# United States Patent

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[33] Japan
[31] 43/59737


[54] **APPARATUS FOR DETECTING THE INJECTION TIMING OF AN INTERNAL COMBUSTION ENGINE**
**6 Claims, 9 Drawing Figs.**


[52] U.S. Cl. ..... 73/119 A
[51] Int. Cl. ..... G01m 15/00
[50] Field of Search ..... 73/119 I; 324/166, 16 T



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**ABSTRACT:** Apparatus for detecting the injection timing of an internal combustion engine, wherein the strain dislocation, or stress change of the injector spring, due to the lift of the needle valve of the injector when fuel is sprayed out of the injector to the ends of the cylinder, is converted to an electrical signal, said signal being used to trigger a stroboscopic lamp so as to flash synchronously with the lift of the needle valve of the injector, the stroboscopic lamp being positioned to illuminate a crank angle scale rotating with the engine crankshaft and a fixed index on the engine block, permitting observation of the crank angle, as if the engine were in static state.

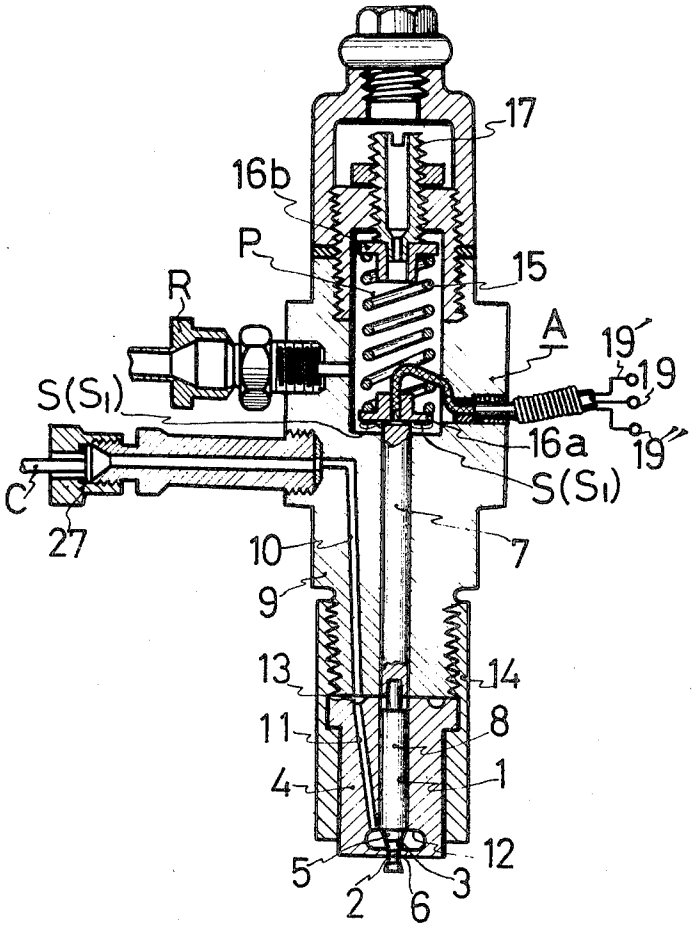



FIG. 1

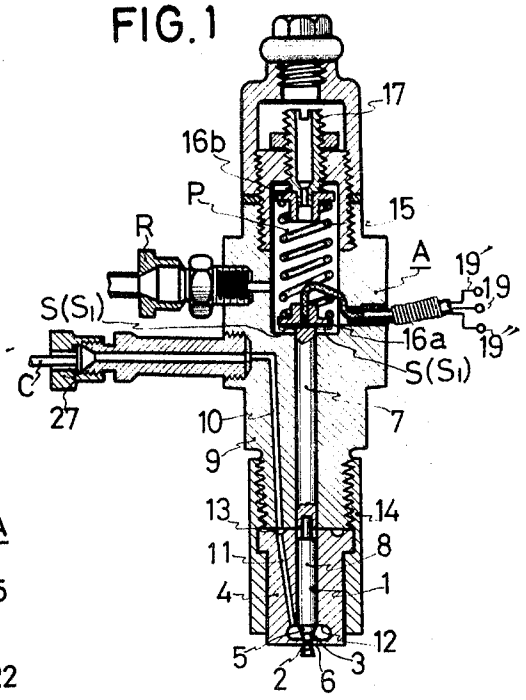



FIG. 2

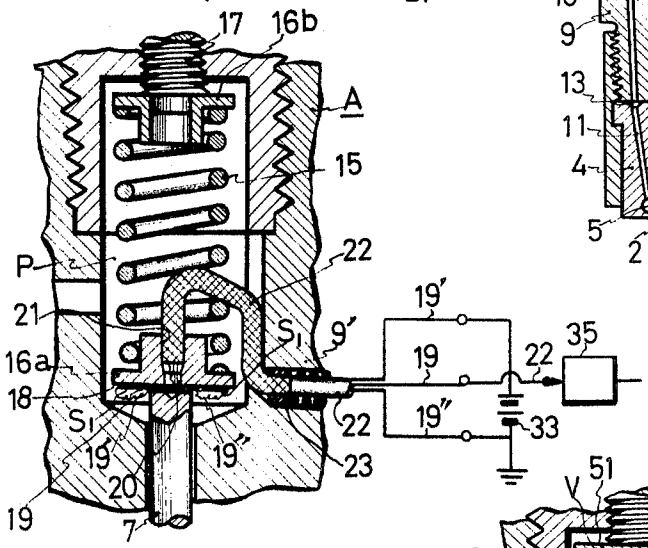
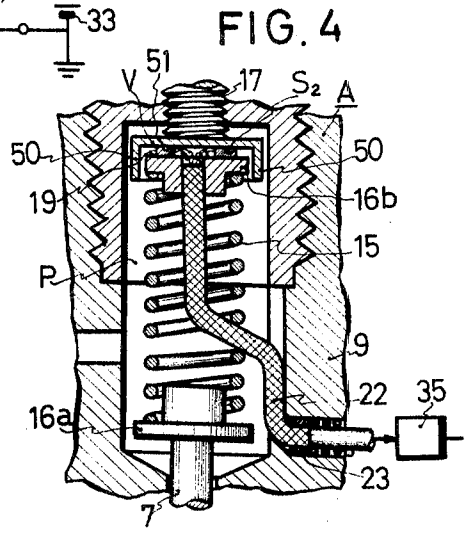



FIG. 4




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FIG. 3

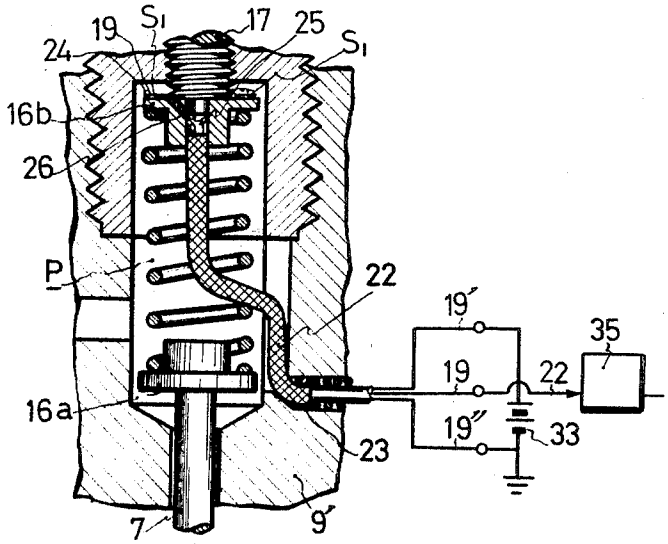



FIG. 5

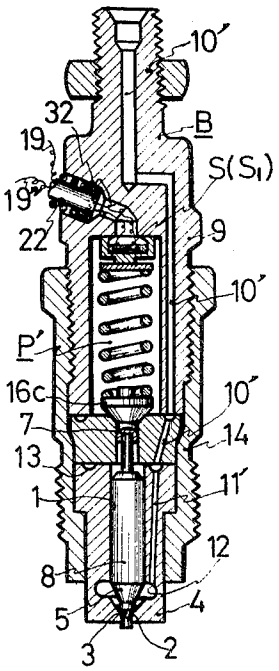
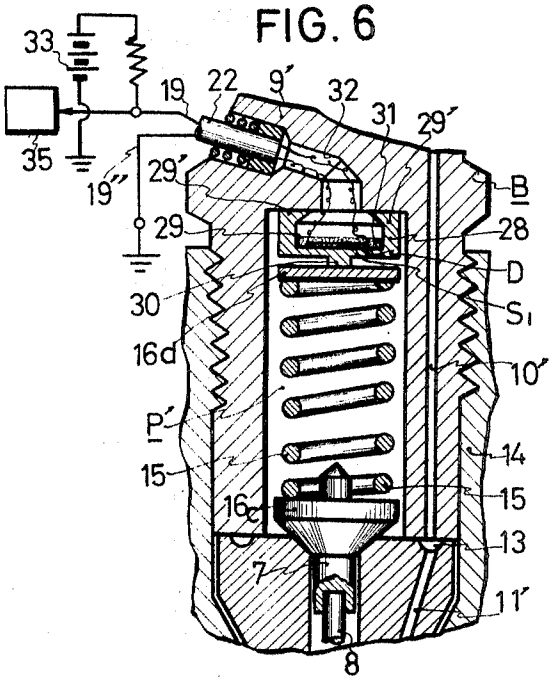



