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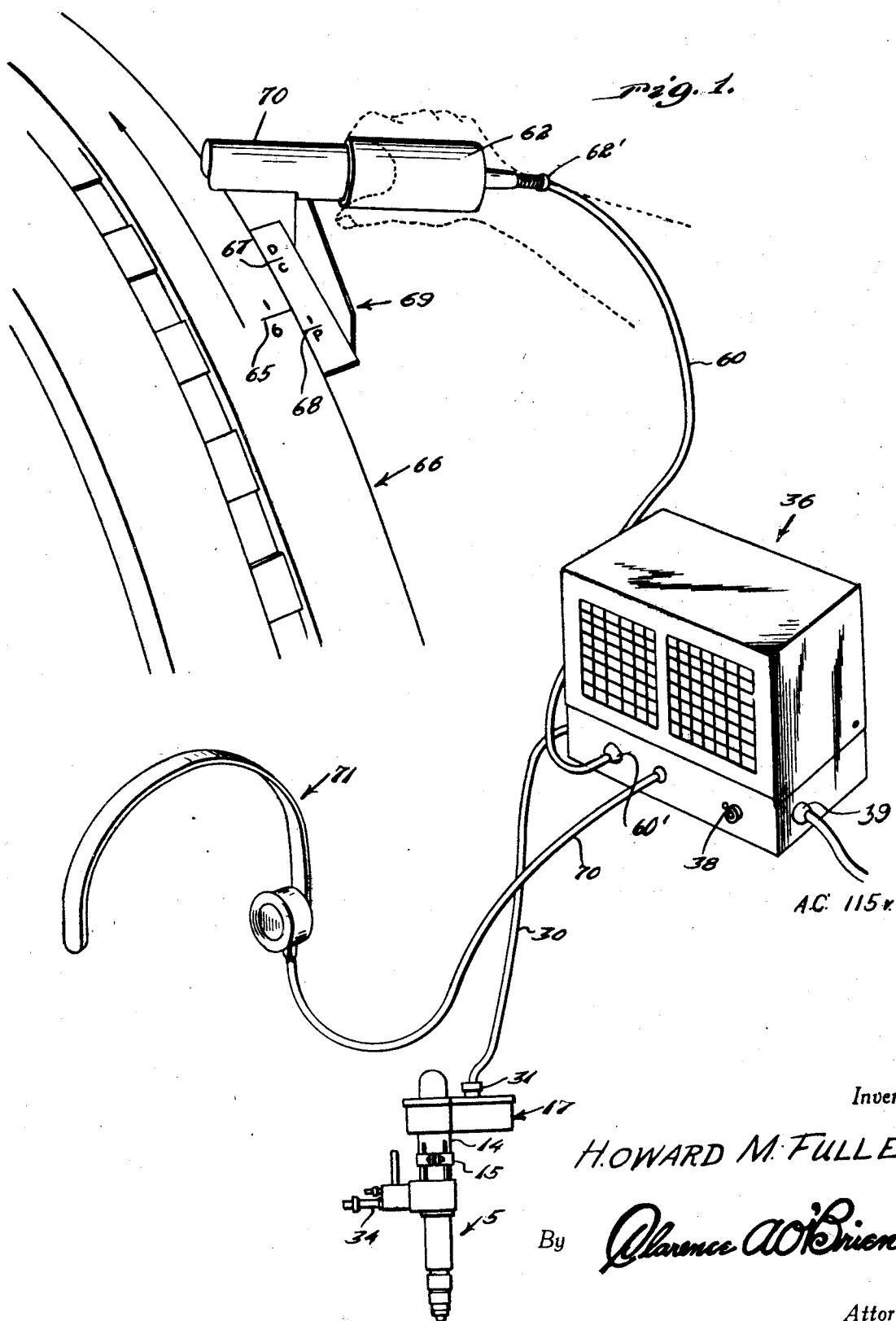
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2,344,037

