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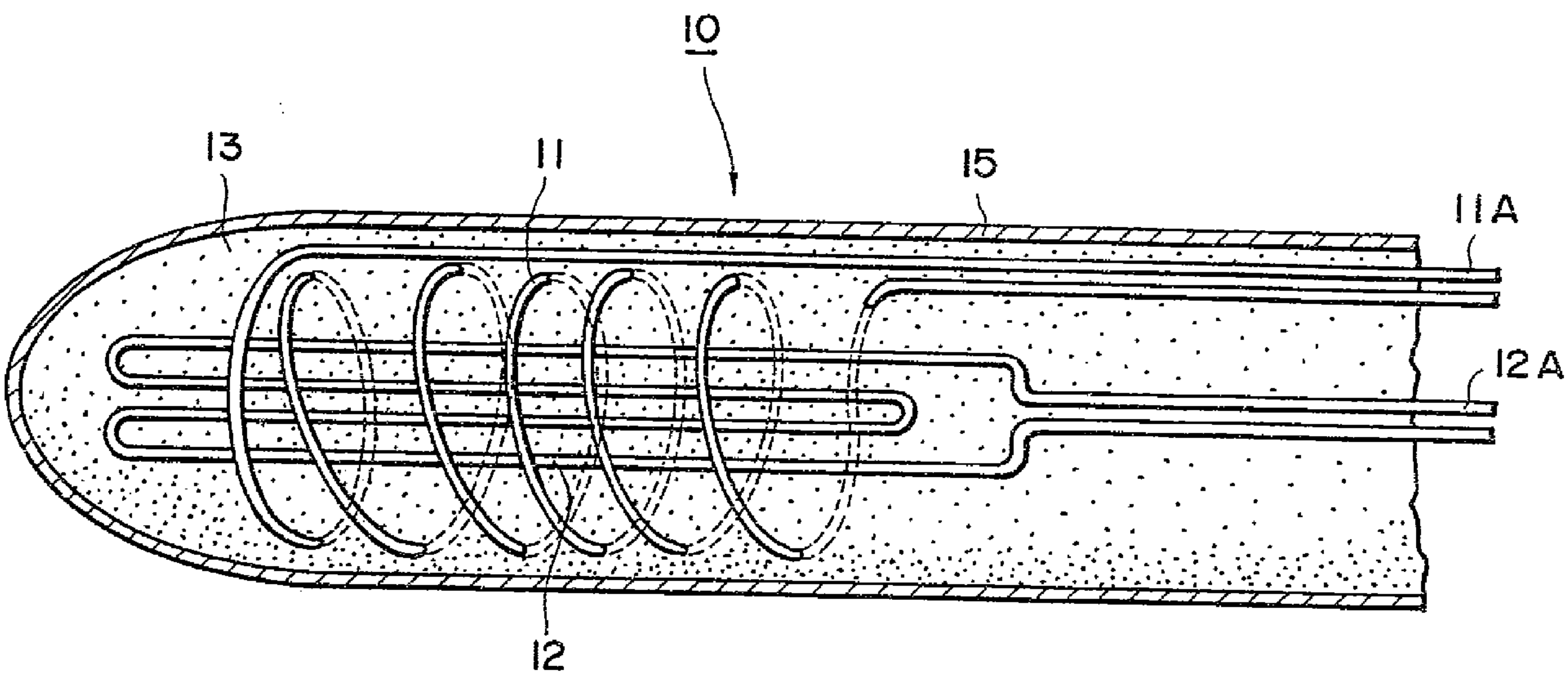
(54) **CAPTEUR DE MESURE POUR LA DETERMINATION DE L'ETAT D'UN FLUIDE ET METHODE DE MESURE CONNEXE**

(54) **MEASURING SENSOR FOR FLUID STATE DETERMINATION AND METHOD FOR MEASUREMENT USING SUCH SENSOR**



(57) A measuring sensor comprising a heating element and a temperature detecting element used to measure a temperature of the heating element are both held out of contact with each other (preferably by an electrically insulative but thermally good conductive material) within a protective tube. For fluid exhibiting slow changes in its state with passage of time, the fluid state is measured utilizing said sensor on the basis of a differential between temperatures prior to and during heating of the heating element. For fluid exhibiting rapid changes in its state with passage of time, the measuring sensor and a separate temperature detecting sensor are used to measure a temperature of the fluid. The measuring sensor is caused to generate heat and the temperature of this sensor is measured, and the fluid state is measured on the basis of a differential between the temperatures of said first-mentioned sensor and the fluid.

ABSTRACT OF THE DISCLOSURE

A measuring sensor comprising a heating element and a temperature detecting element used to measure a temperature of the heating element are both held out of contact with each other (preferably by an electrically insulative but thermally good conductive material) within a protective tube. For fluid exhibiting slow changes in its state with passage of time, the fluid state is measured utilizing said sensor on the basis of a differential between temperatures prior to and during heating of the heating element. For fluid exhibiting rapid changes in its state with passage of time, the measuring sensor and a separate temperature detecting sensor are used to measure a temperature of the fluid. The measuring sensor is caused to generate heat and the temperature of this sensor is measured, and the fluid state is measured on the basis of a differential between the temperatures of said first-mentioned sensor and the fluid.

