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A TEMPERATURE COMPENSATION METHOD IN PRESSURE SENSORS

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(56) Prior Art Documents
US 5146788
US 4715003
US 4192005

(57) Claim
    1. A method of compensating the temperature in pressure sensors of the kind wherein a pressure is sensed by means of a diaphragm connected in an electric bridge circuit comprising four resistances (2, 3, 4, 5) connected in series in a quadrilateral bridge (1), a so called Wheatstone bridge, said resistances changing their values in response to such alterations in the diaphragm configuration as are caused by changes in the detected pressure, c h a r a c - t e r i z e d by supplying the bridge (1) in two diagonally opposite points (8, 9) with a constant current (i$_k$) and supplying output signals from the bridge (1) to a computer that is unaffected by temperature variations at the place of measurement, first measurement points representing the offset of the pressure sensor at a number of tempera- ture levels being plotted in a first graph indicating the voltage as a function of the resulting resistance (R$_B$) of the bridge (1), thereafter interconnecting neighbouring measurement points by straight lines and effecting calculation through interpolation between the measure- ment points, and by determining the sensitivity of the pressure sensor such as voltage/pressure unit in a corresponding manner at different temperature levels by plotting second measurement points in a second graph indicating the sensitivity as a function of the resulting resistance (R$_B$), and interconnecting the last mentioned measurement points in a similar way by means of straight lines and effecting

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calculation through interpolation between the measurement points, and processing the resulting graphs in the computer, whereupon a signal from the pressure reading provides a directly temperature-compensated pressure value which may be read from a third graph indicative of an output signal that is proportional to the prevailing pressure.
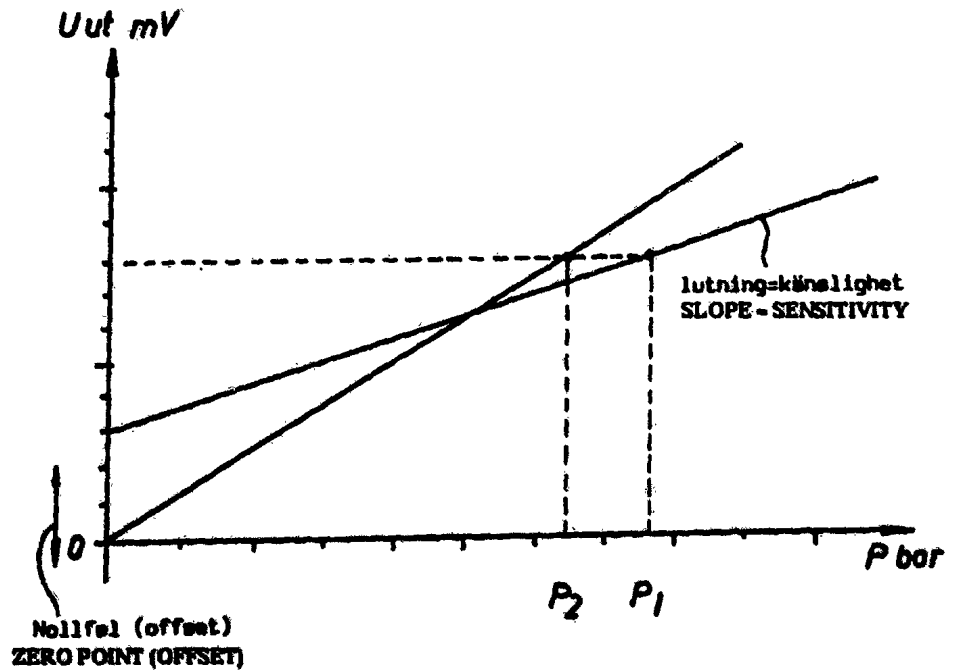
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(54) Title: A TEMPERATURE COMPENSATION METHOD IN PRESSURE SENSORS

