April 2, 1968 KEIJI KODA 3,375,812

IGNITION DEVICE FOR INTERNAL COMBUSTION ENGINE

Filed Nov. 29, 1965 2 Sheets-Sheet 1

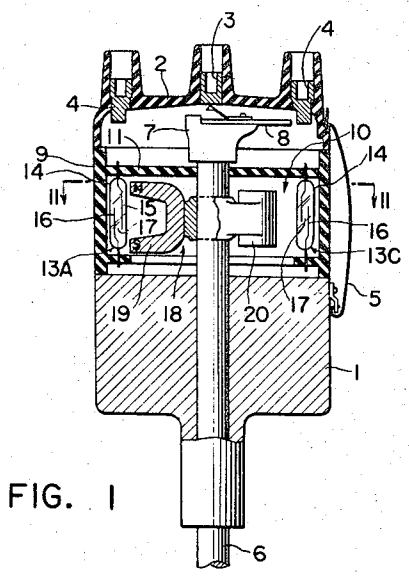


FIG. 1

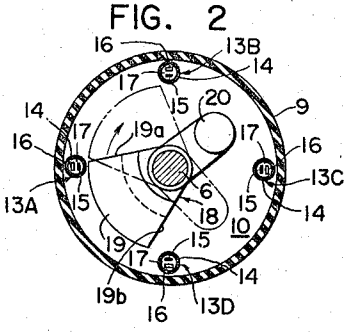


FIG. 2

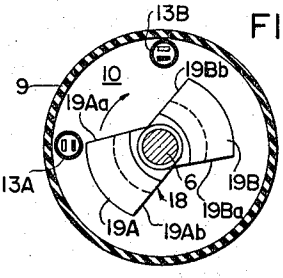


FIG. 4

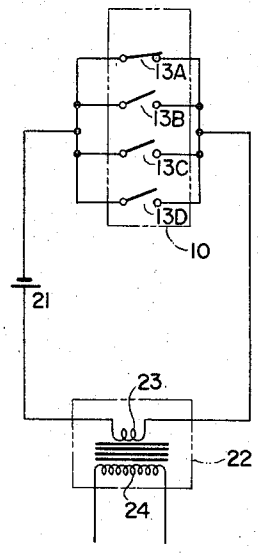


FIG. 3

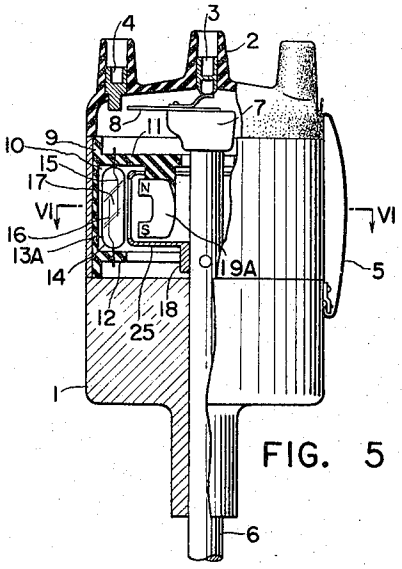


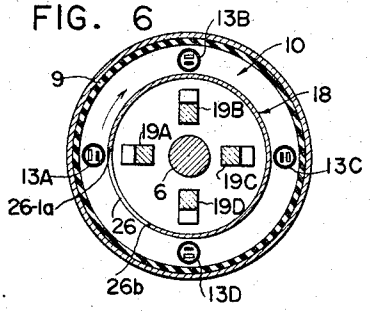
FIG. 5

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FIG. 6



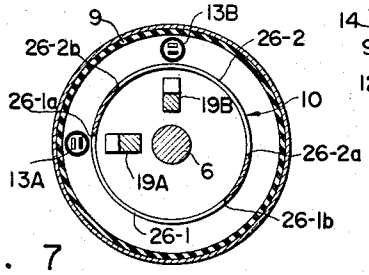


FIG. 7

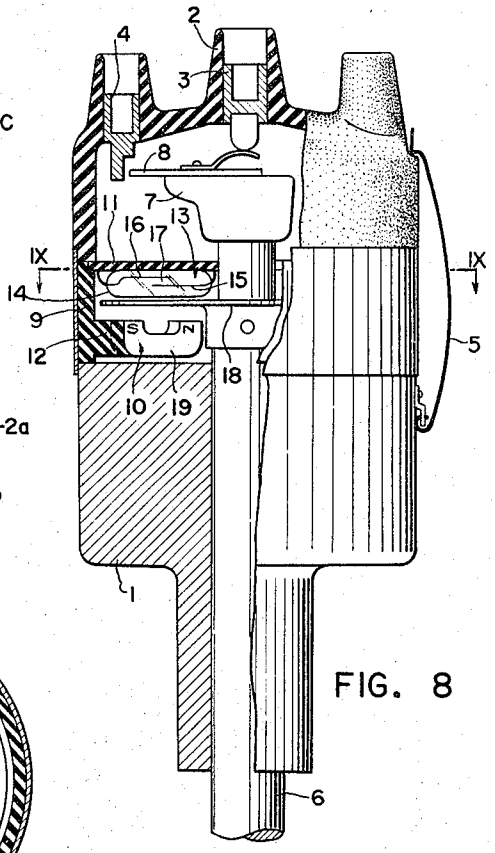


FIG. 8

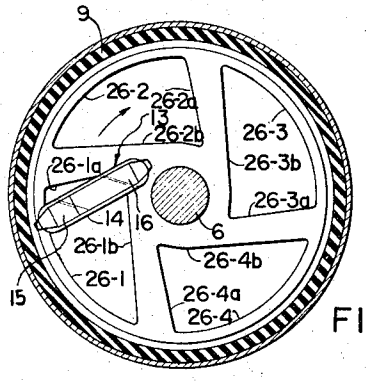
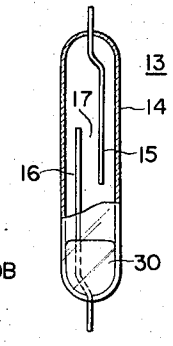


FIG. 9

FIG. 11



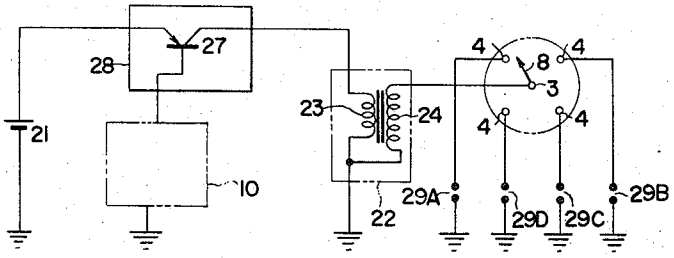


FIG. 10

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3,375,812

IGNITION DEVICE FOR INTERNAL COMBUSTION ENGINE

Keiji Koda, Nagoya, Japan, assignor to Mitsubishi Denki Kabushiki Kaisha, Tokyo, Japan

Filed Nov. 29, 1965, Ser. No. 510,199
Claims priority, application Japan, Dec. 10, 1964, 39/69,509; Mar. 9, 1965, 40/18,693; Mar. 30, 1965, 40/25,309; June 7, 1965, 40/33,652
6 Claims. (Cl. 123—148)

ABSTRACT OF THE DISCLOSURE

A switch device for the primary circuit of an ignition coil in an ignition system for an internal combustion engine has encapsulated ferro-magnetic contacts biased to open the circuit and is closed intermittently by a magnetic flux produced in timed relation with engine rotation.

This invention relates in general to an ignition device for the use of an internal combustion engine and more particularly to a switch incorporated into such an ignition device.

The conventional type of ignition devices previously widely employed comprises generally a cam operated switch, frequently called a contact breaker, capable of being opened and closed by a cam member rotating in synchronization with rotational movement of an internal combustion engine to be operated, the arrangement being such that opening of the switch causes interruption of an input current to an ignition coil thereby to produce an igniting high ignition voltage which is, in turn, utilized to effect igniting discharge across an ignition plug. The switch, however, has been designed to effect generally make-and-break operation as many times, for example from a few thousand to a few ten thousand times per minute, as necessary in synchronization with rotational movement of the associated engine. Therefore, such a switch is