

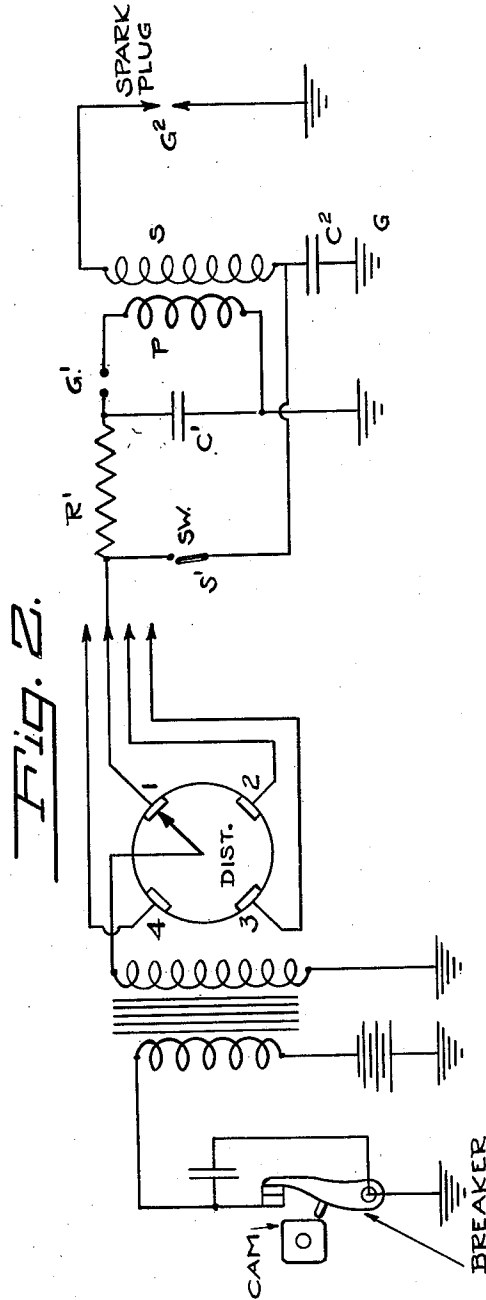
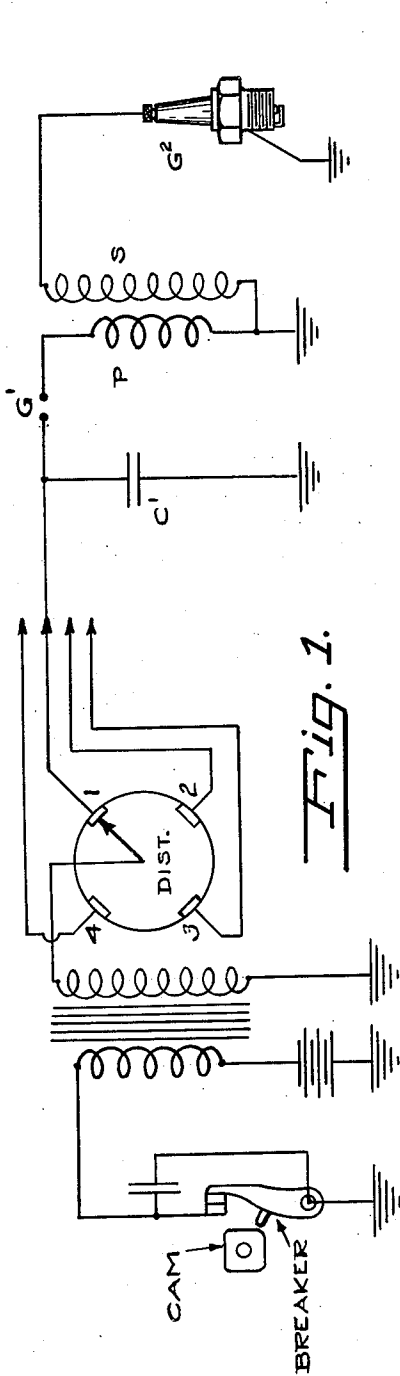
Feb. 14, 1950

