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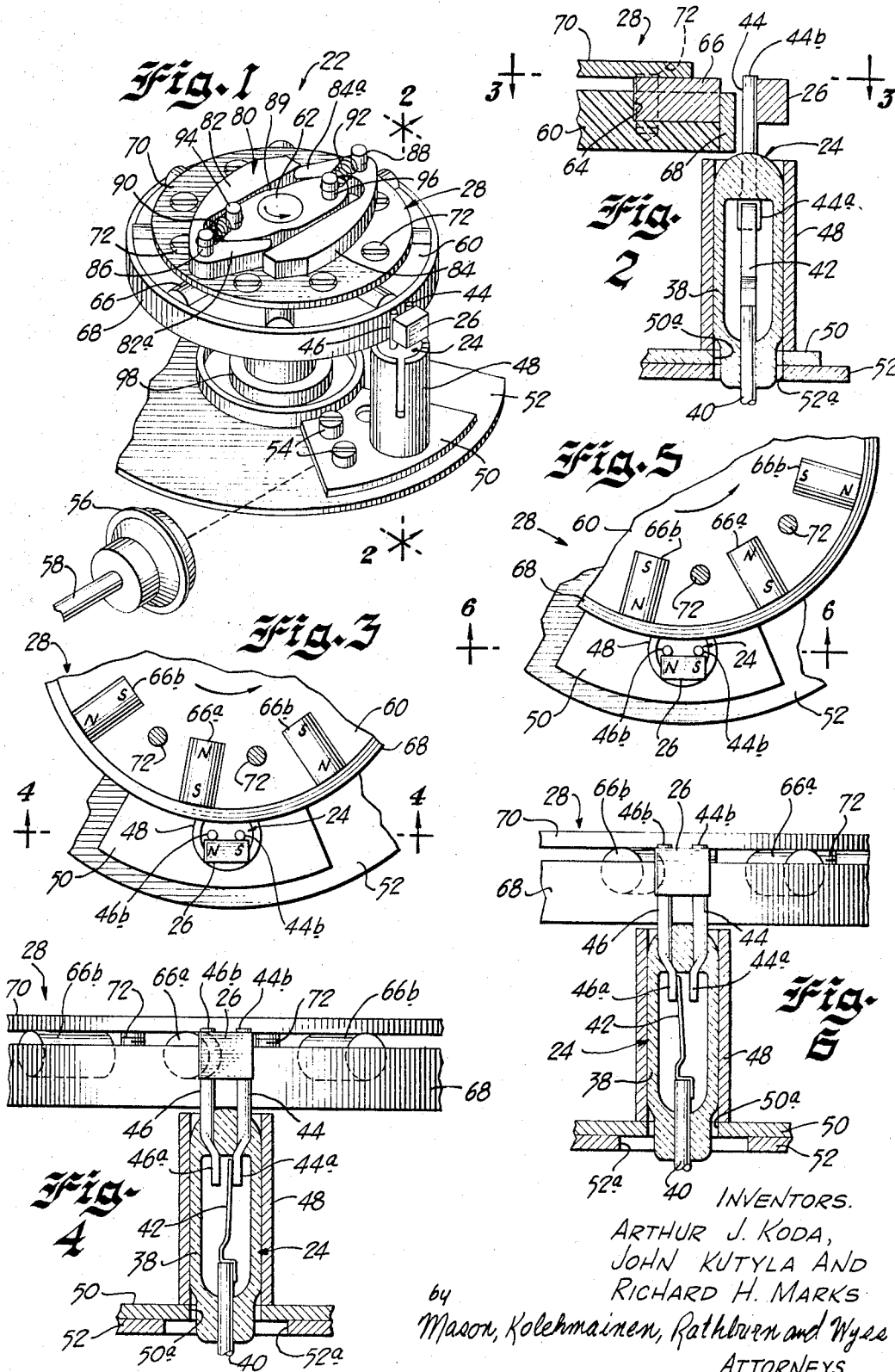
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3,359,455

AUTOMOTIVE DISTRIBUTOR AND IGNITION SYSTEM

Filed July 9, 1964

3 Sheets-Sheet 1



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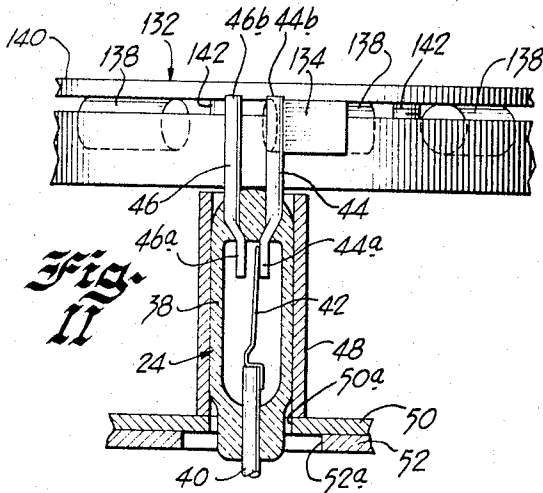
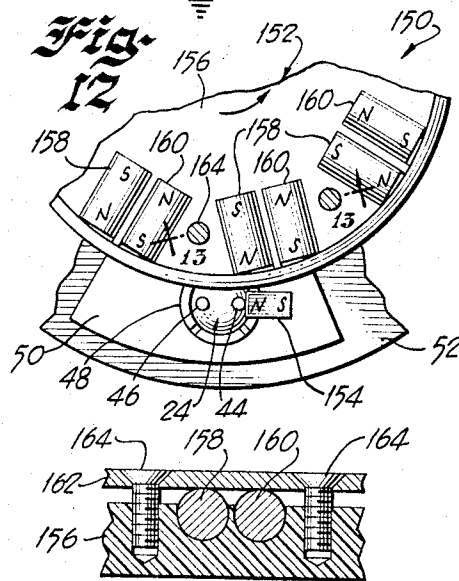
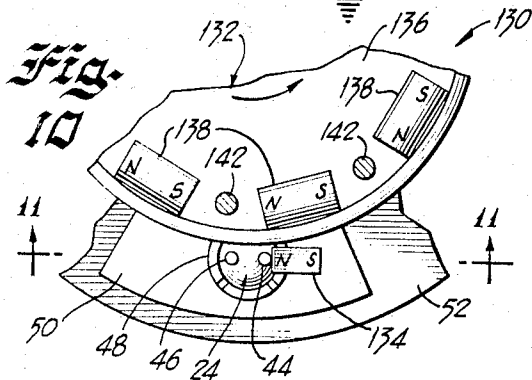
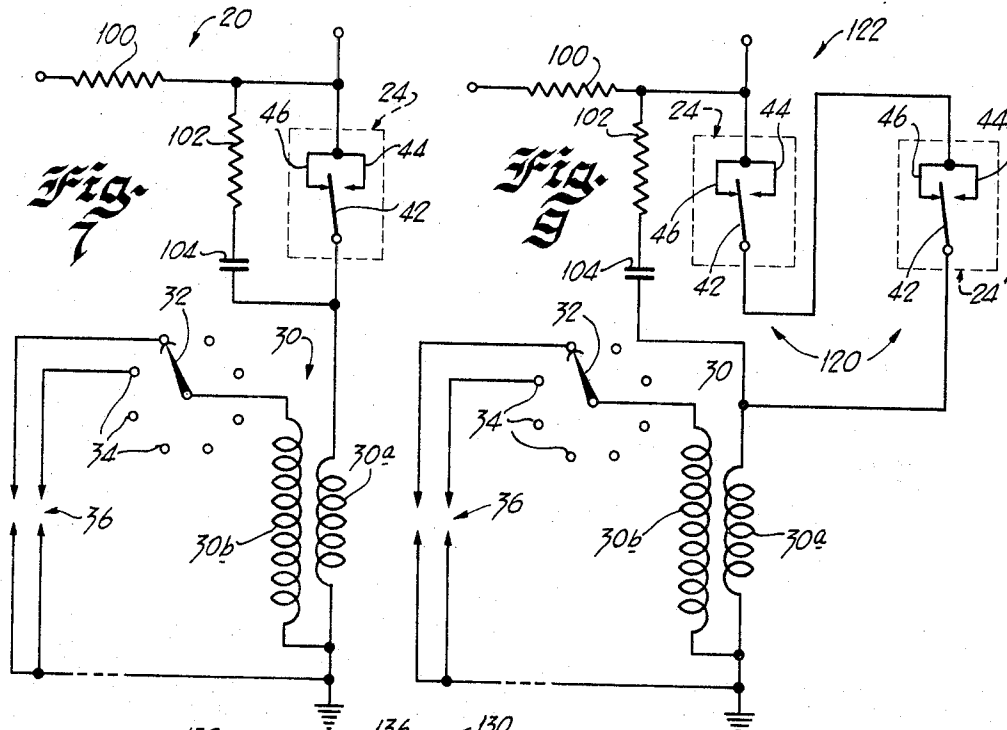
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AUTOMOTIVE DISTRIBUTOR AND IGNITION SYSTEM

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3 Sheets-Sheet 2



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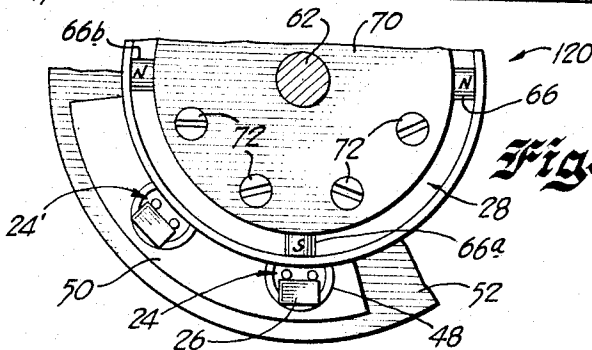
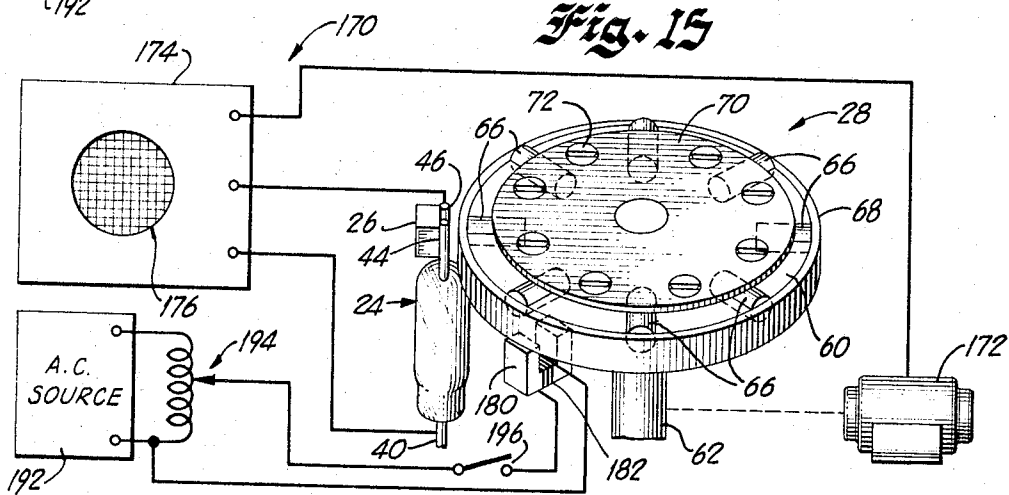
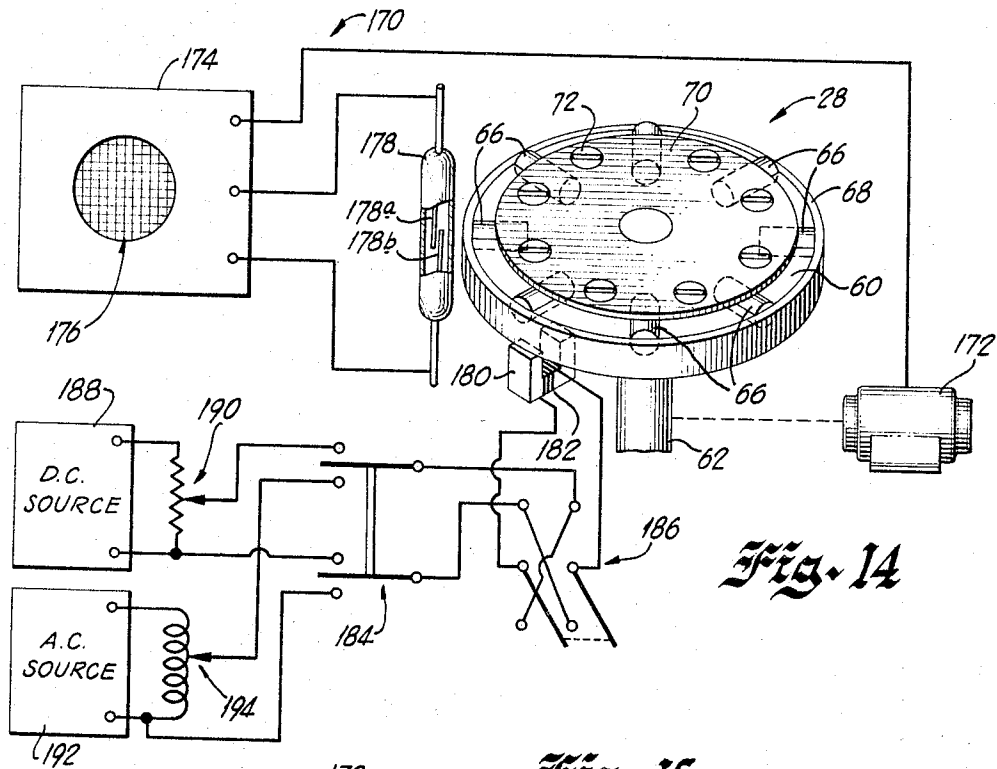
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AUTOMOTIVE DISTRIBUTOR AND IGNITION SYSTEM