STROBOSCOPIC TIMING AND TESTING OF DIESEL AND SIMILAR ENGINES

Filed Nov. 8, 1940

4 Sheets-Sheet 1



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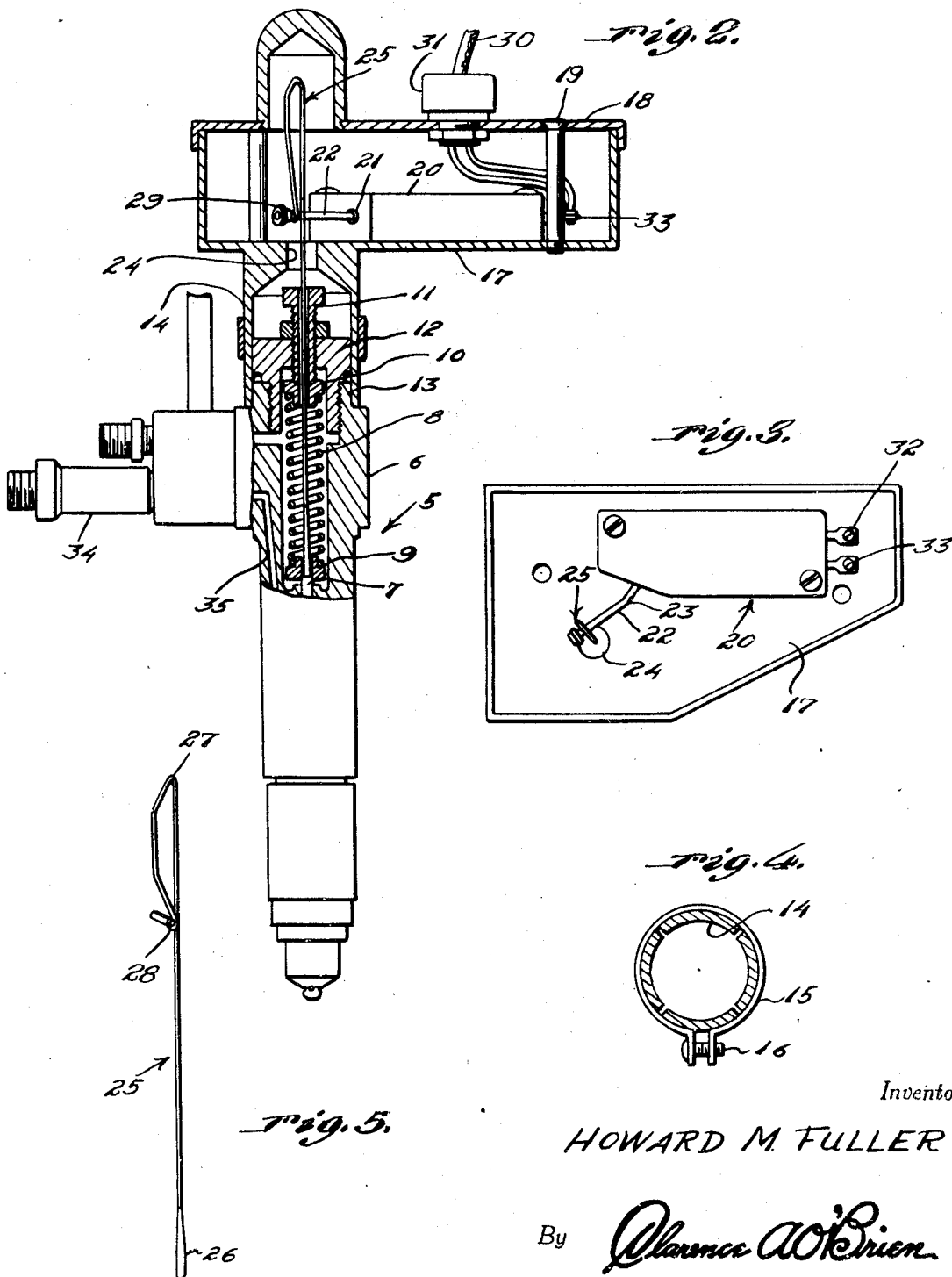
