

Jan. 6, 1959

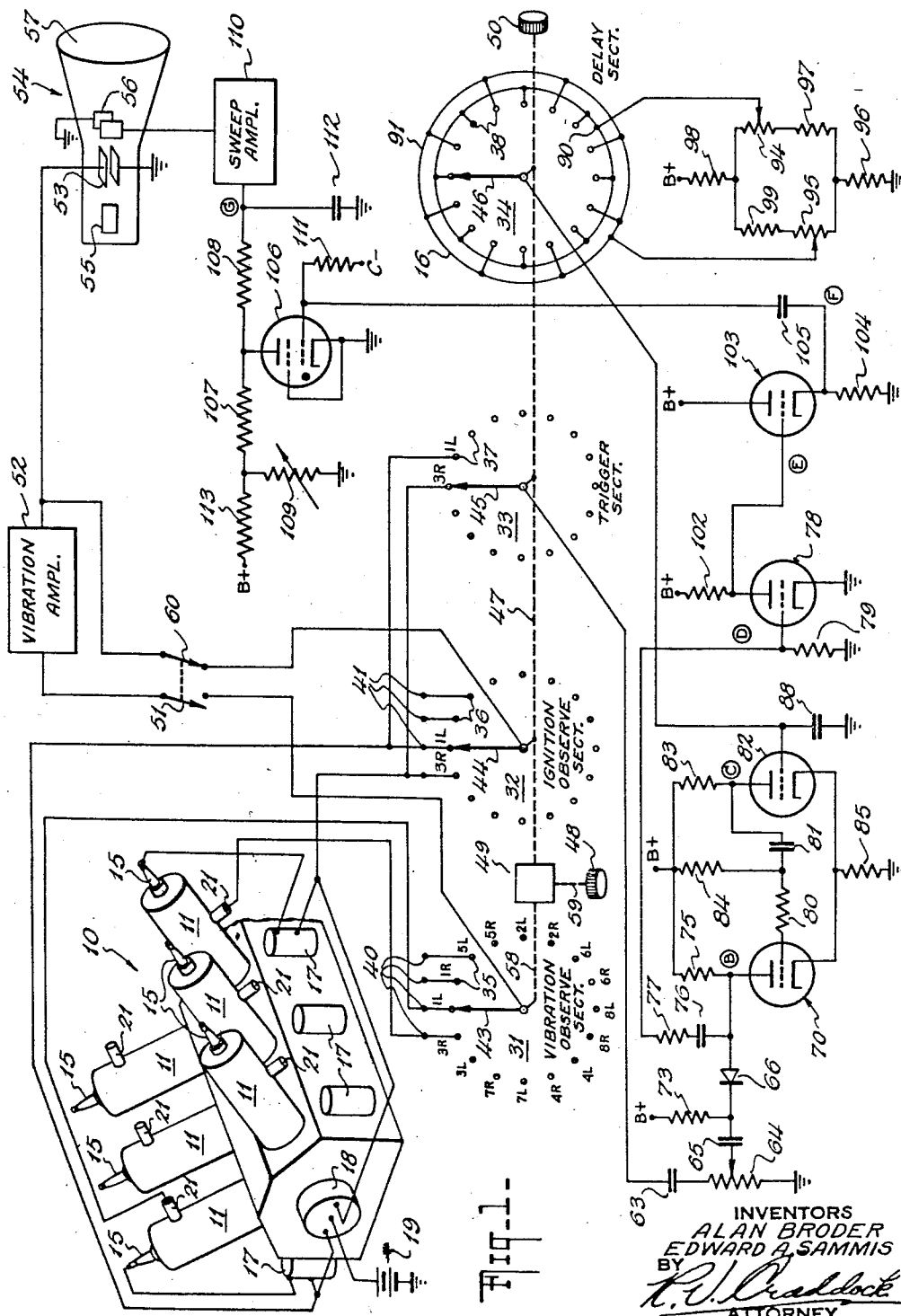
A. BRODER ET AL

2,867,766

ENGINE ANALYZER SYSTEM

Filed May 25, 1955

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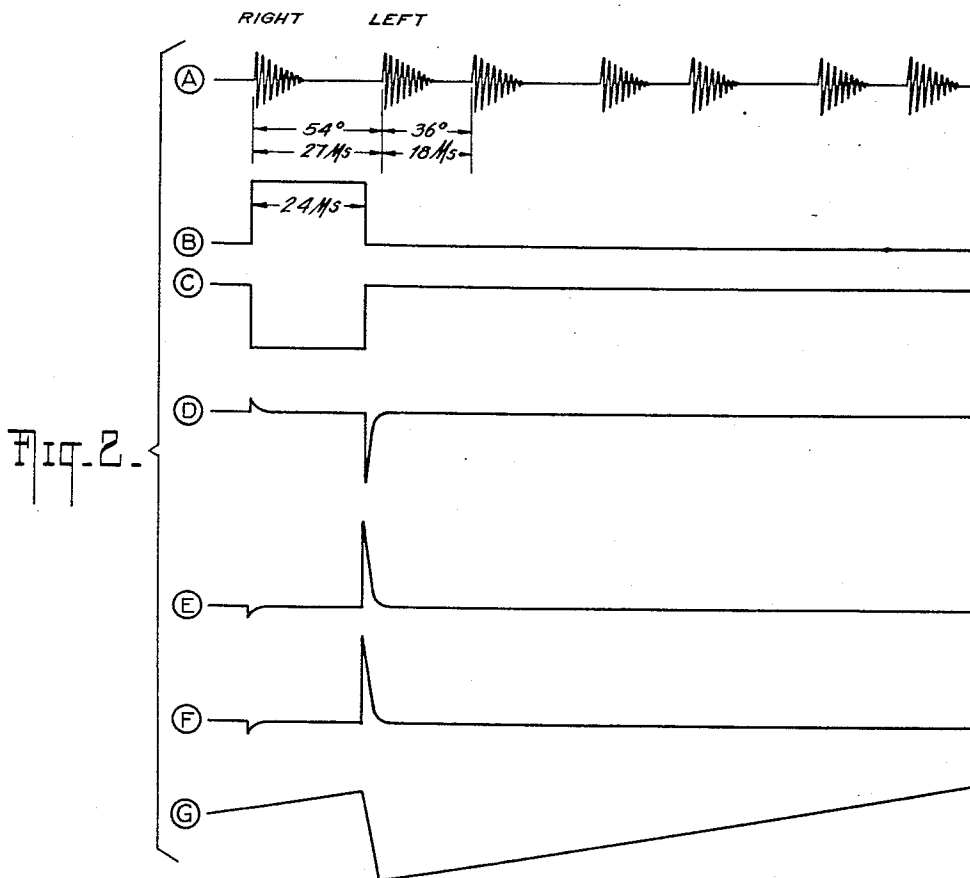
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2 Sheets-Sheet 2



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ENGINE ANALYZER SYSTEM

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8 Claims. (Cl. 324-16)

This invention relates generally to an engine analyzer system and more specifically to such a system in which an ignition impulse is used to initiate the time base.

An engine analyzer showing ignition or vibration waveforms of internal combustion engines may have its time base initiated by a synchronizing wave generator driven from the crank shaft of the engine. However, in some engines it is difficult to satisfactorily mount or drive the synchronizing generator. Moreover, a few engines are intended to rotate at a speed which is unusually low and well below that for which available synchronizing wave generators are designed, resulting in a low amplitude synchronizing wave. If such a slow speed engine's crankshaft, or available drive for the synchronizing generator has an irregular angular velocity, unless the synchronizing generator is specially designed, it may not provide a suitable synchronizing wave since the generator is responsive not only to angular position, but also to angular velocity.

Hence, under some conditions, it may be particularly advantageous to employ the spark plug firing pulses to initiate the time base. Synchronization directly from the ignition signal to be observed has the disadvantage that part of the ignition signal will be lost in the time base fly-back period, making it desirable to start the sweep slightly earlier than the time of firing the cylinder to be studied.

The problem of using spark plug firing pulses for synchronizing is highly complicated if the engine has unequal periods between the firing of its spark plugs. Moreover, it is desirable to initiate the time base of the analyzer at a point on the engine cycle preceding by the least possible time the pattern to be observed. If the initiation of the time base precedes the occurrence to be observed by a substantial period, the time base may be considerably out of synchronism with an irregularly turning crank shaft at said occurrence and give an inaccurate indication of the time of the occurrence in relation to an engine cycle.

It is therefore an object of this invention to provide a trigger circuit synchronized by an ignition pulse to produce a time base for an engine analyzer whereby the complete wave pattern of any cylinder may be observed.

