Nov. 18, 1947. C. M. WOLFE 2,431,006

PRESSURE OPERATED RESISTOR

Filed June 11, 1946 3 Sheets-Sheet 1

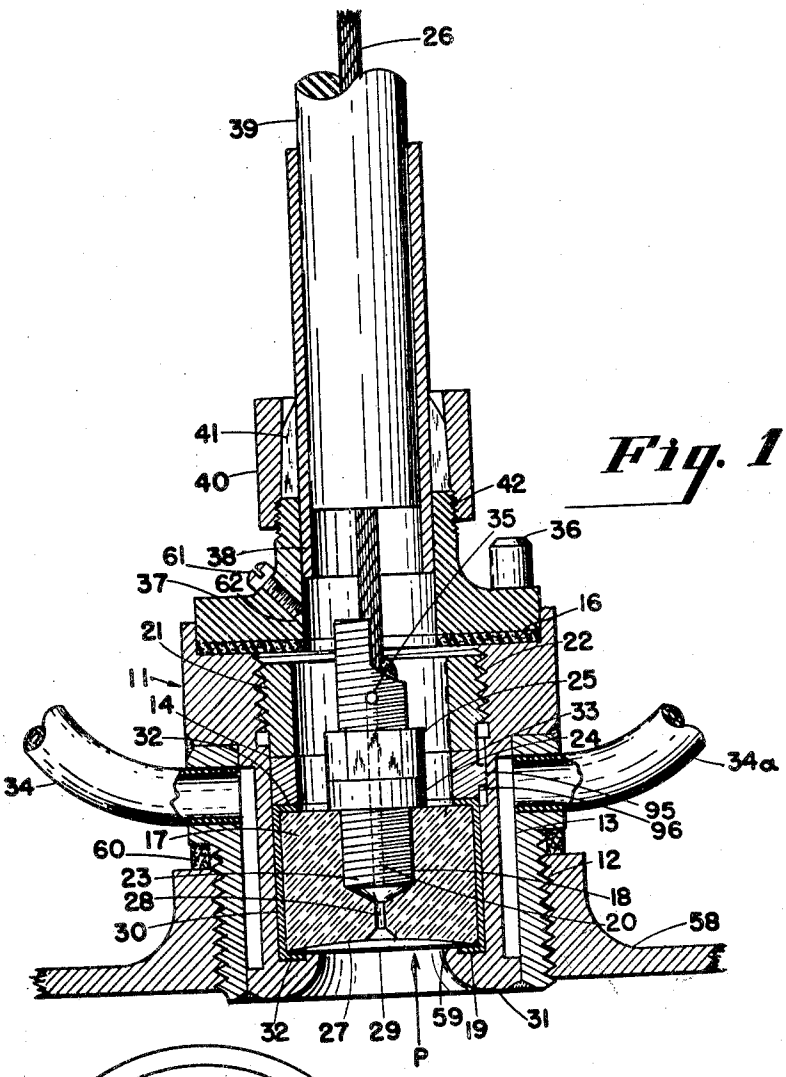


Fig. 1

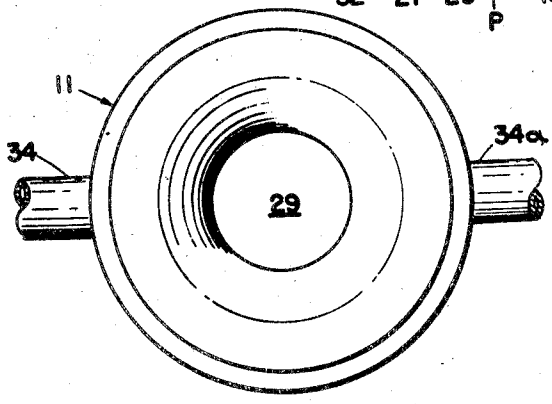


Fig. 2

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PRESSURE OPERATED RESISTOR

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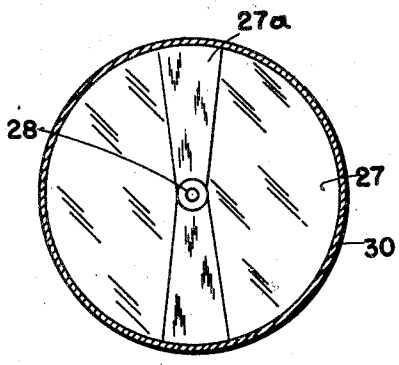