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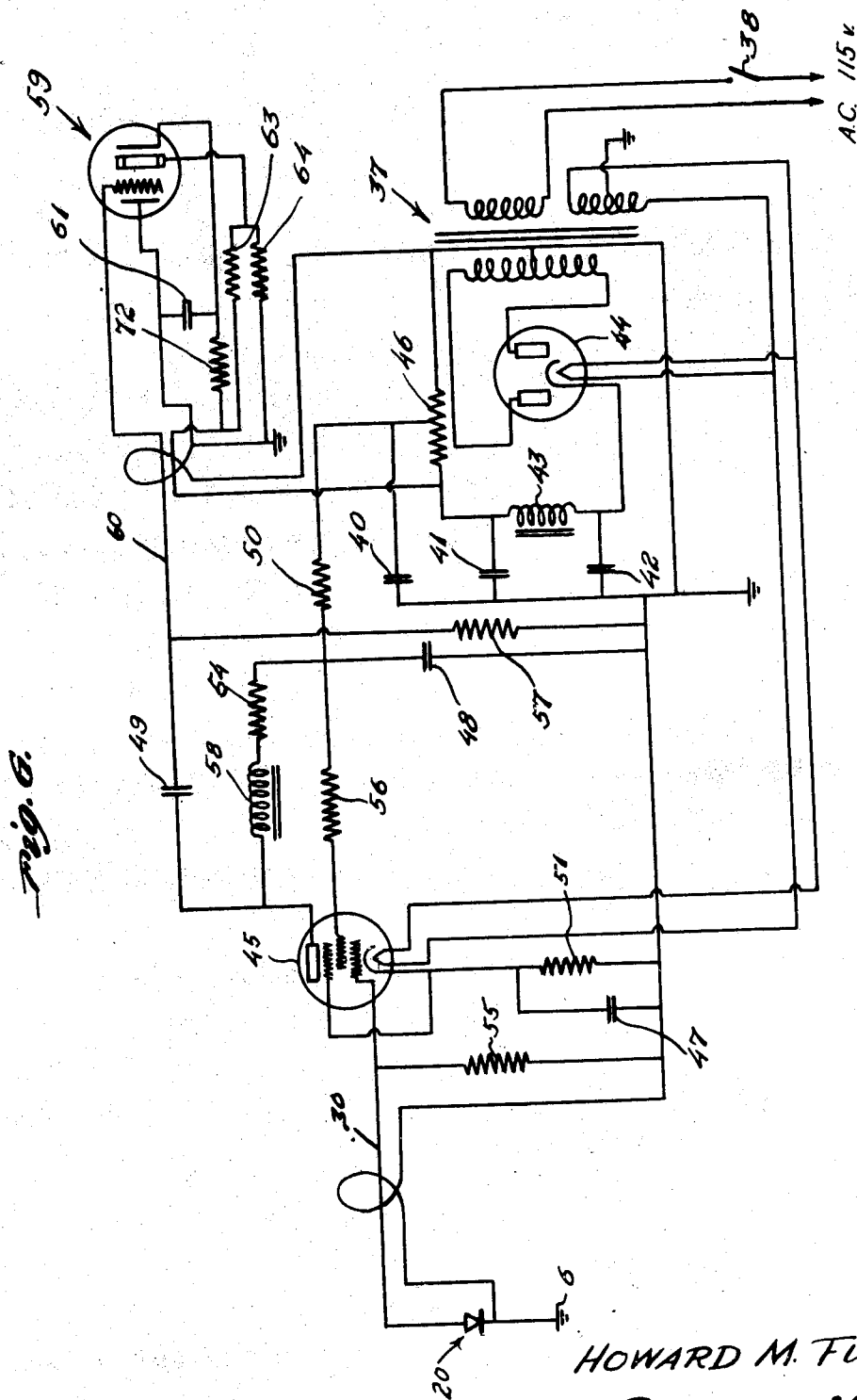
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4 Sheets-Sheet 4