G. L. LANG
IGNITION SYSTEM

2,497,307

Filed June 6, 1946

3 Sheets-Sheet 1



INVENTOR.
GREGOR L. LANG.
BY
Raymond A. Laguerre
ATTORNEY

Feb. 14, 1950

G. L. LANG
IGNITION SYSTEM

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3 Sheets-Sheet 2

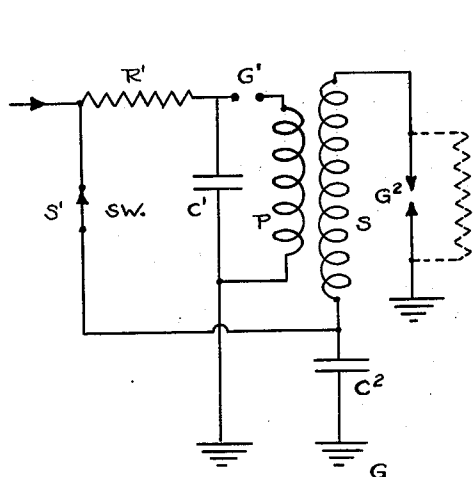


Fig. 3.

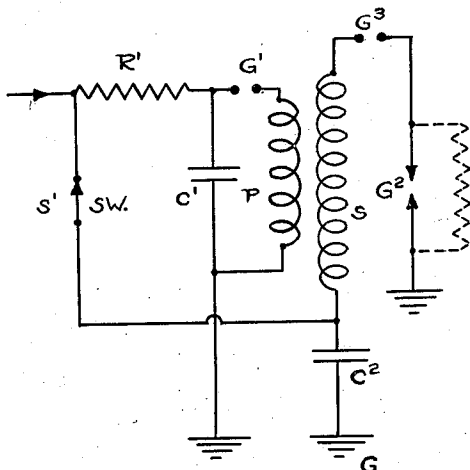


Fig. 4.

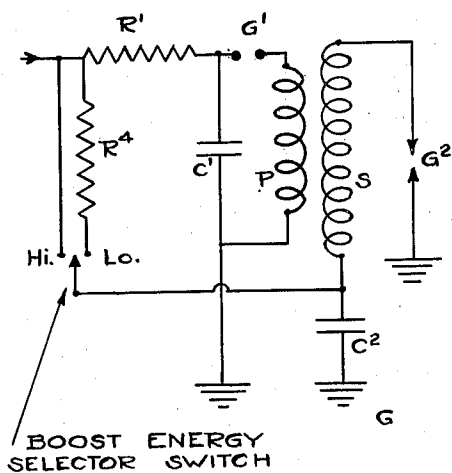


Fig. 5.

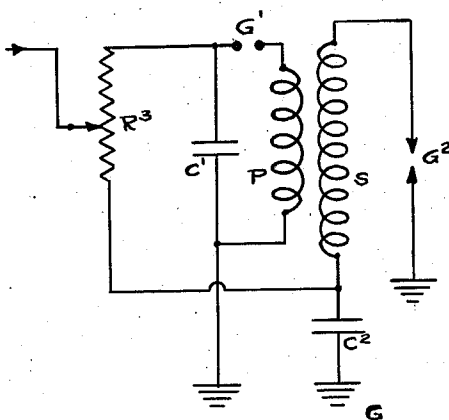


Fig. 6.