This invention relates to a measuring sensor for fluid state determination and a method of measurement using such a sensor. The invention is applicable especially to measurement of temperature to evaluate viscosity or other physical properties of a given fluid as well as to such measurement conducted to localize a fluid level.

It should be understood that the term "fluid" as used herein includes a substance in the form of a gas, liquid, or solids or mixtures of two or more thereof and the term "state" used herein includes not only the stationary or flowing state of a given fluid but also a state of this fluid in which the composition, phase or temperature thereof is steady or variable with the passage of time.

Various methods for measuring the state of a given fluid have already been proposed and the inventors also have disclosed methods for measuring fluid state using metallic thin wire by a hot wire method, for example, in Japanese Patent Application Disclosure Gazettes Nos. 1985-152943; 1987-27622; 1987-40246; and 1987-56849. According to this prior art, changes in physicals properties or the like occurring in given fluids are thermally measured on the basis of the change in temperature with the passage of time occurring when the metallic thin wire placed within the fluid is energized with electric current and thereby the state of the fluid is determined.

Of the sensors used in such measurement, the sensor disclosed in Japanese Patent Application Disclosure Gazette No. 1987-56846 (U.S.P. No. 4,762,427) comprises metallic thin wire wound around a support shaft coated with electrical insulator, the assembly including the wire then being coated with electrical insulator.

The method disclosed in Japanese Patent Application Disclosure Gazette No. 1987-185146 employs, in addition to the measuring sensor exclusively used to measure fluid temperature, such an electrical heating sensor so that the state of this fluid may be determined more accurately on the basis of a differential temperature given by these two sensors.

Usually, a means such as a resistance thermometer bulb, thermistor, thermocouple or radiation thermometer have been utilized as a temperature detecting means for fluid measurement.

The sensor used in the prior art measuring methods and which has been proposed by the inventors comprises, as mentioned above, the metallic thin wire wound on the support shaft and is certainly advantageous in that a length of said metallic thin wire may be dimensioned to be several times the sensor's own length and thereby the electric resistance thereof may be increased so as to obtain a high heating value from a small current value. Such a sensor is advantageous also in that the sensor itself cannot be easily damaged or bent.

However, such prior art device is disadvantageous in that the metallic thin wire is spirally bent, which develops therein a stress strain as said metallic thin wire is wound on the shaft. An annealing process is applied to relieve such stress strain, but this significantly changes the resistance of the wire relative to its initial value.

Since it is difficult to estimate the degree of this change in the resistance value, it is also difficult to obtain a sensor having a desired predetermined resistance value. Even when the sensors are mass-produced, there is no compatibility between sensors unless the sensors are individually calibrated. The characteristic calibration of individual sensors has been disclosed by the inventors in Japanese Patent Application Disclosure Gazette No. 1987-51520 (U.S.P. No. 4,832,504). However, such characteristic calibration of individual sensors is a time-consuming operation.

To minimize bending of the metallic thin wire, the inventors have proposed an improved sensor in Japanese Patent Application Disclosure Gazette No. 1989-44838, in accordance with which the metallic thin wire is rectilinearly arranged in the longitudinal direction and bent only at opposite ends so that stress strain developed in the wire may be substantially reduced. However, this invention requires not only a sophisticated technique for manufacturing the sensor but also a high precision analyzer such as a computer for high precision measurement.

Accordingly, a principal object of the invention is to measure the state of a given fluid with a precision which is slightly lower than the precision expected to be achieved by using the electrical heating type sensor of the prior art but which is practically acceptable and utilizes a relatively simple manufacturing technique, e.g., a conventional digital thermometric mechanism.

The object as set forth above is achieved, according to the invention, by a measuring sensor comprising a sensor protecting tube, a heating element and a temperature detecting element, the temperature detecting element adapted to measure the temperature of said heating element, and both elements being contained within said protective tube so that said temperature detecting element is maintained out of contact with said heating element.

Thermally good conductive but electrically insulative material is preferably interposed between the heating element and the temperature detecting element to keep these elements out of contact with each other.

As described above, the measuring sensor of the invention comprises separate temperature detecting and heating elements which are held out of contact with one another, preferably by the electrical insulator having a good thermal conductivity so the heating element is not always required to be provided in a spiral configuration and therefore can be obtained by a relatively simple manufacturing technique. Additionally, the durability of the measuring sensor as a whole is enhanced by the feature of the invention that the temperature detecting element and the heating element can be contained within the protective tube. Furthermore, the measuring sensor of the invention has a sufficiently rapid responsiveness to achieve the desired measurement when the measuring sensor is used for fluid state measurement not requiring a high level of precision, since the temperature of the heating element is measured by the temperature detecting element. The temperature detecting element may be replaced by any suitable commercially available thermometric device. Moreover, the measuring sensor of the invention can be constructed in a compact form which is convenient for handling.

The measuring sensor of the invention is useful not only as a fluid state measuring means but also as a universal temperature sensor. For a fluid, such as a sampled fluid, exhibiting no change in its state with the passage of time, the invention enables a single measuring sensor to determine a differential temperature.

The invention also provides a method for measurement of fluid state on the basis of a differential temperature before and during heating of the heating element, utilizing said sensor.

The invention further provides a method for measurement of fluid state on the basis of a differential value between two temperature values determined by said sensor and another general temperature sensing device, both placed in the fluid during heating of said sensor.