Fig. 3

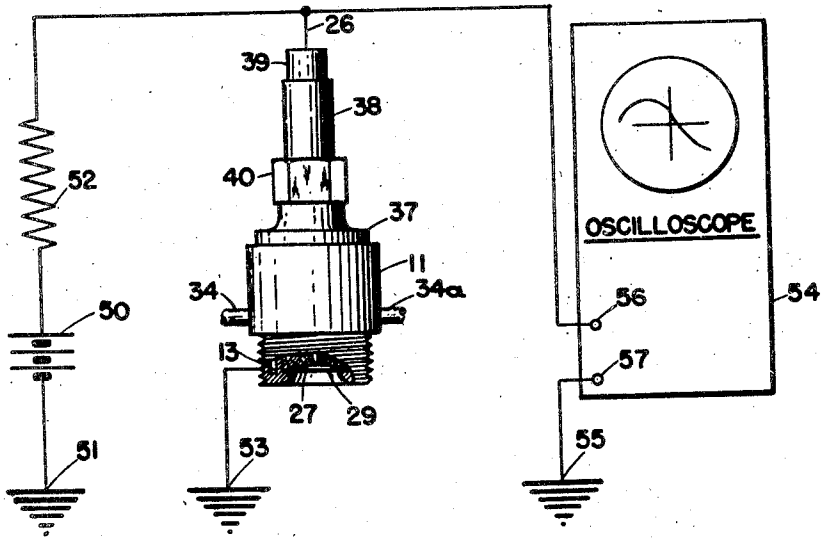


Fig. 4

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PRESSURE OPERATED RESISTOR

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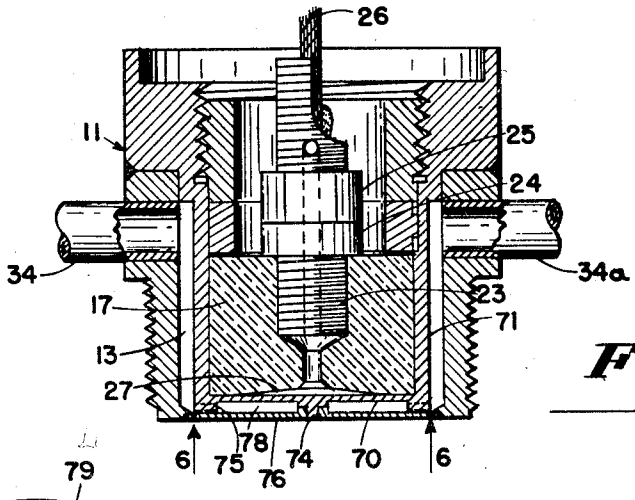