It is also an object of this invention to provide a trigger circuit for an engine analyzer synchronized by the ignition pulse preceding the firing of the cylinder under observation and in which there are unequal periods between the firing of the various cylinders.

It is a further object of this invention to provide a trigger circuit for an engine analyzer in which the time base is initiated by an event in the engine cycle closely preceding the occurrence of the pattern to be observed.

The above objects are accomplished in the device herein set forth by initiating the time base of the display component by a delayed version of the ignition pulse of the cylinder firing immediately before the firing of the cylinder whose firing characteristic is to be observed. The selection of the cylinder to be observed is made by a switch associated with other switches to select the

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proper ignition pulse to trigger the time base and also to select the proper delay for the trigger.

As used herein "ignition pulse" includes the actual electrical pulse applied to the spark plug and also the pulse occurring in some part of the spark plug circuit, such as the primary of the ignition coil, and resulting in such applied pulse. As used herein "delayed version" of the ignition pulse includes a delayed ignition pulse, an ignition pulse which has been changed in shape or amplitude, or both, and also delayed, and a new pulse initiated by the ignition pulse at a time delayed after the occurrence of the ignition pulse.

Other objects and advantages will occur to those skilled in the art from a consideration of the following specification taken in connection with the accompanying drawing in which,

Fig. 1 is a schematic diagram of an engine analyzing system embodying the principles of this invention,

Fig. 2 shows a series of curves useful in explaining the operation of this invention.

In Fig. 1, internal combustion engine 10, only a part of which is shown, has cylinders 11. Each cylinder 11 has at least one spark plug 15 and a vibration pickup 21. For the purpose of this example, it will be assumed that engine 10 is a 16 cylinder V-type engine, that the delay between the firing of a left bank plug and the firing of its right bank mate is approximately 36° of crank shaft rotation, and that the delay following the firing of a right bank plug before the next plug is fired in the left bank is approximately 54°. It is further assumed that the engine is governed at 327 revolutions per minute so that these degree figures are directly expressible in milliseconds, 36° being approximately 18 milliseconds and 54° being approximately 27 milliseconds.

There are provided four wafer-type, ganged, switch sections, which are the vibration-observe section 31, the ignition-observe section 32, the trigger section 33 and the delay section 34. Sections 31 through 34 are respectively provided with contacts 35, 36, 37 and 38, each section having one contact for each cylinder of the engine 10. Contacts 35 of the vibration-observe section 31 are each connected to one of the input terminals 40. The contacts of the ignition-observe section 32 are each connected to one of a set of input terminals 41. The contacts 37 of trigger section 33 are also respectively connected to the input terminals 41.

Each of input terminals 40 is connected to a different one of the vibration pickups 21. Each of the input terminals 41 is connected to the circuit of one of the spark plugs 15.

In the engine 10 shown in Fig. 1, each spark plug 15 is connected through a separate ignition coil 17 to a distributor, or interrupter 18, which connects a low voltage supply 19 in turn to each ignition coil and thus to each spark plug in a predetermined sequence. The ignition coils 17 are shown mounted adjacent each spark plug 15 on engine 10. Each coil 17 consists of an auto-transformer, the low voltage winding of which is connected in series with the low voltage source 19 and interrupter 18, and both coils of which are connected across ground and the associated spark plug. Each input terminal 41 is connected to the ungrounded side of the low voltage winding of a different one of the ignition coils 17.

To avoid unduly complicating the drawing, all of the terminals 40 and 41, there being 16 of each, have not been shown nor have all of the connections from terminals 40 and 41 to the contacts 35 and 36 and to the vibration pickups 21 or to the circuits of the spark plugs 15.

Each of the switch sections 31 through 34 is provided with a wiper arm 43, 44, 45 and 46, respectively.

Arms 44, 45 and 46 are ganged together, being fixedly mounted on rotatable shaft 47 which may be selectively

rotated by knob 50. Arm 43 is fixedly mounted on shaft 58 for rotation therewith. Shafts 47 and 58 are connected together through differential 49, the third shaft 59 of which is provided with a knob 48 for selective rotation. Rotation of knob 50, with knob 48 remaining stationary, will rotate arms 43, 44, 45 and 46 by the same amount. Rotation of knob 48, with knob 50 remaining stationary, will alter the relative rotative position of arm 43 with respect to arms 44, 45 and 46. Rotation prevention means such as brakes or a worm wheel, may be provided on shafts 47 and 58 to insure that these shafts turn only in response to manipulation of their respective knobs 50 and 48. Alternatively, they may be held from rotation manually when desired.