disadvatageous in that its useful life is short due to resulting wear of a cam follower engaging the cam, the consumption of surfaces of the contacts caused by electric arcs generated across the contacts and the like. This usually leads to the necessity of replacing the used switch by a new one after the associated motorcar has travelled a distance of from 3000 to 6000 km.

Further, in the above described type of switches, the engagement of the cam with its cam follower, a dimension of separation between the contacts and the like, affects critically the opening position of the switch. Thus after a new switch has been incorporated into the associated ignition device, the same is required to be readjusted by a skilled technician.

The switch as above described is also designed and constructed such that within a range of low numbers of revolutions of the engine, the cam follower is slowly raised along an included projection on the cam to separate slowly the contacts resulting in a decrease in an opening speed of the switch. This causes an interruption, at which an input current to the ignition coil is interrupted, to decrease with the result that a change in input current becomes gentle leading to a reduction in high igniting voltage.

Moreover, in order to prevent the contacts from chattering, and also due to restrictions for the cam machining technique, an angle at which the projection on the cam is tilted cannot be made small below a certain value and accordingly an angular range over which the switch is in its open position cannot be made large beyond a certain value. This causes a time interval during which the switch is in its closed position to decrease in a high speed operation of the engine. In other words, the switch will be open before the input current to the ignition coil that gradually increases in magnitude through the inductance of the ignition coil for a time interval when the switch is in its closed position will have risen to a sufficient magnitude. Therefore the input current to the ignition coil may change only by a relatively small magnitude upon opening the switch. This causes a high igniting voltage and hence the ignition energy to decrease resulting in a disadvantage in that the ability for the ignition device to ignite the engine is decreased. This disadvantage is significant especially when the device is associated with a multi-cylinder engine including a cam provided with a plurality of projections.

