Aug. 8, 1950 J. E. LINDBERG, JR., ET AL **2,518,427**

ENGINE POWER ANALYZER

Filed May 15, 1947 3 Sheets-Sheet 1

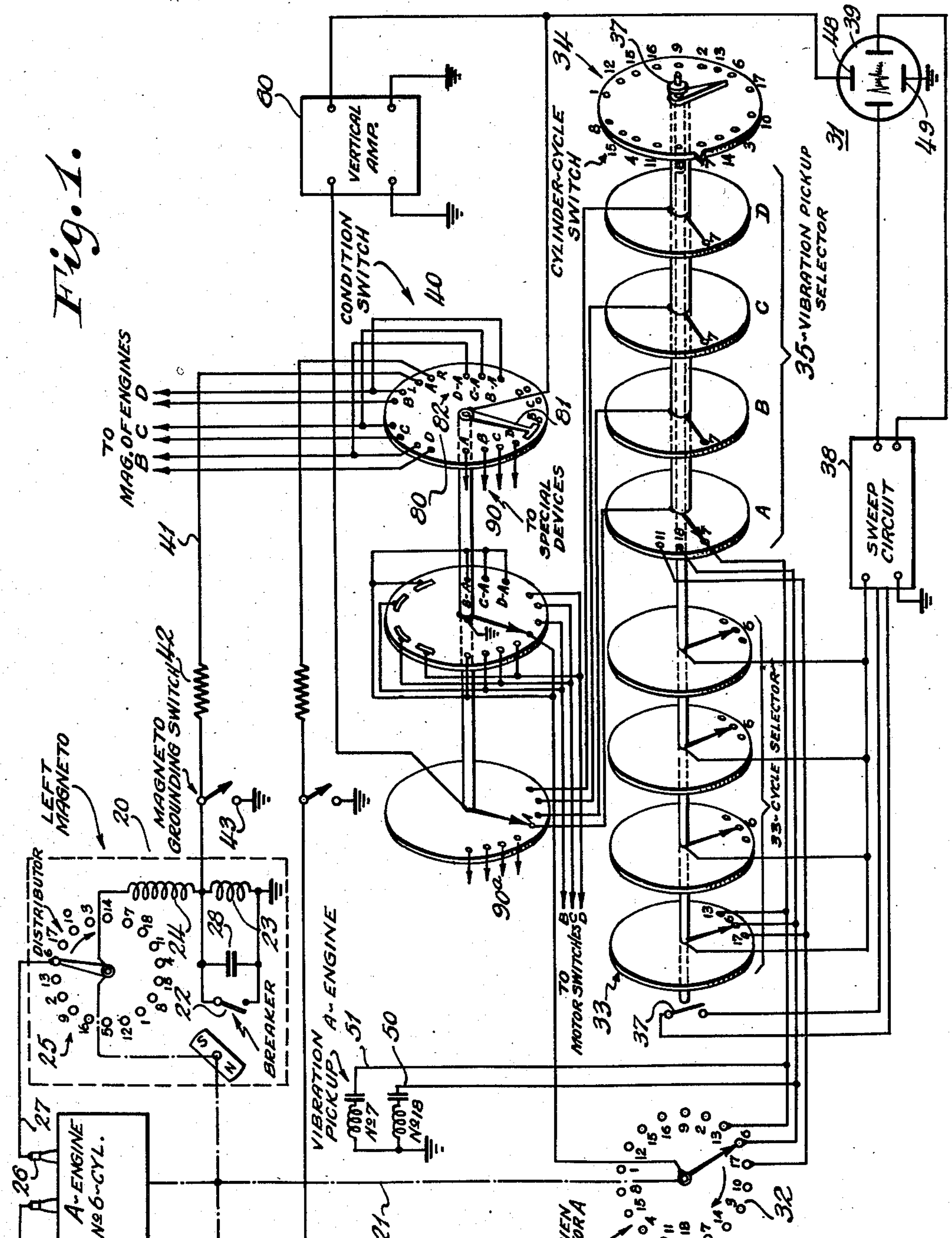

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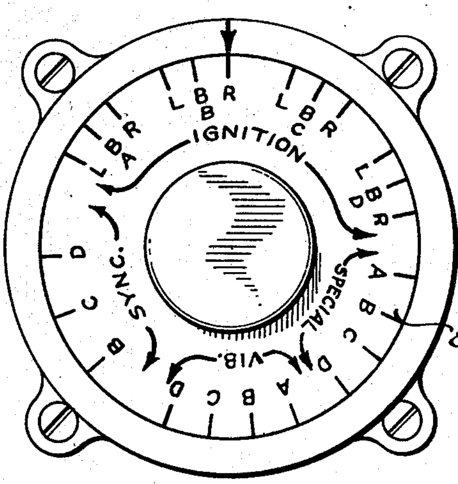
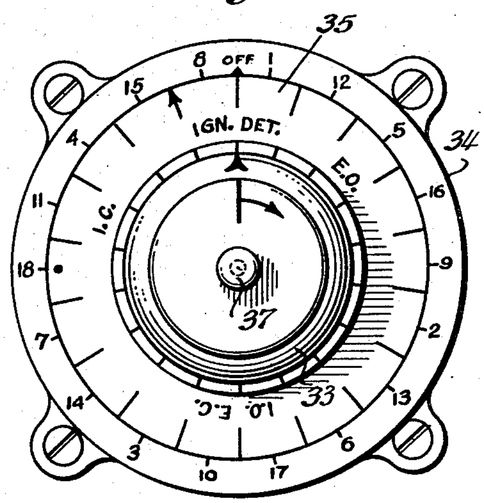
Fig. 2.