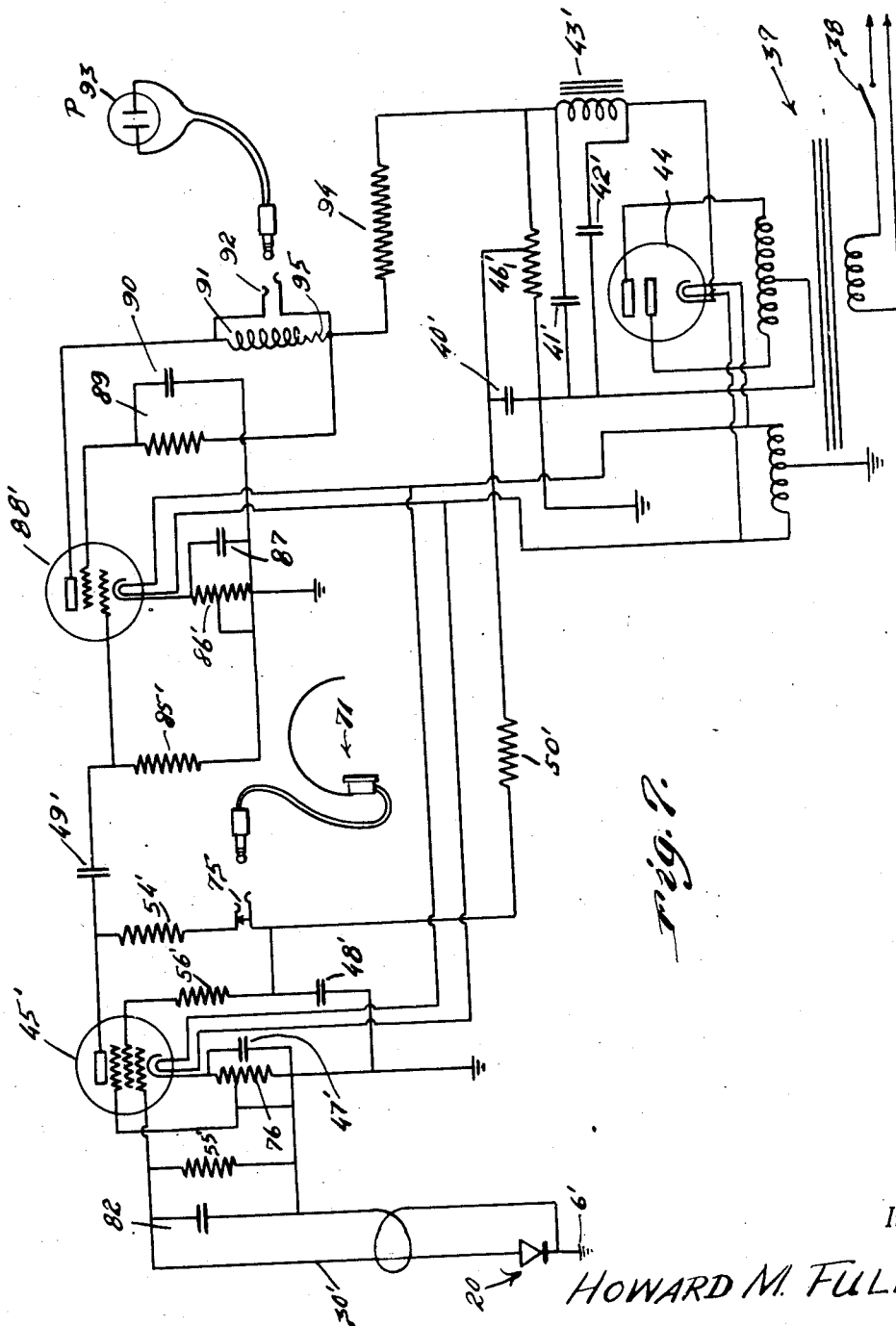


Fig. 2.

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UNITED STATES PATENT OFFICE

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STROBOSCOPIC TIMING AND TESTING OF
DIESEL AND SIMILAR ENGINES

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Application November 8, 1940, Serial No. 364,944

1 Claim. (Cl. 177—311)

My invention relates to method and apparatus for use in testing and timing Diesel engines, and the primary object of my invention is to provide means of the character indicated whose indicators are synchronized with a definite part of the Diesel engine cycle whereby the operation of a solid fuel injection system of a Diesel engine may be accurately checked while the engine is in actual operation and under load, permitting the fuel injection period to be accurately made.

Another important object of my invention is to provide means of the character indicated whereby the operating conditions of the injection valve and fuel pump of the Diesel engine may be accurately checked.

Other important objects and advantages of my invention will be apparent from a reading of the following description taken in connection with the appended drawings, wherein for purposes of illustration I have shown preferred embodiments of my invention.

In the drawings:

Figure 1 is a general fragmentary schematic view showing apparatus in accordance with the present invention.

Figure 2 is an enlarged sectional elevational view of the phono-crystal head mounted on and in operative relation to an injection valve of the Diesel engine.

Figure 3 is a top plan view of the head with the cover removed.

Figure 4 is a horizontal sectional view taken through the lower part of the head and showing the clamp thereon.

Figure 5 is a side elevational view of the wire which operatively connects the valve stem and the phono-crystal needle.

Figure 6 is a schematic wiring diagram showing the electrical components and connections for the stroboscopic embodiment of the invention.

Figure 7 is a similar schematic wiring diagram of the two-element neon light embodiment of the invention.

In order to check the fuel injection timing as it actually takes place in the Diesel cycle, it is necessary that the actual time of opening of the fuel injection valve have an indicator on the flywheel of the engine with respect to top dead center of the piston in the particular cylinder under consideration. The normal injection point is about 6 degrees ahead of top dead center on the compression stroke, but this varies with different grades of fuel oil. The conventional

method of marking dead center and the injection points is to provide a fixed pointer or witness mark on the engine and the two marks on the flywheel, for each cylinder, one indicating the top dead center position, and the other the injection point. When these marks line up with the fixed pointer, the engine is in the position indicated by them, namely, either top dead center or injection point. The engine is known to be in time if the witness marks on the pump line up when the injection point marks on the flywheel line up with the reference mark or fixed point on the engine. The apparent lining up of these witness marks on the pump and flywheel is a rather uncertain and unsatisfactory method of timing because a difference of as little as .005" is hardly noticeable on the pump but produces a difference in witness marks on the flywheel and bracket of about $\frac{1}{4}$ ", or about $\frac{1}{2}$ degree in firing timing. These comparisons or lining up of witness marks are performed while the engine is stopped, so that the only thing that is actually timed is the position of the pump and not the actual opening of the fuel injection valve. Even when the fuel injection pumps are new this method of timing is more or less a cut and try method and provides no way of checking the actual fuel injection point while the engine is in operation.