In addition, a cam operated switch such as above described is required to be inevitably of an open construction. Thus there is a fear that a lubricating oil involved may leak into the switch through a bearing for carrying the associated distribution shaft. When this occurs, the leaked portion of the lubricating oil enters directly a gap between the contacts and then deteriorates through the action of the electric arc which may be produced between the opposed contact surfaces whereby a contact resistance between the opposed contacts increases leading to a great reduction in ignition ability.

The primary object of the invention is, accordingly, to eliminate all the abovementioned disadvantages of the prior art type ignition devices for use with internal combustion engines.

An object of the invention is to provide an ignition device for use with an internal combustion engine including a new and improved switch structure having a long useful life.

Another object of the invention is to provide an ignition device for use with an internal combustion engine including a new and improved exchangeable switch structure capable of being incorporated in the ignition device without the necessity of re-adjusting it through the skilled technique.

A further object of the invention is to provide an ignition device for use with an internal combustion engine including a new and improved switch structure capable of be opened at a sufficiently high rate even in a range of low numbers of revolution of the engine.

Still another object of the invention is to provide an ignition device for use with an internal combustion engine including a new and improved switch structure capable of being maintained in its closed position sufficiently long even in a range of a high number of revolutions of the engine.

Another object of the invention is to provide an ignition device for use with an internal combustion engine including a new and improved switch free from any failure due to lubricating oil having entered the switch.

According to the invention there is provided an ignition device for use with an internal combustion engine, comprising a switch structure connected to a source of direct current and operative to be open and closed in synchronization with rotational movement of the engine, and an ignition coil having an input current applied thereto from the source through the switch. Opening of the switch interrupts the input current to the ignition coil to produce a high ignition voltage. The switch is characterized in that it is a protective tube type switch comprising an enclosed envelope and a pair of engageable contact elements, responsive to magnetic flux, sealed into the envelope and in that there are provided rotor means driven in synchronization with rotational movement of the engine to change a magnetic flux passing from magnet means through the pair of contact elements thereby to open the switch at each time the engine is to be ignited.

In one embodiment of the invention, rotary magnet means may be disposed such that it is driven in synchronization with rotational movement of the engine, and provides a magnetic flux passing through the pair of contact elements of the protective tube type switch in its opposed position with respect to the switch thereby to close the latter and that it is moved from its opposed position to remove the magnetic flux from the pair of contact elements at each time the engine is to be ignited, thereby to open the switch.

Advantageously, stationary magnet means may be disposed opposite to and separated from the switch to provide a magnetic flux passing through the pair of contact elements to close the switch and a rotatory magnetic member or magnetic shutter is rotatably disposed in an annular space formed between the switch and the magnet means. During its rotational movement the magnetic shutter member interrupts the magnetic flux passing from the magnet means through the pair of contact elements each time when the engine is to be ignited, thereby to open the switch.

A semiconductor device such as a transistor may be conveniently associated with the switch so as to be nonconductive through opening of the switch thereby interrupting the input current to the ignition coil.

In order to ensure contacting of the pair of contact elements of the switch an amount of mercury may be sealed into the switch to wet the surfaces of both contact elements.

The invention as to its organization and its method of operation as well as the other objects and advantages thereof will become apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

FIG. 1 is a front elevational view, partly in longitudinal section of a distributor including therein one form of a switch structure embodying the teachings of the invention;

FIG. 2 is a sectional view taken along the line II—II of FIG. 1;

FIG. 3 is a schematic diagram of an electrical circuit which may be used with one embodiment of the invention;

FIG. 4 is a view similar to FIG. 2 but illustrating a distributor including therein another form of the switch structure embodying the teachings of the invention;

FIG. 5 is an elevational view, partly in longitudinal section, of a distributor including therein another form of the switch structure embodying the teachings of the invention;

FIG. 6 is a sectional view taken along the line VI—VI of FIG. 5;

FIG. 7 is a view similar to FIG. 6 but, illustrating a distributor including therein a still further form of the switch structure embodying the teachings of the invention;

FIG. 8 is a front elevational view of a distributor including therein another form of the switch structure embodying the teachings of the invention with the lefthand portion illustrated in longitudinal section;

FIG. 9 is a sectional view taken along the line IX—IX of FIG. 8;

FIG. 10 is a schematic diagram of an electrical circuit which may be used with another embodiment of the invention; and

FIG. 11 is a front elevational view partly in section of a protective tube type switch constructed in accordance with the teachings of the invention.

Throughout figures like reference numerals designate the corresponding or similar components.

