

PATENT SPECIFICATION

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(54) PRESSURE TRANSDUCER

(71) We, ROSEMOUNT INC., a corporation organized and existing under the laws of the State of Minnesota, United States of America, of 12001 West 78th Street, Eden Prairie, Minnesota, 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:—

The present invention relates to a capacitive pressure transducer having a sensing diaphragm.

According to this invention, a pressure transducer has a housing including a surface defining a first capacitor plate, a diaphragm mounted on the housing to be deflected under pressure with respect to said first capacitor plate; said diaphragm comprising a central sensing portion, a peripheral mounting ring fixedly mounted on said housing, and a web portion joining said ring and said central portion; said web portion having a thickness less than the thickness of said central portion, the radial length of said web between the ring and the central portion in relation to the thickness and diameter of the central portion being such that when the diaphragm is deflected under pressure the deflected shape of its central portion substantially corresponds to the deflected shape of a free edge diaphragm. A free edge diaphragm is a diaphragm having zero radial bending moment at its periphery.

In this construction in which the diaphragm includes a central sensing portion and a peripheral mounting ring with a web portion of less thickness than the central portion adjacent the edges of the central portion, the web portion isolates the bending stresses in the central portions of the diaphragm from the peripheral mounting ring. Pressure to be measured deflects the diaphragm toward or away from at least

one stationary capacitor plate formed on a surface of the pressure transducer.

With the present diaphragm construction, the diaphragm can be made to operate satisfactorily over a high pressure range without becoming excessively stressed. The web portion that connects the peripheral mounting ring of the diaphragm to the central portion is more highly stressed than a plate diaphragm of uniform thickness would be, but the overall performance of the diaphragm construction is considerably improved over a uniform thickness diaphragm. This is due to the isolation of stresses from the mounting ring, and the resultant minimization of the hysteresis and instability of the diaphragm.

In the drawings illustrating embodiments of the invention,

Figure 1 is a vertical sectional view through a sensing portion of a pressure transducer utilizing a diaphragm having a central sensing portion and a thin web joining the central portion to an outer mounting ring;

Figure 2 is a vertical sectional view of a diaphragm used in the pressure transducer of Figure 1 with parts broken away from the center portion; and

Figure 3 is a vertical sectional view of a modified form of the diaphragm of Figures 1 and 2.

United States Patent No. 3,618,390 for Differential Pressure Transducer, issued November 9, 1971 shows a typical differential pressure transducer structure. Therefore, the construction of the outer housing of the pressure transducer, and the mounting of the sensing cell and the connection for sensing circuitry is omitted from this description.

Figure 1 of this application corresponds generally to Figure 4 of U.S. Patent No. 3,618,390 but with the new sensing diaphragm construction in place, and generally

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includes the sensing cell 10 which comprises a large metal housing 11, which is made into two sections, 11A and 11B that are placed together along a parting line and 5 which are separated by a measuring or sensing diaphragm 12 made according to the present invention. The metal sections 11A and 11B have cup like, circular cross section cavities 13 which are filled with a rigid 10 insulation material, such as a glass or ceramic material. The insulation filling these cavities is placed into the cavities 13 and fused to the metal walls of the sections 11A and 11B. Because the pressure transducer 15 cell illustrated is used with isolating diaphragms that are in contact with the sensed fluid, and the sensing diaphragm 12 is isolated, the housing sections 11A and 11B 20 each have passageways leading therethrough from the interior to shallow cavities 14 on the opposite sides of each of the housing sections from the glass filled cavities 13. A separate ceramic tube 15 having a plurality of axially extending passageways 16 is positioned in each of the passageways in the 25 housing sections 11A and 11B before the glass filling the cavities 13 is fused into place, and these passageways 16, in connection with an opening 17, provide passageways for fluid or liquid to move between 30 cavities 14 and the pressure sensing chambers formed by diaphragm 12.

Small metal tubes 20 are placed through provided openings in each of the housing 35 sections 11A and 11B, and are fused into place with the ceramic filling material in the cavities 13. The tubes 20 and the ceramic tubes 15 extend out beyond the glass filling when the cavities 13 are filled (the housing 40 is still in two sections at this stage), and the metal tubes 20 also extend out beyond the peripheral wall of the housing sections.

