# PATENT SPECIFICATION (11) 1 573 030

1 573 030

(21) Application No. 16158/77 (22) Filed 19 April 1977
(31) Convention Application No. 682 280 (32) Filed 3 May 1976 in
(33) United States of America (US)
(44) Complete Specification published 13 Aug. 1980
(51) INT. CL.[3] G01L 13/06
G01D 5/42
(52) Index at acceptance
G1N 1A3B 1D2B 1F 1P 7C AFE


(72) Inventor ROBERT CHARLES WHITEHEAD, JR.


(19)

## (54) DIFFERENTIAL PRESSURE TO ELECTRICAL SIGNAL TRANSMITTER

(71) We, HONEYWELL INC. a Corporation organised and existing under the laws of the State of Delaware, United States of America, of Honeywell Plaza, Minneapolis, Minnesota 55408, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a differential pressure to electrical signal transmitter, and according to the invention the transmitter comprises a pressure sensing head including a first block defining two oppositely facing support surfaces one sealed to the periphery of a first diaphragm and the other sealed to a second, control, diaphragm, a first passage interconecting said support faces, said passage and the spaces between said diaphragms and their support surfaces together defining a first chamber of expansible valume, a second block defining two oppositely facing support surfaces one sealed to said control diaphragm and the other sealed to a third diaphragm, and a second passage interconnecting said support surfaces, said second passage and the spaces between said control and third diaphragm and their support surfaces together defining a fourth chamber; means for applying a first fluid whose pressure is to be sensed to a side of the first diaphragm opposite said first chamber; a differential pressure transducer unit located at a position remote from said head and including a transducer element for sensing the pressure difference in second and third chambers located on opposite sides of the element whereby to produce an electrical signal representative of said pressure difference; a capillary tube connecting said first chamber to said second chamber; a substantially incompressible fluid filling said first and second chambers and said capillary tube; a second capillary tube connecting said fourth chamber to said third chamber; a substantially incompressible fluid filling said third and fourth chambers and said second capillary tube; and means for applying a second fluid whose pressure is to be sensed to a side of the third diaphragm opposite said fourth chamber.

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

Figure 1 is a perspective view of a pressure sensing head interconnected with a remote transducer unit to form a differential pressure to electrical signal transmitter in accordance with the teaching of this invention;

Figure 2 is a schematic cross-section of a preferred form of the pressure sensing head shown in Figure 1;

Figure 3 is a cross-section of a preferred form of a differential pressure sensor in the remote transducer unit shown in Figure 1;

Figure 4 is a bottom view of the transducer unit shown in Figure 3 taken along the line 4-4 thereof;

Figure 5 is a schematic diagram of an electrical bridge circuit employed to produce an electrical signal that is responsive to the magnitude of the differential pressure under measurement;

Figure 6 is a sectional view of components of a modified form of the pressure sensing head prior to assembly;

Figure 7 shows the pressure sensing head parts of Figure 6 in an assembled condition;

Figure 8 is an isometric view of a disc-shaped cantilever spring;

Figure 9 is a sectional view of another modified form of the sensing head employing two of the springs of Figure 8; and

Figure 10 is a sectional view of still another modified form of the sensing head shown in Figure 2.

## *DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT*

Referring now to Figure 1, there is shown a differential pressure to electrical signal of current transmitter 10 having a pressure sensing head, indicated by the general reference numeral 12, coupled to a remote transducer unit or capsule 14 by a pair of capillary tubes 16, 18 that extend between the head 12 and the capsule 14. The capsule 14 and capillaries 16, 18 are covered by a trough 23 and a housing 24. Screws 25 secure the housing 24 and trough 23 on the sensing head 12.

The capsule 14 is connected by conductive pins 20 to electric sockets 21 on a printed circuit board 22. The sensing head 12 contains two identical blocks 26, 28 preferably made of stainless steel AISI type 316. As can be seen in Figure 2, each block 26, 28 has an annular dished-out convoluted surface 30, 32, respectively. A convoluted flexible center or control diaphragm 34 extends between these blocks to form two separate chambers 36, 38. The convolutions formed in the diaphragm 34 are annular and follow the contour of annular convoluted surfaces formed on the inner face surfaces 30 and 32. The diaphragm 34 is preferably made of metal such as stainless steel AISI type 316. The outer periphery of the diaphragm 34 is clamped between mating flat surfaces on blocks 26, 28. Preferably, a fluid tight joint between the blocks 26, 28 and the diaphragm 34 is formed by welding these three components together around their entire peripheral surface by means of a tungsten inert gas weld 40, commonly referred to as a TIG weld.

The other side of each of the blocks 26, 28 has an annular convoluted surface 42, 44 also. A convoluted barrier diaphragm 46, which is preferably made of stainless steel AISI type 316, extends along and is in spaced relationship with convoluted wall surface 42. Similarly, a convoluted stainless steel AISI type 316 diaphragm 48 extends along and is spaced from surface 44. Preferably, the diaphragms 46 and 48 are identical.

The outer periphery of each block 26, 28 is recessed, and square frame or ring members 50, 52 are respectively mounted therein. These members are made of stainless steel AISI type 316. The rings 50, 52 are TIG seam welded, as indicated by reference numerals 54, 56, to form a fluid tight joint. Barrier diaphragms 46, 48 are TIG seam welded, as indicated by reference numerals 58, 60, to their frame members 50, 52, respectively. These welds 58 and 60 are fluid tight.