INVENTOR.
GREGOR L. LANG.
BY
Raymond A. Lequin
ATTORNEY

Feb. 14, 1950

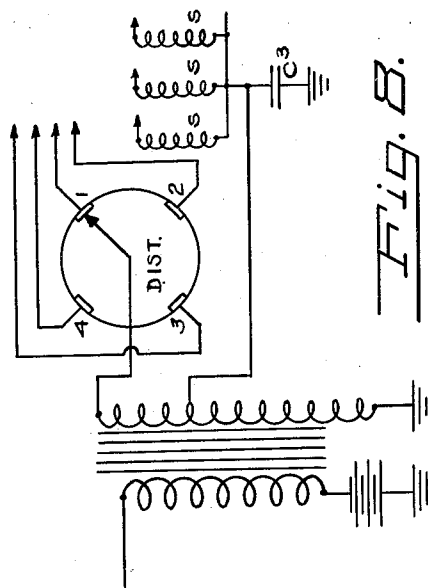
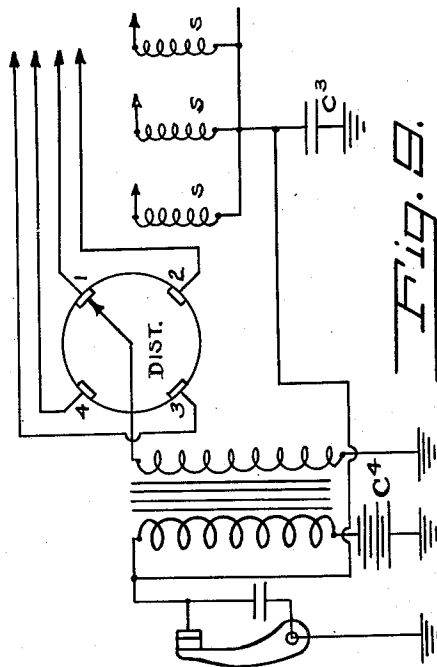
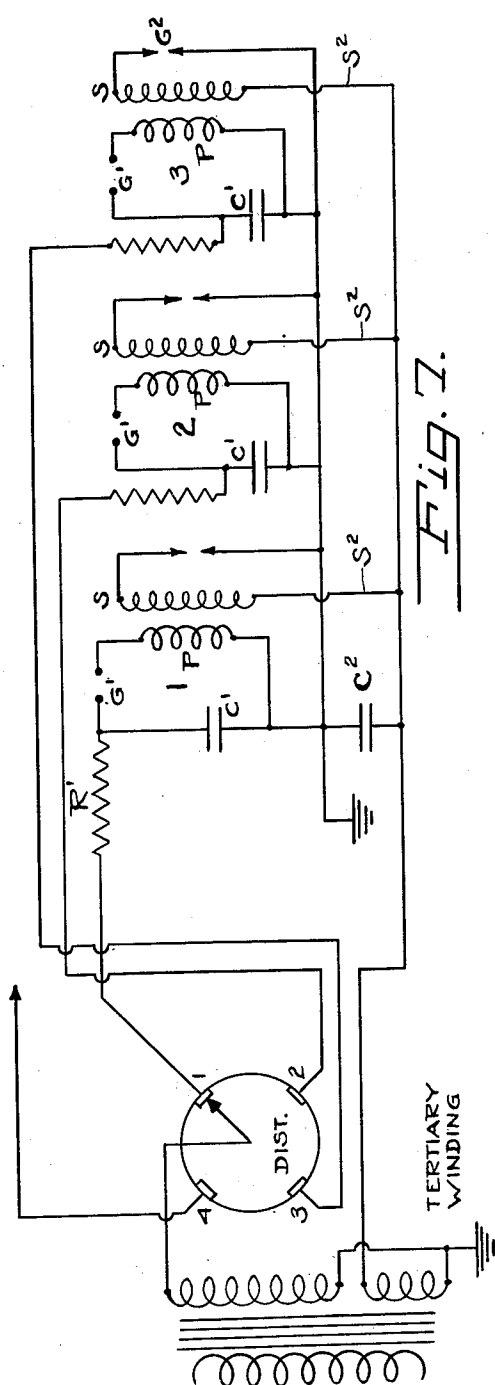
G. L. LANG

2,497,307

IGNITION SYSTEM

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3 Sheets-Sheet 3



INVENTOR.

GREGOR L. LANG.