FIG. 6




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FIG. 7

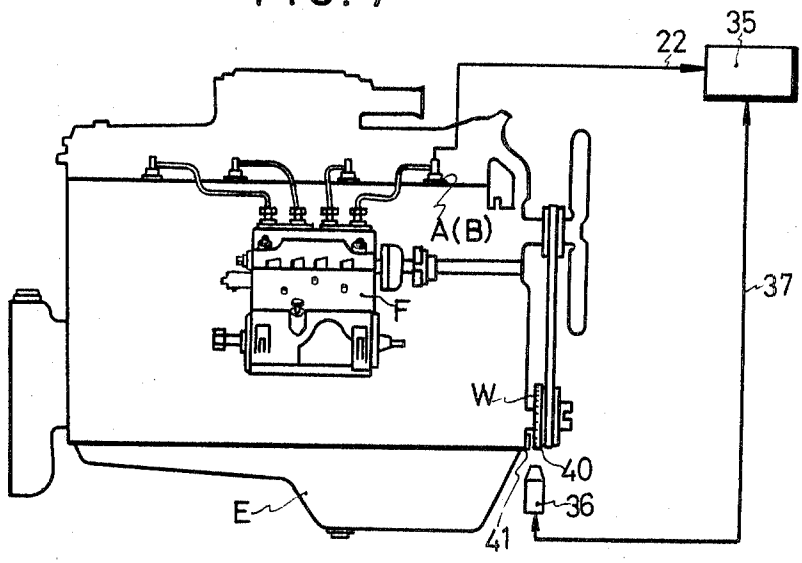
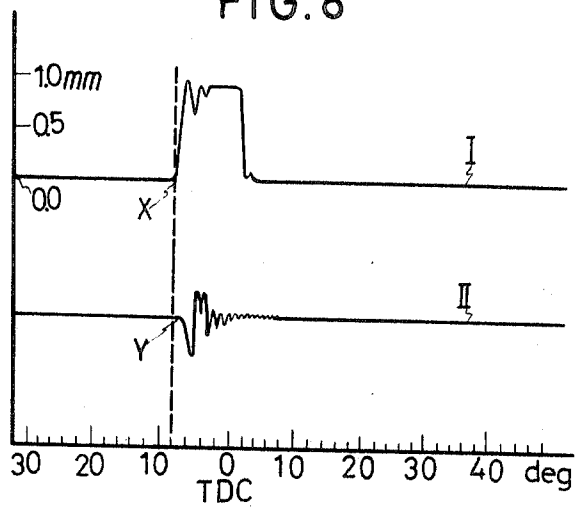


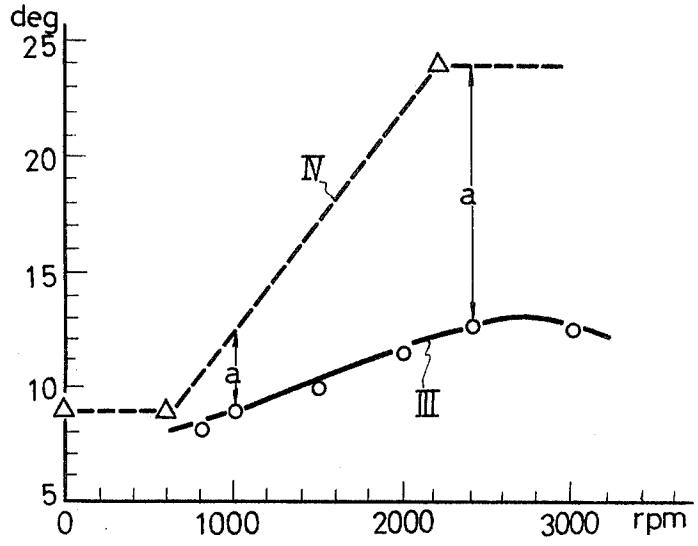

FIG. 8




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FIG. 9




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# APPARATUS FOR DETECTING THE INJECTION TIMING OF AN INTERNAL COMBUSTION ENGINE

## BACKGROUND OF THE INVENTION

The present invention relates to an apparatus for detecting the injection timing in the injector of Diesel or gasoline engines.

Determining the appropriate fuel injection timing of an internal combustion engine is an important problem because it greatly affects the fuel admission and combustion, the engine power, the rate of fuel consumption, and the concentration of smoke from unburned fuel in the exhaust arising from imperfect fuel combustion.

In high-speed engines for automobiles, when the injection timing is advanced, there is a greater tendency for the fuel to be sprayed into the combustion chamber before the compression temperature therein is raised sufficiently to ignite the fuel, causing delay in ignition, abnormal pressure elevation, and heavy knocking. In such engines, there is a tendency to approach the state of constant volume combustion; the drive of the engine becomes rough; and the engine power and fuel consumption are reduced.

When the injection timing is delayed in high-speed engines, fuel enters the combustion chamber and is ignited during the time the piston is lowering and, therefore, the engine power is reduced, and the combustion pressure is gradually lowered. Again, the engine approaches the state of constant pressure combustion. The drive of the engine smooths, but the color of the exhaust gas is darkened; the exhaust temperature is raised, and the amount of consumed fuel is increased.

