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[54] **TIMING DEVICE FOR FUEL INJECTOR**

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Related U.S. Application Data

[63] Continuation of Ser. No. 212,338, Dec. 27, 1971, abandoned.

[52] **U.S. Cl.** ..... **123/139 AQ,** 123/139 AP

[51] **Int. Cl.** **F02m 39/00,** F02d 1/04

[58] **Field of Search** ..... 123/139 AP, 90.17, 90.18, 123/90.19, 139 AQ

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[57] **ABSTRACT**

A hydraulic timing cylinder connected to the lubricating oil system for hydraulically retarding and advancing fuel injection for cranking and running speeds of the engine.

10 Claims, 4 Drawing Figures

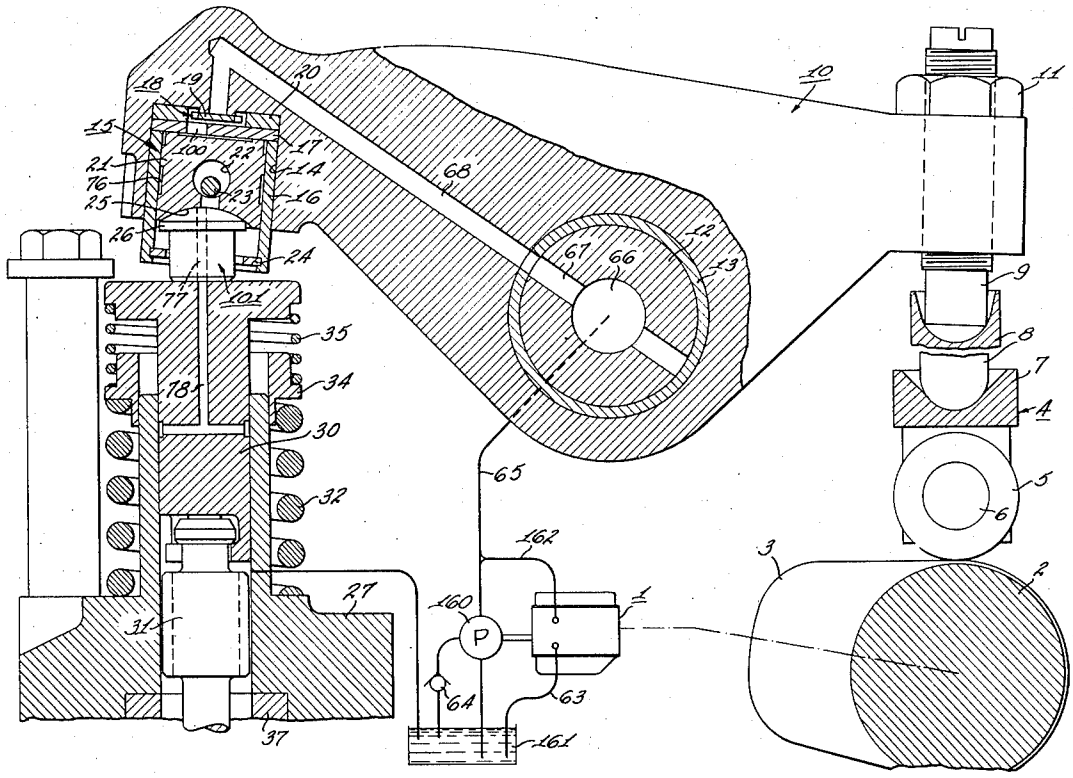
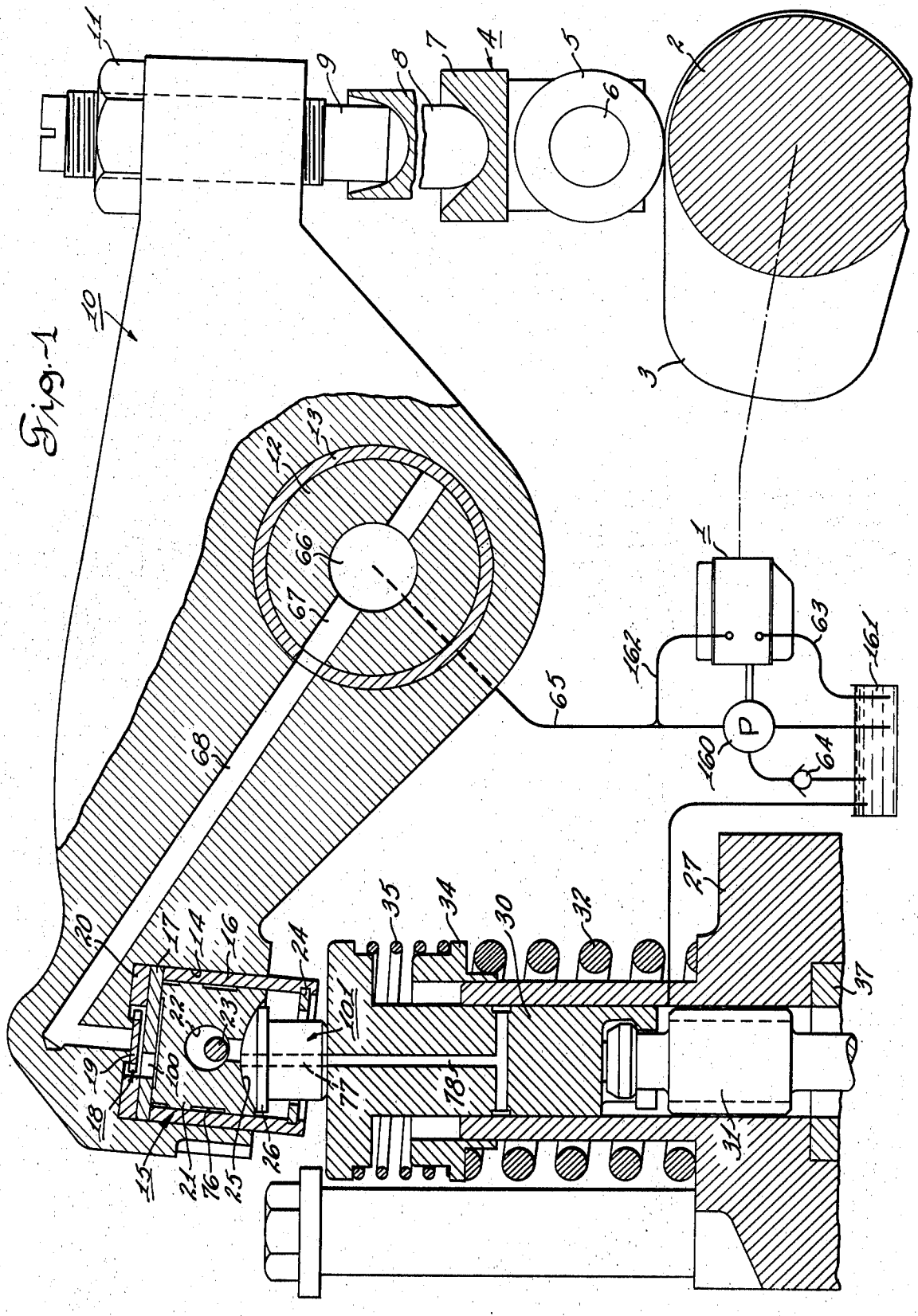