(57) Abstract

The invention concerns a method of compensating the temperature in pressure sensors of the kind wherein a pressure is sensed by means of a diaphragm connected in an electric bridge circuit. The latter comprises four resistances (2, 3, 4, 5) connected in series in a quadrilateral bridge (1), a so called Wheatstone bridge. These resistances change their values in response to such alterations in the diaphragm configuration as are caused by changes in the detected pressure. In two diagonally opposite points (8, 9) the bridge is supplied with a constant current (i_k). First measurement points of offset output signals emanating from the bridge (1) in the pressure sensor at a number of temperature levels are plotted in a first graph indicating the voltage as a function of the resulting resistance (R_B) of the bridge (1), whereupon adjacent measurement points are interconnected by straight lines and calculation is effected through interpolation between the measurement points. The sensitivity of the pressure sensor such as voltage/pressure unit, is determined in a corresponding manner at different temperature levels by plotting second measurement points in a second graph indicating the sensitivity as a function of the resulting resistance (R_B). In a similar way the last mentioned measurement points are interconnected by means of straight lines and calculation is effected through interpolation between the measurement points. The resulting curves are processed in a computer, whereupon a signal from the pressure reading provides a directly temperature-compensated pressure value which may be read from a third graph indicative of an output signal that is proportional to the prevailing pressure.

Uut mV

lutning=känslighet
SLOPE = SENSITIVITY

P bar

P_2 P_1

Nollfel (offset)
ZERO POINT (OFFSET)

1

A temperature compensation method in pressure
sensors

The invention concerns a method for compensation of the
temperature in pressure sensors. The pressure sensor is of the kind
designed to convert a detected pressure into an electric signal which
is registered by a measuring device.

5   A prior-art method used for this purpose consist of applying a
number of resistances on a pressure-sensitive diaphragm, which
resistances change their resistance values in response to changes in
the diaphragm configuration when said diaphragm is exposed to
pressure changes. As a rule, the resistances are electrically connected
10   in a bridge circuit, of the kind known as a wheat stone bridge.

All transducers, independently of whether they comprise
resistances manufactured from thin films or thick films on an
insulating material or through ion implantation in silica materials
(known as piezoresistive transducers), suffer from the disadvantage of
15   being extremely temperature dependent. This means that the
transducer output signal which is representative of a pressure at a
certain moment, changes as the temperature changes, also when the
pressure remains constant. This temperature dependency could, in
some cases, be extremely large.

20   When the pressure transducer is used in applications where the
temperature variations are comparatively small it may be calibrated
once the environmental conditions have stabilized somewhat. There-
after, the effects of temperature changes are essentially negligible.

Other prior-art methods of temperature compensation consist of
25   connecting resistances having known temperature charactersistics in
different diagonals of the bridge or of actively compensating the
output signal for temperature influence by means of electronics built
into the transducer. However, in this case also the electronics are
exposed to said temperature variations and consequently these
30   variations need again be considered. As long as the temperature

2

variations remain small it is, however, possible to obtain acceptable
measurement results by any one of the above methods.

In thermal sterilization by means of vapour in an autoclave the
conditions are, on the other hand, very difficult to master because
during one sequence the pressure varies from between approximately
30 mbar absolute pressure and approximately 5 bar absolute
pressure, i.e. a pressure ratio of approximately 1:150. At the same
time, the temperature varies between approximately 20°C and 140° C.
In addition, the changeovers between maximum and minimum values
and vice versa, both respect to pressure and temperature, take place
rapidly and several times over a comparitively short period during one
process.

However, the above-mentioned prior-art stabilizing methods are
quite insufficient in this application to meet the requirements on
accuracy with respect to the precision of the measured values in
sterilization. Particularly in the case of low pressures the percentage
deviations of measured values are quite considerable, often several
hundred percent. At the same time low pressures are an important
measuring range in this connection.

For such an extreme activity as vapour sterilization various
measures therefore have been taken to prevent the effects of tempe-
rature on the pressure sensor. Examples of such measures are
isolation of the pressure sensor from the autoclave enclosure where
the pressure is measured, transfer of the pressure to the sensor by
way of for instance an oil buffer, a water bag or the use of capillary
tubes. Another way is to cool the pressure sensor to prevent that it
follows the temperature increase inside the autoclave enclosure.

However, all these various previously known methods of
preventing a temperature rise in the pressure sensor cause cavities to
form between the autoclave chamber and the sensor. Such cavities
are not desired and normally they are not either accepted by estab-
lished standard specifications, because inside them an environment is
created that favours collection and growth of micro-organisms. In-
stead, a desired end is to be able to position the sensing diaphragm of
the pressure sensor directly in the wall of the autoclave enclosure,
without using any intermediary tubings or pipings.