Two dished-out head members 61, 63 defining chambers 62, 64 respectively, are connected in fluid seal-tight relationship with their associated rings 50, 52 by means of suitable O-ring seals 66, 68 and with the aid of four bolt and nut connections 70, 72, 74, 76. These head members 61, 63 and bolt and nut connections 70, 72, 74, 76 are made of stainless steel AISI type 316. A separate inlet passageway 78, 80 is formed in each head member 61, 63. Respective high and low pressure process fluids 82, 84, whose differential pressure is to be measured, are applied by way of their respective passageways 78, 80 and chambers 62, 64 to barrier diaphragms 46, 48.

A plurality of passageways 86 interconnect the chamber 36 on the left side of the center diaphragm 34 with the space or chamber 87 between the barrier diaphragm 46 and the convoluted surface 42. A nonconductive, incompressible fill liquid 88 fills this entire region.

A plurality of passageways 90 interconnect the chamber 38 and the space or chamber $87^1$ between the barrier diaphragm 48 and the convoluted surface 44. A nonconductive incompressible fill liquid 89 fills this entire region. Preferably, the characteristics of the two fill liquids are similar.

A pair of passageways 91 and 93 connect the capillary tubes 16 and 18, respectively, to the fill liquids 88 and 89.

Referring now to Figures 1 and 3, the low pressure capillary tube 18 is in fluid tight engagement with capsule 14, extending into a passageway 94 formed in a metal wall 92 of the capsule 14. A glass tube 95 extends between a position in the passageway 94, adjacent the end of the tube 18, and a position in a passageway 98 in a silicon support plate 100. The tube 95 is maintained in fluid tight engagement with the passageway 94 by an epoxy seal 96, and is maintained in fluid tight engagement with the passageway 98 by a suitable seal, such as that produced by the method disclosed in U.S. Patent No. 3,803,874.

The high pressure capillary tube 16 extends through, and is in fluid tight relationship with, an opening 104 in a cover plate 106 of the capsule 14.

A cup-shaped semiconductor wafer 102, such as a silicon wafer, is bonded to the support plate 100, preferably by means of a gold eutectic bonding technique known in the art. The previously referred to high pressure fill liquid 88 fills the high pressure capillary tube 16 and the interior space or sensor chamber of the capsule 14, applying a pressure to the outer surface or face of the wafer 102. The previously referred to low pressure fill liquid 89 fills the low pressure capillary tube 18, the tube 95, and the sensor chamber between the plate 100 and the wafer 102, and applies a pressure to the inner surface of the wafer 102. Thus, the

fill liquids 88 and 89 are caused to act on the respective opposite portions or faces of the wafer 102.

An ion migration shield 108 is mounted adjacent the wafer 102 by a number of stand-offs or rods 110, and is electrically connected to the wafer 102 by a pair of conductors 112.

A wheatstone strain gauge bridge indicated by reference numeral 114 is diffused into the outer surface of the wafer 102. A suitable number of fine wires 116, 118, 120, 122, 123 extend between the bridge 114 and the pins 20. Glass seals 124 form fluid tight seals between the portions of the pins 20 passing through the wall 92 and openings 126 formed in the wall 92.

Figure 5 shows schematically one embodiment of the wheatstone bridge 114 that is diffused into the wafer 102. A temperature compensated amplifier unit 130 and a constant current regulator 132, associated with the bridge 114, are mounted externally to the capsule 14, preferably on the printed circuit board 22.

A detailed description of the amplifier unit 130, and how it is interrelated with the output of the strain gage bridge 114 to provide temperature compensation, appears in the U.S. Patent No. 3,654,545. An electric meter 134, powered by a battery 128, is connected to the bridge circuit 114 for indicating the magnitude of the differential pressure being applied across the wafer 102 in terms of electrical units, for example, four to twenty milliamps, which are equivalent to the operating range that is selected for the transmitter 10.

The wafer 102 and its diffused bridge 114 form a transducer element of the minute displacement type, that is, the element experiences only a minute displacement or deflection as the difference between the fluid pressures in the tubes 16 and 18 traverses its normal operating range. An excessive value of this pressure difference can well result in the degradation, damage, or destruction of the wafer 102 and its diffused bridge 114.

*DETAILED DESCRIPTION OF MODIFICATIONS OF THE SENSING HEAD*

A modified form of the head 12 as shown in Figures 6 and 7 differs from the Figure 2 construction in that the modified form employs three blocks 136, 138, 140, whereas the Figure 2 embodiment employs only two blocks 26, 28. Another difference is that the center block 138 contains two center or control diaphragms 142, 144 in the place of the single diaphragm 34. Each of the diaphragms 142, 144 is connected in a partially tensioned or taut fluid tight sealed condition, by TIG welds 146, 148, to a different surface or side of the center block 138. The opposite sides of block 138 have annular convoluted concave surfaces 149 which follow and are spaced from the contour of associated annular convoluted surfaces formed in the center diaphragms 142, 144.

Blocks 136, 140 are constructed so that they can be moved toward one another, in the direction of the arrows shown in Figure 6, so that their annular convoluted convex surfaces 150, 152 can be brought into compressed engagement with the associated taut diaphragms 142, 144.

Figure 7 shows the blocks 136, 138, 140 of Figure 6 joined together by fluid tight seam TIG welds 154, 156 after the center diaphragms 142, 144 have been compressed in the aforementioned manner into a preloaded condition.

