

March 27, 1956

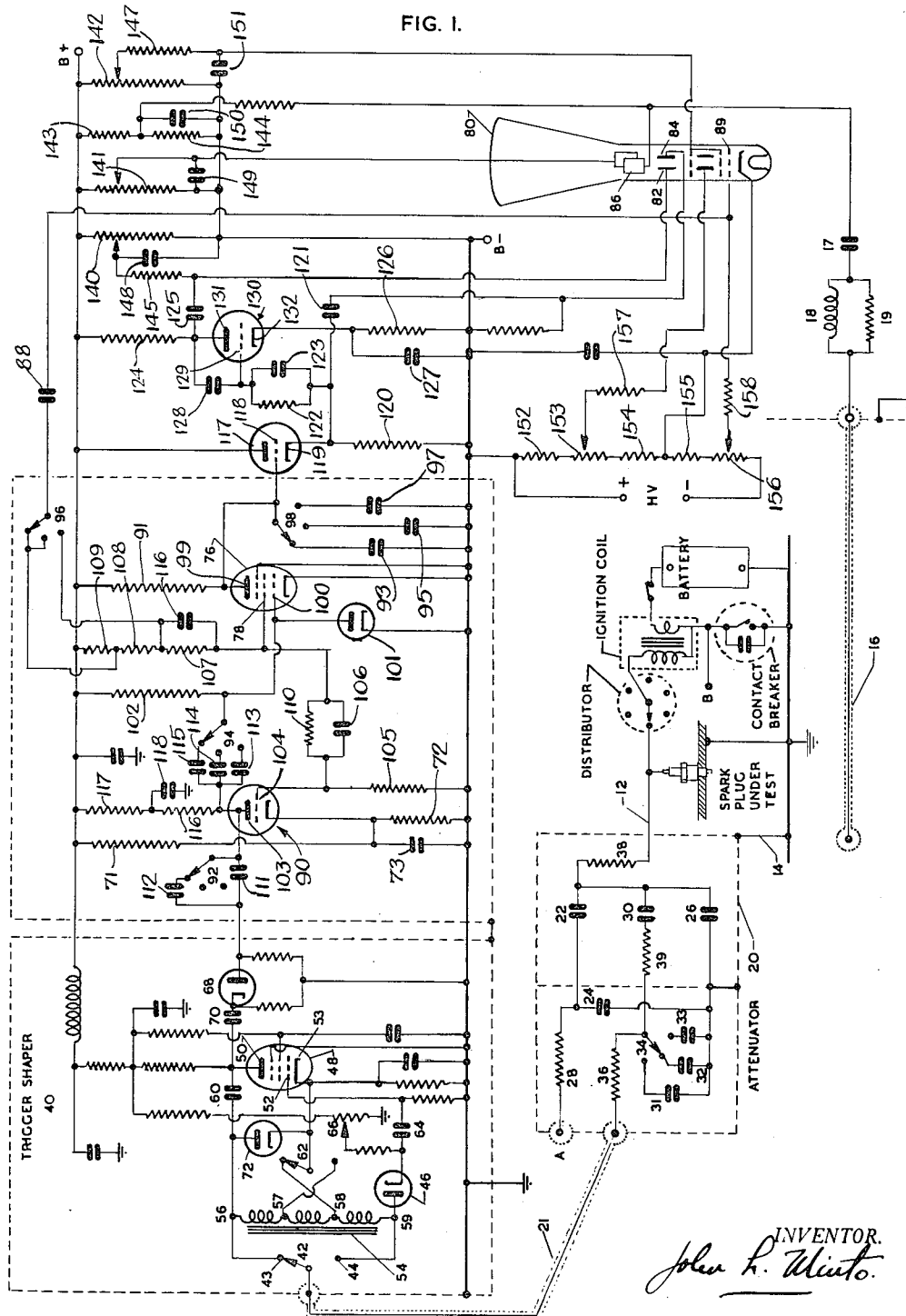
J. L. MINTO
ENGINE ANALYZER

2,740,069

Filed May 31, 1950

3 Sheets-Sheet 1

FIG. 1.



