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An investigation of an electronic ignition system for internal combustion engines

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AN INVESTIGATION OF AN ELECTRONIC IGNITION SYSTEM FOR INTERNAL COMBUSTION ENGINES

BY

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THESIS

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INTRODUCTION

Early in the development of the internal combustion engine, engineers were faced with the problem of igniting a combustible mixture of fuel in an engine cylinder at a specified time with respect to piston position. The use of an electric spark to accomplish ignition was suggested, and it was soon recognized that more accurate timing was possible with electric spark ignition than with other systems that had been tried.

Many types of electric ignition systems have been developed, used, and discarded in favor of systems less expensive and more adaptable to internal combustion engines. Two types which might be classified as high-tension, jump-spark systems are in common use today. These two systems are (1) Battery-coil ignition used mainly on automobiles, and (2) Magneto-ignition used extensively on aircraft engines.

A considerable amount of work has been done to determine the extent to which the character and intensity of the electric spark affect the ignition process. This work has revealed that a certain minimum amount of energy is required from the spark before combustion will occur. Any excess energy over and above that required for combustion appears to have no effect on engine performance.[1] It has also been found that there are many factors which

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(1) Peters, M. F., Summerville, W. L., and Davis, M. An Investigation of the Effectiveness of Ignition Sparks, NACA Tech. Rept. p. 359, 1930.

influence the voltage necessary at the spark plug to produce the required spark for combustion. Included in these factors are spark plug electrode temperature, engine speed, engine compression ratio, intake manifold pressure, fuel-air ratio, and amount and nature of lead-compound deposits on the electrodes.[2]

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(2) Fraas, Arthur P. Combustion Engines. N. Y., McGraw-Hill, 1948, p. 197.

The function of the ignition system, therefore, is to provide a spark in the cylinder with sufficient energy to produce combustion under the maximum adverse conditions.

The Post World War II automobile engine development trend has been toward higher compression ratios for increased power output and leaner fuel-air mixtures for economy. These changes affect the ignition system in that they necessitate higher voltages at the spark plug to produce ignition. If this development trend continues the automotive ignition system as used today will be inadequate and a new system will be necessary.[3]

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(3) Hartzell, H. L. Effect of Post-War Automotive Practices on Ignition Performance, SAE Transactions, Vol. 53, No. 7, pp. 427-431, July, 1945.

The author reasoned that a new ignition system utilizing electronics might solve some of the problems encountered. Therefore, the purpose of this paper is to present an electronic circuit which appears to be adaptable to internal combustion engine ignition together with a discussion of some of the difficulties in making this circuit practical.

REVIEW OF LITERATURE

In 1924 when the automotive industry was struggling with the ignition problem, Robert Bosch, a German Magneto manufacturer, obtained patents on two ignition systems using three element vacuum tubes or triodes as they are known today.[4] These two developments

(4) Bosch, Robert. Vacuum Tubes Applied to Engine Ignition, Automotive Industries, Vol. 50, No. 24, pp. 1287-1289, June 12, 1924.

are similar in that they both employ a high frequency oscillator to provide the energy to cause ignition; they differ in that one requires a mechanical distributor whereas the other employs vacuum tubes to distribute high frequency energy to the various spark plugs.

No doubt the system as patented by Bosch or some adaptation might have been used. However, soon after Bosch obtained his patents, the development of the mechanical distributor made the battery-coil ignition system simple and inexpensive, thereby solving the problem of ignition in automotive engines for a period of approximately twenty years.

In the period from 1926 to 1946 much work was done to improve battery-coil ignition.[5] This was made possible largely through the

(5) Hartzell, H. L. Ignition Progress, Publication of Delco-Remy Division of General Motors Corporation, DR-5091, pp. 10-26, May 4, 1948.

discovery of new insulating materials and the development of new manufacturing processes. Little was done during this period to develop new ignition systems.

Recently, much research has been initiated with the object of applying electronics to the solution of the ignition problem. P. R. Mallory & Company of Indianapolis, Indiana, have developed a high frequency ignition system which is undergoing flight tests on U. S. Army aircraft.[6] A frequency of two to three megacycles is employed.

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(6) High Frequency Aviation Ignition System. Electronics Industries, Vol. 4, No. 6, p. 106, June, 1945.

A patent for a high frequency ignition system has been obtained by W. W. Eitel of Eitel-McCullough Incorporated.[7] Eitel's system

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(7) New Patents Issued. Electronics Industries, Vol. 5, p. 78, December, 1946.

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is unique in that he uses a quarter wave-length transmission line in the cylinder to replace the spark plug.

An experimental system, utilizing the charge on a condenser was developed during the latter part of World War II by the German Bosch Corporation of Reichenbach, Germany.[8] A condenser is dis -

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(8) Poole, Alfred J. Electronic Ignition System in Experimental Stage. Automotive and Aviation Industries, Vol. 96, No. 3, pp. 37 and 90, February 1, 1947.

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charged through the primary of an ignition coil by a thyratron thereby inducing a high voltage in the secondary of the coil.

Delco-Remy Division of General Motors Corporation have indicated that they are conducting serious research on electronic systems, but they will not disclose details of their findings at the present time.[9,10]

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(9) Hartzell, H. L. Ignition Progress, Publication of Delco-Remy Division of General Motors Corporation, DR-5091, p. 9, May 4, 1948.

(10) Personal correspondence from Delco-Remy Division of General Motors Corporation.

DISCUSSION OF PRESENT AUTOMOTIVE IGNITION SYSTEM

Although the operation of the battery-coil ignition system (which hereafter will be referred to as the conventional automotive system or simply the conventional system) is familiar to most engineers, the author feels that a brief discussion of this system should precede a discussion of other systems which are intended to duplicate its function.