Each of the individual housing sections 11A and 11B is ground off and a concave 45 surface which is, in part, substantially spherical is ground into the surface of each of the housing sections. These concave surfaces are shown in Figure 1, and after the shape has been made to correspond to the 50 deflection curvature of the diaphragm 12, the concave surfaces are covered with suitable thin metal coatings forming capacitor plates indicated at 21 and 22, respectively. The capacitor plates also therefore are 55 formed into a shape corresponding to the deflection curvature of the diaphragm. The metal tubes 20 are electrically connected to their respective capacitor plates and form electrical leads for the capacitor plates 21 and 22, which form the stationary capacitor 60 plates for the capacitance type differential pressure sensing cell shown. The passageways 16 in tubes 15 open through the capacitor plates, and the openings or passageways of the tubes 20 also open through

the capacitor plates.

After the two housing sections 11A and 11B have been individually prepared, the metal diaphragm 12 is placed between the 70 sections, and is welded into place with a continuous peripheral bead weld 23 which joins the two housings sections 11A and 11B together and holds the diaphragm. The weld 23 also hermetically seals the chambers on the interior of the housing defined between 75 the stationary capacitor plates 21 or 22, and the diaphragm 12.

First and second isolation diaphragms 24 and 25, respectively, are then welded into place around the peripheries of the depres- 80 sions or cavities 14 formed in each of the housing sections. The isolation diaphragms can be made of thin stainless steel and are corrugated so they will flex easily. The outer surfaces of these isolation diaphragms are 85 open to the pressure to be sensed, through a housing which is not shown.

When assembled, the sensing diaphragm 12 and the isolation diaphragms 24 and 25 form two chambers which are sealed sensing 90 chambers comprising a first chamber 26, and a second chamber 27. These sensing chambers 26 and 27 are filled with a liquid, which may be a silicone base oil, through 95 the respective tubes 20, and then the tubes 20 are sealed at their outer ends. The tubes 20 are used as leads in the capacitor plates after the chambers have been filled. The electrical lead to the diaphragm 12, which is the movable capacitor plate, can be con- 100 nected to the housing 11. Because the chambers 26 and 27 are completely filled and also the passageways 16 in the tubes 15, and the chambers 14, any differential pressure on the isolation diaphragms 24 and 105 25 will cause a deflection of the main sensing diaphragm 12 with respect to one of the other of the stationary capacitor plates 21 or 22. When initially filled, and with the isolation diaphragms at equal pressure, 110 the diaphragm 12 will extend substantially straight and midway between the stationary capacitor plates 21 and 22.

The unit is constructed so that the station- 115 ary capacitor plates 21 and 22 are conformed generally to the deflection curvature of the main sensing diaphragm 12, and are shaped and positioned so that they will substantially fully support the diaphragm 12 across its entire working surface when the 120 diaphragm 12 is subjected to its maximum rated pressure.

It can be seen that the main sensing diaphragm 12 is supported at its outer edge and it is supported all around the periphery. 125 Referring now to Figure 2, a diaphragm for use in a pressure transducer according to the present invention is shown and includes a center sensing portion 30.

The center portion 30 of the sensing dia- 130

phragm 12 is circular in plan view. Also, the outer periphery of the diaphragm 12 is circular. As shown, the diaphragm 12 has an outer mounting ring 31 that is connected to the sections 11A and 11B at its outer edges with the weld 23, and this ring 31 (which is an annular ring) is connected to the center sensing section 30 with a thin web 32. When the diaphragm center portion 30 deflects under pressure, the radial bending stresses at the outer corner where edge surface 30A joins the sensing surfaces, formed by the surfaces of the center portion 30 facing the capacitor plates, will be substantially zero and therefore the main center portion 30 performs nearly equal to a true "free edge" diaphragm in its pressure deflection characteristics. The "free edge" diaphragm is characterized by having a zero radial bending moment at its edge. The condition permitting the center portion 30 to act as a free edge diaphragm is accomplished when the slope of the deflection curve, i.e., the curvature of the diaphragm, at the corner where edge surface 30A joins the sensing surface of center portion 30 (or the angle of edge surface 30A with respect to a reference plane parallel to the undeflected diaphragm) is substantially the same as the slope of the deflection curve of the web 32, i.e. the curvature of the web 32, where it joins edge surface 30A, under the pressure loading to the entire diaphragm assembly.

Thus by having an outer mounting ring 31 that is attached to the housing, and having a thin web 32 of some radial length joining the outer ring 31 and the center diaphragm portion 30, the center diaphragm portion 30 is substantially isolated from its mounting ring so that hysteresis and instability effects are minimized. The bending moments at the outer mounting edges are substantially reduced, and the center portion 30 acts like a "free edge" diaphragm.