The timing of fuel injection should be appropriately adjusted to fall at a time between the above two conditions, so that the combustion pressure will lie within a permissible range, and the color of the exhaust gas will be clear, indicating lowering of the consumed fuel. High-speed engines should always be operated with appropriate injection timing to achieve continuous and stable operation.

To achieve the above-mentioned desirable driving conditions in automobile engines, it is necessary to adjust the injection timing to be proper under any driving state. If the injection timing is too advanced, or too delayed, the crank angle of the crankshaft should be adjusted to overcome the unsatisfactory engine conditions.

An automatic timer is conventionally used to adjust fuel injection timing in accordance with the engine speed in such manner that the injection advancing angle is advanced, or delayed, with respect to a certain normal value of injection timing with changes in the engine's driving state. In addition to such timer, a vacuum-type governor, or centrifugal governor, may be used to adjust the injection timing.

In carrying out the adjustment of the timer, or governor, it is first essential to learn the injection timing of the engine injector.

In constant-speed engines, it is unnecessary to change the injection timing during the operation of the engines when the injection timing is properly adjusted in the beginning. However, the proper injection timing must be determined by trial.

One conventional way of detecting the injection timing involves a static detection method. In this method, a pipe for detecting the injection timing is positioned on the fuel delivery valve holder of a Diesel engine, and the crankshaft pulley is manipulated to rotate the engine little-by-little. The injection timing is determined by the crank angle at the time when the fuel oil surface starts to rise at the bottom end of the detecting pipe. This method has the disadvantage that the injection timing is measured when the engine is stopped, rather than when the engine is operating, it being impossible to measure during engine operation. Further, the rise of the fuel oil surface in the detecting pipe is measured with the naked eye and, therefore, there is usually a visual error due to individual differences in the eyesight of different observers. Furthermore, the actual timing differs from that measured because of the length of the conveying conduit for the high-pressure fuel, and thus the measured time of injection is delayed by the time for transmitting fuel through the high-pressure fuel conduit, making it impossible to measure the actual timing of injection.



Another conventional method of detecting injection timing constitutes a dynamic detection method. In this method, a needle rod is provided in the injector at the upper end of the valve push rod and passing through the center of the nozzle spring so as to contact against the spring holding washer. The fuel, sent under high pressure from the injection pump while the engine is driven, reaches the pressure receiving surface of the valve, and overcomes the spring force to lift the needle valve, and to synchronously lift the needle rod. The lift of this rod is measured by the variation of intensity of a light beam intersected by the rod and striking a photo-transistor, or by variation of capacity in a condenser embodying the rod, these variations being converted into voltage and current. In this manner, the needle rod is mounted on the valve and, therefore, the reciprocating mass of the valve is increased, causing a difference in the rate of injection. Therefore, this conventional method is insufficiently accurate. This deficiency makes it necessary to improve the injector, itself, so that the device becomes complicated and incapable of being handled easily. The engine must be specially designed to provide space for such transistor or condenser, as well as the injector.

## SUMMARY

The present invention aims to solve the above-mentioned problems, defects and disadvantages of conventional apparatus and methods for measuring injection timing, and to provide apparatus for correctly detecting the injection timing of the injector of an internal combustion engine.

Another important object of the invention is to provide an improved apparatus for detecting injection timing by the provision of slight changes in the injector of the internal combustion engine, such changes not otherwise affecting the structure, or mode of operation of the injector.

Another object of the present invention is to provide a method for determining injection timing at any optional engine speed, which is simple and easy to follow and which involves the use of simple and inexpensive apparatus.

In accordance with the invention, the injector needle valve biasing device, which urges the valve toward its seat in the fuel outlet, is outfitted at its far end with at least one strain gauge, defined herein as including any of the well known types as typified by wire, semiconductor and piezoelectric elements, etc., which converts the change in stress or force of the valve spring into an electric signal when the valve is opened to spray fuel into the combustion chamber of the engine, said signal being fed to trigger a stroboscopic lamp positioned to illuminate a crank angle scale rotating with the crankshaft. The scale is observed in conjunction with a fixed indexing mark on the engine block so as to determine the crank angle at the time of injection, as if the engine were static at the time of reading.

With conventional methods of injection timing, whether dynamic or static, the readings cannot be obtained with the accuracy of the present invention, wherein, at the instant when the needle valve of the injector leaves the valve seat to spray fuel into the cylinder and while the engine is rotated at any optional speed, the stroboscopic lamp is instantaneously triggered to yield a synchronized flash which illuminates the crank angle scale to show the injection timing. Thus, the start of buildup of fuel pressure tending to open the injector valve is detected and the flash is emitted only at that instant which corresponds to the instant the valve starts to leave its seat. As a result, the crank angle of the crankshaft can be measured as if the engine were in a static state.

It is thus possible to carry out the proper adjustment to meet the engine conditions by advancing or delaying the injection timing, on the basis of the dynamic injection timing read and measured as mentioned above, taking the state of the engine operation into consideration, and as a result, it is possible to

improve the engine power, to reduce fuel consumption, and prevent the high concentration of exhaust gas caused by imperfect fuel combustion.