In the conventional system, a contact breaker assembly, consisting of a set of breaker points actuated by a cam, is driven by the engine at one-half engine speed, assuming a four-cycle engine. The breaker points interrupt the current flowing in the primary winding of an ignition coil, the secondary winding of which is connected through a distributor to the various spark plugs. Interruption of the current flowing in the primary winding causes damped high frequency voltage oscillations in the primary winding of the ignition coil. This in turn induces in the secondary winding of the ignition coil a high voltage of similar wave shape which breaks down the gap between the spark plug electrodes and provides the ignition spark in the cylinder.

An analysis of the conventional ignition system based on many years of service experience and experimental research has been made by H. L. Hartzell of Delco-Remy Division of General Motors.[11] Hart-

(11) Hartzell, H. L. Ignition Progress. Publication of Delco-Remy Division of General Motors Corporation, DR-5091, pp. 1-8, May 4, 1948.

zell explains that breaker points and the ignition coil are the bottlenecks in obtaining more output from the conventional system. Making a larger ignition coil may give even less output, and enlarging the breaker points will not allow them to carry any more current because of the detrimental effects of oxidation. Hartzell believes that the conventional system will provide adequate ignition for compression ratios up to ten to one with careful design and layout of components. However, he explains that it would be advantageous either to change to a 12 volt supply or to some electronic ignition scheme.

The requirements of new and future internal combustion engines in ignition terms may be summed up in the following quotation;[12]

(12) Personal correspondence with Mr. H. B. Birt, Service Department, Delco-Remy Division of General Motors Corporation, June 16, 1949.

> "Ignition equipment should develop 30,000-35,000 volts across a secondary capacity of 30-70 mmfd. (average value 50 mmfd.). It is desirable, if possible, to have a very steep wave front so that leaky plugs can be fired satisfactorily."

Any proposed ignition system should approach the requirements set forth in the above paragraph or at least excell the characteristics of the present system before it could be considered as a possible replacement.

With these requirements in mind, an electronic circuit called the Inductive Kicker will be analyzed and tested experimentally in an attempt to determine whether or not its characteristics could be made to approach those desired. The characteristics of the Inductive Kicker will also be compared with the characteristics of the conventional system.

THE INDUCTIVE KICKER

Figure 1 is a circuit diagram of the conventional automotive ignition system. Figure 2 is a circuit diagram of the Inductive Kicker. The circuits are very similar in that a source of electrical energy supplies a direct current to the primary of a coil through a switch. In the case of the conventional system this switch is the breaker point set in the distributor. The switch in the Inductive Kicker is the vacuum tube. The condenser which is connected across the breaker points in the conventional system does not appear as an actual circuit component in the Inductive Kicker circuit but is present in the form of the distributed capacitance of the coil as shown by the dotted lines in Figure 2.

The operation of the Inductive Kicker circuit is as follows. The vacuum tube is biased below cutoff by the Battery, E. When a positive pulse of sufficient magnitude arrives at the grid terminals, a-b, the grid potential rises permitting tube plate current flow. This current flows through the primary winding of the transformer, T, for the duration of the pulse. At the end of the pulse time, the grid potential again falls below cutoff. When the tube ceases to conduct, the decay of current flowing in the primary winding permits the energy present in the magnetic field to be dissipated in the self-resonant circuit of the transformer as damped high voltage oscillations. This voltage that appears across the transformer is a complex function of the transformer constants and the value of current flowing through the primary winding. The voltage induced in the secondary winding may be used to fire a spark plug.