Fig. 5

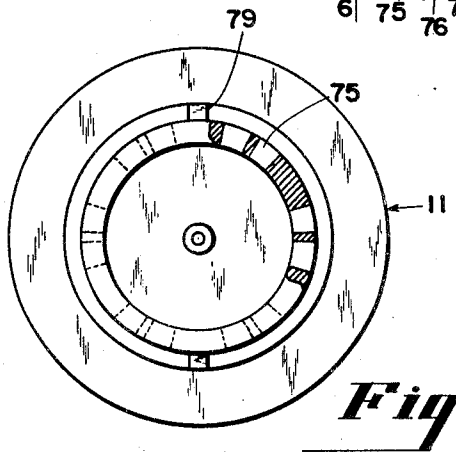


Fig. 6

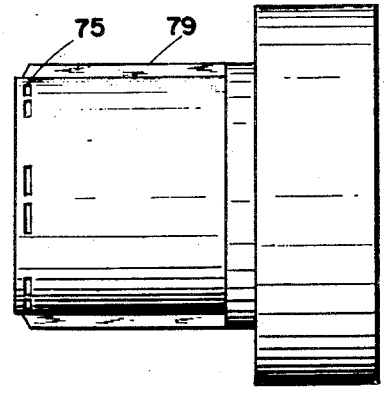


Fig. 7

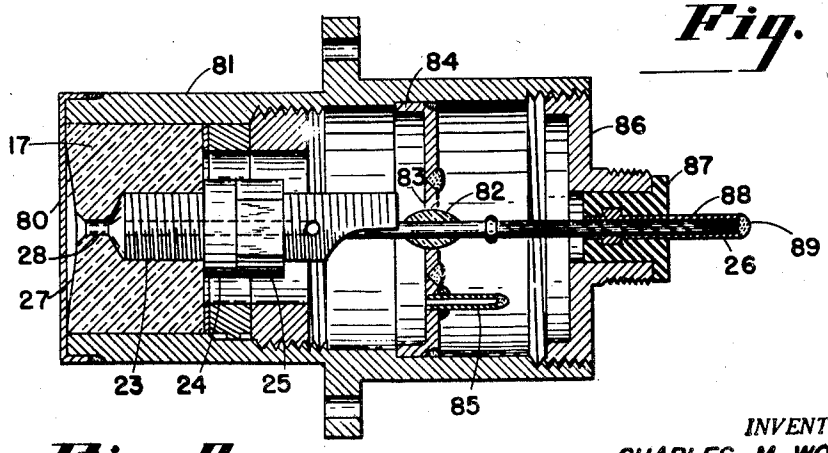


Fig. 8

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UNITED STATES PATENT OFFICE

2,431,006

PRESSURE OPERATED RESISTOR

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Application June 11, 1946, Serial No. 676,071

16 Claims. (Cl. 201—48)

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This invention relates to electrical pressure detecting devices, and more particularly to devices of this character which are especially adapted for detecting rapid variations of pressure.

An object of the invention is to provide a detecting device capable of responding to rapid fluctuations of pressure of the character encountered in the combustion chamber of a motor, in which a charge is fired to produce the power.

A related object is to provide a pressure detecting device capable of withstanding elevated temperatures without deleterious effect.

Although pressure detecting or pickup devices for various purposes have been known and used, it has been difficult to obtain an accurate response to the variations of pressure occurring in a device such as a jet propulsion motor operated by intermittent explosions, for the reasons that there is a rapid variation of pressure involving pressures both high above atmospheric and also subatmospheric pressures; and also because of the high degree of heat generated.

According to my invention, I overcome the difficulties and disadvantages which have been encountered in the use of prior known types of pressure pickup devices by the provision of a pickup which can be introduced into the wall of a motor combustion chamber at a position where the motor losses are relatively low, and which is capable of accurately detecting changes in pressure over a very wide range of pressures including minute pressure changes, wherein the variations may occur at relatively high frequency for example in excess of 200 or 300 cycles per second.

In carrying out my invention I provide an electrical resistance element whose resistance is adapted to be varied in correspondence with changes in pressure so that the change of resistance may be observed or recorded. A feature of my invention is the provision of a refractory type of insulating member on the surface of which I place a layer or film of conducting material, and I provide in cooperation with the coated surface, a pressure sensitive diaphragm adapted to be moved toward and away from the coated surface in correspondence with the pressure being detected. The arrangement is such that change of the deflection of the diaphragm in correspondence with change of pressure causes the diaphragm to move into more or less contact with the conductive coating on the insulating surface, thereby correspondingly lengthening or shortening the electrical path through the coating. The coating is a material of some appreciable resistance per unit length, and accordingly, a corresponding appreciable change of resistance, fluctuating with the pressure, is brought about.

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A preferred feature is the provision of a convex or concave surface of the insulator on which the coating is placed, with a corresponding convexity or concavity of the diaphragm when flexed.

A further feature is the provision of means for protecting the pickup unit against high temperatures.

The invention will be better understood from the following detailed description and the accompanying drawings of which

Fig. 1 shows an enlarged cross section view of an assembled pickup;

Fig. 2 shows a plan view of the pressure responsive end of the assembled pickup;

Fig. 3 shows one manner of plating the curved surface on the insulating member;

Fig. 4 shows schematically one type of wiring hookup using the pickup according to my invention;

Fig. 5 is a cross section view of the lower portion of the pickup showing a liquid cooled type of diaphragm;

Fig. 6 is a plan end view of the central portion of the pickup forming the inner wall of the cooling chamber taken on the lines 6—6 of Fig. 5;

Fig. 7 is a side elevation view of the portion shown in Fig. 6 showing the dividing fins; and

Fig. 8 is a cross section view showing a vacuum type of pickup unit.