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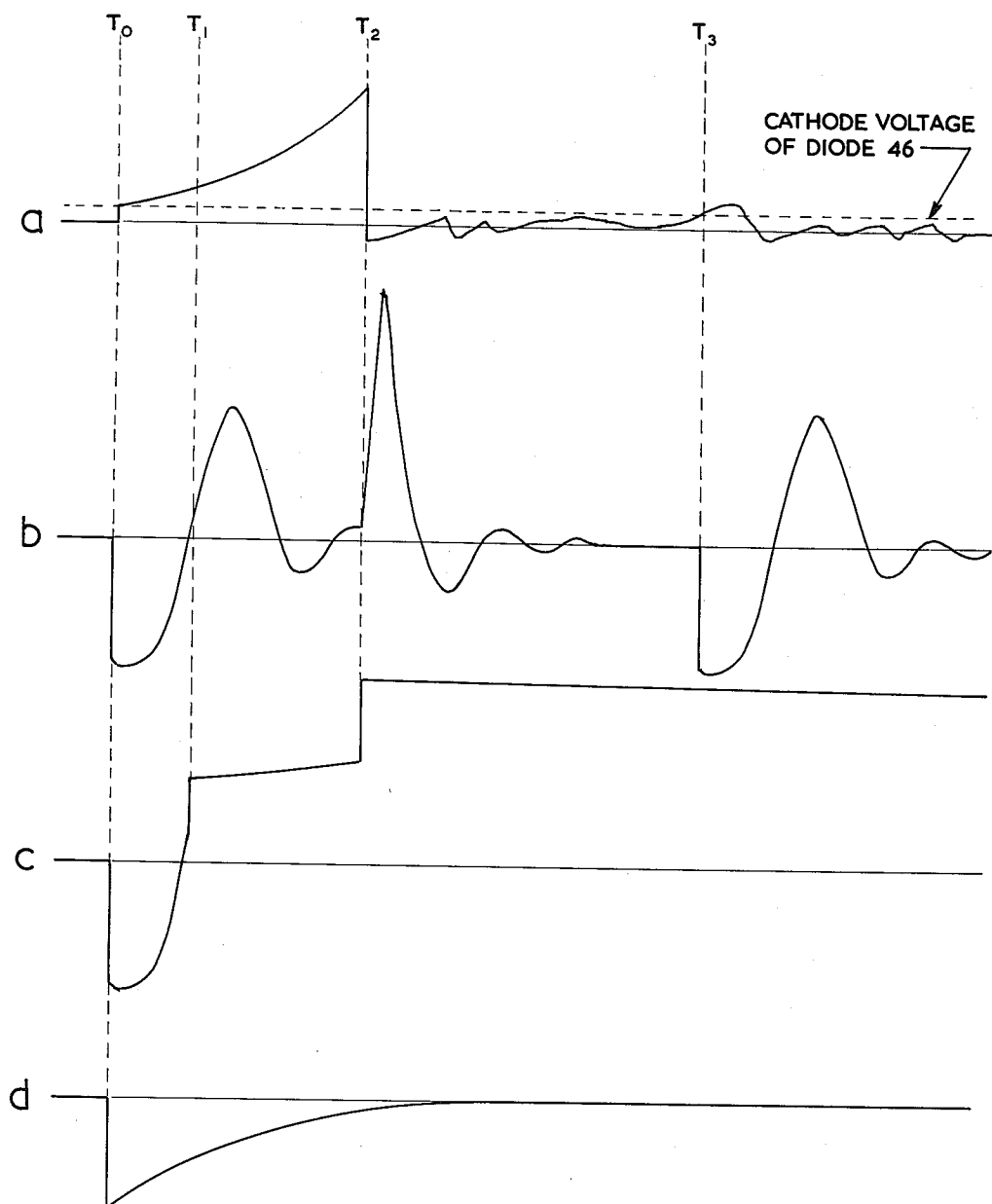
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FIG. 2



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FIG. 3

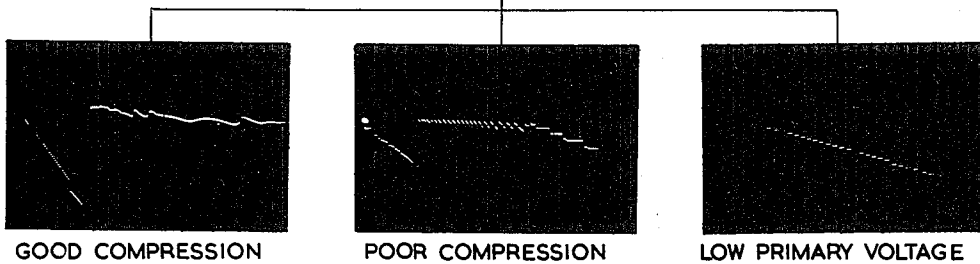


FIG. 4

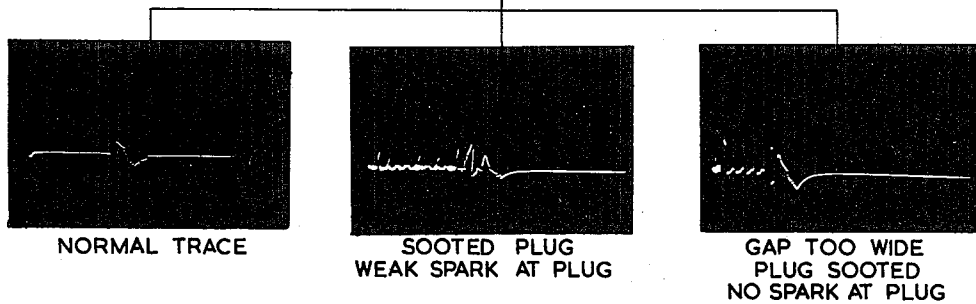


FIG. 5

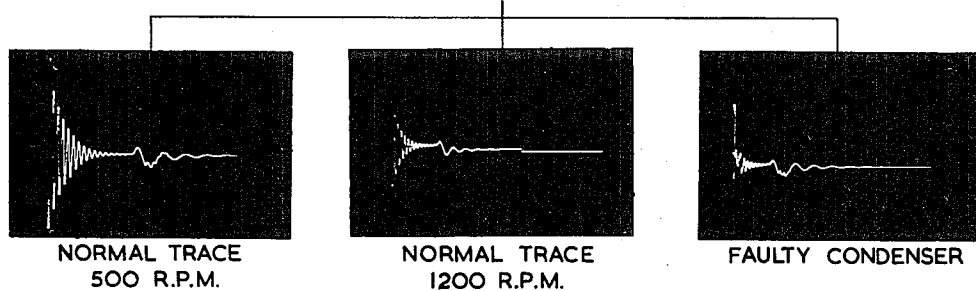
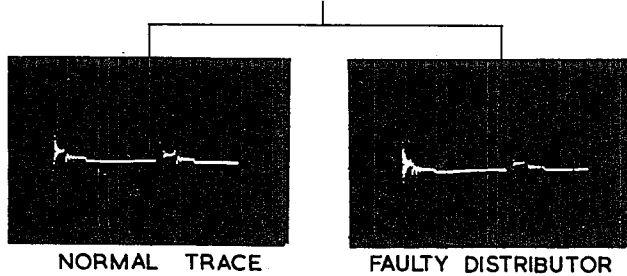