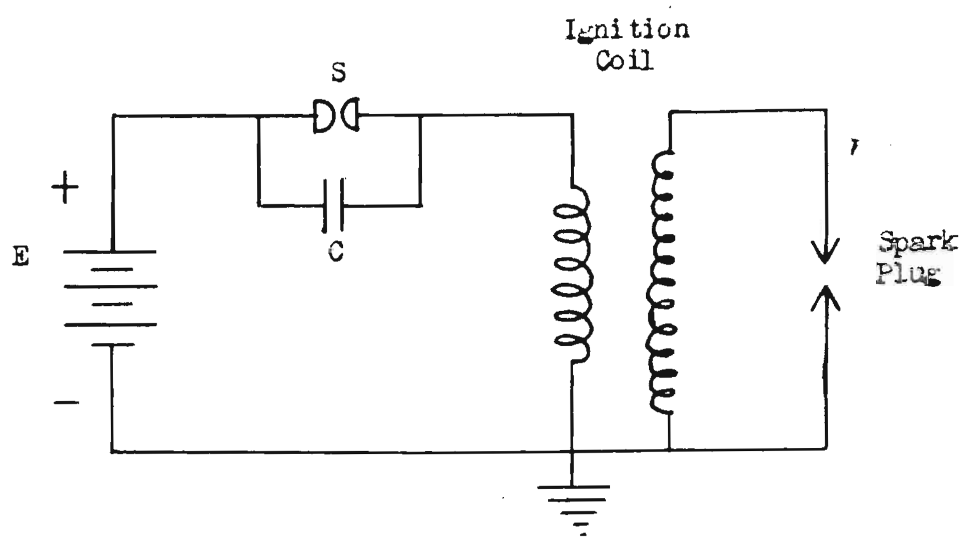


Fig. 1

Conventional Ignition System

E- Storage Battery. S- Breaker Points C- Condenser

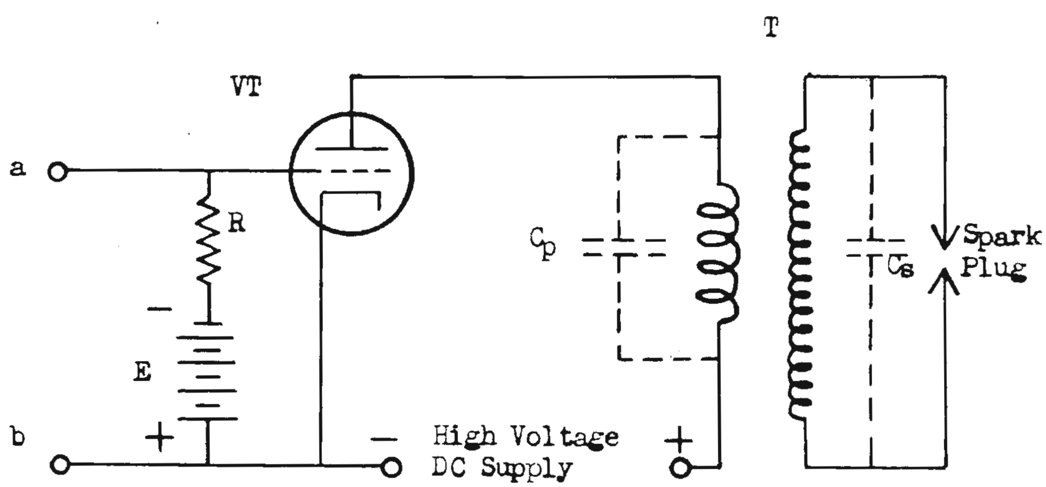


Fig. 2

Inductive Kicker

R - Grid Leak Resistor

E - Bias Voltage

C_p- Primary Distributed Capacitance

VT- Triode Vacuum Tube

C_s- Secondary Distributed Capacitance

T - Transformer

DISCUSSION OF EXPERIMENT

Part I Inductive Kicker

An Inductive Kicker circuit was constructed using an 807 vacuum tube which has a maximum plate current rating of 120 milliamperes and a maximum plate voltage rating of 750 volts. The circuit diagram used for actual construction is shown in Figure 3. High voltage direct current was obtained from a regulated electronic power supply rated at 200 - 300 volts, 200 milliamperes. Heater voltage of 6.3 volts A-C was also obtained from this power supply. A second direct current power supply was available for voltages up to 1000 volts D-C. A Willard 6 volt storage battery was used for the grid bias voltage, E_1, and the 110 volt D-C laboratory supply provided the grid bias voltage E_2. The potentiometer, P, was inserted so that the voltage, E_2, might be varied from 0 to 110 volts. The breaker points in a 623G Delco-Remy distributor were used as the switch, S. The distributor was driven with a 1/4 horsepower D-C shunt motor connected so that its speed could be varied from 0 to 2300 RPM.

Three transformers were available having high turns ratios and high voltage insulation. One of these was a standard Autolite IG 3224JS six volt ignition coil. The other two were high voltage power transformers formerly used in radar equipment. Primary and secondary inductance of each transformer was measured on a General Radio Type 650-A Impedance Bridge. Distributed capacitances of all windings were determined from their self resonant frequencies which

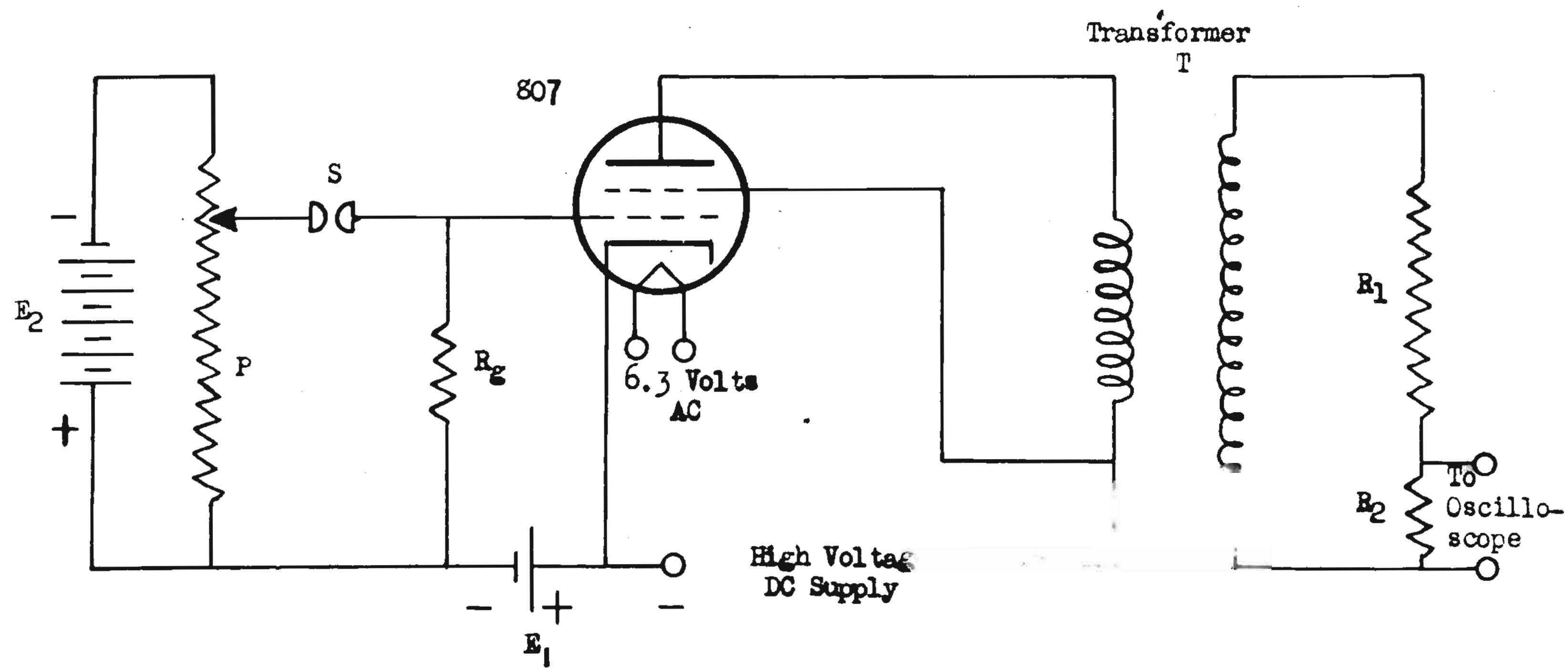


Fig. 3

Inductive Kicker Circuit as Used in Experiment

P - Potentiometer

R_g - 22,000 ohms

R_1 - 36 Megohms

R_2 - Carbon Resistor 4 Megohms

E_1 - 6 Volt Willard Storage Battery

E_2 - 110 Volt DC Laboratory Supply

S - Breaker Points in 623G Delco-Remy Distributor were measured with a General Radio Type 700-A Beat-Frequency Oscillator and a Freed Instrument Company Type 1040 Vacuum Tube Voltmeter. Results of these measurements and voltage ratings are tabulated in Table 1.