In Figure 3, a modified sensing diaphragm 12 is shown. In this particular form, the sensing diaphragm 12 has a center sensing portion 35, a mounting ring 36, and a joining web portion 37. The web portion 37 is non-uniform in thickness, varying from its greatest thickness "T" at its outer edges where it joins ring 36, to a minimum thickness "t" where it joins the center portion 35. The corners where the edge surface 35A of the center diaphragm portion 35 meets the sensing surfaces of the center portion 35A also move like a free edge diaphragm, and the tapered or variable thickness web 37 provides a section where the bending stresses are more evenly distributed over the length (radial length) of the web so that maximum stress is lower than would be found in the uniform thickness web 32 of Figure 2. The design shown in Figure 3 is preferred for

highest pressure ranges, but is more complex to manufacture. It does have the advantage of reducing the level of maximum stress and therefore increasing the pressure range which can be employed with the sensing diaphragm assembly 12 while retaining the benefits of the center portion 35 behaving substantially like a "free edge" diaphragm, and also isolating the clamped ring 36 from the main diaphragm portion 35.

With a radial length "L" for the webs, as shown in Figures 2 and 3, and a typical diaphragm diameter (D) of one and one-half inches, the ratio D/L may vary between 6 and 60. The ratio of L/T is typically greater than 0.5 and less than 5.0. For the design of Figure 3, the ratio of T/t is greater than 1, and preferably no greater than 4.

It should be noted that the diaphragm constructions of Figures 2 and 3 permit use of the diaphragm in differential configuration, or in other words where the deflection characteristics are substantially the same in both directions of deflection of the diaphragm in use.

It should be noted that the edge surfaces 30A and 35A are cylindrical and form right angles with the sensing surfaces of the center portions 30 and 35. The web joins the edge surfaces with only a very small fillet or radius.

WHAT WE CLAIM IS:—

1. A pressure transducer having a housing including a surface defining a first capacitor plate, a diaphragm mounted on the housing to be deflected under pressure with respect to said first capacitor plate; said diaphragm comprising a central sensing portion, a peripheral mounting ring fixedly mounted on said housing, and a web portion joining said ring and said central portion; said web portion having a thickness less than the thickness of said central portion, the radial length of said web between the ring and the central portion in relation to the thickness and diameter of the central portion being such that when the diaphragm is deflected under pressure the deflected shape of its central portion substantially corresponds to the deflected shape of a free edge diaphragm.

2. The pressure transducer of Claim 1 wherein said housing comprises a metal structure, and wherein the ring is welded to the housing to prevent movement of the ring relative to the housing during deflection of said central portion.

3. The pressure transducer of Claim 1 wherein the major portion of an edge surface of the central portion is substantially perpendicular to a sensing surface of the diaphragm.

4. The pressure transducer of Claim 1



phragm 12 is circular in plan view. Also, the outer periphery of the diaphragm 12 is circular. As shown, the diaphragm 12 has an outer mounting ring 31 that is connected to the sections 11A and 11B at its outer edges with the weld 23, and this ring 31 (which is an annular ring) is connected to the center sensing section 30 with a thin web 32. When the diaphragm center portion 30 deflects under pressure, the radial bending stresses at the outer corner where edge surface 30A joins the sensing surfaces, formed by the surfaces of the center portion 30 facing the capacitor plates, will be substantially zero and therefore the main center portion 30 performs nearly equal to a true "free edge" diaphragm in its pressure deflection characteristics. The "free edge" diaphragm is characterized by having a zero radial bending moment at its edge. The condition permitting the center portion 30 to act as a free edge diaphragm is accomplished when the slope of the deflection curve, i.e., the curvature of the diaphragm, at the corner where edge surface 30A joins the sensing surface of center portion 30 (or the angle of edge surface 30A with respect to a reference plane parallel to the undeflected diaphragm) is substantially the same as the slope of the deflection curve of the web 32, i.e. the curvature of the web 32, where it joins edge surface 30A, under the pressure loading to the entire diaphragm assembly.

Thus by having an outer mounting ring 31 that is attached to the housing, and having a thin web 32 of some radial length joining the outer ring 31 and the center diaphragm portion 30, the center diaphragm portion 30 is substantially isolated from its mounting ring so that hysteresis and instability effects are minimized. The bending moments at the outer mounting edges are substantially reduced, and the center portion 30 acts like a "free edge" diaphragm.