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3 Sheets-Sheet 5



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AUTOMOTIVE DISTRIBUTOR AND IGNITION SYSTEM

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17 Claims. (Cl. 315-209)

This invention relates to an automotive distributor and ignition system and, more particularly, to a distributor and electrical ignition system using a sealed magnetic switch, as well as a method of and an apparatus for making and testing the distributor and ignition system.

The automotive systems now in general use are ones in which the battery current flowing in the primary of an ignition coil or transformer is periodically interrupted in a timed relation with the operation of the engine so that the high voltage induced in the secondary winding of the coil can be applied in sequence or distributed to the spark plugs of the engine. The usual arrangement for interrupting the primary current includes a pair of normally closed contacts formed of tungsten or similar material which are connected in series with the primary winding and the battery and which are separated by means of a rubbing block carried on one of the contacts that is biased against a timing cam on the distributor shaft. Although the periodicity of the contact actuation remains substantially unchanged by virtue of the fixed faces of the timing cam, the timing of the interruptions and the consequent sparks can be advanced relative to the engine cycle by centrifugally controlled means and vacuum controlled means in accordance with changes in engine speed and acceleration.

This type of distributor and electrical ignition system is subject to a number of known deficiencies that result in reduced engine performance and frequent replacement of parts or at least remedial maintenance. These disadvantages are both mechanical and electrical in nature, and, even though considerable efforts have been made over the years to obviate these deficiencies or to provide a satisfactory substitute, the distributor-ignition system described above has remained basically unchanged in its approach.

One of the primary sources of difficulty arises from the use of the pivoted breaker contacts which are periodically separated to interrupt the primary current under the control of the displacement of the rubbing block by the successive faces of the cam. The tungsten contacts normally used switch currents of from 3 to 5 amperes in the ambient atmosphere with the result that the contacts not only become pitted, eroded, and oxidized, but are subject to surface contamination from agents in the atmosphere. This frequently necessitates replacement of the breaker contacts. In an effort to provide uniform low contact resistance as well as to insure that the rubbing block follows the configuration of the cam, it is necessary to apply substantial biasing forces to the contacts and, through the rubbing block, to the cam. This transverse application of force to the timing shaft adversely affects the distributor bearings, does not insure adequate contact operation, contributes to rubbing block wear, and aggravates bounce or inadvertent opening and reclosure of the breaker contacts. The wearing of the rubbing block introduces the additional disadvantage of causing a retardation of the timing of the spark.

This type of ignition also suffers from a number of additional electrical difficulties other than those occasioned by the deterioration of the contacts. The speed at which the breaker contacts are separated is determined by the speed at which the timing shaft or cam is rotated. At low or cranking speeds, the contacts are separated relatively

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slowly with the result that the current flowing through the primary of the coil forms a sustained arc between the breaker contacts. This not only injures the contacts but also causes a dissipation of the stored energy with the result that less energy is available for ignition of the combustible mixture. At high speeds, the rubbing block frequently is unable to precisely follow the configuration of the cam with an attendant variation in spark timing. In addition, there is a pronounced tendency at high speeds for the breaker contacts to bounce with the result that the dwell period of the contacts or the period in which they are closed is substantially reduced in duration. This can prevent an adequate increase or build-up in the flux of the coil with the result that the spark voltage is missing or severely attenuated in amplitude. All these factors tend to cause excessive fuel consumption and erratic or inefficient engine performance.

Although many attempts have been made to obviate the problems presented by the breaker contacts now used, virtually the only radical departure from the type of distributor or ignition system described above that has achieved any substantial degree of commercial use is a transistorized ignition system. In general, a transistorized ignition system employs a controlled conduction semiconductor or solid state device as a switch for interrupting and establishing current flow through the winding of the ignition coil. The semiconductor device is periodically placed in conduction under the control of pulses generated in synchronism with the operation of the engine by either magnetic induction means or conventional cam operated contacts carrying, however, a relatively small current. This type of system requires a large number of components with the attendant increase in initial and maintenance costs, and many of the components are so voltage sensitive as to require the addition of further voltage stabilizing and protective devices to the circuit. Even with the additional protection afforded by the liberal use of Zener diodes and other transient protection networks, the semiconductor devices frequently are damaged to the extent that the ignition system is rendered inoperative. A further difficulty inherent in this approach is the inability of service personnel to perform customary engine maintenance without either replacing the entire system or receiving extensive additional training in the care of circuits using solid state devices.

Accordingly, one object of the present invention is to provide a new and improved automotive distributor and ignition system.

Another object is to provide an ignition system providing efficient engine operation over the entire range of engine operating speeds.

A further object is to provide an electrical ignition system capable of economic manufacture and easy maintenance.

A further object is to provide an ignition system in which the primary current flow through the coil is interrupted and established with uniformity over the full operating range of the engine.

A further object is to provide a distributor construction having contact means of virtually unlimited life and uniform contact characteristics.

Another object is to provide an automobile distributor construction in which the distributor shaft is substantially free of externally applied unbalanced forces.

A further object is to provide an automotive ignition system including a sealed magnetic switch periodically operated by moving permanent magnet means to control the generation of a sparking potential.

A further object is to provide an automotive ignition system in which a sparking potential of a uniform magnitude is provided by using the constant transfer time of a sealed magnetic switch.

A further object is to provide an automotive ignition system in which a magnetically biased bistable sealed magnetic switch is operated between its alternate positions by oppositely poled permanent magnets to provide means for controlling the generation of a sparking potential.

Another object is to provide an automotive ignition system including a polarized magnetic switch periodically operated by a plurality of permanent magnets in which the biasing magnet for the sealed magnetic switch is selectively positioned in dependence on the direction of movement of the permanent magnets.

Another object is to provide an electric ignition system or distributor including a magnetically biased bistable sealed magnetic switch with mercury-wetted contacts which is operated by oppositely poled permanent magnets moving in synchronism with the operation of the engine.

Another object is to provide an electrical ignition system using a sealed magnetic switch including a new and improved protective network for the switch.

Another object is to provide an electrical ignition system using a sealed magnetic switch having a fixed operate time in which novel means are provided for compensating for the operate time of the switch.

A further object is to provide a method of making automotive ignition systems in which a sealed magnetic switch is operated by a plurality of spaced and moving magnetic fields which includes the steps of adjusting the magnetic fields to provide operation of the switch at desired points in the path of movement.

A further object is to provide a method of making automotive distributors using a magnetic switch operated by a plurality of moving permanent magnets including the steps of saturating the magnets and then selectively reducing the fields of the permanent magnets until the magnetic switch is operated at the desired intervals.

Another object is to provide a method of making an automotive distributor using a biased magnetic switch periodically operated by a plurality of permanent magnets which includes the steps of adjusting the permanent magnets to achieve substantially equally spaced operation of an unbiased switch and then adjusting the bias applied to the switch to cause its operation by the permanent magnets at the desired times.

A further object is to provide a method of making an automotive distributor having a magnetically biased switch which is operated by a plurality of rotating permanent magnets which includes the steps of adjusting the permanent magnets to achieve proper operation of the switch and then adjusting the bias applied to the switch in accordance with the direction of movement of the permanent magnets to cause its operation at desired intervals.

A further object is to provide apparatus for making automobile distributors which includes means for rotating a plurality of spaced permanent magnets relative to a magnetic field detecting means and means synchronized with the moving means for determining the relative values of the magnetic fields at desired points in the path of movement.

Another object is to provide an apparatus for making automobile distributors in which a sealed magnetic switch is periodically operated by a plurality of spaced permanent magnets which includes means for moving the permanent magnets relative to the sealed magnetic switch, means synchronized with the movement of the permanent magnets for determining the positions in the path of movement at which the switch is operated, and additional means for altering the fields of the permanent magnet to adjust the positions in the path of movement of the permanent magnets at which the sealed switch is actuated.

In accordance with these and many other objects, an embodiment of the invention comprises an electric automotive ignition system including a coil having a pri-

mary winding and a secondary winding that is coupled in sequence to a plurality of spark generating means or spark plugs in an engine by a distributor. The primary winding is connected in series with a potential source, such as an automobile battery, through the mercury-wetted contacts of a sealed magnetic switch. The sealed magnetic switch is operated in synchronism with the engine cycle so that the periodic collapse of the field of the primary winding of the coil induces a high value sparking potential in the secondary winding of the coil which is forwarded over the distributor arm or wiper to the proper one of the spark plugs.

The novel distributor construction embodied in the electrical ignition system comprises a sealed mercury switch mounted with at least some of its magnetic terminals disposed adjacent the path of rotation of a carrier means that is rotated in synchronism with the operation of the engine. The positions of the carrier means and the sealed magnetic switch can be shifted relative to each other by vacuum or centrifugally actuated means to provide speed and acceleration responsive means for advancing the spark with respect to the engine cycle.

In one embodiment of the invention using a bistable sealed switch, oppositely poled biases are applied to two alternately engaged contacts or terminals of the sealed switch, and the carrier is provided with peripherally spaced permanent magnets of alternate and opposite polarities. The alternately engaged contacts or terminals of the switch are connected in common so that the sealed switch provides a conductive circuit for the primary winding of the coil whenever the switch is in either one of its alternate states and so that the energizing circuit for the primary winding is interrupted only during the constant value transfer time in which the armature is moving from engagement with one of the contacts to the other of the contacts. Thus, when relative movement is produced between the magnetic switch and the magnetic field generating means, the armature is moved into alternate engagement with the two magnetic terminals or contacts to periodically interrupt the flow of current in the primary winding.

In a second embodiment using a single-side-stable magnetic switch, the carrier presents oppositely poled magnetic fields to one terminal of the switch in succession so that the armature moves away from and back into engagement with the biased terminal. The biased terminal is the only terminal connected in series between the potential source and the primary winding. Thus, the momentary operation of the single-side-stable switch also provided periodic interruption of the primary current in response to relative movement between the sealed magnetic switch and the permanent magnets on the carrier means.

In one method of manufacturing the novel automotive distributor, permanent magnets on the carrier are saturated, and the sealed switch is disposed adjacent the path of movement of the carrier to be subjected to the fields of the permanent magnets as relative movement is produced between the carrier and the sealed switch. The point at which the switch is operated by the magnetic fields is determined, and the effective fields of the permanent magnets are adjusted so that the sealed switch is operated at the desired positions. Normally, the sealed switch is operated at equally spaced positions corresponding to the intervals in the engine cycle at which the combustible mixture is to be ignited.

In another method of forming distributors and ignition systems embodying the present invention, the permanent magnets on the carrier are saturated and reduced to substantially equal values so that a detecting means, such as a magnetic reed switch, is operated at equally spaced points in the path of relative movement between the carrier and the detecting means. This detecting means is then replaced with an unbiased sealed magnetic switch, and relative movement is again produced between the

permanent magnet and the sealed magnetic switch. The magnetic biasing means for the switch is then moved into proximity to at least one of the magnetic terminals and its position varied while observing the points or positions in the engine cycle at which the switch is operated until such time as the operating points have been adjusted to those required by the engine cycle. The biasing means is then fixed in position.