CONDITION SELECTOR SWITCH

Fig. 3.



CYLINDER CYCLE SWITCH

Fig. 3A.

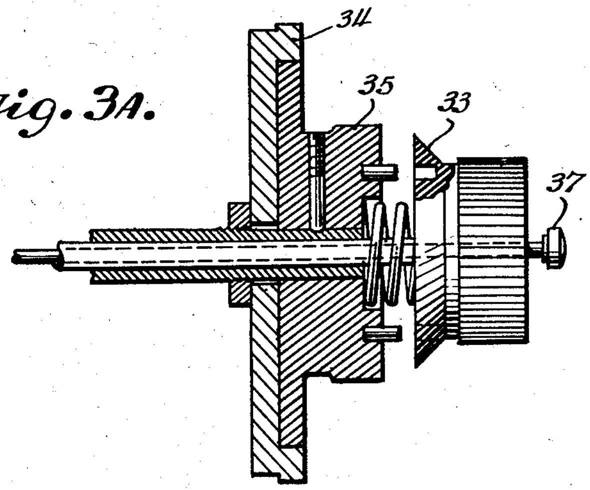


Fig. 5.

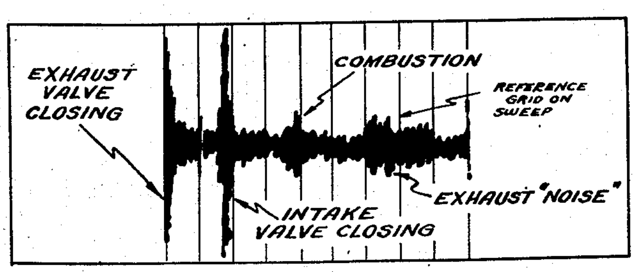


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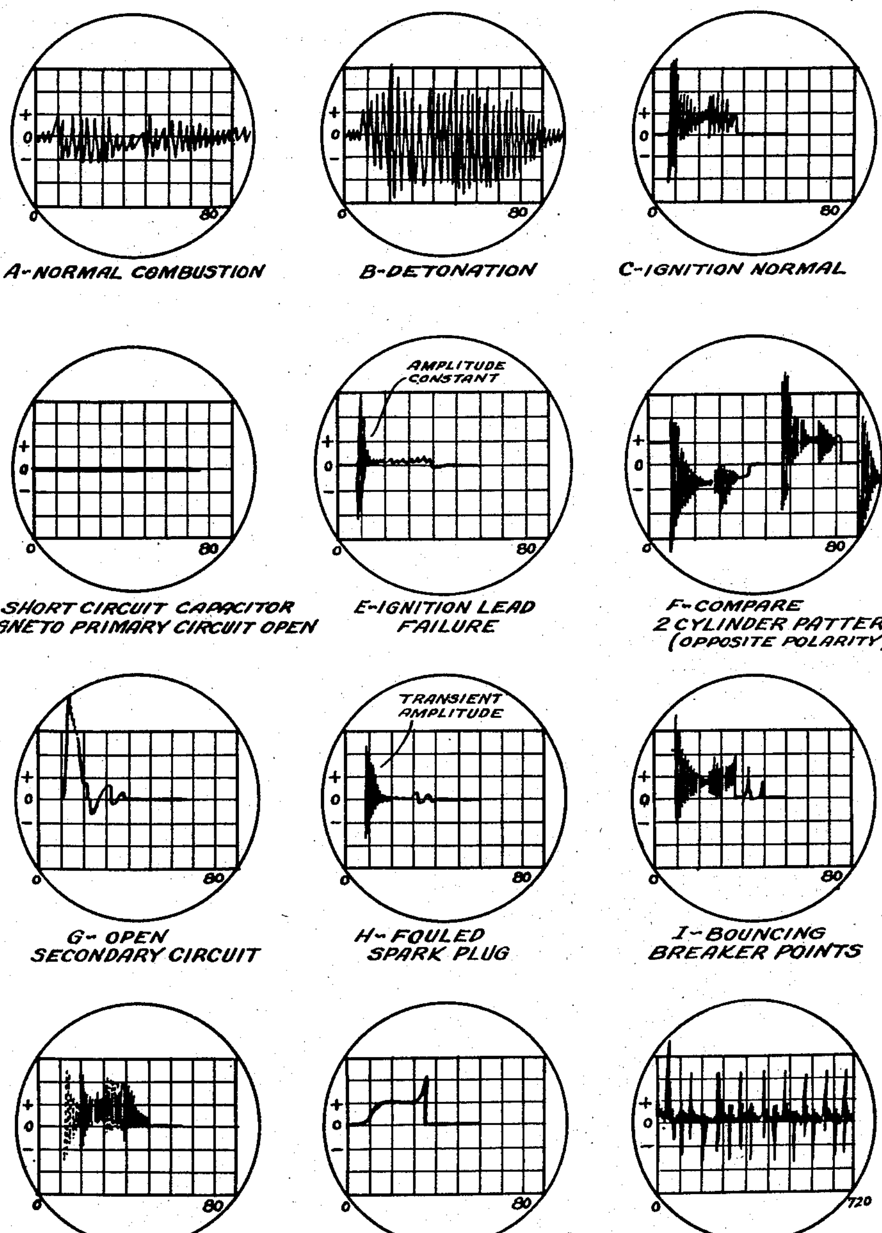
Fig. 4.