The pickup shown in Figs. 1 and 2 comprises a body member 11 in the form of a cylinder provided around its lower outer circumference with threads 12 adapted to thread into a suitable threaded hole through the side of a chamber 58 whose pressure is to be measured; and to prevent leakage, a gasket 60 may be provided between a shoulder of body 11 and the threaded boss of the chamber. The body member 11 is provided with a central opening or bore 14 extending through the body member; and near the lower end of the body member, the body has formed an annular shoulder 59 protruding inwardly so that the diameter of the opening at 59 is substantially less than the diameter of the bore 14, and provides a flat ledge. Below the shoulder 59, the member is flared downwardly and outwardly toward the lower end 31 of the body member.

Within the lower end of bore 14, there is a cylindrical insulating member 17, such as quartz or the like, the lower surface of which is prefer-

ably somewhat concaved at 27, as shown. The insulator is placed within a casing 30 such as metal surrounding the cylindrical insulator wall and bent over the upper and lower surfaces of the insulator to provide retaining annular shoulders 32 for holding the insulator, as shown. The casing 30 is proportioned to fit snugly within the bore 14 and to rest upon a recess 19 or shoulder 59 of body member 11.

In accordance with a feature of my invention, there is fitted between the lower edge of insulating member 27 and the lower annular shoulder of casing 30, a thin diaphragm 29 arranged so that the diaphragm is firmly gripped around the circumference between the insulator and the casing and is free to move or vibrate upwardly toward the concave surface of the insulator in accordance with pressure within the chamber. Insulating member 17 is provided with a centrally located axial hole or bore 18, extending for a distance from the top of the insulator and provided with internal threads; and at the bottom of this threaded bore, a relatively smaller hole or bore 28 is continued centrally or axially through the insulator to the concave surface thereof, so that the space between the concave surface 27 and the diaphragm 29 is in communication with the opening 18.

The insulating member and its casing 30 are held in position by an annular washer 33 provided with a key 95 adapted to move up and down in a key slot 96 to hold the washer against rotation; and the washer is retained by a lock nut 21 threaded into the internal threads 22 formed within the upper portion of body member 11. The arrangement is such that when the lock nut is tightened down against washer 33, the casing 30 is firmly held in position against the recessed surface 19 of the body member.

There is threaded into the opening 18 of the insulating member 17 a stud 23, which is of a suitable metal having high electrical conductivity, such as copper, silver or brass; and the stud is locked in position by a collar 24 and a lock nut 25 both of which are threaded around the outside of the stud above the insulating block. The stud is provided with an axial hole 20 extending from its lowermost end so that it is in communication with opening 28, and extends upwardly to a position above the lock nut 25 where it exits through opening 35 in the side of the stud to the chamber above the insulating block.

Electrical contact is made with the stud by means of an electrical cable wire 26 passing through a surrounding insulating member 39 which is held within a sleeve 38 at the top of the device. The lower end of sleeve 38 is fitted snugly within the central opening through a cap 37 which is bolted or fastened to a body member 11 by suitable bolts or studs 36; and to prevent leakage between the body members and the cap, there is provided a suitable gasket 16. Sleeve 38 is held in position by a split tapered collar 41 which is pressed against sleeve 38 when tapered annular nut 40 is tightened on cap 37.

Since there is a possibility that some of the fluids under pressure in chamber 58 can accumulate in the space between the diaphragm and the plated insulator surface due to imperfect contact between these two surfaces at their periphery, it is desirable to provide a venting means for equalizing the pressure within the unit to that of the surrounding atmosphere. This may be accomplished by providing a threaded vent

hole 62 drilled in the side of cap 37 which may be closed by a machine screw 61.

For the purpose of cooling, if cooling be desired, there is provided an annular space or jacket 13 around the lower portion of the body member 11, through which water or other suitable cooling fluid may flow; and to convey the fluid, there is provided inlet and outlet conduits 34 and 34a, respectively, on opposite sides of the jacket so that the fluid may flow in one conduit, through the jacket and out the other conduit.

The holes 28 and 18 are well coated at least over part of their surfaces, and preferably over all of their surface, with a suitable electrical conductive coating of low resistance which is in contact with the stud 23 and carries the conducting continuity down to the lower surface 27 of the insulating block. This lower surface of the insulating block is also provided with an electrically conductive surface. This electrical conducting surface may extend over the entire surface 27, but preferably it is formed only in strips 27a as shown in Fig. 3. The arrangement is such that the strips 27a or such parts of the surface 27 as are coated, are electrically connected with the stud.

