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Burson et al.

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[45] **May 7, 1974**

[54] **IGNITION TRIGGERING CIRCUIT WITH AUTOMATIC ADVANCE**

[75] Inventors: **Bob O. Burson,** East Longmeadow; **Russell Dale Phelon,** Longmeadow, both of Mass.

[73] Assignee: **R. E. Phelon Company, Inc.,** East Longmeadow, Mass.

[22] Filed: **June 5, 1970**

[21] Appl. No.: **43,845**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 758,563, Sept. 9, 1968, abandoned.

[52] **U.S. Cl.** ..... **123/148 E,** 123/149 D

[51] **Int. Cl.** **F02p 3/06**

[58] **Field of Search** ..... 123/148 E, 149 R, 149 D; 315/209

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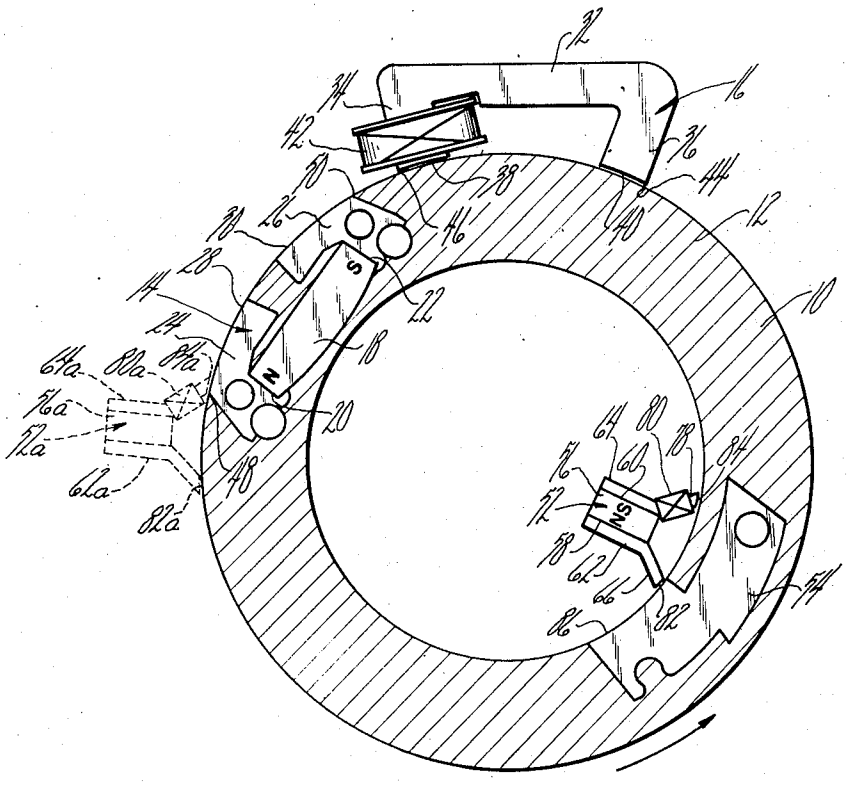
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Primary Examiner—Laurence M. Goodridge
Attorney, Agent, or Firm—McCormick, Paulding & Huber

[57] **ABSTRACT**

In a breakerless ignition system for a spark ignited engine, two separate magnets are used for generating the electrical energy supplied to the spark plug and for generating triggering signals applied to an electronic switch controlling the application of electrical energy to the spark plug. The system is a condenser discharge system wherein a main rotating magnet assembly generates a varying voltage in a generating coil positioned adjacent its path of movement. A condenser is connected with the generating coil through a rectifying means so as to be charged when the voltage induced in the generating coil is of one polarity. A silicon controlled rectifier controls the discharge of the condenser through the primary of a step-up transformer having its secondary winding connected to the spark plug. Triggering signals for the silicon controlled rectifier are provided by a separate stationary triggering magnet and coil assembly. A rotating piece of magnetic material moves past the triggering magnet and coil assembly to induce a triggering voltage in the triggering coil, the magnitude of which at different positions of the rotating piece is dependent on the speed of rotation so that at different engine speeds the triggering level of voltage is obtained at different positions of the rotating part to provide an automatic spark advance.