The outer side walls of the blocks 136, 140 have annular convoluted surfaces 159, 161 covered by spaced, matching, annular convoluted barrier diaphragms 158, 160. The latter are attached to rings in a manner similar to that previously set forth in the description of Figure 2.

A first non-conductive, non-compressible fill liquid 162 fills passageways 164, 165 and chambers that extend between the barrier diaphragm 158 and the left side of each of the center diaphragms 142, 144. Another similar fill liquid 166 fills passageways 167, 168 and chambers that extend between the barrier diaphragm 160 and the right side of each of the center diaphragms 142, 144. The block and diaphragm arrangement shown in Figure 7 thus provides an integral or one piece welded pressure sensing head 170.

A dished-out chamber, not shown, is mounted on each of the opposite sides of the pressure head 170 to enable a high pressure process fluid to be applied to the barrier diaphragm 158 and a low pressure process fluid to be applied to the barrier diaphragm 160, in a manner similar to the arrangement of the head chambers 62, 64 as set forth under the description of Figure 2.

A pair of passageways 169 and 171 connect the capillary tubes 172, 174, respectively, to the fill liquids 162, 166 in blocks 136, 140.

Capillary tubes 172, 174, each containing a separate one of the fill liquids 162, 166, are provided for transmitting pressure changes in these fill fluids to a remote sensor capsule 14 as shown in Figure 1.

Figure 8 shows an isometric view of a disc-shaped cantilever spring 176 having a number of similar spring fingers 178 for use in another modified form of the invention shown in Figure 9. The form of the invention shown in Figure 9 employs three blocks 180, 182, 184, two center diaphragms 186, 188, and two barrier diaphragms 190,

192. These parts are welded together in the same fluid-tight manner as the center diaphragms 142, 144 and the barrier diaphragms 158, 160 are welded to their respective blocks 136, 138, 140 shown in Figure 7.

The inner walls of the blocks 180, 184 each have a smooth dished-out surface 194, 196. The block 182 has two annular grooves 198, 200 into which the outer periphery of a disc-shaped cantilever spring 176 of Figure 8 is inserted. Each of the cantilever springs 176, 176 is positioned within the block 182 so that its respective spring fingers 178 can apply a preloading spring force to a different one of the flat center diaphragms 186, 188.

A number of passageways, for example 202, are employed to apply the pressure of a first non-compressible fill liquid 204, acting on the low pressure side of the pressure sensing head shown in Figure 9, to one side of each of the center diaphragms 186, 188. Another number of passageways, for example 206, are employed to apply the pressure of a second non-compressible fill liquid 208, acting on the high pressure side of the pressure sensing head shown in Figure 9, to the other side of each of the center diaphragms 186, 188. A pair of passageways 209, 211 connects the capillary tubes 210, 212, respectively, to the fill liquids 204, 208 in blocks 184, 180.

Capillary tubes 210, 212, each containing a separate one of the fill liquids 204, 208, are also provided for transmitting pressure changes occurring in these fill fluids to a remote sensor capsule 14, as shown in Figure 1.

Figure 9 shows the blocks 180, 182, 184 and their associated diaphragms 190, 186, 188 and 192 joined together by TIG seam welds in a manner similar to that previously set forth under the description of Figure 7. The block and diaphragm arrangement shown in Figure 9 thus provides an integral or one piece welded pressure sensing head 213.

A dished out chamber, not shown, is mounted on each of the opposite sides of the pressure head 213 to enable a high pressure process fluid to be applied to the barrier diaphragm 190 and a low pressure process fluid to be applied to the barrier diaphragm 192, in a manner similar to the arrangement of the head chambers 62, 64 as set forth under the description of Figure 2.

Figure 10 shows still another modified form of head structure that differs from the embodiment as shown in Figure 2 in that it has a relatively stiff center or control diaphragm 214 and two barrier diaphragms 216, 218 made of thin, flexible flat plates rather than being convoluted as in Figure 2. Another difference is that each of the blocks 220, 222 has a smooth dished-out, or concave, inner surface 224 and 226, respectively, and has outer flat surfaces 228, 230 instead of convoluted surfaces as in Figure 2. A series of passageways 240 and 241 and chambers provides a fluid connection between the inner surface of diaphragm 216 and one side of center diaphragm 214 and a capillary tube 236. Similarly, a series of passageways 242, 243 provides a fluid connection between the inner surface of diaphragm 218 and one side of center diaphragm 214 and a capillary tube 238.

First and second fill liquids 232, 234 are under pressure and fill the respective passageways, chambers and capillary tubes. This arrangement differs from the arrangement of Figure 2 in that the pressure of the fill liquids 232, 234 is selected to bow the barrier diaphragms 216, 218 outwardly into a non-buckling, spherical, dome-shaped or cup-shaped position as shown in Figure 10. All of the other parts of the pressure head not shown in Figure 10, including the addition of dished-out head members 61, 63, may be the same as those shown in Figure 2.

The stiffness of the control or compliance diaphragm 214 should be on the order of one hundred times greater than the stiffness of the barrier diaphragms 216, 218. The stiffness of the control or compliance diaphragm 34 of Figure 2, on the other hand, should be about forty times greater than the stiffness of its associated barrier diaphragms 46, 48.

*MODE OF OPERATION*

The pressure of a process fluid 82 on the high pressure side of an orifice in a flow line, not shown, is applied by way of passageway 78 to the head chamber 62 and against the barrier diaphragm 46. When a pressure change in this high pressure fluid occurs, it is applied by the barrier diaphragm 46 and the fill liquid 88 against one side of the center diaphragm 34, and by way of the capillary tube 16 to one side of the sensor 102 shown in Figure 3.