With the method of the invention as mentioned above, if the fluid state exhibits no change with passage of time, said single measuring sensor comprising the heating element and the temperature detecting element adapted to measure the temperature of said heating element may be used. The fluid state is measured on the basis of the differential temperature between the temperature obtained by said temperature detecting element before heating of said heating element (such being the temperature of the fluid) and the temperature obtained by said temperature detecting element during heating of said heating element (such being the temperature of the sensor).

For a fluid state exhibiting a change with passage of time on the other hand, a general temperature sensing device such as a resistance thermometer bulb may be used with the sensor of the invention to measure such fluid state.

The electrical heating type sensor previously proposed by the inventors has been very useful in the chemical and pharmaceutical industries and the like, in which a high level of precision is required. However, such a degree of precision as is required to measure slight changes in the state of a fluid by the electrical heating sensor of the prior art is usually unnecessary for fluid state measurement or the like in storage equipment for raw materials or during primary processing - for example, during the raw material storage or any process prior to the actual manufacturing process for foods in general wherein the fluid exhibits rapid changes of state. It should be understood, however, that even in such an industry, careful consideration must be given to obtaining a measurement which is free from any error possibly caused by various measurement conditions such as the measurement speed.

The present invention was made in view of these requirements and utilizes the principle that a differential value between the fluid temperature and the sensor temperature may be measured to determine the fluid state. According to the invention, however, there is provided a relatively simplified structure comprising the heating element and the temperature detecting element used to measure the temperature of such heating element, so that the desired measurement can be achieved by use of the single sensor (except when a pair of sensors is used for a fluid exhibiting a change in its state with passage of time) without use of any high level analyzer.

In other words, while the inventors have formerly disclosed a sensor which not only generates heat, but also measures its own temperature, the sensor of the present invention is provided with a heating element which only generates heat and, separate therefrom, a temperature detecting element solely for measurement. This makes it easier to control the heat generated by the heating element and no computing equipment and surrounding equipment to calculate the temperature and the like is required. Accordingly, the measurement is managed by a simple controller, and in consequence, the device itself can be portable.

With the conventional electrical heating-type sensor requiring a pair of sensors, i.e. the heating element and the temperature sensor, it has been essential to prevent these two sensors from being affected by one another and to ensure a sufficient amount of sample to allow use of the apparatus comprising the two sensors for effective measurement of the sampled fluid or the like.

For example, the sensor disclosed by the inventors in Japanese Patent Application Disclosure Gazette No. 1987-185146 is adapted to measure a fluid state by the electrical heating method utilizing a metallic thin wire - namely, by comparatively measuring the sensor temperature, the fluid temperature and the differential temperature therebetween. The disclosed method uses more than two measuring elements respectively for measurement of the heating element temperature and the fluid temperature.

In contrast with this method, the sensor of the present invention is adapted to measure the fluid temperature and the sensor temperature by measuring the temperatures of the heating element before and during heating thereof and thereby determining the comprehensive state of the fluid.

In this way, the sensor of the invention is able to measure the fluid state by use of a single sensor and is particularly useful for fluids exhibiting not rapid but slow change of state with the passage of time.

The sensor of the invention thus requires no consideration be given to such countermeasures as preventing a pair of sensors from being affected by one another, as has been essential with conventional sensors of the electrically heated type.

Although for a fluid exhibiting rapid changes in its state with the passage of time, an additional general temperature detecting sensor must be provided to measure the fluid temperature (as is the case with the prior art), the sensor itself comprising the heating element and the temperature detecting element adapted to measure the temperature of this heating element according to the invention is useful not only in those industrial fields which do not require measurement of slight changes of fluid with high precision but also has no less durability and rapid responsiveness than the high precision measuring sensor.

Of the electrical heating sensors of the prior art, the one disclosed in the previously referred to Japanese Patent Disclosure Gazette No. 1987-56849 (U.S.P. No. 4,762,427) comprises a metallic thin wire wound around a electrically insulative support shaft and then coated, and the one disclosed in the previously referred to Japanese Patent Disclosure Gazette No. 1989-44838 comprises a metallic thin wire inserted into a bore formed through an electrically insulative support shaft and then secured by means of pulverized ceramic or the like. In either case, sophisticated techniques have been necessary to manufacture such sensors. The sensor of the invention, on the contrary, can be inexpensively manufactured by a relatively simple technique, since, according to the invention, the temperature detecting element and the heating element are separately provided and held by the electrically insulative thermal conductor out of contact with each other. Additionally, the sensor of the invention requires none of the high precision analyzers which have been necessary for the measuring methods of the prior art, and can easily perform the desired measurement utilizing conventional digital thermometric equipment.

The invention will now be described further by way of example only and with reference to the accompanying drawings, in which:

Fig. 1 is a sectional view of a measuring sensor constructed in accordance with the invention;

Fig. 2 is a schematic diagram illustrating one method by which the measuring sensor of Fig. 1 is used for measurement;

Fig. 3 is a schematic diagram illustrating a method in which a general temperature detecting sensor is used in combination with the measuring sensor of Fig. 1 to measure a fluid state exhibiting a change with passage of time; and

Figs. 4 and 5 are graphic diagrams showing a process of gelatine solidification as measured by the electrical heating type sensor of the prior art and the measuring sensor of the invention, respectively.

