



## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

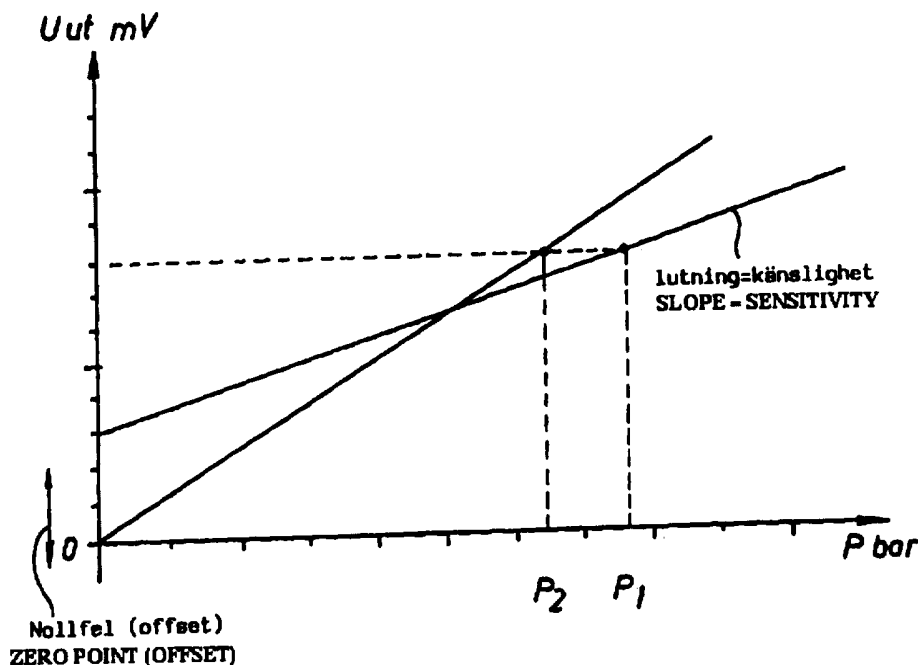
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<p>(21) International Application Number: PCT/SE94/01160</p> <p>(22) International Filing Date: 2 December 1994 (02.12.94)</p> <p>(71) Applicant (for all designated States except US): GETINGE AB [SE/SE]; P.O. Box 69, S-310 44 Getinge (SE).</p> <p>(72) Inventor; and (75) Inventor/Applicant (for US only): MATTSSON, Olle [SE/SE]; Brunngatan 6, S-310 44 Getinge (SE).</p> <p>(74) Agent: AWAPATENT AB; P.O. Box 11394, S-404 28 Göteborg (SE).</p>	<p>(81) Designated States: AM, AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, JP, KE, KG, KP, KR, KZ, LK, LR, LT, LU, LV, MD, MG, MN, MW, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SI, SK, TJ, TT, UA, US, UZ, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG), ARIPO patent (KE, MW, SD, SZ).</p> <p><b>Published</b> With international search report. With amended claims. In English translation (filed in Swedish).</p>	

(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.



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.

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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. Thereafter, the effects of temperature changes are essentially negligible.

25 Other prior-art methods of temperature compensation consist of connecting resistances having known temperature characteristics 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

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  
5 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  
10 and vice versa, both respect to pressure and temperature, take place rapidly and several times over a comparatively short period during one process.

However, the above-mentioned prior-art stabilizing methods are quite insufficient in this application to meet the requirements on  
15 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.

20 For such an extreme activity as vapour sterilization various measures therefore have been taken to prevent the effects of temperature 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  
25 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  
30 form between the autoclave chamber and the sensor. Such cavities are not desired and normally they are not either accepted by established standard specifications, because inside them an environment is created that favours collection and growth of micro-organisms. Instead, a desired end is to be able to position the sensing diaphragm of  
35 the pressure sensor directly in the wall of the autoclave enclosure, without using any intermediary tubings or pipings.

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

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 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 diaphragm but are affected also by changes in temperature. In order to obtain an electrical measurement signal in two diagonally opposite 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 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.

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 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 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 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

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 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.

	<u>R<sub>B</sub></u>	<u>Sensitivity</u>	<u>Offset</u>
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 sensitivity of a couple of pressure sensors as a function of R<sub>B</sub>. 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<sub>B</sub>. The intervals between adjacent measurement points are interconnected by means of straight lines and the calculation is affected thereafter by interpolation between the break points, which is a simplification of a continuous function.

By treating each individual pressure sensor separately in this way and feed in its characteristic values into a computer full temperature compensation is obtained at each temperature level as a result of the computer calculation. In Fig. 2 dotted lines illustrate how, in the case of an output signal, a pressure value P<sub>1</sub> is obtained in the subject case, whereas after the temperature compensation the more correct value P<sub>2</sub> is obtained.