Fig. 1


14
9
8
7
4
5
6
2
10
3
12
13
66
67
68
1
65
162
63
162
P
160
64
20
17
14
16
24
35
34
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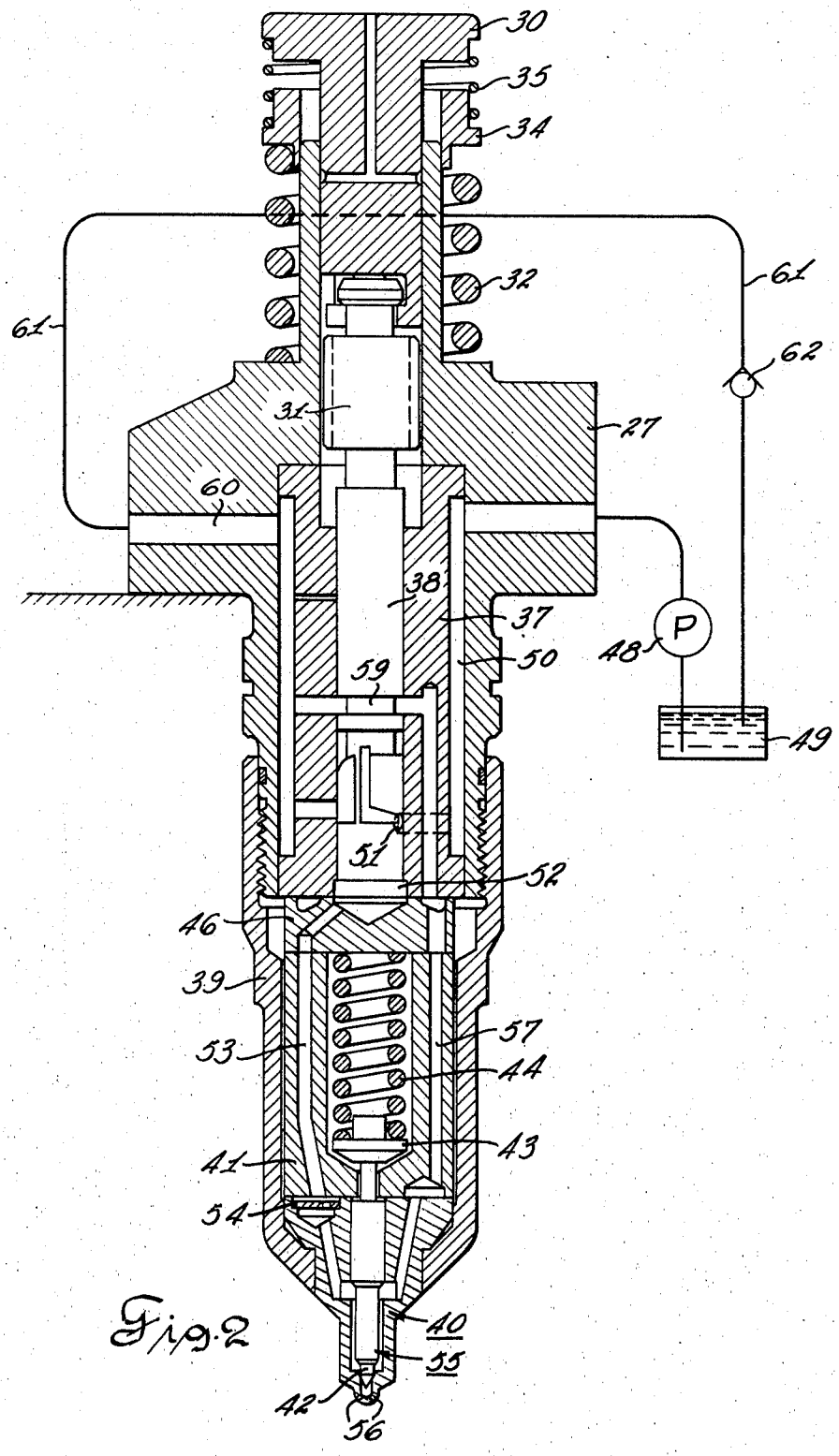

