April 25, 1967 H. P. QUINN 3,316,449

IGNITION CIRCUIT

Filed June 22, 1964

Fig. 1.

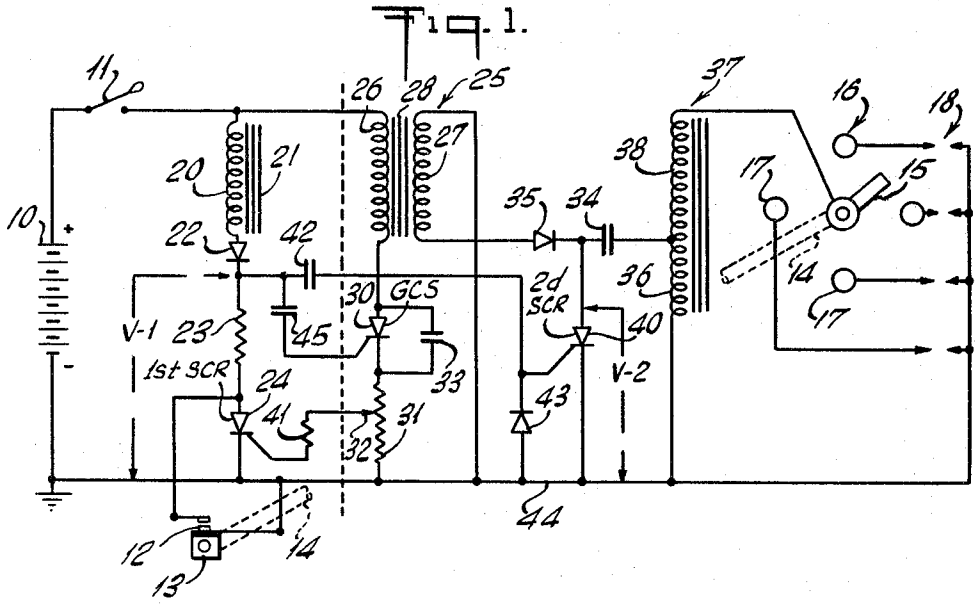


Fig. 2.

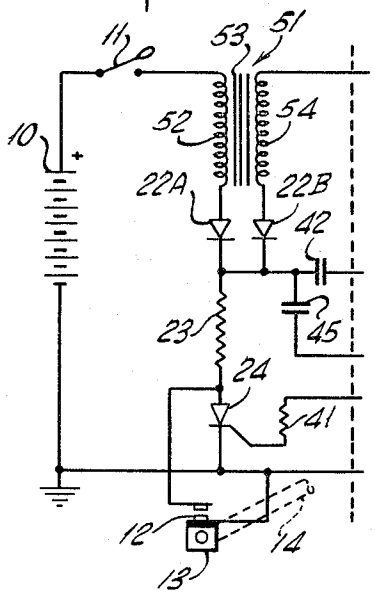
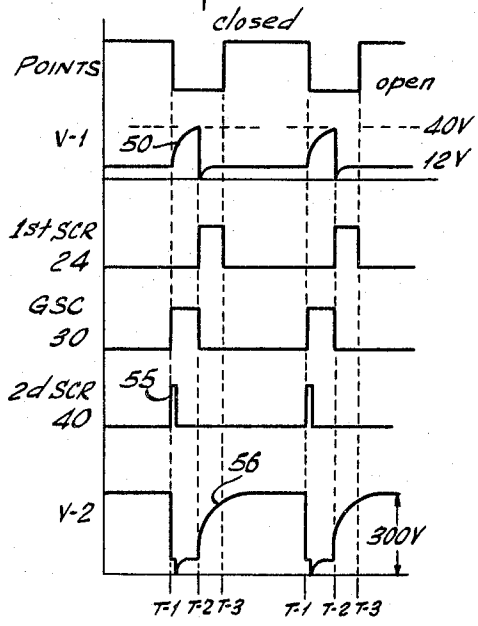


Fig. 3.



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IGNITION CIRCUIT

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This invention relates to an ignition circuit for internal combustion engines which produces a high voltage spark for each spark plug. It has particular reference to a means for producing a high voltage pulse which does not depend upon the speed of the engine. The circuit uses silicon controlled rectifiers, one of which is constructed so that it may be turned off as well as on.