A-NORMAL COMBUSTION

B-DETONATION

C-IGNITION NORMAL

D-SHORT CIRCUIT CAPACITOR MAGNETO PRIMARY CIRCUIT OPEN

E-IGNITION LEAD FAILURE

F-COMPARE 2 CYLINDER PATTERNS (OPPOSITE POLARITY)

G-OPEN SECONDARY CIRCUIT

H-FOULED SPARK PLUG

I-BOUNCING BREAKER POINTS

J-MAGNETO NOT SYNCHRONIZED CONDITION SELECTOR SWITCH AT BOTH

K-OPEN PRIMARY CONDENSER

L-FULL 18 CYL. DIAGRAM

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2,518,427

ENGINE POWER ANALYZER

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Application May 15, 1947, Serial No. 748,286

16 Claims. (Cl. 175—183)

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This invention relates to improvements in apparatus and methods including means for analyzing power conditions of prime movers having particular reference to internal combustion engine analyzers for determining faults and operating conditions thereof in order to effectively maintain the operation of such engines at maximum power output and efficiency.

Although this invention permits the operation of internal combustion engines to better advantage, it has special value when used to analyze the operation of aircraft engines either singly or in multiple units, so as to determine their proper operation and capabilities.

For this reason the invention has been described herein specifically as applied to aircraft engines though the use thereof is in no wise thus limited.

The need for simple and accurate means for the detection and location of troubles which develop in aircraft engines has become increasingly apparent. Methods presently in use are at best approximate and inconclusive and have remained substantially unchanged since the beginning of the aircraft industry.

Presently known methods adapted to determine engine and power faults consist of, in most instances, trial and error expedients in which the diagnosis of faults depends upon the particular skill of the technician involved. These trial and error methods have been found to be completely inadequate when applied to the type of aircraft which are now in use because of the tremendous increase in the number of components which need to be analyzed and the difficulties which are thus encountered.

In the past few years, multi-cylinder engines of great power have come from the development laboratories for use in standard types of passenger and cargo aircraft. These engines run at high indicated pressures, and, in many instances, use dual ignition systems to attain increased fuel burning rates, and to obtain additive factors of safety in case of damage to one ignition system.

Although the failure of a spark plug in a given cylinder of an aircraft engine may merely result in a slight loss in power and perhaps a slight increase in engine vibration, the failure, however, of both spark plugs in a cylinder in an aircraft engine running at high output may eventually mean that the severe vibrational stresses engendered may affect a vital part of the engine. This, in turn, may well lead to the complete failure of the engine.

Moreover, it is often a tedious and time con-

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suming task for the technician to locate the source of trouble in an aircraft engine by means of the expedients presently available. For example, in a pursuit ship employing an 18-cylinder engine including 36 spark plugs, if the engine is running roughly, a routine inspection may lead the technician to believe that some of the spark plugs may be fouled. The technician proceeds, serially, to remove all of the plugs, physically to inspect them for fouling, and to replace what appears to be the defective plugs. This results in considerable loss of time and effort.

Again, this inspection may be useless, for the technician may find even after such inspection in search of a remedy that the difficulty is actually in some other component, for example, in the magneto or in the engine harness rather than in the spark plugs. Thus, it may be necessary to test the harness by means of a high tension voltage leakage check or a low tension continuity check. Further, these spark plugs may warrant inspection in a high pressure chamber for cracked porcelain, fouling, etc.

It is apparent, therefore, that as the size, speed and cost of aircraft increase, the need for keeping the engines operative becomes increasingly important, for, it has been determined that the loss of even one 10-hour period of flight utilization for a multiple engine type of aircraft reaches many thousands of dollars in income loss.

The present invention discloses in a preferred embodiment quick, accurate, portable, and airborne means for determining the operating condition of each component of the ignition system of an aircraft engine without disturbing the engine's electrical wiring, or in any way affecting its performance while in flight.

The present apparatus provides continuous analysis of complete aircraft power plants either on the ground and/or in flight. Thus, the analyzer which includes pictorial indicating means enables an aircraft flight engineer to obtain a complete, visual and overall picture of the operating conditions of the craft's engines at any time during flight. By means of the indicator, predetermined electrical delineations or characterizing patterns are observed representing conditions of engine vibration, ignition system performance, mixture distribution, engine and magneto synchronization, engine roughness and, when desired, hydraulic and/or electrical associated accessories.

From these characteristic patterns, the flight engineer may detect, locate and identify malfunctions and/or any of the above-mentioned engine failures which may occur during the operation of the power plants. Moreover, these patterns are available either for an individual cylinder or simultaneously for all cylinders in a power plant in order to permit the immediate location of the fault and/or adjustment of the power plant for optimum performance.

Thus, an important feature of the present invention is the means offered for obtaining comparison data between separate components of the aircraft whereby all portions of an engine cycle may be immediately utilized so as to determine the nature of the operative conditions present.

The prime object, therefore, of the present invention is to provide simple and complete means for analyzing all types of engine faults and for detecting imperfect performance in either single engines or in multiple engine combinations of power plants.

Another object of this invention is to allow for the detection and location of engine ignition faults.

A further object of the invention is to detect and locate fuel injection, carburetor or air induction system failures.

A still further object of the invention is to make possible means for checking the timing and synchronization of all magnetos on an internal combustion engine.

Yet another object of the invention is to allow for the determination of synchronization and phasing in multiple engine installations so that engines which are over or under speed may be brought to synchronization or into phase.

A further object of the invention is to make possible the positioning of a crankshaft in any desired engine cycle position so as to avoid hydraulic lock following shut down of the engine and/or to place the crankshaft in proper cyclic position to permit various maintenance adjustments to be made.

Still another object of the invention is to make possible remote detection of engine roughness.

Yet another object of the invention is to make possible detection and location of detonation in any cylinder of the power plant.

