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DEVICE FOR ASCERTAINING THE OUTPUT OR INPUT OF A RECIPROCATING ENGINE

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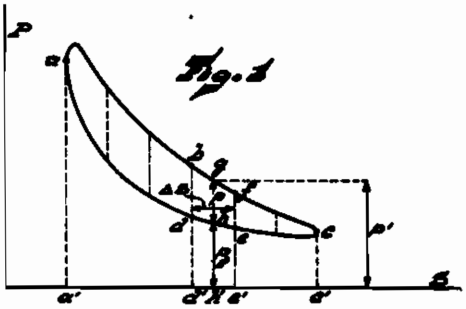

Fig. 1

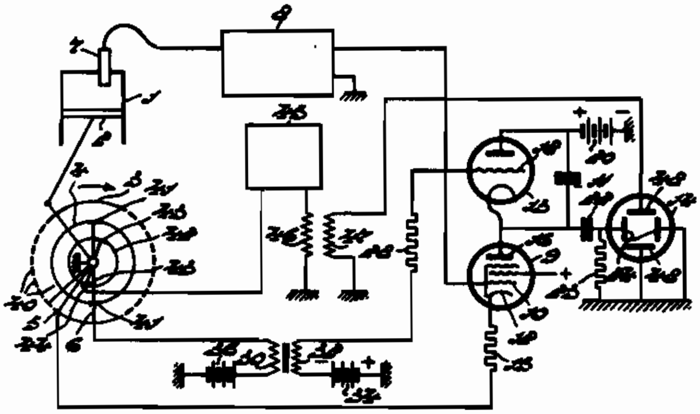

Fig. 2

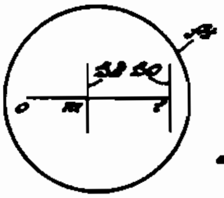

Fig. 3

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DEVICE FOR ASCERTAINING THE OUTPUT OR INPUT OF A RECIPROCATING ENGINE

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For ascertaining the energy delivered or absorbed by a piston engine use is frequently made of the so-called indicator diagram. In this diagram, an example of which is given in Fig. 1 of the accompanying drawing, the pressure P which exists above the piston is plotted on the vertical axis and the paths traversed by the piston on the horizontal axis. The points of reversal of the piston movement are designated *a'* and *c'*. Fig. 1 may represent the indicator diagram of for example a two-cycle internal-combustion engine; in such engine the gases in the cylinder are pre-compressed during the movement of the piston in one direction and the piston absorbs energy (back stroke), whereas during the movement of the piston in the other direction the gases take fire and the piston delivers energy (working stroke). The work performed by the piston during the working stroke *abc* is represented by the surface of the figure *abcc'a'*. During the back stroke the piston expends an amount of energy which is indicated by the surface *adcc'a'*; the useful work performed is consequently represented by the surface of the figure *abcd*. By taking the indicator diagram and measuring the surface area *abcd* it is therefore possible to determine the work performed per cycle of the piston movement and by multiplication into the speed the so-called indicated energy, that is to say the delivered energy without deduction of friction losses or the like.

This method exhibits the drawback that taking and measuring the diagram occupies a certain time so that immediate indication of the energy cannot be obtained.

The invention has for its object to provide a device for so determining the energy delivered or absorbed by a piston engine that immediate indication of the indicated energy can be obtained.

In the device according to the invention by means of which this object is attained a measuring condenser is charged with the interposition of a resistance whose value is so controlled by the output voltage of a device for converting the pressure variations that occur above the piston into electrical potential variations that the charging current is at any one moment proportional to the pressure prevailing in the cylinder at that moment, the piston movement being coupled by mechanical means with means by which the charging circuit is closed during short time intervals whose relative time spacings correspond to equal paths traversed by the piston and by which the measuring condenser is discharged in the extreme positions of the piston further means being provided for indicating the difference between the maximum values of the voltages that occur across the measuring condenser during the working stroke and the back stroke of the piston respectively.