BY

Raymond A. Piquin

ATTORNEY

UNITED STATES PATENT OFFICE

2,497,307

IGNITION SYSTEM

Gregor L. Lang, Longmeadow, Mass., assignor to
American Bosch Corporation, Springfield,
Mass., a corporation of New York

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8 Claims. (Cl. 315—163)

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This invention relates to ignition systems such as are used on internal combustion engines and has particular reference to the provisions of improvements in high frequency ignition systems of the type shown generally in U. S. Patent to Whisler 1,376,846, granted May 3, 1921, and wherein, as illustrated diagrammatically in Fig. 1, a magneto or battery and induction coil is employed as a source of energy which charges condenser C¹ until it reaches a voltage sufficient to jump across gap G¹. The energy previously stored in condenser C¹ discharges through said gap G¹ and the primary P of a high ratio, radio frequency Tesla type transformer. This discharge is of a high current, steep wavefront variety and of a damped oscillatory nature and such discharge in the primary of the Tesla coil gives rise to high voltage oscillations of similar waveform but magnified amplitude in the secondary S and the secondary discharge is used for ignition purposes in the spark plug G².

Such systems have been found to possess certain advantages over more conventional high tension, low frequency battery coil or magneto systems in that they were capable of reducing spark plug erosion, improved ability to fire consistently in spite of oil, carbon, and lead fouling of the spark plugs, and reduced tendency to flashover externally at high altitudes when employed in modern reciprocating type aircraft engines, however, such systems contain certain inherent limitations. For example, the secondary discharge of the Tesla type coil is of a low current, low energy type and low in heat value as compared with more conventional high tension systems, and the high frequency spark is of a very limited ignition value when extremely cold weather starting conditions are encountered or when the fuel employed is of a cruder and less volatile type than gasoline, which drawback has heretofore practically eliminated the high frequency ignition system as a method of igniting jet propulsion motors, oil burners, fuel oil and kerosene engines and the like.

From the foregoing it will be seen that the inherent anti-fouling characteristics of the high frequency or capacity discharge type of ignition system would be most advantageous in those applications if the inherent disadvantages of such systems could be overcome, particularly if a hotter and higher energy spark discharge could be obtained which was not possible with prior constructions wherein the energy per pulse or discharge is definitely fixed by the fundamental energy equation for a charged condenser,

$$E = \frac{CV^2}{2}$$

where E is the energy in joules, C is the capacitance in farads and V is the voltage to which the condenser is charged.

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It is, therefore, the principal object of this invention to produce an ignition system or circuit which combines the high energy, high current and high heat value of a low frequency system with the anti-fouling and other advantages of a high frequency system.

Another object of the invention is to provide an ignition system or circuit of the type set forth in which the electrical energy per discharge may be preadjusted to desired value.

Another object of the invention is to provide an ignition system or circuit in which the electrical energy per discharge may be manually or automatically varied during operation whereby high spark energy may be utilized for starting or operation with low grade fuels and in which the spark energy may be reduced to minimize spark plug erosion during running periods of the engine.

Another object of the invention is to provide a new and improved ignition system or circuit which provides the anti-fouling qualities of a high frequency system and the high energy, hot spark qualities of the conventional high tension system.

Another object of the invention is to provide a new and improved ignition system which produces a relatively high energy ignition spark and in which the energy value is not substantially affected by ignition gap length, compression pressure or other variables.

Another object of the invention is to provide an energy booster circuit as an addition to a high frequency circuit.

Other objects and advantages of the invention will be apparent from the following description taken in connection with the accompanying drawings and it will be understood that many changes may be made in the details of construction and arrangement of parts shown and described, as the preferred forms have been shown by way of illustration only.