Referring now to FIGS. 1 and 2, there is illustrated one form of distributors embodying the teachings of the invention. In FIGS. 1 and 2 a distributor is shown as being an ignition device widely used with a four stroke cycle-four cylinder internal combustion engine and comprises a cylindrical base block **1** of any suitable electrically insulating material and a detachable cap or head member

generally designated by the reference numeral **2**. The cap member **2** may be of the same material as the base member **1** and includes a central electrode **3** centrally disposed on the bottom thereof and a plurality of distribution electrodes **4** in this case four electrodes disposed at substantially equal angular intervals on the peripheral portion of the bottom. A pair of clip member **5** made by any suitable resilient metallic material are provided to clamp and cap member **2** to the base block **1** with a suitable space formed therebetween for a purpose as will be apparent hereinafter. A rotatory shaft **6** is rotatably journalled by and extends through the base block **1** into a cylindrical space formed above the base member. The rotatory shaft **6** can be operatively connected to a crank shaft for the associated internal combustion engine through gears although such components are not shown in FIGS. 1 and 2 and adapted to be driven in the direction of the arrow illustrated in FIG. 2 in synchronization with the engine at a rate corresponding to a half of the number of revolution of the latter. Rigidly secured on the upper end portion of the rotatory shaft **6** is a distributor rotor **7** of any suitable electrically insulation material including a strip-shaped contactor **8** of any suitable electrically conductive material resiliently and electrically connected to the central electrode **3** at all times and having a free end capable of successively opposing to the plurality of distribution electrodes **4** as the rotatory shaft **6** is rotated. All the components as above described are of the conventional constructions.

Sandwiched between the base and cap members **1** and **2** respectively is a cylindrical casing **9** of any suitable electrically insulating material forming a main body of a switch device constructed in accordance with the teachings of the invention. The switch device is generally designated by the reference numeral **10** and comprises the cylindrical casing **9** just described, an upper and a lower support plate **11** and **12** respectively radially extending from the upper and lower end portions of the casing **9** toward the rotatory shaft **6** at right angles to the latter, and a plurality of protective tube type switches **13A** through D disposed at substantially equal angular intervals adjacent the internal peripheral wall of the casing **9**. The type of switch commonly called a reed switch may be preferably used. Since the distributor illustrated is intended to be used with a four stroke cycle-four cylinder engine four of such switches are disposed at substantially equal angular intervals equal to an angle of 90 degrees about the axis of the rotatory shaft **6** as shown in FIG. 2.

Each of the switches **13A** through D includes an enclosed envelope **14** in the form of a tube and a pair of make-and-break contact elements **15** and **16** in the form of a strip made of any suitable ferro-magnetic material and sealed into opposing relationship into the envelope **14** to form a gap **17** therebetween. It is noted that the gap **17** between each of contact elements is formed in the direction perpendicular to the associated radius from the rotatory shaft **6**. The pair of contact elements **15** and **16** are sealed through the both ends of the envelope **15** and extend through the upper and lower support plates **11** and **12** respectively to which they are rigidly secured.

In order to prevent the opposed surfaces of the mating contact elements from oxidizing due to any arc which may occur thereacross upon separating the engaged contact elements, any suitable inert gas is preferably filled in the enclosed envelope **15**. Alternatively the interior of the enclosed envelope may be maintained in a vacuum. The protective tube type switch will be more fully described hereinafter in conjunction with FIG. 11.

In order to open and close the switches **13A** through D magnet means are provided comprising a rotor member generally designated by the reference numeral **18**, and rigidly mounted to the periphery of the rotatory shaft **6**. The rotor member **18** consists of a permanent magnet **19** of U-shaped cross section and a counter weight **20** extending in the diametrically opposite directions. The

magnet **19** includes a pair of opposed pole pieces in the form of a sector radially extending and charged so as to provide an N pole and an S pole as shown in FIG. 1. As shown in FIG. 2, each of the pole pieces has a free edge formed into a circular arc whose center is on the axis of the rotatory shaft **6**. As the rotatory shaft **6** is rotated the free edge of the pair of pole pieces of the magnet **19** are adapted to be disposed successively oppositely to the switches **13**A through D with a very small spacing formed between the same and the internal side of the adjacent switch. In the example illustrated, the free edge of each of the pole pieces has an angular length less than an angle of 90 degrees thereby to be prevented from being simultaneously opposite to any two of the switches for a purpose as will be apparent hereinafter. As well known, the counter weight **2** ensures that the rotatory shaft **6** is maintained in its balanced state.

Referring now to FIG. 3 there is illustrated an electrical circuit used with the distributor as above described. The protective tube type switches **13**A through D are connected in a parallel circuit relationship between a source of direct current such as a battery **21** equipped on the associated vehicle and an ignition coil generally designated by the reference numeral **22**. More specifically the parallel combination of the switches **13**A through D are connected in series to the primary winding **23** of the ignition coil **22** having a secondary winding **24** inductively disposed on the same iron core as the primary winding **22**. The output of the secondary winding **24** then can be electrically connected to the central electrode **3** on the distributor and then successively transmitted to the distribution electrodes **4** by the rotating contactor **8**.