The coating material may be some suitable material such as a metal plating adapted to adhere to the surfaces and to withstand the heat which is present; such as gold, platinum or other metals having high corrosion resistance. The conductivity per unit length of the coated surface may be regulated by regulating the thickness of the film which is deposited on the surface 27. The arrangement is such that when the diaphragm 29 is flexed upwardly toward the insulating block by pressure conditions in the chamber, it comes into contact with the conductive coating on surface 27. Under conditions of light pressure it is in contact only near the periphery; and when the pressure increases, the area of contact increases inwardly toward the center. The amount which the diaphragm is in contact depends on the amount of flexing of the diaphragm. Thus, a relatively high pressure will bring more of the diaphragm over a greater surface of strips 27a than will a lower pressure. The greater the surface of strips 27a which are in contact with the diaphragm, the shorter will be the length of the electrical path to the stud, and consequently the less will be the resistance of the path from the diaphragm to the stud. The amount of this resistance is accordingly a measure of the amount of pressure which is flexing the diaphragm.

It may sometimes be desirable to provide fluid cooling for the diaphragm, as well as around the sides of the device. A modified construction for doing this is shown in Figs. 5, 6 and 7, wherein there is shown a modification of the construction of the lower portion of the arrangement shown in Fig. 1. Except for the changes shown in Figs. 5 to 7, the construction may be the same as shown in Fig. 1.

Referring to Fig. 5, the diaphragm 70, corresponding to the diaphragm 29 in Fig. 1, is built integral with the body portion 71 which encloses the insulating block 17, and at a central position on the bottom of this diaphragm there is provided an extension button 74 adapted to fit tightly into an opening of an outer diaphragm 76, which is adapted to be welded or otherwise suitably fastened around its periphery to the openings in the lower part of the body member. For this purpose the lower periphery member of the body

71 is carried down to meet this outer diaphragm 76. A suitable space 78 is provided between the inner and outer diaphragms, and a number of passageways or slots 75 are cut through the portion of the body member which grips the insulating block so that the cooling fluid is free to flow from jacket 13 through the passages 75 and into chamber 78.

To insure that the cooling fluid will flow through chamber 78, and not merely around the annular chamber 13, there may be provided suitable longitudinal fins 79 attached along the outer circumference of body portion 71, so that when the cooling fluid flows into the chamber 13 at a position between these fins, it cannot flow directly past the fins, but must flow down into the chamber 78 and then to the outlet conduit up through the jacket 13 at the other side of the fins.

It may sometimes be desired to provide a constant reference pressure at the diaphragm, and also to provide a hermetically sealed unit to prevent grit or dirt from impairing the operation. Such a hermetically sealed unit provided with vacuum between the diaphragm and the conductive coated surface of the insulator is shown in Fig. 8. This unit comprises a diaphragm 80 which is firmly attached to the outer shell 81 to form a vacuum type seal by some suitable means, preferably welding. The lead wire 26 coming into the unit is welded to an insulator 82, which in turn is sealed to a plate 83. Plate 83 in turn is attached to a cup-shaped member 84 which is secured to the sides of the shell 81 of the pickup unit. All these joints are made vacuum-tight. The other internal portions of the assembly are similar to those used in Fig. 1. The unit is made vacuum-tight by attaching securely the annular plate 83 to the cup-shaped member 84 by any suitable means such as welding. The unit is then evacuated through conduit 85 provided for this purpose. After a satisfactory vacuum has been attained the end of conduit 85 is sealed off thereby insuring a complete evacuation of the operating portion of the pickup. It is desirable, due to the ease with which insulator 82 may be broken by any undue motion, to firmly anchor cable 26 in a permanent position. This may be done by employing a threaded cap 86 which threads into the inner wall of outer shell 81 of the unit. Cap 86 is provided with an open center in which an electrical insulator 87 may be placed. The central portion of this insulator is provided with a metal channel 88 which is securely held in insulator 87. The metal channel 88 permits cable 26 to slide through easily. When the cable 26 has been placed under the proper tension the projecting end of channel 88 and cable 26 are welded or soldered together thereby permanently anchoring cable 26 and preventing possible breakage due to unnecessary motion. The projecting end 89 of metal channel 88 may be coupled to a standard electrical plug type connection such as a Cannon fitting which in turn will then connect with the cable and recording unit as shown in Figs. 1 and 4.

