flow velocity meter into a voltage and a first comparator outputting a first detection signal corresponding to a state in which a voltage corresponding to an output voltage

of the first shunt resistor is larger than a voltage corresponding to a drive current to be supplied to the flow velocity meter from the constant current circuit, in which the second detection circuit may have a second shunt resistor connected between a detection electrode disposed so as to be able to contact the fluid and a ground and a second comparator outputting a second detection signal corresponding to a state in which a voltage corresponding to an output voltage of the second shunt resistor is larger than a voltage corresponding to the drive current to be supplied to the sensor from the constant current circuit.

(41) (20) Preferably, the control circuit of the present invention may be further provided with a temperature compensation circuit receiving an input from a detection body provided in the sensor.

(42) The detection body is a thermocouple or a member performing an output corresponding to output changes due to temperature changes in a sensor, for example. The temperature compensation circuit can correct the measured flow velocity. Moreover, even when a leakage current is generated from such a detection body, the leakage current can be promptly detected by the leakage current detection circuit.

(43) (21) The present invention can also be regarded as a measurement device having the control circuit and the sensor.

(44) (22) Preferably, the sensor may be a hot wire flow velocity meter.

(45) The present invention provides a blood measurement device having high bending rigidity and excellent propulsion properties and rotational force transmission properties in a blood vessel.

(46) Moreover, according to the present invention, a small size and small-diameter measurement device measuring the flow velocity of a fluid flowing through a lumen is realized in a state of having a safety function to a leakage current.

Description

BRIEF DESCRIPTION OF DRAWINGS

- (1) FIG. 1 is a schematic view illustrating the configuration of a blood measurement device **50** according to a first embodiment of the present invention.
- (2) FIG. 2 is a partially-cut plan view of the blood measurement devices **50** illustrated in FIG. 1.
- (3) FIG. 3 is a perspective view around a connection portion **12**.
- (4) FIG. 4A is a cross-sectional view along the A-A line of FIG. 1, FIG. 4B is a cross-sectional view along the B-B line of FIG. 1, and FIG. 4C is a cross-sectional view along the C-C line of FIG. 1.
- (5) FIG. 5 is an exploded view of a tip guide portion **20**, a shaft **10**, and a cover member **15**.
- (6) FIG. 6 is a partially-cut plan view of a blood measurement device **50** according to a second embodiment of the present invention.
- (7) FIG. 7 is a perspective view of a connection member **30**.
- (8) FIG. 8A is an exploded view of the blood measurement device **50** and FIG. 8B is an exploded view of a connection member **30** and a tip guide portion **20** and a shaft **10**, which are connected to each other.
- (9) FIG. 9 is an entire configuration diagram illustrating a measurement device **100**.
- (10) FIG. 10 is a cross-sectional view of a guide wire **130**.
- (11) FIG. 11 is a perspective view of a sensor **133**.
- (12) FIG. 12 is a functional block diagram of the measurement device **100**.
- (13) FIG. 13 is a circuit diagram of a drive circuit **152**.
- (14) FIG. 14 is a circuit diagram of a first output circuit **153**.
- (15) FIG. 15 is a circuit diagram of a second output circuit **154**.
- (16) FIG. 16 is a circuit diagram of a leakage current detection circuit **156**.
- (17) FIG. 17 is a circuit diagram of a stop circuit **157**.

DETAILED DESCRIPTION OF THE INVENTION

(18) Hereinafter, preferable embodiments of the present invention are described. It is a matter of course that each embodiment is merely one embodiment of the present invention and each embodiment can be altered in the range where the gist of the present invention is not altered.

First Embodiment

(19) Hereinafter, a first embodiment of the present invention is described. A blood measurement device **50** illustrated in FIG. **1** is used for measuring the physical quantities, such as the blood pressure, in a blood vessel of a living body, for example. The blood measurement device **50** has a tubular shaft **10** and a tubular tip guide portion **20** provided in the distal end (equivalent to the tip) of the shaft **10**. The tip guide portion **20** is provided with a measurement element **27** (refer to FIG. **2**) measuring the pressure of blood in a blood vessel. The proximal end (equivalent to base end) of the shaft **10** is connected to a control device **40** as an external device. The control device **40** controls the electric power to be supplied to the measurement element **27** and processes signals to be transmitted from the measurement element **27**, for example.

(20) The shaft **10** is a tubular body having flexibility. The shaft **10** has a length suitable for measuring the blood pressure at a desired position of a blood vessel, which is about 1 to 2 m, for example. The shaft **10** is formed of stainless steel for medical treatment, for example. The outer diameter of the shaft **10** is set corresponding to the thickness of a blood vessel into which the shaft **10** is to be inserted and is several tenths of mm, for example.

(21) As illustrated in FIG. **2**, the shaft **10** has a shaft body portion **11** and a connection portion **12** formed in the distal end of the shaft body portion **11**. The shaft body portion **11** is a tubular body having an almost constant outer diameter over the axial direction. An internal space **13A** of the shaft body portion **11** also has a constant inner diameter over the axial direction. The connection portion **12** is projected in the axial direction from the distal end of the shaft body portion **11**. The connection portion **12** is formed integrally and coaxially with the shaft body portion **11**. The “coaxially” means that the axis line of the connection portion **12** and the axis line of the shaft body portion **11** are positioned on the same virtual straight line. Also in the following description, the “coaxially” refers to a state where the axis line of a pair of members each configured into a cylindrical shape are positioned on the same virtual straight line.

(22) The connection portion **12** is a tubular body having an almost constant outer diameter. The outer diameter of the connection portion **12** is smaller than the outer diameter of the shaft body portion **11**. The inner diameter of the connection portion **12** is larger than the inner diameter of the shaft body portion **11**. An internal space **13A** of the shaft body portion **11** and an internal space **13B** of the connection portion **12** are caused to communicate with each other. The inner diameter of the internal space **13A** of the shaft body portion **11** is set considering the outer diameter of four signal wires **25** to be inserted into and passed through the same in a state of being bundled and the thickness required for the shaft body portion **11**.

(23) As illustrated in FIG. **3** and FIG. **4B**, the cross section of the connection portion **12** has a C-shape. Due to the fact that an opening portion of the C-shape continues in the axial direction, a slit **14** is formed which extends along the axial direction from the distal end toward the proximal end of the connection portion **12**. The slit **14** occupies an about $\frac{1}{3}$ range with respect to the outer periphery of the connection portion **12**.

(24) A core material **26** is inserted into the internal space **13B** of the connection portion **12**. The core material **26** is a wire having flexibility and is formed of stainless steel, for example. In the core material **26**, the outer diameter is reduced in a tapered shape from the proximal end toward the distal end. The tapered shape of the core material **26** does not need to be formed ranging from the proximal end to the distal end and may be formed in one portion in the range from the proximal end to the distal end.

(25) The core material **26** extends from the internal space **13B** toward the distal end of the connection portion **12** to be inserted into and passed through the inside of the tip guide portion **20**.

The proximal end of the core material **26** is positioned between the proximal end and the distal end of the slit **14** of the connection portion **12**. The outer diameter around the proximal end of the core material **26** is equal to the inner diameter of the internal space **13B** of the connection portion **12**. The vicinity of the proximal end of the core material **26** is fitted into the internal space **13B** of the connection portion **12** to be bonded. The outer diameter around the proximal end of the core material **26** is larger than the inner diameter of the internal space **13A** of the shaft body portion **11**. (26) As illustrated in FIG. **1** and FIG. **2**, the cover member **15** is a tubular body having a constant outer diameter and a constant inner diameter over the axial direction. The cover member **15** is formed of stainless steel or resin, such as polyimide, for example. The outer diameter of the cover member **15** is equal to the outer diameter of the shaft body portion **11** in the shaft **10**. The inner diameter of the cover member **15** is equal to the outer diameter of the connection portion **12** in the shaft **10**. The dimension along the axial direction of the cover member **15** is shorter than the dimension along the axial direction of the connection portion **12**. Therefore, the distal end of the connection portion **12** is projected outward from the cover member **15** in a state where the cover member **15** is fitted onto the connection portion **12** of the shaft **10**.