Now a first embodiment of the sensor constructed according to the invention will be described with reference to Fig. 1. The measuring sensor 10 comprises a spiral heating element 11, a serpentine temperature detecting element 12 centrally located inside said heating element 11, a good thermal conductor 13 interposed between said heating element 11 and said temperature detecting element 12, and a protective tube 15 containing the assembly. Reference numerals 11A and 12A designate wire leads of said heating element 11 and temperature detecting element 12, respectively. Referring to Fig. 2, and assuming that the fluid to be monitored exhibits not rapid but slow change in its state as time elapses, the sensor 10 is immersed into a reservoir 17 of the fluid 16, and the heating element 11 is then energized with electric current from a power source 18 and the heat output of the element 11 detected by the temperature detecting element 12 is converted by a temperature converter 19 to provide the corresponding temperature of the sensor. Thus, the temperature of the sensor measured before heating is obtained as a temperature of the fluid and the temperature measured during heating is obtained as a temperature of the sensor itself.

A second embodiment of the sensor according to the invention is described with reference to Fig. 3, which illustrates a situation where the fluid state to be measured exhibits rapid changes with the passage of time. Accordingly, this embodiment of the sensor comprises the sensor 10 and a general temperature detecting sensor 21, both fixed within a fluid passage 20. The heating element 11 of the sensor 10 is energized with electric current from the power source 18 and generates heat and the output of this heating element detected by the temperature detecting element 12 is again converted by the temperature converter 19 to a corresponding temperature which is read as the temperature of the sensor. The temperature of the fluid 16 is measured by the temperature detecting sensor 21 and reference numeral 22 designates a temperature detector.

In this manner, the temperature of the fluid and the sensor may be measured to determine the fluid state on the basis of the differential temperature therebetween.

As the electrically insulative good thermal conductor 13, crystalline alumina, ceramic or the like is preferred and is preferably powdered to facilitate construction of the sensor. However, it should be understood that said conductor 13 may also be formed from solid material.

It is essential here that the conductor 13 should be able to hold the heating element and the temperature detecting element out of electrical contact with each other. Furthermore, the distance between these two elements is preferably as short as possible in order to assure that the temperature detected by the temperature detecting element substantially approximates the actual temperature of the heating element.

The material chosen for the good thermal conductor is not critical, provided it is electrically insulative and high precision of measurement is not critical.

The temperature detecting element may be placed around the heating element, instead of being placed inside it as in the illustrated embodiment, when it is desired to measure a surface temperature of the measuring sensor. Alternatively, the temperature detecting element may be placed in opposition to the heating element, if desired.

Thus, the relative position of the temperature detecting element and the heating element may be selectively changed depending on the most important output value to be considered in relation to the fluid state.

EXAMPLE A

To localize a fluid level utilizing the sensor of the invention, as disclosed by the inventors in Japanese Patent Application Disclosure Gazette No. 1987-27622, the sensor may be designed to have an overall length substantially equal to the height of the reservoir. A temperature corresponding to the metallic thin wire temperature θw of the aforesaid prior art sensor may be considered as the temperature detected by the temperature detecting element of the invention, since the level within the reservoir is linearly related to the sensor temperature.

In other words, the temperature detected by the sensor is linearly variable as the level ascends or descends, in proportion to the length of the sensor which is immersed in the fluid.

Accordingly, the temperature measurement may be continuously performed by the temperature detecting element as the heating element. The component of the sensor constructed according to the invention may be energized for heat generation and the change in level with corresponding change in temperature may be recorded in relation to the respective temperatures so that the level can be derived from the corresponding temperature.

Owing to the unique feature of the invention (differing from the conventional metallic thin wire) that the sensor is placed within the protective tube, the sensor of the invention is able to resist a certain degree of shock possibly occurring, for example, during washing and is useful for a wide range of equipment including large equipment such as general reservoirs.

EXAMPLE B

To determine a fluid state changing with passage of time, particularly a coefficient of kinematic viscosity, utilizing the sensor of the invention as illustrated by Fig. 3, one of a plurality of sensing elements may be used as a general fluid temperature detecting element while the other one may be used as the sensor itself to detect two temperatures. The difference therebetween may be continuously or intermittently measured and compared to determine the fluid state, in accordance with the prior art disclosed by the inventors in Japanese Patent Application Disclosure Gazette No. 1987-185146.

The differential temperature between two temperatures corresponds to the value $\Delta\theta Wi$ indicated in the above-mentioned Disclosure Gazette and is reflective of the coefficient of kinematic viscosity, so that change in $\Delta\theta Wi$ with the passage of time may be plotted graphically to determine the change in the coefficient of kinematic viscosity.

In this example, it is important to determine a change in the coefficient of kinematic viscosity and thereby to know a change in the fluid state including the viscosity change therein, rather than to determine an exact coefficient value of kinematic viscosity. The relationship between the differential temperature which can be determined by the temperature detecting method of the invention and the coefficient of kinematic viscosity is similar to the relationship which was found by the above-mentioned prior art, so the sensor of the invention is useful where the fluid exhibits a significant change in its coefficient of kinematic viscosity.

In this regard, according to the method of the present invention, an experiment to determine solidification of gelatine with the passage of time indicated, as shown by Fig. 5, a result similar to the experimental result (See Fig. 4) conducted according to the measuring method of the above-referenced prior art.

With the sensor of the invention, as has previously been described, it is also possible to derive the differential temperature $\Delta\theta W$ from comparison of a temperature measured by the temperature detecting element prior to heating of the sensor and a temperature measured during heating of the heating element being energized with electric current, without use of any separately provided general temperature detecting element.