A further object of the invention is to determine the place of failure or misadjustment of a valve system of an engine.

The invention in another of its aspects relates to novel features of the instrumentalities described herein for achieving the principal objects of the invention and to novel principles employed in those instrumentalities, whether or not these features and principles are used for the said principal objects or in the said field.

Other objects of the invention and the nature thereof will become apparent from the following description considered in connection with the accompanying drawings, wherein like reference characters describe elements of similar function, and the scope of the invention is determined from the appended claims.

Referring to the drawings:

Fig. 1 is a schematic wiring diagram of a power plant analyzer system illustrative of a preferred embodiment of the present invention;

Figs. 2 and 3 are illustrations of the faces of the condition selector and cylinder cycle selector switches used in the present embodiment of the invention;

Fig. 3A is a cross sectional view of the cylinder cycle selector switch;

Fig. 4 illustrates characteristic patterns formed on the indicator of the engine analyzer for various engine conditions; and

Fig. 5 is a vibration diagram used to determine exhaust valve closing.

The novel power plant analyzer, hereinafter described, uses a cathode ray tube indicator to plot the primary magneto voltage or vibration pickup voltage of a craft's engines as the ordinate of a graph and plots timing degrees of the engine as the abscissa of the same graph.

To provide accuracy in analysis, the abscissa of the graph is at all times synchronized with the actual rotational position of the engine crankshaft by means of a trip action sweep generator circuit controlled by means of individual engine driven switches.

Although this synchronization of the actual rotational position of the engine crankshaft with the sweep generator has been illustratively shown as being dependent on the number of selector points included by the engine driven switch, it is not intended to limit the mode or means of synchronization thereto but to include as well other means by which substantially continuous synchronization may be obtained for any rotational position of the engine crankshaft.

In Fig. 1 there is illustrated a preferred embodiment of the engine power analyzer as used in an aircraft having four eighteen-cylinder engines with dual ignition, although it will be apparent that the invention may be applied with advantage to any cyclically operable power plant. The dual ignition system is indicated schematically in the drawing as right and left magnetos. However, an explanation of the invention in conjunction with left magneto **20** is deemed sufficient to disclose its manner of operation with any conventional ignition system.

Magneto **20** is a standard well-known unit. The type shown is diagrammatic of the rotating permanent magnet type. The distributor **25** is driven by engine and magneto gearing at one-half engine speed. Rotation of the permanent magnet induces current flow in the primary coil **23** when the breaker points **22** are closed. At a timed point of maximum current flow in the primary winding **23** the breaker points **22** are opened inducing a high voltage in the secondary coil winding **24** causing a high voltage current flow across the gap of the distributor **25** and across the gap of the spark plug **26** selected by the distributor.

The electrical impedances of spark plug **26**, spark plug leads **27**, and distributor **25**, as well as the condition of breaker points **22** and breaker point condenser **28** will all effect the voltages which appear initially across primary coil **23** and subsequently thereacross by reflection.

In many instances both the primary and secondary coils **23** and **24**, respectively, are wound about a common core. However, this type of winding may not be required since the voltages induced in the secondary coil do not necessarily require a common core relationship or connection.

By observing the wave shape and voltage across the primary winding **23** of magneto **20**, the condition of the various impedance elements enumerated above may be determined for purposes of ignition analysis; also analysis of combustion conditions may be made in certain cases (since the impedance vs. crank angle across the spark plug **26** is affected in an unique manner by mixture distribution, turbulence, detonation, etc. in its cylinder). For certain other analysis vibration pickups such as **50** and **51** are mounted on each cylinder and the voltage output of these vibration pickups is selectively studied to analyze conditions in the various cylinders.

To do these analyses there is provided a cathode ray indicator tube 31 having a screen 39 on which a voltage vs. time graph of a chosen phase of engine function may be studied, for example, detonation. (See Figs. 4A and 4B).

A voltage which is indicative of the studied condition appears as a vertical deviation that represents an ordinate of the graph. The abscissa of this graph is a horizontal type sweep generated as hereinafter discussed.

A multiple selector point engine driven switch 32, whose rotation may be conveniently converted into time or degrees of engine crank shaft rotation, is individually provided for each engine of the power plant.

Engine driven switch 32 may be mounted at each engine on the spare tachometer drive or other convenient point, and is, as stated, driven at one-half engine speed; i. e., one complete engine switch cycle per engine cycle. Switch 32 may further be conveniently designed so as to have as many selector points 1—18 as there are cylinders for the engine.

As designed, selector points 1—18 will be arranged in cylinder firing order and are so geared and timed to the engine under observation so as to make effective contact once with each selector point corresponding to a cylinder at the same chosen cyclic position for each cylinder as the engine rotates through a complete cycle.

Thus in the preferred embodiment, switch 32 has been timed so that contact is made for each cylinder selector point 40 degrees before top dead center of its cylinder power stroke.

Engine driven switch 32 is used to trigger a time base circuit 38 which initiates a time base sweep across the screen of cathode ray tube 31 only when effective contact is made with a predetermined selector point, as described below.

This engine driven switch 32 is connected to section 33 of another switch. Section 33 is the cycle selecting portion of a coaxial type, multiunit, cylinder cycle selector switch 34 (more fully shown in Figs. 3 and 3A).

The cycle selecting portion 33 of switch 34 selects the point in the engine timing diagram at which the cathode ray tube horizontal sweep will be initiated and therefore determines the initial point of the timing diagram to appear on the screen. When studying patterns of magneto primary voltage versus engine timing degrees the cycle selector portion 33 of switch 34 selects the cylinder ignition pattern it is desired to study as indicated by the cycle selector pointer.