3

Of course, it is always possible to position a separate temperature sensor on or adjacent the diaphragm for the purpose of measuring the existing temperature during the pressure sensing operation. However, this does not solve the problem since the pressure sensor
5   only provides information on the temperature at its place of mounting on the diaphragm and not on the actual effects to which the pressure-sensitive resistances are exposed.

The subject invention provides a method making it possible to position the diaphragm of the pressure sensor as desired directly in
10   the wall of an autoclave chamber in order to eliminate undesired cavities while at the same time temperature compensation is achieved in all temperature ranges that are relevant in the autoclave process, providing excellent measurement results within the measurement range in question. The type of pressure sensor that may be considered
15   in this connection is one which detects a pressure by means of a diaphragm which is connected in an electric bridge circuit consisting of four resistances interconnected in series in a quadrangle, known as a wheat stone bridge, said resistances changing the values in response to changes of configuration of the diaphragm caused by changes in
20   the detected pressure. The characterising features of this method appear from the dependent claims.

The invention will be defined in closer detail in the following with reference to the accompanying drawings wherein

Fig. 1 illustrates a bridge circuit which serves as the measuring
25   means in a pressure sensor, not illustrated, in an autoclave and which is connected to the diaphragm of the pressure sensor,

Fig. 2 is a graphical representation wherein the slope of the curves illustrate the sensitivity of the pressure sensor expressed in mV/bar,
30   Fig. 3 is a graphical representation wherein the curves represent the sensitivity of two different pressure sensors as the function of the resulting resistance across the bridge circuit and

Fig. 4 is a graphical representation wherein curves represent so called offset with respect to two different pressure sensors as a
35   function of the resulting resistance across the bridge circuit.

The method in accordance with the invention is intended to be utilized with the type of pressure sensors wherein the sensor is

4

provided with a diaphragm which alter its configuration in response to
pressure changes and which is connected with an electrical bridge
circuit 1. As appears from Fig. 1 this bridge circuit consists of four
interconnected resistances 2, 3, 4, and 5 which are connected in
5   series in quadrangle and form a circuit generally referred to as a
wheat stone bridge. The resistances 2, 3 ,4, 5 change their values
primarily in response to changes of the configuration of the dia-
phragm but are affected also by changes in temperature. In order to
obtain an electrical measure-ment signal in two diagonally opposite
10   points 6, 7 in the bridge circuit 1 when measuring a pressure, two
oppositely positioned points 8, 9 in the bridge circuit 1 is supplied
with current or voltage. This supply of current or voltage is constant
in order not to affect the output in points 6, 7.

When the supply is in the form of a constant voltage, the voltage
15   drop between the two supply points 8, 9 will always be constant,
independently of how the four resistances 2, 3, 4, 5 change their
values individually. The output signal between the two other points 6,
7 follows the values of the four resistances in the conventional
manner.

20   However, if the bridge 1 is supplied with constant current it
becomes possible to also measure the total resistance of the bridge
across the two supply points 8, 9. This magnitude is an excellent
reference of the temperature dependency of the pressure sensor since
it is directly related to the resistances 2, 3, 4, 5 that are active for
25   pressure readings.

Each pressure sensor has a sensitivity expressed for instance in
mV/bar. In the ideal case the output signal from a pressure sensor,
as illustrated in Fig. 2, forms a straight line departing from zero and
with a slope corresponding to the sensitivity of the pressure sensor.In
30   reality, the zero point (offset) as well as the slope (sensitivity) are
affected by the temperature.

In the manufacture of pressure sensors the offset and slope are
measured as functions of the total bridge resistance of the associated
pressure sensor across the temperature range relevant to the pressure
35   sensor. The bridge resistance R_B is the relation between the voltage U_B
across the bridge 1 and the supply current i_k through the bridge. The
table below relates to a certain pressure sensor the temperature

5

dependency of which is measured from room temperature at intervals
of 20°C up to approximately 140°C. The values corresponding to the
offset and the sensitivity are registered as functions of the bridge
resistance at seven different temperature levels in accordance with the
5   example given. The measured values are stored in the memory of a
computer and are the data on which the temperature compensation
calculations are based.