From the foregoing it will be readily appreciated that the switch device **10** is operated by both the rotatory shaft **6** and the rotor **18** driven in synchronization with and a rate corresponding to a half of the number of revolution of the engine crank shaft. With the rotor **18** brought in its position illustrated at solid line in FIG. 2 where the leading edges **19***a* of the rotor opposes to the particular switch **13**A a magnetic flux from the magnet **19** passes through a path extending from the N pole of the magnet through the contact element **15**, the gap **17** and the contact element **16** of the switch **13**A back to the S pole of the same magnet. This magnetic flux attracts both contact elements **15** and **16** toward each other to cause the gap **17** to collapse with the result that one of the contact elements contacts the other contact element. Thus upon closing the switch **13**A an input current to the primary winding **23** of the ignition coil **22** immediately begins to flow therethrough and then gradually increases in magnitude in accordance with a certain time constant. The rotatory shaft **6** is further rotated until the rotor **18** is rotated to its position illustrated at dot-and-dash line in FIG. 2. At that time the tail edge of the rotor **18** will be disposed opposite to the switch **13**A. This causes extinguishment of the magnetic flux passed from the magnet **19** through the switch **13**A. Therefore the resilience of both contact elements **15** and **16** causes the one of the contact elements to separate from the other contact element resulting in opening of the switch **13**A. This opening of the switch **13**A causes interruption of the input current to the primary winding **23** of the ignition coil **32**. A change in input current due to this interruption permits a high ignition voltage to be produced across the secondary winding **24**. Here it is to be noted that when the tail edge **19***b* of the rotor **18** is disposed opposed to the switch **13**A the contactor **8** on the distribution rotor **7** is designed and constructed to be opposed to a selected one of the distribution electrodes **4** with a very small gap formed therebetween. Therefore it will be understood that under these circumstances, the high ignition voltage thus produced is transmitted to an ignition plug in a first cylinder of the associated engine through the central electrode **3**, the contactor **8**, the associated one of the distribution electrodes **4** thereby to ignite the first cylinder.

When the crank shaft has been rotated through an angle of 180 degrees after the ignition of the first cylinder, a time at which a second cylinder is to be ignited is reached. At that time the rotor **18** has been further rotated through an angle of 90 degrees from its position where the same performed the operation of igniting the first cylinder and the tail edge **19***b* is disposed opposed to the succeeding switch **13**B. Then the process as above described in conjunction with switch **13**A is repeated to produce a high ignition voltage which, in turn, ignites the second cylinder. Thus it will be appreciated that each time the rotor **18** has been rotated through an angle of 90 degrees after the ignition of the second cylinder, a third and a fourth cylinder are successively ignited resulting in operation of the four stroke cycle-four cylinder engine.

As previously described, the switch device **10** includes a plurality of protective tube type switches **13**A through B adapted to be externally operated by the magnetic flux but not by engagement of a rotating component with a stationary component as in the conventional type of cam-operated switches. This leads to an advantage that the useful life of the switch is greatly prolonged. In this connection only wear of the contact elements **15** and **16** becomes into question. In order to alleviate this problem of wearing the contact elements, the enclosed envelope **14** can be maintained in a vacuum or have any suitable inert gas such as argon filled therein to prevent oxidation of the contact elements **15** and **16** resulting from any arc which may occur therebetween upon separating them. The results of experiments indicated that the useful life of the present switch device was as long as 5 to 10 times as compared with the conventional cam-operated switches.

Also, unlike the conventional cam-operated switches in which the cam may engage its follower at different postions in operation, the present switch has its opening position remaining unchanged in operation. This leads to another advantage that even if the contact elements of the switch would have been worn such switch can be simply replaced by a new switch without the necessity of effecting adjustment through a skilled technique or by a skilled technician.

Preferably, the tail edge **19***b* of the permanent magnet **19** is machined to form a sharp corner between the same and the associated arc-shaped front edge whereby the tail edge is allowed to be instantaneously separated away from the adjacent switch **13**. This ensures that even in the range of a low number of revolutions of the engine, the respective switches **13**A through D can perform the quick opening operation to increase an interruption speed at which the input current to the ignition coil **23** is cut off with the result that the input current sharply reduces to zero magnitude to produce a sufficiently high ignition voltage across the coil. Also the quick opening of the switch causes an arc to be difficult to occur between the contact elements thereof resulting in an increase in the life of the switch.