(27) As illustrated in FIG. **2**, the tip guide portion **20** has a first coil body **21** connected to the distal end of the connection portion **12**, an element holding body **22** connected to the distal end of the first coil body **21**, a second coil body **23** connected to the distal end of the element holding body **22**, and a tip member **24** provided in the distal end of the second coil body **23**. FIG. **2** illustrates constituent components in a longitudinal cross section except the element holding body **22**, the distal end of the first coil body **21**, and the proximal end of the second coil body **23**. Therefore, the element holding body **22** is illustrated in a plan view.

(28) In the first coil body **21**, a stainless steel wire having a constant diameter is wound around in a spiral shape having a constant diameter, for example. The proximal end of the first coil body **21** is fitted onto the outside of the distal end of the connection portion **12**. The outer diameter of the first coil body **21** is equal to the outer diameter of the cover member **15**. The core material **26** and the four signal wires **25** are inserted into and passed through an internal space **21A** of the first coil body **21** along the axial direction. Therefore, the inner diameter of the first coil body **21** is sufficiently larger than the outer diameter of the core material **26**.

(29) As illustrated in FIG. **2** and FIGS. **4A-4C**, the element holding body **22** holds the measurement element **27**. The element holding body **22** has a cylindrical shape and is formed of stainless steel, for example. The element holding body **22** is coaxially connected to the distal end of the first coil body **21**. As illustrated in FIG. **4A**, the core material **26** is inserted into and passed through an internal space **22D** of the element holding body **22** along the axial direction. In a part of the peripheral wall of the element holding body **22**, an opening portion **22A** is provided. In the internal space **22D** of the element holding body **22**, a support plate **22B** on which the measurement element **27** is to be mounted is provided. The support plate **22B** is disposed between the core material **26** inserted into and passed through the internal space **22D** and the opening portion **22A** of the element holding body **22**. The support plate **22B** has a flat plate shape and one of the front and rear side surfaces serving as the maximum surface faces the opening portion **22A**. The measurement element **27** is a pressure sensor, for example. The measurement element **27** is mounted on one of the front and rear side surfaces of the support plate **22B** facing the opening portion **22A**.

(30) For the measurement element **27**, a configuration known as a pressure sensor is adopted. For example, the measurement element **27** has a diaphragm which is bent by pressure and outputs an electric signal corresponding to the bending amount. To the measurement element **27**, the four signal wires **25** are connected, for example. The four signal wires **25** are used for supplying electric power to the diaphragm, transmitting output signals from the diaphragm, and the like. The four signal wires **25** are extended from the measurement element **27** to the proximal side in the internal space **22D** of the element holding body **22**. In the four signal wires **25**, leads are insulation-coated with an external coating material.

(31) As illustrated in FIG. 2, each signal wire **25** is inserted into and passed through the inside of the element holding body **22** to be inserted into and passed through the inside of the first coil body **21** along the axial direction. Moreover, the four signal wires **25** reach the internal space **13B** of the connection portion **12** through the slit **14** of the connection portion **12**. The four signal wires **25** are inserted into and passed through the internal space **13A** of the shaft body portion **11** from the internal space **13B** of the connection portion **12** along the axial direction to be electrically connected to the control device **40**.

(32) In the second coil body **23**, a stainless steel wire having a constant diameter is wound in a spiral shape having a constant diameter, for example. The proximal end of the second coil body **23** is coaxially connected to the distal end of the element holding body **22**. The core material **26** is inserted into and passed through the inside of the second coil body **23** along the axial direction.

(33) The tip member **24** is formed of stainless steel in a hemisphere shape, for example. The tip member **24** is attached to the distal end of the second coil body **23**. To the tip member **24**, the tip of the core material **26** inserted into and passed through the inside of the second coil body **23** is connected.

(34) [Method for Assembling Blood Measurement Device **50**]

(35) The blood measurement device **50** is assembled by assembling the tip guide portion **20** and the core material **26** beforehand, fitting the cover member **15** onto the connection portion **12** of the shaft **10**, and then connecting them.

(36) The tip guide portion **20** is obtained by integrally assembling the first coil body **21**, the element holding body **22**, the second coil body **23**, the tip member **24**, and the core material **26** as illustrated in FIG. 5. When the tip guide portion **20** has the other constituent members, the other constituent members are also integrally assembled. In the assembled tip guide portion **20**, the core material **26** is extended to the outside from the proximal end of the first coil body **21**. The four signal wires **25** are also extended to the outside from the proximal end of the first coil body **21**. The cover member **15** is fitted onto the connection portion **12** of the shaft **10**.

(37) When the tip guide portion **20**, the shaft **10**, and the cover member **15** are combined, the four signal wires **25** extending from the tip guide portion **20** are caused to enter the internal space **13B** through the slit **14** of the connection portion **12**, and further inserted into and passed through the internal space **13A** of the shaft body portion **11**. Then, the core material **26** extending from the tip guide portion **20** is inserted into the internal space **13B** of the connection portion **12** to be fitted therein. The proximal end of the core material **26** is positioned between the proximal end and the distal end of the slit **14**, so that the signal wires **25** extend to the inside and the outside of the connection portion **12** through the slit **14** which is not closed by the core material **26**. The core material **26** and the connection portion **12** are bonded with an adhesive or the like. The proximal end of the first coil body **21** is fitted onto the outside of the distal end of the cover member **15**. The first coil body **21**, the connection portion **12**, and the cover member **15** are bonded with an adhesive. Thus, the blood measurement device **50** is assembled.

(38) [Operational Effects of First Embodiment]

(39) The blood measurement device **50** is used for measuring the changes of the blood pressure at a predetermined position in a coronary artery, for example. In this case, the blood measurement device **50** is inserted into a blood vessel with the tip member **24** as the head. The blood measurement device **50** inserted into the blood vessel is caused to advance in the blood vessel by the application of force (propulsive force) toward the distal end to an end portion on the proximal side of the shaft **10**. The tip member **24** inserted into the blood vessel is directed in a predetermined direction by the rotational operation of the end portion on the proximal side of the shaft **10** around the axis line.

(40) The position of the tip member **24** in the blood vessel can be grasped based on the position of the tip member **24** in an X-ray transmission image of the blood vessel.

(41) Due to the fact that the tip member **24** is caused to advance in the blood vessel, the element

holding body **22** is positioned at a predetermined portion in the blood vessel. When the end portion on the proximal side of the shaft body portion **11** is rotationally operated around the axis line in such a state, the rotational force given to the shaft body portion **11** is transmitted to the tip guide portion **20** through the connection portion **12**. Thus, the tip guide portion **20** is rotated around the axis line.

(42) In this case, only the signal wires **25** may be inserted into and passed through the internal space **13A** of the shaft body portion **11**, and therefore thickness of the shaft body portion **11** can be increased. Thus, the shaft body portion **11** is difficult to be twisted by the rotational force given to the shaft body portion **11**. Thus, the rotation given to the shaft body portion **11** is efficiently transmitted to the tip guide portion **20**.