In this way, the measurement which has usually been accomplished with a pair of sensors according to the prior art can be achieved in accordance with the invention by use of a single sensor.

While the invention has been particularly shown and described with reference to a preferred embodiment thereof, it will be understood by those skilled in the art that the foregoing and other changes in form and details can be made therein without departing from the spirit and scope of the invention.

CLAIMS

1. A sensor for measuring the state of a fluid, comprising a heating element and a temperature detecting element used to measure a temperature of the heating element both held out of contact with each other within a sensor protecting tube,

wherein the shape of the protecting tube is a substantially elongated bar,

the heating element is disposed substantially along the length of and within the protecting tube for substantially uniformly heating the protecting tube,

the temperature detecting element is disposed within the heating element generally centrally thereof and extending over the length of the heating element, and

the temperature of the heating element is measured as a function of resistance induced in the temperature detecting element by heat from the heating element.

2. A measuring sensor as recited in claim 1, wherein the heating element and the temperature detecting element for measuring the temperature of the heating element are held by an electrically insulative but thermally good conductive material out of contact with each other within the protective tube.

3. A measuring sensor as recited in claim 1, wherein the heating element is spirally shaped.

4. A measuring sensor as recited in claim 1, wherein the temperature detecting element is serpentine.

5. A measuring sensor as recited in claim 2, wherein the electrically insulative but thermally good conductive material is crystalline alumina or ceramic.

6. A method for measurement of a fluid state utilizing the measuring sensor as recited in claim 1, said method comprising the steps of immersing said sensor in the fluid, detecting temperatures prior to and during heating of the heating element, and measuring the fluid state on the basis of a differential of both temperatures.

7. A method for measurement of a fluid state, said method comprising the step of placing in said fluid the measuring sensor as recited in claim 1 and a separate temperature detecting sensor used to measure a temperature of the fluid, causing said measuring sensor to generate heat and detecting the temperature of said measuring sensor, and measuring the fluid state on the basis of a differential between the temperature of said measuring sensor and the fluid temperature.