The sealed magnetic switch having mercury-wetted contacts embodied in the present invention not only has virtually unlimited life but also has uniform contact resistance so as to obviate the need for replacing these contacts during the operating life of the engine. The armature of the switch is separated from the contacts at extremely high acceleration regardless of the speed of operation of the engine to avoid arcing at low engine speeds and is magnetically biased in its closed positions to prevent contact bounce. In addition, the switch is operated to provide a substantially uniform transfer time regardless of engine speed to provide a fixed dwell or closed circuit time during which the flux build-up in the coil attains a uniform level with the attendant avoidance of any reduction in engine performance at either high or low speeds. Further, the use of magnetic coupling between the magnetic operating means and the magnetic switch during operation of the distributor avoids any change in engine timing arising from the wear of components such as the rubbing block. This also avoids the application of unbalanced forces to the timing or distributor shaft with the result that wear of the bearings is reduced. In addition, the time lag in the response of the vacuum and mechanical advance means in conventional constructions resulting from the friction loading or mechanical drag on the cam is minimized.

Many other objects and advantages of the present invention will become apparent from considering the following detailed description in conjunction with the drawings in which:

FIG. 1 is a perspective view partially in schematic form of an automotive distributor embodying the present invention;

FIG. 2 is an enlarged sectional view taken along line 2—2 in FIG. 1;

FIG. 3 is a sectional view taken along line 3—3 in FIG. 2 illustrating one set of relative positions of a magnetic switch and magnetic operator means included in the distributor construction;

FIG. 4 is an enlarged sectional view taken along line 4—4 in FIG. 3 illustrating the corresponding state of the sealed magnetic switch;

FIG. 5 is a fragmentary sectional view similar to FIG. 3 illustrating a different set of relative positions of the sealed magnetic switch and the magnetic operator means;

FIG. 6 is an enlarged sectional view taken along line 6—6 in FIG. 5 showing an alternate operative state of the sealed magnetic switch;

FIG. 7 is a schematic circuit diagram of an electrical ignition system embodying the present invention;

FIG. 8 is a top plan view in partial section of a distributor construction similar to that shown in FIG. 1 but including a pair of sealed magnetic switches;

FIG. 9 is a schematic circuit diagram of an electrical ignition system using the distributor construction shown in FIG. 8;

FIG. 10 is a top elevational view in partial section illustrating a modification of the distributor construction using a single-side-stable magnetic switch;

FIG. 11 is an enlarged sectional view taken along line 11—11 in FIG. 10;

FIG. 12 is an alternate embodiment of the distributor construction shown in FIG. 10 using a single-side-stable sealed magnetic switch;

FIG. 13 is a sectional view taken along line 13—13 in FIG. 12;

FIG. 14 is a schematic diagram of an apparatus for

carrying out a method for manufacturing and testing automotive distributors embodying the present invention; and

FIG. 15 is a schematic diagram of an apparatus for performing another step in the method of manufacturing the automotive distributors.

Referring now more specifically to FIGS. 1—7 of the drawings, therein is illustrated an electric ignition system 20 (FIG. 7) which embodies the present invention and which includes a novel distributor construction or assembly 22 (FIG. 1). The distributor construction 22 includes a sealed magnetic switch 24 that is magnetically biased for bistable operation by a biasing magnet 26. The switch 24 is disposed adjacent the path of movement of a carrier or operator assembly indicated generally as 28 which is rotated in synchronism with the operation of an engine and which provides alternate magnetic fields of opposite polarity for operating the sealed magnetic switch 24. The contacts of the switch 24 are connected together and to a source of potential, and the armature of the sealed magnetic switch 24 is connected to one terminal of the primary winding 30a (FIG. 7) of a conventional ignition coil 30. A secondary winding 30b of the ignition coil 30 is connected to a distributor arm or wiper 32 which engages a plurality of distributor points 34 in sequence to apply a spark potential or voltage to corresponding spark generating means or spark plugs indicated generally as 36.

In operation, the armature of the sealed magnetic switch 24 normally engages one of the terminals or contacts of the switch 24 to complete an energizing circuit for the primary winding 30a of the ignition coil 30. In response to relative movement between the carrier 28 and the switch 24, the armature is moved out of engagement with the previously engaged contact and into engagement with the alternate one of the contacts so that current flow through the primary winding 30a is interrupted during this transfer time. The collapse of the flux field occasioned by interrupting the flow of current through the primary winding 30a induces a high voltage in the secondary winding 30b which is applied over the wiper 32 and the engaged distributor point 34 to a selected one of the spark plugs 36. The reclosure of the switch 24 reestablishes the current flow through the winding 30a and prepares the ignition system 20 for applying firing potential to the next spark plug 36 selected by the distributor arm 32.

The sealed magnetic switch 24 provides mercury-wetted contacts of uniform low resistance operating in a controlled atmosphere and has an established operating life measured in terms of billions of operations. Thus, the switch is not a component that is subject to failure and replacement in the manner of the contacts previously used. The sealed switch 24 is substantially free from bounce in its biased mode of operation and possesses a substantially constant transfer time or open period time so that the angular time afforded for flux build-up due to current flowing in the primary winding 30a remains substantially constant over the entire operating speed range of the associated engine, thereby supplying sparking potentials of a uniform maximum value over the full range of speeds at which the engine is operated.

The armature of the magnetic switch 24 separates from an engaged contact with a high rate of acceleration approaching 1500 g's with the result that substantially no energy is dissipated in arcing at the contacts, even at low or cranking speeds of the engine. In this manner, the electrical ignition system 20 and the improved distributor construction 22 afford efficient and substantially trouble-free engine performance over periods of time exceeding the useful operating life of most internal combustion engines.

Referring now more specifically to the construction of the distributor assembly 22, the sealed magnetic switch 24 included therein comprises an elongated dielectric or glass

housing 38 in the lower end of which a terminal 40 is sealed. The inner end of the terminal 40 carries a flexible magnetic armature 42 provided with capillary or other means for maintaining its opposite surfaces wetted with mercury supplied from a pool thereof (not shown) within the lower end of the elongated housing 38. A pair of magnetic terminals or contact members 44 and 46 are sealed in the upper end of the envelope 38 (FIGS. 4 and 6) and are provided with offset lower ends 44a and 46a adapted to be alternately engaged by the upper free end of the magnetic armature 42. The outer ends of the magnetic terminals or contacts 44 and 46 project upwardly in substantially parallel spaced positions and are secured to the biasing magnet 26. Although the switch 24 can comprise any suitable construction, it preferably comprises a sealed switch of the type shown and described in detail in the contemporaneously filed application of Herman P. Hempel, Ser. No. 381,446, which application is assigned to the same assignee as the present application.

As set forth above, the biasing magnet 26 is secured to the portions 44b and 46b of the magnetic contacts 44 and 46. The biasing magnet 26 renders the sealed magnetic switch 24 bistable, i.e., the armature 42 will be retained in engagement with either of the contact portions 44a or 46a following engagement therewith and until positively displaced into engagement with the other one of these contacts. The biasing magnet 26 is secured to the upper portions 44b and 46b by any suitable means such as soldering or epoxy cement in a position with the magnetic axis of the magnet extending generally transverse to the longitudinal axes of the terminals 44 and 46. Although the magnet 26 can be secured to the terminals 44 and 46 with any polar orientation, the magnet 26 shown in the drawings includes a north pole disposed adjacent the terminal 46 and a south pole disposed adjacent the terminal 44. The magnetic bias applied by the magnet 26 is sufficient to impart bistability to the sealed switch 24. In other words, the bias applied by this magnet is sufficient to retain the upper end of the armature 42 in contact with either of the contact portions 44a or 46a of the terminals 44 and 46 following engagement therewith and until such time as the armature 42 is positively deflected into engagement with the alternate one of these terminals. In addition, the biasing magnet 26 renders the switch 24 polarity sensitive so that the armature 42 will engage the terminal 44 only when an applied flux field of a polarity identical to the bias applied to this terminal becomes predominant or, alternatively, will engage the terminal 46 only when the applied flux field has a polarity the same as that applied to the terminal 46. In general, the degree of magnetic bias applied to the terminals 44 and 46 by the magnet 26 is substantially the same although this will be varied in dependence on manufacturing variations in the production of the switch 24 and on the direction of rotation of the carrier 28 relative to the switch 24.

The sealed magnetic switch 24 has a low uniform contact resistance between the armature 42 and either of the contacts 44 and 46 of 25-40 milliohms and has a substantially constant transfer time of from .2 to .5 milliseconds. This transfer time is the time elapsed between separation of the armature 42 from one of the contacts 44 or 46 and the subsequent engagement between this armature and the alternate one of the contacts 44 or 46. The armature 42 separates from the contacts 44 and 46 with an acceleration approaching 1500 g's. The switch 24, which is operable over a temperature range from around -40° C. to 105° C., can be operated through two hundred switch cycles per second or four hundred contact interruptions per second, which is a speed of approximately one hundred and fifty miles per hour for an eight cylinder automobile engine operating in high gear. The life of the switch 24 has been established to be in excess of one billion operations, and a billion switch operations corre-

sponds to approximately two hundred thousand miles of operation of an automobile engine.

To provide means for mounting the sealed magnetic switch 24 adjacent the permanent magnet operator assembly 28, an elongated dielectric housing 38 of the switch is disposed within a non-magnetic or brass sleeve 48. The sleeve 48 is secured to or carried on the upper surface of a plate 50 that is secured to the upper surface of a timing plate 52 which is rotatably mounted on the housing of the distributor. The lower end of the dielectric housing 38 and the terminal 40 extend downwardly through a pair of aligned openings 50a and 52a in the plates 50 and 52, respectively, to permit the terminal 40 to be connected to one terminal of the primary winding 30a (FIG. 7) of the ignition coil 30. The plate 50 is secured to the timing plate 52 by a plurality of headed fasteners or machine screws 54. The plate 52 is mechanically linked to a conventional vacuum unit 56 which is coupled over a line 58 in the intake manifold side of the engine. The vacuum unit 56 provides means for adjusting the position of the sealed magnetic switch 24 relative to the operator assembly 28 and thus provides means for advancing or retarding the spark potential in dependence on the vacuum existing in the intake manifold of the engine. In this manner, the position of the magnetic switch 24 is shifted in dependence on the load applied to the engine.

The operator assembly 28 for actuating the sealed magnetic switch 24 is operated or rotated in synchronism with the operation of the engine and comprises a generally circular dielectric plate 60 coupled to a distributor shaft 62 and having a plurality of peripherally spaced and generally radially extending recesses 64 for receiving a plurality of permanent magnets 66. A circular ring of non-magnetic material 68 surrounds the member 60 and closes the outer ends of the recesses 64. The ring 68 is spaced about 1/16 of an inch from the magnetic terminals 44 and 46. The operator assembly 28 is provided with a number of permanent magnets 66 equal to the number of cylinders in the engine or, in instances in which more than a single magnetic switch 24 is provided, the product of the number of switches and the number of permanent magnets or magnetic field reversals is equal to the number of cylinders. The permanent magnets 66, which are provided with longitudinal magnetic axes lying generally along radii of the plate 60, are so mounted on the member 60 as to present alternate poles of opposite polarity. A top plate 70 of non-magnetic material is secured in spaced position above the member 60 by a plurality of machine screws 72 so as to secure or clamp all of the permanent magnets 66 in position within the recesses 64. Although the magnets 66 are shown as being cylindrical in configuration and having axially extending magnetic axes, the magnetic field generating means can be electromagnetic in nature and can comprise permanent magnets of various configurations so long as rotation of the assembly 28 presents successive oppositely poled fields to the magnetic switch 24. Similarly, although the supporting structure of the permanent magnets 66 comprises a multipart construction, the magnets 66 could, for instance, be cast or molded in a unitary block of non-magnetic material.

