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TACHOMETER

3,059,480

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2 Sheets-Sheet 1

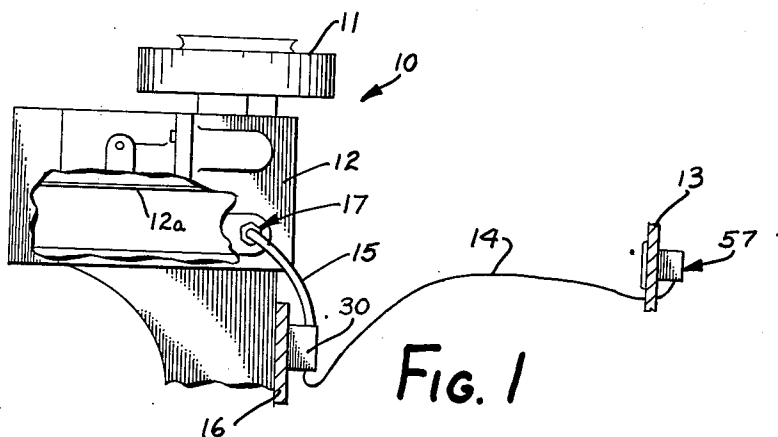


Fig. 1

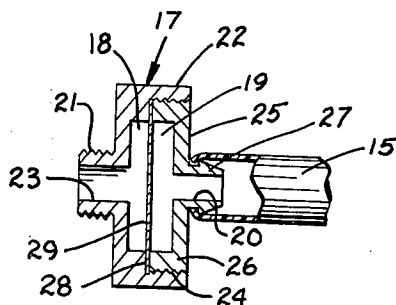


Fig. 2

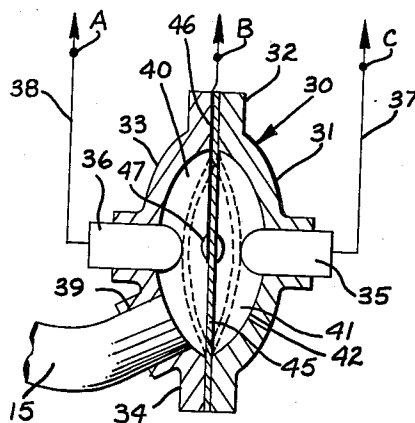


Fig. 3

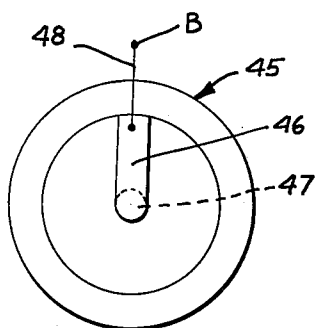


Fig. 4

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2 Sheets-Sheet 2

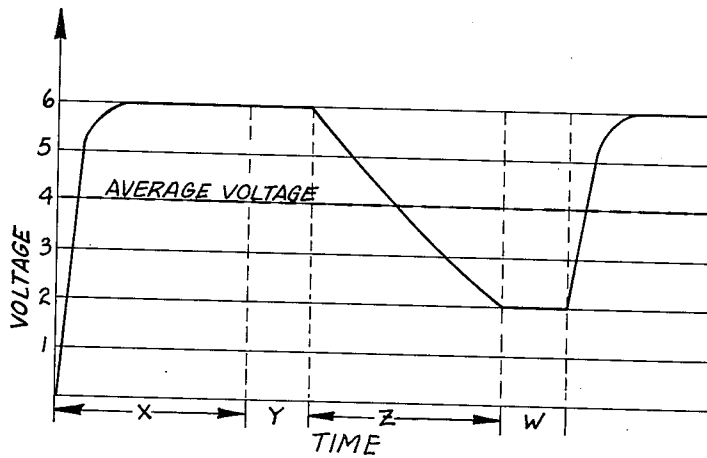


FIG. 6

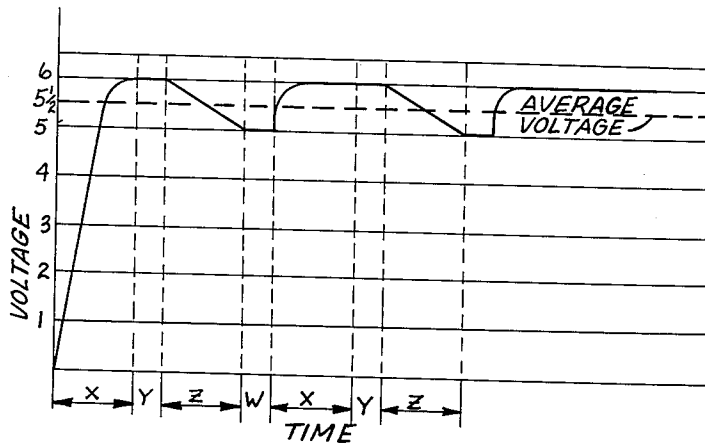


FIG. 7

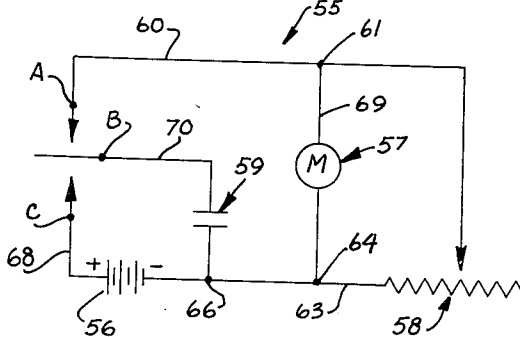


FIG. 5

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This invention concerns tachometers for reciprocating internal combustion engines, and more particularly tachometers of the type which base their indication on the repetition rate of pressure variations inside the engine.

Present tachometers usually use the ignition system of the engine to provide impulses which are counted by an appropriate mechanism to provide an indication of the number of engine revolutions per minute. This method is unsatisfactory for four reasons: first, separate models of tachometers have to be provided for engines with different numbers of cylinder or different ignition systems; second, misfirings or other ignition disturbances can cause false readings; third, failure of the tachometer can interfere with proper operation of the ignition system; and fourth, installation of a tachometer in the ignition system requires skilled labor and is time-consuming.

The present invention avoids these disadvantages by measuring the repetition rate of pressure variations in the engine itself. It is therefore particularly adapted to two-cycle engines, in which the crankcase is divided into pressure-tight compartments, one for each cylinder, in which the fuel mixture is compressed on the downstroke of the piston, and a vacuum created to suck in fresh fuel on the upstroke of the piston. The pressure variations thus created are transmitted to a pressure-operated