Owing to the hermetic sealing of the unit, dirt is not likely to get in between the diaphragm and the conductive coating on the insulator. It will be recognized that if grit or dirt should get in there, it would change the electrical resistance of the unit and thereby impair the readings obtained from it.

Although the conductive coating material placed on the surface of the insulator is preferably inherently a good electrical conductor, nevertheless, owing to the thinness of the layer, it has an appreciable resistance along its path from the central hole 28 to the position of contact with the diaphragm; and accordingly a small change in the length of this path due to a variation in pressure will cause sufficient change of the resistance to be detected.

In the embodiments herein above described, the refractory having the coated conductive layer is shown as having a concave surface against which the diaphragm is flexed by pressure. It should be recognized, however, that the coated surface of the insulator may be some other shape than concave. It may, for example, be made convex if desired, with a corresponding suitable shape for the diaphragm to enable it to function in the manner described. The diaphragm which is to operate in cooperation with the coated insulating surface will usually be a flat surface as illustrated. However, the diaphragm surface may, if desired, be made concave, somewhat according to the concavity of the insulating surface; or concave, if the insulating surface be convex.

The diaphragm should be of a suitable material having the desired thermal resisting properties required by its location; and also a sufficiently high natural frequency of vibration to enable it readily to respond to the rapid variations of pressure which it is desired to be detected. A diaphragm for performing in this manner may be a thin sheet of stainless steel, or Invar, or other suitable metal alloy. The diaphragm could, if desired, be made of an insulating material such as quartz, particularly fused quartz, coated with a suitable deposited conductive coating or film of metal, making contact with the grounded or base element of the unit. Quartz diaphragms can reach a natural frequency as high as 50,000 cycles per second without any difficulty. This property, in addition to the fact that quartz has a low temperature coefficient of expansion, makes it a desirable diaphragm material for operations at high temperatures.

Although the entire surface of the insulator, which is juxtaposition with the diaphragm, may be coated, as noted above, it will often be desirable for the purpose of providing a linear relationship between change of resistance and change of pressure, to coat only a portion of the surface, and to make this coating in the shape of the strips illustrated in Fig. 3.

At the condition of reference pressure, which in many cases will be atmospheric pressure, only a small portion of the plated or metalized surface on the insulating surface is in contact with the diaphragm surface; and under this condition the resistance from the diaphragm to the cable is a certain appreciable amount. When pressure is applied in the direction indicated by the arrow P in Fig. 1, the diaphragm becomes flexed toward the coated insulating surface, thereby increasing the amount of area of the insulating surface 27 covered by the diaphragm, and reducing the length of path of the coating 27*a* on the insulation surface which is not covered by the diaphragm. This appreciably reduces the resistance of the path to the cable, thereby causing a lower voltage to result across the pickup device when voltages are applied to it. Conversely, when the pressure decreases the length of the path along the coating 27*a* which is not in contact with the diaphragm, increases, and since the resistance

per unit length of the coating 27a on the insulating surface is much greater than the resistance per unit length of the diaphragm, the resistance across the pickup increases appreciably. When the pressure becomes sub-atmospheric, the resistance continues to increase because even less of the diaphragm will be in contact with the coating 27a than under the condition of reference pressure.

The operation of the pickup at sub-atmospheric pressures can be facilitated by proper adjustment of the contours of the contacting surfaces of the diaphragm and end of the insulator. This may be done by selecting the contour of the diaphragm 29, and surface 27 of the insulator 17 so that the diaphragm is capable of responding to pressures below atmospheric. This result will be achieved by making the normal point of contact between the two surfaces occur at a point closer to the center of the insulator, thus placing a wider surface of the diaphragm and insulator in contact under normal pressures. This will permit the diaphragm to pull away from the insulator under reduced pressures thus in effect increasing the diametrical path between the points of contact of diaphragm 29 and curved surface 27. The insulator and diaphragm are so positioned with respect to shoulder 19 as to provide ample room for motion of the diaphragm away from the curved surface 27 when the pressure falls below atmospheric.