FIG. 6



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2,740,069

ENGINE ANALYZER

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Application May 31, 1950, Serial No. 165,302

9 Claims. (Cl. 315—22)

This invention relates principally to an internal combustion engine analyser of the type which produces a visual indication on a cathode ray tube of the functioning and condition of the electrical ignition system, and from such indication, through the application of known physical phenomena and laws, provides a basis for evaluating the over-all and specific performance of said engine. Though the instrument has other applications, it is especially adapted for use in connection with evaluating performance and diagnosing mal-functioning of conventional internal combustion engines. It may be readily attached to any electrically-fired internal combustion engine for simultaneously checking the performance of various components, particularly electrical, compression and mixture components, while in their normal place and during operating conditions, either in shop tests or road tests.

Heretofore in order to test such various components, of any automobile, boat or other internal combustion-engine device, it has been necessary for a mechanic first to remove them from the engine and place them in a bench-testing device which, however, does not fully simulate engine operating conditions, and, in no case checks such components while functioning in place. Moreover, such checking has not evaluated compression conditions.

By the present invention, the various electrical components of an electrically-fired internal combustion engine can be tested in actual operation, without removing them from the engine, by a simple circuit connection from my device to the ignition system to be tested, and different sorts of defects can be ascertained in the ignition system, such as defective spark plugs, coils, or condensers, as well as certain faulty compression and mixture conditions.

In general, the principle upon which the invention operates is by the application of a voltage rise in the ignition system, such as that at a spark plug prior to the occurrence of the spark, to a trigger circuit to generate a saw-tooth sweep pulse for application to the horizontal beam deflection plates of a cathode ray tube to provide a horizontal time base. At the same time, signals from the ignition system, either from the high voltage secondary or the low voltage primary of the ignition system, are applied to a vertical beam deflecting plate of the cathode ray tube so the signals, corresponding, for example to the spark plug discharges, are shown for evaluation on the screen of the cathode ray tube.

The usual type of cathode ray tube synchroscope, in which each separate input pulse produces a separate saw-tooth sweep pulse, is quite unsuitable for use as an engine analyser, since present day ignition systems do not produce merely one voltage rise for each discharge of the spark plug under examination. Many other voltage rises are present which are greater in amplitude than the voltage rise necessary to produce a saw-tooth sweep pulse for application to the horizontal plates of the cathode ray tube synchroscope. These impulses arise from two sources: (1) under certain conditions the spark at the

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plug may be extinguished some 60 to 70 microseconds after the spark first occurred, and be re-established some 20 to 30 microseconds later; (2) with the higher compression and wider plug gaps in use in modern engines, radiation from one plug lead to another is quite frequently sufficient to cause cross-firing of the engine. It is obvious that a voltage rise induced in the lead to the plug under examination sufficient to produce a spark at that plug will also be sufficient to produce, with the usual type of synchroscope, a saw-tooth sweep pulse which will correspond to a signal other than the desired one. Hence, a number of signals may appear simultaneously on the screen of the cathode ray tube in superimposed position, making it impossible to distinguish the desired signal for evaluation.

My invention involves a novel arrangement by which a single saw-tooth sweep only is generated by the initial voltage rise in the ignition system preceding the discharge of the spark plug at a time well before the desired portions of the corresponding signal are applied to a vertical beam deflection plate of the cathode ray tube, thus providing, for the first time in the art, a practical and useful cathode ray tube engine analyser in which the saw-tooth synchronising sweep pulse is generated by the voltage rise in the ignition system itself.

It is a feature of my invention that the voltage rise for generating the saw-tooth sweep pulse may be taken from the high voltage secondary of the engine ignition coil, through an attenuator connected to the terminal of the spark plug under test, while the signal impulse may be taken either from the high voltage secondary through an attenuator or from the low voltage primary of the engine ignition coil.

It is a further feature of my invention that the generation of a saw-tooth sweep pulse is prevented until a predetermined time interval has elapsed after the generation of a preceding saw-tooth sweep pulse, thus preventing the generation of saw-tooth sweep pulses by other than the initial voltage rise in the ignition system preceding the spark discharge with corresponding multiple traces on the screen of the cathode ray tube.

For the purpose of further explaining the foregoing and other features of my invention, reference is made to the following description of a preferred embodiment of my invention, when taken in connection with the accompanying drawings, in which:

Fig. 1 is a general circuit diagram of the engine analyser of my invention, in conjunction with an engine ignition system;

Fig. 2 is a series of illustrations of the pulses obtained at various points in the circuit of Fig. 1;

Fig. 3 is a series of illustrations of typical waveforms at point A of Fig. 1 obtained with the device of Fig. 1, as portrayed on the screen of the cathode ray tube with the instrument on range A;

Fig. 4 shows typical waveforms at point A of Fig. 1, as portrayed on the screen of the cathode ray tube with the instrument on range B;

Fig. 5 shows typical waveforms at point B of Fig. 1, as portrayed on the screen of the cathode ray tube with the instrument on range B; and

Fig. 6 shows typical waveforms at point B of Fig. 1, as portrayed on the screen of the cathode ray tube with the instrument on range C.