When cylinder vibrations are being studied the cylinder (vibration pickup) selecting portion 35 of switch 34 selects any chosen cylinder vibration pickup for observation, and the cycle selecting portion 33 of switch 34 then determines the portion of the engine cycle diagram to appear on the screen 39. The engine driven switch 32 and the cycle selector switch 33 both have their segments numbered in firing order of the engine and corresponding numbered points are connected as shown in Fig. 1.

By means of the cycle selecting portion 33 of the switch 34, any one of the spaced selector points on the engine driven switch 32 which is to initiate a time base synchronizing pulse just immediately prior to ignition in the selected cylinder may be determined and chosen.

For example, on an eighteen cylinder engine, the circuit has been so designed to generate a sweep across the tube in 1/9 of a complete cycle at cruising engine speed. By means of altering the time constant in sweep circuit 38, as by means of including a capacitance in parallel with the sweep circuit, the sweeping beam speed may be varied so that it traverses a sweep across the screen once for each engine cycle. Physically, this is accomplished by utilizing push button switch 37.

Because the point of initiation of the cathode-ray tube sweep is timed to the engine and is selected and known, and since the sweep rate is selected, a horizontal grid of engine timing degrees can be provided on the screen 39 of the cathode-ray tube as shown in Fig. 4. This grid may also provide a vertical scale calibrated in voltage. In Fig. 5 an alternate method of providing a reference horizontal grid scale is shown. Here a 720° vibration pickup pattern is shown for a selected cylinder. The cycle selector has been placed at exhaust valve closing; therefore the pattern is initiated with the pattern of exhaust valve closing. Vertical lines or pips occur every 40° along the horizontal scale caused by a slight pulse capacitively induced into the vibration pickup circuit each time engine driven switch 32 touches each of its segments. These pips serve as an excellent horizontal scale reference grid which expands or contracts with the sweep speed to give always a true reference grid of crank angle degrees on the horizontal sweep.

Provision may be made for locking the cycle selecting portion 33 of switch 34 to the cylinder vibration pickup selecting portion 35 of switch 34, as by means of a friction coupling, or by means of a pin, as shown in Fig. 3A, so that both switches may be rotated simultaneously, affording opportunity for observing one particular function (such as combustion) on each cylinder in turn.

A condition selector switch 40, also a multiunit type of switch, is used to select for observation the desired engine of the aircraft and the condition for which the performance of the engine is to be tested and analyzed. By means thereof, voltage representations indicative of such operative conditions are placed directly on the vertical deflection plates of the indicator cathode ray tube 31.

By means of electrical conducting lead wires 41, condition selector switch 40 is connected to any desired magneto primary through to ground. In each of the electrical circuits connecting condition selector switch 40 to the primary of a magneto, there is placed a protective resistor 42 which is usually placed at each magneto grounding switch 43 in the flight control panel of an aircraft.

These resistors are important in that they protect the engines of the power plant from being affected in any way by any possible fault, including a complete electrical short circuit developed in the analyzer.

Since the analyzer is essentially a voltage measuring system operating at a very high impedance, it is not appreciably affected by the series protective resistor which is usually about 3,000 ohms.

As stated, the magneto primary voltage is applied directly through resistor 42 to the upper vertical deflection plate 48 of the cathode ray tube. The lower vertical deflection plate 49 of the cathode ray tube is here shown as being grounded.

Since there is no discriminating circuit or vertical amplifier in this circuit, it is assured that any change in the ignition pattern viewed on the cathode ray tube screen 39 is a true picture of the voltage characteristics of the primary circuit of the magneto and that such characteristics are not due to some extraneous fault which might have occurred in a discriminator circuit or a vertical amplifier, if included.

Thus, individually, it is the condition selector switch 40 which properly selects the condition desired to be analyzed and it is the cylinder cycle switch 34 which determines the cylinder and phase of the cylinder cycle for which the selected condition is to be tested.

A voltage pattern indicative of such condition and of such cyclic portion of a selected cylinder is, by means of these switches placed upon a cathode ray tube whose horizontal sweep is synchronized and triggered by its associated engine driven switch 32.

Again, when analyzing ignition patterns, if it is desired that several cylinders be placed under observation on the horizontal base of the cathode ray tube, as for comparison or other purposes, the sweep circuit constants are adjusted so as to alter the sweep duration and thus enable the several patterns for the individual cylinders to be read thereon.

By referring to Fig. 2, it is observed that the condition selector switch has been divided into separate sections according to the power plant function desired to be studied. The switch has four sections marked respectively: Ignition, Sync (synchronization), Vib (vibration analysis) and Special (external analysis).

The present engine power analyzer includes the use of vibration or detonation pickups such as 50, 51 for all or part of the cylinders of the aircraft engine. Such pickups are now known in the art, a preferred form being shown in the application to Lancor, Serial No. 517,657. These pickups are connected to condition selector switch 40 through the cylinder selector portion 35 of the cylinder cycle switch 34. This provides means for selecting any particular vibration pickup for vibration analysis and for placing its voltage output on the indicator screen for characterization study.

To do this, however, it may be necessary to utilize a vertical amplifier 60 in order to obtain sufficient vertical deflection on the indicator screen 39.