(43) In the blood measurement device **50** of this embodiment, the shaft body portion **11**, the connection portion **12**, and the tip guide portion **20** are all coaxially configured. Thus, the rotational force transmission properties of the shaft body portion **11**, the connection portion **12**, and the tip guide portion **20** are entirely further improved. As a result, the tip guide portion **20** is efficiently rotated following the rotational force given to the shaft body portion **11**, so that the rotation followability of the tip guide portion **20** is improved.

(44) The opening portion **22A** of the element holding body **22** is directed in a predetermined direction by the rotation of the tip guide portion **20**. Thus, the detection surface of the measurement element **27** is also directed in the same direction as the direction in which the opening portion **22A** is directed. In such a state, the pressure of the blood flowing through the inside of the blood vessel is measured by the measurement element **27**. When the blood flows into the element holding body **22** from the opening portion **22A** of the element holding body **22**, the blood abuts on the detection surface of the measurement element **27**. Thus, the measurement element **27** detects the pressure of the blood, and then outputs a predetermined signal to the control device **40** through the signal wires **25**. The control device **40** calculates the blood pressure based on the signal transmitted from the measurement element **27**.

(45) Since the cover member **15** is fitted onto the connection portion **12** of the shaft **10**, the connection portion **12** or the core material **26** are difficult to be broken or the like, even when the connection place between the connection portion **12** and the core material **26** is bent.

(46) Since the proximal end of the core material **26** is positioned between the proximal end and the distal end of the slit **14**, space in which the signal wires **25** are movable is provided in the slit **14**. Thus, even when the connection place between the connection portion **12** and the core material **26** is bent, the proximal end and the signal wires **25** of the core material **26** become difficult to contact.

Second Embodiment

(47) Hereinafter, a second embodiment of the present invention is described. The connection portion **12** is integrally formed with the shaft body portion **11** in the first embodiment described above. However the connection portion of the present invention may be configured as a member separate from the shaft **10**. In the following description, those designated by the same reference numerals as those of the first embodiment refer to the same members.

(48) As illustrated in FIG. 6, a shaft **60** has a shaft body portion **61** and a boss portion **62** provided in the distal end of the shaft body portion **61**. The shaft body portion **61** is a tubular body having an almost constant outer diameter over the axial direction. An internal space **63A** of the shaft body portion **61** has a constant inner diameter over the axial direction. The boss portion **62** is projected in the axial direction from the distal end of the shaft body portion **61**. The boss portion **62** is integrally formed with the shaft body portion **61**. Therefore, the internal space **63A** of the shaft body portion **61** and an internal space **63B** of the boss portion **62** have the same inner diameter. The inner diameters of the internal spaces **63A** and **63B** are set considering the outer diameter of the four signal wires **25** to be inserted into and passed through the same in a state of being bundled and the thickness required for the shaft body portion **61**.

(49) As illustrated in FIG. 7, a connection member **30** (an example of the connection portion) has a

connection body portion **31** and a support portion **32** of a substantially cylindrical shape. In this embodiment, the connection body portion **31** and the support portion **32** each are configured as independent individual members. Due to the fact that the support portion **32** is inserted into the distal end of the connection body portion **31** to be bonded to the connection body portion **31**, whereby the connection body portion **31** and the support portion **32** are integrated.

(50) The connection body portion **31** is a tubular body having a constant outer diameter and a constant inner diameter over the axial direction. The connection body portion **31** is formed of stainless steel or resin, such as polyimide, for example. The outer diameter of the connection body portion **31** is equal to the outer diameter of the shaft body portion **61** in the shaft **60**. The inner diameter of the connection body portion **31** is equal to the outer diameter of the boss portion **62** in the shaft **60**. The proximal end in the connection body portion **31** is fitted into the boss portion **62** of the shaft **60** to be coaxially connected to the shaft **60**. The outer diameter of the connection body portion **31** is equal to the outer diameter of the first coil body **21**.

(51) The support portion **32** has a C-shaped cross sectional shape. Due to the fact that an opening portion of the C-shaped cross sectional shape continues in the axial direction, a slit **32A** extending along the axial direction over the proximal end and the distal end of the support portion **32** is formed. The support portion **32** is formed of stainless steel, for example.

(52) The slit **32A** of the support portion **32** occupies an about $\frac{1}{3}$ range with respect to the outer periphery of the support portion **32**. An internal space **32B** of the support portion **32** has an outer diameter equal to the outer diameter around the proximal end of the core material **26** described later. The outer diameter of the support portion **32** is equal to the inner diameter of the connection body portion **31**. The length along the axial direction of the support portion **32** is almost half the length along the axial direction of the connection body portion **31**.

(53) As illustrated in FIG. **6**, the vicinity of the distal end of the support portion **32** is projected from the distal end of the connection body portion **31**. The proximal end of the support portion **32** is positioned in an internal space **31A** of the connection body portion **31** and does not reach the proximal end of the connection body portion **31**. In other words, the proximal end of the support portion **32** is positioned on the side of the distal end relative to the proximal end in the connection body portion **31**. Therefore, there is space where the support portion **32** is not present near the proximal end of the internal space **31A** of the connection body portion **31**.

(54) The core material **26** is inserted into the internal space **32B** of the support portion **32**. The proximal end of the core material **26** is substantially the same position as the proximal end of the support portion **32**. The outer diameter around the proximal end of the core material **26** is equal to the inner diameter of the internal space **32B** of the support portion **32**. The vicinity of the proximal end of the core material **26** is integrated with the support portion **32** by being inserted into and passed through the internal space **32B** of the support portion **32** to be bonded. The outer diameter around the proximal end of the core material **26** is larger than the diameter of the distal end in the internal space **13B** of the boss portion **12** in the shaft **10**.

(55) [Method for Assembling Blood Measurement Device **50**]

(56) The blood measurement device **50** is assembled by connecting the connection member **30** to the tip guide portion **20** assembled beforehand, and then connecting the connection member **30** to the shaft **60**.

(57) The tip guide portion **20** is obtained by integrally assembling the first coil body **21**, the element holding body **22**, the second coil body **23**, the tip member **24**, and the core material **26** as illustrated in FIG. **8A**. When the tip guide portion **20** has the other constituent members, the other constituent members are also integrally assembled. In the assembled tip guide portion **20**, the core material **26** is extended to the outside from the proximal end of the first coil body **21**. The four signal wires **25** are also extended to the outside from the proximal end of the first coil body **21**.

(58) When the tip guide portion **20** and the connection member **30** are combined, the four signal wires **25** extending from the tip guide portion **20** are brought into a state of being inserted into and

passed through the inside of the slit 32A of the support portion 32 and the internal space 31A of the connection body portion 31 to extend to the outside from the proximal end of the connection body portion 31. Then, the core material 26 extending from the tip guide portion 20 is inserted into the internal space 32B of the support portion 32 of the connection member 30. The core material 26 and the support portion 32 are bonded with an adhesive or the like. The proximal end of the first coil body 21 is fitted onto the outside of the distal end of the support portion 32. The first coil body 21, and the support portion 32 and the connection body portion 31 are bonded with an adhesive. (59) As illustrated in FIG. 8B, the four signal wires 25 extending from the connection body portion 31 of the connection member 30 are inserted into and passed through the internal space 63A of the shaft body portion 61 and the internal space 63B of the boss portion 62 in the shaft 60 to be extended to the outside from the proximal end in the shaft 60. Then, the proximal end of the connection body portion 31 is fitted to the outside of the boss portion 62 in the shaft 60. The connection body portion 31 and the boss portion 62 are bonded with an adhesive. Thus, the blood measurement device 50 is assembled.

(60) [Operational Effects of Second Embodiment]

(61) The same operational effects as those of the first embodiment are demonstrated also by the second embodiment described above.