Arm 43 of the vibration-observe switch section 31 is connected to one terminal of switch 51, the other terminal of switch 51 is connected through vibration amplifier 52 to the vertical deflecting plates 53 of cathode ray tube 54. Cathode ray tube 54 also includes electron gun 55, horizontal deflecting plates 56 and screen 57 providing a visible trace upon impingement thereon by the electron beam.

The wiper arm 44 of the ignition-observe switch section 32 is connected to one terminal of the switch 60. The other terminal of which is connected directly to the vertical deflection plates 53. The movable contacts of switches 51 and 60 are ganged for simultaneous and opposite operation so that switch 51 is open when switch 60 is closed and vice versa.

The wiper arm 45 of trigger switch section 33 is connected through condenser 63 and potentiometer 64 to ground. The movable tap of potentiometer 64 is connected through condenser 65 and through rectifying crystal 66 to the plate of triode 70. The junction of crystal 66 and condenser 65 is connected through resistor 73 to a source of plus potential. The plate of triode 70 is connected through a resistor 75 to a source of plus potential and through condenser 76 and resistor 77 to the grid of triode 78 which is also connected through resistor 79 to ground.

The grid of triode 70 is connected through resistor 80 and condenser 81 in series to the plate of triode 82 which is also connected through resistor 83 to a source of plus potential. The junction of resistor 80 and condenser 81 is connected through resistor 84 to a source of plus potential. The cathodes of triode 70 and 82 are connected together and through resistor 85 to ground. The grid of triode 82 is connected through condenser 88 to ground and to the wiper arm 46 of delay switch section 34.

Alternate ones of the contacts 38 of delay switch section 34 are connected to bus 90 while intermediate ones of the contacts 38 are connected to the bus 91. Bus 91 is connected to the sliding contactor of potentiometer 95. Bus 90 is connected to the sliding contactor of potentiometer 94. One end of the potentiometer 95 is connected through resistor 96 to ground and to one end of resistor 97. The other end of resistor 97 is connected to one end of potentiometer 94, the other end of which is connected through resistor 98 to a source of positive potential. The other end of potentiometer 95 is connected through resistor 99 to the low potential end of resistor 98.

The cathode of triode 78 is connected to ground and its plate is connected through resistor 102 to a source of positive potential and to the grid of triode 103. The plate of triode 103 is connected directly to a source of positive potential. The cathode of triode 103 is connected through resistor 104 to ground and, through condenser 105, to the control grid of a gas filled tetrode 106. The cathode of tetrode 106 is connected to ground and to the shield grid while its plate is connected to the junction of resistors 107 and 108. The control grid of tetrode 106 is connected through resistor 111 to a source of negative biasing potential $c-$. The other end of resistor 107 is connected through resistor 113 to a source of plus potential. The junction of resistors 107 and 113 is connected through variable resistor 109 to ground. The

other end of resistor 108 is connected to the input of sweep amplifier 110 and through condenser 112, to ground. The output of sweep amplifier 110 is connected to the horizontal deflection plates 56 of cathode ray tube 54.

The spark plug circuits are connected from coils 17, as explained above, through terminals 41 to the contacts 36 of ignition-observe switch section 32 so that contacts 36 taken in one direction (shown as clockwise in Fig. 1) are connected to the spark plugs 15 in their firing order. Vibration pickups 21 are connected through terminals 40 to contacts 35 of vibration-observe switch section 31 so that contacts 35 taken in the same direction as contacts 36, are connected to the pickups 21 in the order of firing of their respective cylinders. The contacts 37 of trigger switch section 33 are connected through terminals 41 to spark plugs 15 so that, taken in the same direction as contacts 36, the contacts 37 are connected to spark plugs 15 in their firing order. The wiper arms 44 and 45 are arranged so that when arm 44 of the ignition-observe section rests on any contact 36 corresponding to any one cylinder being observed, then arm 45 of the trigger section rests on the contact connected to the spark plug of the cylinder which immediately precedes said observed cylinder in the firing order. The contacts 35, 36 and 37 in Fig. 1 are each marked with a number to show their corresponding cylinder number and with a letter (R or L) to indicate whether the corresponding cylinder is in the right or left bank. When arm 44 is connected to a cylinder such as 1L, which is preceded by a 27 millisecond non-firing interval, the grid of tube 82 is connected to potentiometer 94. On observing cylinders preceded by 18 millisecond non-firing intervals, the grid of tube 82 is connected to potentiometer 95.