All of the embodiments of the invention described above operate on the principle that the electrical resistance from the cable wire 26 to the base or body portion is dependent on the pressure in the chamber and that the unit changes its resistance in correspondence to changes in chamber pressure. Accordingly, a suitable electrical circuit for detecting and indicating the changes of resistance may be used for the pressure measurement. A suitable measuring circuit, for example, is shown in Fig. 4.

In Fig. 4, the circuit comprises a battery 50, connected at one side to ground 51, and connected at the other side in series with a resistor 52. The series arranged battery and resistor is connected across the input terminals 56 and 57 of an oscilloscope 54, so that the viewing screen of the oscilloscope can be made to give a picture of the variation in pressure through the cycles of pressure pulsations in the chamber. The pressure pickup unit is shunted across the oscilloscope to provide a shunting effect in correspondence with the change of pressure. For this purpose, the cable wire 26 is connected to one terminal 56 of the oscilloscope and the diaphragm side of the unit, which is the grounded side, is connected to a ground 53, the same as the other terminal of the oscilloscope. Accordingly, the fluctuations or pulsations of pressure in the chamber are converted to corresponding variations of shunting conductance across the oscilloscope, which has the effect of varying the voltage on the oscilloscope input terminals from the battery; and in this way, the pattern at the screen of the oscilloscope is produced, so that it represents the pressure pattern in the chamber.

The circuit of Fig. 4 is given by way of illustration rather than of limitation, as it will be recognized that other means may be used to obtain the indications of pressure variation at the pickup device. If desired, a recording form of oscillograph may be used to make a record of the pressure changes.

Not only is the pickup device useful for recording fluctuations or pulsations of pressure, but it is also useful for producing an indication of static pressures.

It will be recognized that the meter or detecting instrument connected to terminals 26 and 53 may if desired be calibrated so as to read directly in pressure.

The apparatus described possesses the advantage that it may be constructed to meet a broad range of requirements by proper selection of material for the diaphragm and by increasing or decreasing the diaphragm thickness and diameter. Thus, the apparatus may be easily adapted for the measurements of either low or high pressures and can be used for recording pulsating pressures alternating at high frequency.

A decided advantage in favor of this type of device is that it possesses simplicity of mechanical design as well as simplicity of the electrical circuit. The unit possesses the further advantages that it can be made small in size, has a large output voltage, is substantially free from the effects of vibration and temperature, and is capable of responding to steady pressures as well as pulsating or oscillating pressures. The combination of all these advantages make it particularly desirable for use in many difficult test problems.

A further advantage of the apparatus is that it may be employed for measuring pressures generated in a chamber under considerable temperature without affecting the durability or life of the apparatus. The use of the cooling jacket, described above, enables the apparatus to be effectively used under conditions which would cause the speedy deterioration of most existing pressure devices.

I claim:

1. An electrical pressure pickup unit comprising an electrical insulator having a curved end and provided with a central bore extending throughout the insulator, which is parallel to the longitudinal axis of said insulator, a metal film deposited on said curved end of the insulator and on the walls of the central bore, a metal surfaced diaphragm whose outer circumference is proportioned to normally rest against the outer circumference of said curved surface of the insulator, a metal stud firmly secured in the central bore of said insulator making contact with the deposited metallic film on the sides of the bore, said stud being provided with a vent hole extending from the closed end of the stud and opening in the unengaged portion of the stud, a housing surrounding said insulator and diaphragm provided with an opening to expose said diaphragm to pressure, means for attaching said housing, locking means for holding said insulator and diaphragm rigidly in place within said housing and electrical conducting means attached to said metal stud for connecting the inner portion of pickup unit with an external circuit.

2. An electrical pressure pickup unit according to claim 1 in which said diaphragm is made of metal.

3. An electrical pressure pickup unit according to claim 1 in which the diaphragm is of refractory material having a high melting point and a high natural frequency of vibration and having a metal film deposited on the surface thereof.

4. An electrical pressure pickup unit according to claim 1 in which the diaphragm is constructed of quartz having a metal film deposited on the surface thereof.

5. An electrical pressure pickup unit according to claim 1 in which the diaphragm is constructed of fused quartz having a metal film deposited on the surface thereof.

6. An electrical pressure pickup unit according to claim 1 in which the metal film deposited on the curved end of the insulator is confined to a diametrical strip extending from the outer circumference of the insulator and passing through the center.