(62) Since the connection body portion 31 is fitted onto the support portion 32 of the connection member 30, the support portion 32 and the core material 26 are difficult to be broken or the like, even when the connection place between the support portion 32 and the core material 26 is bent.

(63) Since the support portion 32 is positioned on the side of the distal end of the connection body portion 31 in the connection member 30, the space in which the signal wires 25 is movable is formed on the side of the proximal end of the connection member 30. Thus, even when the connection member 30 is bent, the proximal end of the core material 26 and the signal wires 25 become difficult to contact each other.

(64) The proximal end of the core material 26 may be positioned on the distal side relative to the proximal end of the connection body portion 31 in the connection member 30. Therefore, not only the configuration in which the proximal end of the core material 26 is positioned in the internal space 31A of the connection body portion 31 but a configuration in which the proximal end of the core material 26 is positioned in the internal space 32B of the support portion 32 may be acceptable.

(65) The connection member 30 may be configured so that the connection body portion 31 and the support portion 32 are individually configured and may not be configured so that the support portion 32 is inserted into the connection body portion 31. More specifically, a configuration in which the connection body portion 31 and the support portion 32 are integrally molded may be acceptable.

Modification of First Embodiment and Second Embodiment

(66) In the embodiments described above, the passage according to the present invention is formed by the slit 14 formed in the connection portion 12 or the slit 32A formed in the support portion 32. However, in place of the configuration, a groove extending in the axial direction may be formed in the outer peripheral surface of the proximal end of the core material 26 and the internal space of the groove may be used as a passage which the signal wires 25 are inserted into and passed through, for example. The number of the slit or the groove is not limited to one and two or more of the slits or the grooves may be formed, and the signal wires 25 may be separately inserted into and passed through the slits or the grooves.

(67) The measurement element 27 held by the element holding body 22 is not limited to the pressure sensor and may be one capable of measuring the physical quantities of blood in a blood vessel. The measurement elements 27 may also be a flow velocity sensor measuring the flow velocity of blood in a blood vessel, a flow rate sensor measuring the flow rate of blood in a blood vessel flow, a temperature sensor measuring the temperature of blood, or the like, for example. The

number of the signal wires connected to the measurement element **27** is not limited to 4 and may be 2, 3, or 5 or more.

(68) Not only the configuration in which the measurement element **27** electrically measures information on the physical quantities of blood but a configuration in which the measurement element **27** optically measures the same may be acceptable. In this case, an optical fiber is used as the signal wire **25**.

(69) The embodiments described above are configured so that the tip guide portion **20** has two coils of the first coil body **21** and the second coil body **23**, the measurement element **27** is provided in the element holding body **22**, and the tip member **24** is provided at the tip of the second coil body **23**. However, the tip guide portion **20** is not limited to the configuration described in the embodiments and the tip guide portion **20** may be configured by one coil body and a tip member provided at the tip of the coil body and configured so that the measurement element **27** is provided in the coil body.

(70) The blood measurement device **50** is not limited to the configuration of being used as the guide wire and the blood measurement device **50** may be configured as a catheter.

Third Embodiment

(71) FIG. **9** illustrates a measurement device **100**. The measurement device **100** is a device measuring the flow velocity of blood flowing through the inside of a human blood vessel. To the measurement device **100**, an AC-DC adapter **111** is connected and a personal computer **112** is connected through a cable **113**. The flow velocity of blood is an example of the physical quantity of blood.

(72) The AC-DC adapter **111** is a converter converting a commercial alternating voltage (for example, AC 100 V) into a DC voltage (for example, DC 15 V), and then outputting the converted voltage. The AC-DC adapter **111** may be incorporated in the measurement device **100** to be a part of the measurement device **100**.

(73) In the personal computer **112**, analysis software is installed. The analysis software analyzes signals input into the personal computer **112** from the measurement device **100**, and then displays the analysis results on a monitor.

(74) The measurement device **100** has a body **120** to which the AC-DC adapter **111** and the personal computer **112** are connected and a guide wire **130** connected to the body **120**. The guide wire **130** is equivalent to the long member.

(75) The body **120** has a power supply switch **121** turning on/off a power supply input from the AC-DC adapter **111**, a sensor connector **122** to which the guide wire **130** is connected, and a function switch **123** on the front surface side. The body **120** has external output connectors **115** (FIG. **12**) for connection with the cable **113** and a power supply connector **114** (FIG. **12**) to which the AC-DC adapter **111** is connected on the rear surface side. The body **120** has a control circuit **150** (FIG. **12**) in a chassis. The control circuit **150** is described later.

(76) The guide wire **130** has a connection connector **131** to be connected to the sensor connector **122** of the body **120**, a shaft **132** extending from the connection connector **131**, and a sensor **133** disposed at the tip of the shaft **132**. The guide wire **130** is attached to the body **120** for each measurement (operation), for example. The “tip” means the end opposite to the end (proximal end) in which the connection connector **131** is provided.

(77) The shaft **132** has a thickness which allows the insertion of the shaft **132** into a human blood vessel and a length which allows the tip to reach a measurement portion, such as the chest, from an insertion portion, such as the limbs. The shaft **132** is formed by spirally wining stainless steel, for example, and can be bent corresponding to the curve of a blood vessel.

(78) As illustrated in FIG. **10**, the shaft **132** has a cylindrical shape and is hollow. In the hollow shaft **132**, a linear core wire **135** (FIG. **11**), a plurality of leads **136**, and a thermocouple **137** are disposed. The thermocouple **137** is equivalent to the detection body.

(79) One end (proximal end) of each of the leads **136** and the thermocouple **137** is connected to a

terminal of the connection connector **131** (FIG. 9). The leads **136** and the thermocouple **137** are electrically connected to the control circuit **150** (FIG. 12) through the connection connector **131** and the sensor connector **122**. The other end (tip) of each of the leads **136** and the thermocouple **137** extends to the tip of the guide wire **130** to be connected to the sensor **133**.

(80) The sensor **133** has a holder **141**, a bobbin **142** held by the holder **141**, a heater **143** wound around the bobbin **142**, and a detection electrode **144** for leakage current detection (FIG. 11).

(81) The holder **141** has a cylindrical shape having the substantially same diameter as that of the shaft **132**. The holder **141** is disposed at the tip of the shaft **132** in such a manner that the axis line is aligned with the axis line of the shaft **132**. The holder **141** is fixed to the shaft **132** with an adhesive or the like.

(82) The holder **141** has an opening **145** in the peripheral wall. The opening **145** is provided along the axial direction (horizontal direction in FIG. 10) of the holder **141**. The heater **143** is cooled by the blood flow through the opening **145**, and then the flow velocity is measured. A detailed description is given later.

(83) The bobbin **142** around which the heater **143** is wound is disposed in the holder **141**. The bobbin **142** has a cylindrical shape and is disposed in the holder **141** in such a manner that the axis line is aligned with the axis line of the holder **141**.

(84) As illustrated in FIG. 11, the heater **143** is spirally wound around the outer peripheral surface of the bobbin **142**. The heater **143** is a resistance wire, such as a nickel wire or a platinum wire, for example. One end (right end in FIG. 11) of the heater **143** is connected to the tip of one lead **136**. The other end (left end in FIG. 11) of the heater **143** is connected to the tip of the other one lead **136**. The other one lead **136** is drawn out to the left end of the bobbin **142** through the inside of the bobbin **142** to be connected to the other end of the heater **143**. The heater **143** receives a DC current supplied by the two leads **136** to generate heat.