Referring to Fig. 1, the lead wires from the cathode ray tube engine analyser are connected to the engine ignition system by simple spring clips or other suitable means, one connection being made by attaching the attenuator lead wire 12, to the high voltage secondary of the engine ignition coil at the spark plug under test, and the attenua-

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tor ground wire 14 to any suitable point on the engine at ground potential.

The signal lead wire 16 to the vertical beam deflection plate 86 of the cathode ray tube 80, provided with a blocking condenser 17 and preferably a filter comprising a radio frequency choke 18 and resistor 19, may be attached either directly to the low voltage primary of the ignition coil, for instance at the breaker points, point B of Fig. 1, or to the terminal A on the attenuator, as hereinafter more fully explained. Both forms of connection are preferred to enable a complete analysis of the ignition system to be made.

The average ignition system in good condition is capable of producing a voltage rise of 20,000 to 25,000 volts, whereas the voltage necessary to break down the spark plug gap insulation is of the order of 8,000 to 12,000 volts depending on plug gap and the extent to which the mixture is compressed. Hence, in a good ignition system there is a factor of safety of 100%, and this may be reduced considerably without affecting the functioning of the motor.

On the other hand, an ignition system in poor condition has a very low margin of safety, hence, a load may be imposed by the attenuator to reduce the output voltage from the ignition coil to a point where mal-functioning of the system is clearly visible on the screen of the cathode ray tube, as hereinafter more fully explained.

The attenuator generally designated at 20 consists of two capacity voltage dividing networks which may be enclosed in a metal case connected to the engine analyser by a shielded line 21, enabling the attenuator to be placed near the spark plug under test and connected to it by a short lead wire 12.

The dividing network for reducing the input voltage for application to the plates of the cathode ray tube when the signal input lead 16 is connected to terminal A on attenuator 20 consists of condensers 22 and 24 connected in series arrangement between the input lead from the spark plug under test and ground. The signal voltage is taken from the junction of the condensers 22 and 24 through a resistor 28 which acts as a terminating resistor for the line 16 to the vertical plate 86 of cathode ray tube 80, preventing reflections of the input signal which might cause faulty operation of the device.

The constants of the attenuator 20, in particular the value of resistor 38, and of condensers 22, 26, and 30, may be so chosen as known in the art to provide a suitable ignition system load to reduce the voltage in the ignition system a substantial amount, preferably to a value greater than about two-thirds of its value without such a load. Under such circumstances, the load placed on the ignition system does not in any way affect the performance of an ignition system which is in good condition, i. e. which has a 100% factor of safety, but will cause mal-functioning of a system which has a lower factor of safety, and which is thus likely to break down in the near future.

A similar network is provided for reducing the input voltage for actuating the trigger shaper circuit consisting of condenser 30 and resistor 39 in series arrangement with either condenser 31, 32 or 33, a switch 34 being provided to permit the switching of the condensers 31, 32 and 33 to adjust the triggering voltage to the desired value for actuating the trigger shaper circuit. A terminating resistor 36 is provided for the shielded line 21.

The attenuator 20 reduces the very high voltage from the secondary of the ignition coil to a value suitable for actuating both the trigger shaper circuit and the vertical deflecting plate of the cathode ray tube 80 without affecting the transient rise of ignition voltage.

If desirable, the amplitude of high frequency radiated signals such as those in the present day ignition systems used with high compression engines may be reduced by the use of a low pass filter in series with the input lead 12 from the spark plug under test to the attenuator 20,

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The resistor 38, the resistor 39, and the condenser 26 constitute a filter suitable for such purpose.

The trigger shaper circuit, generally designated at 40, generates a single sharply rising pulse which is substantially independent of the rate of rise of the input voltage rise from attenuator 20, and is then positively prevented from generating a second pulse for a predetermined time thereafter, all as hereinafter more fully explained. Such a uniform sharply rising pulse is necessary for actuating the cathode ray tube saw-tooth sweep generator circuit to produce consistent results under varying degrees of mal-functioning of the ignition system under test, as the characteristics of the input voltage rise from line 21 are not suitable for actuating directly a cathode ray tube saw-tooth sweep generator circuit, since both the polarity and the rate of voltage rise may vary considerably depending upon the characteristics of the ignition system.

The circuit of the trigger shaper is that of a modified blocking oscillator, normally prevented from oscillating by means of a unilateral current device such as diode 46 in the grid circuit of a pentode vacuum tube 48, said diode 46 acting to break the feedback loop between the plate 50 and grid 52 of the pentode vacuum tube 48 except when a signal of sufficient magnitude is applied to the plate of the diode 46. An input switch 42 permits switching the input line 21 to either terminal 43 or 44 of the input of the trigger shaper circuit to enable tests to be made on either positively or negatively grounded ignition systems.

If a negative voltage rise is applied to switch 42 by the line 21 from attenuator 20, switch 42 is moved to connect line 21 to terminal 43, supplying said pulse to terminal 56 of blocking oscillator transformer 54 and to the plate 50 of the pentode vacuum tube 48 through the direct current isolation condenser 60. The windings of the blocking oscillator transformer 54 are arranged in series aiding thus forming in effect a single winding, with taps 57 and 58 at intermediate points on said winding between the end terminals 56 and 59 thereof, one of said taps being connected by switch 62 in accordance with the polarity of the input pulse to the cathode 53 of the pentode vacuum tube 48. If desired, said switch 62 may be mounted on a common shaft with switch 42. Since the taps 57 and 58 are held at points of substantially constant potential, a negative signal applied to the terminal 56 of the blocking oscillator transformer 54 will result in a positive signal at the terminal 59 of the blocking oscillator transformer. Similarly, if a positive pulse is applied to switch 42 by the line 21, and switch 42 is moved to connect line 21 to terminal 44 and thus to the terminal 59 of the blocking oscillator transformer 54 that is connected to the grid 52 of the pentode vacuum tube 48 through the diode 46 and blocking condenser 64, a negative pulse will appear at the other terminal 56 of the blocking oscillator transformer 54. Switches 42 and 62, then, permit the trigger shaper circuit to function in the same manner whether a positive or a negative voltage rise is supplied to the attenuator 20 by the spark plug under examination.