7. An electrical pressure pickup unit according to claim 1 in which the metal film deposited on the curved end of the insulator covers only a portion of the end surface.

8. An electrical pressure pickup unit according to claim 1 in which a cooling jacket is provided within the walls of said housing and substantially surrounding said insulator.

9. An electrical pressure pickup unit comprising an electrical insulator having a curved end surface having an outer circumference and provided with a bore extending through the insulator, a metal film on said curved end surface and on the walls of the central bore, a metal surfaced diaphragm whose outer circumference is proportioned normally to rest with its metal film against the outer circumference of said curved surface, a metal stud held in the central bore of said insulator and making contact with the metal film on the sides of the bore, said stud being provided with a vent hole extending from the end of the stud adjacent the diaphragm and leading to a position away from the diaphragm, a housing surrounding said insulator and diaphragm and provided with an opening to expose to pressure the side of said diaphragm opposite the insulator, a liquid cooling jacket provided in the wall of said housing and substantially surrounding the insulator, a liquid cooling jacket substantially covering the face of said diaphragm, a conduit for connecting the cooling jacket in the housing with the cooling jacket in front of the diaphragm and means for attaching an electrical conductor to said metal stud for connecting said stud with an external circuit.

10. An electrical pressure pickup unit comprising an electrical insulator having a curved end and provided with a central bore extending through the said insulator which is parallel to the longitudinal axis of said insulator, a metal film deposited on said curved end and on the walls of said central bore, a housing surrounding said insulator, attaching means for firmly securing said housing, a metal surfaced diaphragm having its outer circumference securely attached to the outer circumference of said housing to form a vacuum-tight joint, a metal stud firmly secured in said central bore making contact with the metal film deposited on the inner surface of said bore, said stud provided with a vent hole extending from the closed end of the stud and opening in the unengaged portion of the stud, an electrical conductor attached to said metal stud, said conductor securely embedded in an insulating material to form a vacuum-tight seal, a plate attached to said insulating material so as to form a vacuum-tight seal, said plate securely attached to the inside of said housing so as to form a vacuum-tight seal, an electrical cable attached to said conductor and means for permanently securing the electrical cable in a fixed position with respect to said housing.

11. An electrical detecting device adapted to respond to pressures in a chamber, said device comprising an insulating member having a surface coated with an electrical conducting material, a diaphragm held in relation to the surface of the member such that a portion of the diaphragm is in contact with a corresponding portion of the conducting coating on the insulating member, and means for communicating the pressure to be measured to the diaphragm to flex the diaphragm in response to the pressure whereby the amount of diaphragm surface in contact with the conductive coating varies in correspondence with the pressure.

12. Apparatus according to claim 9 in which the coated surface of the insulator is concave and the diaphragm is substantially flat and is held at its periphery against the coating of the surface.

13. Apparatus according to claim 9 in which the diaphragm has a natural frequency in the order of 50,000 cycles per second.

14. Apparatus according to claim 9 in which the conductive coating on the insulating member is in the form of a strip of the coating.

15. An electrical detecting device adapted to respond to fluctuating pressures in a chamber, said device comprising an insulating member having a surface coated with an electrical conducting material, an electrical conducting diaphragm held in relation to the conducting material such that a portion of the diaphragm is in contact with a corresponding portion of the conducting material, said insulating member having a hole through it in communication with the conducting material at one end and in communication with a conducting terminal at the other end, an electrical conducting material passing through the hole and connecting the terminal with the coated material on the surface, and means for communicating the pressure to be measured to the diaphragm to flex the diaphragm in response to the pressure, whereby the amount of diaphragm surface in contact with the conductive coating varies in correspondence with variations of the pressure.

16. An electrical detecting device adapted to respond to pressures in a chamber which is subjected to heat, said device comprising an insulating block having a surface coated with an electrical conducting material, a metallic diaphragm held in relation to the surface such that a portion of the diaphragm is in contact with a corresponding portion of the coating, an outer diaphragm covering and connected to the first-mentioned diaphragm, and means for communicating the pressure to be measured to the outer diaphragm to flex it in response to the pressure whereby the flexing of the outer diaphragm correspondingly flexes the first-mentioned diaphragm to vary the amount of coated surface with which the first-mentioned diaphragm is in contact, in accordance with changes of pressure.

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