In order to measure the peak values of output voltage for the Inductive Kicker and the conventional system, a voltage divider consisting of resistors R_1 and R_2 was connected across the secondary winding of the transformer, T, as shown in Figure 3. The total resistance of the voltage divider, $R_1 + R_2$, was made very large in order that no appreciable load would be presented to the secondary winding of the transformer. A resistance of 36 megohms was chosen for R_1 and a resistance of 4 megohms for R_2. This provided a total resistance of 40 megohms and a ratio of voltage appearing across the secondary winding of the transformer to that appearing across R_2 of 10/1. The input terminals of a Dumont Model 224-A Cathode Ray Oscilloscope were connected across the resistor R_2, and the oscilloscope was calibrated to 10 volts peak per division. The peak values of voltage observed on the oscilloscope were then 1/10 the total voltage output.

However, it was found that appreciable error resulted because of the input impedance of the oscilloscope. The oscilloscope used had an input resistance of 2 megohms and an input capacitance of 30 micromicrofarads. This in effect placed a 2 megohm resistor and a 30 micromicrofarad capacitor in parallel with the resistor R_2 causing an equivalent impedance across the R_2 portion of the voltage divider much smaller than the value of R_2 alone. Since the reactance of the input capacitance of the oscilloscope varies inversely with frequency, it was necessary to compute the equivalent impedance of the R_2 portion of the voltage divider for the various frequencies encountered. The ratio of the equivalent impedance of the R_2 portion to the total impedance of the voltage divider then provided a ratio of the voltage measured on the oscilloscope to the voltage actually appearing across the secondary of the transformer.

Run I

Transformer No. 2 (see Table 1) was connected into the circuit and waveforms of primary and secondary voltages were observed on the cathode-ray oscilloscope. A photograph of the secondary voltage wave is shown in Figure 4.

Output voltages of transformers No. 2 and No. 3 were measured by the method described above for various values of plate supply voltage between 200 and 1000 volts D-C. The effect of plate supply voltage on output voltage for these two transformers is shown in Figure 5.

Frequency of the output voltage oscillation was measured by comparing the frequency of the observed waveform on the oscilloscope with the output frequency of a Hewlitt-Packard Model 200-C Audio Oscillator. The frequency measured is given in Table 2.

Run II

Transformers No. 1 and No. 3 were connected in the circuit and waveform, peak voltages, and frequency data were taken for each with a plate supply voltage of 330 volts. The waveforms of output voltage were very similar to those obtained for transformer No. 2. Peak voltage and frequency data for transformers No. 1 and No. 3 are given in Table 2, along with similar data obtained in Run I for transformer No. 2.

TABLE 1

TRANSFORMER CONSTANTS

Transformer	Primary	Secondary	Turns Ratio	Description
No. 1	L_p= 6.5 mh. C_p= 0.22 mfds. R_p= 1.2 ohms f_r= 4200 cps.	L_s= 27 Henries C_s= 53 mmfds. R_s= 3500 ohms f_r= 4200 cps.	1/65	IG3224JS Autolite Ignition Coil.
No. 2	L_p= 0.4 Henries C_p= 0.08 mfds. R_p= 6.6 ohms f_r= 900 cps.	L_s= 95 Henries C_s= 104 mmfds. R_s= 2500 ohms f_r= 1600 cps.	1/15	Power transformer 115/1735 volts 60 cps.
No. 3	L_p= 1 Henry C_p= 0.0516mfds. R_p= 5 ohms f_r= 700 cps.	L_s= 400 Henries C_s= 0.36 mmfd. R_s= 9000 ohms f_r= 42,000 cps.	1/20	Power transformer 115/2300 volts 60 cps.