Referring to the drawings:

Fig. 1 is a diagrammatic view of a prior art form of high frequency ignition system;

Fig. 2 is a diagrammatic view of the basic circuit of the present invention;

Fig. 3 is a fragmentary view showing part of the circuit shown in Fig. 2 and showing the effect of serious fouling across the gap of the spark plug;

Fig. 4 is a view similar to Fig. 3 and showing means for overcoming such fouling;

Fig. 5 is a fragmentary view showing a modified form of the invention;

Fig. 6 is generally similar to Fig. 5 but shows a slightly different form of the invention;

Fig. 7 is generally similar to Fig. 2 but shows a portion of the circuit common to all of the spark plugs or engine cylinders instead of a separate circuit for each plug or cylinder;

Figs. 8 and 9 are fragmentary views of the form

of the invention shown in Fig. 7 but showing modified arrangements.

Referring more particularly to the drawings wherein similar reference characters designate corresponding parts throughout, the form of the invention shown in Fig. 2, includes, in addition to the elements contained in the prior construction shown in Fig. 1, some of which has been previously described, the condenser C2 which is connected in series between the normally grounded end of the Tesla coil secondary L2 and ground G; and the resistor R1 which provides a path through which the condenser C1 receives its charge from the common power source simultaneously with condenser C.

As will be seen from Fig. 1, in prior type conventional oscillatory ignition circuits or systems, the only energy delivered to the ignition spark gap or spark plug is a portion of the energy originally stored in condenser C1, translated in frequency by the primary circuit, transformed in voltage by the Tesla coil and conducted to the firing electrodes. In such a circuit or system a considerable portion of the original stored energy is lost in this process due to various losses inherent to the circuit. An approximation of the energy actually reaching the ignition gap may be made by applying the basic energy equation previously stated,

$$E = \frac{CV^2}{2}$$

to both the primary and secondary circuits.

If we assume, for example, that the primary storage condenser C1 has a capacitance of .006 microfarad (mfd.) charged to a peak voltage of 2 kv. giving an energy value of .012 joule or 12 millijoules, and that in the secondary circuit the crest voltage may reach a value of 16 kilovolts across a total capacitance of 25 micromicrofarads, which equals .0032 joule or 3.2 millijoules (mij.), the indicated conversion efficiency based on the ratio of 3.2 to 12 is 26.7 per cent. In the case of a primary break-down value of 2.2 kilovolts, the energy stored would be approximately 15 millijoules, giving a translation efficiency of 21.5 per cent.

It is apparent that any attempt to materially raise the spark energy at the ignition spark gap by increasing the stored energy in the primary circuit would place upon the magneto or battery coil a burden likely to be beyond its capabilities, for example, to double the secondary spark energy from 3.2 mj. to 6.4 mj. would require a primary circuit energy of from 25 to 30 mj. and most conventional ignition coils would not be expected to operate under such a condition; and further, even if such secondary spark energy were raised from 3.2 mj. to 6.4 mj., it would not be sufficient for starting purposes when extreme conditions of cold weather, oil fouling or frost fouling of spark plugs were encountered, and it is possible that even 15 to 20 mj. of energy would be required at the ignition gap under such conditions. This is entirely out of the question with prior systems of this type.

The system or circuit of the present invention is capable of making an energy of 15 to 20 mj. available at the igniting gap, for starting purposes, without exceeding the energy potentiality of standard conventional ignition coils, and in addition can be constructed to provide switching means for reducing the energy at the igniting gap, after the engine starting has been successfully accomplished, for the purpose of

minimizing spark plug electrode erosion. This switching or controlling means may be arranged to completely eliminate the energy boost employed for starting purposes and cause the system to revert to a straight or normal high frequency system operating at a predetermined ignition gap energy of from 2 to 5 mj., or it may be arranged to permit operational adjustment of ignition gap energy at any desirable intermediate level between the 20 mj. maximum boost level and the zero boost or straight high frequency system level of from 2 to 5 mj.

In the circuits or systems of both Fig. 1 and Fig. 2, there is shown for the purpose of explaining the invention only a system for a single spark plug, and it is of course obvious that to adapt the circuit or system to any desired number of spark plugs or engine cylinders that it would only be necessary to provide each spark plug or engine cylinder with all of the high frequency conversion components except the energy source and distributor.