Many types of ignition circuits have been developed for supplying spark plugs with high voltage discharges which ignite the charge within a piston chamber. Substantially all of these circuits or arrangements require a definite engine speed before operating properly. While this characteristic does not generally affect the operation during normal speed operations, there are conditions at slow speed when starting, and at very high speeds, wherein the circuit does not produce sufficient voltage or wherein the voltages in the circuit are more than normal and may cause insulator breakdown. The present circuit can be arranged to provide an 80 microsecond, high voltage spark which is quite independent of the speed of the engine. The usual breaker contacts are employed but they pass very little current and for this reason have a long life.

As used throughout the specification and claims, the term "silicon controlled rectifier" refers to a semiconductor having four layers and three terminals. This component has been described in prior publications and is well-known in the art. The term "gate controlled switch" (G.C.S.) is the same as the silicon controlled rectifier except that it is arranged to turn off the current flow as well as turn it on. For this purpose a positive pulse is applied to the control electrode to make the device conductive and a negative pulse is applied to the control electrode to make the device nonconductive.

One of the objects of this invention is to provide an improved ignition circuit which avoids one or more of the disadvantages and limitations of prior art arrangements.

Another object of the invention is to provide a high voltage spark of constant duration which is independent of the speed of the engine.

Another object of the invention is to increase the current flow through semiconductor components by using only silicon rectifier devices.

Another object of the invention is to reduce the current carried by the breaker contacts.

The invention comprises an ignition circuit for internal combustion engines having a spark plug in each combustion chamber and includes, a source of direct current and a pair of breaker contacts controlled to open and close in synchronism with the movements of the engine's pistons. The circuit also includes a first charging circuit comprising an inductor and the anode-cathode circuit of a first silicon controlled rectifier. The breaker contacts are bridged across the anode-cathode circuit of this first rectifier. A second charging circuit comprises a primary winding of a charging transformer, a gate controlled switch and a voltage divider. A storage circuit is provided for collecting and storing a charge in a storage capacitor prior to discharging the capacitor through the primary winding of an output transformer. This charging circuit includes the storage capacitor, the secondary winding of the charging transformer, and a silicon rectifier. The storage capacitor is discharged through the anode-cathode circuit of a second silicon controlled rectifier. The high voltage pulse is applied to the spark plugs by

the usual distributor and the secondary winding of the output transformer.

For a better understanding of the present invention, together with other and further objects thereof, reference is made to the following description taken in connection with the accompanying drawings:

FIG. 1 is a schematic diagram of connections of the preferred embodiment of the ignition circuit.

FIG. 2 is a schematic diagram of an alternate circuit showing only a portion of the complete arrangement.

FIG. 3 is a graph indicating some of the voltages and currents which exist in the circuit during its operation.

Referring now to FIG. 1, the circuit comprises the usual battery **10**, an on-off switch **11**, and a pair of breaker contacts **12** which are operated by a cam **13** secured to a shaft **14** which connects with a rotary arm **15** in the distributor **16**. The distributor **16** contains the usual stationary contacts **17**, each connected to one of a plurality of spark plugs **18**.

The circuit also includes an inductor **20** having a winding on a ferromagnetic core **21**. The inductor is connected in series with a rectifier **22**, a limiting resistor **23**, and a first silicon controlled rectifier **24**. The breaker contacts are connected across the anode-cathode circuit of this first control rectifier.

The circuit also includes a charging transformer **25** having a primary winding **26**, a secondary winding **27**, and a core **28**. The primary winding **26** is connected in series with the anode and cathode of a gate controlled switch **30** and a voltage divider **31** having a mid-point adjustable connector **32**. A capacitor **33** is shunted around the gate control switch **30** in order to slow down the rate of rise of voltage during the turn-off operation of this component in order to reduce the generation of heat within the switch.

The circuit contains a storage capacitor **34**, this capacitor receiving its charge from a charging circuit which includes the secondary winding **27** of charging transformer **25**, a diode rectifier **35**, and the primary winding **36** of an output transformer **37** having a secondary winding **38** coupled to the distributor **16**. Storage capacitor **34** is discharged through the primary winding of output transformer **37** by means of a second silicon controlled rectifier **40** having its anode-cathode circuit connected between one terminal of the storage capacitor and the negative terminal of the battery **10**.