The pressure of the process fluid 84 that is simultaneously present on the low pressure side of the aforementioned orifice is applied by way of passageway 80 to the head chamber 64 and against the barrier diaphragm 48. When a pressure change in this low pressure fluid occurs, it is applied by barrier diaphragm 48 and the fill liquid 89 against an opposite side of the center diaphragm 34, and by way of capillary tube 18 to an opposite side of the sensor 102 shown in Figure 3.

When an increase in the temperature of the process fluid occurs, there is a tendency for additional heat to be transmitted from this fluid by way of the barrier diaphragms

46, 48 to the fill fluids 88, 89. This increase in temperature of the fill liquids 88, 89 causes the barrier diaphragm 46 to expand outwardly in a right to left direction, and the barrier diaphragm 48 to simultaneously expand outwardly in a left to right direction. As this increase in temperature takes place, the fill liquid 88 will apply the same increase in pressure to one side of the center diaphragm 34 as the fill fluid 89 applies to the opposite side of the diaphragm 34. The position of the center diaphragm is therefore not affected by a change in temperature of the process fluid. No unbalanced pressure change will therefore take place in the fill fluids 88, 89, that are acting on the opposite sides of the sensor 102, when an increase in the temperature of the fluid occurs. The present transmitter thus provides a reliable sensor to accurately convert a high-low differential pressure of a process fluid into a proportional electric signal even when the process fluid under measurement is a hot liquid whose temperature is constant or varying from one temperature level to another.

Another feature of the present transmitter is that the sensor 102 is positioned at a remote location from the pressure head 12 rather than being positioned within the pressure head and in a fluid fill that is adjacent a barrier diaphragm from which heat and/or pulses from the process fluid may be emitted. With the present transmitter, the heat and pulses which each of the fill liquids 88, 89 receives from its associated hot process fluid are substantially dissipated through the length of capillary tubing 16, 18, which tubing may well be three or more inches long, and may be exposed to the effect of a cooling atmosphere. Thus, the transmission of sensor-damaging heat and/or pulses from the process fluids to the transducer element by way of the fill liquids is minimized.

Also, since this remote transducer construction does not place the transducer element within the pressure sensing head, there is no need to bring the electrical conductors or output leads from inside the head to the exterior thereof. This makes it unnecessary to provide the temperature-resisting lead seals which are required when the element is located within the head.

Moreover, the disclosed remote transducer construction provides several additional practical advantages. Specifically, it permits either the pressure head or the transducer element to be replaced in an installation without affecting the other of these parts. It prevents the transducer from being damaged during the welding and other head fabrication processes. It simplifies the design of the head. Finally, it permits the transducer capsule to be filled with the fill fluid as soon as the capsule is constructed, thereby facilitating the testing of the element, and maintaining its characteristics in a stable condition.

The center diaphragm 34 is of a predetermined stiffness sufficient to allow an overloading or excessive process fluid pressure, acting on either the high or low pressure barrier diaphragm 46, 48, to force that overloaded diaphragm into bottomed-out engagement with its associated convoluted surface 42 or 44, without bottoming-out of the central diaphragm 34. This prevents an overload process fluid pressure, acting on either the low or high pressure side of the pressure head 12, from being applied by way of the fill fluids 88, 89 to the sensor 102 anud degrading or rupturing the sensor.

The aforementioned bottoming-out action will take place without the center diaphragm 34 bottoming-out on either the convoluted surface 30 of block 26 or the convoluted surface 32 of block 28. This is made possible because the volume of fluid 88, 89 that is displaced by either one of the barrier diaphragms 46, 48, during an overload which seats it against its associated wall 42, 44, will be less than the resulting change in volume of the fluid that must be displaced in chambers 36 or 38 before the center diaphragm 34 would be allowed to be seated against the walls 32 or 30.

The diaphragms 46, 34 and 48 are sized for each particular operating range of the transmitter so that the aforementioned bottoming-out action can occur only after full scale pressure has been exceeded. This is accomplished by selecting a prescribed stiffness for the center diaphragm 34 to suit the selected range, and by selecting two matched flexible barrier diaphragms 46, 48.

Pins 20, connected to the bridge 114 of the element 102, are shown plugged into sockets 21 of the board 22 that is located in the housing 24. This construction provides an easy, reliable way of connecting the leads of the bridge 114 to the circuit board 22.

The version of the transmitter shown in Figure 7 has a high pressure overload control diaphragm 142 and a low pressure overload control diaphragm 144, each of which is pre-loaded in a direction toward its associated barrier diaphragm 158, 160. Pre-loading or prestressing of the control diaphragms 142, 144 to a desired prestressed condition is obtained by TIG welding the control diaphragms to center section 138 and then clamping sections 138, 140 and 136 together and TIG welding them. The pre-load is selected so that the barrier diaphragms 158, 160 will transmit the differential pressure to the remote element 102 in a manner as previously described. Neither the high pressure nor the low pressure

center diaphragms 142, 144 move until the differential pressure value surpasses the aforementioned full scale range of the transmitter 10. When the full scale range of the transmitter is passed, either the high pressure or low pressure center control diaphragm 142, 144 starts to move, and this action allows the barrier diaphragm 158 to bottom-out on block surface 159, or barrier diaphragm 160 to bottom-out on block surface 161. The main advantage of this construction is that the entire full scale differential pressure signal is transmitted to the element 102 with an infinitesimally small amount of barrier diaphragm motion.