L_p is primary winding inductance

L_s is secondary winding inductance

C_p is primary winding distributed capacitance

C_s is secondary winding distributed capacitance

R_p is primary winding resistance

R_s is secondary winding resistance

f_r is self-resonant frequency of winding

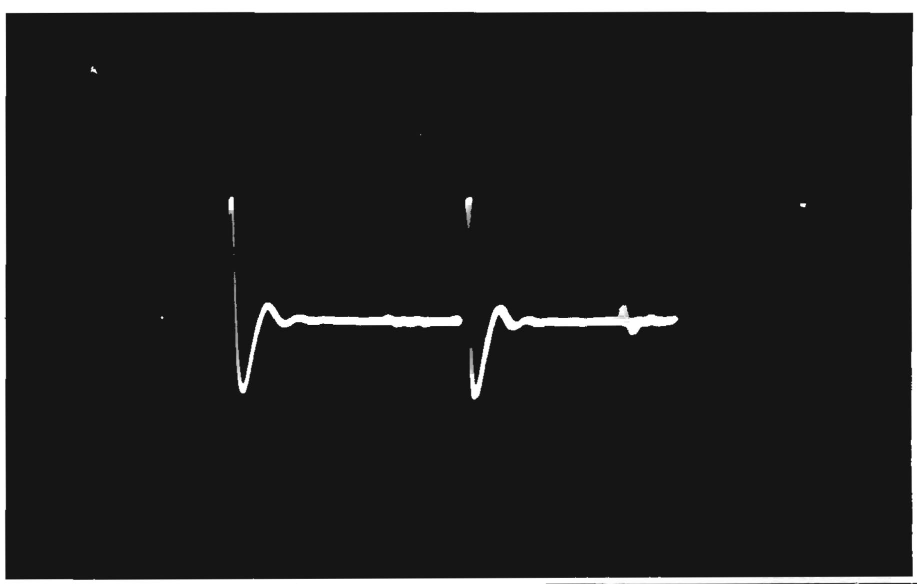


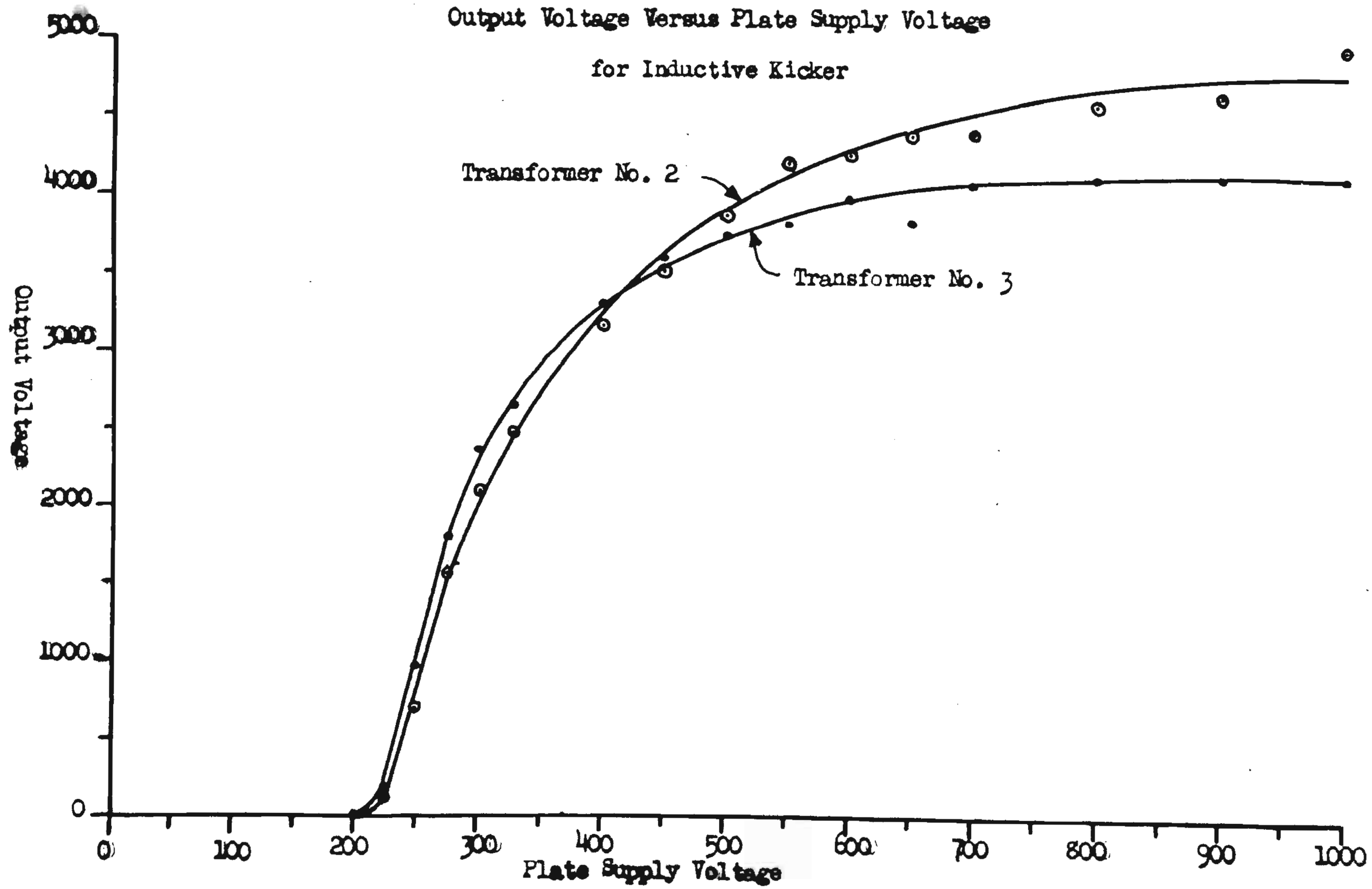
Fig. 4.

Output voltage waveform of Inductive Kicker.

Fig. 5

Output Voltage Versus Plate Supply Voltage

for Inductive Kicker



Run III

In an effort to determine the effect of primary winding inductance on voltage developed across this inductance, first the primary and then the secondary winding of each transformer was connected into the plate circuit of the 807 tube. Peak voltage values and frequency were measured for each of these inductances. Data from this run is tabulated in Table 3.

Part II

Conventional Ignition System

A conventional ignition system was constructed using the following equipment:

623G Delco-Remy Distributor

IG3224JS Autolite Ignition Coil

Willard 6 volt Storage Battery

Using the methods described in Part I, peak voltages and frequency of oscillation were measured for both primary and secondary windings of the ignition coil. These results are given in Table 4.

A photograph was taken of the output voltage of the ignition coil with its secondary winding open circuited. This photograph is shown in Figure 6.

Part III

Voltage Versus Speed Characteristics of the Two Systems

One of the undesirable characteristics of the conventional ignition system is its drooping voltage versus speed characteristic.[13]

TABLE 2

PEAK VOLTAGE AND FREQUENCY OF OUTPUT VOLTAGE WAVES OF THREE TRANSFORMERS TESTED

Transformer	Frequency	Peak Output Voltage
No. 1	3000 cps.	768
No. 2	870 cps.	2480
No. 3	480 cps.	2670

TABLE 3

VOLTAGES DEVELOPED ACROSS INDUCTANCES OF VARIOUS VALUES

Inductance	Peak Voltage	Frequency
6.5 mh.	105	3200 cps.
0.4 Henries	147	870 cps.
1.0 Henries	155	400 cps.
27.0 Henries	480	3400 cps.
95.0 Henries	245	1220 cps.
400.0 Henries	620	600 cps.