Three coupling circuits are employed to control the two silicon controlled rectifiers and the gate controlled switch. One of these circuits comprises a resistor **41** connected between the mid-point **32** of voltage divider **31** and the control electrode of the silicon controlled rectifier **24**. A second coupling circuit comprises a capacitor **42** connected between one terminal of resistor **23** and the control electrode of the second silicon controller rectifier **40**. This circuit also includes a diode rectifier **43** which is connected between the control electrode of rectifier **40** and the ground conductor **44** in order to bypass the reverse pulse when the gate controlled switch **30** is being turned off. A third coupling circuit comprises a capacitor **45** connected between the same terminal of resistor **23** and the control electrode of gate controlled switch **30**.

The operation of this circuit is as follows: When points **12** are open before starting, no current flows in any portion of the circuit because both silicon controlled rectifiers **25** and **40** are in their nonconductive condition and the gate controlled switch **30** is also nonconducting. When points **12** are closed for the first time, current flows through inductor **20**, diode **22**, resistor **23**, and points **12** to conductor **44** to set up a current which provides magnetic flux in core **21**. The variations of current value in this and other circuits may be understood by ref-

erence to curve **50** shown in FIG. 3. This current is not large enough to supply operating voltage pulses to capacitors **42** and **45** because at this time they are separated from the ground conductor only by a small resistor **23**.

When the breaker points open (time $T-1$) the magnetic flux in inductor core **21** collapses and generates a voltage pulse which is applied through diode **22** to coupling capacitors **42** and **45**. The pulse transmitted through capacitor **42** does nothing because the storage capacitor **34** has not been charged. The pulse transmitted through capacitor **45** turns on the gate controlled switch **30** and a current flows from battery **10** through primary winding **26**, gate controlled switch **30**, and the voltage divider **31**. This current produces a magnetic flux in core **28**. This current builds up slowly because of the inductance in winding **26** but when it reaches a sufficient value the voltage at contact point **32** is sufficient to apply a voltage to the control electrode of rectifier **24** to make it conducting whereby current is restored to the inductor winding **20** (time $T-2$). Rectifier **24** remains in its conducting condition until breaker points **12** are again closed (at time $T-3$). The points short-circuit the rectifier and cause it to revert to its nonconducting condition.

When the silicon controlled rectifier **24** was turned on, capacitor **45** was discharged and a pulse through it was applied to the gate controlled switch **30** to turn it off. This action reduces the current through winding **26** to zero and the flux in core **28** collapses, thereby generating a current pulse (**56**, see FIG. 3) in winding **27** which applies a quantity of electricity to the storage capacitor **34** through diode **35** charging it to about 300 volts. Next, the points open for a second time and current pulses are again sent through capacitors **42** and **45** as before. This time the silicon controlled rectifier **40** is made conductive and the storage capacitor **34** discharges through this rectifier and primary winding **36** of the output transformer **37**, thereby sending a high voltage pulse through distributor **16**, to one of the spark plugs **18**.

The action continues sending a pulse from inductor **20** to control the current through primary winding **26** and when this current is turned off, another pulse is applied to the storage capacitor which then discharges to send a pulse through the output transformer to one of the plugs. It should be obvious from the above explanation that the time delay between the closing of the contact points **12** and the activation of the first controlled rectifier **24** depends only upon the rate of charge through inductor **20**. Also, the control of the other components in this circuit does not depend upon the speed of the engine.

The circuit shown in FIG. 2 contains the same battery **10**, the same switch **11**, and the same coupling capacitors **42** and **45**. Also the breaker points **12** and the operating cam **13** are the same as shown in FIG. 1. In FIG. 2 the inductor has been replaced by a transformer **51** having a primary winding **52**, a core **53**, and a secondary winding **54**. Both windings are connected to the junction of capacitors **42** and **45** in series with rectifiers **22A** and **22B** respectively. The grid controlled rectifier **24** and the resistor **23** are the same as before. This circuit is more reliable and permits the use of larger inductances and therefore more powerful transfer pulses. In the circuit shown in FIG. 1, the inductance of primary winding **26** may be too high, causing the current to build up slowly when the G.C.S. **30** is triggered by a positive pulse through capacitor **45**. If the anode-cathode current is less than a critical value, the G.C.S. is not made conductive and no transfer pulse to charge capacitor **34** is generated. The circuit shown in FIG. 2 eliminates this problem by providing more inductance (in winding **54**) to charge capacitor **45**, therefore lengthening the time of the trigger pulse. By using a transformer rather than a single coil, it is possible to have a high inductance secondary for a long trigger pulse, and a low inductance primary for a fast charging time.