The operator assembly 28, which is rotated in synchronism with the engine by the shaft 62, is coupled to the shaft by a centrifugally actuated assembly 80 to provide means for shifting the position of the assembly 28 relative to the shaft 62 in response to changes in the speed of operation of the engine. The provision of the assembly 80 thus provides means for changing the timing of the sparking potential relative to the engine cycle. The assembly 80 includes a pair of flyweights 82 and 84 which are pivotally mounted on the plate 70 by a pair of pivot pins 86 and 88, respectively. A pair of cam follower surfaces 82a and 84a on the flyweights 82 and 84 are continuously biased into engagement with the outer cam surfaces on a cam plate 89 secured to the shaft

62 by a pair of tension springs 90 and 92 which extend between the upper ends of the pivot pins 86 and 88 and a pair of pins 94 and 96 carried on the ends of the cam plate 89. The shaft 62, which rotates in a counterclockwise direction (FIG. 1) in synchronism with the operation of the engine, rotates about an axis concentric with the timing plate 52 and is provided with a bearing structure 98. The shaft 62 can be rotated or angularly shifted relative to the plate or member 60 and is coupled thereto through the assembly 80.

When the shaft 62 is rotated, the cam surfaces on the cam plate 89 bear against the cam follower surfaces 82a and 84a on the flyweights 82 and 84 which are mounted on the plate 70 and transmit rotary movement of the shaft 62 to the operator assembly 28 so that the permanent magnets 66 are rotated past the magnetic switch 24 in a counterclockwise direction. As the speed or rotation of the shaft 62 is increased, the free ends of the elongated arms of the flyweights 82 and 84 are displaced outwardly away from the axis of rotation of the shaft 62, and, because of the bearing engagement between the cam surfaces on the cam plate 89 and the follower surfaces 82a and 84a on the flyweights 82 and 84, rotate the circular plate 60 counterclockwise relative to the shaft 62. Considered with respect to their prior positions relative to the shaft 62, the permanent magnets 66 are now advanced with respect to this shaft. Since the magnetic switch 24 is operated by the fields of the magnets 66, advancing the position of the permanent magnets 66 relative to the shaft 62 advances the actuations of the magnetic switch 24 within the cycle of rotation of the shaft and thus, the engine cycle. The cam plate 89 and the followers 82a and 84a of the flyweights 82 and 84 are so designed as to provide an effective distributor advance of the sparking potential of around 12-15° as the engine speed is advanced from zero to four thousand r.p.m.'s.

Thus, the centrifugally actuated assembly 80 advances the times at which the switch 24 is operated relative to the engine cycle by advancing the positions of the permanent magnets 66 relative to the shaft 62. The vacuum assembly 56 advances the operation of the switch 24 by moving the timing plate 52 in a clockwise direction relative to the shaft in response to changes in engine conditions. The clockwise movement of the timing plate 52 advances the position of the magnetic switch 24 relative to the permanent magnets 66 and the shaft 62 and thus advances the time of operation of the switch 24 within the engine cycle.

Referring now more specifically to the electrical ignition system shown in FIG. 7, the armature 42 of the sealed switch 24 is connected to one terminal of the primary winding 30a of the ignition coil 30, and the two contacts 44 and 46 are connected together and to a source of direct current potential, either directly or through a series ballast resistor 100 having a value on the order of 1 ohm. To provide a network for suppressing any possible arcing when the armature 42 is separated from either of the contacts 44 or 46, a contact protection network including a series connected resistance element 102 and a capacitor 104 is connected in parallel with the sealed magnetic switch 24. The capacitor 104, which also performs the dual function of resonating the ignition coil 30, can have any suitable value, although a capacitor of .22 microfarad has been used in ignition systems 20 constructed in accordance with the present invention. The construction and value of the resistance element 102 has been determined to be of substantial importance in insuring the absence of arcs in the sealed magnetic switch 24. In the past, it has been determined that it is necessary to provide no less than .5 ohms in contact protection networks for mercury switches of a construction similar to the switch 24, and it has previously been possible to use resistance elements of any suitable construction, such as alloy resistance wire or

conventional wire wound elements. In the ignition system 20, it appears to be necessary to use copper wire of relatively large gauge in the formation of the resistor 102. In one system constructed in accordance with the present invention, thirty-four inches of twenty-four gauge copper wire was used, and in another instance, seventeen and one-half inches of .125 x .002 inch insulated copper strip in a tight coil was used in forming the element 102. The resistance element in these systems apparently must have a value around .1 ohm or less, and the elements 102 described above have a value of .05-.1 ohm. The resistance element 102 should be made of a metal having a resistivity on the order of 2.8×10^{-8} ohm-m. or less. Although the necessity for providing this type of construction and this value and composition for the resistance element 102 is not fully understood, it is believed that it may be due to the skin effect arising from high frequency potentials involved in the abrupt switching of the highly inductive load.

Assuming that the ignition system 20 and the distributor construction 22 are in the condition illustrated in FIG. 7 in which the armature 42 engages the contact 46 and is magnetically held in engagement with this contact, the primary winding 30a is energized from the unidirectional potential source, and a primary current on the order of three to five amperes is flowing through this circuit. The distributor construction 22 is in such a condition that the counterclockwise rotation of the shaft 62 moves a permanent magnet 66a presenting a south pole into proximity to the leading magnetic terminal or contact element 46 (FIGS. 3 and 4) which is engaged by the armature 42 and which is biased by the north pole of the magnet 26. The magnetic field presented by the permanent magnet 66a is combined in the terminal 46 with the bias flux and tends to cancel the bias provided by the permanent magnet 26 to reduce or nullify the field holding the upper end of the armature 42 in engagement with the magnetic terminal or contact 46. When the permanent magnet 66a reaches a position indicated schematically in FIG. 3, the oppositely poled biasing field applied to the terminal 44 by the biasing magnet 26 overcomes the forces tending to hold the armature 42 in engagement with the contact 46 and transfers the armature 42 to a position engaging the magnetic contact 44 (FIG. 4). The field of the permanent magnet 66a tends to reinforce the bias field applied to the terminal 44 by the biasing magnet 26 in its counterclockwise movement past the magnetic switch 24 from the position shown in FIG. 3 to the position shown in FIG. 5. Thus, the magnetic switch 24 is now in the state shown in FIG. 4 of the drawings.

As set forth above, the magnetic switch 24 requires a substantially constant period of time for mechanical transfer of the armature 42 from the position engaging one of the contacts 44 or 46 to a position engaging the other of these contacts. Consequently, when the armature 42 is transferred from a position engaging the terminal 46 to a position engaging the terminal 44 due to the movement of the operator assembly 28 in advancing the permanent magnet 66a relative to the switch 24, the armature 42 is out of engagement with the contacts 44 and 46 for a period of from .2 to .5 milliseconds. During this period, the primary current flowing through the winding 30a of the ignition coil 30 is interrupted, and the collapse of the flux field induces a high potential in the secondary winding 30b which is applied by the wiper 32 to the proper one of the spark plugs 36. The high rate of acceleration with which the armature 42 is separated from the contact 46 substantially prevents the formation of arcs and thus, the dissipation of energy stored in the primary winding 30a.

When the armature 42 moves to the position shown in FIG. 4, it is magnetically held in engagement with the terminal or contact 44, and the energizing circuit for the primary winding 30a is again established through the engaged armature 42 and contact 44. This current builds

up to assume a constant value, and the flux field for the ignition coil 30 is again fully established. Continuing movement of the operator assembly 28 moves the following permanent magnet 66b of an opposite polarity toward the terminal 46 of the sealed magnetic switch 24. The polarity of the field provided by the permanent magnet 66b is the same as the polarity of the magnetic bias applied to the terminal 46 by the magnet 26. Thus, these two fields are additive in nature and provide a strong field that is effective when the magnet 66b reaches a position indicated schematically in FIG. 5 to overcome the oppositely poled biasing field applied to the armature 42 by the magnetic contact 44. At this time, the armature 42 is transferred from the position shown in FIG. 4 to the position shown in FIG. 6 and is held in engagement with the magnetic terminal 46 by the combined fields of the operator magnet 66b and the biasing magnet 26. The movement of the magnet 66b past the terminal 44b is not effective to shift the position of the magnetic armature 42 because it reduces the effective strength of the south pole of the magnet 26 on the terminal 44b. Thus, the sealed magnetic switch 24 has been transferred from a position in which the armature 42 engages the contact 44 to one in which the contact 46 is again engaged by the movement of the second or oppositely poled permanent magnet 66b relative to the sealed magnetic switch.

The open circuit period during which the armature 42 is transferred from the contact 44 to the contact 46 again interrupts the primary current flowing through the winding 30a so that the secondary winding 30b again applies a high level of potential to the spark plug 36 selected by the distributor arm or wiper 32. This operation using the fields of the permanent magnets 66 and the bias magnet 26 in an additive sense when the contact 46 is to be engaged and in an opposing sense when the terminal 44 is to be engaged continues in the manner described above during each cycle of rotation of the operator assembly 28 to cause eight momentary interruptions in the energizing circuit for the primary winding 30a. If the distributor construction 22 is to be used with a six cylinder engine, the assembly 28 includes only six permanent magnets 66, and the sealed magnetic switch 24 interrupts the primary circuit only six times during each cycle of revolution.

The conventional breaker points used with an eight cylinder engine have a dwell angle or a closed circuit period of approximately 30° out of the 45° between cylinders in an eight cylinder engine at idle and normal speeds. By using the ignition system 20 and the distributor construction 22 of the present invention, the sealed magnetic switch 24 provides a dwell angle or closed primary circuit condition of around 43° at idle and normal speeds and thus allows a substantially longer time for a complete flux build-up in the ignition coil 30. Thus, the system 20 and the distributor 22 provide an arrangement in which the closed circuit time is more than 95% of the available 45° of the engine cycle compared with 67% in a conventional system. Further, since the open circuit period in which current does not flow through the primary winding 30a is the transfer time of the magnetic switch 24, and since this transfer time is substantially constant regardless of the speed at which the switch 24 is actuated, the ignition system 20 provides a dwell angle or closed contact period in excess of 40° at engine speeds as high as 150 miles per hour. As set forth above, this cannot be obtained with conventional ignition systems, and the uniform dwell time at high and low speeds provided by the ignition system 20 and the distributor assembly 22 substantially enhances engine performance at higher speeds as well as lower speeds.

The relatively short and fixed period of time during which the energizing circuit for the primary winding 30a is interrupted, which period is set by the transfer time of the switch 24, is also believed to contribute in an additional manner to the stability of the sparking potential at high speeds. Tests that have been made on the system 20

and the distributor 22 indicates that the transfer period of the switch 24 can be made short enough, considered relative to the other ignition circuit constants, that the flux in the ignition coil 30 does not completely decay during the open circuit period. The effective inductance value of the primary winding 30a is proportional to the coil flux level, and the incomplete decay of the flux during the circuit interruption results in the presentation of a smaller inductive impedance to the energizing circuit when the switch 24 recloses. This reduced impedance permits the primary current to reach a greater value than is attained with prior constructions and to reach this value in a shorter period of time. Because of the fact that the open circuit period provided by the present invention remains constant over the full range of operating speeds, the ignition circuit constants can be designed to prevent complete flux decay during the open circuit period. The fact that the open circuit period interval varies with speed in prior construction means that an arrangement providing a short enough open circuit period to prevent complete flux decay at lower speeds might not provide any effective decay at higher speeds in which the open circuit period would be much less in duration. Alternatively, if the open circuit period is made long enough at high speeds, the flux will completely decay during the longer open circuit period at low speeds. This has the result that the primary energizing circuit in prior arrangements "sees" different load impedances varying with engine speed.

The operator assembly 22 in the illustrated distributor construction 22 is rotated counterclockwise direction relative to the magnetic switch 24. The distributor 22 can also be constructed with an operator assembly 28 rotating in a clockwise direction relative to the magnetic switch 24 by reversing or inverting the arrangement of the components in the centrifugally actuated assembly 80 and by reversing the interconnection between the vacuum unit 56 and the timing plate 52. When the operator assembly 28 rotates in a clockwise direction with the biasing magnet 26 of the same polarity as that shown in FIGS. 1-6 of the drawings, the movement of one of the permanent magnets 66a into proximity to the leading terminal 44 provides an operating flux in an aiding relation to the biasing flux applied to this terminal by the magnet 26. This flux overcomes the holding force latching the armature 42 against the terminal pin 46 and causes the armature 42 to be transferred to a position engaging the terminal pin 44. When a magnet 66b on a clockwise rotating operator assembly 28 moves into proximity to the forwardly positioned or leading magnetic terminal 44, the flux of the operator magnet 66b opposes the biasing flux provided by the magnet 26 and reduces its effectiveness to the point at which the armature 42 is transferred from a position engaging the magnetic contact 44 to one engaging the contact 46. In this manner, the distributor construction 22 can be constructed for either clockwise or counterclockwise rotation. Further, with the distributor construction 22 embodying either clockwise or counterclockwise rotation, the sequence of operation of the magnetic switch, i.e., the order in which the magnetic contacts 44 and 46 are alternately engaged, can be reversed by reversing the direction of polarization of the biasing magnet 26.