This pre-loading, or prestressing, is done so that, during the operation of the transmitter, a pressure slightly greater than its full scale differential pressure will be required in order to balance the preload and start the center control diaphragm 142 or 144 moving inward.

In the arrangement of Figure 9, the flat control diaphragms are pre-loaded by disc-shaped cantilever springs 176, 176, and the high pressure and low pressure overload control diaphragms 186, 188 can be of a stiffness similar to that of the barrier diaphragms 190, 192 because the cantilever springs 176, 176 provide the calibrated stiffness for the overload protection of the sensor 102. The springs 176, 176 are made in three sizes, namely, one for the one thousand inch range transmitter, one for the two hundred and fifty inch range transmitter, and one for the three lower transmitter ranges, namely, the one hundred and five, forty and fifteen inch ranges. The high pressure and low pressure overload control diaphragms 186, 188 are cross connected by passageways 202, 206 to the fill volumes so that they will sense the true differential pressure across the transmitter.

The version of the transmitter shown in Figure 10 uses flat diaphragms 216, 218 for the barrier diaphragms and a flat diaphragm 214 for the control diaphragm. The high pressure and low pressure fills 232, 234 are kept at a volume to retain the barrier diaphragms 216, 218 in a dome or spherical shaped operating position. The substantially flat center diaphragm is stiffer than the dome-shaped barrier diaphragms so that the barrier diaphragms will not bottom-out until the differential pressure has surpassed the full scale value. When full scale has been surpassed, the center diaphragm 214 continues to move until the barrier diaphragm 216 or 218 bottoms on its back plate. After either the barrier diaphragms 216, 218 has bottomed-out, the diaphragm 214 has room for additional movement in the event of thermal expansion of the fill fluid 232, 234. Three center diaphragms, each having a different stiffness, are used for the above-noted differential pressure ranges, namely, one for the one thousand inch range, one for the two hundred and fifty inch range, and a third to cover the one hundred and five inch, forty inch, and fifteen inch ranges.

The barrier diaphragms 158, 160 of Figure 7; 190, 192 of Figure 9; and 216, 218 of Figure 10 are generally made of stainless steel AISI type 316. When the chemical corrosion nature of the process fluid under measurement is extremely high, the aforementioned barrier diaphragms are made of other material, such as tantalum or those known under the trademarks Hastelloy or Monel. These latter materials have greater resistance to chemical corrosion than stainless steel. The center diaphragms 142, 144 of Figure 7; 186, 188 of Figure 9; and center diaphragm 214 of Figure 10 are preferably made of stainless steel AISI type 316.

It is noted that the transmitters illustrated herein have been illustrated, by way of example, as being of the type in which each of the two applied pressures, whose differential is to be sensed, acts on the transducer element by way of a corresponding barrier diaphragm, fill fluid, and capillary tube. It is noted further, however, that the disclosed control diaphragm means and capillary means for protecting the transducer element from excessive pressure, heat, and/or pulses are equally effective in transmitters wherein the differential pressure to be sensed is the difference between one pressure which acts on one side of the element by way of a barrier diaphragm, fill fluid, and capillary tube, and an atmospheric or a fixed pressure which acts on the other side of the element. That is, said element protecting means are equally effective where the two applied pressures are one process pressure and an atmospheric or a fixed pressure, and where only a single barrier diaphragm, fill fluid and capillary tube are therefore required and utilized. Thus, when the element 102 senses the difference between an atmospheric pressure or a fixed pressure and a process pressure transmitted to the wafer by a single barrier diaphragm, fill fluid, and capillary tube, the control diaphragm 34, etc., operates in the same manner as that described above to protect the element from excessive pressure. Likewise, the capillary tube which transmits the single process pressure to one side of the element operates in the same manner as that described above to minimize the transfer of heat and/or pulses from the process fluid to the element.

It is further noted that, although the control diaphragm means and the capillary means cooperate to protect the element in

the illustrated embodiments of the present invention, either of these means can be used individually to protect the element in those cases wherein the protection afforded by the other of the means is not required or desired.

In summary, there has been provided an improved differential pressure to electrical signal transmitter structure which embodies a relatively simple and compact arrangement for preventing excessive pressures from being applied across a differential pressure transducer element of the minute displacement type. The improved structure also embodies a construction which effectively isolates the transducer element from damaging heat and/or pulsations that are present in the process fluid applied to the head portion of the transmitter, and which avoids the need for relatively costly seals at the points where the element leads leave the transmitter.

WHAT WE CLAIM IS:

1. A differential pressure to electrical signal transmitter, comprising a pressure sensing head including a first block defining two oppositely facing support surfaces one sealed to the periphery of a first diaphragm and the other sealed to a second, control, diaphragm, a first passage interconnecting said support faces, said passage and the spaces between said diaphragms and their support surfaces together defining a first chamber of expansible volume, a second block defining two oppositely facing support surfaces one sealed to said control diaphragm and the other sealed to a third diaphragm, and a second passage interconnecting said support surfaces, said second passage and the spaces between said control and third diaphragms and their support surfaces together defining a fourth chamber; means for applying a first fluid whose pressure is to be sensed to a side of the first diaphragm opposite said first chamber; a differential pressure transducer unit located at a position remote from said head and including a transducer element for sensing the pressure difference in second and third chambers located on opposite sides of the element whereby to produce an electrical signal representative of said pressure difference; a capillary tube connecting said first chamber to said second chamber; a substantially incompressible fluid filling said first and second chambers and said capillary tube; a second capillary tube connecting said fourth chamber to said third chamber, a substantially incompressible fluid filling said third and fourth chambers and said second capillary tube; and means for applying a second fluid whose pressure is to be sensed to a side of the third diaphragm opposite said fourth chamber.