FIG. 1

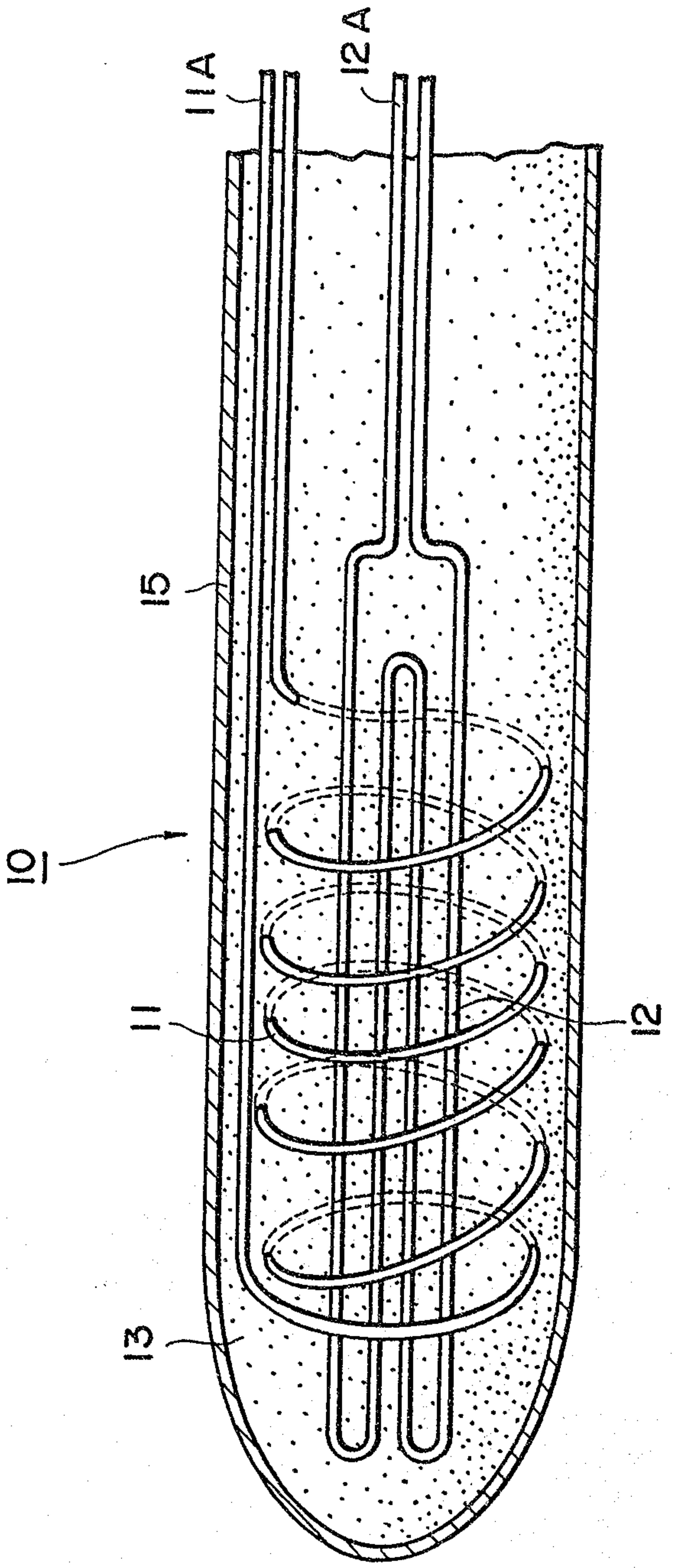


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FIG. 2

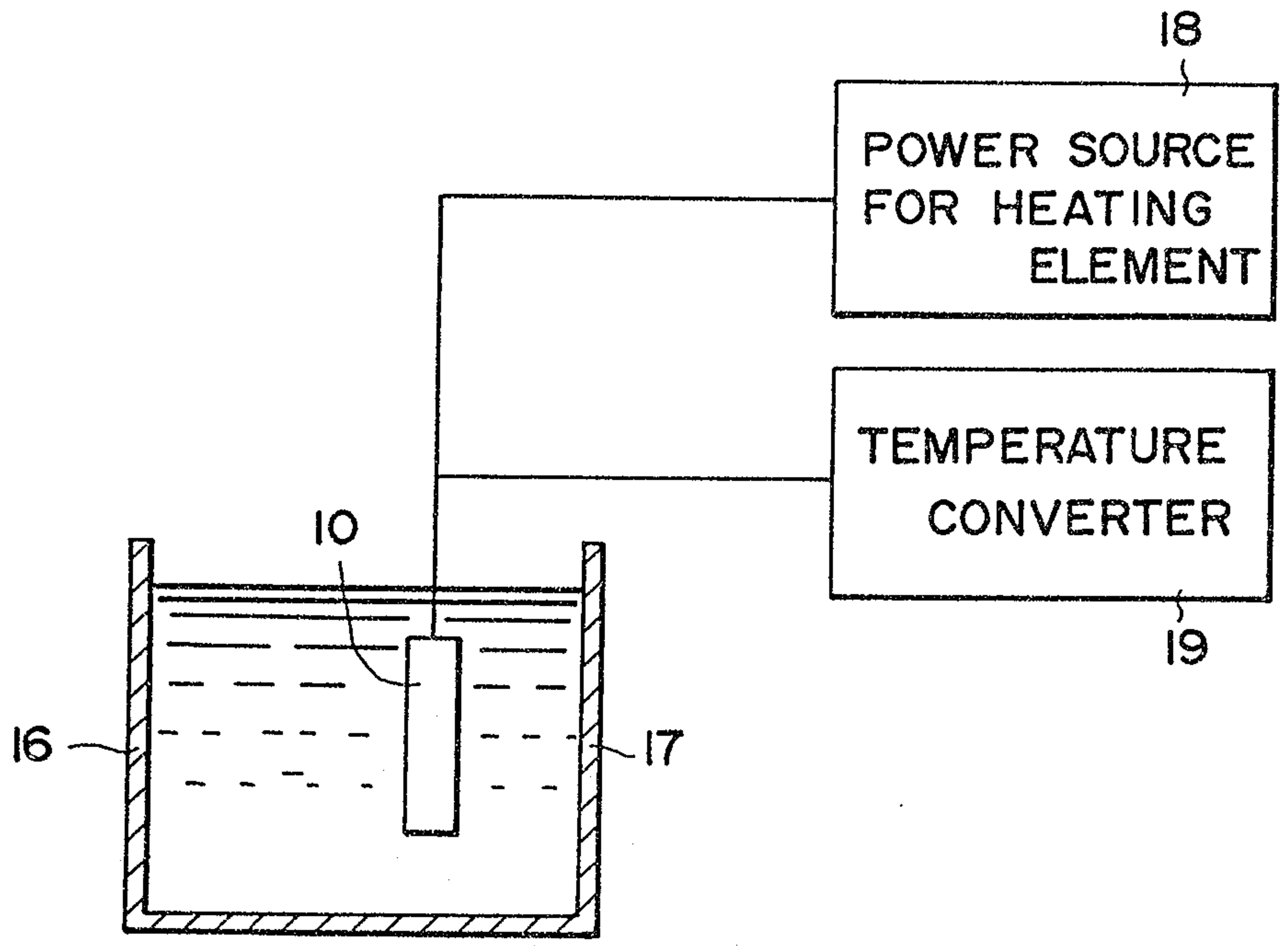