switch through a pressure-resistant conduit which may be attached to the crankcase at any desired non-critical location. The switch utilizes the alternating compression and vacuum to alternately charge a condenser from a constant power source and discharge it through a microammeter associated with a resistor. The microammeter indicates the average discharge current, which is proportional to the frequency of operation of the switch.

The primary object of this invention is therefore to provide a tachometer for internal combustion engines which measures pressure variation pulses in the engine itself.

Another object of this invention is to provide means for utilizing pressure variations in an internal combustion engine to switch an electrical circuit for providing an indication of engine speed.

Still another object is to provide a switching device utilizing both compression and vacuum pulses for switching an electrical tachometer circuit.

A further object of this invention is to provide a tachometer which is inexpensive, easily installed, accurate, usable without changes on any two-cycle engine, and whose failure does not prevent the functioning of the engine.

These and other objects and advantages will become more apparent upon a perusal of the following specification, taken in conjunction with the accompanying drawings in which:

FIG. 1 is a side elevational view of the tachometer assembly.

FIG. 2 is a cross sectional view of a coupling diaphragm of the assembly.

FIG. 3 is a cross sectional view of the pressure switch of the tachometer assembly.

FIG. 4 is a side elevational view of the electrical contact diaphragm.

FIG. 5 is a schematic view of the electrical circuit of the tachometer assembly.

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FIG. 6 is a graph showing the voltage across the storage condenser when the engine is running at low r.p.m.

FIG. 7 is a graph showing the voltage across the storage condenser when the engine is running at a higher r.p.m.