An essential fact in the discovery and the application of the principles of the present invention is that the fuel injection valves in certain types of Diesel engines open by hydraulic pressure, and are similar in action to a safety valve, the opening thereof being extremely fast and the valve remaining open while the fuel is being forced into the cylinder, and closing almost as rapidly by spring action. In line with this fact I discovered that by resting a wire on the upper end of the valve stem, any motion of the fuel injection valve itself can be transmitted out of the valve body to any mechanism with which the wire may be connected without appreciably affecting the action of the valve, if the mechanism is light enough or lacking in inertia. A suitable mechanism of this character comprises a phono-pickup crystal laid on its side and having a stiff wire held in the needle hole with the wire resting on the upper end of the fuel injection valve stem, so that any motion of the valve stem is transmitted to the crystal, and this physical motion converted into an E. M. F. or voltage by the action of the crystal. It is important to note that because of the sudden

ness, or explosive-like action of the fuel injection valve, the instantaneous frequency of the impulse transmitted by the crystal is of high value, but that the average frequency of the valve action is extremely low. Therefore, for present purposes, the fidelity of the motion transmitted is not regarded but only the point in time at which the motion starts. The crystal is, therefore, used as a timing instrument rather than as a sound transmitting or converting device.

The voltage set up by the crystal is fed to the grid of a 6J7G tube through a length of crystal mike cable and suitable connectors. The voltage amplified by this tube is fed through a .003 mfd. condenser and a two conductor shielded cable and connectors, to a stroboscopic tube. In the stroboscopic tube the impulse is converted into a strong flash of light of very short duration. This light is in phase with the signal received. That is to say, there is no appreciable time lapse or delay between the signal and the flash.

The Stroboscopic tube is supported near the fly-wheel bracket of the engine. As the injection valve opens, the opening impulse is detected and the tube caused to flash. Since the time delay of the equipment is extremely small, the witness marks on the flywheel revealed by the stroboscopic flash show the real or actual position at which the fuel injection valve opens or operates. If the marks do not appear in their proper relative positions, the necessary adjustment may be accurately estimated and later made. A suitable electrical circuit for the arrangements indicated is set forth in Figure 6 of the drawings.

In Figure 7 of the drawings is set forth an arrangement wherein a common two-element neon light may, with slight modifications and additions to the apparatus described, be adapted for use as a timing indicator whose use is, however, limited to use in a darkened room.

The arrangement described below is contemplated for application to Diesel engines employing the solid injection system using a single fuel pump per cylinder known as the Bosch injection system, by the use of optical indicators.

Referring in detail to the drawings, the numeral 5 generally designates one of the injection valves which comprises the valve body 6 of a conventional type in which the valve stem 7 operates in a well-known manner. The valve is closed by a spring 8 compressed between the element 9 and the element 10, the latter being held in a vertically-adjusted position by the adjusting screw 11 which is threaded in the screw 12. The upper part of the valve body as indicated by the numeral 13 is reduced to approximately the same diameter as the nut 12, so that the nut 12 and the portion 13 snugly accept the expansible sleeve 14 which telescopes thereon and has a contractible clamping ring 15 which is adapted to be tightened by a screw 16 to lock the sleeve 14 in place. The sleeve depends from the bottom of a casing 17 which is horizontally elongated and provided with a removable cover 18 which is held in place by a screw or bolt 19 threaded into the bottom 17.

On the bottom 17 is supported the phono-crystal cartridge 20 and which has operatively extending from the needle hole 21 thereof the stiff wire arm 22 which is deflected at an angle as indicated by the numeral 23 in a horizontal plane to a position at one side of the axis of the hole 24 in the upper part of the sleeve 14 as shown in Fig-

ure 2. The valve stem motion transmitting wire is generally designated 25 and this transmits mechanically the motion of the valve stem 7 to the stiff wire arm 22 and hence to the crystal within the cartridge. The stiff light wire 25 passes axially through the hole 24 and downwardly through the hole in the adjusting screw 11 and the holes in the upper and lower elements 13 and 9, respectively, to engage the upper end of the valve stem as shown. The wire 25 has an enlargement 26 at its lower end to fairly snugly engage the hole in the lower element 9 and prevent any sidewise or transverse motion of the wire 25 in its operative engagement with the upper end of the valve stem 7, in the operation of the valve stem. The wire 25 is straight from the enlargement 26 to a point 27 where it is hairpin bent and returns downwardly with the depressed terminal of this portion of the wire coiled as indicated by the numeral 28 around the outer end portion of the stiff wire 22 and soldered as indicated by the numeral 29. The wire 25 is preferably of spring steel and the stiff wire 22 also of steel. With regard to the stiff wire 22, it will be observed that the undeflected portion thereof is axially aligned with the approximate center of the hole 24 in the bottom 17 of the casing with the deflected portion deflected a sufficient amount to present the straight portion of the wire 25 in concentrically spaced relation with the sides of the hole 24. A single shielded conductor 30 has a suitable connection 31 with the casing and its wires connect with the terminals 32 and 33, respectively, of the crystal 20. The mechanical connection between the sleeve 14 and the valve body 6 acts as an electrical ground for the entire apparatus.