In operating the device shown in Fig. 1, the ganged switches 51 and 60 are thrown to the left if it is desired to observe an ignition pattern on the screen 57 of cathode ray tube 54. If, for example, it is desired to observe the ignition pattern of the first cylinder in the left bank of engine 10, knob 50 is rotated until the wiper arm 44 of the ignition observe switch section 32 makes connection with the contact of the input terminal connected to the first left cylinder. Wiper arm 45 of the trigger switch section 33 is ganged with wiper arm 44 of section 32 in such manner that when wiper arm 44 connects with the first left cylinder, wiper arm 45 connects with the third cylinder of the right bank, the cylinder which fires immediately preceding the firing of the first left cylinder. Whatever cylinder is selected for observation by the wiper arm 44, the wiper arm 45 will automatically make connection with the cylinder firing immediately preceding thereto.

The successive ignition patterns of seven of the cylinders as they fire successively is shown in Plot A of Fig. 2. It will be noted that the left bank cylinder follows its preceding firing in the right bank by 54° while the succeeding firing in the right bank follows by 36° . The various ignition patterns shown in Plot A each appear in one of the circuits associated with one of the spark plugs 15. The composite of ignition pattern shown in Plot A does not appear in any one wire in Fig. 1. The other plots B through G of Fig. 2 do appear in various parts of Fig. 1 and a notation is made in Fig. 1 of these parts.

With wiper arms 44 and 45 resting on contacts 36, and 37, respectively corresponding to cylinders 1L and 3R, respectively, the ignition pattern from the third right cylinder is applied through potentiometer 64 which is employed for threshold control to prevent small spurious signals from initiating a time base sweep on screen 57 of tube 54. The crystal diode 66 is used to insure that only the negative portion of the trigger signal is applied to the multivibrator consisting of tubes 70 and 82. Resistor 73 biases the diode 66 in a non-conductive direction so that a large signal is needed to trigger multivibrator 70-82, and the small spurious signals present will not appear at the multivibrator input.

The multivibrator 70 and 82 is monostable. Triode 70 being the normally conducting section, triode 82 is biased beyond cutoff by the current from the common cathode resistor. The trigger pulse arriving from the trigger switch section 33 through the crystal 66 from the third right cylinder is the negative portion of the ignition signal and momentarily lowers the plate voltage of triode 70. This reduces the cathode voltage on triode 82 allowing it to conduct, dropping its plate voltage and in turn cutting off triode 70 through the action of the coupling condenser 81 and resistor 80. The voltage to which the plate of triode 82 drops, and thus the amount of charge thrown on condenser 81 is controlled by the grid voltage on triode 82. The cut-off time duration of triode 70 is the delay period and this time is adjustable by varying the grid voltage of triode 82 and thus the charge on condenser 81. This means is used to secure the two time delays of 15 milliseconds and 24 milliseconds which would allow 3 milliseconds of sweep to precede the observed ignition signal. This grid voltage selection is made by the delay section of the wafer switch which chooses the appropriate bleeder. A relatively low potential is supplied by potentiometer 95 when the firing of the observed cylinder is preceded by an 18 millisecond non-firing interval, and a relatively high potential is supplied by potentiometer 94 when the firing of the observed cylinder is preceded by a 27 millisecond non-firing interval.

During this delay period the ignition signal which has initiated the cycle may still be coming in through the plate of triode 70 but the effect of this can only be to pull the plate in a negative direction from B+ and since the tube is already cut off, a drop in plate potential will not affect it. Thus, the multivibrator 70 and 82 is effectively isolated from the ignition circuit through the delay period.