In order that the invention may be clearly understood and readily carried into effect it will now be described more fully with reference to the accompanying drawing.

For the purpose of determining the surface area of the figure *abcde* in Fig. 1 which is the difference between the surface areas *abcc'a'* and *adcc'a'*, the latter two figures may be divided into a plurality (*n*) of equally wide vertical strips (for example *bfd'e'* and *dee'd'* respectively having a width ΔS) of approximately trapezoidal form. The surface area of such a strip, for example the strip *bfe'd'* or *dee'c'*, is consequently equal to the product of the width ΔS into the height P_1 or P_2 respectively in the centre of the strip. The surface area of the figure *abcc'a'* is the sum of the surface areas of the trapeziums and is therefore equal to $\Sigma P_1 \Delta S$. Since the stroke length *a'e'* of the piston and the number of strips *n* is always the same,

$$\Delta S = \frac{a'e'}{n}$$

is a constant amount. Thus $\Sigma p_1 \Delta S = \Delta \Sigma P_1$, and ΣP_1 indicates the surface area *abcc'a'* on a certain scale, that is to say the energy delivered by a given engine during one working stroke of the piston. Similarly and on the same scale, ΣP_2 represents the surface area *adcc'a'* and the energy absorbed during the back stroke of the piston so that $\Sigma P_1 - \Sigma P_2$ indicates the energy delivered per piston cycle.

Fig. 2 shows an example of the device according to the invention. A cylinder **1** comprising a piston **2** whose delivered energy has to be determined drives a shaft carrying two contact discs **3** and **4** which will be described more fully hereinafter and on which slide brushes **5** and **6** respectively. The cylinder **1** contains a device **7** for converting pressure variations into variations of an electric value, for example of a capacity, said device supplying, jointly with a device **8**, an output voltage which is proportional to the pressure in the cylinder **1**. The device **7** may be constituted, for example, by a condenser one electrode of which is shaped in the form of a diaphragm and is subjected on one side to the pressure that prevails in the cylinder. The device **8** may be for example a high-frequency generator supplying a constant current through the condenser and may contain a detector rectifying the high-frequency voltage across the condenser **7**. This rectified voltage is dependent on the impedance of the condenser **7**; this impedance depends on the capacity of the condenser and this capacity is inversely proportional to the spacing of the electrodes and hence depends on the deflection of the diaphragm which is acted upon by the pressure P in the cylinder so that this pressure eventually determines the rectified voltage across the condenser **7**. For the purpose of obtaining a satisfactory operation the output voltage of the device **6** must be proportional to the pressure P.

The output voltage of the device **6** is supplied to the control grid **10** of a discharge tube **9**, which in the case illustrated is a pentode. The anode **16** of the tube **9** is connected to one terminal of a condenser **11** whose other terminal is connected to the positive terminal of a source of direct voltage earthed on the other side. for example a battery **20**. The condenser **11** is shunted by the anode-cathode circuit of a gas-discharge tube **13**. The anode **16** of the tube **6** and the cathode of the tube **13** are interconnected and, with the interposition of a condenser **22**, connected to an earthed resistance **23** and to one of the deflecting plates **24** of the cathode-ray tube **14**. The other deflecting plate **24** is earthed. The control grid **16** of the tube **13** is normally negatively polarised relatively to the cathode of the tube **13** by a battery **34** via a resistance **28** and the winding **32** of a transformer **30**, **32**. The brush **6** is connected, with the interposition of the winding **30** of the transformer **30**, **32**, to one terminal of a battery **38** earthed on the other side.

The cathode **12** of the tube **9** is connected to the brush **5** with the interposition of a resistance **15**. The contact discs **3** and **4** are constituted by discs of insulating material respectively carrying earthed conductive laminations **40** and **41** of given width at given distances. The number of laminations **40** on the disc **3** is $2n$, whereas the disc **4** carries two laminations **41** which are so arranged that periodically after one series of n laminations **48** associated with a working or back stroke of the piston has passed past the brush **5**, the brush **6** contacts with one of the laminations **41**.