Moreover the switch device **10** can be provided with means for rendering an angular range over which each of the switches is in its open position, sufficiently small while rendering an angular range over which the latter is in its closed position, sufficiently large. With the embodiment illustrated, an angle subtended between the leading and tail edges **19***a* and *b* of the permanent magnet **19** substantially corresponds to the angular range for the each switch in its closed position while 90 degrees minus that angle substantially corresponds to the angular range for each switch in its open position. According to the teachings of the invention, the angular range over which each switch is in its open position can be chosen to be small enough to ensuring that when one switch performs its opening operation the next succeeding switch is prevented from being in its closed position. In this connection, any leakage flux from the permanent magnet

becomes no problem. The results of experiments, however, indicated that the angular range over which each switch is in its open position was in the order of 10 degrees measured about the axis of the rotatory shaft while the angular range over which it is in its closed position could be increased up to the order of 80 degrees. In contrast, any of the conventional cam-operated switch or contact breakers could not have both an angular range over which the contacts involved are in separated position, less than approximately 20 degrees and an angular range over which the contacts are in engaged position, more than approximately 70 degrees.

With an ignition device comprising a contact breaker such as above described, at approximately 4500 r.p.m. at which the associated engine is operated decreases the high ignition voltage to approximately 70% of the maximum possible magnitude due the short time interval during which the breaker is in its closed position. On the contrary, if the switch device **10** according to the invention includes the switches adapted to be in open position over an angular range of 10 degrees a reduction of the high ignition voltage to 70% of the maximum possible magnitude occurred when the number of revolution of the associated engine increased to approximately 5800 r.p.m. This proves that the invention greatly improves the ignition ability.

It is recalled that the protective tube type switches **13**A through D are of the perfectly enclosed construction. Therefore even if a lubricant involved would have leaked from a bearing unit for the distributor shaft **6** into the switch device the leaked portion of the lubricant is prevented from entering the gap between the contact elements in each switch. This ensures complete elimination of a failure that might be caused by the contact elements being in bad contact state due to leakage lubricant being deteriorated by the arcs occurring between the contact elements.

Referring now to FIG. 4, there is illustrated a modification of the invention wherein a switch device includes a pair of protective tube type switches and a pair of rotatory permanent magnets for igniting a four stroke cycle-four cylinder internal combustion engine. As shown in FIG. 4, a switch device **10** includes a pair of protective tube type switches **13**A and **13**B spaced away from each other by an angular distance of 90 degrees, and rotor means **18** consists of a pair of permanent magnets **19**–A and **19**–B mounted in diametrically opposed relationship on a rotatory shaft **6**. The switches illustrated in FIG. 4 are identical in construction to those previously described in conjunction with FIGS. 1 and 2 and each of the permanent magnets **19**–A and **19**–B is also identical in construction to the magnet **19** illustrated in FIGS. 1 and 2. In operation the tail edge **19**A*b* of the permanent magnet **19**–A successively travels past the switches **13**A and **13**B to ignite in succession a first and a second engine cylinder in the same manner as previously described and the tail edge **19**B*b* successively travels past the switches **13**A and **13**B to ignite similarly a third and a fourth engine cylinder. Thus, at each time the rotor **18** has rotated through 90 degrees, the associated one of the engine cylinders is ignited whereby the four stroke cycle-four cylinder engine is operated in the manner as previously described in conjunction with FIGS. 1 through 3.

Referring now to FIGS. 5 and 6, there is illustrated another modification of the invention. An arrangement illustrated comprises four protective tube type switches **13**A through D disposed at substantially equal angular intervals as in FIGS. 1 and 2 and a stationary permanent magnet **19**–A, **19**–B, **19**–C or **19**–D disposed oppositely to each of the switches. Each permanent magnet is of a U-shaped cross section as the permanent magnet **19** shown in FIGS. 1 and 2 and includes a pair of pole end faces opposite in polarity and facing the associated switch to form a gap therebetween. In this example it is noted that the permanent magnets are supported to an upper support plate **11** of a switch casing **9** as clearly shown in FIG. 5.

The arrangement comprises further a cup-shaped member **25** of any suitable magnetic material serving as the rotor **18** previously described in conjunction with FIGS. 1 and 2. The cup-shaped member or shutter **25** has a bottom rigidly secured on a rotatory shaft **6** and a cylindrical wall portion or axial extension extending upwardly between the switches **13** and the permanent magnets **19** and provided with a single window **26** circumferentially extending through an angle slightly less than an angle of 90 degrees. The cup-shaped member or shutter **25** cooperates with the permanent magnets **19**–A through **19**–B to effect closing and opening of the switches **13**A through **13**B. More specifically, when the window **26** on the cup-shaped member **25** is disposed opposite to one of the switches, the member permits a magnet flux from the associated permanent magnet to pass to that switch to close the latter. At the instant the tail edge **26***b* of the window **26** travels past the now closed switch, the cup-shaped member **25** acts as a shutter and begins to prevent the flux from the magnet from passing through the switch to open the latter. Thus it will be appreciated that the switches are successively open once for each quarter of one complete revolution of the rotary shaft **6** whereby the associated engine of four stroke cycle-four cylinder type is periodically ignited to be operated.