As previously stated, the system of the present invention, as shown in Fig. 2, has in addition to the elements of the prior type as shown in Fig. 1, a boost or auxiliary storage condenser C2, in a series connection between one end L2 of the Tesla coil secondary S and ground; and the resistor R1, which may optionally be a radio frequency choke, which serves to provide a path through which the boost condenser C2 may be charged in parallel with the high frequency storage or primary condenser C1.

It will be noted that both condensers C1 and C2 will be charged in parallel and approximately simultaneously by the voltage or energy pulse originating in the secondary winding of the energy source.

The impedance R1 which may be a resistor or a reactance coil is required to effectively isolate the primary and secondary circuits in a radio frequency sense during the discharge which follows the completion of the charging of the two condensers and the resulting breakdown of the primary circuit spark gap G1.

To better explain the invention, the following example is given for which purpose the following values have been assumed: energy source, 25 mj. per pulse at 2100 v. peak; converter condenser C1, .004 mfd.; boost condenser C2, .006 mfd.; isolating resistor R1 2000 ohms; converter gap G1, breakdown at 2000 v. peak; ignition gap G2, breakdown at 4000 v. peak minimum.

With the switch S1 closed, as shown in Fig. 2, the condensers C1 and C2 will receive simultaneous charges from the rising voltage due to the pulse of energy originating in the magneto or battery coil secondary. Condenser C1 will lag slightly behind condenser C2, due to a slight phase shift introduced by resistor R1 connected in the circuit between condenser C1 and the voltage source. For an energizing pulse wavefront having an 800 cycles per second characteristic, the instantaneous voltage across condenser C1 will be approximately 96 per cent of that across condenser C2 at any instant during the charging portion of the operating sequence. It follows that the voltage across condenser C1 appearing across gap G1 will reach the 2000 v. breakdown value of gap G1 during the charging voltage wave. At that instant the charge stored in condenser C2, unable to discharge through the transformer and ignition gap G2 due to the gap's wide spacing and high break-down value, will have reached a

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voltage equal to 104 per cent of that across condenser C1 or 2080 v. The energy values in storage at this instant will be .008 joule in condenser C1 and .012 joule in condenser C2, making a total of .020 joule.

The breakdown of gap G1 now follows with the resulting rapid conversion of the stored energy from condenser C1 into high frequency oscillatory energy, with the oscillation involving condenser C1, the gap G1 and inductance P. A portion of this oscillatory energy is transferred by inductive coupling from the Tesla coil primary to the secondary circuit, where it appears in a high voltage form across the ignition gap G2.

The discharge across ignition gap G2 is up to this point, a normal high frequency discharge and if no charge resided in condenser C2, the high frequency discharge across gap G2 would continue in a normal manner to extinction. However, the charge stored in condenser C2 now finds a discharge path open to it, through the closed circuit which includes the transformer secondary S, the ionized ignition gap G2 and return through ground. The resulting surge of current or oscillatory discharge due to condenser C2 and the secondary coil S, occurs at a much lower frequency than that of the condenser C1 and primary P circuit, and two beneficial results accrue from this fact. One is an intensification and prolongation of the ionized or arc discharge across ignition gap G2, that is, the discharge initiated by the condenser C1 and primary P circuit is continued and prolonged by the condenser C2 discharging through the secondary S; the other is that the primary circuit which includes condenser C1 and primary P is anti-resonant at the much lower oscillating frequency of the circuit which includes condenser C2 and secondary S, and thus only a negligible part of the condenser C2 energy is drained off into the condenser C1 and primary P circuit by inductive coupling. This permits practically all of the condenser C2 energy to be expended or dissipated in the form of useful heat at the discharge arc of ignition gap G2.

The second or boost condenser C2 of the present invention provides two principal operational advantages over the conventional high frequency system. One is a material increase in crest current value with a corresponding increase in arc intensity at ignition gap G2 and the other is the prolongation of the arc discharge at ignition gap G2 for some considerable period of time after the oscillation of the initiating circuit (gap G1 and primary P) has decayed to a substantially zero amplitude.