Fuel is supplied to the injection valve at a pressure of approximately 3,000 pounds per square inch through the fuel conduit 34 for injection. This conduit is connected by a passage 35 with the lower part of the bore of the valve body in a well-known manner, so that when the stated pressure is exceeded, the valve stem 7 is raised so as to compress the spring 8. As the valve stem rises it opens small holes in the tip of the valve through which the fuel escapes into the combustion chamber (not shown). It is the movements of the valve stem working against the closing spring 8 which the pickup wire 25 transmits to the phono-crystal. In this way any motion of the valve stem is reproduced at the terminals 32 and 33 of the crystal as an electrical impulse proportionate with respect to and in time phase with such motion.

The single shielded conductor 30 connects the crystal head with the cabinet which is generally designated 36, the shielded cable 30 being what is commonly known as "Crystal mike cable." The connecting means 31 are what is commonly known as "mike" connectors.

The cabinet 36 is in the form of a suitable casing enclosing a chassis (not shown) on which is mounted one 110 v. to 350-0-350 v. to 6.3 v. power transformer 37, a power on or off switch 38, a power flush plug receptacle 39, one 8-8-8 mfd. inverted can dry-electrolytic condenser shown in sections indicated by the respective numerals 40, 41 and 42, one 20 henry filter choke 43, one type 84 rectifier tube and socket 44, one type 6J7G tube and socket 45, one 50,000 ohm 80 watt voltage divider 46, one 8 mfd. dry electrolytic condenser 47, one .01 mfd. paper condenser 48, one .003 mfd. paper condenser (600 volts) 49, and associated resistors. These resistors comprise the 50,000

ohm resistor 50, the 51,000 ohm resistor 51, the 200,000 ohm resistor 54, the 5 megohm resistor 55, and the two megohm resistors 56 and 57. The foregoing resistances rate 1 watt, 2 watt, 1 watt, 1/2 watt and 1 watt, respectively. These are supplemented by a 28 henry 50 m. a. choke 58.

The foregoing circuit as shown in Figure 6 is arranged so that the same acts as a detector and amplifier. It is necessary to use shielded cable as a means of transmitting the electrical impulse generated by the crystal 20 to the chassis of the amplifier or relay, to make the action of the relay and connected light stable. With the circuit as shown the crystal impulse is fed to the control grid of the tube here designated 45 where there is a 5 megohm resistor 55 across the circuit to provide a load for the crystal and a leak for the grid. Due to the action of the tube 45 and connected resistors, inductance capacity and voltage, the signal or impulse received is amplified or enlarged in amplitude. From the plate circuit of the tube 45 the amplified signal is picked off by the action of the .003 mfd. condenser 49.

The condenser 49 allows the signal to pass to the stroboscopic tube 59 through one of the conductors of the shielded cable 60 but keeps the high D. C. voltage used in the amplifier tube out of the stroboscopic control circuit. Upon energizing the control circuit of the stroboscopic tube, the tube discharges the condenser 61 which has built up an electrostatic charge. This condenser is housed in the stroboscopic tube socket and reflector 62. Two-conductor pin type connectors are used for terminals between the amplifier chassis and the two-conductor shielded cable, and also between the two-conductor shielded cable and the stroboscopic tube socket and reflector.

By proportioning the resistors 63 and 64 so that about 95 volts exist between ground and the second grid, the stroboscopic tube may be made to flash or fire upon very small crystal movements. The discharge of the condenser 61 through the stroboscopic tube produces a strong light of extremely short duration, namely, approximately 7 micro seconds. Any moving line, when viewed under a light of only a few micro seconds, appears to stand still and have no motion. This is due to the persistency of vision and is called stroboscopic effect.

Because the time elapsing between the point in time at which the crystal is stressed, i. e., the valve opens, until the stroboscopic fires is also of the order of micro seconds, the time delay in the crystal amplifier and the stroboscopic may be considered as negligible or the action of the unit may be considered as instantaneous or that the light flashes at the same instant that the fuel injection valve stem starts to move.

The marks 65 on the flywheel 66 and the marks 67 and 68 on the engine frame bracket 69 consist of white marks on a dark background so arranged that they may be easily seen from the engine room floor. On a six cylinder engine there are three marks on the flywheel, one to indicate the top dead center of each crank position and two marks 67 and 68 on the bracket 69 on the engine frame. When the engine is in position of top dead center, the mark 65 on the flywheel and that on the bracket 69 are laid out so as to line up. The top dead center mark 67 on the bracket is not used after it is once established, because it is only a reference mark for use in establishing the injection point mark 68. The injection point mark 68 is found by dividing the circumference of the flywheel by 360 degrees and multi-

plying this by the number of degrees ahead of top dead center that the engine should start to receive the fuel. This gives the position in inches with reference to top dead center, if the circumference has been measured in inches. The distance should be measured from the top dead center mark 67 on the bracket 69 and in such a direction from this mark that a point on the flywheel passes the injection point mark 68 before the same point passes the top dead center mark 67. The conventional marking of a so-called four-cycle engine is one D-C mark on the flywheel for each two cylinders and a 1-P mark also on the flywheel for each cylinder. On two-cycle engines there is one D-C mark on the flywheel for each cylinder and one 1-P mark for each cylinder.