The positive voltage rise appearing at terminal 59 of the blocking oscillator transformer will be transmitted to the grid 52 of the pentode vacuum tube 48 through diode 46 and condenser 64. I prefer to bias the cathode of the diode 46 to prevent triggering of the circuit by small positive voltage rises, such bias being obtained from voltage divider 66. The voltage divider 66 is adjusted so that the wanted signals, i. e., those occurring in the ignition system immediately after the opening of the contact breaker points, are fed to the grid 52 of the pentode vacuum tube 48, but all other smaller signals occurring at other times are prevented from passing to said grid. The pentode 48 is thus prevented from oscillating until the positive voltage at the plate of the diode 46 exceeds the positive voltage applied to the cathode of the diode 46 from the voltage divider

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66. When this occurs, the feedback loop is completed through the diode 46 and the pentode vacuum tube 48 begins oscillation, the blocking oscillator transformer 54 acting as a tuned circuit incorporating a feedback loop from plate 50 to grid 52 of the pentode vacuum tube 48. The oscillation of the pentode vacuum tube 48 produces a first negative pulse at its plate 50, and such negative pulse is passed through blocking condenser 70 and diode 68 to the sweep generator circuit.

A second unilateral current device such as a diode 72 is connected between the plate 50 of the pentode vacuum tube 48 and the cathode 53 of the tube 48 to provide the blocking action for said pentode. It functions in the following manner:—voltage changes at the plate of diode 72 which make the diode plate positive with respect to the diode cathode are rectified by the diode 72 and a positive voltage derived from the rectifying process appears at the cathode of the diode 72. As the cathodes of the diode 72 and the pentode vacuum tube 48 are connected together, the existing positive voltage at the cathode 53 of the pentode vacuum tube 48 is increased, this increase being sufficient to cut off the trigger circuit by preventing further flow of electron current through the pentode vacuum tube 48. The plate 50 of the pentode vacuum tube 48 is thereby raised to the level of the B+ supply and is held at that potential for a time determined by the time constants of the cathode and plate circuits of pentode 48. These time constants are made of such duration that the pentode vacuum tube 48 is rendered inoperative for a period in excess of that during which any undesired potential changes at the plate of the tube may be expected, thus preventing the generation of output pulses by input voltage changes from line 21 within such predetermined interval of time. I prefer that such interval be at least 500 microseconds and preferably of the order of 1000 to 3000 microseconds.

Fig. 2 illustrates the waveforms at various points in the trigger shaping circuit. At Fig. 2a a typical waveform at the output of the attenuator is shown; other examples will be seen in Figs. 3 and 4 as portrayed on the screen of the cathode ray tube. At time T_0 on Fig. 2a, the distributor rotor gap breaks down and the rising voltage in the ignition system secondary is transferred to the high tension ignition cable going to the spark plug to which the attenuator cable 12 is connected. The voltage rise at this time exceeds the bias voltage applied to the cathode of the diode 46, which voltage is indicated by a horizontal dotted line on Fig. 2a), and the pentode 48 starts oscillating, a negative output pulse being produced in approximately 0.2 microsecond after diode 46 begins to conduct. The output pulse from pentode 48 without diode 72 in the circuit is shown at T_0 in Fig. 2b. After the initial negative pulse the plate voltage of the pentode 48 swings positive in the usual blocking oscillator manner and were it not for the large voltage change produced by the spark discharge at T_2 , the blocking oscillator oscillations would die away rapidly. The voltage change due to the spark discharge produces a large positive swing at the plate of the pentode 48, and the latter half of the blocking oscillator waveform is repeated. At T_3 , the voltage at the input to the trigger shaper again exceeds the bias voltage on diode 46 and a second output trigger results.

In Fig. 2c the effect of the addition of diode 72 is seen. The initial positive swing of the plate voltage of pentode 48 makes the plate of the diode 72 positive with respect to its cathode, and the diode 72 conducts, thereby producing a positive voltage at the cathode. As the cathodes of the diode 72 and the pentode 48 are connected together, this positive voltage is also applied to the cathode of the pentode 48, thereby reducing the plate current of pentode 48 and raising the plate potential towards B+ voltage. The second positive voltage

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rise at T_2 caused by the spark discharge raises the plate potential of pentode 48 in a similar manner, in this case to the level of the applied B+ voltage. The time constants of the cathode and plate circuits are chosen to maintain the flow of current in pentode 48 at a level below that which is necessary to enable the pentode 48 to produce a gain greater than unity for a predetermined period of time. If the gain of the pentode stage is less than unity, the tube cannot oscillate and no output pulse can be produced.

Fig. 2d shows the output trigger pulse at the plate of the isolating diode 68.

This trigger shaping circuit is capable of producing a sharply rising negative trigger pulse from a small change in input voltage and is immediately thereafter automatically rendered inoperative, although the subsequent changes in the input circuit are much greater in amplitude than the small voltage change which produced the first trigger pulse. By this means, the radio frequency and other disturbances in the ignition system are prevented from affecting the action of the sweep generator and clean sweeps, free from subsequent re-triggering, are produced.