## BRIEF DESCRIPTION OF THE DRAWINGS

Although certain specific embodiments of the invention have been shown and described, it is obvious that many modifications thereof are possible. The invention, therefore, is not intended to be restricted to the exact showing of the drawings and description thereof, but is considered to include reasonable and obvious equivalents.

FIG. **1** is a vertical sectional view of an injector to be used in practicing this invention;

FIG. **2** is an enlarged cross-sectional view of the main portion of the injector of FIG. **1**;

FIGS. **3** and **4** are similar enlarged cross-sectional views showing modifications of the injector of FIG. **1**;

FIG. **5** is a vertical sectional view of another injector capable of use with this invention;

FIG. **6** is an enlarged cross-sectional view of the main portion of the injector of FIG. **5**;

FIG. **7** is a diagrammatic view showing the complete timing apparatus of the present invention applied to a Diesel engine;

FIG. **8** is a line graph showing the injection timing, injection pressure and the crank angle as measured by the present invention; and

FIG. **9** is a graph comparing the injection timing as detected with the present invention with that of the conventional method.

The present invention will be explained with respect to two types of injectors used in gasoline, Diesel, or constant-speed engines, namely, the injector A, FIG. **1**, in which injection pressure is adjusted by threading the injection pressure adjusting screw **17**, and the injector B, FIG. **5**, in which the injection pressure is adjusted by changing the spring seating washer **16***c* to one of different thickness.

As shown in FIGS. **1**—**4**, the injector A has a nozzle **4** secured to a nozzle holder **9** by a capnut **14**. A chamber **12** is provided in nozzle **4** near its inner end and is pierced by a fuel outlet opening **2** surrounded by a valve seat **3** on the fuel pressure receiving surface **5**. A valve sleeve **1** extends axially of the nozzle and houses and guides a freely slidable needle valve **8** to seat **3** for closing the outlet **2**. The chamber **12** is connected to the fuel feed source with injection pump (not shown), by the fuel passage **11** passing upwardly through the nozzle **4**, and the fuel passage **10** passing through the nozzle holder **9**, and communicating with each other. The upper surface of the nozzle **4** has an annular groove **13**, and said fuel passages **10** and **11** are connected by holes entering said groove. On the wall of the injection nozzle holder **9** is a boss. The fuel return pipe R is connected to the bore of holder **9** through this boss. A fuel feed conduit C, with edge filter **27**, is connected to the outer end of fuel passage **10** by an unnumbered coupling member. A push rod **7** coaxially engages the needle valve **8** and freely moves up and down in the bore of nozzle holder **9**.

One end **6** of the needle valve **8** contacts the valve seat **3**, and the other end contacts the push rod **7**. The rod is connected to the nozzle coil spring **15** which constitutes a part of the valve biasing device P, and this connection is through the spring seat **16***a*. The spring **15** is compressed between seats **16***a* and **16***b*. The pressure exerted against the needle valve can be adjusted from the outside by threading in or out the screw **17** which bears against spring seat **16***b*. When the coil spring force is overcome by the fuel oil pressure exerted against the pressure receiving surface **5** and opposed valve surface, the valve **8** will lift and open the fuel outlet to the engine cylinder.

As thus far described, the structure of the injector is conventional. According to the invention, one or more wire, semiconductor, or like strain converting elements $S_1$ are adhered on the nozzle spring seat **16***a* (FIGS. **1** and **2**) on the side toward the valve rod **7** and valve **8**, or on the nozzle spring seat **16***b* (FIG. **3**), on the side toward the adjusting screw **17**.

As the pressure of the fuel oil exerted on the pressure receiving surface **5** of the needle valve **8** overcomes the resistance of the nozzle spring **15** to open the fuel outlet **2** and spray fuel out into the cylinder, a change of resistance arises in element $S_1$ due to the increase of pressure, and this change of resistance is converted into an electric signal by the strain converting element $S_1$. The strain converting element $S_1$ is insulatedly adhered on the end surface **18** of spring seat **16***a* in a manner resistant to entrance of oil between the adhered parts, using a thermosetting resin such as an epoxy or phenolic resin which is oil resistant. The strain converting element, therefore, effectively transmits the strain without being softened or damaged by oil penetration. The input lead wires **19'**, **19''**, to be connected across a battery **33** are led to the element S through cable **22**. Wire **19''** is connected to ground. The output wire **19** of strain converting element $S_1$ is led out through the axial bore **21** of seat **16***a* into the center space of the nozzle spring **15** through the same cable and thence between the spring coil so as not to disturb the working of the spring. The cable leaves the injector through a radial hole in the wall of the injector body **9**. Preferably, in FIGS. **2** and **3** two strain elements are used, their input terminals being connected to wires **19'** and **19''**, respectively, through small coils (not shown), and their output terminals being connected together and to wire **19** through another small coil.