It will be seen that in the above described circuit or system that the relative amounts of energy given up at ignition gap G2 as useful heat by the two discharge circuits will vary greatly. Assigning a conversion efficiency of 25 per cent to the converter circuit consisting of condenser C1, primary P, and gap G1, an energy value of .002 joule would dissipate at gap G2 with a loss of .006 joule out of the original .008 joule stored in condenser C1. Assuming 80 per cent efficiency for the secondary boost circuit, an additional .0096 joule of energy would be dissipated at gap G2 as long as switch S1 is closed and the boost circuit operative. It is thus apparent that for starting purposes, or other engine applications where high ignition spark heat value is required, the addition of .0096 joule of energy to the .002 joule due to the normal high frequency circuit

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results in a total gap energy dissipation of .0116 joule.

When switch S1 is opened, the boost circuit is rendered inoperative and the system reverts to normal high frequency operation, without appreciable assistance or hindrance from the condenser C2, with an ignition gap G2 energy level of .002 joule.

It is pointed out that the energy stored in condenser C2 is held retained in storage and cannot in itself initiate a discharge at gap G2 until a discharge path is presented to it by the discharge of the C1, P and G1 circuit. The two discharges are overlapping and merge into the other without detectable or measurable separation.

It has been found that the operation of the boost circuit does not substantially detract from the excellent anti-fouling characteristics of the high frequency system with which it is associated.

From Fig. 3 it will be seen that the existence of a serious carbon or moisture fouling shunt R2 across ignition gap G2 would tend to discharge condenser C2 or prevent its acquisition of a full charge during the charging period by acting as a resistance shunt in parallel across both condenser C2 and the energy source. This has been found not to be a serious drawback unless the fouling shunt R2 approximates a value of 15,000 ohms or less and in such cases the addition of a series protective gap G3 in series with the Tesla coil secondary S, as shown in Fig. 4, may provide a partial solution.

The switch S1, Fig. 2, may be arranged to provide manual or automatic cut-off of the boost circuit after the engine start has been successfully accomplished. This switch S1 could be in the form of a bi-metal or other type of thermal switch arranged in appropriate thermal relationship to some part of the engine such as the exhaust manifold cylinder head or cooling fluid. The warming up of the engine would then cause the switch S1 to be broken and thereby disconnect the boost circuit for such time as the engine may remain at an elevated temperature.

This disconnection of the boost circuit serves to minimize or eliminate unnecessary erosion of the spark plug electrodes during warm running periods of engine operation. The straight or normal high frequency system is usually capable of effective continued running of an engine after the cold run-in period is past.

An exception to the above might be an engine running on low grade fuel in which case the thermal switch might be of the double acting snap type as indicated in Fig. 5 and in this case the system would operate on high boost for starting and drop by manual or automatic switch operation to reduced boost for continued operation or running.

In Fig. 6 a modified form of the arrangement of Fig. 5 is shown wherein the boost energy is smoothly and continuously variable through the range of maximum boost to substantially zero boost by manual or automatic manipulation or adjustment of the potentiometer R3.

In Figs. 7, 8 and 9 are shown arrangements whereby a single common boost circuit may be employed for any desired number of cylinders which are to be operated by the same ignition system.

In the form shown in Fig. 7 a tertiary winding as specified would make the use of such a common boost circuit possible. In this case the secondary return leads S2 of the secondaries S of the several Tesla type transformers are made

common and returned to ground through a common boost condenser C2. In this case the common condenser C2 is charged and discharged in a rapid manner and is used successively in conjunction with the various high frequency converters as selected by the distributor.

The same result might be obtained with further economy in construction by utilizing the structures of Figs. 8 and 9.

In Fig. 8, the common boost condenser C3 is fed from an intermediate tap in the secondary coil S of the energizing source.