FIG. 3

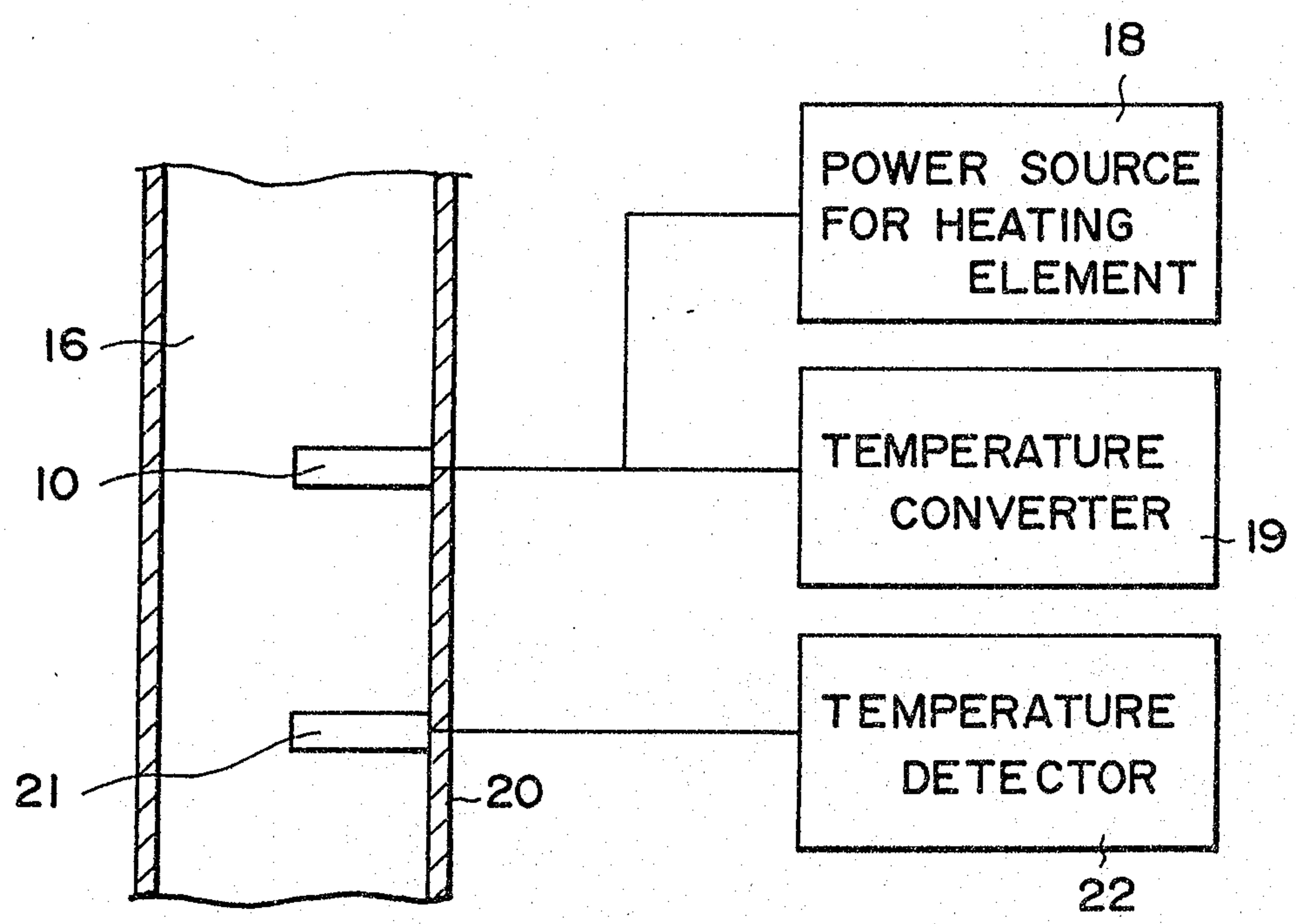

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FIG. 4