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Fig. 2

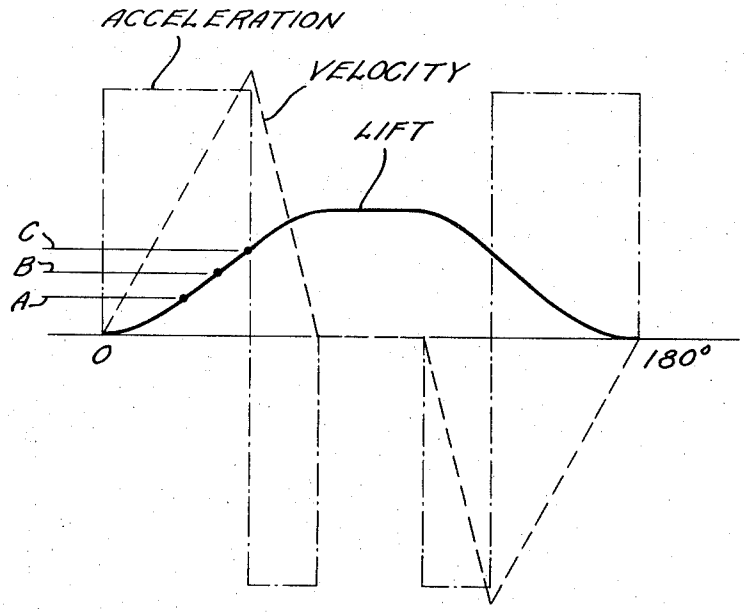

ACCELERATION
VELOCITY
LIFT
C
B
A
0
180°

Fig. 3

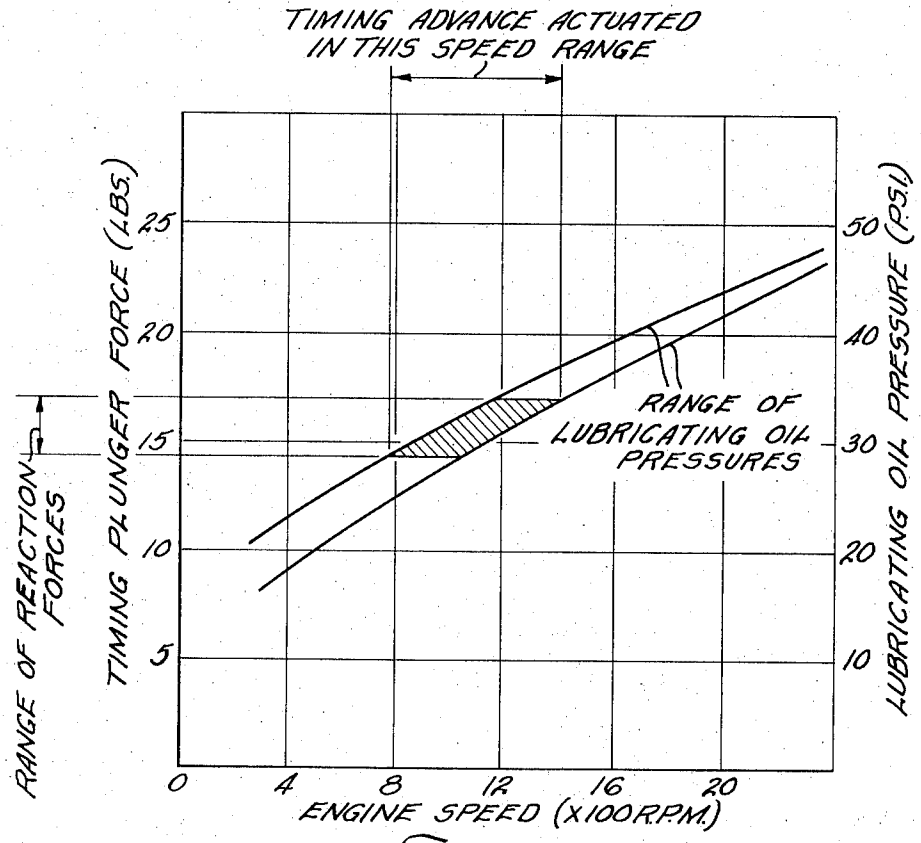

TIMING ADVANCE ACTUATED IN THIS SPEED RANGE
RANGE OF REACTION FORCES
TIMING PLUNGER FORCE (LBS.)
25
20
15
10
5
RANGE OF LUBRICATING OIL PRESSURES
LUBRICATING OIL PRESSURE (P.S.I.)
50
40
30
20
10
0
4
8
12
16
20
ENGINE SPEED (X100R.P.M.)

Fig. 4

TIMING DEVICE FOR FUEL INJECTOR

This is a continuation application of my application Ser. No. 212,338 filed Dec. 27, 1971, now abandoned.