(85) The detection electrode **144** is an electrode for detecting a leakage current from the sensor **133** into blood. The detection electrode **144** is disposed on the outer peripheral surface of the bobbin **142** at a position facing the opening **145**. For the detection electrode **144**, a metal piece fixed to the bobbin **142** or metallic foil vapor-deposited, for example, to the bobbin **142** is usable. The detection electrode **144** is connected to the tip of the lead **136** different from the lead **136** connected to the heater **143**. Temporarily, when a leakage current is generated in blood, the leakage current is detected by the detection electrode **144**. A detailed description is given later.

(86) The tip of the thermocouple **137** is attached to the outer peripheral surface of the bobbin **142** together with the detection electrode **144**. The tip of the thermocouple **137** is disposed at a position facing the opening **145**. Therefore, the thermocouple **137** can output a voltage corresponding to the temperature of blood. The output voltage is used for the correction of the flow velocity.

(87) As illustrated in FIG. 10, the holder **141** is filled with a sealing member **146** for insulation between the heater **143** and blood and between the thermocouple **137** and blood or for fixation of the heater **143** and the bobbin **142**. The sealing member **146** contains an insulation material. For materials of the sealing member **146**, silicon, epoxy, polyamide, polyimide, high-density polyethylene, and the like are used, for example. A configuration in which the detection electrode **144** is not covered with the sealing member **146** is adopted so that a leakage current can be detected. For example, an opening or a notch exposing the detection electrode **144** is provided in the sealing member **146**.

(88) A description is given for the measurement of the flow velocity by the sensor **133**. A constant DC current (constant current) is supplied to the heater **143** from the body **120** through the two leads **136**. Thus, the heater **143** generates heat. The temperature of the heater **143** increases by the generation of heat. The value of resistance of the heater **143** changes by the temperature increase. More specifically, the value of resistance of the heater **143** changes by the supply of the DC current. The change of the value of resistance is dependent on the current value of the DC current to be supplied.

(89) The heater **143** is cooled by the blood flow as described above. When cooled, the value of resistance of the heater **143** changes corresponding to the cooling degree. The cooling degree is dependent on the flow velocity of the blood flow. More specifically, the value of resistance of the heater **143** is dependent also on the flow velocity of blood.

(90) Thus, the change of the value of resistance of the heater **143** is dependent on the current value of the DC current to be supplied and the flow velocity of blood. The current value of the DC current to be supplied is known (preset value). Therefore, when the current value corresponding to the preset value is reduced from the voltage of the heater **143**, the voltage corresponding to the flow velocity of the blood flow can be obtained. The flow velocity can be calculated from the voltage. Thus, the sensor **133** is a hot wire flow velocity meter measuring the flow velocity of blood.

(91) The supply of the constant current to the heater **143**, the detection of the voltage of the heater **143**, the detection of the temperature of blood by the thermocouple **137**, and the detection of a leakage current are performed by the control circuit **150** illustrated in FIG. **12**.

(92) The control circuit **150** is realized by a pattern circuit board, which is not illustrated, disposed in the body **120** and various electronic components, such as an integrated circuit (IC), a resistor, a diode, a capacitor, and a transistor mounted on the circuit board. A single circuit board may be used or a plurality of circuit boards connected to each other by leads may be used.

(93) The control circuit **150** has a power supply circuit **151**, a drive circuit **152**, a first output circuit **153** outputting a heater voltage, a second output circuit **154** outputting the flow velocity, a temperature compensation circuit **155**, a leakage current detection circuit **156**, and a stop circuit **157**.

(94) The power supply circuit **151** is a DC-DC converter converting a DC voltage of a constant voltage value into a DC voltage of another constant voltage value. The power supply circuit **151** has an input end and one or two or more output ends. The input end is electrically connected to the power supply connector **114** through the power supply switch **121**. To the power supply connector **114**, the above-described AC-DC adapter **111** is electrically connected. More specifically, a constant DC voltage is input into the power supply circuit **151** from the AC-DC adapter **111**. The “electrically connected” described above means conducting by a pattern, a lead wire, and the like of the circuit board.

(95) The power supply circuit **151** converts an input 15 V DC voltage into 5 V, 10 V, 12 V, and the like, for example. The power supply circuit **151** can be configured using one or two or more so-called power supply ICs, such as a switching regulator and a series regulator, for example. Moreover, an insulation type using a transformer may be used for circuit protection or the like. Moreover, a simple constant voltage circuit using a Zener diode and the like may be additionally used.

(96) One of the output ends of the power supply circuit **151** is connected to the drive circuit **152**. The drive circuit **152** is a drive circuit driving the heater **143**. Specifically, the drive circuit **152** is configured by a constant current circuit using negative feedback of an operational amplifier as illustrated in FIG. **13** and outputs a constant DC current (constant current).

(97) The drive circuit **152** has two voltage dividing resistors **R2** and **R3**, an operational amplifier **OP1**, a transistor **TR1**, a determination resistor **R1** determining a current value, and a protection capacitor **C1**. One end of the protection capacitor **C1** is connected to a constant voltage **V1** which is one of the output ends of the power supply circuit **151**. The other end of the protection capacitor **C1** is grounded. The protection capacitor **C1** reduces a rush current, for example, when the power supply switch **121** is turned on.

(98) The two voltage dividing resistors **R2** and **R3** are connected in series, connected to the constant voltage **V1** (and the protection capacitor **C1**) in one end on the side of the voltage dividing resistor **R2**, and grounded in the other end on the side of the voltage dividing resistor **R3**. The two voltage dividing resistors **R2** and **R3** divide the constant voltage **V1** and outputs divided voltages from a connection point between the two voltage dividing resistors **R2** and **R3**.

(99) The connection point between the two voltage dividing resistors R2 and R3 are connected to a positive terminal (+) of the operational amplifier OP1. More specifically, the divided voltage is input into the positive terminal (+) of the operational amplifier OP1. The output terminal of the operational amplifier OP1 is connected to a gate of the transistor TR1. On the other hand, a negative terminal (−) of the operational amplifier OP1 is connected to an emitter of the transistor TR1 and is grounded through the determination resistor R1. A collector of the transistor TR1 is connected to a constant voltage V2 which is one of the output ends of the power supply circuit 151 through the heater 143. Therefore, a constant current $I_c = V2/R1$ is supplied to the heater 143. The constant voltages V1 and V2 may be different from each other or may be the same. A variable resistor may be connected in series to the determination resistor R1 for the adjustment of a current value. The constant voltage from the power supply circuit 151 may be directly input into the positive terminal (+) of the operational amplifier OP1 without dividing the constant voltage V1.

(100) The first output circuit 153 illustrated in FIG. 14 is a circuit detecting a voltage (heater voltage) of a collector end (a end of FIG. 13) of the transistor TR1. For the first output circuit 153, a voltage follower using an operational amplifier OP2 is used. Specifically, a positive terminal (+) of the operational amplifier OP2 is connected to the a end through a protection resistor R4 and a negative terminal (−) is connected to the output terminal. Therefore, the operational amplifier OP2 outputs a voltage equal to the voltage of the a end.

(101) The output terminal of the operational amplifier OP2 is electrically connected to one of terminals of the external output connectors 115 (FIG. 12) provided on the rear surface side of the body 120. More specifically, the first output circuit 153 outputs a heater voltage to the outside. The voltage follower is used for the first output circuit 153. This is because impedance conversion for external output is performed. The output terminal of the operational amplifier OP2 is grounded through the capacitor C2 for noise rejection or the like.

(102) The second output circuit 154 illustrated in FIG. 15 is a circuit detecting a change of the heater voltage. For the second output circuit 154, a differential amplifier circuit using an operational amplifier OP3 is used. When specifically described, the second output circuit 154 has the operational amplifier OP3, three protection resistors R5, R6 and R7, and a determination resistor R8.