In Fig. 9 the charging energy for the condenser C3 is obtained from the primary circuit of the ignition system. It will be noted that in Fig. 9 the condenser C3 is connected directly in parallel with the primary breaker condenser C4 and might therefore be dispensed with entirely.

From the foregoing it will be seen that I have provided simple, efficient and economical means for obtaining all of the objects and advantages of the invention.

Having described my invention, I claim:

1. In a high frequency ignition system comprising a capacitance, high frequency transformer and spark gap adapted to furnish energy to a spark plug, an auxiliary energy booster circuit adapted to supply additional energy to the discharge of the high frequency circuit, said booster circuit comprising a condenser and impedance and switch means for connecting and disconnecting said booster circuit to said high frequency circuit.

2. In a high frequency ignition system comprising a capacitance, high frequency transformer and spark gap adapted to furnish energy to a spark plug, an auxiliary energy booster circuit adapted to supply additional energy to the discharge of the high frequency circuit, said booster circuit comprising a condenser and impedance and switch means for automatically connecting and disconnecting said booster circuit to said high frequency circuit.

3. In a high frequency ignition system comprising a capacitance, high frequency transformer and spark gap adapted to furnish energy to a spark plug, an auxiliary energy booster circuit adapted to supply additional energy to the discharge of the high frequency circuit, said booster circuit comprising a condenser and impedance and a thermal switch for connecting and disconnecting said booster circuit to said high frequency circuit.

4. In a high frequency ignition system comprising a capacitance, high frequency transformer and spark gap adapted to furnish energy to a spark plug, an auxiliary energy booster adapted to increase the energy supplied the spark plug, said booster circuit comprising a condenser serially connected with the secondary of the high frequency ignition system and automatically operated switch means for connecting said booster circuit to said high frequency circuit whereby said booster circuit will supply additional energy to the discharge of the high frequency circuit.

5. In combination with a high frequency igni-

tion system comprising a capacitance, high frequency transformer and spark gap adapted to furnish energy to a spark plug, an energy booster circuit including a condenser and an impedance, said booster circuit being adapted to supply additional energy to the discharge of the high frequency circuit and a series spark gap for isolating the high frequency and booster circuits from the spark plug during charging of said condenser to prevent the diversion of energy from said condenser during the charging thereof.

6. In combination with a high frequency ignition system comprising a capacitance, high frequency transformer and spark gap adapted to furnish energy to a spark plug, an energy booster circuit comprising a condenser and an impedance, said booster circuit being adapted to supply additional energy to the discharge of the high frequency circuit and means for automatically disconnecting the condenser of the booster circuit from the spark plug during the charging of said condenser to prevent the diversion of energy from said condenser during the charging thereof.

7. In combination with a high frequency ignition system comprising a capacitance, high frequency transformer and spark gap adapted to furnish energy to a spark plug, an energy booster circuit comprising a condenser and an impedance, said booster circuit being adapted to supply additional energy to the discharge of the high frequency circuit and means for automatically disconnecting the condenser of the booster circuit from the spark plug during the charging of said condenser and for automatically connecting said condenser to said spark plug when said condenser has become charged to prevent the diversion of energy from said condenser during the charging thereof.

8. In combination with a high frequency ignition system comprising a capacitance, high frequency transformer and spark gap adapted to furnish energy to a spark plug, an energy booster circuit comprising a condenser and an impedance, said booster circuit being adapted to supply additional energy to the discharge of the high frequency circuit and a spark gap for disconnecting the condenser of the booster circuit from the spark plug during the charging of the condenser to prevent the diversion of energy from said condenser during the charging thereof.

GREGOR L. LANG.

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Disclaimer

2,497,307.—*Gregor L. Lang*, Longmeadow, Mass. IGNITION SYSTEM. Patent dated Feb. 14, 1950. Disclaimer filed July 18, 1951, by the inventor, the assignee, *American Bosch Corporation*, consenting.
Hereby enters this disclaimer to claim 1 of said patent.
[*Official Gazette August 14, 1951.*]