This invention relates to fuel injection for an internal combustion engine and more particularly to a variable hydraulic timing cylinder connected to a hydraulic system having a pump operating responsive to engine speed for retarding and advancing fuel injection for cranking and running speeds of the engine.

Fuel injection on a diesel engine occurs at a predetermined angle of the crankshaft rotation in relation to top dead center of the engine crankshaft and piston and this angle remains essentially fixed throughout the engine speed range. For starting purposes, however, when the engine is rotated by a starting device at low speed, it would be desirable to close the fuel port to initiate fuel injection at a later point in the engine cycle. In other words it would be desirable to retard the port closing in relation to top dead center of the respective engine cylinder.

This invention relates to an engine driven camshaft operated fuel injection pump wherein the movement of the cam is transmitted to the pump plunger through a cam follower, and usually through a push rod and the rocker arm. This type of operation is usually used for the unit injector but may be used for certain in line multiplunger fuel injector pumps as well. Fuel injection occurs after the pump plunger has been moved by the cam through the initial portion of its stroke, and commences after the inlet port has been closed by the advancing injection plunger. Dephasing the cam responsive to the engine speed requires a complicated mechanism and is not economical. Accordingly, the use of a hydraulic cylinder in the fuel pump operating mechanism will overcome this problem, wherein expansion of the hydraulic cylinder is responsive to the pressure of pressurized fluid from a pump driven in proportion to engine speed. At cranking speed the pressures are sufficiently low such that the hydraulic timing cylinder is collapsed. When the pump speed increases and the pressure increases to a predetermined pressure, the timing cylinder expands to thereby advance timing of injection. The hydraulic timing cylinder is positioned at some point between the cam and the hydraulic plunger of the high pressure fuel injector.

Accordingly, it is an object of this invention to provide automatic hydraulic timing device for a fuel injector pump.

It is another object of this invention to provide an automatic timing advance mechanism for a unit fuel injector.

It is a further object of this invention to provide a hydraulic timing cylinder in the injection pump actuating means to retard fuel injection at cranking speeds and to automatically advance fuel injection at operating speeds of the engine.

It is a further object of this invention to provide a fuel injection pump actuating means including a hydraulic timing cylinder connected to the lubrication oil system of the engine whereby the hydraulic timing cylinder collapsed to retard fuel injection at cranking speeds and expands when a predetermined pressure is reached in the lubricating oil system to automatically advance fuel injection timing at engine operating speeds.

The objects of this invention are accomplished by employing an engine driven cam shaft driving a cam follower. The cam follower in turn drives through the push rod and rocker arm to operate a unit fuel injector. The hydraulic timing cylinder is positioned intermediate the rocker arm and the unit fuel injector to operate the plunger in a predetermined timing relation. This timing relation is changed by varying the length of the hydraulic timing cylinder. It is noted that a unit fuel injector is used in the description of this invention. It is understood, however, that a distributor type fuel injection pump or even a multiplunger fuel injection pump might be adapted for use with the hydraulic timing cylinder.

The lubrication oil system is connected through a rocker arm shaft having a passage which in turn is intermittently connected to a passage in the rocker arm which supplies pressurized oil to the timing cylinder. The timing cylinder, accordingly, operates in such a manner that at cranking speeds the lubrication oil pressure is too low to expand the timing cylinder consequently the timing of the fuel injection is retarded.

When a predetermined pressure in the lubrication oil system is reached the hydraulic timing cylinder expands and initiation of fuel injection is advanced. Accordingly, the oil pressure increases in response to engine speed and as the engine speed increases fuel injection timing is advanced for substantially all operating speeds.

The preferred embodiment of this invention is illustrated in the attached drawings.

FIG. **1** illustrates a cross section view of the fuel pump actuating means.

FIG. **2** illustrates a cross section view of a unit injector which is operated by the fuel injection pump operating means.

FIG. **3** is a graph of the acceleration, velocity, and lift diagram for the fuel injection pump plunger of the unit injector.

FIG. **4** is a chart illustrating engine speed and timing of a fuel injection pump responsive to a range of lubricating oil pressures.