Under conditions which would require that the pentode vacuum tube 48 be held in an inoperative condition for longer than is possible by the use of a rectifying diode in conjunction with pentode 48, a multivibrator such as is well known in the art may be triggered by the initial negative output pulse from the trigger shaper and a blanking pulse of any desired duration produced by such multivibrator may be employed to cut off or otherwise suppress the pentode vacuum tube 48.

The horizontal sweep generator circuits are of a conventional type well known in the art and are used to provide a saw-tooth sweep voltage pulse for application to the horizontal beam deflection plates 82 and 84 of the cathode ray tube 80 for the purpose of scanning a signal impulse such as that provided by the rise and decay of the voltage of an engine ignition system when such impulse is applied to the vertical beam deflection plate 86 of the cathode ray tube 80.

A gate generator circuit, also well known in the art, is provided to supply a voltage pulse of substantially square waveform which increases the brilliance of the cathode ray tube 80 only for the length of time necessary to observe the desired signal trace, thus avoiding return traces which serve only to confuse an observer. Such a gate pulse may be obtained from the screen grid 78 of the sweep generator tube 76.

The output pulses of both the sweep amplifier and the gate generator control the cathode ray tube through its associated circuit components in the usual manner, the sweep generator and amplifiers providing the saw-toothed pulse to be applied to the horizontal plates 82 and 84 of the cathode ray tube 80, enabling observation of the signal voltage as directly applied to the vertical plate 86 of the tube 80, while the gate generator provides a square pulse which is applied to the beam intensity control grid 89 of the cathode ray tube 80. In the preferred embodiment shown, the horizontal sweep generating multivibrator consists of the triode 90, the pentode 76 and the diode 101, the diode 68 acting as a switch isolating the trigger shaper circuit 40 from said multivibrator except when a large negative voltage is present at the cathode of the diode 68, that is, during the production of a trigger by the trigger shaper.

In the absence of a trigger from the trigger shaper, the triode 90 is quiescent, the grid bias obtained from the junction of the resistors 71 and 72 being sufficient to completely cut off the flow of plate current in said triode. Under these conditions, the plate 103 of the triode 90 has a positive potential equal to that of the B+ supply. The cathode condenser 73 increases the gain of the triode 90 when plate current starts to flow by preventing the degeneration which would occur if the cathode resistor

72 were not by-passed for signal currents. The pentode 76 then passes maximum plate current, being limited only by the resistors 107, 108, and 109 in series with the screen grid 78 and by the resistor 91 in series with the plate 99. Because of such high plate current flow, the plate potential of pentode 76 is only a few volts above ground. The grid 100 and the screen grid 78 of pentode 76 act as the grid and plate respectively of a triode vacuum tube. The actual plate 99 of the pentode plays no part in the action of the multivibrator formed by the triode 90 and the triode formed by the grid 100 and the screen grid 78 of the pentode tube 76. The plate 99, is, however, connected electronically to the other electrodes in the tube, and its potential is controlled by the action of the grid and screen grid of the tube. The diode 101 and resistor 102 maintain the pentode grid 100 at a constant potential a few volts below ground during the quiescent period.

On the arrival of a sharp negative trigger pulse from the trigger shaper—through suitable condensers selected by the switches 92 and 94—at the grid 100 of the pentode 76, the plate current through the tube is decreased, allowing the screen grid 78 to rise to a higher voltage. This voltage rise is transferred through the resistor 110 and the condenser 106 to the grid 104 of the triode 90. This reduction of grid bias on the triode 90 results in a flow of plate current through the tube and the plate potential falls, the fall in potential being transferred to the grid 100 of the pentode 76 through one of the condensers 113, 114, or 115 as selected by the switch 94, thereby reinforcing the negative trigger voltage and still further decreasing the flow of plate current through the pentode 76. The action is regenerative and results in the cessation of plate current flow in the pentode 76 and the passage of a large plate current in the triode 90, such action preferably being complete in approximately 0.1 micro-second after the arrival of the trigger pulse.

At the end of the regenerative action, one of the condensers 113, 114, 115 is charged and so produces a large negative voltage on the grid 100 of the pentode tube 76. Then, until one of the condensers 113, 114, or 115 has discharged through resistor 102, no current can flow in the pentode 76, and the multivibrator remains in the described condition with the triode 90 conducting and the pentode 76 cut-off. The discharge of the condenser 113, 114, or 115 to a potential which will permit current to flow in the pentode tube 76 will occur after a period of time determined by the capacity of the condenser and the value of the resistor 102. Switch 94 permits selection of a condenser of appropriate value for the time interval desired.

The triangular sweep voltage is produced as follows: While condenser 113, 114, or 115 is discharging, no current flows in the pentode 76 and the plate 99 tries to rise towards B+. However, this rise cannot take place until the condenser 93, 95, or 97 selected by switch 98 has charged positively, and the potential at the plate 99 of the pentode rises exponentially at a rate determined by the capacity of the condenser selected by switch 98 and the value of resistor 91. The rate of movement of the spot of light across the screen of the cathode ray tube 80 is controlled by selection of the appropriate condenser 93, 95, or 97. The time during which the spot is permitted to move across the cathode ray tube screen is controlled by selection of the appropriate condenser 113, 114, or 115; and during this period, the spot of light is increased in intensity by the application of a rectangular positive pulse from the screen grid 78 of the pentode through switch 96 and condenser 88 to the grid 89 of the cathode ray tube 80.