As shown, the vibration pickups may be capacitively coupled to the wires connecting cycle selector switch 32 with its corresponding engine driven switch 32 so that only one set of wires would have to be run from each engine to the cylinder-cycle selector switch. The vibration pickups of cylinders in firing order are connected to the conductors at their engine driven switch; however all vibration pickup connections are offset by a given number of cylinders as shown in Fig. 1 so that the synchronizing pulse engine driven switch pulse will not blank an important section of the vibration pickup pattern. The corresponding connections are made between the cylinder (vibration pickup) selector switch 35 and the conductors at the switch 33 to thus complete the connection from each vibration pickup to its corresponding switch section 35. In lieu of the above, separate direct conductors could be run from each cylinder vibration pickup to its corresponding point on the switch 35.

The system of ignition analysis described is based on the fact that any departure from the normal operation of the ignition system will alter the shape of the voltage vs. time graph placed on the cathode ray tube screen 39. Likewise, each type of engine failure or trouble will produce its own characteristic voltage vs. time diagram.

By observing these characteristic patterns, it is possible to detect and locate many such engine faults as:

(a) Fouled spark plug
(b) Open circuit in any part of ignition system
(c) Short circuit in any part of ignition system
(d) Shorted or open magneto primary condensers
(e) Shorted magneto secondary condenser
(f) Improper breaker point adjustment
(g) Bouncing breaker points
(h) Excessively large or very small spark plug gaps
(i) Low output magnetos
(j) Proper E-gapsetting—on ground only with breaker points accessible.

Several of these characteristic patterns have been illustrated and labelled in Figs. 4A to 4L.

The extreme versatility and range of the power analyzer may be evident from the many other operating conditions that may be predeterminedly selected for study in accordance with the switch positions on both the condition selector switch 40 and the cylinder cycle selector switch 34. In this way many operational difficulties may be preliminarily located and often anticipated prior to actual occurrence.

As a further utilization of the "ignition" section 80 of switch 40 the characteristic patterns for both magnetos of any engine, here illustrated as A, may be placed for comparison purposes upon the screen of the cathode ray tube indicator.

Since, as stated, the sweep of the cathode ray tube indicator may be calibrated in terms of degrees, this comparison may be effectively determined as a differential in degrees in operating conditions of both magnetos.

To do this, arm 81 of the condition selection switch is adapted so that it may connect either one or both of the magneto contacts L, R. If the switch connects both contacts L, R, the left and right magnetos will have their characteristic ignition patterns placed on the indicator screen 39 simultaneously.

By this means the failure of either magneto to fire its respective spark plugs in synchronism with the other is determinable. For, if both magnetos are synchronized the characteristic patterns of the magnetos will appear superimposed on each other. If there is any mistiming in the firing of the magnetos the degree of crankshaft deviation and the leading magneto is determined.

Further, many other operative conditions are determinable with the engine analyzer. By use of the analyzer it has been found that the lack of combustion in any cylinder will alter the shape of the ignition voltage-time diagram.

This is apparently caused by the lack of ionization in the combustion chamber in the absence of combustion. If valve operation is known to be satisfactory, it is substantially certain that the lack of combustion in the presence of ignition in a fuel injection engine is caused by injector failure.

Tests in flight have shown that the ignition patterns are changed in a very readable manner by carburetor mixture changes and by power changes which have an effect on distribution. Further, it was found that in a small laboratory engine, detonation could be detected by noting large vertical pips in the combustion portion of the ignition pattern which accompanied audible detonation.

Again, turning to the synchronizer section 82 of condition selector switch 40, as shown on the face of Fig. 2, the cathode ray tube horizontal sweep may be locked with the A engine as standard. By placing ignition energy from any other engine switch such as D on the vertical deflecting plates of the cathode ray tube the synchronization between these engines can be checked.

If the ignition pattern of the D engine is stationary then D and A are synchronized.

If, however, the ignition pattern moves to the left the D engine is overspeed. If the pattern moves to the right then D engine is underspeed. The rate of movement is an indication of the rate of over or underspeed of the D engine with respect to the A engine.

In this manner each of the aircraft engines may be synchronized very accurately and simply against A engine as standard.

Since the engine driven switch 32 and the magneto breaker points 22 are driven from different gear train points, each of which has inertia and gear back-lash, engine roughness will cause an oscillating phase difference between these two gear train points which will result in a horizontal oscillation of the ignition pattern viewed on the screen. This provides a good roughness indication as it gives the operator the same impression as direct observation of a rough engine.

Such a roughness indication is of particular value in modern aircraft engine installations in which the engine is submerged inside of a fixed cowl or duct and thus cannot be directly observed.

Engine driven switch 32 and cylinder cycle selector switch 34 make it possible for the flight or ground crew to position any engine in any chosen crankshaft engine cycle position. This enables an aircraft crew always to position the engine to that point which is least likely to result in hydraulic lock in the engine when left idle for some length of time.

The procedure used is to place the cylinder cycle selector switch 34 in the engine cycle position at which it is desired to leave the engine and then turn the engine around manually or by means of the starter until a horizontal sweep appears on the screen.

This procedure can also be of use as a position indicating device to permit the engine to be turned to certain desired cyclic positions while doing maintenance work on the engine.

Further, the cyclic position of the engine can always be checked by rotating the cylinder cycle selector switch 34 until the indicator tube sweeps and then reading the position of the cycle selector switch.

When starting aircraft engines as precaution against hydraulic lock, it is standard practice to turn the engine over one complete revolution prior to starting the engine. At present, propeller blade rotation is counted to indicate when the engine has completed one engine cycle.

With the engine analyzer this procedure can be simplified by rotating the engine until two successive sweeps occur on the analyzer to indicate that the engine has completed at least one cycle.

As discussed previously, by means of condition selector switch 40 the cylinder vibration characteristics of any engine may be selected for analysis; by means of the cylinder selector portion 35 of the cylinder cycle selector switch any cylinder vibration pick-up on that engine may be studied.