12 Claims, 9 Drawing Figures



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SHEET 1 OF 3

FIG. 1

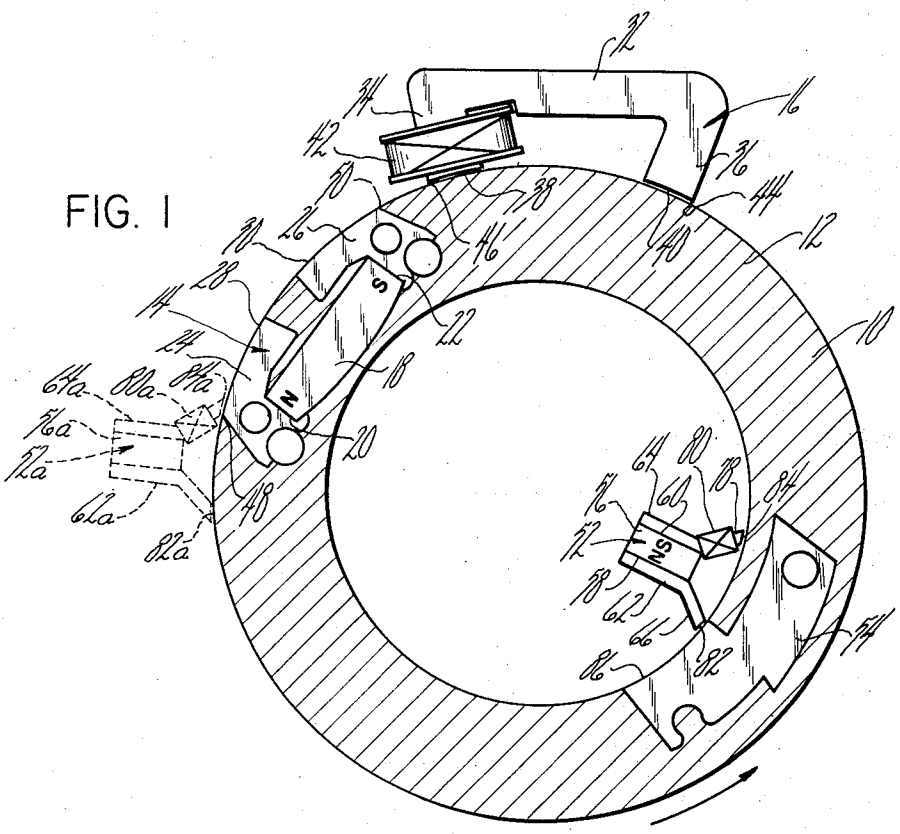


FIG. 3

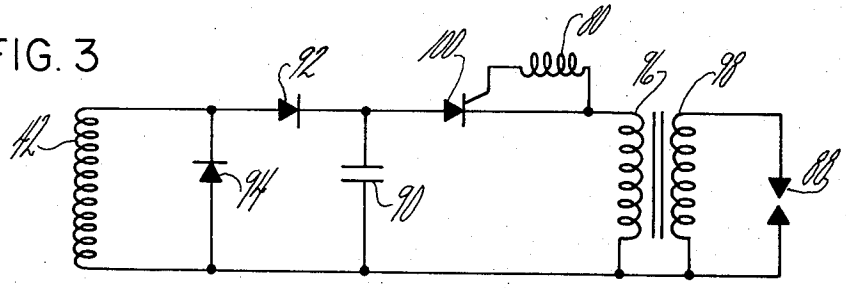
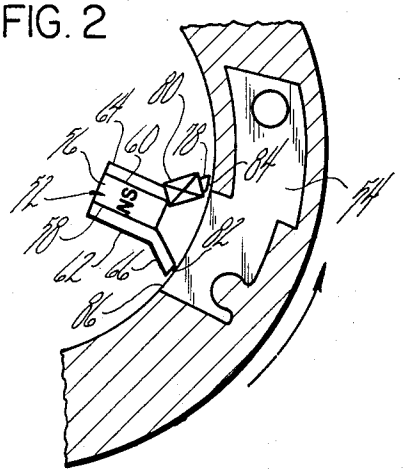


FIG. 2



INVENTORS
BOB O. BURSON
RUSSELL DALE PHELON

BY

McCormick Paulding & Huber

ATTORNEYS

FIG. 4

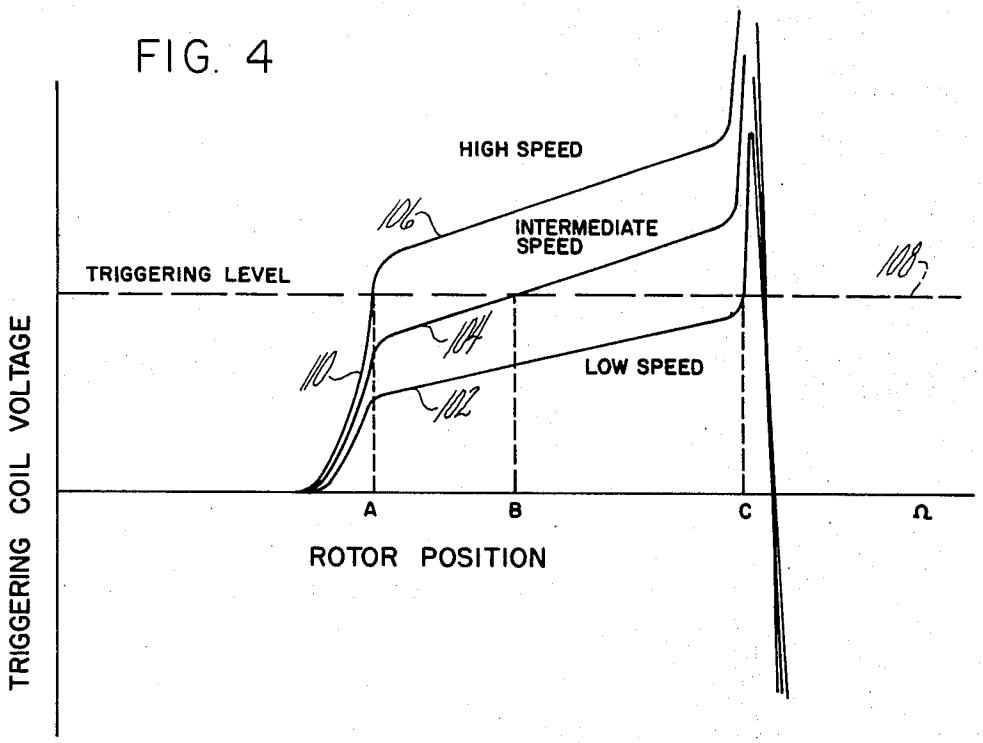
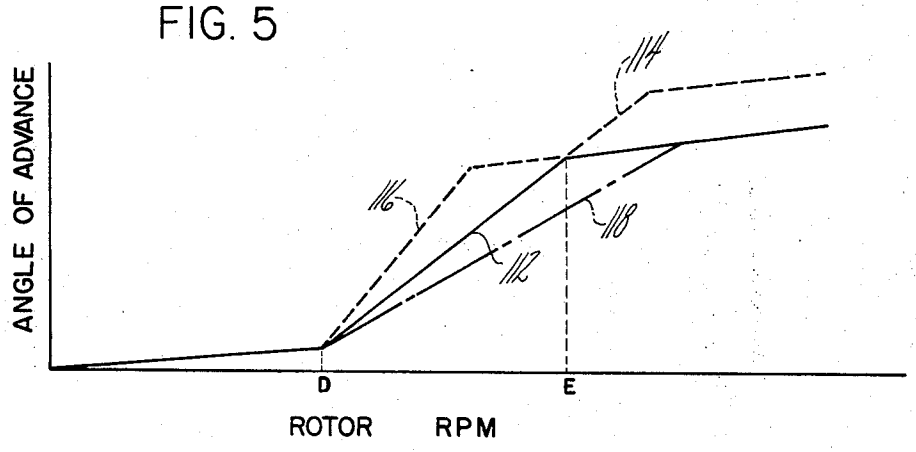