The operation of that part of the device shown in Fig. 2 which is hitherto described is as follows: The condenser **11** may be charged from the battery **20** with the interposition of the anode-cathode resistance of the tube **9**, the resistance **15**, the brush **5** and a lamination **40** and the smaller the anode-cathode resistance of the tube **9**, that is to say the greater the charging current, the more quickly the condenser is charged. The charging current strength is governed by the voltages of the control grid **10** and hence by the pressure in the cylinder **1**. The condenser **11**, however, is only charged during the moments the brush **5** is placed on one of the laminations **40**, as otherwise the charging circuit would be interrupted. The laminations **40** are so distributed about the circumference of the disc **3** and the number of laminations is such that the brush **5** is placed on a lamination **40** each time the position of the piston **2** corresponds to the centre of one of the strips into which the figures *abcc'a'* and *adcc'a'* of Fig. 1 are divided (for example to the centre *gh'* of the strip *bfe'd'*). The number of laminations past which the brush **5** passes per cycle of the piston movement is therefore $2n$. The condenser **11** is thus charged both during the upward and the downward stroke of the piston **2** a given number of times (n times) over a short time interval with a current strength proportional to the instantaneous pressure P in the cylinder **1**. Since the time interval over which charging periodically occurs is identical at any one time in the case of constant speed and width of the laminations **40**, the charging voltage of the condenser **11** at any one time increases according to the mean pressure P which has prevailed in the cylinder over the charging time interval concerned. The total charging voltage which is given to the condenser during the working stroke is therefore proportional to the value already referred to ΣP_1 which is a measure of the surface area *abcc'a'*. The total charging voltage which is given to the condenser during the back stroke is proportional to the value already referred to ΣP_2 which is a measure of the surface *adcc'a'*. The difference between these two charging voltages is consequently a measure of the energy delivered per piston cycle.

In order that optimum proportionality may be obtained between the anode current and the grid voltage of the tube **9** the cathode conductor includes a feedback resistance **15**.

Fig. 3 shows the fluorescent screen of the cathode-ray tube **14**. Under the influence of the increasing voltage of the condenser **11**, which is supplied to the deflecting plates **24**, the luminous spot of the cathode-ray tube **14** describes a straight line *ol* during the working stroke of the piston, the length of this line depending on the voltage of the condenser and being therefore, similarly thereto, a measure of the surface *abcc'a'*. At the end of the working stroke (*abc*), a short time after the brush **5** (Fig. 2) passes over the last lamination **40** associated with the working stroke, the brush **6** slides over an earthed lamination **43** on the contact disc **4** so that the winding **30** has current passing through it for a short time. This results in a voltage being induced in the winding **32** and being supplied to the grid **18** of the gas-discharged tube **13** so that the tube **13** breaks down with the result of discharge of the condenser **11**. The luminous spot then snaps back again to the point o (Fig. 3). In the same manner as above described the luminous spot moves from o to *m* during the back stroke (*adc*) in conformity with the surface *adcc'a'*. The difference in length *lm* of the lines *ol* and *om* is therefore a measure of the surface *abcd* and hence of the indicated energy. At the end of the back stroke the brush **6** slides again over a lamination **41** and the grid **18** is given a positive voltage which brings about a break-down of the tube **13** and a discharge of the condenser **11** so that the cycle described can start again.

The shaft of the motor (Fig. 2) carries a third contact disc **42** over two earthed laminations **43** of which a brush **44** slides in such manner that it slides over one of them after the brush **5** has left the last of the laminations **40** but before the brush **6** comes into contact with the lamination **41**. The brush **44** is connected to one of the output terminals of a high-frequency oscillator **45** whose other output terminal is connected to one end of the primary **46**, earthed on the other side, of the transformer **46**, **47**. The secondary **47** of the transformer **46**, **47** is connected to the deflecting plates **48** of the tube **14**.