FIG. **1** illustrates engine **1** driving a camshaft **2** having a cam **3.** The cam **3** drives the follower **4** which includes a roller **5** engaging the cam surface. The roller is rotatably supported on a shaft **6** which is carried in the follower sleeve **7.** The cam follower **4** operates push rod **8** which in turn drives the rocker arm timing adjusting screw **9** which is locked to the rocker arm **10** in the adjusted position by the lock nut **11.**

The rocker arm **10** is supported on a rocker arm shaft **12** which is received within the bushing **13.** The rocker arm **10** defines a cylindrical opening **14** which receives the hydraulic timing cylinder **15.** The hydraulic timing cylinder **15** includes sleeve **16** received in the recess with a spacer **17.** The spacer **17** has an opening **100** to permit the flow of hydraulic fluid through the spacer from the passages **66** and **68** through the check valve **18.** The check valve **18** is a flat check valve in which the valve element **19** is triangular in shape permitting the downward flow of hydraulic fluid through the annulus **20** and preventing return flow of hydraulic fluid. The piston **21** is received in the sleeve **16.** The piston forms a cross opening **22** of larger diameter than the pin **23** to permit reciprocal movement of the piston **21** to the extent of the difference in diameters of the opening **22** and pin **23.** The snap ring **24** is received in the lower end of the sleeve **16.** A socket **25** is formed on piston **21** receiving the ball end **26** of stud **101.**

The fuel injector shown is a unit fuel injector. The injection holder **27** is supported on the engine by suitable fastening means. Unit injector consists essentially of a follower **30** connected to the plunger **31** and received within the follower spring **32.** The follower spring **32** is freely extended between the spring spacer **34** and the holder **27.** The auxiliary spring **35** engages an annular surface on the spring spacer **34** and a similar radial flange on the follower **30** to compressively retain spring **35.**

The holder **27** receives the barrel **37** which embraces the plunger **38.** The cap nut **39** threadedly engages the holder **37** and seats the nozzle assembly **40** firmly against the lower spring retainer **41.** The nozzle assembly **40** forms a differential valve **55** with a needle **42.** Needle **42** is biased to a closed position by the spring seat **43** engaging the spring **44** which is received in the lower spring retainer **41.** The upper spring retainer **46** engages the upper portion of the spring **44** compressively forcing the spring seat **43** downwardly.

The fuel injection system consists essentially of a fuel supply pump **48,** fuel tank **49** and pumping the fuel into the inlet passage **50.** The inlet passage **50** is in communication through the inlet port **51** to the high compression chamber **52.** The high pressure fuel injection pumping chamber **52** supplies fuel through the passages **53** through the check valve **54** to the differential valve **55.** Fuel is injected through the orifices **56** in the nozzle assembly **40.** Return for the fuel is returned through the passage **57** and the annulus **59** to the outlet passage **60** and return conduit **61** through the check valve **62** to the fuel tank **49.** Initiation of fuel injection can be varied by rotation of the plunger **31** in response to the control rack on the engine. This control is used to control fuel injection timing during the operating speeds of the engine.

The engine **1** has a lubricating oil system which consists essentially of lubrication oil pump **160** driven by the engine **1.** The pump **160** receives lubrication oil from the reservoir **161** and supplies the lubricating oil through the conduit **162** to the engine **1** with a return passage **63** to the reservoir **161.** A relief valve **64** is also provided in the system to return excess oil to the reservoir.

The conduit **65** on the high pressure side of the pump **160** supplies oil to the axial passage **66** in the rocker arm shaft **12.** The radial port **67** is in communication with the passage **68** in the rocker arm **10** when the cam follower **4** is operating on the base circle of the cam **3.** Passage **68** supplies pressurized oil through the check valve **18** to the hydraulic timing cylinder **15.** When the engine speed reaches a predetermined value the pressure in the passage **68** is sufficient to bias the piston **21** downwardly against the opposing force of the auxiliary spring **35** and thereby advancing the timing of fuel injection.

FIG. **3** illustrates the acceleration, velocity, and lift curves for the cam **3** for **180°** of cam rotation. It is noted that the acceleration is constant for the initial portion of the curve and abruptly changes to deceleration. The cam follower spring **32** is of sufficient strength to overcome inertia forces of the drive mechanism of the injector and maintain contact between the follower and the cam as the follower rides over the nose of the cam.