As set forth above, the centrifugal assembly 80 can effectively advance the spark 12-15° as the engine speed is increased to four thousand r.p.m.'s. In fact, the cam surfaces on the cam plate 89 are so constructed and arranged as to provide not only the twelve to fifteen degrees of advance normally provided to insure complete combustion of the mixture at the proper point in the engine cycle, but also an additional 12-15° of advance that is not "seen" by the engine to compensate for the operate time of the sealed magnetic switch 24. The construction of this switch is such that a finite time is required following the establishment of the proper magnetic conditions for operating the switch before the inertia of the armature 42 can

be overcome to move this armature out of engagement with the engaged one of the two magnetic contacts 44 and 46. This separation initiates the open circuit or transfer time interval. This time required to place the armature 42 in movement following the establishment of correct magnetic operating conditions or the operate time of the switch 24 remains fixed at around 1 millisecond over the entire range of operating speeds of the engine and is independent of the speed of rotation of the operator assembly 28. At low speeds, the delay in the operation of the switch 24 occasioned by the operate time is not appreciable.

However, as engine speed and consequently the speed of rotation of the operator assembly 28 increases, the angular arc of movement through which the carrier 28 advances following the establishment of proper magnetic operating conditions and prior to the actual interruption of the primary current becomes progressively larger. Since the actual separation of the armature 42 from the contacts 44 or 46 determines the time at which the spark potential is generated, the time lag occasioned by the operate time appears as a progressively increasing delay in the spark as engine speed increases. Accordingly, the cam plate 89 is cut to provide twelve to fifteen degrees of spark advance in addition to the twelve to fifteen degrees normally provided or whatever degree of advance is prescribed by the engine manufacturer. Thus, as the flyweights 82 and 84 are displaced outwardly in response to an increase in the speed of rotation of the shaft 62, the operator assembly 28 is advanced relative to the shaft 62 a first increment of movement to compensate for the operate time of the switch 24. This spark advance is not apparent to the engine because the switch 24 operates to interrupt the primary current at the point that is expected by the engine. The displacement of the flyweights 82 and 84 also provides a second increment of advance, dependent on the speed of rotation of the shaft, to effect an advance of the time in the engine cycle at which the spark potential is generated to compensate for higher engine operating speeds in the conventional manner.

As described above, the sealed magnetic switch 24 is operated to close a circuit through the leading magnetic contact or terminal 46 by applying the operating fields from the permanent magnets 66b to the terminal 46 in an additive or aiding relation to the biasing field from the magnet 26. This switch is operated to close a conductive circuit through the trailing magnetic terminal 44 by applying the operating fields from the magnets 66a to the leading terminal 46 in a bucking or opposed relation to the biasing field from the magnet 26. The sealed switch 24 has the characteristic that it responds faster or has a shorter operate time when fluxes are applied to the terminal pin 46 in an additive sense than when the fluxes from the biasing magnet and the operating magnet are applied in an opposed or bucking relationship. Since the switch 24 must be operated at equally spaced time intervals relative to the engine cycle, it is necessary to compensate for this phenomenon in the distributor construction 22. This can be done in either of two manners. In the first place, the strengths of the fields of the operating magnets 66 that supply the additive fields can be made smaller than the fields of the permanent magnets providing bucking or opposing fields. This would mean that in the counterclockwise rotating assembly 28, the fields of the magnets 66b providing fields of the same polarity to the leading terminal 46 as the biasing field provided by the magnet 26 are made less in magnitude than the bucking fields of the magnets 66a. In the same manner, with a clockwise rotating operating assembly 28 in which the fields of the magnets 66a are applied to the leading magnetic terminal 44 in an additive sense to the bias field, the strengths of the fields of the magnets 66a would be made less than the oppositely poled fields provided by the magnets 66b. This technique involves using different strength fields for adjacent ones of the permanent magnets 66

and sometimes makes it more difficult to properly adjust the operator assembly 28.

When the magnets 66 are the same in size, the difference in effective field strength is obtained during adjustment by "knocking down" the fields with an alternating current field. This adjustment of adjacent magnets can become time consuming. This can be obviated by making the alternate magnets 66 that are to provide the fields of lesser strength smaller in size than the remaining magnets. In this way, effective fields of different strengths can be provided without requiring one magnet to be "knocked down" considerably more than the adjacent magnets during adjustment.

A second technique can be used that obviates the difficulties sometimes encountered using permanent magnets 66 of different strengths in the operator assembly 28. More specifically, the biasing magnet 26 can be so adjusted in strength or in its position relative to the terminals 44 and 46 that the bias applied to the leading terminal considered relative to the direction of rotation of the assembly 28 is less than the bias applied to the terminal spaced rearwardly relative to the direction of rotation of the operator assembly 28. As an example, in the counterclockwise rotating assembly 28 in which a closed circuit is completed through the pin 46 by adding the fluxes supplied by the biasing magnet 26 and the permanent magnets 66b, the strengths of all of the magnets 66 are set substantially the same, but the bias applied by the magnet 26 to the terminal 46 is made less in strength than the bias applied by the magnet 26 to the magnetic terminal 44. In this manner, the armature 42 is operated to engage the magnetic terminal 46 by the magnets 66b at the same time in the engine cycle or the path of relative movement between the operator assembly 28 and the switch 24 as the armature 42 is operated to engage the magnetic terminal 44 by the permanent magnets 66a.

Similarly, in a clockwise rotating operator assembly 28, the bias applied by the magnet 26 to the leading magnetic contact 44, which is positioned forwardly in the path of relative movement between the carrier 28 and the switch 24 when the carrier 28 is rotated in a clockwise direction, is made less than the bias applied to the magnetic terminal 46. Thus, when the armature 42 is actuated by the magnets 66a to engage the contact 44 with the operating and biasing fluxes applied in an aiding relation, these operations will take place with the same relative separation as when the armature 42 engages the magnetic contact 46 with opposing fluxes from the magnets 66b and 26 applied to the magnetic contact 44.

The sealed magnetic switch 24 has a useful operating range extending up to two hundred switch cycles or four hundred circuit interruptions per second, and this operating speed is adequate for eight cylinder engines operating at speeds as high as 150 miles per hour in high gear. However, there are some instances in which it would be desirable to provide means either to operate the sealed switch 24 at a lower speed or to provide an ignition system operable at a higher number of revolutions per minute. The distributor 22 utilizes a single sealed magnetic switch 24 in combination with an operator assembly 28 having a single magnetic field generating means or permanent magnet 66 for each of the cylinders in the engine. However, a number of other arrangements can be used so long as the product of the number of sealed switches and the number of operating fields is equal to the number of cylinders in the engine. Thus, if the repetition rate at which the sealed switch 24 is operated is to be reduced, the number of sealed switches in the circuit can be increased, while reducing the number of operating field generating means. In an eight cylinder engine, the rate of repetition at which the field switch 24 is operated can be reduced by a factor of two by providing four operating fields in combination with two sealed magnetic switch units.

A distributor construction 120 employing a pair of

sealed magnetic switches 24 and 24' is illustrated in FIG. 8 of the drawings. The distributor construction 120 is substantially identical to the distributor 22 except that only four permanent magnets of alternate polarities spaced 90° from each other are provided in the operator assembly 28. To illustrate this substantial identity, like reference numbers are used in the distributor constructions 22 and 120 to designate similar components. One of the sealed magnetic switches 24 is mounted on the plate 50 with the terminals 44 and 46 disposed adjacent the path of rotation of the operator assembly 28. The second sealed magnetic switch unit 24' is secured to the plate 50 or by means of a separate plate 50 to the timing plate 52 in a position spaced from the switch 24 along the path of rotation of the operator assembly 28 at a distance that is an odd multiple of one half of the distance separating any two successive permanent magnets 66 on the carrier assembly 28. This spacing is such that the four permanent magnets 66 on the operator assembly 28 causes alternate operation of the sealed magnetic switches 24 and 24' at equally spaced time intervals synchronized with the rate of rotation of the distributor shaft 62.

As an example, with the operator assembly 28 rotating in a counterclockwise direction and with the same bias applied to both of the switches 24 and 24' as shown in FIGS. 1-6, the permanent magnet 66a adjacent the switch 24 operates this sealed switch to provide a sparking potential by moving the armature 42 from a position engaging the terminal 46 to one engaging the terminal 44. The following permanent magnet 66b next operates the sealed magnetic switch 24' by moving the armature 42 in this switch from a position engaging the terminal 44 to one engaging the terminal 46. This same magnet 66b will then operate the armature 42 in the sealed switch 24 from a position engaging the terminal 44 to one engaging the terminal 46. The distributor 120 provides the same number of circuit interruptions as the distributor 22 but, by using a pair of sealed magnetic switches 24 and 24' and half the number of permanent magnets 66, the rate of repetition at which the individual switches 24 and 24' are operated is reduced by a factor of two.

The distributor 120 can be used in an ignition system 122 (FIG. 9) that is substantially identical to the ignition system 20 except that the sealed switches 24 and 24' are connected in series between the potential source and one terminal of the primary winding 30a of the ignition coil 30. A single network including the resistance element 102 and the capacitor 104 connected in shunt with the two switches 24 and 24' is adequate although similar networks individual to each of these switches can be provided. The armature 42 of the sealed switch 24 is connected to the two magnetic contacts 44 and 46 in the sealed magnetic switch 24' rather than directly to the terminal of the primary winding 30a. Since the sealed switches 24 and 24' are connected in series, the primary winding 30a is maintained in an energized state except when either of the switches 24 and 24' is being operated from a position engaging one of the contacts 44 or 46 to one engaging the other of these contacts. In other words, the sealed magnetic switch 24 interrupts the flow of current through the primary winding 30a to provide a sparking potential for a given one of the spark plugs 36, and a second sealed switch unit 24' interrupts the flow of primary current to provide a sparking potential for the next spark plug 36 in the firing order.

Although the ignition system 20 and the distributor constructions 22 and 120 using a bistable sealed magnetic switch 24 form a preferred embodiment of the invention, the ignition system 20 can also be used with a distributor construction 130 (FIGS. 10 and 11) or 150 (FIGS. 12 and 13) in which the switch 24 is biased for a single-side-stable operation. In the single-side-stable state, only the terminal 44 is connected to the potential source, and the terminal or magnetic contact 46 does not form a part of

the electrical circuit. When an operator assembly 132 in the construction 130 or an operator assembly 152 in the construction 150 is moved relative to the sealed magnetic switch 24, the armature 42 of the sealed switch is momentarily moved out of engagement with the contact 44 to interrupt the flow of current through the primary winding 30a and is then restored into biased engagement with this contact to initiate the flux build-up in the ignition coil 30.

To bias the sealed switch 24 for single-side-stable operation in the distributor constructions 130 and 150, a biasing magnet 134 or 154 is disposed adjacent or secured to the magnetic terminal or contact 44 to apply a flux of a given polarity thereto. In FIGS. 10-12 of the drawings, the bias magnets 134 and 154 are so arranged that the north pole of the biasing magnet is disposed adjacent the magnetic terminal 44 to apply a similarly poled biasing flux thereto. The bias magnets 134 and 154 can also be mounted adjacent the terminals 44 and 46 in the manner shown and described in detail in U.S. Patent No. 3,076,878 to provide single-side-stable operation. This bias normally holds the armature 42 in contact with the magnetic contact 44 to normally complete the energizing circuit for the primary winding 30a of the ignition coil 30. The switch 24 is mounted on the timing plate 52 in the distributor constructions 130 and 150 in the same manner as in the distributor construction 22 and can be connected to the vacuum unit 56 in the same manner as in the distributor construction 22.

The operator assembly 132 in the distributor construction 130 includes a circular supporting plate or member 136 having a plurality of peripherally spaced and generally peripherally extending recesses in which a plurality of magnetic field generating means or permanent magnets 138 are disposed. A non-magnetic plate 140 for holding the magnets 138 in position is secured to the member 136 by a plurality of fasteners 142. The plate 136 is coupled to the shaft 62 through a centrifugally actuated assembly identical to the assembly 80.