In the arrangement illustrated in FIGS. 5 and 6, an angle subtended by the window **26** corresponds to an angular range over which the individual switches each are in its closed position while 90 degrees minus that angle corresponds to an angular range over which the switches each are in its open position. As in the embodiment illustrated in FIGS. 1 and 2, the last mentioned angular range can be made sufficiently small while the first mentioned angular range be made sufficiently large. In other respects, the arrangement is substantially identical to that shown in FIGS. 1 and 2.

The arrangement shown in FIGS. 5 and 6, is particularly advantageous in that the cup-shaped member or magnetic shutter **25** can be made in an extremely thin-walled structure to decrease the mass of the rotor **18**. This leads to a decrease in mass of the rotatory part of the switch device and therefore to a simplification of the structure of a bearing unit for the rotatory shaft **6**. Moreover, the shutter axial extension and tubes can be disposed in axially parallel planes to make the device compact radially. In addition, the rotatory shaft **6** is also axially carried at the bottom of a base block **1** (not shown). Therefore bearing means for axially carrying the rotatory shaft **6** and hence lubricating means can be made in simple structures.

FIG. 7 shows an arrangement similar to that illustrated in FIGS. 5 and 6 excepting that a pair of switches as previously described are used to ignite a four stroke cycle-four cylinder internal combustion engine. As in FIGS. 5 and 6, a pair of protective tube type switches **13**A and **13**B are spaced away from each other by an angle of 90 degrees and associated with a pair of stationary permanent magnets **19**–A and **19**–B disposed oppositely to the respective switches.

In order to operate a four stroke cycle-four cylinder internal combustion engine, a cup-shaped member or magnetic shutter **25** similar in both shape and material to that as above described in conjunction with FIGS. 5 and 6 is provided on the cylindrical portion with a pair of windows **26**–**1** and **26**–**2** subtending a larger angle and disposed symmetrically with respect to the axis of a rotatory shaft **6** and includes a pair of solid cylindrical portions left between the pair of windows. The window **26**–**1** has its tail edge **26**–**1***b* diametrically opposed to the tail edge **26**–**2***b* of the window **26**–**2**. At the instant the tail edge **26**–**1***b* of the window **26**–**1** successively travels past the switches **13**A and **13**B a first and a second engine cylinder are successively ignited and the tail edge **26**–**2***b*

of the window 26–2 serves to ignite a third and a fourth engine cylinder. In other respects, the arrangement is substantially identical to that illustrated in FIGS. 5 and 6.

Referring now to FIGS. 8 and 9, there is illustrated another modification of the invention wherein a single switch of protective tube type is used to ignite a four stroke cycle-four cylinder internal combustion engine. An arrangement illustrated comprises a single switch 13 of protective tube type such as previously described horizontally disposed on the internal or lower surface of an upper support plate 11 of a switch casing 9 with a gap 17 between a pair of contact elements 15 and 16 disposed axially of a rotatory shaft 6. While the switch may be ordinarily positioned so as to have its longitudinal axis disposed in a radial direction with respect to the axis of the rotatory shaft, the same in the example illustrated is positioned at an angle to a diameter passing through the axis of the shaft 6 for the purpose of reducing the radial dimension of the switch device 10 (see FIG. 9).

Operatively associated with the single switch 13 is a single permanent magnet 19 of U-shaped cross section disposed below the switch and supported on the internal surface of the lower support plate 12 of the switch casing 9 with a pair of pole end faces opposite in polarity facing the switch.

In order to close and open the switch 13, a rotor 18 having a radial extension of any suitable magnetic material in the form of a disk or magnetic shutter 25 is rotatably disposed between the switch 13 and the permanent magnet 19 and is provided with four windows 26–1, 26–2, 26–3 and 26–4 defined by leading edge 26–1*a* through 26–4*a*, tail edges 26–1*b* through 26–4*b* and front arc-shaped edges respectively. As in the previous arrangements, a first, a second, a third and a fourth engine cylinder are successively ignited at the instances the tail edges 26–1*b* through 26–4*b* travel past the switch 13 respectively. It is to be noted that the tail edge of each window is selected to run in such a direction that when the tail edge is disposed opposed to the switch, the entire length thereof will have substantially instantaneously traveled past the switch with the result that opening of switch is quickly effected. In other respects, the arrangement is substantially identical to that illustrated in FIGS. 5 and 6. This device has the shutter and switch tube means in radially parallel planes thereby making the device compact axially.

Referring now to FIG. 10, there is illustrated another circuit which may be associated with any of the arrangements as previously described to ignite the associated engine. The circuit illustrated comprises a source of direct current 21, an ignition coil 22 and a pulse amplifier generally designated by reference numeral 27. The amplifier 27 includes a PNP transistor 28 having an emitter electrode connected to a positive terminal of the source 21, a base electrode connected to a switch device 10 such as previously described, and a collector electrode connected to the primary winding 23 of the ignition coil 22. The ignition coil 22 includes a secondary winding 24 the output from which can be selectively connected to ignition plugs 29–A, 29–B, 29–C and 29–D for a first, a second, a third and a fourth engine cylinder through a central electrode 3, a distributor contactor 8 and selected one of distribution electrodes 4.