FIG. **4** illustrates the timing advance and retardation of the fuel injection system. The advance and retardation of the fuel injection system is shown to operate within a range which allows for variations in the spring **35,** lubrication oil viscosity, and individual tolerance of parts in the system providing the expansion and contraction of the hydraulic timing cylinder **15.**

The operation of the system will be described in the following paragraphs.

When the engine is at a standstill and the injection cam **3** is operating on its base circle, the position of parts is as shown in FIG. **1** of the drawings. The timing piston **21** of cylinder **15** is bottomed against the spacer **17** and the injector plunger **31** must advance by the maximum amount of cam stroke until the port closing occurs. The point of port closing is shown to be the point B on the graph shown in FIG. **3.** In this position the timing device is at its maximum retard.

Let us consider the events after the engine is started and the engine speed increases. In the lubricating system the lubrication oil is delivered to the engine from the oil reservoir by means of a positive displacement lubrication oil pump **160** to the main lubricating oil gallery, bearings, and other parts of the engine with excess oil passing through the bypass passage and relief valve **64.** The lubrication oil pressure is function of engine speed. As the engine speed increases so does the pressure in the lubrication oil system. FIG. **4** illustrates a typical pressure curve wherein at a given engine speed the pressure valve may vary somewhat depending on the oil temperature, relief valve setting, bearing clearances, etc.

The relief valve setting and the force of the auxiliary spring **35** are adjusted in such a way that at some predetermined intermediate engine speed the lubrication oil system pressure overcomes the force of the auxiliary spring **35.** The lubrication oil then goes around the check valve **18** through the openings in the spacer **17** and into the timing cylinder **15.** In the interval between injections when the fuel pressure in the injection pumping chamber **52** is equal to the supply pressure, the lubrication oil pressure is able to push the timing piston **21** in the downward direction until it contacts the pin **23.** Therefore when the camshaft rotates to the beginning of the next cam lift, the timing piston **21** and through it the plunger follower **30** and the injection plunger **31** will already have partially advanced toward closing so that the port closing of port **51** and the corresponding start of fuel injection occurs earlier in the engine cycle. This point is illustrated by the point A on the graph of FIG. **3.** During the injection, the injection pressure forces check valve **18** against the seat to prevent the efflux of lubricating oil trapped in the timing cylinder.

Shortly after the port closing the auxiliary spring **35** collapses and the plunger follower **30** contacts spring spacer **34.** Further movement of the plunger follower compresses the main spring **32** which is designed to develop sufficient force at the beginning of the cam lift which is point C on the graph in FIG. **3** to overcome the cam deceleration and prevent the inertia forces from separating the components of the injector drive.

Only a small quantity of lubricating oil flows out through the clearance between the outside diameter of the timing piston **21** and inside diameter of the sleeve **16.** This lubrication oil leakage collects in the recess **76** and through the cross opening **22** and the axial passage **77** of the stud **101** and flows through passage **78** in the

follower **30** providing pressurized lubrication of the follower.

After completion of the cam lift when the cam follower returns to the cam base circle and the pressure and the injector pumping chamber has returned to the low values of fuel supply pressure, the lubrication oil system pressure will again open the check valve and resupply the timing cylinder **15**, bringing it back to the extreme of its stroke when the pin **23** contacts the upper portion of the passage **22.**

When the engine slows down again the lubricating oil pressure falls below the value which is able to overcome forces of auxiliary spring **35**, while the cam is on its base circle the lubricating system is unable to resupply the timing cylinder and leakage from it, which will still continue during each injection will gradually return the timing plunger **21** to its bottom position again retarding the start of fuel injection.

The values of lubricating oil pressure and the force of the auxiliary spring **35** are chosen preferably in such a way that the advance action takes place at an engine speed which is above the low idle speed of the engine but somewhat below the minimum speed at which the engine is operated under load.