HIGH SPEED
INTERMEDIATE SPEED
LOW SPEED
TRIGGERING LEVEL
106
108
110
104
102
TRIGGERING COIL VOLTAGE
A
B
C
Ω
ROTOR POSITION

FIG. 5


114
116
118
112
ANGLE OF ADVANCE
D
E
ROTOR RPM

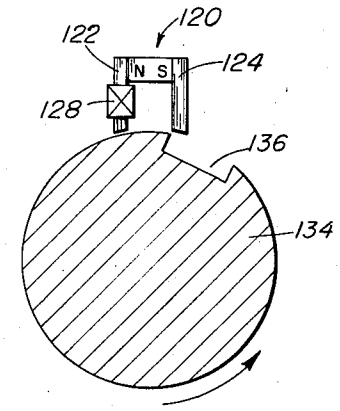


FIG. 7

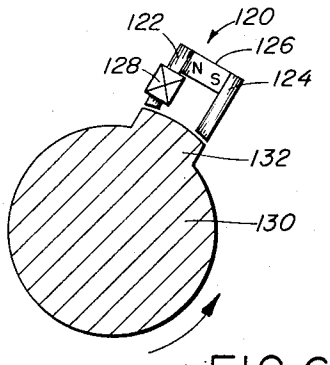


FIG. 6

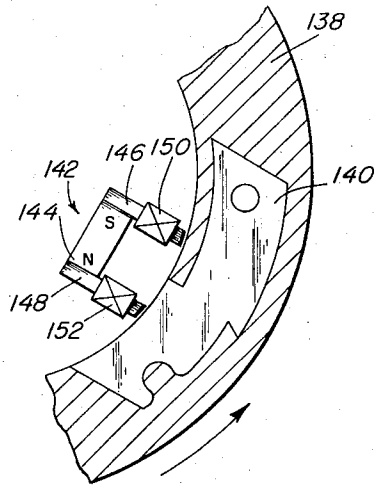


FIG. 8

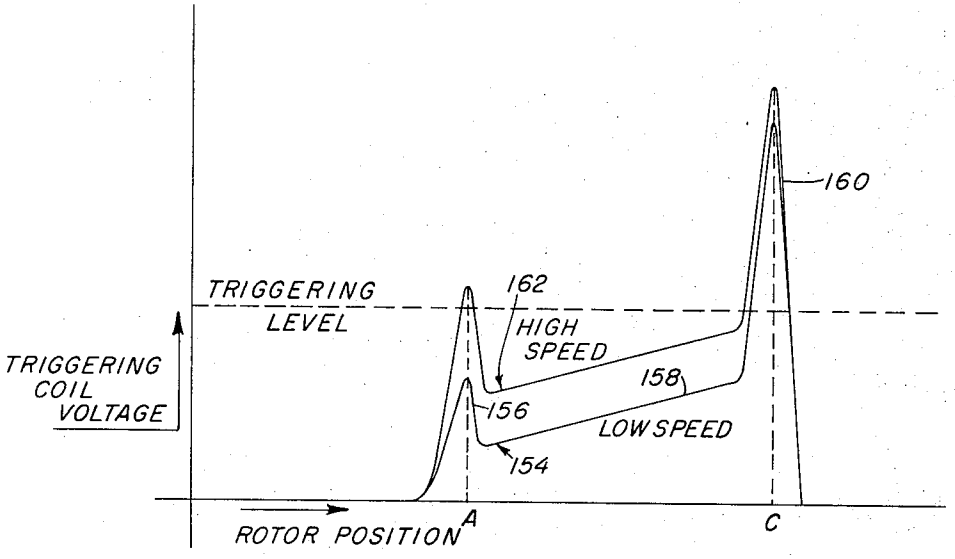


FIG. 9

IGNITION TRIGGERING CIRCUIT WITH AUTOMATIC ADVANCE

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of application Serial No. 758,563, filed September 9, 1968 for "Ignition Triggering Circuit with Automatic Advance now abandoned."

BACKGROUND OF THE INVENTION

This invention relates to ignition systems for spark ignited engines of the type including a triggered electronic switch and deals more particularly with a means for generating a triggering signal controlling the timing of the spark.

The general object of this invention is to provide an improved breakerless ignition system having a triggering circuit of simple, reliable construction and which additionally provides for a desirable, smooth automatic advance in the timing of the spark as the speed of the engine is varied over a given range of speeds. A still further object of this invention is to provide, in a breakerless ignition system, a simple low-cost construction of means for triggering the occurrence of the spark, such means being particularly well adapted for use with a condenser discharge system.

SUMMARY OF THE INVENTION

The invention resides in an ignition system for a spark ignited engine wherein the application to the spark gap device of electrical energy for producing a spark is controlled by an electronic switch, such as a silicon controlled rectifier, controlled by triggering signals. These triggering signals are produced by a stationary triggering magnet and coil assembly positioned adjacent a rotating part of the engine having an irregularity thereon which varies the reluctance of the triggering magnet flux circuit through the triggering coil as the irregularity passes the location of the triggering magnet and triggering coil. The irregularity is preferably mounted on the same part which carries a main magnet assembly used for generating the electrical power supplied to the spark gap device. In one embodiment of the invention, the irregularity is a piece of magnetic material also used as a counterweight to counterbalance such main magnet assembly in the rotating part, the rotating part having a rim of non-magnetic material in which the magnet assembly and counterweight are embedded. In another embodiment of the invention, the main magnet assembly includes two pole pieces of magnetic material, one of which in addition to serving as part of the main magnet assembly also serves as the irregularity for varying the reluctance of the triggering magnet flux path through the triggering coil. In another embodiment of the invention, the irregularity is a gap or slot formed in the rotating part which is made of magnetic material. The triggering magnet and coil assembly has two legs forming two angularly spaced pole faces, and the irregularity has length at least equal to the spacing between such pole faces. The waveform of the triggering signal may be either in the form of a voltage ramp followed by a spike, or in the form of an initial spike followed by a ramp and a subsequent spike, depending on whether the triggering coil is received on only the trailing one of said legs or on both of said legs.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a view taken through a rotor comprising part of an ignition system embodying this invention.