Basically, the tachometer of this invention receives an input in the form of pressure variations from a pressure-tight enclosure within the engine, such as the crankcase of a two-cycle engine, into which the tachometer is connected by an appropriate fitting. These pressure variations are transmitted to a pressure-responsive switch through a pressure-resistant conduit. Gas-tight pressure-transmitting means such as a flexible gas-tight membrane may be interposed in said conduit to prevent corrosive gases from the engine from reaching the pressure-responsive switch. The switch preferably consists of a housing or casing having two chambers separated by a flexible contact-bearing diaphragm, one chamber being connected to the pressure-transmitting conduit, the other being open to the atmosphere. The contacts on the latter diaphragm are used to close a charging circuit for a storage condenser when the pressure in the first chamber is greater than atmospheric pressure, and a discharging circuit when it is less than atmospheric pressure, or vice versa. The condenser is so connected that it charges substantially instantly, but discharges so slowly that it can discharge only partially in each cycle even at slow engine speed. Alternatively, the condenser may be made to discharge fully during each cycle at all engine speeds, in which event discharge current flow occurs during a variable proportion of the vacuum pulse duration. In either case, the average discharge current of the condenser is dependent on the duration of the vacuum pulse of the engine, and hence on the engine speed. The average discharge current of the condenser is measured by a microammeter and provides an indication of engine speed.

A preferred form of tachometer assembly according to this invention is shown in FIG. 1 and is designated generally as 10. The assembly includes the coupling diaphragm 17 which is secured to the crankcase 12 of a two cycle engine. A hose 15 connects the diaphragm coupling with a pressure-sensitive switch designated generally as 30, an electrical connection 14 which is part of the electrical circuit designated generally as 55, and the tachometer 57 which is a component of the electrical system 55 and is secured to the dashboard 13 of a boat.

FIG. 1 shows an outline of a two cycle engine, which in the instant case is an outboard motor. The motor has a flywheel 11, and a crankcase 12 having a partition 12a in which the piston (not shown) operates. The motor is secured to the stern 16 of a boat.

The coupling diaphragm is designated generally as 17 (FIG. 2) and is secured to the crankcase portion of one of the cylinders as shown in FIG. 1. The coupling diaphragm 17 is a separable member having a generally cup-shaped coupling and nut portion 22. The bottom of the coupling and nut member 22 is provided with a threaded male fitting 21 which is adapted to screw into a threaded aperture formed in the crankcase of the engine. The interior of the nut and coupling member 22 forms a first diaphragm chamber 18. A coupling passageway 23 forms a path of communication between the crankcase and the first diaphragm chamber 18. The nut and coupling 22 has a threaded counterbore 24, and a shoulder 28 formed at the base of the counterbore. The threaded counterbore 24 is adapted to receive the threaded flange of a connector element 25 now to be described.

The connector element 25 is also formed in the shape of a cup, the interior of which forms a second diaphragm chamber 19. The connector 25 has a threaded flange 26 which is adapted to engage the threads of counterbore 24. The base of the connector 25 is provided with an

outwardly projecting nipple 27. The nipple 27 receives one end of hose 15. The nipple 27 is provided with a connector passage 20 which communicates with the second diaphragm chamber 19 and the interior of hose 15.

A disc-shaped flexible membrane or diaphragm 29 seats against the shoulder 28 of nut and coupling 22 and is held in position thereon by the end of connector flange 26 which abuts thereagainst when the connector 25 is screwed into the nut and coupling 22. The chambers 18 and 19 are in effect formed by the flexible diaphragm 29 which separates the area within the nut and coupling 22 from the area within the connector 25. The flexible diaphragm 29 may be made from a material such as metal, or a flexible type of plastic, both of which are resistant to the effects of gasoline, oil and other substances to which they are likely to be subjected. A preferred material for diaphragm 29 is neoprene-coated fabric. The flexible diaphragm also acts as a seal, preventing the oil, gas and vapors within the cylinder from entering the hose 15.

The hose 15 connects to the nipple 27 and leads to a pressure switch which is designated generally as 30. The pressure switch 30 is best shown in FIGURE 3.