2. The transmitter of Claim 1, wherein the control diaphragm is stiffer than said first mentioned diaphragm and in such that an overload value of said first pressure causes the first diaphragm to engage its support surface and cause the control diaphragm to move away from its support surface, thereby preventing an overload condition occurring at said transducer element.

3. The transmitter of Claim 2, wherein the control diaphragm is preloaded to urge it toward its support surface.

4. The transmitter of any one of the preceding claims, wherein the or each diaphragm is contoured in cross-section and wherein each support surface is provided with a shape complementary to that of its respective diaphragm.

5. The transmitter of Claim 4, wherein the contours are provided by annular convolutions.

6. The transmitter of any one of the preceding claims, wherein the head includes a third block defining two oppositely facing support surfaces and disposed intermediate said first and second blocks, and wherein said control diaphragm is provided by two diaphragm elements each sealed to a respective one of the support surfaces of the third block and to a support surface of a respective first or second block, a third passage connecting said first chamber to a space formed between that one of the diaphragm elements disposed remote from the first chamber and the support surface provided for that diaphragm by the third block, and a fourth passage connecting said fourth chamber to a space formed between the other diaphragm element and the support surface provided for that other diaphragm by the third block.

7. The transmitter of Claim 6, wherein each diaphragm element is preloaded whereby to urge it toward its respective support surface provided by said first or second blocks.

8. The transmitter of any one of the preceding claims, wherein the ratio of the stiffness of the second diaphragm to that of the first and/or third diaphragms is of the order of forty to one.

9. The transmitter of any one of the preceding claims, wherein the transducer element is provided by a strain sensing resistance means which is diffused into a semiconductor wafer.

10. The transmitter of any one of the preceding claims, wherein the or each capillary tube is three or more inches long.

11. A differential pressure to electrical signal transmitter substantially as herein described with reference to Figures 1 to 5 or Figure 1 to 5 as modified by Figures 6 and 7, Figures 8 and 9 or Figure 10 of the accompanying drawings.

JOHN RIDDLE,
Agent.

Printed for Her Majesty's Stationery Office by The Tweeddale Press Ltd., Berwick-upon-Tweed, 1980.
Published at the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained

1573030 COMPLETE SPECIFICATION
6 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 1

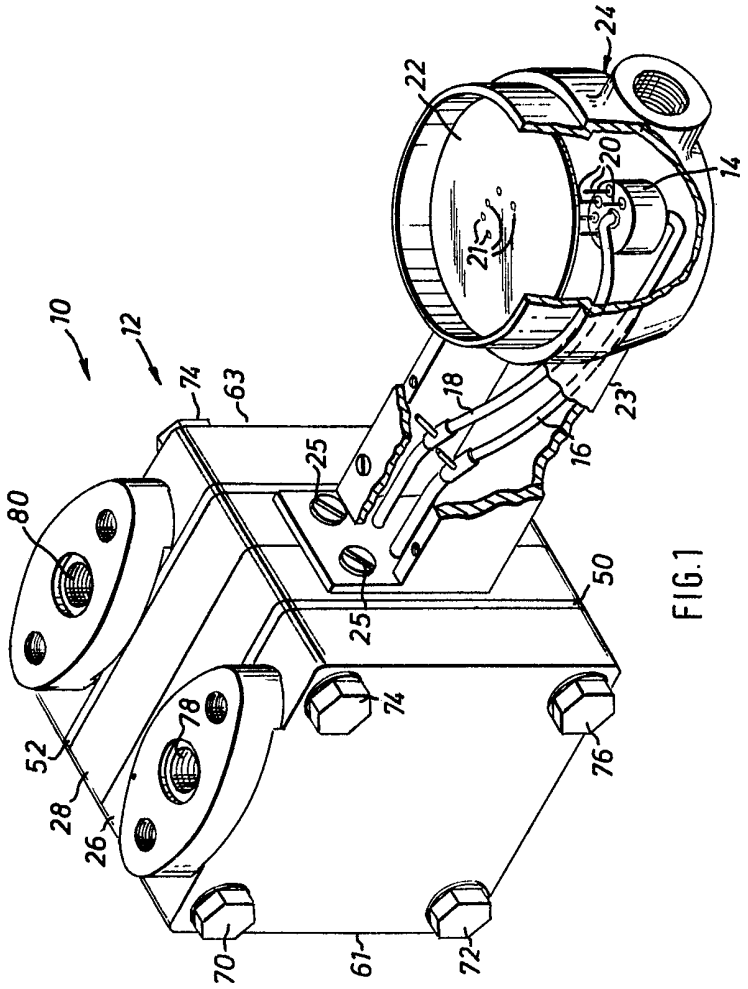



FIG.1

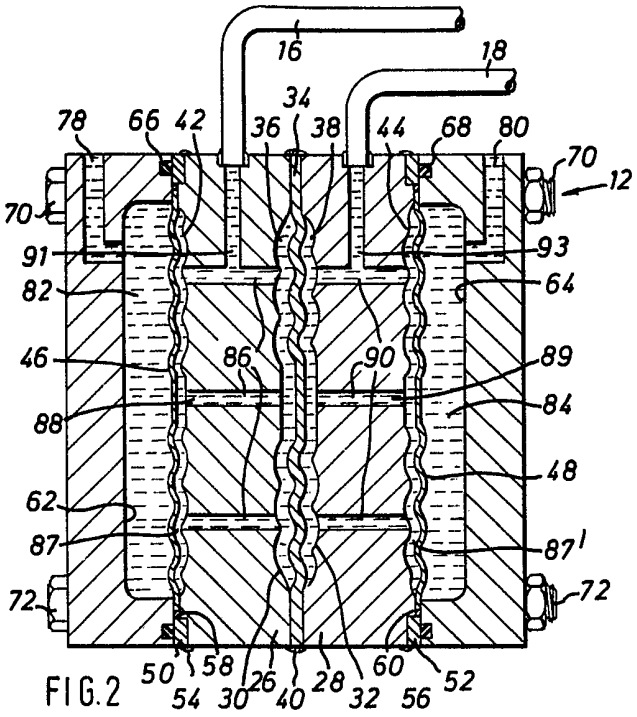

16
18
34
78
66
42
36
38
44
68
80
70
12
70
91
93
82
64
46
86
90
89
88
84
48
62
87
87'
72
72
50
58
26
28
60
52
54
30
40
32
56