FIG. 2 is a fragmentary view similar to FIG. 1 but showing the rotor in a position advanced from that of FIG. 1.

FIG. 3 is a schematic wiring diagram of the ignition system of which the elements of FIG. 1 are a part.

FIG. 4 is a diagram illustrating the voltage waveforms induced in the triggering coil at different speeds of the rotor of FIG. 1 and indicating the manner in which the automatic advance is obtained.

FIG. 5 is a diagram illustrating different forms of advance versus speed characteristics which may be obtained for different configurations of the triggering circuit elements in a system similar to that of FIGS. 1 and 3.

FIG. 6 is a sectional view taken through a rotating part of an engine, and shows another embodiment of this invention.

FIG. 7 is a sectional view taken through a rotating part of an engine, and shows another embodiment of this invention.

FIG. 8 is a view generally similar to FIG. 2 but shows still another embodiment of this invention.

FIG. 9 is a diagram illustrating the voltage waveforms induced in the triggering coils of FIG. 8 at different speeds of the rotor and indicating the manner in which the automatic advance is obtained.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

This invention consists of an ignition system for a spark ignited engine wherein separate means are provided for supplying electrical energy used to provide the sprak at the spark plug or other spark gap device and for generating a triggering signal used to control the timing of the occurrence of the spark. As shown herein, the means for supplying electrical energy for the spark plug is also a generating means, and each of the separate generating means includes a part mounted on a rotating engine part rotated in synchronism with the operation of the engine. Each of these ignition system parts may be mounted on separate rotating engine parts, but preferably, and as shown herein, both ignition system parts are carried by the same engine part. In FIG. 1, this engine part is shown to be a rotor **10**, which may, for example, be a flywheel attached to the crankshaft or camshaft of the engine, the rotor **10** having a rim **12** of non-magnetic material, shown in section in FIG. 1, and being rotated in the direction of the arrow as the engine operates.

FIG. 1 shows the generating means used for producing the electrical energy for the spark gap device and the generating means for producing the triggering signals used to control the timing of the spark. FIG. 3, in turn, shows the remainder of the ignition system, which is connected with the generating means of FIG. 1 and with the spark gap device. Considering first FIG. 1, the generating means for producing the electrical energy used to energize the spark gap device consists of a main magnet assembly **14**, embedded in the rim **12** of the rotor **10**, and a stationary generating coil means **16** arranged for excitation by the main magnet assembly.

The main magnet assembly includes a permanent magnet **18** having circumferentially spaced end faces **20** and **22** of opposite magnetic polarity. Engaging these opposite end faces **20** and **22**, and also embedded in the non-magnetic material of the rim **12**, are two pole pieces **24** and **26** of magnetic material, preferably laminated. The pole pieces extend to the outer surface of the rim **12** and provide two circumferentially extending and circumferentially spaced pole faces **28** and **30** of opposite magnetic polarity.

The generating coil means **16**, which cooperates with the magnet assembly **14**, includes a stator core **32** of magnetic material, preferably laminated, having two radially inwardly directed legs **34** and **36** circumferentially spaced from one another along the outer surface of the rim **12** and having arcuate pole faces **38** and **40** spaced close to the path of movement of the magnetic pole faces **28** and **30** so that as the moving and stationary pole faces pass one another a relatively small air gap is formed therebetween. A generating coil **42** is mounted on the stator pole **34**. The stator pole faces **38** and **40** are spaced from one another by a distance such that the leading edge **44** of the leading face **40** is spaced from the trailing edge **46** of the trailing face **38** by a distance approximately equal to the spacing between the leading edge **48** of the leading rotor face **28** and the trailing edge **50** of the trailing rotor face **30**, with the circumferential extent of both the stator faces **38** and **40** being substantially less than the circumferential extent of the rotor pole faces **28** and **30**. Therefore, it will be obvious that as the main magnet assembly **14** passes the generating coil means **16**, the magnet **18** and its associated pole faces **28** and **30** will act to induce a magnetic flux in the stator **32** which first passes in one direction and then in the opposite direction through the coil carrying pole **34** to, in turn, induce a voltage in the generating coil **42**, which is first of one polarity and then of the opposite polarity.

The means shown in FIG. **1** for generating triggering signals consists of a separate triggering magnet and coil assembly **52**, fixed relative to the stationary structure of the engine, and a flux varying irregularity carried by the rotor in the form of a piece of magnetic material **54** embedded in the rim **12**. In this case, the piece **54** is located approximately diametrically opposite from the main magnet assembly **14** and serves as a counterweight for balancing the rotor against the weight of the main magnet assembly. The triggering magnet and coil assembly **52** is located inside of the rim **12** and includes a small permanent magnet **56** having end faces **58** and **60** of opposite magnetic polarity. Associated with the magnet **52** is a stator core comprised to two pieces of magnetic material **62** and **64** which respectively engage the opposite end faces **58** and **60** of the magnet and which extend radially inwardly from the magnet toward the rim **12** to provide two circumferentially spaced stator poles or legs **66** and **78**. A triggering coil **80** is mounted on the stator leg **78**, and the two poles **66** and **78** have end faces **82** and **84** located in a common circle concentric with the axis of rotation of the rotor **10**, and circumferentially spaced from one another.

For cooperation with the stator end faces **82** and **84** of the triggering magnet and coil assembly, the magnetic piece or counterweight **54** includes a pole face **86** located on the inner surface of the rim **12** and arranged so as to pass the stator pole faces **82** and **84** with a small air gap in between. The spacing between the leading and trailing edges of the rotor pole face **86** is approximately equal to the spacing between the leading edge of the leading stator face **82** and the trailing edge of the trailing stator face **84** so that at least one position of the rotor, the rotor face **86** overlaps both of the stator faces **82** and **84**.