(103) The positive terminal (+) of the operational amplifier OP3 is connected to the a end through the protection resistor R5. A negative terminal (−) of the operational amplifier OP3 is connected to a constant voltage V3 which is one of the output ends of the power supply circuit 151 through the protection resistor R6 and is grounded through the protection resistor R7. The determination resistor R8 is connected between the positive terminal (+) and the negative terminal (−) of the operational amplifier OP3. The operational amplifier OP3 amplifies a difference between the heater voltage and the constant voltage V3 with an amplification degree corresponding to the determination resistor R8, and then outputs the amplified difference. The constant voltage V3 is set to a voltage equal to the heater voltage when the heater 143 is not cooled by the blood flow, for example. More specifically, when the heater 143 is not cooled by the blood flow, the second output circuit 154 outputs 0 V. However, the constant voltage V3 may be set to another voltage value. For example, the constant voltage V3 may be set to the same voltage as the constant voltage V1 or the constant voltage V2. A voltage obtained by dividing an output voltage from the power supply circuit 151 by the voltage dividing resistor may be set as the constant voltage V3.

(104) The second output circuit 154 configured as described above amplifies and outputs a variation from the reference value (V3) in the heater voltage. The variation is equivalent to the flow velocity. More specifically, the second output circuit 154 outputs a voltage corresponding to the flow velocity of blood. When described in detail, the heater voltage is a value corresponding to a current value of the supplied DC current and the flow velocity of blood as described above. The above-described reference value (V3) is equivalent to the current value of the supplied DC current. Therefore, the above-described variation is equivalent to the flow velocity of blood and the second

output circuit **154** outputs a voltage corresponding to the flow velocity of blood.

(105) The output terminal of the operational amplifier OP3 of the second output circuit **154** is electrically connected to one of the external output connectors **115**. More specifically, the second output circuit **154** outputs a voltage equivalent to the flow velocity of blood to the outside (personal computer **112**).

(106) The temperature compensation circuit **155** is an amplifier circuit which amplifies an output voltage of the thermocouple **137**, and then outputs the amplified output voltage to the outside. The temperature compensation circuit **155** converts and amplifies 0°C . to 50°C . to voltages of 0 V to 50 V, and then outputs the converted and amplified voltages. Since a general configuration can be adopted for the temperature compensation circuit **155**, a detailed description is omitted. For example, an amplifier circuit using an operational amplifier is usable as the temperature compensation circuit **155**. In order to accurately match 0°C . to 0 V and match 50°C . to 50 V, a variable resistor for correction may be provided in the temperature compensation circuit **155**. When the temperature compensation of the thermocouple **137** itself is required, a thermocouple compensation circuit may be provided in the temperature compensation circuit **155** or the temperature compensation of the thermocouple **137** itself may be performed from a predetermined formula in the personal computer **112**. The (blood) temperature detected by the thermocouple **137** is used for the correction of the flow velocity.

(107) Next, the leakage current detection circuit **156** detecting a leakage current is described. The leakage current detection circuit **156** has a first detection circuit **161** and a second detection circuit **162** as illustrated in FIG. **16**. The first detection circuit **161** is a circuit detecting a leakage current from the heater **143** into blood. On the other hand, the second detection circuit **162** is a circuit detecting a leakage current from the entire guide wire **130** into blood.

(108) The first detection circuit **161** has a first shunt resistor Rs1, an operational amplifier OP4 amplifying a voltage between both ends of the first shunt resistor Rs1, and a first comparator COM1 comparing an output of the operational amplifier OP4 with the constant voltage V2. One end (a end) of the first shunt resistor Rs1 is connected to the connection point (a end of FIG. **12**) between the heater **143** and the transistor TR1 and the other end is grounded (earthed). Thus, a voltage of a size corresponding to a feedback current from the heater **143** is generated in the first shunt resistor Rs1. The voltage is amplified by the operational amplifier OP4, and then compared with the V2 which is the voltage corresponding to an input current ($V2/R1$) into the heater **143** in the first comparator COM1. More specifically, the input current and the feedback current are compared in the first comparator COM1. A negative terminal (−) of the first comparator COM1 may be connected to a constant voltage other than the constant voltage V2, and the constant voltage may be set as a comparison target.

(109) The first comparator COM1 outputs 0 V until the leakage current from the heater **143** exceeds a threshold value, and then outputs a constant voltage when the leakage current from the heater **143** exceeds a threshold value. The threshold value is determined by the value of resistance of the first shunt resistor Rs1, the amplification degree of the operational amplifier OP4, and the constant voltage V2. Thus, the first detection circuit **161** judges that the leakage current from the heater **143** into blood exceeding a constant value is a leakage current, and then outputs a constant voltage (first detection signal). The first detection signal is output from a c end of FIG. **16**, and then input into the stop circuit **157** described later (FIG. **17**).

(110) The first detection signal changes a voltage of an output end (OUT) of the first detection circuit **161**. When specifically described, the output terminal of the first comparator COM1 is connected to a base of the transistor TR2 as a switching element. An emitter of the transistor TR2 is grounded. A collector of the transistor TR2 is connected to a constant voltage V4. The collector of the transistor TR2 is electrically connected to one of the external output connectors **115**. The transistor TR2 is turned on or off depending on whether the first comparator COM1 outputs the first detection signal. As a result, an output voltage to the external output connector **115** is the

constant voltage V4 or 0 V. The constant voltage V4 may be the same voltage as or may be different from V1, V2, and V3. Between the collector and the emitter of the transistor TR2, a diode D1 for prevention of backflow is connected.

(111) The second detection circuit 54 has a second shunt resistor Rs2, an operational amplifier OP5 amplifying and outputting a voltage between both ends of the second shunt resistor Rs2, and a second comparator COM2 comparing an output of the operational amplifier OP5 with the constant voltage V2.

(112) One end of the second shunt resistor Rs2 is connected to the above-described detection electrode 144 and the other end is grounded (earthed). Therefore, a voltage corresponding to a leakage current from the entire guide wire 130 into blood is generated in the second shunt resistor Rs2. The voltage is amplified by the operational amplifier OP5, and then compared with the constant voltage V2 in the second comparator COM2. A negative terminal (−) of the second comparator COM2 may be connected to a constant voltage other than the constant voltage V2, and the constant voltage may be set as a comparison target.

(113) The second comparator COM2 outputs 0 V until the leakage current exceeds a threshold value, and then outputs a constant voltage when the leakage current exceeds a threshold value. The threshold value is determined by the value of resistance of the second shunt resistor Rs2, the amplification degree of an operational amplifier OP6, and the constant voltage V2. Thus, the second detection circuit 162 judges that the leakage current from the entire guide wire 130 into blood exceeding a constant value is a leakage current, and then outputs a constant voltage (second detection signal). The second detection signal is output from a d end of FIG. 16, and then input into the stop circuit 157 described below (FIG. 17).

(114) The second detection signal changes a voltage of an output end (OUT) of the second detection circuit 162. When specifically described, the output terminal of the second comparator COM2 is connected to a base of a transistor TR3 as a switching element. An emitter of the transistor TR3 is grounded. A collector of the transistor TR3 is connected to the constant voltage V4. The collector of the transistor TR3 is electrically connected to one of the external output connectors 115. The transistor TR3 is turned on or off depending on whether the second comparator COM2 outputs the above-described second detection signal. As a result, an output voltage to the external output connector 115 is the constant voltage V4 or 0 V. The constant voltage V4 may be the same voltage as or may be different from V1, V2, and V3. Between the collector and the emitter of the transistor TR2, a diode D2 for prevention of backflow is connected.