As shown in Fig. 3A, the analyzer is provided with a cylinder cycle timing disc 35 which indicates the selected cylinder. Thus, cycle selector switch 33 can be turned to any cylinder cycle event as marked on the dial and a characteristic pattern broken down as shown in Fig. 5.

For example, to study the vibration caused by exhaust valve closings, the cycle selector would be pointed at "E. C." on the dial as shown in Fig. 3 and the expanded pattern of the exhaust valve closing vibration would appear on the indicator screen for study. By pushing on the sweep control push button 37 the complete 720° vibration pattern appears on the screen, as shown in Fig. 5 started on the left by the vibration energy of the exhaust valve closing.

After selecting with the cycle-selector switch 33 the particular part of the vibration cycle for study, the cycle selector can be pressed to engage a lock with the cylinder selector 35, as shown in Fig. 3A, and the two selector switches turned in locked phase relation to allow successive study on the screen of the same condition and the identical phase of the cycle in each of the cylinders in their firing order.

For the analysis of faults in the hydraulic and electrical accessories of the power plant, external jack points 90 and 90*a* (for voltages requiring amplification) are provided on the condition selector switch 40 marked "special" to choose and analyze the time function curve of these units. From electrical accessories and circuits, representative voltage energy is applied to the vertical deflecting plates of the indicator. For hydraulic accessories the pressure to an electric pickup is used to provide a voltage that can be applied to the vertical deflection plates of the indicator. The resulting pressure or voltage vs. time curves show existing accessory faults.

The uses of the power analyzer, as detailed above, are merely illustrative and not exhaustive and since many changes could be made in the above construction and many apparently widely different embodiments of the 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. An ignition system analyzer for an internal combustion engine including a cathode ray tube, vertical and horizontal deflection means for the electron beam in said tube, means to impress signals from all spark plugs of the engine seriatim on said vertical deflection means, a sweep voltage generating device to impress deflecting voltages on said horizontal deflection means, and means to initiate the operation of the sweep generating device selectively at any desired point in an engine cycle.

2. An ignition system analyzer for an internal combustion engine including a cathode ray tube, vertical and horizontal deflection means for the electron beam in said tube, means to impress signals from all spark plugs of the engine seriatim on said vertical deflection means, a sweep voltage generating device to impress deflecting voltages on said horizontal deflection means, and means to initiate the operation of the sweep generating device selectively at any desired point in an engine cycle, said last-recited means comprising a potential source adapted when connected to the sweep circuit to initiate its operation, a multiple contact switch having a contact for each engine

cylinder arranged in cylinder firing order, a wiper arm for said switch connected to said potential source and arranged to wipe each contact during each engine cycle, a second switch having contacts corresponding to and connected to the contacts of the first switch, a wiper arm for said second switch connected to said sweep circuit, and means to selectively engage the wiper arm of the second switch with any of its contacts.

3. An ignition system analyzer for an internal combustion engine including a cathode ray tube, vertical and horizontal deflection means for the electron beam in said tube, means to impress signals from all spark plugs of the engine seriatim on said vertical deflection means, a sweep voltage generating device to impress deflecting voltages on said horizontal deflection means, the time constant of said sweep generating device being such that a spark plug firing is completed during the electron beam trace, means to vary the time constant of the sweep generating device whereby an engine cycle is completed during the electron beam trace, and means to initiate the operation of the sweep generating device selectively at any desired point in an engine cycle, said last-recited means comprising a potential source adapted when connected to the sweep circuit to initiate its operation, a multiple contact switch having a contact for each engine cylinder arranged in cylinder firing order, a wiper arm for said switch connected to said potential source and arranged to wipe each contact during each engine cycle, a second switch having contacts corresponding to and connected to the contacts of the first switch, a wiper arm for said second switch connected to said sweep circuit, and means selectively to engage the wiper arm of the second switch with any of its contacts.

4. A vibration analyzer for an internal combustion engine having a vibration pickup device mounted on each cylinder thereof, said analyzer including a cathode ray tube, vertical and horizontal deflection means for the electron beam in said tube, means to impress signals from the vibration pickup devices seriatim on said vertical deflection means, a sweep voltage generating device to impress deflecting voltages on said horizontal deflection means, and means to initiate the operation of the sweep generating device selectively at any desired point in an engine cycle.

5. A vibration analyzer for an internal combustion engine having a vibration pickup device mounted on each cylinder thereof, said analyzer including a cathode ray tube, vertical and horizontal deflection means for the electron beam in said tube, means to impress signals from the vibration pickup devices seriatim on said vertical deflection means, a sweep voltage generating device to impress deflecting voltages on said horizontal deflection means, and means to initiate the operation of the sweep generating device selectively at any desired point in an engine cycle, said last-recited means comprising a potential source adapted when connected to the sweep circuit to initiate its operation, a multiple contact switch having a contact for each engine cylinder arranged in cylinder firing order, a wiper arm for said switch connected to said potential source and arranged to wipe each contact during each engine cycle, a second switch having contacts corresponding to and connected to the contacts of the first switch, a wiper arm for said second switch connected to said sweep circuit, and means selectively to engage the wiper arm of the second switch with any of its contacts.