The output spring coils **19** is connected to a wave or pulse former **35**. This may comprise any conventional combination of amplifying and differentiating means and multivibrators, which are well known to those skilled in the art. Use of a single strain gauge element $S_1$ results in a pulse series of decreasing amplitude. Use of a piezoelectric element results in a pulse signal as shown in curve I, FIG. **8**. Use of an amplifier in pulse former **35** changes the pulse to rectangular shape of equal amplitudes. Use of a differentiating means in pulse former **35** increases the width or time span of each individual pulse, and addition of a monostable multivibrator removes the noise. The pulse width may be made constant by use of a monostable, multivibrator, which also reduces excess current. Curve II, FIG. **8**, is an example of the pulse shape obtained by amplification through a high pressure coil in pulse former **35**.

When the strain converting elements $S_1$ are placed on the adjusting screw side of the nozzle spring seat **16***b*, as shown in FIG. **3**, they are adhered on the outer end surface **24** in the manner previously described. The input and output lead wires of the strain converting elements $S_1$ pass through holes **26**, slightly inclined to the seat upper end surface **24**, and are led out into the center space of the spring **15** in cable **22** which passes through the axial hole **25** in the spring seat **16***b*.

Instead of wire, or semiconductor strain gauge elements, a crystal piezoelectric element, FIG. **4**, such as barium titinate and zirconium lead titinate, or like piezoelectric elements, can be used to detect fuel oil injection pressure. A piezoelectric element supporting seat V having a depending flange portion **50** which covers the outer periphery of the nozzle spring seat **16***b*, is provided between the spring seat and the adjusting screw **17** in the needle valve biasing device P. The piezoelectric element $S_2$ for obtaining an electric output generated by the outside stress applied thereto, is pinched between the inner surface **51** of seat V and the upper surface **24** of spring seat **16***b*. These surfaces and the outer surface **50** of seat V, with which the adjusting screw **17** engages, are parallel to one another and thus the element $S_2$ is held in a manner resistant to oil penetration. The output lead wire **19** of the piezoelectric element $S_2$ is led out into the central space of the nozzle spring **15** by means of the cable **22** passing through the axial hole **25** of the nozzle spring seat **16***b* and thence between the spring coils to the radial hole **23** in the wall of the nozzle holder **9**, the cable being suitably sealed against oil leakage through passage **23** and is connected to wave former **35**.

The injector B is of the type in which the injection pressure is adjusted by the plate pressure of a plain washer. The strain converting element $S_1$ is provided therein as shown in FIGS. **5** and **6**. The needle valve biasing device P' comprises the nozzle coil spring **15** urging the needle valve in the direction to con-

tact the valve seat 3. The spring seat 16*c* is provided on the upper end of the push rod 7, and the other end of which engages the needle valve 8. The coil spring 15 is compressed between seat 16*c* and washer 16*d*. The pressure exerted by the biasing device P' against needle valve 8 in the direction of the valve seat can be adjusted by substituting for washer 16*d* another washer of a different thickness.

In adding the strain converting element $S_1$, it should be adhered directly to the nozzle spring seat 16*c* or to the washer 16*d* in an insulated manner and so as to resist entrance of oil between the adhered parts. For example, the sensing device 28 may be in the form of a cup having a depending peripheral sidewall 29' and a thin resilient bottom wall D acting as a diaphragm. The top of wall 29' is made to contact against the correspondingly-shaped top wall portion of the hollow space 29 in the injection nozzle holder 9, and the semiconductor strain converting element $S_1$ is adhered on the upper flat surface 31 of bottom wall D near the center thereof. Near the center of the undersurface of diaphragm D is formed the projection 30, which contacts the upper surface of the washer 16*d*. When the valve is lifted, the pressure of the valve spring exerted through washer 16*d* and projection 30 will bend, or arch the diaphragm D and the adhered strain elements $S_1$ to yield an electric signal. The output wire of semiconductor $S_1$ is led upwardly out of the injector device by cable 22 which passes through hole 32 provided in the wall portion 9' of the injection nozzle holder 9. This passage is also sealed against leakage of oil. The output wire 19 is connected to one terminal of the electric source, cells 33, through a resistance, and to the pulse former 35. The other cell terminal is connected to ground, as is the input terminal of the semiconductor, by the wire 19'' in the cable.

In the present invention, when it is desired to determine only the time when the strain for injecting fuel is initially exerted and the absolute value of the strain is not so important, only one semiconductor strain gauge element may be used, as is shown in FIGS. 5 and 6, it being unnecessary to compensate for temperature changes.

The strain converting elements employed may be a crystal piezoelectric element in which case the electric output is large. Therefore, when such elements are used, it is possible to obtain more than several kilovolts of outputs which avoids the need to employ an amplifier, and the output signal can be directly fed to the trigger circuit of a stroboscopic lamp.