In the circuit illustrated, a protective tube type switch 13 in the switch device 10 is not required to control directly an input current to the primary winding 23 of the ignition coil 22 but is required only to control such an input current divided by the amplification factor of the transistor 27. In other words, the switch is sufficient only to control a low current resulting in a decrease in wear of the contact elements 15 and 16 of the switch 13 and accordingly in increase in useful life of the latter. Instead of the PNP transistor, an NPN transistor may be employed if desired. Also a multi-stage amplifier including a plurality of PNP or NPN transistors may be utilized when required. When such a multi-stage amplifier is used, the larger the number of amplifier stages the lower the magnitude of current to be controlled by the switch 13. Thus the switch will have a longer useful life.

The switches 13 of the protective tube type used with the embodiments as previously described are generally called a reed switch comprising an enclosed envelope 14, a pair of contact elements 15 and 16 sealed thereinto. The interior of the enclosed envelope 14 may be maintained in a vacuum or have an amount of any suitable inert gas such as argon sealed therein whereby the contact elements 15 and 16 are protected against damage due to arcing therebetween.

If desired such a reed switch may be replaced by a so-called "mercury contact switch" comprising an enclosed envelope having enclosed therein an amount of electrically conducting liquid such as mercury as will be subsespently described in conjunction with FIG. 11.

As shown in FIG. 11, a switch 13 comprises an enclosed envelope 14, a pair of spaced contact elements 15 and 16 to form a contact gap 17 therebetween and mercury 30 enclosed therein in an amount insufficient to wet directly those portions of the surfaces of the contact elements forming the gap 17. The mercury 30 is normally disposed on the bottom portion of the envelope 14 and adapted to move upwardly by its capillary action to wet the surfaces of the contact element 16. If the contact elements 15 and 16 contact each other by the external magnetic field resulting from the permanent magnet as previously described then that portion of mercury adhering to the surface of the contact element 16 is also applied to the contact element 15 with the result that the surfaces of both contact elements 15 and 16 are wetted by the mercury 30. The mercury adhering to the surfaces of the contact elements 15 and 16 serves to increase the magnitude of the current which may flow through the contacting portions of the elements when they are brought into contact relationship and also to prevent the contact elements 15 and 16 from wearing directly due to arcing therebetween resulting in an increase in the useful life of the switch. This is true in the case mercury is replaced by any other suitable liquid conductor.

While the invention has been illustrated and described in conjunction with the permanent magnet for operating the protective tube type switch, it is to be understood that any electromagnet means including an energizing winding disposed around an iron core is, if desired, provided to operate such switch with the satisfactory result.

Also while the invention has been described in terms of a four stroke cycle-four cylinder internal combustion engine, it is equally applicable to two stroke cycle engines or engines including any desired number of engine cylinders by suitably changing the number of protective tube type switches, the positions where the switches are disposed in the associated switch casing and the shape of the rotor.

From the foregoing it will be appreciated that the present invention has provided an ignition device greatly increased in useful life and including a switch device which need not be re-adjusted through a skilled technique and resuitlng in easy replacement thereof. Moreover, the device increases greatly a change in input current to an ignition coil and thereby produces a sufficiently high ignition voltage. In addition, this ignition voltage can be maintained at a sufficiently high magnitude even if the associated engine is operated at a sufficiently high number of revolutions. This ensures that the engine is permitted to be ignited with a very high electrical energy and thereby to increase its power ouptput. Further the invention eliminates any failure due to deterioration of the contact portions of the switch device and improves ignition ability.

What I claim is:

1. An ignition device for internal combustion engines comprising, at least one stationary tube switch having

make-and-break contacts responsive to magnetic flux for closing thereof and normally open in the absence of application of magnetic flux thereto, at least one stationary permanent magnet disposed applying magnetic flux to said contacts for closing said contacts, a rotary magnetic shutter driven in operation in timed relationship with the internal combustion engine to which said ignition device is applied for periodically interrupting application of magnetic flux to said contacts to alternately open said switch upon interruption of said magnetic flux and close it by allowing said magnet to apply flux to said contacts, an output circuit comprising an ignition coil to receive a voltage output from said source under control of said switch to develop a high ignition voltage for application to said internal combustion engine.

2. An ignition device according to claim 1, including an amplifier amplifying the output applied to said ignition coil.

3. An ignition device according to claim 2, in which said amplifier comprises a transistor.

4. An ignition device according to claim 1, in which said tube switch comprises a mercury switch.

5. An ignition device according to claim 1, wherein

said shutter has an axial extension for interrupting the magnetic flux flowing from the magnet to the tube switch, and said tube switch being disposed in a plane substantially axially parallel to said extension.

6. An ignition device according to claim 1, wherein said shutter has a radial extension for interrupting the magnetic flux flowing from the magnet to the tube switch and said tube switch being disposed in a plane substantially parallel with said radial extension.

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