The pressure-sensitive switch 30 is constructed of a pair of generally similar convex housing or casing members 31 and 33. The edges of the members are provided with outwardly projecting flanges 32 and 34 which have complementary faces. The complementary faces of the flanges 32 and 34 are adapted to engage an electrical contact diaphragm member 45 which is sandwiched therebetween. Any well-known fastening means is used to clamp the casings 31 and 33 together in the vicinity of the flanges 32 and 34.

The area between the electrical contact diaphragm 45 and the interior of the casing 31 forms a chamber 41 vented to the atmosphere by a conduit 42. A chamber 40 is formed in the area between the electrical contact diaphragm 45 and the casing 33. The chamber 41 is at atmospheric pressure and the chamber 40 is above or below atmospheric pressure as controlled by the operation of flexible diaphragm 29 in the coupling 17.

Casing 31 is provided with an electrical contact 35 which is disposed in the geometric center thereof and extends into the chamber 41. The electrical contact 35 is positioned in the chamber 41 so that the electrical contact diaphragm 45 will make contact therewith when pressure is applied to the diaphragm. The electrical contact diaphragm 45 will then assume the right-hand dotted-line position as shown in FIGURE 3. A lead 37 connects the electrical contact 35 with an electrical terminal C.

The casing 33 has a similar electrical contact 36 disposed in the geometric center thereof and projecting into the chamber 40. The electrical contact diaphragm 45 makes contact with the electrical contact 36 when a vacuum is applied to the chamber 40 which will cause the electrical contact diaphragm 45 to assume the left-hand dotted-line position as shown in FIGURE 3. A lead wire 38 connects the contact 36 with an electrical terminal A.

The casing 33 also has a hose connection 39 which receives one end of the hose 15. The hose connection 39 can be of any conventional design.

The casings 31 and 33 are made of a dielectric material so as to insulate the electrical contacts 35 and 36 from each other.

FIGURE 4 shows a side elevation view of the electrical contact diaphragm 45 in detail. The electrical contact diaphragm is constructed of a material such as nylon with a neoprene covering. Centrally disposed in the electrical contact diaphragm 45 is a contact rivet 47. The contact rivet 47 extends through the electrical contact diaphragm 45 so that it is capable of making contact with both the electrical contacts 35 and 36. A very thin conductor ribbon or strip 46 is connected to the contact

rivet 47 in any manner to produce a good electrical connection, and extends along the face of the electrical contact diaphragm 45 to a point adjacent the outer periphery thereof. A lead wire 48 is then connected to the ribbon 46 and makes connection with an electrical terminal B. The conductor ribbon 46 is made of a material such as phosphorus bronze, and is on the order of .003 inch thick. The contact ribbon 46 must be extremely thin to render it sufficiently flexible to flex with the electrical contact diaphragm 45. Although the conductor ribbon 46 is a preferred type of electrical connection between the rivet 47 and the terminal B, it is to be understood that other connection means may be employed. It has been found that a fine wire will also operate satisfactorily for such a connection.

The electrical terminals A, B, and C shown in FIG. 3 are the same as the electrical terminals A, B, and C shown in FIG. 5.

As shown in FIG. 5, a wire 60 leads from the terminal A and is connected to the movable contact of a calibrating potentiometer 58 and, through wire 69, to one side of the microammeter 57. One fixed terminal of the potentiometer 58 is connected to a source of direct current electromotive force such as the negative side of a battery 56 by a wire 63. The other side of the meter 57 is connected to wire 63 at 64. The microammeter 57 is calibrated to read in revolutions per minute and constitutes the tachometer. A line 70 connects the terminal B to wire 63 at 66. The line 70 contains a condenser 59. The positive side of battery 56 is connected to terminal C by wire 68. The operation of the electrical circuit 55 will be described in conjunction with the operation of the tachometer assembly.