	R_B	Sensitivity	Offset
10	3164	90.70	5.11
	3285	90.73	5.14
	3407	91.08	5.02
	3570	91.50	4.83
	3744	92.25	4.59
15	3900	93.40	4.40
	4152	94.42	4.57

   In Fig. 3 is shown an example of a graphical representation
wherein a couple of curves illustrate the measured values of the
20   sensitivity of a couple of pressure sensors as a function of R_B. In Fig.
4 is shown in a corresponding manner a graphical representation of
the offset in a couple of pressure sensors as a function R_B. The inter-
vals between adjacent measurement points are interconnected by
means of straight lines and the calculation is affected thereafter by
25   interpolation between the break points, which is a simpli-fication of a
continuous function.

   By treating each individual pressure sensor separately in this
way and feed in its characteristic values into a computer full tempera-
ture compensation is obtained at each temperature level as a result of
30   the computer calculation. In Fig. 2 dotted lines illustrate how, in the
case of an output signal, a pressure value P_1 is obtained in the sub-
ject case, whereas after the temperature compensation the more
correct value P_2 is obtained.

   In Fig. 1 two resistances R_1 and R_2 are indicated, said
resistances being connected in parallel across reistances 3 and 4,
respectively, and being inserted for the purpose of coarse temperature
compensation. In addition, a couple of resistances R_3 and R_4 are

6

connected, the purpose of which is to minimize the offset. Advant-
ageously, these resistances R_1, R_2, R_3, R_4 can, however, be positioned
in the control system where they are exposed to smaller temperature
variations than they are when positioned closely adjacent a pressure
sensor. This is illustrated by dash and dot lines and by a line dis-
continuity 10 and 11, respectively. The coarse compensation obtained
by means of these resistances R_1, R_2, R_3, R_4 requires less correction of
the computer software which considerably increases the measurement
accuracy.

7

CLAIMS

1. A method of compensating the temperature in pressure
sensors of the kind wherein a pressure is sensed by means of a
diaphragm connected in an electric bridge circuit comprising four
resistances (2, 3, 4, 5) connected in series in a quadrilateral bridge
5   (1), a so called Wheatstone bridge, said resistances changing their
values in response to such alterations in the diaphragm configura-
tion as are caused by changes in the detected pressure, c h a r a c -
t e r i z e d by supplying the bridge (1) in two diagonally opposite
points (8, 9) with a constant current (i_k) and supplying output signals
10   from the bridge (1) to a computer that is unaffected by temperature
variations at the place of measurement, first measurement points
representing the offset of the pressure sensor at a number of tempera-
ture levels being plotted in a first graph indicating the voltage as a
function of the resulting resistance (R_B) of the bridge (1), thereafter
15   interconnecting neighbouring measurement points by straight lines
and effecting calculation through interpolation between the measure-
ment points, and by determining the sensitivity of the pressure sensor
such as voltage/pressure unit in a corresponding manner at different
temperature levels by plotting second measurement points in a
20   second graph indicating the sensitivity as a function of the resulting
resistance (R_B), and interconnecting the last mentioned measurement
points in a similar way by means of straight lines and effecting
calculation through interpolation between the measurement points,
and processing the resulting graphs in the computer, whereupon a
25   signal from the pressure reading provides a directly temperature-
compensated pressure value which may be read from a third graph
indicative of an output signal that is proportional to the prevailing
pressure.

2. A method as claimed in claim 1, c h a r a c t e r i z e d by
30   positioning the two first resistances (R_1, R_2) which are coupled in
parallel across its individual resistance (3 and 4, respectively) in the
bridge circuit and intended for coarse temperature compensation, and
two other resistances (R_3, R_4) coupled in series with their respective
one of the remaining resistances (2 and 5, respectively) in the bridge
35   circuit and intended to minimize the deviation from zero of an output

AMENDED SHEET (ARTICLE 19)

8

signal, in an environment where the temperature variations are smaller than they are adjacent the pressure sensor.