6. A vibration analyzer for an internal combustion engine having a vibration pickup device mounted on each cylinder thereof, said analyzer including a cathode ray tube, vertical and horizontal deflection means for the electron beam in said tube, means to impress signals from the vibration pickup devices seriatim on said vertical deflection means, a sweep voltage generating device to impress deflecting voltages on said horizontal deflection means, the time constant of said sweep generating device being such that a predetermined fraction of an engine cycle is completed during the electron beam trace, means to vary the time constant of the sweep generating device whereby an engine cycle is completed during the electron beam trace, and means to initiate the operation of the sweep generating device selectively at any desired point in an engine cycle, said last-recited means comprising a potential source adapted when connected to the sweep circuit to initiate its operation, a multiple contact switch having a contact for each engine cylinder arranged in cylinder firing order, a wiper arm for said switch connected to said potential source and arranged to wipe each contact during each engine cycle, a second switch having contacts corresponding to and connected to the contacts of the first switch, a wiper arm for said second switch connected to said sweep circuit and means selectively to engage the wiper arm of the second switch with any of its contacts.

7. A vibration analyzer for a cyclically operable engine having a vibration pickup device mounted thereon, said analyzer including a cathode ray tube, first coordinate and second coordinate deflection means for the electron beam in said tube, means to impress signals from the vibration pickup device on one of said deflection means, a sweep voltage generating device to impress deflecting voltages on the other of said deflection means, and means to initiate the operation of the sweep generating device selectively at any desired point in an engine cycle.

8. A performance analyzer for a cyclically operable engine including a cathode ray tube, first coordinate and second coordinate deflection means for the electron beam in said tube, means to impress signals from the firing means of the engine on one of said deflection means, a sweep voltage generating device to impress deflecting voltages on the other of said deflection means, and means to initiate the operation of the sweep generating device selectively at any desired point in an engine cycle.

9. A performance analyzer for a cyclically operable engine including a cathode ray tube, first coordinate and second coordinate deflection means for the electron beam in said tube, engine driven means to impress signals from the firing means of the engine on one of said deflection means, a sweep voltage generating device to impress deflecting voltages on the other of said deflection means, and engine driven means to initiate the operation of the sweep generating device selectively at any desired point in an engine cycle.

10. An ignition system analyzer for an internal combustion engine including a cathode ray tube, first coordinate and second coordinate deflection means for the electron beam in said tube, means to impress signals from all spark plugs of the engine seriatim on one of the deflection means, a sweep voltage generating device to impress deflecting voltages on the other deflection means, the time constant of the sweep generating device being such that a spark plug firing is completed

during the electron beam trace, means to vary the time constant of the sweep generating device whereby an engine cycle is completed during the electron beam trace, and means to initiate the operation of the sweep generating device selectively at any desired point in an engine cycle.

11. A vibration analyzer for an internal combustion engine having a vibration pickup device mounted on each cylinder thereof, said analyzer including a cathode ray tube, first coordinate and second coordinate deflection means for the electron beam in said tube, means to impress signals from the vibration pickup devices seriatim on one of the deflection means, a sweep voltage generating device to impress deflecting voltages on the other deflection means, the time constant of the sweep generating device being such that a predetermined fraction of an engine cycle is completed during the electron beam trace, means to vary the time constant of the sweep generating device whereby an engine cycle is completed during the electron beam trace, and means to initiate the operation of the sweep generating device selectively at any desired point in an engine cycle.

12. A performance analyzer for an internal combustion engine having a plurality of signal pickup devices mounted thereon, said analyzer including a cathode ray tube, first coordinate and second coordinate deflection means for the electron beam in said tube, means to impress signals from the pickup devices seriatim on one of the deflection means, a sweep voltage generating device to impress deflecting voltages on the other deflection means, the time constant of the sweep generating device being such that a predetermined fraction of an engine cycle is completed during the electron beam trace, means to vary the time constant of the sweep generating device whereby an engine cycle is completed during the electron beam trace, and means to initiate the operation of the sweep generating device selectively at any desired point in an engine cycle.

13. An ignition system analyzer for a cyclically operable engine including a cathode ray tube, first coordinate and second coordinate deflection means for the electron beam in said tube, means to impress signals from all spark plugs of the engine seriatim on one of said deflection means, a sweep voltage generating device to impress deflecting voltages on the other of said deflection means, and means to initiate the operation of the sweep generating device selectively at any desired point in an engine cycle, said last recited means comprising engine driven means to transmit a sweep initiating signal at a predetermined point in the combustion cycle of each engine cylinder, and means selectively to apply said initiating signals to the sweep generating device.

14. An ignition system analyzer for an internal combustion engine including a cathode ray tube, first coordinate and second coordinate deflection means for the electron beam in said tube, means to impress signals from all spark plugs of the engine seriatim on one of the deflection means, a sweep voltage generating device to impress deflecting voltages on the other deflection means, the time constant of the sweep generating device being such that a spark plug firing is completed during the electron beam trace, means to vary the time constant of the sweep generating device whereby an engine cycle is completed during the electron beam trace, and means to initiate the operation of the sweep generating device selectively at any desired point in an engine cycle, said last recited means comprising engine driven means to transmit a sweep initiating signal at a predetermined point in the combustion cycle of each engine cylinder, and means selectively to apply said initiating signals to the sweep generating device.

15. An ignition system analyzer including a cathode ray tube, first coordinate and second coordinate deflection means for the electron beam in said tube, means to impress signals from the ignition system on one of said deflection means, a sweep voltage generating device to impress deflecting voltages on the other of said deflection means, and means to initiate the operation of the sweep generating device selectively at any desired point in an ignition system cycle.

16. A performance analyzer for an engine having signal pickup means mounted thereon, said analyzer including a cathode ray tube, first coordinate and second coordinate deflection means for the electron beam in said tube, means to impress signals from the signal pickup means on one of said deflection means, a sweep voltage generating device to impress deflecting voltages on the other of said deflection means, and means to initiate the operation of the sweep generating device selectively at any desired point in an engine cycle.

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