During the period of discharge of condenser 113, 114, or 115 the screen grid 78 of the pentode 76 will remain at a potential determined by the values of the resistors 107, 108, and 109 in series with resistors 105 and 110; the whole potential divider being connected between the

B+ supply and ground. This results in the production of a rectangular positive pulse of the same time duration as the discharge time of the condenser 113, 114, or 115: By tapping between resistors 107, 108, and 109 the amplitude of the rectangular pulse may be suitably chosen for the sweep rate involved and by inverting this positive pulse in a vacuum tube amplifier and applying the resulting negative pulse through a switch diode to the suppressor grid of the pentode 48, said pentode may be prevented from functioning for a period of time determined by the time constant of the condenser connecting the plate of the switch diode to the suppressor grid and a resistor connected in the lead between the suppressor grid and ground, thus providing a blocking pulse from the multivibrator, an alternative to the blocking pulse means as hereinbefore described.

When the negative voltage on the grid 100 of the pentode 76 has fallen to a value at which plate current can flow in the pentode 76, the voltage at the screen grid 78 starts to fall, as does the voltage at the plate 99. The fall in voltage at the screen grid 78 is transferred to the grid 104 of the triode 90 through the condenser 106 and the resistor 110, resistor 110 being included to complete the potential divider between B+ and ground as described above, while the condenser 106 prevents the slowing down of the rate of transference of the pulse between the screen grid 78 and the triode grid 104. Condenser 116 is connected across the resistor 107 for a similar reason.

The fall in voltage fed to the grid of the triode 90 causes a reduction of plate current in that tube, with a consequent rise in voltage at the plate 103. This voltage rise is transferred to the grid 100 of the pentode 76 and a reversal of the previously described regenerative action takes place, resulting in cessation of plate current in the triode 90, the flow of maximum plate current in the pentode 76, and the discharge of condenser 93, 95, or 97 through the pentode tube 76. The circuit has thus reverted to its original condition prior to the arrival of a trigger pulse from the trigger shaper and remains in that condition until another pulse is produced by the trigger shaper. The discharge of condenser 93, 95, or 97 through the pentode tube stops the movement of the spot across the cathode ray tube screen, and the spot is returned very rapidly to its original position on the screen. As no rectangular positive pulse is produced at the screen grid of the pentode 76 during this reversal action the beam of electrons in the cathode ray tube is not intensified and the return trace is not visible.

As hereinbefore stated, the voltage at the plate 99 of the pentode tube 76 rises exponentially towards B+. By suitable choice of values of condensers 113, 114, and 115 which determine the duration of this period, and of condensers 93, 95, and 97 which determine the rate of rise of voltage during this period; use is made only of the early part of the exponential rise at the plate of the pentode 76; this rise being reasonably linear. This approximately linear rise may be made completely linear, as now will be described.

The rising voltage at the plate of the pentode 76 is transferred directly to the grid of the triode 117 which is connected as a cathode follower having a gain of approximately unity. The resulting signal appearing at the cathode is transferred through condenser 121 to the horizontal deflection plate 84 of the cathode ray tube 80. The voltage rise so applied to the deflection plate 84 is exponential in form. The signal at the cathode of the triode 117 is also transferred through condenser 123 and resistor 122 to the grid of the triode 130. The rate of rise of voltage at the grid 129 of triode 130 is slowed down by the series resistor 122, as the stray and tube capacities at the grid 129 have to charge through resistor 122. This effect is most pronounced at the start of the rise of the exponential signal at the grid, and therefore the start of the voltage rise is slowed down in relationship

with the later, more slowly rising portion of the incoming signal.

To allow the grid of triode 130 to be conductively connected to the cathode of triode 117, the resistor 126 is made large to raise the cathode of triode 130 to a suitable grid bias level. At the beginning of the voltage rise at the grid of triode 130, the bias voltage is such that the transconductance of the tube is low. As the voltage rises at the grid, the bias is reduced and the stage gain is increased. These two effects produce a hyperbolic voltage fall at the plate of the triode 130. The shape of this hyperbolic fall may be controlled by the correct choice of condenser 123 which modifies the effect of the series resistor 122 and of condenser 127 which controls the rate of rise of voltage at the cathode of triode 130; and therefore the transconductance at different portions of the signal from triode 117.

By suitable choice of condensers 123 and 127, the hyperbolic voltage fall applied through condenser 125 to the horizontal deflection plate 82 of the cathode ray tube may be made of such shape that when combined with the exponential voltage rise applied through condenser 121 to the horizontal deflection plate 84 of the cathode ray tube the spot of light is made to travel at a uniform rate across the screen of the cathode ray tube.

The vertical and horizontal positions of the spot on the cathode ray tube screen are controlled by variable resistors 140 and 141; variable resistance 142 allows the voltage on the final anode 87 of the cathode ray tube to be set for optimum overall focus; and variable resistances 153 and 156 control the focus and brilliance of the spot respectively.

By observation of the rate of rise, amplitude, and character of the waveforms of the ignition system voltage rise as portrayed on the screen of the cathode ray tube, and by analysis and comparison of such waveforms with normal waveforms, the condition of the various ignition system components may be easily checked. Furthermore, the condition of valves and rings may be determined, as the amplitude of the voltage rise is affected by the compression. Since faulty rings will give a constant, though low, compression from stroke to stroke, and faulty valves will give a variable compression from stroke to stroke due to variations in seating, it may be determined which is at fault, and in what particular cylinder the trouble arises, all of such information being obtained without the use of an accessory drive on the motor to provide a triggering or synchronizing voltage.