Immediately after the brush **5** has left the last lamination **40** the brush **44** is earthed by one of the laminations **43** with the result that the high-frequency current passes through the winding **46** and thus induces a high-frequency voltage in the winding **47** which is supplied to the deflecting plates **48**. At this moment the luminous spot has arrived, for example after the working stroke, in the point *l* (Fig. 3) under the influence of the charging voltage of the condenser **11** and is stationary, since the condenser is not charged any further. Under the influence of the high-frequency voltage at the deflecting plates **48** the spot then describes a line **50** normal to the line *ol* which clearly indicates the place of the point *l*. The place of the point *m* is similarly indicated by a line **52** which is described at the end of the back stroke due to the passage of the second lamination **42** under the brush **44**. The indicated energy is therefore clearly indicated by the spacing between the lines **50** and **52**.

Generally, the device already comprises a high-frequency oscillator so that the oscillator **45** does not involve a complication. Instead of using the oscillator **45**, use may be made of a source of direct voltage.

It was assumed hereinbefore that the speed of the motor always remained constant. If such is not the case, for example due to an increase of the speed at a given delivered energy per stroke, the brush **5** will sojourn on each of the laminations **40** each time during a proportionally shorter period so that the charging periods of the condenser **11** becomes shorter, whereas the number of charging periods per stroke remains unvaried at all times. The total charge after each stroke is thus decreased so that the measuring voltage across the condenser **11** is lower in the case of an increasing speed, the measuring voltage being inversely proportional to the speed in the case of invariable energy per stroke. This proportionality permits of the energy being determined by means of a simple calculation.

According to a further object of the invention, in order to avoid the need for this calculation, provision may be made of electrical or mechanical means which are coupled to the shaft of the motor and which permit of the effect involved being compensated. The shaft may, for example, have coupled to it an alternating current generator supplying a control voltage which is proportional to the speed and which after rectification is supplied to, for example, the suppressor grid or the screening grid of the tube **9**, thus bringing about an increase in mutual conductance of the tube **9** which is proportional to the speed and which compensates for the shortening of the charging periods.

Compensation may be obtained mechanically by giving the laminations **40** a width increasing in the axial direction and by causing axial displacement of the brush **5** in the direction of the greatest width of the laminations **40** by means of an automatic regulator with increasing speed so that the time during which the brush **6** contacts with a lamination **40** is independent of the speed and is unvaried at all times.

The work of the motor, that is to say the energy delivered per second, is equal to the energy delivered per double stroke (cycle) multiplied by the number of cycles per second i. e. the speed. According to the invention, even this multiplication may be performed automatically, viz. by the control voltage obtained by the first-mentioned electrical compensation method being supplied to two grids of the tube **9** both of which have a multiplicative influence on the anode current of this tube by which the condenser **11** is charged.

In a modification of the device according to the invention, instead of using the contact discs **3**, **4** and **42** with the laminations **40**, **41** and **43** and the brushes **5**, **6** and **44**, use may be made of one or more discs having formed in it apertures distributed along the circumference of concentric circles and opposite the apertures there is on one side of each disc a source of light and on the other side a photo-electric cell. The disposition and arrangement may be such that at moments corresponding to those at which the laminations **40**, **41** and **43** would make contact with the associated brushes the photo-electric cells concerned receive light across the apertures and, by means of suitable devices, perform the same functions as the laminations **40**, **41** and **43** with the brushes **5**, **6** and **44**.

A voltage-measuring instrument may be connected in parallel with the deflecting plates **24** of the tube **14** so as to permit direct reading of the indicated energy. From the foregoing it will be understood that the charging voltage of the condenser **11**, which is set up during the back stroke, must be supplied to the voltmeter in a sense opposite to the charging voltage during the working stroke. This may be ensured by means of a commutator on the shaft of the motor which reverses the polarity of the voltage supplied to the voltmeter after every working stroke and back stroke.

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