(115) The above-described detection signals (first detection signal and second detection signal) output by the leakage current detection circuit 156 are input into the stop circuit 157 illustrated in FIG. 17 through the function switch 123. The stop circuit 157 stops the drive of the drive circuit 152 when a detection signal is input. When described in detail, the stop circuit 157 has a transistor TR4 which is a switching element, a signal maintaining capacitor C3, and a discharge resistor R9. A gate of the transistor TR4 is connected to the c end of the first detection circuit 161 and the d end of the second detection circuit 162 through the function switch 123. The transistor TR4 is turned on by a detection signal output by the first detection circuit 161 or the second detection circuit 162. More specifically, the transistor TR4 is turned on when either the first detection circuit 161 or the second detection circuit 162 detects a leakage current when the function switch 123 is turned on.

(116) A collector (b end) of the transistor TR4 is connected to a b end (FIG. 13) of the drive circuit 152. On the other hand, an emitter of the transistor TR4 is grounded. Therefore, when the leakage current detection circuit 156 detects a leakage current, so that the transistor TR4 is turned on, the positive terminal (+) of the operational amplifier OP1 of the drive circuit 152 is grounded. More specifically, the current supply to the heater 143 is stopped.

(117) One end of the signal maintaining capacitor C3 is connected to the gate of the transistor TR4 and the other end is grounded. Therefore, when the leakage current detection circuit 156 detects a leakage current, the signal maintaining capacitor C3 is charged by a detection signal. On the other

hand, the discharge resistor R9 is connected in parallel to the signal maintaining capacitor C3. Charges stored in the signal maintaining capacitor C3 are discharged through the discharge resistor R9.

(118) When charged by the detection signal from the leakage current detection circuit 156, the signal maintaining capacitor C3 maintains the ON operation of the transistor TR3 during a certain period of time, even after the leakage current detection circuit 156 has stopped outputting a detection signal. More specifically, even after the detection signal is stopped, the stop of the current supply to the heater 143 is maintained during a certain period of time. The certain period of time is determined based on the capacity of the signal maintaining capacitor C3 and the value of resistance of the discharge resistor R9. To the stop circuit 157, circuit protection diodes D3 and D4 are connected.

(119) Next, the use of the measurement device 100 is described with reference to FIG. 9 and FIG. 12. First, the guide wire 130 is inserted into a human blood vessel. When the tip of the guide wire 130 reaches a measurement portion (for example, coronary artery), the power supply switch 121 and the function switch 123 of the body 120 are turned on, so that the sensor 133 is driven. More specifically, a constant current is supplied to the heater 143 from the drive circuit 152. In that case, the first output circuit 153 outputs a heater voltage, the second output circuit 154 outputs a voltage corresponding to the flow velocity of blood, and the temperature compensation circuit 155 amplifies and converts an output of the thermocouple 137, and then outputs the amplified and converted output. The leakage current detection circuit 156 monitors the presence or absence of a leakage current. Specifically, the first detection circuit 161 monitors a leakage current from the heater 143 into blood and the second detection circuit 162 monitors a leakage current from the guide wire 130 into blood. Before the guide wire 130 is inserted into a human blood vessel, the power supply switch 121 and the function switch 123 may be turned on.

(120) The heater voltage detected by the first output circuit 153, the voltage (flow velocity voltage) output by the second output circuit 154, and the signal voltage output when the leakage current detection circuit 156 detects a leakage current are output from the external output connectors 115, and then input into the personal computer 112 through the cable 113. In the personal computer 112, the flow velocity is calculated from the flow velocity voltage by installed analysis software. The “calculation” includes the calculation by a formula (stored in the analysis software beforehand) and the determination of the flow velocity using a flow velocity determination table (stored in the analysis software beforehand) indicating the correspondence relationship between the flow velocity voltage and the flow velocity.

(121) The calculated flow velocity is corrected by an input voltage input from the temperature compensation circuit 155. For example, a correction value is calculated by the formula input beforehand or a correction value is determined using the conversion table indicating the correspondence relationship between the input voltage and the correction value. The flow velocity is corrected by the determined correction value.

(122) The corrected flow velocity and the above-described heater voltage are displayed on a monitor. When the leakage current detection circuit 156 detects a leakage current, the supply of the constant current to the heater 143 is stopped, and then a signal voltage transmitting the detection of the leakage current is input into the personal computer 112, so that the detection of the leakage current is displayed on a monitor or an alarm is issued. In the personal computer 112, the pressure of blood may be calculated from the calculated flow velocity, and then the calculated pressure may be displayed on a monitor.

Operational Effects of Third Embodiment

(123) The measurement device 100 according to the third embodiment can detect that a constant leakage current is generated by the leakage current detection circuit 156. The detection of the leakage current can be output to the outside, and then displayed on a monitor or an alarm can be issued.

(124) Since the function switch **123** is provided, a drive stop function of the sensor **133** by the stop circuit **37** can be turned off when it is not appropriate to stop the drive of the sensor **133** or the drive of the sensor **133** needs to resume.

(125) Since the thermocouple **137** and the temperature compensation circuit **155** are provided, the temperature of the calculated flow velocity can be corrected.

(126) Since the detection circuits of both the first detection circuit **161** and the second detection circuit **162** are provided in the leakage current detection circuit **156**, both the leakage current from the heater **143** and the leakage current from the entire guide wire **130** can be separately detected.

(127) Since the stop circuit **157** is provided, the current supply to the heater **143** is immediately stopped when a leakage current is detected. Moreover, since the signal maintaining capacitor **C3** is provided, the current supply to the heater **143** is prevented from being frequently turned on/off (chattering).

Modification of Third Embodiment

(128) The third embodiment describes the example in which the leakage current detection circuit **156** has the first detection circuit **161** and the second detection circuit **162**. However, the leakage current detection circuit **156** may have only the first detection circuit **161** or only the second detection circuit **162**.

(129) The third embodiment describes the configuration in which the signal voltage from the first detection circuit **161** and the signal voltage from the second detection circuit **162** are individually input into the personal computer **112**. However, only the signal voltage from the first detection circuit **161** or only the signal voltage from the second detection circuit **162** may be input into the personal computer **112**. A configuration may be adopted in which, when an output end of the first detection circuit **161** and an output end of the second detection circuit **162** are connected, so that at least either one of the first detection circuit **161** and the second detection circuit **162** detects a leakage current, a signal voltage transmitting the detection of the leakage current is input into the personal computer **112**.

(130) The third embodiment describes the configuration in which the flow velocity is corrected and calculated with the personal computer **112**. However, the calculation and the correction of the flow velocity may be performed in the control circuit **150**. For example, the flow velocity may be corrected and calculated by converting an output of the thermocouple **137** into a suitable voltage using an amplifier circuit, and then inputting the converted voltage and the heater voltage into a differential amplifier circuit. Thus, a voltage equivalent to the corrected and calculated flow velocity is output to the personal computer **112** through the external output connectors **115**.

(131) The third embodiment describes the example in which the thermocouple **137** is provided in the guide wire **130**. However, a reference heater may be provided in place of the thermocouple **137**. For the reference heater, one having the same configuration as that of the heater **143** is used. The reference heater is provided at the tip of the guide wire **130** as with the heater **143**. However, the reference heater is provided so as not to be exposed to blood. Therefore, the voltage of the reference heater is a value not dependent on the flow velocity of blood and dependent on the temperature of blood. The voltage of the reference heater is output to the outside from the temperature compensation circuit **155**. The personal computer **112** determines a correction value by the voltage of the reference heater, and then corrects the flow velocity. The reference heater is equivalent to the detection body for use in the temperature compensation as with the thermocouple **137**. The calculation and the correction of the flow velocity can also be performed not with the personal computer **112** but with the control circuit **150**. For example, a differential amplifier circuit which amplifies and outputs a difference between the voltage of the heater **143** and the voltage of the reference heater is provided in the control circuit.