The injection timing detection method of this invention is carried out by using the injector A or B, as described above, in place of the injector of the engine (for example Diesel engine E, FIG. 7), whose injection timing is desired to be detected, the injector being connected to the injection pump so that the engine is driven. The injection pressure of the injector A or B is preadjusted, to be the same as the injection pressure of the removed injector, by changing the pressure of the nozzle spring using a commercially available nozzle tester. Next, as is shown in FIG. 7, the output lead wire 19 of the stress converting element S in the injector A or B is connected through cable 22 to the wave former 35 wherein the electric signal as a pulse from said stress converting element S is amplified and differentiated and simultaneously the noise is removed and excess current is reduced. The output from said wave former 35 is fed to the trigger circuit of a stroboscopic lamp 36 through wire 37. The lamp 36 is positioned to illuminate the scale 40 wherein the crank angle between minus 40° to plus 40° in the neighborhood of the top dead center is marked on the flywheel W connected to the engine crankshaft. Fixed on a stationary portion of the engine block opposite scale 40 is an index mark 41 for reading with respect to said crank angle scale 40.

The mode of use and method of operation may be explained as follows: The injection nozzle outlet 2 of the injector A or B is closed by valve 8 under pressure of spring 15. However, when fuel is supplied to the chamber 12 synchronously with the reciprocating driving movements of the plunger of the injection pump, and the fuel oil pressure reaches the normal injection pressure, the biasing spring pressure is overcome, to open the outlet 2 and spray the fuel out into the engine cylinder. The force, or stress change, applied to the needle valve 8, each time the valve leaves seat 3 to spray out the fuel is converted into an electric signal by the stress converting element $S_1$ in the injector. This signal causes exciting current to pass through wire 37 (FIG. 7) to the ignition coil of the trigger circuit of the stroboscopic flash lamp 36, and a resulting high voltage pulse generated in the secondary circuit thereof is supplied to the stroboscopic trigger electrode. Thus, lamp 36 emits a flash synchronous with the lifting of the valve of the injector A or B. The injection timing is read under the flash of the lamp by observing the relative position of the fixed mark 41 with respect to the crank angle scale 40 just as if the engine were stopped, rather than in operation.

When the electric signals caused by stress changes in the converting element S are fed to an oscillograph, the variation of the nozzle valve lift, as well as the injection timing of the injector, can be viewed. For this purpose, the cable 37 connecting the differential amplifier and the stroboscopic lamp 36 is connected to an oscillograph (not shown), and a line graph of the injection timing, nozzle valve lift, and crank angle, as shown in FIG. 8 is obtained. In FIG. 8 the abscissa shows the crank angle. For curve I, the ordinate shows the nozzle valve lift in millimeters when the engine speed is 1,000 r.p.m. For curve II, the ordinate shows the trigger pulse (the primary voltage) in the stroboscopic flash lamp 36 at a time when the charging current passes momentarily through the primary of the trigger circuit to emit the flash of the lamp. The normal injection pressure of said injector is 100 kilograms/cm$^2$.

Thus, when the pressure of fuel oil supplied from the injection pump connected to the fuel feed source overcomes the pressing force of the nozzle spring of the needle valve pressing device, the needle valve leaves the valve seat and fuel is sprayed out into the cylinder. At this moment, the stress converting element S in the needle valve pressing device causes the electric signal to show the stress change due to the nozzle valve lift as shown by curve I of FIG. 8, and the point X of said curve I indicates the start of valve opening and of the fuel injection as occurring at minus 8° crank angle. The pulse continues on curve I to show a maximum valve lift of 1.0 mm. the valve remaining open to plus 4° crank angle. This, of course, is a measure of the amount of fuel injected.

At the time the valve leaves the valve seat, the signal X delivers charging current instantaneously to the primary side of a transformer in the trigger circuit of the stroboscopic lamp and since it is desirable that the trigger pulse curve II not be delayed with respect to the start of the valve lift, a conventional differential amplifier is employed to electrically amplify and differentiate this signal and to maintain the time lag thereof within a permissible range. Thus, the rising point Y in curve II shows the start of the current charging the primary side of the lamp trigger circuit as only very slightly lagging behind point X. These signal pulses indicating injection timing, valve lift and lamp triggering can be observed in scanned wave form on the oscillograph. It is possible in this way to measure and compute the amount of the sprayed fuel for any selected injection pressure under any optional engine speed.

The engine injection timing, observed in the manner described above, can be adjusted to meet the engine operating conditions. For example, the injection advancing angle may be advanced or delayed by means of an automatic timer, a vacuum type governor, or a centrifugal governor, for automatically adjusting the injection timing, with respect to the normal value of the injection timing in consideration of the effect of the timing on the engine driving state.

It is also possible to simultaneously learn the engine speed by counting the frequency of electric output pulses X within a unit time utilizing an electromagnetic counter or electrocounter, or by converting said pulse into its analogue value by means of an analogue circuit to obtain a voltage reading.

In FIG. 9 the ordinate shows the injection timing in relation to the crank angle (degrees), and the abscissa shows the en-

gine speed (r.p.m. Curve III shows measurements of the injection timing in accordance with the method of the present invention, in comparison with curve IV showing measurements obtained by the conventional static injection timing detection method. To obtain curve IV, the injection timing had certain measurements made with the engine stopped, while others were obtained from the properties of the engine governor.