If the stroboscopic tube light 59 is held with its shield 70 over the moving flywheel in such a manner that anything passing under the light is illuminated by it, the white marks will appear to be stationary or stopped. Since the light flashes the instant the injection valve opens, the position in the Diesel cycle at which the fuel injection actually takes place is shown with respect to the top dead center. By measuring the distance from the mark 65 to the mark 68 and dividing the distance by the proper constant for the engine, such as 60, the result will be the thickness of the shims which should be added to or subtracted from the pump tappet to bring the fuel injection point into proper firing time or relation. When the Diesel engine is firing at the proper time, the witness mark 65 on the flywheel and the witness mark 68 on the bracket 69 coincide. Another cable 70 may be plugged in the box 36 to energize a head phone 71 to give an audible check on the testing operations.

The head phone 71 is used only in connection with the two-element neon light arrangement which is diagrammed in Figure 7 of the drawings.

Discussion of current flow in Figure 6

It will be assumed that the power lead is connected to the proper outlet supplied with 115 v. A. C. and that the switch is in the on position, and that the power has been turned on for sufficient length of time to allow the cathodes of the tubes to heat to the proper temperature. The circuit discussed will be that of Figure 6.

The action of the rectifier circuit to produce a high voltage source of D. C. power is as follows. Due to the current flowing in the primary of the power transformer 37, magnetism linking the primary, the high voltage secondary, and the filament lighting, or heating secondary, a voltage is induced in these windings. Because of the check valve action of the rectifier tube 44, current flows through it and its connecting elements in one direction only. By use of 40, 41, 42 and 43 the current passed by the rectifier tube is smothered out so that the potential across 46 has a comparatively smooth wave shape or a comparative constant difference in contrast to pulsating unidirectional current that would flow if they were omitted.

46 provides a small load for the rectifier tube and transformer to prevent damaging peak voltage developing, also to provide a method of obtaining D. C. voltages other than the maximum. 46 also acts as a discharge resistor for condenser 41, 42, 40 after the apparatus is shut off.

Upon movement of the crystal a voltage is generated across its terminals. This causes a cur-

rent to flow through the single conductor cable and resistor 55. This also causes a voltage to exist or fluctuate across the first grid and cathode of tube 6J7G tube 45. If this voltage is of the proper instantaneous polarity it will increase the flow of electrons from the cathode to the plate, or increase plate current. The opposite polarity will cause a decrease in plate current. Resistance 55 also acts as a leak for current from the first grid when this element becomes positive because of excessive signal fluctuations. Grid two acts as, in most cases, an accelerator for the electrons which have passed through the first grid. It is connected to the high voltage source through 56 and 50. High or signal frequency currents are allowed to pass back to cathode by condensers 48 and 47. Grid 3 acts as a collector for electrons which may be wandering around, due to secondary emission, in the space between plate and grid two. It also acts as a quick action stop for the electron flow. After striking the plate the electrons pass through inductance 58, resistance 54 and 50 to the high voltage source. This path is taken by the D. C. component of the tube current only. The D. C. component of the 6J7G tube 45 current also flows from the ground or low voltage side to the cathode through 51. This current causes the cathode due to 51 to be at a negative or lower voltage than ground.

The A. C. or signal component of plate current due to the low impedance of condenser 49 and the high impedance 58, passes through 49, 57 and 47. The passage of current through 57 causes a voltage to exist across its terminals, one side of which is connected to the control grid of the stroboscopic tube 59. 57 also acts as a leak for a charge that may build up on the grid of the stroboscopic tube.

The stroboscopic tube 59 is a cold cathode neon tube. It has two grids in addition to a plate and cathode. When connected as shown it has at all times a high voltage across the cathode and plate. The plate as in other tubes being positive. Grid 2 is connected by use of a voltage divider to plate and cathode. The purpose of this divider is to maintain a constant voltage on grid 2, the value of which should never exceed 95 v. between grid and cathode. The purpose is to excite the tube to a point near the flash or firing point. Thus a small voltage applied to the first grid provides enough additional excitation to cause the gas in the tube to ionize and fire between cathode and plate thus discharging condenser 61. The instantaneous discharge of 61 produces a large current flow through the stroboscopic tube. This current due to the neon gas produces an intense light. The duration of this light is very short, approximately 8 micro seconds. 72 is in series with the plate so that the tube will go out upon discharging 61. Condenser 61 is recharged between intervals of firing.

Thus, upon the slightest movement of the crystal a strong light of very short duration is made to flash in time phase or synchronism with crystal movement. In fact, the light flash has been completed before the crystal has completed its initial movement, and several flashes may occur during a fuel valve opening.

Discussion of current flow in Figure 7

This modification comprises a two-element neon light arrangement.