(132) The third embodiment describes the configuration in which the flow velocity is corrected by the thermocouple **137**. However, a configuration in which the thermocouple **137** is not provided can also be adopted. For example, supposing that the temperature of blood is a predetermined

value, the flow velocity may be corrected by a correction value corresponding to the predetermined value. Alternatively, the body temperature of a patient is measured before an operation, and then the flow velocity may be corrected by a correction value corresponding to the measured body temperature.

(133) The third embodiment describes the example using the constant current circuit using negative feedback of the operational amplifier as the drive circuit **152**. However, other constant current circuits may be used.

(134) The third embodiment describes the example in which, when a leakage current is detected, the drive of the sensor **133** is stopped during a certain period of time by the signal maintaining capacitor **C3**. However, another configuration, e.g., a configuration in which, when a leakage current is detected once, the drive of the sensor **133** is continuously stopped unless manually reset, may be adopted. For example, an electromagnetic relay or the like which can be manually reset may be provided in place of the transistor **TR4** in the stop circuit **157**.

(135) The third embodiment describes the configuration in which, when a leakage current is detected, the supply of a constant current from the drive circuit **152** to the heater **143** is stopped. However, when a leakage current is detected, the power supply switch **121** itself may be turned off.

(136) The third embodiment describes the configuration in which the flow velocity is calculated or displayed utilizing the personal computer **112**. However, a configuration not using the personal computer **112** is also acceptable. For example, a microcomputer replacing the analysis software is provided in the control circuit **150**, a liquid crystal display unit replacing the monitor is provided in the body **120**, and a display driver IC and the like are further provided in the control circuit **150**. When the configuration is adopted, it is not necessary to connect the personal computer **112** to the body **120**, and the heater voltage, the flow velocity, the presence or absence of leakage current detection, and the like are displayed on the liquid crystal display unit in the body **120**.

(137) It is a matter of course that the control circuit **150** of the present invention is usable for flow velocity meters other than the sensor **133**, blood pressure sensors, such as the measurement element **27**, and the like.

Other Modifications

(138) The measurement of the pressure and the flow velocity of blood may be always performed or may be intermittently performed. Specifically, the drive circuit **152** may always output a constant current or may intermittently output a constant current. For example, a switching element is provided in an output end of the drive circuit **152**, and then a drive signal of a constant frequency is input into the switching element to turn on/off the switching element. As a result, the drive circuit **152** intermittently outputs a constant current. In addition, an intermittent output of a constant current can be performed using existing techniques.

(139) Due to the fact that the measurement of the pressure and the flow velocity of blood is intermittently performed, the measurement accuracy is improved. When specifically described, when a leakage current is generated, the voltage level of a reference voltage may shift. The reference voltage is the ground or a generated constant voltage. When the voltage level shifts, the detection accuracy decreases. Due to the fact that a constant current is intermittently output, the shift of the voltage level of the reference voltage is suppressed. As a result, the measurement accuracy is improved.

(140) It is desirable that, when a constant current is intermittently output, a duty ratio which is a ratio of a period in which a constant current is output to a period in which a constant current is not output is made variable. For a technique of varying the duty ratio, existing techniques are usable. It is desirable that the change of the duty ratio can be performed from the outside with a potentiometer (digital variable resistor) or the like. For example, when the amount of a leakage current is large, the duty ratio is decreased. When the amount of a leakage current is small, the duty ratio is increased.

REFERENCE SIGNS LIST

(141) 10, 60 Shaft 11, 61 Shaft body portion 12 Connection portion 14, 32A Slit (Passage) 15 Cover member 20 Tip guide portion 21 First coil body 22 Element holding body 23 Second coil body 24 Tip member 25 Signal wire 26 Core material 27 Measurement element 30 Connection member (Connection portion) 31 Connection body portion 32 Support portion 50 Blood measurement device 110 Measurement device 123 Function switch 132 Shaft (Long member) 133 Sensor 137 Thermocouple (Detection body) 150 Control circuit 152 Drive circuit (Constant current circuit) 155 Temperature compensation circuit 156 Leakage current detection circuit 157 Stop circuit 161 First detection circuit 162 Second detection circuit Rs1 First shunt resistor Rs2 Second shunt resistor COM1 First comparator COM2 Second comparator C3 Signal maintaining capacitor R9 Discharge resistor

Claims

1. A control circuit for a sensor provided in an elongated member insertable into a lumen to measure a physical quantity of a fluid in the lumen, the control circuit comprising: a drive circuit configured for supplying a drive current to the sensor, a leakage current detection circuit, and a stop circuit; wherein the leakage current detection circuit includes: a shunt resistor configured for converting, into a voltage, one of either a feedback current from the or a leakage current, and a comparator configured to receive a detection voltage corresponding to the voltage from the shunt resistor and a constant voltage, the comparator configured to output a detection signal in a first state when the detection voltage is larger than the constant voltage; wherein the stop circuit is configured for stopping supply of the drive current to the in response to the detection signal output from the comparator; wherein the drive circuit comprises a first operational amplifier and has a drive-circuit first input and a drive-circuit second input coupled to a common input of the first operational amplifier; wherein the drive-circuit first input is a constant-voltage first signal; and wherein the stop circuit is configured to provide the drive-circuit second input to the drive circuit, wherein the drive-circuit second input has a ground state when the detection signal is in the first state.

2. The control circuit according to claim 1, wherein the leakage current detection circuit includes either one or both of a first detection circuit and a second detection circuit, and the leakage current is either one or both of a first leakage current and a second leakage wherein the shunt resistor configured for converting into the voltage includes either one or both of a first shunt resistor configured for converting into a first voltage and a second shunt resistor configured for converting into a second voltage; wherein the comparator configured to receive the detection voltage and output the detection signal includes either one or both of a first comparator configured to receive a first detection voltage and output a first detection signal, and a second comparator configured to receive a second detection voltage and output a second detection signal; wherein the first detection circuit comprises the first shunt resistor and the first comparator, and the second detection circuit comprises the second shunt resistor and the second comparator; wherein the first shunt resistor configured for converting into the first voltage converts the feedback current into the first voltage, wherein the feedback current corresponds to a difference between a predetermined current and the first leakage current, the predetermined current corresponding to one of either the drive current of the or a constant current, and the first comparator is configured to receive the first detection voltage corresponding to the first voltage from the first shunt resistor and the constant voltage, wherein the second shunt resistor configured for converting into the second voltage converts the second leakage current into the second voltage, wherein the second leakage current flows between the fluid and a ground, and the second comparator is configured to receive the second detection voltage corresponding to the second voltage from the second shunt resistor and the constant voltage, and wherein the stop circuit is configured for stopping supply of the drive current to the sensor in response to at least one of the first detection signal output from the first detection circuit and the

second detection signal output from the second detection circuit.

3. The control circuit according to claim 2, wherein the stop circuit includes: a switching element configured for turning on and off supply of the drive current to the sensor in response to either one or both of the first detection signal and the second detection signal; and a signal maintaining capacitor configured for being charged by either one or both of the first detection signal and the second detection signal and maintaining the switching element in a conduction state.

4. The control circuit according to claim 1, further comprising: a function switch configured for turning on or off an input of the detection signal from the leakage current detection circuit to the stop circuit.

5. The control circuit according to claim 1, further comprising: a temperature compensation circuit configured for receiving an input from a detection body provided in the sensor.

6. A measurement device comprising: the control circuit according to claim 1; and the sensor.

7. The measurement device according to claim 6, wherein the sensor is a hot wire flow velocity meter.