TABLE 4

EXPERIMENTAL DATA FOR CONVENTIONAL IGNITION SYSTEM

Battery Voltage	Measured Peak Voltage Primary	Secondary	Frequency	Engine Speed	Breaker Point Setting
5.7 Volts	676 Volts	11,600 Volts	3000 cps.	400 RPM	0.025"

(13) Hartzell, H. L. Ignition Progress, Publication of Delco-Remy Division of General Motors Corporation, pp. 7-8, May 4, 1948.

It was believed that this characteristic could be eleminated in the Inductive Kicker system by providing for the 807 vacuum tube a trigger pulse which was independent of engine speed; so the circuit of Figure 7 was proposed for this purpose.

The operation of the circuit is as follows. The grid potential of the tube VT1, a 6J5 triode, is varied by means of the switch, S, the switch being the breaker points in 623G Delco-Remy distributor. A square wave appears in the plate circuit of the tube VT1 and is differentiated by the resistance capacitance combination, $C_1 - R_3$. The wave then appears at the grid of the tube VT2, another 6J5 triode, as a pulse with an amplitude of 35 volts and a pulse width of 200 microseconds. Since this pulse is initiated only by the leading edge of the square wave, the frequency of the square wave will have no effect upon the pulse characteristic as long as the period of the square wave is greater than 400 microseconds.

This circuit was constructed in order that it could be tested experimentally. Waveforms were observed at various points and are given on the circuit diagram in Figure 7.

The width of the pulse was measured by calibrating the sweep of the oscilloscope to 200 microseconds per division using a known frequency supplied by a General Radio Type 700-A Beat-Frequency Oscillator.

The vacuum tube VT2 was inserted in order to couple the output

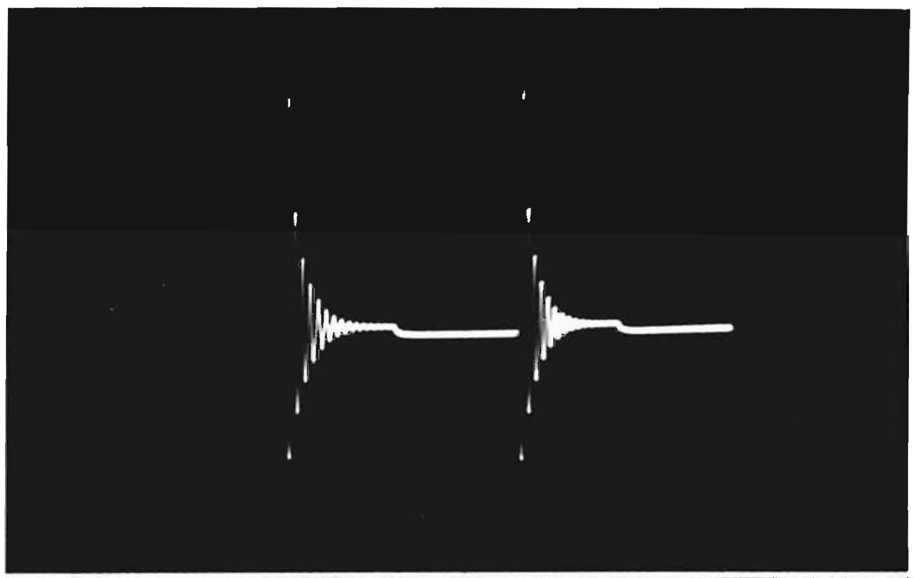


Fig. 6.

Output voltage waveform of conventional ignition system.