If desired, the engine analyser of my invention may be used to measure directly the compression ratio of a cylinder, since the amplitude of the voltage rise in the ignition system secondary has been shown by Paschen's Law to be directly proportional to the pressure of the mixture in the cylinder, the electrode shape and gap of the spark plug, and to a lesser extent to such factors as the temperature, and the chemical composition of the explosive mixture. Hence by the use of a calibrated engine analyser to measure the voltage rise at the spark plug of the cylinder under test, assuming the spark plug to be in new condition, the compression ratio may be read directly on the screen of the cathode ray tube, since for practical purposes, the temperature and composition of the explosive mixture may be ignored.

The cathode ray tube engine analyser is preferably provided with three ranges, A, B and C, the desired range being selected by range switch 92, 94, 96 and 98, which switches circuit components in the sweep generator and gate circuits, as is well known in the art, to provide the proper length of sweep and gate waveforms for the range desired.

Range A comprises the highest sweep speed, permitting the examination of the characteristics of the spark plug discharge, its speed being high enough to show the high frequency oscillations set up by the spark discharge.

Examples of typical waveforms at point A of Figure 1 with the analyzer on range A, are shown in Fig. 3.

Range B comprises a slower sweep speed and permits the examination of the entire signal trace from the spark plug under examination, from the initial rise of voltage in the secondary of the ignition coil to the return of the system to conditions for beginning of the cycle of the next spark plug to be fired.

Fig. 4 shows typical waveforms at point A of Fig. 1 on range B, and Fig. 5 typical waveforms at point B of Fig. 1 also on range B.

Range C comprises the slowest sweep speed and permits observation of the waveforms accompanying two or more sparks as said sparks follow each other in the firing order of the engine. This range permits examination of the period during which the contact breaker points are closed prior to the spark in each cylinder. Observation of the distance between successive waveforms as seen on the cathode ray tube screen, and the proportion of this distance during which the points are closed, gives the closed period in degrees of distributor shaft rotation. A simple nomogram may be provided with the instrument to facilitate the calculation.

In addition, use of range C not merely confirms the presence of cross-firing in the engine as indicated by ranges A and B, but enables the operator to determine which cylinder is cross-firing, and which other cylinders are being affected. Indications of irregularities in the shape of the distributor cam, looseness in the spark advance plate, wear in the distributor shaft bearing, and faulty contact breaker action may be observed on ranges A and B, but are confirmed and precisely located on range C.

Typical examples of the waveforms taken from point B of Fig. 1 as seen on the cathode ray tube with the instrument on range C are shown in Fig. 6.

From the foregoing description it will be seen that the engine analyser of my invention as herein described permits tests of ignition systems and their associated components as well as compression conditions to be made without complicated mechanical attachments, while the engine is under operating conditions. Such tests may be simply and easily made by a person without technical knowledge by a simple comparison of the observed pattern with illustrations of typical patterns showing various engine faults.

I claim:

1. An internal combustion engine analyser comprising a cathode ray tube having vertical and horizontal beam deflecting means, horizontal sweep means for said cathode ray tube, signal actuated trigger means producing a trigger pulse for actuating said horizontal sweep means, trigger blocking means rendering said signal actuated trigger means itself inoperative for a predetermined interval of time after said trigger means has been actuated to produce a trigger pulse, and means for applying a signal to said trigger means and to said vertical beam deflecting means.

2. An engine analyser according to claim 1 in which said signal actuated trigger means includes an oscillator having vacuum tube means, and said blocking means includes a unilateral current device arranged and connected to said oscillator vacuum tube means to cut off said vacuum tube means by preventing flow of electron current therein.

3. An engine analyser according to claim 1 in which said signal actuated trigger means includes an oscillator having vacuum tube means, and said blocking means includes a multivibrator arranged and connected to said vacuum tube means to cut off said vacuum tube means by preventing flow of electron current therein.

4. An internal combustion engine analyser comprising a cathode ray tube having vertical and horizontal beam deflecting means, horizontal sweep means for said cathode ray tube, signal actuated trigger means producing a trigger pulse for actuating said horizontal sweep means, said trig-

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ger means including blocking oscillator means with a feedback circuit having means arranged and connected therein to break said feedback circuit and prevent operation of said oscillator means except when a signal is applied to said trigger means.

5. An internal combustion engine analyser as claimed in claim 4 in which said means arranged and connected to break said feedback circuit includes a unilateral current device.

6. An engine analyser according to claim 5 in which said oscillator further includes bias voltage means connected to said unilateral current device to prevent operation of said oscillator except when a signal of greater amplitude than said bias voltage is applied to said trigger means.

7. An internal combustion engine analyser comprising a cathode ray tube having vertical and horizontal beam deflecting means, horizontal sweep means for said cathode ray tube, signal actuated trigger means producing a trigger pulse for actuating said horizontal sweep means, trigger blocking means actuated by said signal actuated trigger means rendering said signal actuated trigger means itself inoperative for a predetermined interval of time after said trigger means has been actuated to produce a trigger pulse, and means for applying a signal to said trigger means and to said vertical beam deflecting means.

8. An internal combustion engine analyser as claimed

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in claim 7 in which said signal actuated trigger means includes blocking oscillator means with a feedback circuit having means arranged and connected therein to break said feedback circuit and prevent operation of said oscillator means except when a signal is applied to said trigger means.

9. An internal combustion engine analyser as claimed in claim 8 in which said means arranged and connected to break said feedback circuit includes a unilateral current device.

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