In Fig. 1 two resistances R<sub>1</sub> and R<sub>2</sub> are indicated, said resistances being connected in parallel across resistances 3 and 4, respectively, and being inserted for the purpose of coarse temperature compensation. In addition, a couple of resistances R<sub>3</sub> and R<sub>4</sub> are

connected, the purpose of which is to minimize the offset. Advantageously, 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 discontinuity 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.

## CLAIMS

1. A method of compensating the temperature in pressure sensors of the kind wherein this 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 wheat stone bridge, said resistances changing their values in response to such alterations in the diaphragm configuration as are caused by changes in the detected pressure, characterized by supplying bridge (1) in two diagonally opposite points (8, 9) with a constant current ( $i_k$ ) and by plotting first measurement points of offset output signals emanating from the bridge (1) in the pressure sensor at a number of temperature levels in a first graph indicating the voltage as a function of the resulting resistance ( $R_B$ ) of the bridge (1), thereafter interconnecting adjacent measurement points by straight lines and effecting calculation through interpolation between the measurement 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 calculation through interpolation between the measurement points, and processing the resulting curves in a computer, whereupon an output signal from the pressure sensor provides a directly temperature-compensated pressure value which may be read from a third graph indicating output signals as a function of the detected pressure.

2. A method as claimed in claim 1, characterized by 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 circuit and intended to minimize the deviation from zero of an output signal, in an environment where the temperature variations are smaller than they are adjacent the pressure sensor.

## AMENDED CLAIMS

[received by the International Bureau on 22 March 1996 (22.03.96);  
original claim 1 amended; claim 2 unchanged (2 pages)]

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, characterized 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 temperature 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 measurement 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 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.

2. A method as claimed in claim 1, characterized by 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 circuit and intended to minimize the deviation from zero of an output