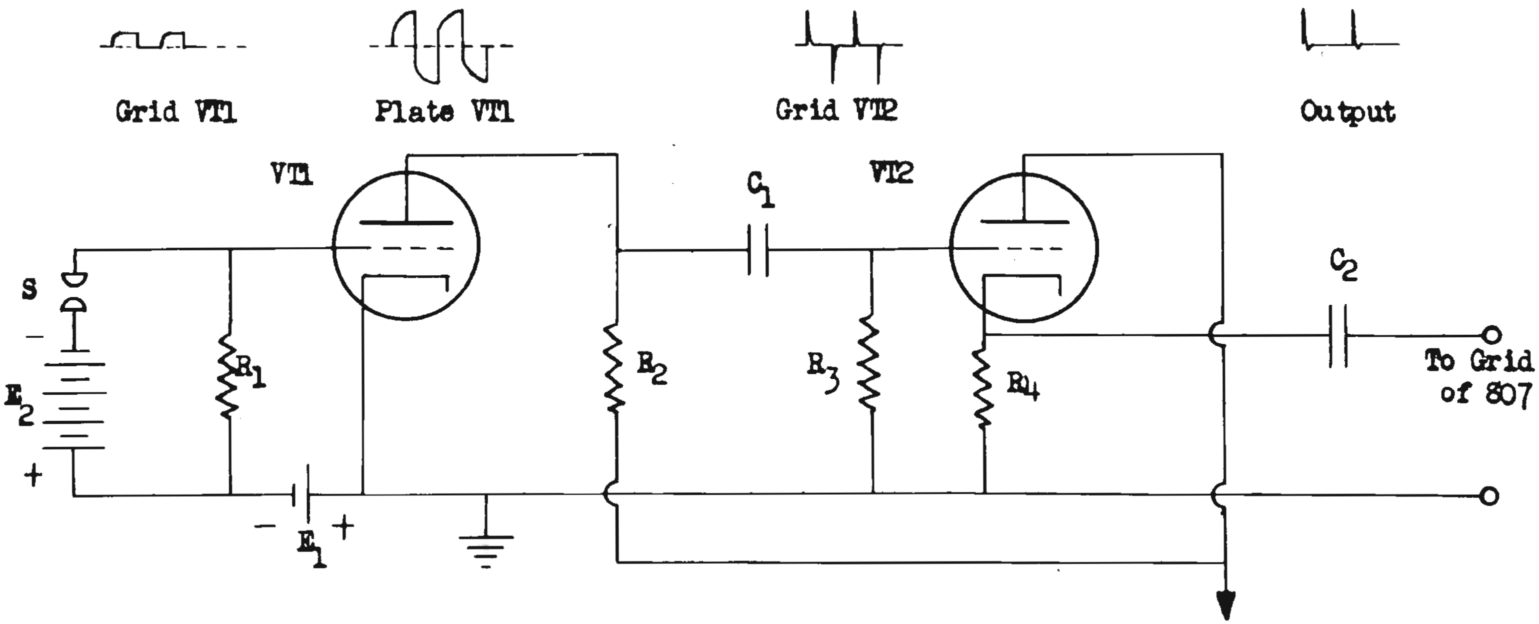


Fig. 7

Pulse Circuit

R_1 - 500,000 ohms

R_2 - 500,000 ohms

R_3 - 500,000 ohms

R_4 - 22,000 ohms

C_1 - 500 mmfds.

C_2 - 0.01 mfd.

VT1 - 6J5 Tube

VT2 - 6J5 Tube

S - Breaker Points

E_1 - Battery, 45 Volts

E_2 - Battery, 6 Volts

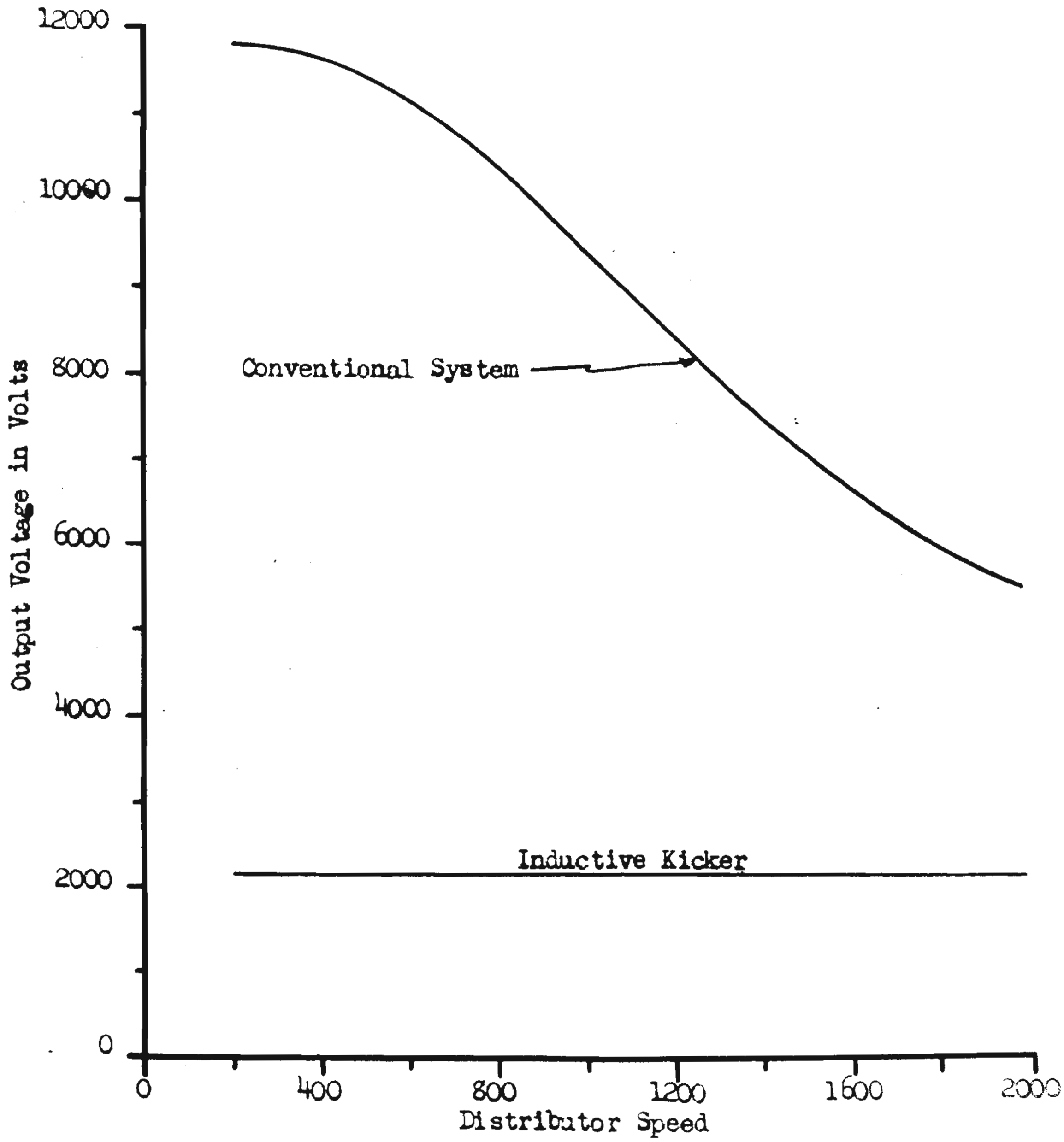
of the pulse generator, VT1, to the grid circuit of the 807 tube in the Inductive Kicker circuit. VT2 operates as a cathode-follower presenting a high impedance to the output of tube, VT1, and a low impedance to the grid of the 807 tube in the Inductive Kicker.

The output terminals of the pulse circuit as shown in Figure 7 were connected across the grid resistor R_g of the 807 tube shown in Figure 3. Switch, S, potentiometer, P, and voltage E_2 were removed from the circuit of Figure 3 for this run. Output voltage of the Inductive Kicker was measured for various distributor speeds between 200 and 2000 RPM.

Output voltage of the conventional system was also measured for various distributor speeds between the same limits as for the Inductive Kicker. The effect of speed on output voltage of the two systems is shown in Figure 8.