Returning to a description of the cycle of multivibrator 70—82, as condenser 81 continues to discharge through resistors 84, 85 and triode 82, the point is reached where the grid voltage to triode 70 has risen sufficiently high that triode 70 will not remain cut off. As triode 70 begins to conduct, the increased current through resistor 85 reduces the flow of current through triode 82 raising its plate voltage, and by the coupling through condenser 81, raises the grid voltage on triode 70. The effect is cumulative and the multivibrator 70—82 snaps back into its original stable condition with triode 70 conducting and triode 82 cut off. The positive pulse appearing at the plate of triode 70 and the negative pulse appearing at the plate of triode 82 are respectively shown in Plots B and C of Fig. 2. These pulses occur when tube 70 is cut off and have a duration equal to the delay period.

The waveform at the plate of triode 70 is differentiated and somewhat attenuated by the network consisting of condenser 76 and resistors 77 and 79. The resultant waveform as applied to the grid of triode 78 is shown as Plot D of Fig. 2. This wave D is amplified in triode 78. The positive going portion of wave D at the initiation of the delay period saturates triode 78 but the negative going trailing edge of the pulse from the plate of triode 70 at the end of the delay period cuts off triode 78 causing a large positive pulse to appear at its plate. The wave-form appearing at the plate of triode 78 is shown in Plot E of Fig. 2.

The cathode follower output tube 103 provides a low impedance output so that the shunt capacity in the cable connecting the trigger circuit with the engine analyzer's sweep circuit, and the shunt capacity in the analyzer's thyatron grid circuit will not load down the amplifier and reduce pulse amplitude. Condenser 105 removes from the output signal the high unipotential level that was supplied by the cathode follower. The output from the cathode of triode 103 is shown in Plot F of Fig. 2.

The positive pulse in the output shown in Plot F applied to the sweep thyatron 106 in the engine analyzer initiates a new sweep. The residual negative pulse pres-

ent at the cathode follower will not affect the operation of the thyatron.

It will be seen from Fig. 2 that the sawtooth voltage produced by the condenser 112 is initiated slightly before the beginning of the ignition pulse to be observed from the first left bank cylinder. The total time delay between the beginning of the ignition pulse from the third right cylinder and the beginning of the ignition pulse from the first left cylinder is 54° of crank shaft revolution or approximately 27 milliseconds. The delay provided by multivibrator 70—82 under the control of the delay switch section 34 is 24 milliseconds which corresponds approximately to 48° of crank shaft rotation. This means that the cathode ray tube trace will begin approximately 6° of crank shaft rotation or 3 milliseconds before the beginning of the ignition pattern of the first left cylinder which it is desired to observe.

As the ignition-observe switch section arm 44 is rotated, the arm 46 of delay change-over switch section 34 is rotated in synchronism therewith to always provide the necessary bias to the grid of tube 82 to produce the proper delay after the firing pattern of the preceding cylinder is applied to the plate of triode 70. If the ignition-observe switch section arm 44 were moved to observe the firing of a right bank cylinder the arm 46 of delay switch section 34 would be moved to provide a delay of 15 milliseconds instead of the 24 milliseconds used in the observation of a left bank cylinder.

If a vibration signal is to be observed, switches 51—60 are thrown to their right position which disconnects ignition observe switch section 32 from the vertical deflection plates 53 and connects the vibration observe switch section 31 through the vibration amplifier 52 to the plates 53. The cylinder to be observed is now selected by the position of the arm 43 of section 41.

The ignition pattern always occurs at one point of a cylinder cycle, but it may be desired to observe a vibration pattern at any point of a cylinder cycle to study such occurrences as intake valve closing, combustion, the exhaust stroke, exhaust valve closing, etc. Since the entire cycle for a cylinder is not shown on the time base appearing on screen 57, it becomes desirable to alter the rotational relation between arm 43 and arms 44—46. Differential 49 is provided for this purpose and knob 48 serves to set a difference in rotational angle between arm 43 and the other arms. Knob 48 may be calibrated to show the occurrence being studied (combustion, exhaust stroke or etc.), while knob 50 may be calibrated to show the cylinder being studied.

In using the trigger system herein disclosed with ignition systems having one ignition coil feeding the spark plugs of all cylinders through one or more distributors, it is required that the trigger section 33 be fed from the spark plug side of the distributor, as the circuit otherwise would be unable to separate the various spark plug signals on either the coil primary circuit or the secondary circuit on the coil side of the distributor. In many applications, however, the connections to the breaker points of the distributor for the observation signal and to the spark plugs for the synchronization signal would be more convenient than installing a rotating synchronizing generator.