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

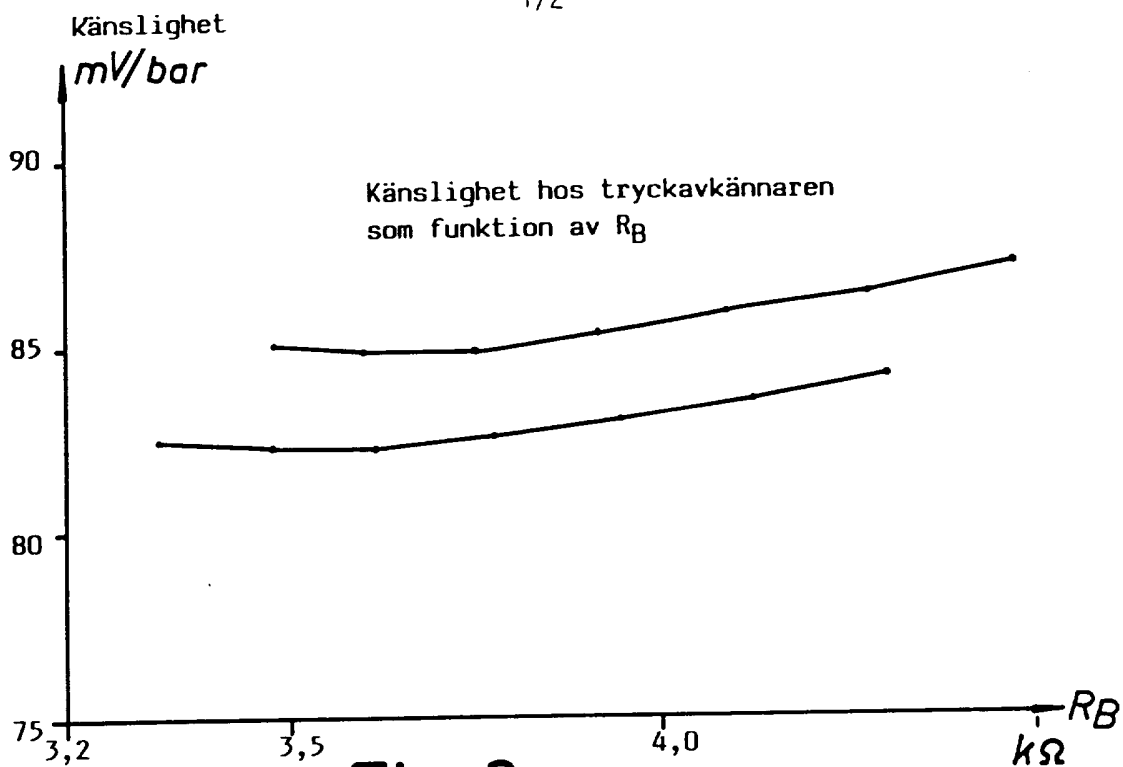


Fig. 3

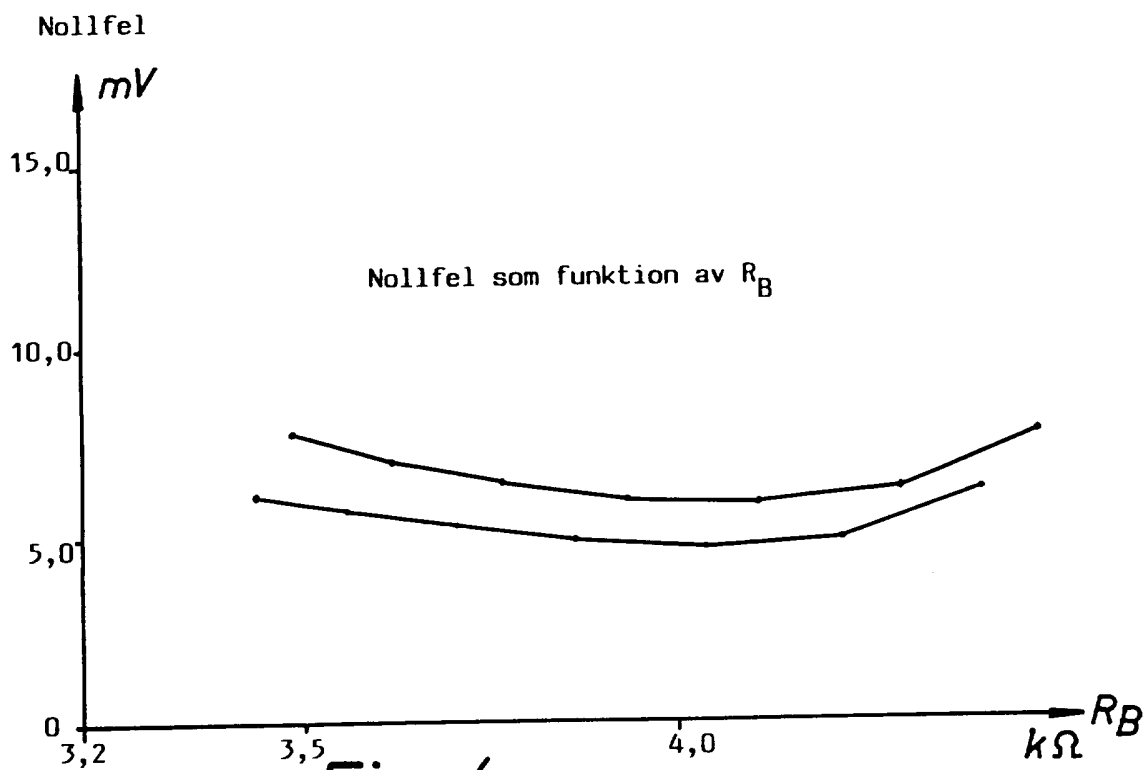
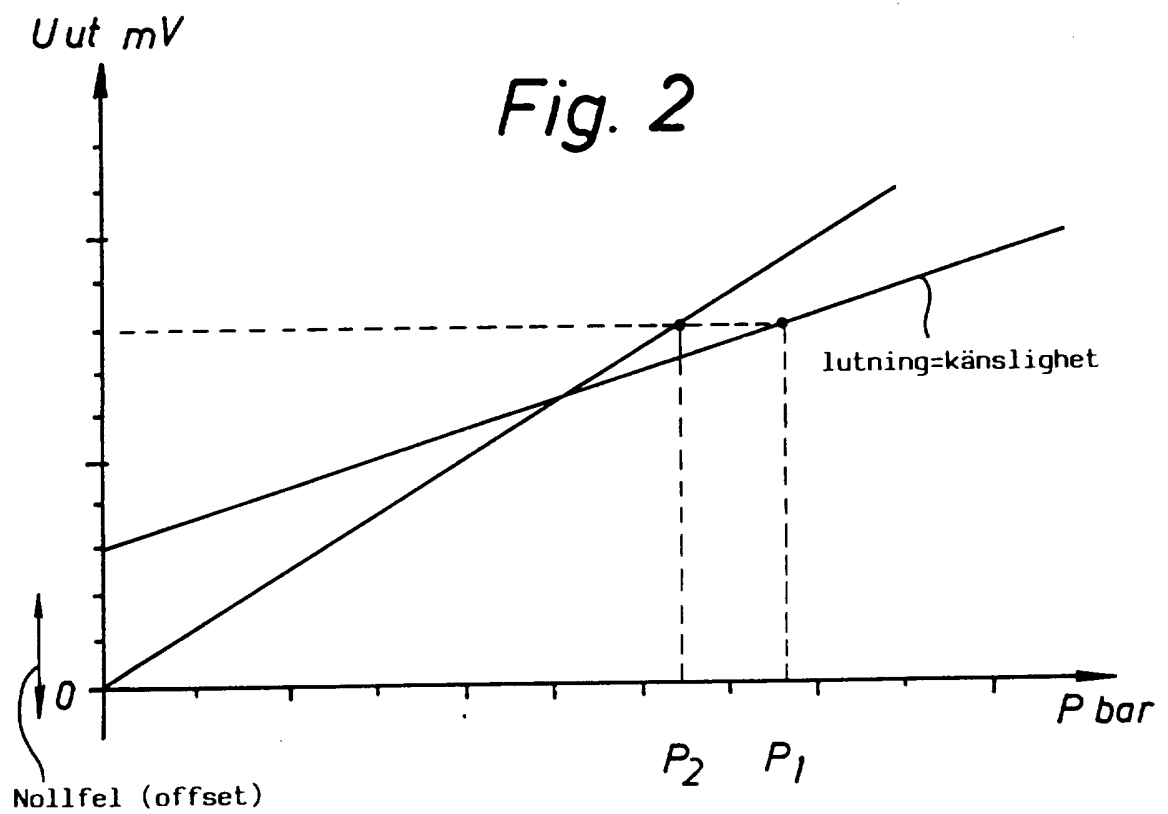
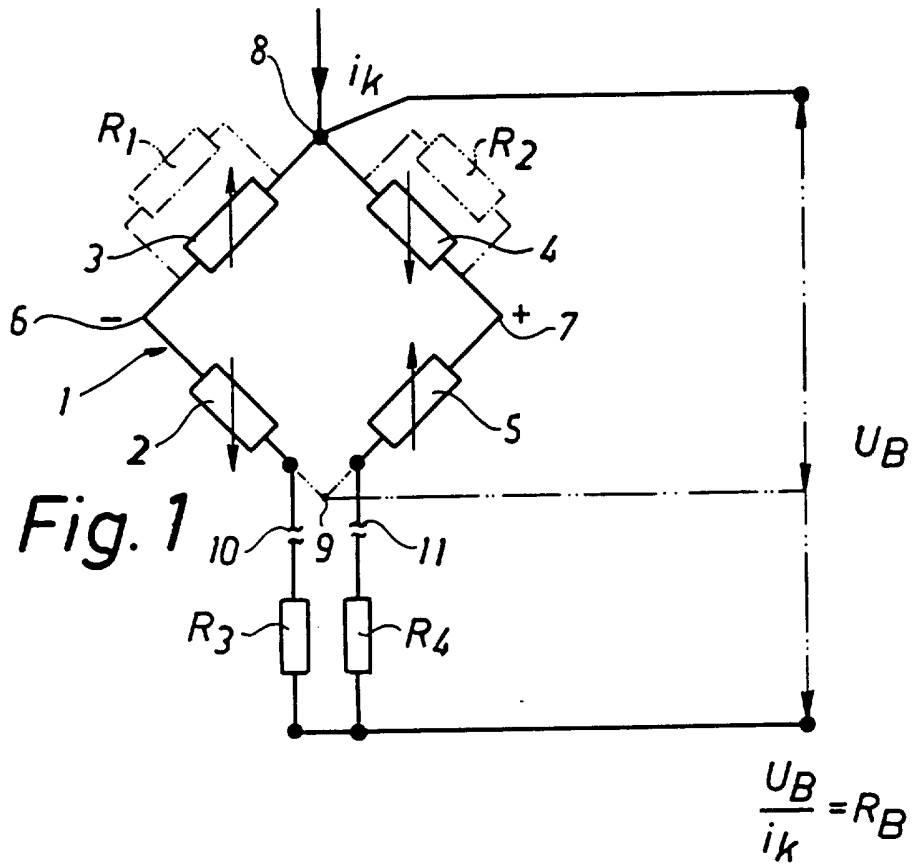


Fig. 4



## 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

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## 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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Date of the actual completion of the international search

16 June 1995

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, A, 5146788 (JOHN W. RAYNES), 15 Sept 1992 (15.09.92), column 20, line 62 - column 22, line 14, figures 1,4	1
Y	--	2
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**INTERNATIONAL SEARCH REPORT**  
Information on patent family members

03/05/95

International application No.  
PCT/SE 94/01160

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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