From a consideration of FIGS. **1** and **2**, it will be obvious that as the rotor **10** rotates, the magnetic piece **54** in the rim **12** serves to vary the reluctance of the flux circuit of the triggering magnet **56** through the triggering coil **80** to induce a varying voltage in the triggering coil. FIG. **1** shows the position of the rotor just as the leading edge of the rotor face **86** comes into alignment with the leading stator face **82**. Prior to the reaching of this position, the flux through the triggering coil is substantially constant and no voltage is induced therein. However, as the FIG. **1** position is reached, the leakage pattern of the flux path is changed and a greater amount of flux flows through the triggering coil **80**. As the rotor face **86** advances over the pole face **82**, the reluctance of the flux path still further decreases, primarily as a result of increasing leakage, until the rotor face **86** overlaps both of the stator faces **82** and **84**. At this point, the reluctance of the flux path through the triggering coil **80** is rapidly reduced as a result of the flux path passing directly through the stator pieces **62** and **64** and the rotor piece **54** with little leakage. The net effect of this is that the voltage waveform induced in the triggering coil **80** consists of a ramp portion which occurs throughout the time the rotor moves from the position of FIG. **1** to the position of FIG. **2** followed by a spike initiated approximately at the rotor position of FIG. **2** at which both of the stator pole faces start to move onto the rotor pole face **86**. After the rotor moves beyond the position shown in FIG. **2** and the pole face **82** moves off of the rotor face **86**, the reluctance of the flux path through the triggering coil **80** again decreases and a voltage of opposite polarity is induced therein. The magnitude of the ramp voltage induced in the triggering coil **80** as the rotor moves from the FIG. **1** to the FIG. **2** position depends on the speed of the rotor so that the voltage signal from the triggering coil may be used to provide an automatic advance, as explained in more detail hereinafter in connection with FIG. **4**.

FIG. **3** is an electrical shcematic diagram showing the portion of the ignition system connected between the generating coil **42** and triggering coil **80** and the spark gap device. The spark gap device is shown at **88** in FIG. **3** and may be a conventional spark plug. The circuit of FIG. **3** is of the type referred to as a condenser discharge system, and includes a condenser **90** connected with the generating coil **42** through a rectifier means, consisting of two diodes **92** and **94**, so that the condenser **90** is charged when the voltage induced in the generating coil **42** is of one polarity. That is, as the main magnet assembly **14** passes the generating coil means **16**, a voltage waveform is induced in the generating coil **42** which is first of one polarity and then of the other polarity, and only that portion of the wave which is of one polarity is used to charge the condenser. The condenser **90** is, in turn, connected with the primary coil **96** of a step-up transformer having its secondary coil **98** connected in series with the spark plug **88**. In the circuit between the condenser **90** and the primary winding **96** is an electronic switch consisting of a silicon controlled rectifier **100** having its anode

and cathode terminals connected in series with the condenser and the primary winding. The triggering coil **80** controls the conduction of the silicon controlled rectifier **100** and is connected between the triggering terminal and the cathode of the silicon controlled rectifier.

In the normal operation of the system shown in FIGS. **1** and **3**, the main magnet assembly **14** first passes the generating coil means **16** and induces the voltage in the generating coil **42** which charges the condenser **90.** After a charge is built up on the condenser **90,** it is initially prevented from passing to the primary winding **96** of the step-up transformer by the silicon controlled rectifier **90** which is at that time in a non-conducting state. Sometime after the main magnet assembly **14** passes the generating coil assembly **16,** however, the rotor face **86** provided by the counterweight **54** moves past the stator faces **82** and **84** of the triggering magnet and coil assembly and induces a triggering voltage in the triggering coil **80** which switches the silicon controlled rectifier to a conducting state, thereby discharging the condenser **90** through the primary winding **96** of the step-up transformer and inducing a high potential in the secondary winding **98** to cause the occurrence of a spark at the spark plug **88.** As the pole face **86** of the magnetic piece **54** moves away from the pole faces **82** and **84** of the triggering magnet and coil assembly, a reverse voltage is induced in the triggering coil **80** and a reverse voltage is applied across the anode and cathode terminals of the silicon controlled rectifier, as a result of resonance between the condenser **90** and winding **96,** to positively switch the silicon controlled rectifier to a non-conducting state, thereby conditioning it for operation on the following cycle.

As mentioned, the voltage waveform induced in the triggering coil **80** is one which, in conjunction with the silicon controlled rectifier **100,** operates to produce an automatic advance in the timing of the occurrence of the spark in response to changes in the speed of the rotor **10** and the associated engine. Referring to FIG. **4,** the lines **102, 104** and **106** indicate generally the shape of a voltage waveform induced in the triggering coil **80** at different speeds of the rotor **10.** The horizontal line **108** indicates the level of voltage required to obtain switching of the silicon controlled rectifier from its non-conducting state to its conducting state. The rotor position A corresponds generally to the position shown in FIG. **1** at which the leading edge of the rotor pole face **86** starts to move over the leading stator pole face **82.** The rotor position C represents generally the rotor position shown in FIG. **2** at which the leading edge of the rotor pole face starts to move over the trailing stator pole face **84.**

The line **102** in the FIG. **4** is the voltage waveform obtained at a low speed of the rotor, and it will be noted that at this low speed the voltage induced in the triggering coil does not rise above the triggering level **108** throughout the ramp portion located between the rotor positions A and C. At the rotor position C, however, a spike occurs in the waveform which carries the voltage above the triggering level so that firing occurs at approximately this rotor position. At all speeds below that represented by the line **102,** triggering and firing of the spark plug is produced by the spike portion of the waveform which always occurs at approximately the rotor position C. Therefore, over a given range of low engine speeds firing will always occur at approximately the same rotor position.

The line **104** in FIG. **4** represents the voltage waveform induced in the triggering coil **80** at an intermediate speed, and from this line, it will be noted that it crosses the triggering level **108** at a rotor position B, switching of the silicon controlled rectifier **100** and firing of the spark plug therefore occurring at this rotor position. The line **106** of FIG. **4** represents the waveform induced in the triggering coil **80** at a relatively high speed, and in this waveform all of its ramp portion is located above a triggering level **108.** However, it should be noted that as the leading edge of the rotor face **86** moves onto the leading stator pole face **82,** a short initial rapid change in the reluctance of the flux path through the triggering coil **80** is produced, which produces a sharp rise in voltage preceding the ramp portion, this sharp rise being indicated at **110** in FIG. **4** in connection with the line **106.** Therefore, at relatively high speeds, triggering occurs at the point where the initial steep rise portion of the voltage waveform crosses the triggering level **108,** the rotor position at which this firing occurs being at approximately the rotor position A for all speeds higher than that represented by the line **106.**

The overall result produced by the triggering means, explained above in connection with FIG. **4,** is that at relatively low speeds of the rotor and engine, firing occurs at or near the rotor position C, which may, for example, correspond to approximately the top dead-center position of the piston associated with the spark plug **88.** After this given range of low speeds is passed, an intermediate range of speeds is entered throughout which the timing of the spark is advanced as the speed is increased the advancing of the timing increasing with speed until firing occurs at the rotor position A. After the rotor speed is increased to the point where firing occurs at the rotor position A, further increases in speed affect substantially no change in the timing of the spark with the spark occurring at all such higher speeds at approximately the rotor position A.