In the said conventional static method, the pipe for detecting the injection timing is provided on the delivery valve holder of the injection pump and the engine is rotated by turning the crankshaft pulley until the fuel almost starts to overflow, the injection pump body being tilted to the right or left, little-by-little, and the oil surface in said detecting pipe begins to rise. This indicates the injection timing is, for example, at 8° before the top dead center of the crankshaft. The thus obtained injection timing is regarded to be the normal injection timing. Thus, the time when the injection pump starts operation is regarded to be the injection timing, but the length of the fuel pipe connecting the injection pump to the injector is ignored by this measurement. Thus, the conventional method of measurement does not take into consideration the difference (see a in FIG. 9) between the start of the operation of the plunger of the injection pump and the start of the operation of the injector and, therefore, it is impossible to obtain the actual injection timing as is shown in curve III.

In accordance with the present invention, the injection timing and the injection pressure are obtained by dynamic measurement, and there is no danger that differences are present between the actual timing and rate of injection and their measured values.

As explained in the foregoing paragraphs, the present invention is characterized by the provision on the engine to be timed of an injector having a stress converting element adhered to its valve biasing device, and the stress change in said valve biasing device, at the time the valve leaves the valve seat to spray out the fuel, is converted into an electric signal. The thus obtained signal is employed to pass exciting current to trigger a stroboscopic lamp so as to flash synchronously with the lift of the injector valve. A scale showing the crank angle and rotating synchronously with the crankshaft of the engine and an opposed, fixed, indexing mark are illuminated by the lamp flashes, and are observed to read the crank angle at the time of the injection just as if the engine were in static condition.

Therefore, in accordance with the present invention, the injection timing of the injector can be detected while driving the constant speed or variable speed engine, and it is thus possible to correct the timing adjustment to meet the engine driving conditions by advancing or delaying the injection timing. As thus measured and adjusted, the operation of the engine is improved; the engine power is increased; and the amount of fuel fed to the engine is reduced, preventing high concentration of unburned gas in the exhaust due to imperfect fuel combustion.

A further advantage of the invention relates to the important function of preventing engine after-burn by abruptly stopping fuel injection and avoiding dripping of fuel through the injector outlet. When secondary injection occurs after normal injection finishes, the lifted condition of the valve during secondary injection is accompanied by a stress change in the valve biasing device which is also converted into an electric signal by the stress converting element added to the injector, and thereby causes a flash of the stroboscopic lamp. This of course, is easily observed, or detected, and adjustments can be then made to prevent the after-burn, or secondary injection.

The present device can be easily attached and removed as it occupies the same space as an injector without the device and the device can be easily adjusted and rebuilt.

Although certain specific embodiments of the invention have been shown and described, it is obvious that many modifications thereof are possible. The invention, therefore, is not intended to be restricted to the exact showing of the drawings and description thereof, but is considered to include reasonable and obvious equivalents.

The embodiments of the invention in which we claim an exclusive property of privilege are defined as follows:

**1.** Apparatus for dynamically detecting the injection timing of an internal combustion engine, comprising a fuel injection nozzle and holder therefor, a fuel outlet in said nozzle surrounded by a valve seat, a valve closing said outlet when engaging said seat, fuel passage means in said nozzle and holder arranged to feed fuel against said valve to displace the valve from the seat, valve biasing means pressing said valve against the valve seat, and a strain gauge acted on by said valve biasing means so as to detect the stress of said biasing means whereby each time said valve is about to leave its seat to inject fuel into an engine, the stress in the valve biasing means changes and this change is reflected in an electrical signal provided by said strain gauge.

**2.** Apparatus according to claim **1**, in combination with an internal combustion engine, a fuel feed source connected to said fuel passage means, a crank angle scale connected to rotate synchronously with the crank shaft of said internal combustion engine, an index mark fixed on the block of said engine opposite said scale, a stroboscopic lamp positioned to illuminate said scale and index, and electric circuit means connecting said strain gauge to said stroboscopic lamp and operative to energize the stroboscopic lamp upon the occurrence of a predetermined change is the electric signal produced by the strain gauge thereby indicating the crank angle at the time of fuel injection during operation of the engine.

**3.** Apparatus according to claim **1**, wherein said valve biasing means comprises a plurality of members including a stationary seat and a movable seat, a coil spring seated between said seats, and a push rod, the movable seat pressing against one end of the push rod whose other end engages said valve, said seats and said push rod being disposed in axial alignment with said valve, and said strain gauge being engaged with one of said members.

**4.** Apparatus according to claim **3**, wherein said strain gauge is a semiconductor.

**5.** Apparatus according to claim **3**, wherein said strain gauge is a piezoelectric element.

**6.** Apparatus according to claim **3**, wherein one of said seats for the coil spring includes a pressure sensitive device embodying a diaphragm, said strain gauge element being adhered to the diaphragm.