The chart in FIG. 3 shows the curves and pulses which exist in the circuit shown in FIG. 1. It is obvious from this chart that the firing pulse occurs when the points open at time $T-1$. This pulse is created by the discharge pulse **55** through the silicon controlled rectifier **40**. It is also obvious from the curve shown in FIG. 3 that the charging rate, illustrated by curve **56** for charging storage capacitor **34**, starts a definite time after the opening of the points **12** regardless of the speed of the engine.

The foregoing disclosure and drawings disclose two embodiments of the present invention. It will be obvious to those skilled in the prior art that many changes can be made in these embodiments without departing from the spirit and scope of the invention. Therefore, it will be understood that this is intended to cover all changes in the disclosed embodiments which do not depart from the spirit and scope of the invention as set forth in the appended claims.

What is claimed is:

1. An ignition circuit for an internal combustion engine having a spark plug in each combustion chamber comprising,

a source of direct current;

a pair of breaker contacts controlled to open and close in synchronism with the movements of the engine's pistons;

an inductor including a winding on a ferromagnetic core for generating a current pulse when current through the winding is cut off;

a charging transformer including a primary winding and a secondary winding on a ferromagnetic core for generating a charging pulse in its secondary winding when current is cut off in its primary winding;

a storage capacitor for storing a quantity of electricity produced by said secondary winding;

an output transformer including a primary winding and a secondary winding for transferring the electricity stored in the storage capacitor to a distributor and spark plugs;

a first charging circuit connected across said source of current including in series, said inductor, and a first silicon controlled rectifier having an anode, a cathode, and a control electrode, said breaker contacts connected across the anode and cathode;

a second charging circuit connected across said source and including in series, the primary winding of the charging transformer, a voltage divider, and a gate controlled switch having an anode, a cathode, and a control electrode;

a first coupling circuit comprising a resistor connected between a mid-point on the voltage divider and the control electrode of the first silicon controlled rectifier for making the rectifier conductive when a current through the primary winding of the charging transformer reaches a predetermined value;

a capacitor charging circuit connected across the secondary winding of the charging transformer including in series, said storage capacitor, and the primary winding of the output transformer;

a storage capacitor discharge circuit for discharging the storage capacitor and generatnig a spark at one of the spark plugs, said discharge circuit including in series connection, the storage capacitor, the primary winding of the output transformer, and the anode-cathode circuit of a second silicon controlled rectifier;

a second coupling circuit comprising a first capacitor connected between one end of the inductor and the control electrode of said silicon controlled rectifier for making the second rectifier conducting when the breaker contacts are opened;

and a third coupling circuit comprising a second capacitor connected between one end of the inductor and the control electrode of the gate controlled switch

for making the switch conductive when the breaker contacts are opened and for making the switch non-conductive when the current through the inductor is cut off.

2. An ignition circuit as claimed in claim 1 wherein a diode rectifier is connected in series with said first charging circuit to prevent the discharge of two coupling capacitors connected between the first charging circuit and other controlled rectifiers.

3. An ignition circuit as claimed in claim 1 wherein said capacitor charging circuit includes a diode rectifier in series with the secondary winding to prevent the discharge of the storage capacitor through the secondary winding.

4. An ignition circuit as claimed in claim 1 wherein a capacitor is connected across the anode-cathode circuit of the gate controlled switch to prevent the rapid rise of voltage across these components when current through the switches is cut off.

5. An ignition circuit as claimed in claim 1 wherein said inductor is replaced by a transformer having a

primary winding connected in series between the positive terminal of the source of potential and the anode of the first silicon controlled rectifier, and a secondary winding connected in series between the primary winding of the charging transformer and the junction of said first and second coupling capacitors.

6. An ignition circuit as claimed in claim 1 wherein a diode rectifier is connected across the control electrode and the cathode of the second silicon controlled rectifier to by-pass the negative pulse generated by the reduction of current in the inductor when the gate controlled switch is being made non-conductive.

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