The solid line **112** of FIG. **5** indicates the manner in which the timing of the spark is advanced in response to the rotor speed as explained above. That is, throughout a low range of speeds from zero to D, the firing occurs at substantially a zero or very low angle of advance. At speeds between D and E, the angle of advance increases substantially linearly with increases in the rotor speed and at speeds in excess of E, the angle of advance remains approximately constant. It should also be noted that by changing the physical characteristics of the rotor face **86** and of the triggering magnet and coil assembly, different characteristics of angle of advance versus rotor speed may be obtained. For example, the length of the spacing between the stator pole faces **82** and **84** determines the length of the ramp portions of the voltage curves shown in FIG. **4.** The slope of the ramp portions of these curves may, in turn, be varied by varying the shape or orientation of the stator poles **66** and **70,** by changing the strength of the magnet **56,** or by changing the number of turns of winding of the triggering coil **80.**

Therefore, as indicated in FIG. **5,** a system providing for a greater amount of advance, as indicated by the line **114,** may be obtained by increasing the spacing between the stator pole faces. Alternatively, a system having approximately the same amount of advance as that

represented by the line **112**, but in which the advance occurs over a smaller range of rotor speeds, may be obtained by increasing the steepness of the ramp portions of FIG. **4**, as by increasing the number of turns of winding on the coil **80**, the characteristic of such a system being illustrated by the line **116** of FIG. **5**. The line **118** of FIG. **5** illustrates the characteristic of a system having substantially the same amount of advance as the system represented by the line **112** but wherein the advance occurs over a greater range of rotor speeds as a result of the ramp portions of FIG. **4** having a lesser degree of steepness, as a result, for example, of the coil **80** having a smaller number of turns. From FIG. **5**, it will therefore be obvious that almost any desired form of advance versus rotor speed characteristic may be obtained by properly designing the elements of the triggering signal generating means.

In the embodiment of the invention above described, a separate magnetic piece or counterweight **54** is used as an irregularity for varying the flux through the triggering coil **80**. The use of this piece for per forming the flux varying function is, however, not necessary, and if desired, the leading pole piece **24** of the main magnet assembly **14** may be used for this purpose. The broken lines of FIG. **1** illustrate a triggering magnet and coil assembly positioned to make use of the leading pole face **24** as the flux varying element. In this broken line illustration, the parts have been given the same reference numbers as in the full line representation except for having the suffix *a* added thereto. In this case, the magnet and triggering coil assembly **52***a* is located on the outside of the rotor rim **12** similarly to the generating coil means **16**, and is further so arranged that the stator pole faces **82***a* and **84***a* are located close to the path of movement of the rotor or magnet pole faces **28** and **30**. The spacing between the leading edge of the leading stator pole face **84***a* and the trailing edge of the trailing stator pole face **82***a* is approximately equal to the spacing between the leading and trailing edges of the rotor pole face **28**. Therefore, it will be obvious that as the pole piece **24** is rotated past the magnet and pole assembly **52***a*, a voltage is induced in the triggering coil **80***a* in the same manner as described above in connection with the movement of the rotor pole face **86** past the triggering magnet and coil assembly **52**.

In the previously described embodiments of the invention, the irregularity for varying the flux through the magnet and coil assembly has consisted of a piece of magnetic material embedded in the non-magnetic material of the rotor rim. Obviously, however, the irregularity may take many other different forms. For example, FIG. **6** shows a triggering magnet and coil assembly **120** which is generally similar to the triggering magnet and coil assembly **52** of FIG. **1** except for the two pieces of magnetic material **122** and **124** which make up the stator core being comprised of straight pieces of material rather than pieces that are bent as are the pieces **62** and **64** of FIG. **1**. The triggering magnet and coil assembly **120** in addition to the two stator pieces **122** and **124** includes a permanent magnet **126** and a coil **128** received on the trailing leg of the stator core as provided by the piece **122**. The triggering magnet and coil assembly **120** is located adjacent a rotating part **130** of the engine which is made of a magnetic material and which, for example, may be the shaft to which the flywheel of the engine is connected. The direction of rotation of the part **130** is shown by the arrow in FIG. **6**. The irregularity which cooperates with the triggering magnet and coil assembly **120** is a raised protuberance **132** having a circumferential length at least approximately equal to the circumferential spacing between the leading edge of the leading piece **124** of the stator core and the trailing edge of the trailing piece **122** of the stator core. Therefore, it will be obvious that the effect of the irregularity **132** in inducing a voltage in the coil **128** is similar to the effect of the counterweight **54** in inducing a voltage in the triggering coil **80** of FIG. **1**.

FIG. **7** shows another form of irregularity which may be used in practicing this invention. In this figure, the triggering magnet and coil assembly is indicated at **120** and is identical with that shown in FIG. **6**. This triggering magnet and coil assembly, in the FIG. **7** arrangement, is located adjacent a rotating part **134** which is made of a magnetic material and which again may, for example, be the shaft of the engine to which the flywheel is attached. To provide a flux varying irregularity for cooperation with the triggering magnet and coil assembly **120**, the part **134** has formed therein a slot or gap **136** which moves past the triggering magnet and coil assembly during each revolution of the part **134**, the part **134** being normally rotated in the direction of the arrow. The affect of the gap **136** on the flux through the triggering magnet and coil assembly **120** of FIG. **7** is substantially the reverse of the affect of the protuberance **132** of FIG. **6** on the flux through the triggering magnet and coil assembly of FIG. **6**. That is, as the gap **136** of FIG. **7** approaches the triggering magnet and coil assembly, the flux through such assembly is reduced rather than increased. However, the rate of change of the flux, and consequently the voltage waveform induced in the triggering coil **128** of FIG. **7**, will be the same as that of FIG. **6**, the length of the gap **136** in the circumferential direction being at least as long as the circumferential spacing between the leading edge of the leading piece **124** and the trailing edge of the trailing piece **122**.