It will be assumed that the power lead is connected to the proper outlet supplied with 115 v. A. C. and that the switch is in the on position, and that the power has been turned on for suf-

ficient length of time to allow the cathodes of the tubes to heat to the proper temperature.

The action of the rectifier circuit to produce a high voltage source of D. C. power is as follows: Due to the current flowing in the primary of the power transformer, magnetism linking the primary, the high voltage secondary and the filament lighting, or heating secondary, a voltage is induced in these windings. Due to the check valve action of the rectifier tube, current flows through it and its connecting elements in one direction only. By use of 40', 41', 42' and 43' the pulsating current passed by the rectifier tube is smothered out so that the potential across 46' has a comparatively smooth wave shape or a comparatively constant difference in contrast to pulsating unidirectional current that would flow if they were omitted.

46' provides a small load for the rectifier tube and transformer to prevent damaging peak voltage developing, also to provide a method of obtaining D. C. voltage other than the maximum. 46' also acts as a discharge resistor for condenser 40', 41', 42', after the apparatus is shut off.

Upon movement of the crystal a voltage is generated across its terminals. This causes a current to flow through the single conductor cable, resistor 55' and condenser 82 in parallel with the resistor. This also causes a voltage to exist or fluctuate across the first grid and cathode of 6J7G tube 45'. If this voltage is of the proper polarity it will increase the flow of electrons from the cathode to the plate, or increase the plate current. The opposite polarity will cause a decrease in plate current. Resistance 55' also acts as a leak for current from the first grid when this element becomes positive because of excessive signal fluctuations. Grid 2 acts as, as in most cases, an accelerator for the electrons which have passed through the first grid. It is connected to the high voltage source through 56' and 50'. High or signal frequency currents are allowed to pass back to cathode by condenser 48' and 47'. Grid 3 acts as a collector for electrons which may be wandering around, due to secondary emission, in the space between plate and grid 2. After striking the plate the electrons pass through resistance 54', closed circuit phone jack 75 and phones 71 if plug is inserted in jack, resistance 50' and then to the high voltage source on resistance 46'. This path is taken by the D. C. component of the tube current and part of the A. C. component. The D. C. component of the tube 45' flows from the ground or low potential side to the cathode through 76. This current causes the cathode, due to 76, to be at a positive or higher voltage than ground.

The major part of the A. C. or signal component of plate current due to the comparative low impedance of condenser 49' passes through 49' and 85', and thus to the ground. The passage of current through this resistor causes a voltage to exist across its terminals and thus a voltage exists across the control grid and cathode of 6L6G tube 88'. This resistor 85' also acts as a leak for a current that may flow if the amplified signal should swing positive or become greater than the voltage across the cathode biasing resistor 86'.

The D. C. component of current in the 6L6G tube 88' flows similar to that of the 6J7G tube, the exception being that there is no third grid. The current flowing from the cathode is acted upon by the first grid and made to increase or decrease in magnitude as the voltage upon this element

changes. The second grid as in the previous tube acts as an accelerator. The D. C. component of current flows through resistors 83 and 94 and thus to the high voltage source. The A. C. or signal component is by-passed by condensers 90 and 87, directly back to the cathode. Upon striking the plate the D. C. component of current passes through the combination of inductance 91 and resistance 94 and then to the high voltage source.

The D. C. component also flows from ground or low potential side of power supply to the cathode through resistor 86'. This current causes the cathode due to 86' to be at a positive or higher voltage than ground. The A. C. component or signal component passes through condenser 87 and thus to the cathode.

The resistance of 95 and 94 is such that with no signal impressed on the control grid the plate current causes a voltage to exist across the inductance 91 and resistance 95 which just will not ignite the neon lamp connector across this element. Or the voltage across the inductance 91 and resistance 95, caused by the steady flow of current, is just below the ignition voltage of the neon lamp. The resistance 94 provides a load for the tube. The inductance 91 may be selected so that the resistance inherent to its construction will act as resistance 95.

As a signal is impressed on the control grid of the 6L6G, 88' tube, the plate current is caused to increase. This increase in plate current, due to the high impedance of the inductance and the comparatively low impedance of the neon lamp, flows through the neon lamp, causing it to ignite or flash. Thus, upon a movement of the crystal, a signal is generated, amplified and flashed and indicated with extremely small time loss.

Although I have shown and described herein preferred embodiments of my invention, it is to be understood that I do not wish to limit the application of the invention thereto, except as may be required by the scope of the subjoined claim.

Having described the invention, what is claimed as new is:

In combination with a fuel injection valve having a reciprocating valve stem, a housing mounted on said valve and including a portion overlying the outer end of said valve stem, a rod supported in said valve for reciprocation by said stem, a phono-crystal in said housing, said phono-crystal having an actuating needle projecting therefrom, and means operatively connecting said needle and the outer end of said rod.

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