Assembly and Operation

The installation of the tachometer assembly 10 on the outboard motor and boat is not difficult. The crankcase of one cylinder of the outboard motor is bored and tapped to receive the male fitting 21 of coupling diaphragm 17. The coupling diaphragm 17 is secured in position upon the crankcase 12 of the outboard motor by applying a wrench to the nut and coupling portion 22 of the coupling diaphragm 17. The pressure switch 30 is secured to the boat in an out-of-the-way position by appropriate fastening means. The hose 15 is connected to the hose connection 39 of casing 33. The opposite end of the hose 15 may be connected to nipple 27 by merely pressing the hose thereon. The tachometer 57 is secured in an appropriate position on the dashboard 13 of the boat. A separate dry cell or battery 56 may be used, or if the outboard motor has a direct current electrical system, the electromotive force may be obtained by connection of the circuit with the system's power source (not shown). The line 14 shown in FIG. 1 schematically represents an electrical connection between pressure switch 30 and tachometer 57, and in its schematic representation includes the electrical circuit 55 (FIG. 5), the exact location of which is immaterial. When the appropriate electrical connections have been made as shown herein, the tachometer assembly 10 is fully installed and ready for operation.

The tachometer assembly 10 starts operation upon the starting of the engine. As previously described, each stroke of a piston in a given cylinder results in an increase in pressure on the compression portion of the stroke, and a decrease in pressure upon the expansion part of the stroke, in respect to a particular given point such as the point of connection of diaphragm coupling 17. Thus, each time the pressure is increased at the diaphragm coupling 17, the flexible diaphragm 29 will flex toward the right, as viewed in FIG. 2. Each time a vacuum is created in the vicinity of the diaphragm coupling 17, the flexible diaphragm 29 will move to the left as viewed in FIG. 2.

Each time the flexible diaphragm 29 moves toward the right, there will be an increase of pressure in the chamber

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40 of pressure switch 30, and each time the flexible diaphragm 29 moves to the left, a vacuum will be created in the chamber 40 of pressure switch 30. This is true because the pressure fluctuations of the diaphragm coupling 17 will be conveyed to the pressure switch 30 by the pressure-resistant hose 15 which connects the two members. Thus, the electrical contact diaphragm 45 moves simultaneously with the flexible diaphragm 29, and in the same direction.

Assuming there is a pressure increase in the chamber 40, the electrical contact diaphragm 45 will move to the right-hand dotted-line position as shown in FIG. 3. An electrical connection is then made between the electrical contact 35 and contact rivet 47. This completes an electrical circuit through the conductor ribbon 46, lead 48, terminal B, wire 70, capacitor 59, direct current electro-motive source 56, wire 68, terminal C, lead 37, electrical contact 35, and contact rivet 47 back to the conductor ribbon 46. This connection causes a charge to be built up on the condenser 59, according to well-known electrical principles.

When the piston has moved to a position so as to create a vacuum, a vacuum will be created in the chamber 40, and the electrical contact diaphragm 45 will pass from the dotted-line position on the right to the dotted-line position on the left and will make an electrical connection with the electrical contact 36. During the interval of movement, the electrical circuit 55 is completely open. Connection of electrical contact diaphragm 45 with electrical contact 36 completes a circuit to the tachometer 57. The electrical current flow in this position is that associated with the discharge of condenser 59. Thus, from the condenser 59 the flow is through line 70 to terminal B, line 48, conductor ribbon 46, contact rivet 47, electrical contact 36, line 38, terminal A, line 69, line 69, tachometer 57 and potentiometer 58 in parallel, a portion of line 63, and back to the condenser 59. This flow is read by the tachometer 57 in revolutions per minute.

FIGS. 6 and 7 best show one possible mode of operation of the electrical circuit 55 to produce an r.p.m. reading on the tachometer. The average current flowing through the meter is a function of the number of pressure variations in the crankcase of the engine per minute, and thus an indication of the number of times a minute the flywheel is rotating.