The polarity of the permanent magnets 138 is such that a field of a polarity opposite to the bias applied to the terminal 44 is moved adjacent the pin 46 as the operator assembly 132 is rotated in a counterclockwise direction. The field of the leading pole face of the permanent magnet 138 overcomes the effect of the bias magnet 134 and moves the armature 42 out of engagement with the magnetic terminal 44 and into engagement with the terminal 46. This interrupts the primary current flowing through the winding 30a of the ignition coil 30 and provides the spark potential. As the assembly 132 rotates further in a clockwise direction, the trailing pole face of the permanent magnet 138 is moved adjacent the terminal 44 and applies flux of a polarity similar to that applied by the bias magnet 134 to this terminal. This moves the armature 42 into engagement with the magnetic terminal 44 so that the energizing circuit for the primary winding 30a is again established.

The construction of the operator assembly 132 is such that a single permanent magnet 138 is provided for each of the cylinders in the engine when only a single sealed switch 24 is provided. However, it is possible to provide a plurality of the sealed switches 24 connected in series, as in the ignition circuit 122, in combination with an operator assembly 132 having half the number of the permanent magnets 138 shown in FIG. 10 to provide means for reducing the repetition rate at which each of the individual sealed switches 24 is operated. If two sealed switches 24 are used, they are spaced apart relative to the path of rotation of the operator assembly 132 in the manner set forth above in the description of the distributor 120 shown in FIG. 8 of the drawings.

The distributor construction 150 operates in substantially the same manner as the distributor 130 and is the same in construction except for a modification in the magnetic circuit provided in the operator assembly 152. The

assembly 152 includes a supporting member or carrier 156 having radially extending openings or recesses for receiving successive pairs of oppositely poled magnets 158 and 160. These magnets are secured in position on the member 156 by a top plate 162 of non-magnetic material which is secured to the member 156 with the magnets 158 and 160 interposed therebetween by a plurality of machine screws 164.

The polarity of the field presented at the outer edge of the circular member or carrier 156 by the pole face of the magnet 160 is the same as that presented by the leading pole face of the magnet 138 in the operator assembly 132, and the polarity of the field presented by the outer pole face of each magnet 158 is the same as that provided by the trailing pole face of each of the magnets 138 in the assembly 132. Thus, as each pair of magnets 158 and 160 is moved past the sealed switch 24, the armature therein is moved out of engagement with the magnetic terminal 44 to interrupt the primary energizing circuit and is then moved back into engagement with this terminal to complete the energizing circuit. This provides the momentary primary circuit interruption to permit the decay of the flux field in the ignition coil 30 and the production of the ignition potential. As in the case of the distributor 30, the number of pairs of magnets 158 and 160 used in the assembly 152 can be reduced by a factor of two by providing two sealed magnetic switches 24 with the terminals 44 and the armatures 42 connected in series between the potential source and the coil 30a and with the switches spaced apart an odd multiple of half of the distance between successive pairs of magnets on the supporting plate 156.

Both of the distributor constructions 130 and 150 can be operated in either clockwise or counterclockwise direction after making suitable revisions in the centrifugally actuated assembly 80 and in the interconnection between the vacuum unit 56 and the timing plate 52. If the operator assemblies 132 and 152 are rotated in a clockwise direction, it is also desirable to mount the bias magnets 134 and 154 to apply an oppositely poled bias to the terminals 46 rather than the magnetic terminals 44. This is desirable because it results in a positive actuation of the armature 42 away from the normally engaged contact rather than using a flux opposing relation between the operator magnets and the biasing magnets to obtain switch actuation. It is possible, however, to obtain switch actuation of a less positive nature with the magnetic switches 24 biased for single-side-stable operation by applying a magnetic bias to the leading terminals 44 or 46 of the sealed switches 24 in both of the constructions 130 and 150 rather than to the trailing terminal as illustrated in the drawings. Further, the polarities of the bias and operating fields can be reversed. In addition, although the sealed switches 24 are described as directly controlling the primary of an ignition coil, these switches can also be used to control amplifying means, such as solid state devices, for providing the sparking potential.

When the ignition system 20 and the distributor construction 22 are to be manufactured, the distributor construction is assembled in substantially the manner illustrated in FIG. 1 and placed in a test fixture including manually actuated or controllable means for rotating the shaft 62. A field structure including an energizing winding capable of being connected to a direct current voltage source of either polarity and an alternating current potential source is disposed adjacent the path of rotation of the operator assembly 28 in a position to apply an electromagnetic field to the permanent magnets 66. The field structure preferably is spaced somewhat from the sealed magnetic switch 24. The magnetic contacts 44 and 46 and the armature terminal 40 of the sealed magnetic switch 24 are connected to an indicating means, such as an oscilloscope or other means, capable of providing an output signal or visual display of the open circuit or closed circuit condition of the switch 24.

The operator assembly 28 is then rotated to a position disposed adjacent the field structure, and the winding thereon is connected to a direct current potential of one polarity that is of sufficient value to saturate the magnetic material of the adjacent permanent magnet 66 with a field of a given polarity. The operator assembly 28 is then rotated to place the next permanent magnet 66 adjacent the field structure, and the polarity of the direct current potential is reversed to saturate this magnet with a field of an opposed polarity. This operation is continued until all of the permanent magnets 66 on the operator assembly 28 have been saturated with fields of alternate and opposite polarities.

The winding on the field structure is then connected to an alternating current potential source of a given value so that the field produced in the field structure by the alternating current energization of the operating winding is capable of reducing the oppositely poled fields of the permanent magnets 66 to a given level. The operator assembly 28 is then rotated or indexed past the field structure to reduce or "knock down" the saturated magnets 66 to a field strength value equal to or slightly greater than the desired operating value. A given one of the permanent magnets is then moved in correct direction toward the sealed magnetic switch 24, and the indicating means is observed to determine the point in the path of rotation of the operator assembly 28 at which the magnetic switch 24 is actuated. If the switch is operated prior to the desired point, the operator assembly 28 is indexed to move the related permanent magnet 66 into proximity to the field structure, and the level of the alternating current energization of the field structure is adjusted to reduce the field strength of the permanent magnet.

The permanent magnet is again moved in the proper direction toward the sealed magnetic switch 24, and the time of operation is observed. This alternate checking and adjusting of the magnet 66 is continued until the sealed magnetic switch 24 is operated in the desired or correct point in the path of relative movement between the sealed magnetic switch 24 and the operator assembly 28. This operation is continued in sequence until such time as all of the permanent magnets have been adjusted to values which cause operation of the sealed magnetic switch 24 at the desired positions. By the use of this method in which the strengths of the individual permanent magnets 66 are adjusted to cause operation of the switch 24 at the desired positions in the path of relative movement between the switch and the operator assembly 28, it is not necessary to precisely position the permanent magnets on the plate 60 or to provide sealed magnetic switches 24 of absolutely uniform operating characteristics.

When the individual strengths of the permanent magnets 66 have been adjusted so that the switch 24 is operated at equally spaced positions in the path of relative movement between the switch and the operator assembly 28, the distributor construction 22 is removed from the test fixture, and the next distributor construction to be adjusted and tested is placed in the fixture. It is desirable to test the distributor construction 22 with as many of the magnetically susceptible components of its construction in place as possible so as to prevent any alteration in the magnetic circuits for the magnets 66 and the switch 24 that might affect the adjusted operating characteristics.

As described above, the magnetic armature 42 of the sealed magnetic switch 24 is operated to engage alternate ones of the magnetic contacts 44 and 46 by the application of operating and bias fluxes in aiding or opposing relationship to the leading magnetic contact 44 or 46 considered relative to the direction of rotation of the operator assembly 28. In other words, with the operator assembly 28 rotating in a counterclockwise direction, the flux of the magnet 66b is applied in an additive relationship in the leading magnetic contact 46 to cause engagement of this contact by the armature 42, and the

flux of the alternate magnet 66a is applied in opposing relationship to the leading magnetic contact 46 to cause the armature 42 to engage the magnetic contact 44. When the operator assembly 28 is rotated in a clockwise direction or opposite direction with the same polarity of bias applied by the magnet 26, an opposite operation occurs, i.e., the operating and biasing fluxes are applied in an additive relationship in the terminal 44 to transfer the armature 42 to engagement with the contact 44 and in an opposing relationship to cause a transfer of the armature 42 to the magnetic contact 46. With this selective use of additive and bucking flux relationships in the leading terminal or magnetic contact of the switch 24, there is the tendency described above for the switch 24 to operate when the fields are in an additive relation with the operating magnet 66 spaced a greater distance from the switch 24 than when the flux from an operating magnet 66 is applied in an opposed or bucking relationship. This would result in the operation of the magnetic switch 24 at unequally spaced points in the path of relative movement between the operator assembly 28 and the sealed magnetic switch 24.

In carrying out the method described above for making, testing, and adjusting the distributor construction 22, this tendency to operate the sealed magnetic switch 24 at different and unequally spaced positions in the path of relative movement between the switch and the operator assembly 28 is corrected or compensated by altering the fields of the permanent magnets 66 and, more specifically, by reducing the strength of those permanent magnets 66 whose flux is applied to the leading magnetic terminal or contact 44 or 46 in an aiding relationship. This results in adjacent permanent magnets 66 having substantially different field strengths. With magnets 66 of different field strengths disposed in proximity on the supporting member 60, there is a pronounced tendency for an adjustment in the strength of the field of a given magnet 66 to affect the effective field strengths of adjacent magnets, and it has been determined that it is frequently necessary following the adjustment of the field strength of a given one of the magnets 66 to make corrective adjustments in the remaining magnets. This means that the strengths of all of the magnets 66 may require repeated adjustment before the sealed magnetic switch 24 is operated at the desired uniformly spaced positions in the path of relative movement between the switch 24 and the operator assembly 28. This is not only time consuming but also tends to result in operator assemblies 28 of non-uniform characteristics so that, for instance, it is not possible to replace a given operator assembly 28 in an engine with another preadjusted assembly without, to a degree, matching the characteristics of the operator assembly 28 to the switch 24.

A method of making and testing distributor constructions 22 that obviates the difficulties of the method referred to above is described below with reference to the testing apparatus 170 shown in FIGS. 14 and 15 of the drawings. In the practice of this method, the oppositely poled fields of the permanent magnets 66 are of substantially uniform strength, and the effect on the timing of the operation of the magnetic switch 24 resulting from the selective addition or opposition of the biasing and operating fluxes in the leading magnetic contact 44 or 46 is compensated for by the use of the bias magnet 26 to apply different biases to the terminals 44 and 46 in dependence on the switch operating characteristics and the direction of rotation of the operator assembly 28 with which the switch 24 is to be used. The practice of this method results in standardized components and a substantial reduction in the time required to manufacture distributor assemblies 22.

A completed operator assembly 28 is inserted in a test fixture so that the distributor shaft 62 is coupled to a drive means 172. The operator assembly 28 preferably is coupled with the centrifugally actuated assembly 80 or any other assemblies including components that might affect

the magnetic fields or paths of the magnets 66 so that these would not be altered following adjustment by the addition of a magnetically susceptible component. The drive means 172 is controllable to rotate the operator assembly 28 over the range of speeds encountered in operation of the distributor assembly 22.

The test apparatus 170 also includes an indicating or detecting means 174 including a visual display means indicated generally as 176. The indicating means 174 includes an input coupled to the drive means 172 over which synchronizing signals are received. Another input to the indicating means 174 is coupled to an unpolarized magnetic field detecting means, such as a conventional magnetic reed switch 178 including a pair of normally separated magnetic reeds 178a and 178b that are moved into engagement to complete a conductive circuit through the switch 178 in response to the application of a magnetic field of either polarity of at least a given strength. The magnetic detecting means or reed switch 178 is disposed closely adjacent the path of rotation of the operator assembly 28. The drive means 172 and the indicating or detecting means 174 can, for instance, comprise a unit of equipment manufactured by Sun Electric Co., Chicago, Ill. and identified as Distributor Tester, Model 500.

The test apparatus 170 also includes a field structure 180 disposed adjacent the path of rotation of the operator assembly 28 with its pole faces generally aligned with the axial length of the magnets 66. A winding 182 on the structure 180 is connected to a selector switch 184 through a reversing switch 186. The selector switch 184 is operable to alternate states to select either a direct current potential source 188 whose output is adjusted by a potentiometer 190 or an alternating current potential source 192 whose output is adjusted by a tapped or variable transformer 194.