It will be understood that the connection from the terminals 41 to the spark plug circuits could be made directly to the spark plugs 15 rather than to the coils 17 as shown in Fig. 1. However, since high voltage pulses are applied to the spark plugs 15, direct connections thereto necessitate the use of a step-down voltage divider which affects the ignition pattern. Moreover, easy access to a well insulated high voltage system is usually difficult to find.

The device could be used on an engine with a crankshaft having a variable angular velocity if a voltage properly varying with engine speed is applied to the potenti-

ometers 95 and 94 through the resistor 98 in place of the constant potential shown in Fig. 1.

While the embodiment of this invention set forth above employs an ignition pulse for triggering the time base of the analyzer, it will be understood that any changing physical characteristic associated with and bearing a time relation to a cylinder cycle may be used for this purpose. Such characteristics might include vibration, fuel injection, internal cylinder pressure and temperature. The triggering system herein disclosed is thus adaptable to a compression-ignition type of engine, the injection mechanisms being a convenient triggering means.

If the engine is provided with a dual ignition system, the performance of all the spark plugs could be observed by adding a second ignition-observe section to the switch of Fig. 1 with a wiper arm fixed for rotation with shaft 47. The contacts of this second ignition-observe section would be connected through a separate set of input terminals to the second set of spark plugs. The stationary contact of switch 60 would then be connected to the wiper arm of either of the ignition observe sections by a two position switch. With this arrangement the trigger pulses would be provided from the original set of spark plugs with either set under observation.

While it is desirable to have the time base sweep on screen 57 triggered as short a time as possible before the occurrence of the beginning of the pattern to be observed, it is possible that in some engines, the preceding spark plug firing might occur less than the desirable period (here taken as 3 milliseconds) before the observed pattern. In such case the trigger pulse could advantageously be derived from the circuit of the spark plug immediately preceding by two (or more if necessary) of the observed pattern.

It will further be understood by those skilled in the art that the trigger circuit herein disclosed and consisting of switch sections 31, 32, 33 and 34 and the circuitry associated with triode 70, 82, 78 and 103 could either be incorporated in a complete engine analyzer component along with the cathode ray tube, the amplifying and sweep circuits, or said trigger circuit could be manufactured as a separate unit to be interconnected with and used with a separate analyzer normally employing the output of a rotating wave generator to achieve synchronization. Input terminals 49 and 41 would normally be prongs of a jack into which a cable plug would fit, the cable would contain the wires connected to the plugs 15 and the vibration pickups 21.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A trigger delay circuit including at least observe and trigger switch means, each having an equal plurality of contacts and a wiper arranged to selectively make connection with any of its associated contacts, a first plurality of input terminals each of which is connected to a different contact on each of said observe and trigger switch means, a first output terminal connected to the wiper of said observe switch means, a delay means connected to the wiper of said trigger switch means, a second output terminal connected to the output of said delay means, ganging means connected to each of said wipers and arranged to move said observe wiper to any associated contact connected with a selected input terminal and to simultaneously connect the trigger wiper to a corresponding contact connected to a different input terminal, a delay switch including a plurality of contacts equal in number to the contacts on each of said switches and a wiper arranged to make connection with any of said last-mentioned contacts, said ganging means being arranged to

connect the wiper of said delay switch means to a contact corresponding to the contact connected by the wiper of the observe switch, the contacts of said delay switch being connected to said delay means so that said delay means provides one delay when said delay switch wiper connects with alternate contacts and another delay when said wiper connects with intermediate contacts, said delay means including a monostable multivibrator comprising two electron discharge devices each having a cathode plate and control electrode and in which the delay switch wiper is connected to the grid of one of said multivibrator tubes, and alternate contacts of said delay switch means being connected to one bias potential of the discharge devices and intermediate contacts of said delay switch means being connected to another bias potential of the discharge devices.

2. A method of analyzing the operation of an internal combustion engine having a plurality of alternately firing cylinders with unequal periods between successive firing cycles of a given duration for half the cylinders and of a duration different than the given duration for the other half of the cylinders comprising the steps of producing a pulse corresponding to a timed cyclic event associated with the cylinder firing immediately preceding the firing of the cylinder to be observed, delaying said pulse by a delay period of one duration for half the cylinders and another duration different than the one duration for the other half of the cylinders, initiating the production of a time base by the said delayed pulse, and displaying on the time base a changing physical characteristic of the cylinder chosen to be observed.