FIG.2

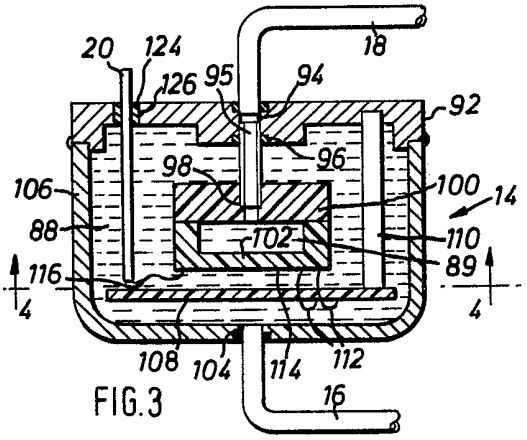

20
124
18
126
95
94
92
98
96
106
100
14
88
102
110
116
89
4
4
108
104
114
112
16

FIG.3

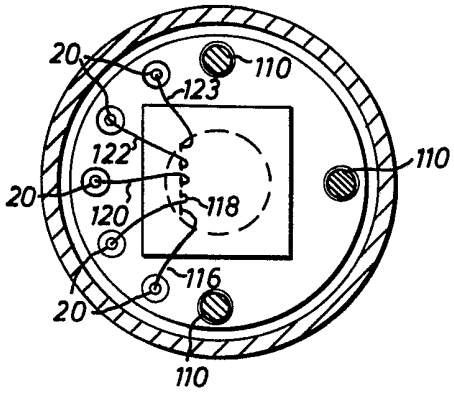

20
110
123
122
110
20
120
118
116
20
110

FIG. 4

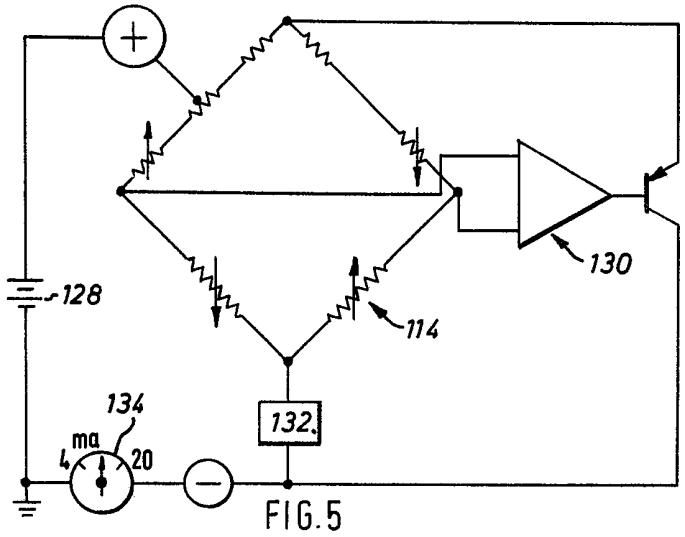

128
130
114
134
ma
4
20
132

FIG. 5

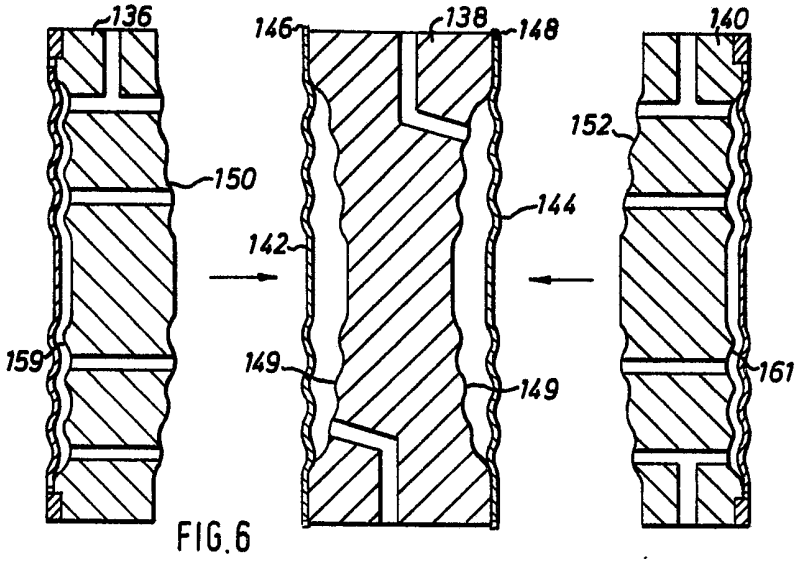

136
146
138
148
140
152
150
144
142
159
149
149
161

FIG.6

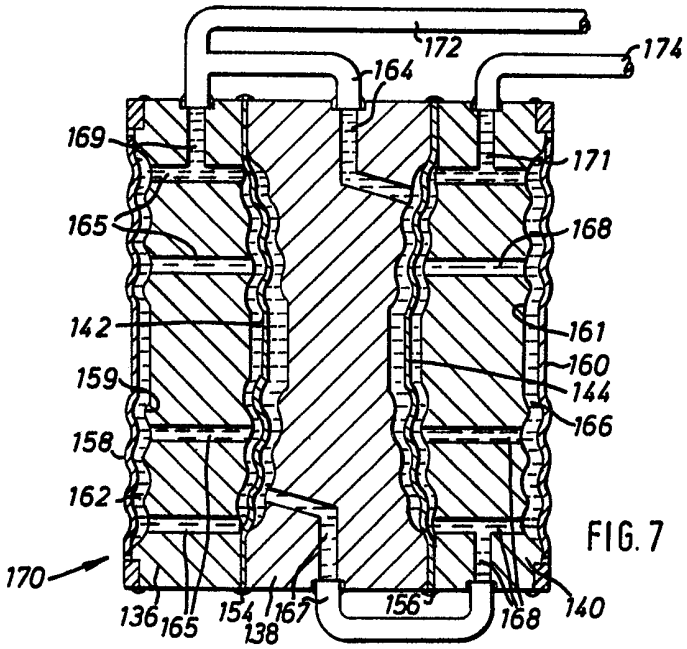

172
174
164
169
171
165
168
142
161
160
159
144
166
158
162
170
136
165
154
167
138
156
168
140

FIG.7

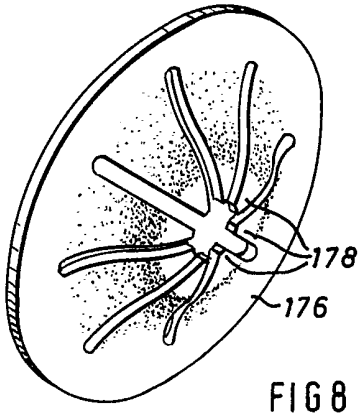

178
176

FIG 8

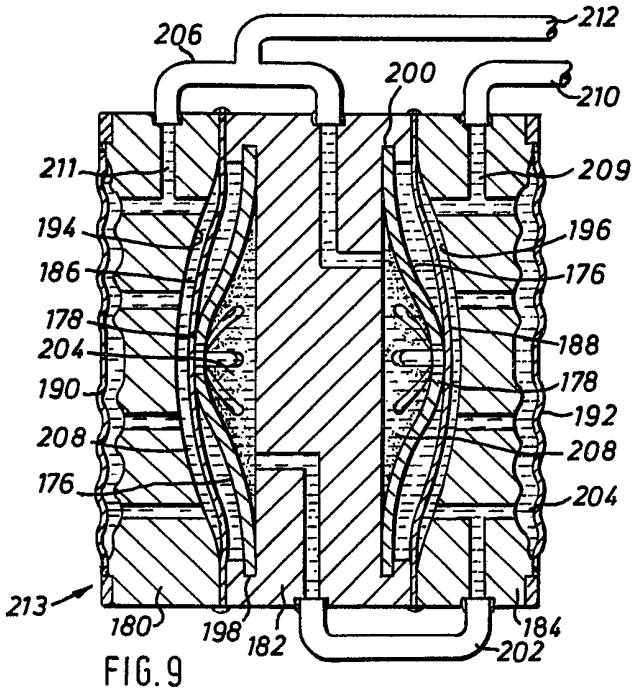

206
212
200
210
211
209
194
196
186
176
178
188
204
178
190
192
208
208
176
204
213
180
198
182
184
202

FIG. 9

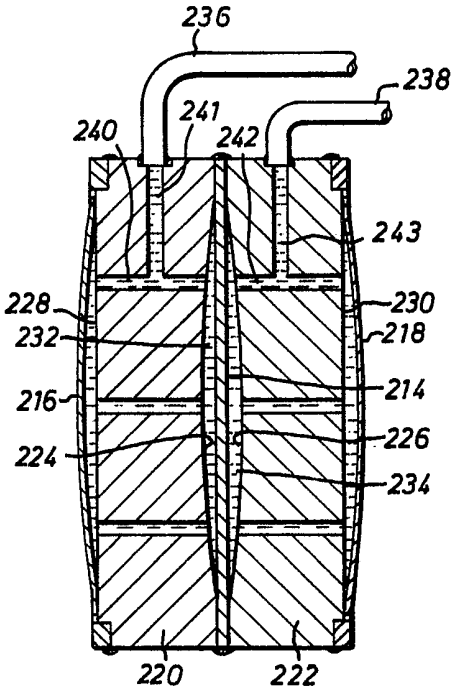

236
238
241
240
242
243
228
230
232
218
214
216
226
224
234
220
222

FIG.10