When the operator assembly 28 is to be adjusted or tested is placed in the fixture, the selector switch 184 is actuated to connect the potentiometer 190 to the reversing switch 186 which is in an open condition. The operator assembly 28 is then rotated to a position in which one of the permanent magnets 66 is disposed immediately above the pole faces of the field structure 180. The reversing switch 186 is then closed in one direction to energize the winding 182 with direct current potential of a given polarity so that the adjacent permanent magnet 66 is driven to saturation with a magnetic field of a first polar alignment. The reversing switch 186 is then opened, and the operator assembly is indexed to place the next adjacent magnet 66 above the pole pieces of the field structure. The reversing switch 186 is then closed to its alternate condition so that the winding 182 is energized with a voltage of an opposite polarity to saturate the adjacent permanent magnet 66 with a field of an opposite polar alignment. The reversing switch 186 is then opened and the operator assembly is indexed to positions in which the remaining ones of the permanent magnets are disposed above the field structure 180. By selectively actuating the reversing switch 186, all of the permanent magnets are saturated to provide magnetic fields of alternate and opposite polarities.

Following completion of these operations, the reversing switch 186 is opened, and the selector switch 184 is actuated to connect the reversing switch to the alternating current potential source 192. The adjustable transformer 194 is then set to provide an alternating current potential of a strength sufficient to reduce the permanent magnet 66 below saturation and to a value substantially the same but somewhat higher than that desired in the completed operator assembly 28. The switch 186 is then closed to either of its positions so that the winding 182 is energized to produce an alternating field in the field structure 180. The operator assembly 28 is indexed or rotated past the field structure 180 so that all of the magnets 66 are "knocked down" from their saturated condition to the field strength

desired in the distributor assembly 22. The switch 186 is then opened.

The magnetic detecting or sensing means provided by the reed switch 178 is then used in conjunction with the indicating means 174 to detect the fields of the magnets 66. To accomplish this, the drive means 172 is energized so that the shaft 62 and the connected operator assembly 28 are rotated at a desired speed. During rotation, the drive means 172 provides a synchronizing signal to the indicator 174 to synchronize its operation with the rotation of the operator assembly 28. This rotation can be in either direction. During rotation of the operator assembly 28, the movement of the successive permanent magnets 66 past the reed switch 178 causes a momentary engagement of the reeds 178a and 178b so that an output signal is applied to the indicating means 174. The synchronizing or scanning signal applied to the indicating means 174 from the drive means 172 produces a visible display on the means 176, such as the face of a cathode ray oscilloscope, of the time interval at which the magnetic reed switch 178 is operated by each of the permanent magnets 66. If one or more of the output signals from the reed switch 178 do not occur at regularly spaced or the expected time intervals or positions in the path of relative movement between the operator assembly 28 and the switch 178, the deviation of the time of operation from the desired position is noted.

The drive means 172 is then stopped and the magnet 66 causing the advanced or retarded operation of the detecting means 178 is disposed above the field structure 180. By adjusting the magnitude of the alternating current potential supplied by the adjustable transformer 194, the winding 182 is energized by the closure of the switch 186 to apply an alternating current field to the adjacent permanent magnet 66 to reduce its strength to the point at which this magnet causes the operation of the magnetic detecting means 178 at the desired position in the path of rotation of the operator assembly 28. If one of the permanent magnets 66 has been reduced too far below saturation, this magnet can again be returned to its saturated state by using the selector switch 184 and the reversing switch to connect the direct current potential source 188 to the winding 182 of the field structure 180. This saturated magnet is then reduced by the use of the alternating current potential source 192 to energize the winding 182 of the field structure 180 so that this magnet 66 produces operation of the magnetic detecting means 178 at the desired position in the path of movement of the operator assembly 28.

This operation is continued until the magnetic detector 178 is operated at regularly spaced intervals during rotation of the operator assembly 28 by the drive means 172. If desired, the operation of the detecting means 178 can be checked at several speeds in the engine operation range by changing the speed of the drive unit 172. Although the method described above includes the steps of selectively altering the strengths of the magnets 66 to insure operation of the switch 178 at regularly spaced intervals in the path of relative movement between the operator assembly 28 and the detecting means 178, the fields of the magnets 66 will be substantially the same. Further, because the magnet size and spacing from the detector 178 are well controlled, only one or two magnets ordinarily require adjustment. This means that the operator assembly 28 produced by this method can be used in distributor constructions 22 in which the operator assembly 28 is to be rotated in either a clockwise or a counterclockwise direction.

If the apparatus 170 is used only for producing and adjusting operator assemblies 28, the adjusted and completed operator assembly 28 is removed from the test fixture, and another similar assembly is inserted and adjusted in the manner described above using the unbiased magnetic detecting means 178. This method would be used for producing operator assemblies that are to be

assembled with the completed distributor construction 22 at a different station or for producing operator assemblies 28 used as replacement parts. However, if the apparatus 170 is to be used for producing completed distributors, the magnetic detecting assembly or reed switch 178 is disconnected from the indicating means 174 and removed. The magnetic switch 24 (FIG. 15) is placed in the non-magnetic sleeve 48 of the distributor construction 22 to be disposed immediately adjacent the path of rotation of the adjusted operator assembly 28. However, the switch 24 is not provided with a bias magnet 26.

The sealed magnetic switch 24 (FIG. 15) is connected to the input terminals of the indicating means 174 with the terminals 44 and 46 connected together and to one input terminal and with the armature 42 connected to the other input terminal of the indicating means 174. The circuit for energizing the field structure 180 can remain the same as that shown in FIG. 14 or can comprise nothing more than the simplified circuitry illustrated in FIG. 15 comprising the alternating current potential source 192, the adjustable transformer 194, the field structure 180, the operating winding 182, and a manually operable switch 196 for selectively energizing the winding 182.

The motor 172 is then placed in operation, and the bias magnet 26 is coated with an adhesive material, such as epoxy cement, and moved into juxtaposition to the magnetic terminals 44 and 46. The magnetic switch 24 is now provided with some bias by the magnet 26, and the operator assembly 28 is rotated in the direction in which it is to be rotated when the distributor construction 22 is installed. The operator views the visual display means 176 in the indicating means 174 and determines the positions at which the switch 24 is operated by the magnets 66 on the rotating operator assembly 28. The operator moves the biasing magnet 26 relative to the pins 44 and 46 until such time as the times or positions at which the switch 24 is operated are correct. At this time, the permanent magnet 26 is allowed to remain in position until the cement dries or, alternatively, the magnet 26 is rigidly secured in position by soldering it to one or both of the magnetic pins 44 and 46.

The effect of adjusting the position of the biasing magnet 26 relative to the terminals 44 and 46 during the rotation of the operator assembly 28 is to vary the degree of magnetic bias applied to the two magnetic terminals 44 and 46. More specifically, the adjustment of the magnet 26 reduces the level of bias, of either polarity, applied to the leading magnetic contact or terminal 44 and increases the magnetic bias applied to the trailing magnetic contact or terminal 46. By reducing the magnetic bias applied to the leading terminal, the permanent magnet 66 providing a field in a flux aiding relationship with the biasing field to the leading magnetic terminal 44 or 46 must be positioned closer to the switch 24 before the switch will operate. Similarly, the permanent magnet providing a flux bucking the bias flux in the leading terminal need not be positioned as closely to the switch 24 because the bias flux to be overcome before the switch operation is less. In this manner, the permanent magnets 66 can provide fields of substantially equal strength, and the bias magnet 26 can be shifted relative to the terminals 44 and 46 during the assembly of the distributor 22 to adjust the periods at which the switch 24 is operated to those required by the engine cycle. This is true regardless of the direction of rotation of the operator assembly 28 and the direction of polarization of the bias magnet 26.

In the event that the adjustment of the permanent magnet 26 does not bring the points in the path of relative movement between the switch 24 and the operator assembly 28 at which the switch 24 is operated to those desired, rotation of the drive means 72 can be stopped after determining the permanent magnet responsible for the improperly positioned operation. This magnet can then be indexed over the field structure 180, and the field reduced by the closure of the contact 196 in conjunction

with the adjustment of the transformer 194 to obtain the desired energizing signal for the winding 182. If necessary, this magnet can be saturated by use of the direct current potential source 188 followed by selective reduction of the field by the use of the alternating current potential source 192.

The distributor construction 120 (FIG. 8) using the ignition system 122 can be manufactured and adjusted in the same manner as the distributor construction 22 by using the test apparatus 170 shown in FIG. 14 of the drawings to adjust all of the permanent magnets 66 to substantially equal field strengths. When the two unbiased switches 24 and 24' are placed in the two sleeves 48 provided in the distributor construction 22, the two sealed switches 24 and 24' are connected in series with the input to the indicating means 174, and the bias magnets 26 are individually adjusted on the two switches 24 and 24' until the correct positioning of the switch actuation within the engine cycle is obtained.

The testing apparatus 170 shown in FIG. 15 of the drawings can be used in manufacturing and adjusting distributor constructions 22 in which the operator assembly 28 is rotated in either a clockwise or a counterclockwise direction. With the operator assembly 28 rotating in a counterclockwise direction, the adjustment of the bias magnet 26 will be such that a smaller bias of either polarity is applied to the magnetic terminal or contact 46, which is the leading contact considered relative to the counterclockwise rotation of the operator assembly 28. Similarly, if the operator assembly 28 is rotated in a clockwise direction, the positioning of the bias magnet 26 is such that a lesser bias of either polarity is applied to the magnetic contact or terminal 44, which is the leading contact considered relative to the clockwise rotation of the operator assembly 28.

The testing assembly 170 can also be used to manufacture bistable of magnetically biased switch units 24 to be used as replacement parts. This is possible because the operator assemblies 28 are adjusted to a standard condition by using the apparatus 170 shown in FIG. 14. One of the adjusted operator assemblies 28 is coupled to the drive means 172 shown in FIG. 15, and successive switches 24 are mounted adjacent the path of rotation and coupled to the indicating means 174 to permit the bias magnet to be adjusted to a position in which the switch is operated at proper timed intervals within the cycle of rotation of the operator assembly 28. If desired, the sealed switch 24 with the connected bias magnet 26 in proper position can then be "potted" or otherwise placed in a protective housing to permit their direct insertion into distributor constructions in the field. These switches are provided with suitable indicia or identification plates indicating their adjustment for use with either clockwise or counterclockwise rotating distributor assemblies.

The apparatus 170 shown in FIG. 14 of the drawings can be used for adjusting and testing distributor assemblies 22 manufactured in accordance with the first method described above in which the permanent magnets 66 of opposite polarities are provided with fields of different values rather than a substantially uniform value. In carrying out this method, the unpolarized magnetic reed switch 178 is replaced by a sealed magnetic switch 24 to which the bias magnet 26 has previously been secured in a position supplying balanced biases. The field structure 180 is then selectively energized in the manner described above by the direct current potential source 188 and the alternating current potential source 192 to adjust the fields of the individual magnets 66 to the values at which the biased magnetic switch 24 is operated at the correct times in the engine cycle.

The distributor constructions 130 and 150 (FIGS. 10-13) using single-side-stable sealed magnetic switches 24 can also be manufactured, tested, and adjusted by using the test apparatus 170 shown in FIG. 14, although the physical position of the field structure 180 should be

rotated 90° so that it is aligned with the peripherally extending magnets 138 used in the distributor construction 130. The sealed switch 24 to which the bias magnet 134 has been attached is connected to the indicating means 174 in place of the reed switch 178, and the magnets 138 or 158 and 160 are then saturated to provide fields of the magnetic alignment described above. These fields are then selectively reduced to values corresponding to those required to operate the sealed switch at the desired points in the engine cycle.

Although the present invention has been described with reference to a number of illustrative embodiments thereof, it should be understood that numerous other modifications and embodiments can be devised by those skilled in the art that will fall within the spirit and scope of the principles of this invention.

What is claimed and desired to be secured by Letters Patent of the United States is:

1. An automotive ignition system for use with a plurality of spark generating means comprising a rotatable distributor shaft, first permanent magnet means movable in synchronism with the distributor shaft, a glass enclosed magnetic switch having a movable magnetic armature and a pair of spaced contacts, said magnetic switch being positioned adjacent the path of movement of the first permanent magnet means so that the field of the first permanent magnet means moves the armature between the pairs of spaced contacts, second permanent magnet means applying a bias to the magnetic switch to condition the magnetic switch for bistable operation in which the armature is releasably retained in engagement with the contacts, inductive means coupled to the spark generating means for energizing the spark generating means, a potential source, and circuit means including the armature and the two contacts connecting the inductive means to the potential source for controlling the energization of the inductive means by the potential source, the inductive means being energized by the circuit means through the armature and the contact engaged by the armature and the energization of the inductive means being interrupted in the period in which the armature moves between the contacts.