In connection with all of the previously described embodiments of the invention, it should be understood that the circumferential length of the irregularity used with the triggering magnet and coil assembly may be greater than the length between the poles of the triggering magnet and coil assembly without affecting that portion of the signal induced in the triggering coil used to effect triggering of the ignition system. The important consideration is that the circumferential length of the irregularity be at least approximately equal to the spacing between the leading edge of the leading stator pole and the trailing edge of the trailing stator pole so that at one position of the rotor the leading stator pole overlaps the irregularity and remains overlapped therewith until reaching a second rotor position at which both stator poles are simultaneously overlapped with the irregularity. Of course, if the spacing between the stator poles is increased to increase the angle of advance, the irregularity must be of such a circumferential length as to accommodate such increased spacing.

In all of the preceding embodiments of the invention, the triggering coil of the triggering magnet and coil assembly has consisted of a single coil placed on the trailing pole or leg of the stator core. This causes to be induced in the triggering coil a voltage waveform similar to that shown in FIG. **4** consisting essentially of an ini-

tial gradually rising ramp portion followed by a sharply rising spike. This, as previously mentioned, provides a variable advance during intermediate speeds of the engine at which triggering is effected by the ramp portion of the voltage waveform which reaches the triggering level at different rotor positions for different rotor speeds. If desired, the triggering magnet and coil assembly may also be constructed so as to provide for a simple two-step type of advance wherein the firing occurs at one rotor position for low rotor speeds and at another rotor position for higher rotor speeds with no intermediate degrees of advance. This is accomplished by constructing the triggering coil of two separate coils or coil segments and by placing them individually on the two stator poles and connecting them in series aiding relationship. Such an arrangement is shown in FIG. **8** wherein the rotating part is indicated at **138** and carries a counterweight **140** of magnetic material, the part **138** being similar to the rotor **10** of FIG. **1.** The triggering magnet and coil assembly is indicated at **142** and consists of a magnet **144** and two stator pieces **146** and **148.** Received on the stator piece **146** is a coil **150** forming one part of the triggering coil and similarly received on the stator piece **148** is another coil **52** forming another part of the triggering coil. The two coils **150** and **152** are connected in series aiding relationship, and in the ignition system of FIG. **3,** for example, may replace the single coil **80** therein illustrated. The part **138** in FIG. **8** rotates in the direction of the arrow.

FIG. **9** shows the triggering signal developed across the two series connected coils **150** and **152** of FIG. **8** as the counterweight **140** moves therepast at different speeds. More particularly, considering the low speed waveform **154,** as the pole face provided by the counterweight **140** moves toward the leading stator piece **148** there is a rather rapid increase in the leakage flux which passes through the leading triggering coil **152** but which does not pass through the trailing triggering coil **150.** This produces an initial spike **156** in the voltage waveform which occurs at the illustrated rotor position A, the rotor position A, as in FIG. **4,** being the position at which the pole face of the counterweight **140** starts to move into overlapped relationship with the stator pole provided by the stator piece **148.** Following the initial spike **156,** a gradual increase in the leakage flux through both the triggering coils **152** and **150** produces a ramp shaped portion **158** of the voltage waveform which, at the rotor position C, is followed by a sharply rising spike **160** occurring when both of the pole pieces **146** and **148** of the triggering magnet and coil assembly move simultaneously into overlapped relationship with the pole face provided by the counterweight **140.**

As will be evident from FIG. **9,** at the low rotor speeds the triggering signal does not rise to the triggering level until the rotor reaches the position C at which the terminal spike **160** is induced in the triggering coils. Therefore, at all low speeds of the engine firing occurs at the rotor position C. At higher speeds of the engine, as represented by the higher speed waveform **162** of FIG. **9,** the initial spike produced in the waveform at the rotor position A exceeds the triggering level so that at such higher speeds the triggering occurs at the rotor position A rather than the rotor position C.

We claim:

1. A trigger signal producing means for use in a breakerless ignition system for a spark ignited engine having at least one spark gap device and a part rotated in synchronism with the operation thereof, and which ignition system includes a triggered electronic switch the triggering of which determines the timing of the firing of said at least one spark gap device, said trigger signal producing means comprising means defining a flux varying irregularity carried by said rotatable part of said engine for rotation therewith, and a stationary triggering magnet and coil assembly located adjacent the path of said flux varying irregularity, said triggering magnet and coil assembly including a triggering magnet and a triggering coil fixed relative to one another and said triggering magnet and coil assembly also having two pole faces comprising opposite ends of a low reluctance path passing through said coil for the flux of said triggering magnet, said two pole faces of said triggering magnet and coil assembly being located close to and facing the path of said flux varying irregularity and being spaced from one another circumferentially of said path so that as said rotatable part is rotated said flux varying irregularity varies the amount of flux from said triggering magnet passing through said triggering coil, and said flux varying irregularity having a circumferential length at least approximately as great as the circumferential spacing between the leading edge of the leading one of said two pole faces and the trailing edge of the trailing one of said two pole faces and being continuous along said circumference length thereof so that as said irregularity is moved toward and past said triggering magnet and coil assembly by the rotation of said rotatable part said leading one of said two pole faces first overlaps said irregularity and then remains overlapped with said irregularity until after said trailing pole face subsequently overlaps said irregularity simultaneously with said leading pole face.

2. A trigger signal producing means as defined in claim **1** further characterized by said flux varying irregularity comprising a pole face defined by a quantity of magnetic material.