FIG. 6 represents a case where the engine is rotating at a slow r.p.m., showing that the time intervals of contact of the electrical contact diaphragm 45 with the electrical contacts 35 and 36, indicated as X and Z, are rather long. The curve representing the action of the condenser shows that the condenser is fully charged to 6 volts during the initial period of the interval X, there being no resistance in the circuit to delay the charging process. The time interval in which the electrical contact diaphragm 45 moves from its contact with electrical contact 35 to its contact with electrical contact 36 is indicated by Y in FIG. 6. During this interval the condenser remains fully charged. However, as soon as electrical contact diaphragm 45 makes contact with the electrical contact 36, the condenser starts to discharge at a rate determined by the combined resistance of the potentiometer 58 and the coil of meter 57. The time interval of discharge of the condenser is indicated by Z in FIG. 6. As can be seen, the condenser has a considerable amount of time to discharge, and the voltage will fall to approximately two volts. During the movement of the electrical contact diaphragm 45 from its contact with electrical contact 36 back to its contact with electrical contact 35 (interval W), the condenser is disconnected from both circuits and remains at the two-volt level. This cycle repeats itself upon each compression and expansion stroke of the engine.

The microammeter or tachometer 57 sees or reads discharge current I_{av} , which is proportional to the average voltage V_{avZ} across the condenser during the interval Z

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(about four volts in the example of FIG. 6) times the portion of one complete cycle taken up by the interval Z. Mathematically, this can be expressed as

$$I_{av} = \frac{V_{avZ} \left(\frac{Z}{Z+X+Y+W} \right)}{R}$$

R being the total resistance of the meter and potentiometer connected in parallel. The parenthetical fraction is mainly a function of the construction parameters of the pressure-responsive switch and varies but little with varying engine speeds. This average remains the same as long as the time intervals X and Z remain constant.

However, should this time interval be shortened (i.e. the motor speed up), an exponential curve such as shown in FIG. 7 results. In this instance the initial contact X charges the condenser almost instantaneously to six volts. This is possible since there is no resistance in the condenser circuit during the charge portion of the cycle. The time interval Y has been shortened, and the time interval Z has also been shortened. Due to the shortened time interval Z, the condenser is allowed to discharge only to a voltage of five volts before the end of the interval Z. Thus, it can be seen that the curve fluctuates between five and six volts. The meter 57 now sees or reads an average voltage of about $5\frac{1}{2}$ volts during the interval Z, rather than an average voltage of 4 volts as in the example of FIG. 6.

Another possible mode of operation (not shown) of the circuit is as follows: R is set so that the condenser 59 discharges fully during the interval Z even at the highest engine speed. Since the time required for a complete discharge is dependent only on R and not on the switching frequency, discharge current will flow through the meter 57 for a fixed time t each cycle. As the engine speed increases, t becomes an increasingly greater part of the cycle. The average current through the meter (designating the mean discharge current of the condenser during the time t as I_m) can be expressed by the formula

$$I_{av} = I_m \frac{t}{X+Y+Z+W}$$

The average current read by the tachometer 57 is thus directly proportional to the frequency of pressure fluctuation within the crankcase of the cylinder regardless of which mode of operation is used. The greater the rate of reciprocation, the more revolutions per minute of the flywheel, and the greater the average current through to the tachometer 57. By properly calibrating the tachometer 57, a very accurate reading of the number of revolutions per minute is obtained. The calibration resistor 58 shown in the electrical circuit 55 is utilized initially to properly set up the circuit, i.e. to vary the quantity R. This is generally necessary to compensate for the large variations in the capacity of condenser 59, since even expensive condensers usually have a very large tolerance.

The present invention discloses a tachometer assembly which is quick and easy to install. This tachometer system cannot cause failure of the engine should it itself fail, since it is not connected to a vital component of the engine such as the ignition system. The tachometer system disclosed herein is very accurate since it actually counts the piston movements rather than the movements of a supporting component such as a distributor or magneto. It can be secured to most any point of the crankcase, and is extremely rugged and durable in construction, since it has a minimum number of moving parts. Therefore, its useful life is long, and very little maintenance is necessary. Furthermore, it can be universally used with all two-cycle crankcase scavenging engines, and need not be modified or changed due to modifications in the engine such as is necessary in a system associated with the ignition system of the engine.

While a preferred embodiment of this invention has been described, it will be understood that other modifications and improvements may be made thereto. Such of these modifications and improvements as incorporate the principles of this invention are to be considered as included in the hereinafter appended claims unless these claims by their language expressly state otherwise.