2. An automotive ignition system for use in an engine having spark generating means comprising permanent magnet means providing oppositely poled magnetic fields and movable along a repetitive path in synchronism with the operation of the engine, sealed magnetic switch means having a movable armature and two mercury-wetted contacts alternately closed and opened by movement of the armature in response to oppositely poled magnetic fields, means mounting the sealed switch means adjacent the path to be operated by oppositely poled fields of the permanent magnet means, said permanent magnet means operating the armature to provide a fixed time interval between the opening of each contact and the closure of the other contact, inductive means including a pair of coils, a potential source having two oppositely poled terminals, said pair of coils having a common point connected to one of the terminals of the potential source, means for coupling the spark generating means to said one terminal and one of the coils, and circuit means connecting the two contacts of the sealed magnetic switch means in parallel and connecting the armature and parallel contacts in series with the other coil and the other terminal of the potential source so as to connect the other terminal of the potential source to the other coil and to interrupt this connection during the fixed time interval.

3. An ignition system for use with a plurality of spark generating means in an engine comprising first magnetic means movable through a repetitive path in synchronism with the operation of the engine, a magnetic switch means including a pair of spaced contacts alternately engaged by a magnetic armature, second magnetic means for biasing the magnetic switch for bistable operation in

which the armature is releasably retained in engagement with alternate ones of the contacts, means mounting the magnetic switch adjacent the repetitive path of movement to be operated by the first magnetic means so that the armature alternately engages the spaced contacts, the fields of the first magnetic means operating the armature for the magnetic switch means to provide a constant time period for transfer between the spaced contacts, inductive means coupled to the spark generating means for energizing the spark generating means, a potential source, and circuit means connecting the potential source to the inductive means through the armature and alternately engaged contacts of the magnetic switch for periodically energizing the inductive means, the energization of the inductive means being interrupted during the constant time period.

4. The ignition system set forth in claim 3 in which the first magnetic means includes a number of pole structures equal to the number of spark generating means.

5. The ignition system set forth in claim 3 in which the magnetic switch means includes a sealed glass housing containing a quantity of mercury for wetting the contacts between the magnetic armature and the spaced contacts.

6. An electrical ignition system for an engine having a spark generating means comprising a potential source, inductive means having a pair of windings with a common terminal connected to one terminal of the potential source, means for coupling the other terminal of one of the windings to the spark generating means, capacitive means, means connecting the capacitive means in series between the other terminal of the other winding and the other terminal of the potential source, magnetic switch means connected in parallel with the capacitive means, said magnetic switch means comprising a sealed glass housing having a mercury-wetted magnetic armature alternately movable into and out of engagement with a pair of spaced mercury wetted contact members fixedly carried on the housing and having the characteristic of separating the armature from the contacts at a constant acceleration when the magnetic conditions required for operation have been established, and permanent magnet means repetitively movable over a given path passing in proximity to the magnetic switch in synchronism with the operation of the engine and at varying speeds in dependence on the speed of operation of the engine, said permanent magnet means operating the magnetic switch to alternately open and close a conductive path through the armature and alternate ones of the contact members of the switch means between the other terminal of the potential source and the other terminal of the other winding, the separation of the armature from the contact member to open the conductive path occurring at a constant acceleration independent of the speed of movement of the permanent magnet means, said permanent magnet means operating the magnetic switch means to provide a substantially constant transfer time in which the armature is moved between stable positions engaging alternate ones of the contact members.

7. An electrical ignition system for use in an engine operable at different speeds M and having a given number X of spark generating means comprising a supporting structure, carrier means, means mounting the carrier means and the supporting structure for cyclic movement relative to each other along a given path, drive means connected between the supporting structure and the carrier means for producing cyclic relative movement between the carrier means and the supporting structure at a speed N synchronized with the speed M of the engine, magnetic means on the carrier means providing a number Y of spaced magnetic fields of alternate opposite polarities, a number Z of magnetically operated and polarity sensitive bistable switches mounted on the supporting structure disposed adjacent the carrier means in a position to be operated by the magnetic fields of the magnetic means, a potential

source, an ignition pulse generating means connected to the spark generating means, and means including the magnetically operated switches connected between the potential source and the ignition pulse generating means for periodically energizing the spark generating means, the product of the number Y of magnetic fields, the ratio N/M, and the number Z of magnetically operated switches being equal to the number X of spark generating means the speeds N and M being measured in the same units of increments of movement per unit of time.

8. The ignition system set forth in claim 7 in which the number Z of magnetically operated switches is two and in which the two magnetically operated switches are separated on the supporting means along the given path a distance that is an odd number multiple of one half of the distance along the given path that separates adjacent magnetic fields on the carrier means.

9. An electrical ignition system for use in an engine having a given number of spark generating means comprising a supporting structure, carrier means, means mounting the carrier means and the supporting structure for cyclic movement relative to each other along a given path, drive means connected between the supporting structure and the carrier means for producing cyclic relative movement between the carrier means and the supporting structure at a speed synchronized with the speed of the engine, magnetic means on the carrier means providing a number of spaced magnetic fields of alternate opposite polarities, two magnetically operated and polarity sensitive bistable switches mounted on the supporting structure disposed adjacent the carrier means in a position to be operated by the magnetic fields of the magnetic means, the two switches being separated by a distance along the given path that is an odd number multiple of one half of the distance along the given path between adjacent fields on the carrier means, the product of the number of magnetic fields and the number of magnetically operated switches being equal to the number of spark generating means, a potential source, inductive means coupled to the spark generating means for energizing the spark generating means, and circuit means connecting the two switches in series with the inductive means and the potential source.

10. An electrical ignition system for use with an engine having spark generating means comprising a sealed magnetic switch having electrically conductive elements operable between open and closed circuit conditions by the application of a given magnetic field, magnetic field producing means, means for repetitively moving the sealed magnetic switch and the magnetic field producing means relative to each other along a given path at different speeds corresponding to different operating speeds of the engine, the field from the magnetic field producing means being applied to the sealed magnetic switch to operate the switch a fixed delay interval following the application of said given field, a potential source, an ignition pulse generating means connected to the spark generating means, circuit means connecting the potential source to the ignition pulse generating means through the sealed magnetic switch to apply a sparking potential to the spark generating means in response to operation of the sealed magnetic switch, and compensating means connected between the magnetic field producing means and the sealed magnetic switch for compensating for the delay in the application of the sparking potential to the spark generating means caused by the fixed delay interval of the switch by adjusting the relative positions of the sealed magnetic switch and the magnetic field producing means in the path of relative movement said compensating means including means responsive to the speed of relative movement between the sealed magnetic switch and the magnetic field producing means for automatically adjusting the relative positions of the sealed magnetic switch and the magnetic field producing means along the given path.

11. An electrical ignition system for use with an engine

having spark generating means comprising a sealed magnetic switch having electrically conductive elements operable between open and closed circuit conditions by the application of a given magnetic field, magnetic field producing means, means for repetitively moving the sealed magnetic switch and the magnetic field producing means relative to each other along a given path at different speeds corresponding to different operating speeds of the engine, the field from the magnetic field producing means being applied to the sealed magnetic switch to operate the switch a fixed delay interval following the application of said given field, a potential source, an ignition pulse generating means connected to the spark generating means, circuit means connecting the potential source to the ignition pulse generating means through the sealed magnetic switch to apply a sparking potential to the spark generating means in response to operation of the sealed magnetic switch, and means responsive to the speed of relative movement between the sealed magnetic switch and the magnetic field producing means and connected between the magnetic field producing means and the sealed magnetic switch for adjusting the positions of the sealed magnetic switch and the magnetic field producing means toward and away from each other along the path of relative movement in a relationship that is a function of the amount of relative movement occurring between the sealed magnetic switch and the magnetic field producing means during the fixed delay interval.

12. An electrical ignition system for an engine having spark generating means comprising a supporting member, magnetic field generating means on the supporting member, a sealed magnetic switch including a magnetic armature movable into and out of engagement with a magnetic terminal, means for moving the sealed switch and the supporting member relative to each other in a synchronized relation with the speed of operation of the engine so that the magnetic field of the magnetic field generating means controls repeated movement of the armature into and out of engagement with the magnetic terminal, a potential source, inductive means coupled to the spark generating means for applying a sparking potential to the spark generating means, means connecting the sealed magnetic switch in series with the potential source and the inductive means for controlling the energization of the spark generating means, and a network connected in parallel with the sealed magnetic switch including a capacitor and a resistance element consisting of a material having a resistivity of 2.8×10^{-8} ohm-m. or less and having a value on the order of .05 ohm.

13. In a distributor construction for use in an engine, a sealed magnetic switch having an armature alternately operable into engagement with two spaced magnetic terminals, magnetic means providing a plurality of magnetic fields, means for moving the magnetic means and the sealed magnetic switch relative to each other along a given path and in synchronism with operation of the engine, and means for applying different degrees of magnetic bias to the two magnetic terminals to bias the leading terminal considered with respect to the direction of relative movement less than the other terminal, the leading terminal being the terminal first subjected to a given one of the magnetic fields during the relative movement between the magnetic means and the sealed magnetic switch along the given path and the other terminal being the terminal subjected to the given magnetic field at a time subsequent to the time at which the given field was applied to the leading terminal.

14. In a distributor construction for an engine, a shaft rotated in synchronism with operation of the engine, a plurality of spaced permanent magnets driven through a path of rotation by the shaft, a bistable magnetic switch disposed adjacent the path of rotation and operated by the fields of the permanent magnets, said bistable switch having two magnetic terminals disposed adjacent the path of rotation and sequentially subjected to the fields of the

permanent magnets, and biasing means for applying a magnetic bias to the two terminals, the bias applied to the leading terminal considered relative to the direction of rotation of the permanent magnets being less than the bias applied to the trailing terminal of the switch, the leading terminal being the terminal first subjected to the field of a given one of the permanent magnets during the rotation of the magnets past the bistable magnetic switch and the trailing terminal being the terminal subjected to the field of the given one of the permanent magnets at a time that is subsequent to the time at which the field of the given one of the permanent magnets was applied to the leading terminal.

15. In a distributor construction for use with an engine, a plurality of permanent magnets provided with alternate opposite polarities, a sealed magnetic switch having a pair of spaced magnetic terminals alternately engaged by an armature, distributor shaft for producing rotary movement between the sealed magnetic switch and the permanent magnets so that the armature is operated to alternately engage the two magnetic terminals by the oppositely poled fields of the permanent magnets, and means for applying magnetic biases of opposite polarities to the two magnetic terminals, the bias applied to the leading terminal considered with respect to the direction of relative movement between the sealed magnetic switch and the permanent magnets being less than the bias applied to the other magnetic terminal, the leading terminal being the terminal first subjected to the field of a given one of the permanent magnets during the relative movement between the magnetic switch and the permanent magnets and the other magnetic terminal being the terminal subjected to the field of the given permanent magnet subsequent to the time at which the field of the given permanent magnet was applied to the leading terminal.

16. The automotive distributor set forth in claim 13 including centrifugally operated means driven by the engine, and means controlled by and coupled to the centrifugally operated means for varying the relative positions of the carrier magnetic means and the sealed magnetic switch to vary the effects of the magnetic fields on the magnetic switch means.

17. An electrical ignition system for use with an engine operable over a given range of speeds and having spark generating means comprising an inductive means for supplying a sparking potential, distributor means connected to the inductive means for applying the sparking potential to the spark generating means in synchronism with the operation of the engine, a direct current potential source, a sealed magnetic switch operable to two alternate conducting states and providing a transfer period between the alternate conducting states in which the sealed magnetic switch does not provide a conductive path, means connecting the sealed magnetic switch to the inductive means and the direct current potential source to provide a flow of current through the inductive means for developing a flux field during both of the alternate conducting states and to interrupt the flow of current through the inductive means during the transfer period, the duration of the transfer period being less than the time required for the decay of the flux field produced during the alternate conducting states, and operating means for operating the magnetic switch to its alternate conductive states in synchronism with the distributor means, said operating means operating the switch to provide a transfer period that is substantially uniform in duration over the range of operating speeds of the engine.

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