In Figure 3, a modified sensing diaphragm 12 is shown. In this particular form, the sensing diaphragm 12 has a center sensing portion 35, a mounting ring 36, and a joining web portion 37. The web portion 37 is non-uniform in thickness, varying from its greatest thickness "T" at its outer edges where it joins ring 36, to a minimum thickness "t" where it joins the center portion 35. The corners where the edge surface 35A of the center diaphragm portion 35 meets the sensing surfaces of the center portion 35A also move like a free edge diaphragm, and the tapered or variable thickness web 37 provides a section where the bending stresses are more evenly distributed over the length (radial length) of the web so that maximum stress is lower than would be found in the uniform thickness web 32 of Figure 2. The design shown in Figure 3 is preferred for

highest pressure ranges, but is more complex to manufacture. It does have the advantage of reducing the level of maximum stress and therefore increasing the pressure range which can be employed with the sensing diaphragm assembly 12 while retaining the benefits of the center portion 35 behaving substantially like a "free edge" diaphragm, and also isolating the clamped ring 36 from the main diaphragm portion 35.

With a radial length "L" for the webs, as shown in Figures 2 and 3, and a typical diaphragm diameter (D) of one and one-half inches, the ratio D/L may vary between 6 and 60. The ratio of L/T is typically greater than 0.5 and less than 5.0. For the design of Figure 3, the ratio of T/t is greater than 1, and preferably no greater than 4.

It should be noted that the diaphragm constructions of Figures 2 and 3 permit use of the diaphragm in differential configuration, or in other words where the deflection characteristics are substantially the same in both directions of deflection of the diaphragm in use.

It should be noted that the edge surfaces 30A and 35A are cylindrical and form right angles with the sensing surfaces of the center portions 30 and 35. The web joins the edge surfaces with only a very small fillet or radius.

WHAT WE CLAIM IS:—

1. A pressure transducer having a housing including a surface defining a first capacitor plate, a diaphragm mounted on the housing to be deflected under pressure with respect to said first capacitor plate; said diaphragm comprising a central sensing portion, a peripheral mounting ring fixedly mounted on said housing, and a web portion joining said ring and said central portion; said web portion having a thickness less than the thickness of said central portion, the radial length of said web between the ring and the central portion in relation to the thickness and diameter of the central portion being such that when the diaphragm is deflected under pressure the deflected shape of its central portion substantially corresponds to the deflected shape of a free edge diaphragm.

2. The pressure transducer of Claim 1 wherein said housing comprises a metal structure, and wherein the ring is welded to the housing to prevent movement of the ring relative to the housing during deflection of said central portion.

3. The pressure transducer of Claim 1 wherein the major portion of an edge surface of the central portion is substantially perpendicular to a sensing surface of the diaphragm.

4. The pressure transducer of Claim 1

wherein said surface defining said first capacitor plate is configured to substantially conform to the shape of said diaphragm as said diaphragm is deflected toward said first capacitor plate, said first capacitor plate being spaced from the diaphragm a distance whereby said central portion is supported substantially across its entire sensing surface by said first capacitor plate when said diaphragm is subjected to a preselected maximum pressure.

5. The pressure transducer of Claim 1 wherein said housing is constructed in two sections, said first capacitor plate being positioned on a first housing section, and a second surface of a second housing section defining a second capacitor plate, said diaphragm being mounted to said housing between said first and second capacitor plates, and means to permit subjecting said diaphragm to differentials in pressure on opposite sides thereof.

6. The pressure transducer of any of the preceding claims wherein said central portion is circular, and has a diameter D , and said web portion extends in radial direction between the central portion and said ring a distance L , and wherein the ratio D/L ranges between 6 and 60.

7. The pressure transducer of Claim 6 wherein said web portion extends in radial direction a distance L , and said web portion is of a substantially uniform thickness T , and wherein the web portion is constructed to a proportion whereby the ratio L/T is

greater than 0.5 and is less than 5.0.

8. The pressure transducer of Claim 6 wherein the web portion extends annularly around the central portion and increases in thickness in radially outward direction from a thickness t adjacent the edge of said central portion to a thickness T adjacent said ring and the ratio of T/t is greater than 1 and is no greater than 4.

9. The pressure transducer of Claim 1 wherein said central sensing portion has a sensing surface and an edge surface substantially perpendicular to said sensing surface, said edge surface surrounding said central portion, and said web portion being defined by a pair of substantially planar surfaces, at least one of which joins said edge surface of said central portion with a small fillet.

10. The pressure transducer of Claim 1 wherein said central sensing portion has a first surface facing the first capacitor plate, said web portion being defined by a pair of oppositely facing generally radially extending flat surfaces extending between said peripheral mounting ring and said central sensing portion.

11. A pressure transducer as claimed in claim 1 and constructed in accordance with Figures 1 and 2, or Figures 1 and 3 of the accompanying drawings.

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