Fig. 8

Output Voltages of Conventional System and Inductive Kicker Versus Distributor Speed



CONCLUSIONS

The results of Run I as plotted in Figure 6 show that the output voltage of the Inductive Kicker using transformer No.2 approaches 5000 volts as a maximum. The shape of this curve indicates that this maximum is limited by saturation of the magnetic core of the transformer. Similar data taken with transformer No. 3 shows a maximum output voltage of only 4200 volts with 1000 volts applied by the plate supply. It can be seen that transformer No. 3 produces a steeper output voltage versus plate supply voltage curve than does No. 2 until saturation occurs.

Since the turns ratio of transformer No. 3 is 1 to 20, whereas the turns ratio of transformer No. 2 is 1 to 15, it appears that a higher turns ratio affects the output voltage appreciably until saturation occurs. The above observations seem to indicate that a transformer with a high turns ratio and a large magnetic core to prevent saturation would produce higher output voltages than were obtained in this experiment.

Run I was repeated with transformer No. 1 which has a turns ratio of 1 to 65. However, it was found that the impedance of the primary winding of this transformer was too low to absorb appreciable power from the plate circuit of the 807 tube.

It was hoped that the procedure of Run III would reveal a simple relationship between primary winding inductance and voltage developed. However, an analysis of the results of this run indicated that the inductances used were of such varying physical construction that no conclusions were possible.

In Part II of the experiment the peak voltage value for the conventional system was found to be 11,600 volts at an engine speed of 400 RPM with 0.025" breaker point setting and a battery voltage of 5.7 volts. The desired voltage output for new engines should be 30,000 to 35,000 volts peak as was stated previously. It is obvious that both the conventional system and the Inductive Kicker fail to meet the desired conditions. The possibility of improving the conventional system to meet the desired output conditions has been very carefully analyzed by ignition experts who have found that it is unlikely that 30,000 to 35,000 volts can be obtained from the conventional system.[14]

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(14) Hartzell, H. L. Ignition Progress, Publication of Delco-Remy Division of General Motors Corporation, pp. 1-26, May 4, 1948.

While the results of this experiment did not approach those desired, it is believed that failure to do so was attributable to the fact that the components employed in the Inductive Kicker were not designed to operate under the conditions that prevailed in this experiment. In fact it is believed to be rather remarkable that the high voltages developed were obtained in view of the deficiencies of the various circuit components. For example, had not saturation occurred at such a low value of plate voltage in Run I, it is apparent that the pre-saturation slope of the curves in Figure 6 would very rapidly have led to an output voltage equal to or greater than the conventional system limit of 11,600 volts.

Some of the conditions which must be satisfied by components of this electronic ignition circuit are as follows:

1. The vacuum tube must have a high arc-over voltage rating between plate and cathode so that higher voltages may be developed across the primary of a step-up transformer.

2. The transformer must be designed with a large magnetic core so that saturation of this core will not limit the output voltage. The transformer should have as high a turns ratio as is possible and should be constructed such that the distributed capacitances of both windings can be kept to a minimum. The self resonant frequency of the transformer should be 3000 cycles per second or higher in order to obtain a steep wave front.

From the results of Part III shown in Figure 7, it can be seen that the Inductive Kicker when equipped with the pulse forming network has the highly desirable zero-slope voltage versus speed characteristic which it has never been possible to achieve with the conventional system techniques.

SUMMARY

Some new ignition scheme for internal combustion engines may be a necessity in the near future if engine development trends continue toward higher compression ratios and leaner fuel-air ratios. The requirements of such new engines in ignition terms are a voltage of 30,000 to 35,000 volts with a very steep wave front.

The conventional ignition system now in use possesses two limiting factors; the breaker points and the ignition coil, which tend to prohibit the conventional system from approaching required conditions.

In this investigation the Inductive Kicker circuit was found to give output voltages of sufficient value to produce ignition of an engine. The voltages observed in the investigation were approximately one-half the peak voltages produced by the conventional system; however, there is not reason to conclude that higher voltages can not be obtained from the Inductive Kicker if it is constructed with components specifically designed to satisfy its requirements.

It was also found that the Inductive Kicker as an ignition circuit, would require very small current flow (2.5 ma.) through the breaker points. This would increase the life of the breaker points to that limited by mechanical design. Other types of low current switches might be employed to replace the breaker points, such as a phototube strategically located with respect to a light source and some moving part in the engine as proposed by Robert Bosch.[15]

(15) Poole, Alfred J., Electronic Ignition System in Experimental Stage, Automotive and Aviation Industries, Vol. 96, No.3, pp. 37 and 90, February 1, 1947.

The use of a pulse forming network in the timing device would make the output voltage independent of engine speed since the actual ignition circuit is controlled only by the output of the timing device, and the output of the timing device may be made independent of engine speed.

However, the disadvantages of the Inductive Kicker, as with other electronic ignition systems, are (1) a high voltage D-C power supply is necessary to supply plate voltage to the electron tubes used; (2) the equipment needed for the system would be expensive; (3) the system would be more complicated, requiring skilled servicing.

APPENDIX

Table 1

VARIATION IN OUTPUT VOLTAGE FOR VARIOUS PLATE SUPPLY VOLTAGES

Plate Supply Voltage	Peak Output Voltages Transformer No. 2	Transformer No. 3
200	7	7
225	140	200
250	700	980
275	1570	1800
300	2100	2380
330	2480	2670
400	3150	3300
450	3500	3600
500	3850	3720
550	4200	3800
600	4230	3950
650	4380	3800
700	4380	4080
800	4560	4100
900	4600	4200
1000	4900	4200

TABLE 2

OUTPUT VOLTAGE VERSUS SPEED FOR TWO SYSTEMS

Distributor Speed in RPM	Peak Output Voltage Conventional System	Peak Output Voltage Inductive Kicker
200	11,600	2170
600	11,500	2170
900	9600	2170
1200	8400	2170
1500	7200	2170
1800	5770	2170
2100	5280	2170

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