1/2

Känslighet

mV/bar

90

Känslighet hos tryckavkännaren
som funktion av R_B

85

80

$75_{3,2}$ 3,5   4,0 R_B
                                                                          $k\Omega$

Fig. 3

Nollfel

mV

15,0

Nollfel som funktion av R_B

10,0

5,0

0
3,2   3,5   4,0 R_B
                                                                          $k\Omega$

Fig. 4

$$\frac{U_B}{i_k} = R_B$$

Fig. 1

Fig. 2

lutning=känslighet

Nollfel (offset)
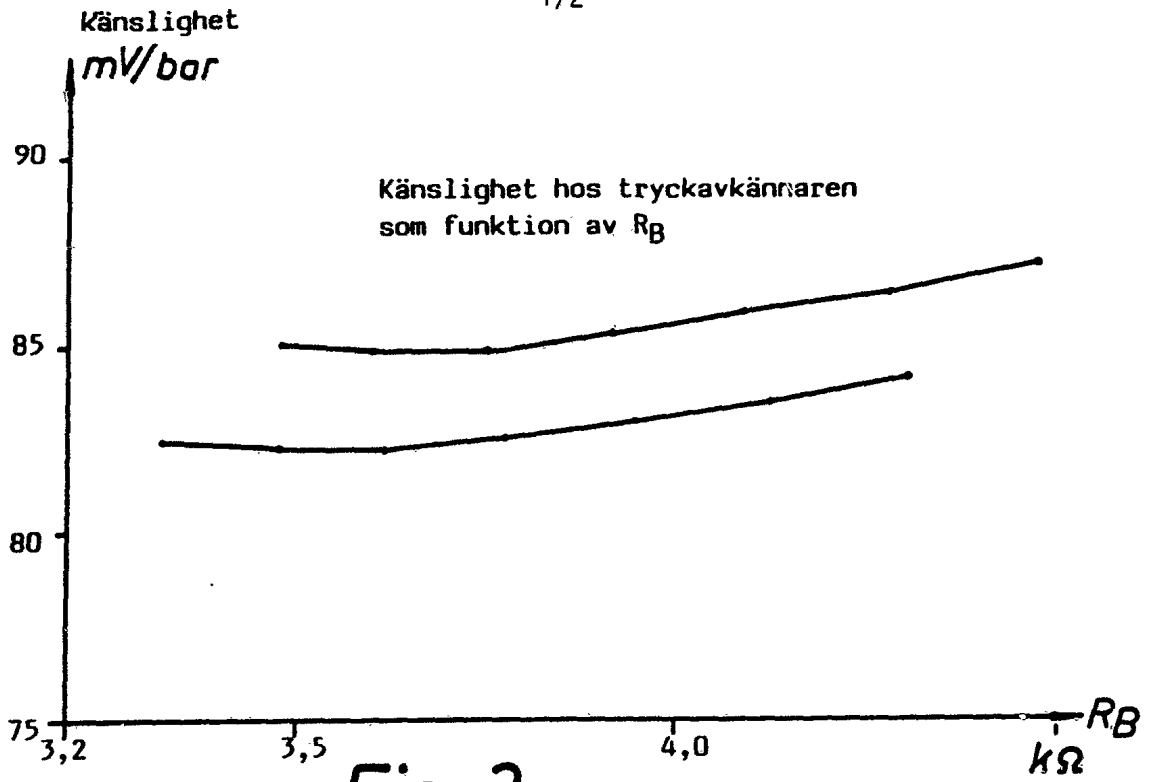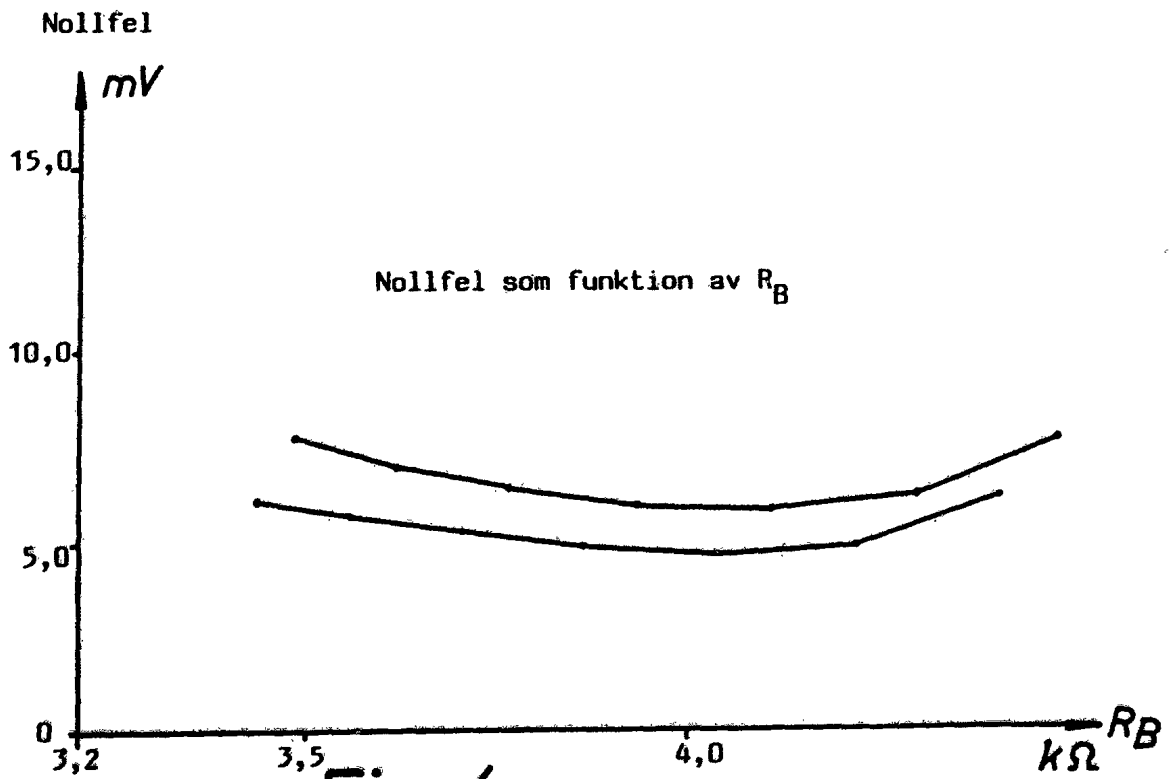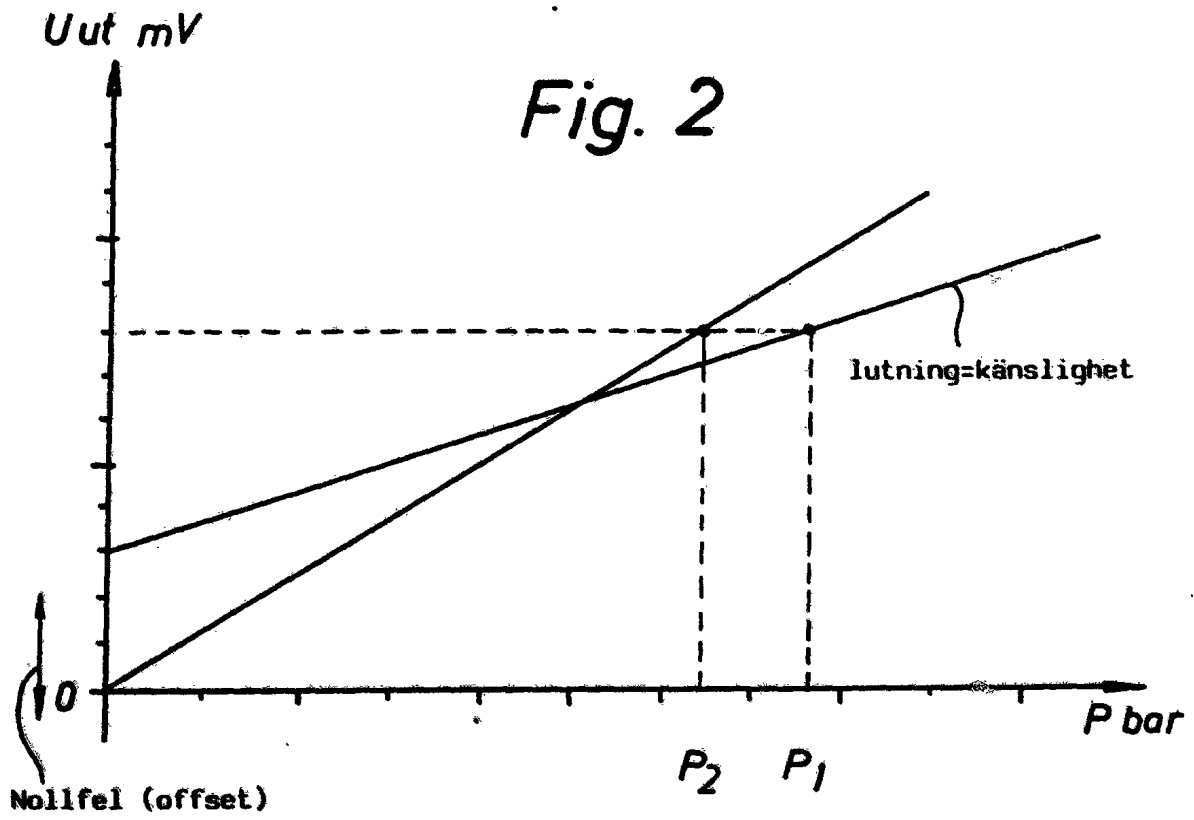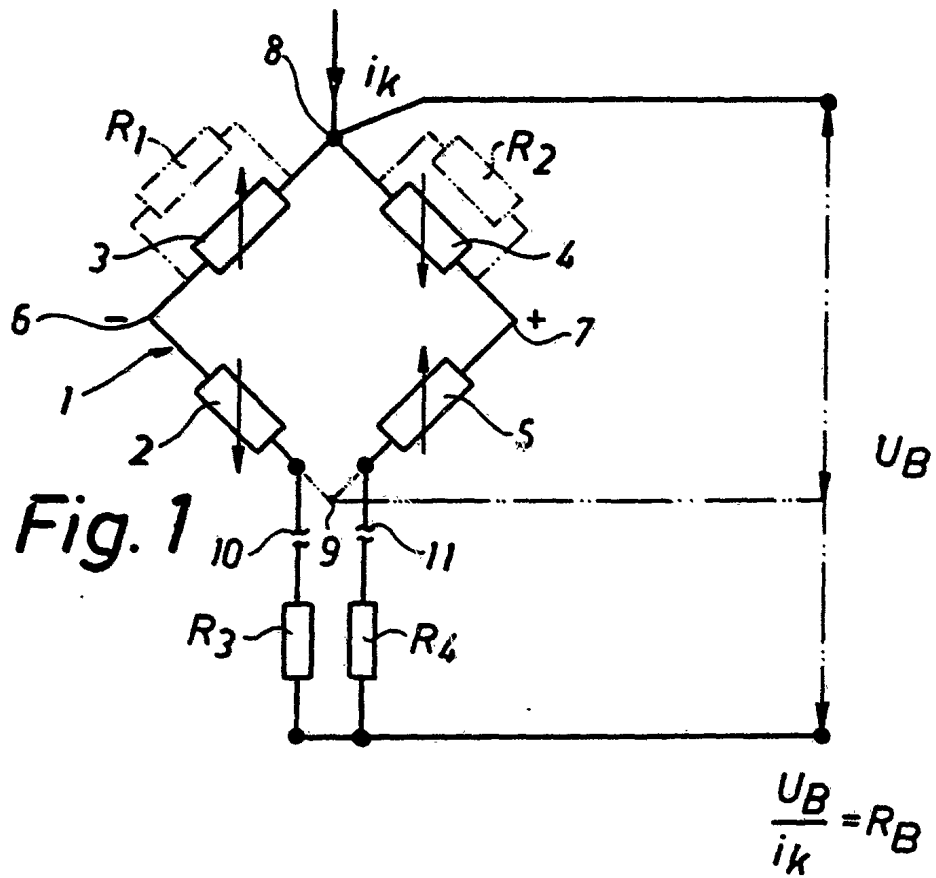
INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 94/01160

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: G01L 19/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: G01D, G01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, A, 4192005 (ANTHONY D. KURTZ), 4 March 1980 (04.03.80), column 4, line 6 - column 12, line 28, figure 1	1
Y		2

X	US, A, 4715003 (HANS W KELLER ET AL), 22 December 1987 (22.12.87), column 7, line 37 - column 8, line 20, figure 2	1
Y		2

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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 June 1995	29 -06- 1995
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Lars Jakobsson Telephone No. +46 8 782 25 00

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INTERNATIONAL SEARCH REPORT

International application No.

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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Y		2
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