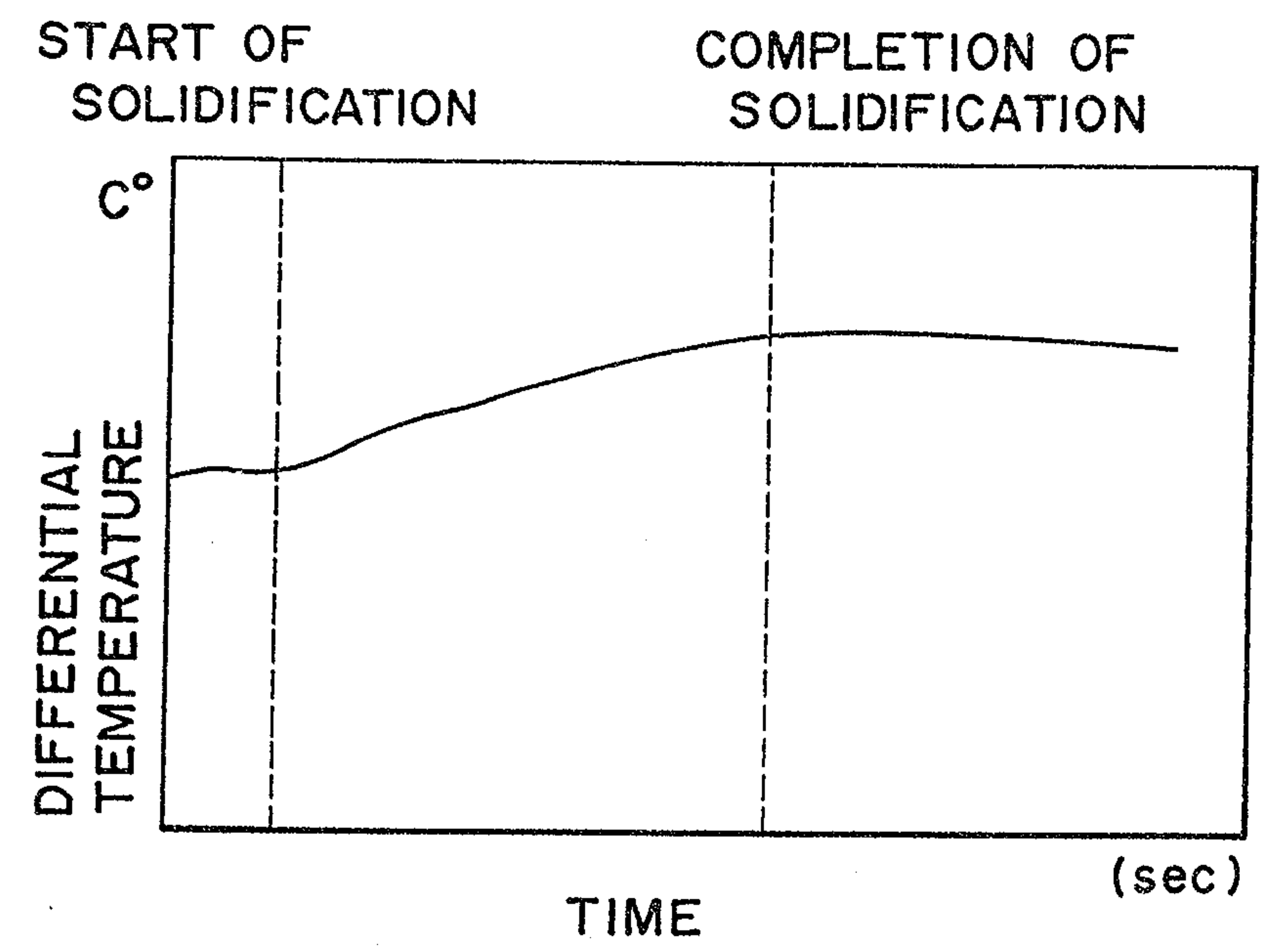
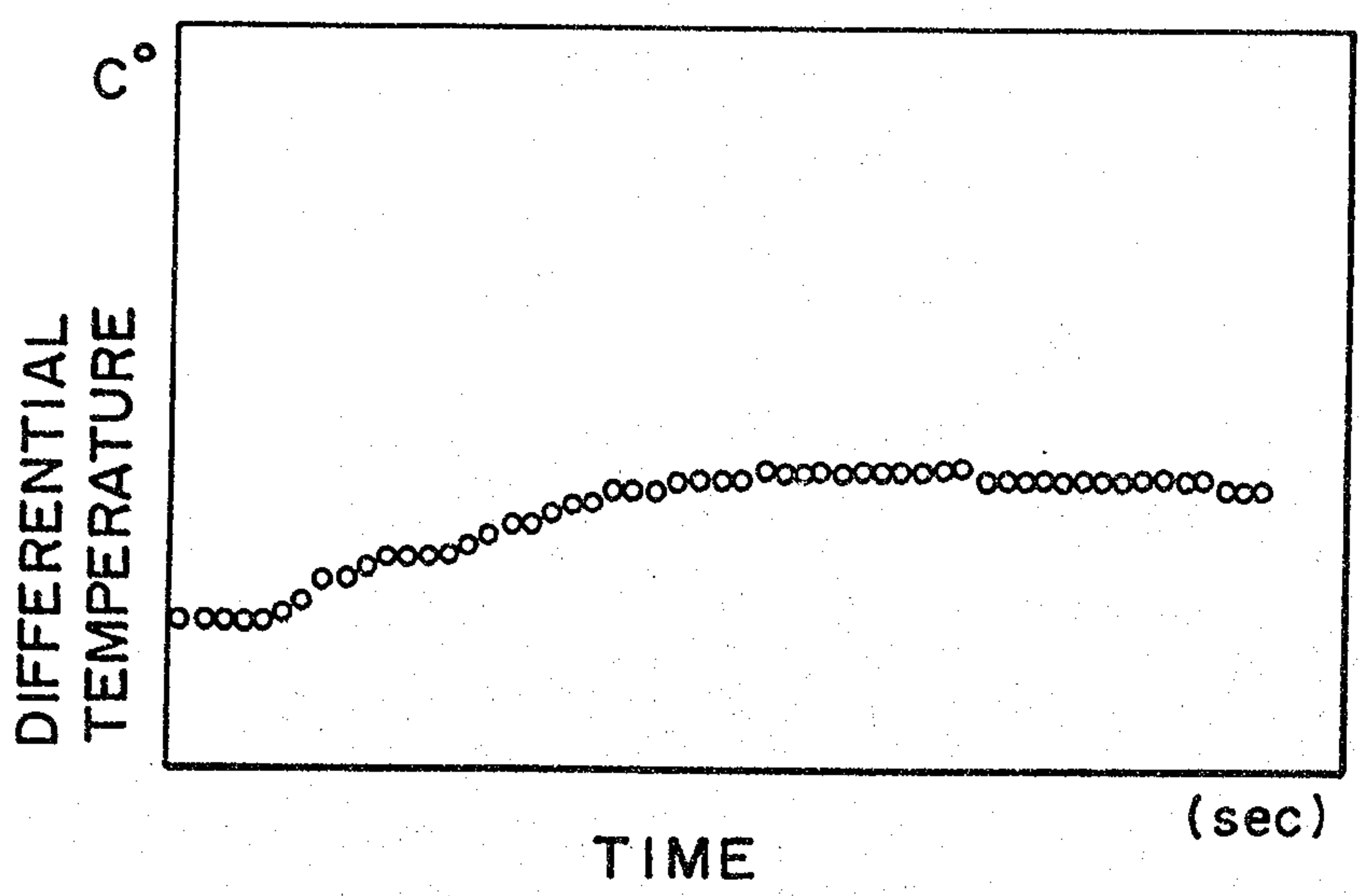


FIG. 5



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