3. An engine analyzer for an engine wherein a plurality of successively firing cylinders have unequal time periods separating the occurrence of a characteristic of each cylinder operation to be observed, said engine analyzer comprising means adapted to be associated respectively with each of said cylinders for supplying a signal representing said characteristic, a cathode ray tube, an electrical circuit including a first switch for selectively coupling any one of said means to said tube, means for generating and applying a sweep wave to said tube, means including a second switch operable with said first switch for selecting the next previously fired cylinder to that chosen by the first switch and for supplying a control signal in timed relation to the occurrence of a preselected event in the cycle thereof for initiating an operation of said sweep wave generating means, and means operable with said switches for selectively effecting time delays of different but predetermined lengths between the occurrence of said control signals and the initiation of operation of said sweep wave generating means.

4. An engine analyzer for an engine wherein a plurality of successively firing cylinders have unequal time periods separating the occurrence of a characteristic of each cylinder operation to be observed, said engine analyzer comprising means adapted to be associated respectively with each of said cylinders for supplying a signal representative of said characteristic, a cathode ray tube, an electrical circuit for selectively coupling any one of said means to said tube, a sawtooth waveform generator for operating said tube, means for triggering said generator in accordance with a control signal corresponding to a timed cyclic event in the previously fired cylinder, and selective delay means for the control signal effecting time delays of different but predetermined lengths depending on the selected cylinder for operating said triggering means.

5. An engine analyzer comprising a set of terminals each adapted to be connected to a pickup associated with a different cylinder of an internal combustion engine and adapted to provide an electrical wave representative of one type of characteristic of the operating cycle of the observed cylinder, a sawtooth waveform generator, means for triggering said generator, means for obtaining a control signal for said triggering means corresponding to a timed cyclic event in the cylinder firing previously to the

observed cylinder, and means for providing a given time delay of one duration for half of the cylinders and a delay of a different duration for the other half of the cylinders between the occurrence of said control signal and the initiation of said sawtooth generator depending on the observed cylinder.

6. An engine analyzer comprising a set of terminals each adapted to be connected to a pickup associated with a different cylinder of an internal combustion engine and adapted to provide an electrical wave representative of one type of characteristic of the operating cycle of the observed cylinder, a cathode ray tube, a sawtooth wave generator for operating said tube, first switching means arranged to connect the terminal of the cylinder operating previously to the cylinder being observed for obtaining a control signal to control said wave generator, means for providing time delays of different but predetermined lengths between the occurrence of said control signal and the initiation of said sawtooth generator, and second switching means ganged to said first switching means arranged to connect the terminal of the cylinder being observed to said cathode ray tube.

7. An engine analyzer for an engine wherein a plurality of successively firing cylinders have unequal time periods separating the occurrence of a characteristic of each cylinder operation to be observed including a set of terminals each adapted to be connected to a pickup associated with a different cylinder of the engine to provide an electrical wave representative of one type of characteristic of the operating cycle of the associated cylinder, a cathode ray tube, a sawtooth waveform generator for operating said tube, a control circuit for said generator including two time delay circuits providing different time delayed operations of said control circuit, and cylinder selector means comprising a first switch connecting the control circuit to the terminal of the cylinder fired pre-

viously to the observed cylinder and a second switch ganged to the first switch including one of the time delay circuits in said control circuit depending on the cylinder chosen to be observed.

8. A trigger delay circuit including at least observe and trigger switch means, each having an equal plurality of contacts and a wiper arranged to selectively make connection with any of its associated contacts, a first plurality of input terminals each of which is connected to a different contact on each of said observe and trigger switch means, a first output terminal connected to the wiper of said observe switch means, a delay means connected to the wiper of said trigger switch means, a second output terminal connected to the output of said delay means, ganging means connected to each of said wipers and arranged to move said observe wiper to any associated contact connected with a selected input terminal and to simultaneously connect the trigger wiper to a corresponding contact connected to a different input terminal, and a delay switch including a plurality of contacts equal in number to the contacts on each of said switches and a wiper arranged to make connection with any of said last-mentioned contacts, said ganging means being arranged to connect the wiper of said delay switch means to a contact corresponding to the contact connected by the wiper of the observe switch, the contacts of said delay switch being connected to said delay means so that said delay means provides one delay when said delay switch wiper connects with alternate contacts and another delay when said wiper connects with intermediate contacts.

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