3. A trigger signal producing means as defined in claim **1** for use in a breakerless ignition system for a spark ignited engine wherein said part rotated in synchronism with the operation of said engine is a rotor with a rim of non-magnetic material having embedded therein a single permanent magnet assembly cooperable with a stator assembly for producing power for said ignition system, further characterized by said flux varying irregularity comprising a pole face on said rotor rim defined by a counterweight of magnetic material embedded in said rim at a location generally diametrically opposite from said permanent magnet assembly so as to balance said rotor.

4. A trigger signal producing means as defined in claim **1** for use in a breakerless ignition system for a spark ignited engine wherein said part rotated in synchronism with the operation of said engine is a rotor with a rim of non-magnetic material having embedded therein a permanent magnet assembly cooperable with a stator assembly for producing power for said ignition system and which permanent magnet assembly includes two pole pieces of magnetic material defining two circumferentially extending and circumferentially spaced rotor pole faces, further characterized by said flux varying irregularity consisting of one of said rotor pole faces.

5. A trigger signal producing means as defined in claim 1 further characterized by said rotatable part being made of magnetic material and said flux varying irregularity comprising a gap formed in said rotatable part.

6. A trigger signal producing means as defined in claim 1 further characterized by said triggering magnet and coil assembly including two pieces of magnetic material engaging said triggering magnet at the opposite magnetic poles thereof, said two pieces of magnetic material extending from said triggering magnet toward said path of said flux varying irregularity and defining said two pole faces at their ends remote from said triggering magnet, said triggering coil being mounted on at least one of said two pieces of magnetic material.

7. A trigger signal producing means as defined in claim 6 further characterized by said triggering coil consisting of a single coil mounted on the trailing one of said two pieces of magnetic material.

8. A trigger signal producing means as defined in claim 6 further characterized by said triggering coil consisting of two separate coils each mounted on a respectively associated one of said two pieces of magnetic material and electrically connected to one another in series aiding relationship.

9. In a breakerless ignition system for a spark ignited engine having at least one spark gap ignition device and a part rotatable in synchronism with the operation thereof, the combination comprising a triggered electronic switch the triggering of which determines the timing of the firing of said at least one spark gap device, said triggered electronic switch having a triggering terminal and being triggered when the voltage applied to said triggering terminal rises from a low value to a given higher triggering level, and a trigger signal producing means connected with said triggering terminal for supplying triggering signals thereto, said trigger signal producing means including a flux varying irregularity carried by said rotatable part of said engine for rotation therewith, and a stationary triggering magnet and coil assembly located adjacent the path of said flux varying irregularity, said triggering magnet and coil assembly including a triggering magnet and a triggering coil fixed relative to one another and said triggering magnet and coil assembly also having two pole faces comprising opposite ends of a low reluctance flux path passing through said coil for the flux of said triggering magnet, said two pole faces of said triggering magnet and coil assembly being located close to and facing the path of said flux varying irregularity and being spaced from one another circumferentially of said path so that as said rotatable part is rotated said flux varying irregularity varies the amount of flux from said triggering magnet passing through said triggering coil, said flux varying irregularity having a circumferential length at least approximately as great as the circumferential spacing between the leading edge of the leading one of said two pole faces and the trailing edge of the trailing one of said two pole faces and being continuous along said circumference length thereof so that as said irregularity is moved toward and past said triggering magnet and coil assembly by the rotation of said rotatable part said leading one of said two pole faces first overlaps said irregularity and then during a given number of degrees of subsequent rotation of said rotatable part remains overlapped with said irregularity as said trailing pole face is moved closer thereto so as to gradually change the amount of flux through said triggering coil and induce a gradually increasing voltage therein during said given number of degrees of rotation and so as to suddenly change the amount of flux through said triggering coil and induce a spike in the voltage of said triggering coil at the position of said rotatable part where said trailing pole face moves into overlapped relation with said flux varying irregularity simultaneously with said leading pole face, said triggering magnet and triggering coil being so selected that at speeds of said rotatable part corresponding to low cranking speeds of said engine the maximum value of the voltage induced in said triggering coil during said given number of degrees of rotation is less than said triggering level and the maximum value of said voltage spike is greater than said triggering level and so that at other higher speeds of said rotatable member the maximum value of the voltage induced in said triggering coil during said given number of degrees of rotation is greater than said triggering level.

10. The combination defined in claim 9 further characterized by said triggering magnet and coil assembly including two pieces of magnetic material engaging said triggering magnet at the opposite magnetic poles thereof, said two pieces of magnetic material extending from said triggering magnet toward said path of said flux varying irregularity and defining said two pole faces at their ends remote from said triggering magnet, said triggering coil consisting of a single coil mounted on the trailing one of said two pieces of magnetic material.

11. The combination defined in claim 9 further characterized by said triggering magnet and coil assembly including two pieces of magnetic material engaging said triggering magnet at the opposite magnetic poles thereof, said two pieces of magnetic material extending from said triggering magnet toward said path of said flux varying irregularity and defining said two pole faces at their ends remote from said triggering magnet, said triggering coil consisting of two separate coils each mounted on a respectively associated one of said two pieces of magnetic material and electrically connected to one another in series aiding relationship.

12. Means for repetitively producing a trigger signal for an electronically triggered ignition system for an internal combustion engine which trigger signal includes a gradual rise portion followed by a sharply rising spike portion and the steepness and maximum value of which gradual rise portion increase as the speed of said engine increases, said means comprising a part rotatable in synchronism with said engine and having an arcuate pole face defined by a quantity of magnetic material, and a stationary triggering magnet and coil assembly including a triggering magnet and a triggering coil fixed relative to one another and said triggering magnet and coil assembly also having two stationary pole faces comprising opposite ends of a low reluctance path passing through said coil for the flux of said triggering magnet, said two pole faces being located close to and facing the path of said arcuate pole face so as to form a small air gap therebetween as said arcuate pole face moves therepast so that as said rotatable part is rotated said quantity of magnetic material varies the amount of flux from said triggering magnet passing through said triggering coil, said two stationary pole faces being spaced from one another along the path of said arcuate pole face, and said arcuate pole face having a length in the direction of its path of movement at least approximately as great as the spacing between the leading edge of the leading one of said two stationary pole faces and the trailing one of said stationary pole faces said arcuate pole face being continuous along said length thereof.

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