I claim:

1. A tachometer for reciprocating internal combustion engines having an enclosure in which a gaseous fluid is alternately compressed and decompressed at a rate corresponding to the speed of the engine, comprising: a housing having a pair of chambers, said chambers being connected in pressure-transmitting relationship with said enclosure and with the atmosphere, respectively, a flexible diaphragm separating said chambers, movable contact means carried by said diaphragm and cooperating with fixed contact means carried by said housing to alternately close and open a pair of electrical circuits, and electrical means associated with said circuits for producing an indication representative of the frequency of said closing and opening.

2. The device of claim 1, in which said diaphragm is made of an electrically non-conducting fabric, said movable contact means comprise a metal strip affixed to said fabric, and said housing is made of dielectric material.

3. A tachometer for reciprocating internal combustion engines having an enclosure in which a gaseous fluid is alternately compressed and decompressed at a rate corresponding to the speed of the engine, comprising: a housing having a pair of chambers, one of said chambers being maintained at atmospheric pressure; pressure-tight conduit means connecting the other of said chambers to said enclosure; gas-tight corrosion-resistant pressure transmitting means interposed in said conduit to prevent fumes from said engine from entering said other chamber; a flexible diaphragm separating said chambers, movable contact means carried by said diaphragm and cooperating with fixed contact means carried by said housing to alternately close and open a pair of electrical circuits; and electrical means associated with said circuits for producing an indication representative of the frequency of said closing and opening.

4. The device of claim 3, in which said pressure-transmitting means comprises a membrane of fabric coated with a resilient, gas-tight and corrosion-resistant material.

5. A tachometer for reciprocating internal combustion engines having an enclosure in which a gaseous fluid is alternately compressed and decompressed at a rate corresponding to the speed of the engine, comprising: a pair of electrical circuits, means operated by the pressure of said gaseous fluid for alternately opening one of said circuits and closing the other as the engine is operating, one of said circuits when closed causing a condenser to be charged substantially instantaneously, the other when closed causing said charge to be released at a predeter-

mined rate, and indicating means actuated by the discharge current of said condenser and responsive to the average current through said indicating means during a cycle of operation for indicating the speed of said engine.

6. A tachometer for reciprocating internal combustion engines having an enclosure in which a gaseous fluid is alternately compressed and decompressed at a rate corresponding to the speed of the engine, comprising: a pair of electrical circuits, means operated by the pressure of said gaseous fluid for alternately opening one of said circuits and closing the other as the engine is operating, one of said circuits when closed connecting said condenser directly across a source of direct current, the other when closed connecting the terminals of said condenser together through an electrical discharge path, and indicating means associated with said path to provide an indication of the average current flow therethrough.

7. A tachometer for two-cycle reciprocating internal combustion engines having a crankcase in which a gaseous fluid is alternately compressed and decompressed at a rate corresponding to the speed of the engine, comprising: a housing having a pair of chambers, one of said chambers being maintained at atmospheric pressure; pressure-tight conduit means connecting the other of said chambers to said crankcase; a gas-tight corrosion-resistant flexible membrane interposed in said conduit to prevent fumes from said engine from entering said other chamber; a flexible diaphragm separating said chambers, movable contact means carried by said diaphragm and cooperating with fixed contact means carried by said housing to alternately close and open a pair of electrical circuits; one of said circuits when closed connecting a condenser directly across a source of direct current, the other when closed connecting terminals of said condenser together through a current measuring device associated with an adjustable resistor, whereby the indication of said current measuring device is representative of the average current through said current measuring device and is in turn indicative of the speed of said engine, and said resistor permits calibration of said current measuring device.

References Cited in the file of this patent

UNITED STATES PATENTS

1,335,238	Hopkins	Mar. 30, 1920
2,419,099	Wall	Apr. 15, 1947
2,473,542	Philpott	June 21, 1949
2,702,883	Petroff	Feb. 22, 1955
2,724,088	Smith	Nov. 15, 1955
2,879,467	Stern	Mar. 24, 1959

FOREIGN PATENTS

210,708	Germany	June 8, 1909
743,182	Great Britain	Jan. 11, 1956