In a typical example, an industrial engine as shown in FIG. **4** which is designed to develop maximum output at 2200 rpm the cranking speed might be 150 to 250 rpm, the low idle speed approximately **600** rpm and the low speed at which the engine is being operated in full throttle could be around 1500 rpm. In such a case, the timing mechanism would be designed to advance the timing plunger at speeds between 800 and 1200 rpm which is the shaded portion in the graph. Because in this speed range the engine is not operated under load the exact speed of which one of the engine cylinders begins to advance its injection would not be very critical. Variations in the lubrication oil system pressure, the individual tolerances of the parts, and the variations in the force of the auxiliary spring **35** would therefore not affect critically the engine performance.

It s understood that the lubrication oil system is used to control the hydraulic timing cylinder since the lubrication oil system is built into the engine. A separate hydraulic system might be used, however, it would require additional components on the engine and for this reason the lubrication oil system is more economical. It is further understood that the cam follower spring **32** is substantially stronger than the auxiliary spring **35** and extends to its freely extended length. The auxiliary spring permits the operation of the hydraulic timing cylinder during the phase of cam rotation when the cam follower is operating on its base circle of cam **3.**

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. An automatic hydraulic timing mechanism for a fuel injection pump on an engine comprising, a fuel injection pump including resilient means and a plunger, said resilient means including a follower spring extending to a free length and an auxiliary spring biasing said plunger to its return position, said plunger defining initially a retarded position of said plunger when said auxiliary spring is expanded and initially an advance position of said plunger when said auxiliary spring means is contracted, a fuel injection pump actuating mechanism for driving said fuel injection pump, an expansible hydraulic timing cylinder including a check valve in said mechanism for transmitting the driving force to operate said fuel injection pump, means defining a variable volume chamber in said hydraulic timing cylinder for receiving hydraulic fluid, means in said hydraulic timing cylinder defining a fully contracted position with a minimum volume position of said variable volume chamber for retarding fuel injection, said auxiliary spring in said fuel injection pump continuously pressing against said hydraulic timing cylinder throughout the fuel injecting pumping cycle and expanding while biasing said hydraulic timing cylinder to the fully contracted position when pressure of hydraulic fluid in said variable volume chamber is below a predetermined pressure with operation below intermediate engine speeds, means in said hydraulic timing cylinder defining a fully expanded position for advancing fuel injection when hydraulic fluid in said variable volume chamber at a pressure above said predetermined pressure causes said auxiliary spring to contract with operation above intermediate engine speeds, a hydraulic system including a hydraulic pump connected through said check valve to said variable volume chamber of said hydraulic timing cylinder for expanding said cylinder when pressure of hydraulic fluid is above said predetermined pressure, means connected to the said hydraulic pump adapted for driving said hydraulic pump proportional to the engine speed to thereby provide retardation of fuel injection timing at cranking speed and automatic advance of fuel injection when operating above intermediate engine speeds when the hydraulic pressure is above said predetermined pressure.

2. An automatic hydraulic timing mechanism for a fuel injection pump on an engine as set forth in claim **1** wherein said fuel injection pump actuating mechanism includes an engine driven cam defining a base circle, a cam follower, a push rod operated by said cam follower, a rocker arm operated by said push rod and defining means for connection to said hydraulic timing cylinder.

3. An automatic hydraulic timing mechanism for a fuel injection pump on an engine as set forth in claim **1** wherein said hydraulic timing cylinder includes a piston, movement limiting stops engaging said piston defining said two positions including said contracted position for retardation of fuel injection timing at cranking speeds and said expanded position for fuel injection during operating speeds for said engine.

4. A fuel injection pump on an engine as set forth in claim **1** including an internal combustion engine, means connecting said hydraulic pump with said engine for driving said hydraulic pump in proportion to the engine speed to thereby provide retardation of fuel injection at cranking engine speeds and advance of fuel injection for all operating engine speeds.

5. An automatic hydraulic timing mechanism for a fuel injection pump on an engine as set forth in claim **2,** wherein said auxiliary spring biases said hydraulic timing cylinder to the fully contracted position when said follower is operating on the base circle of the cam.

6. An automatic hydraulic timing mechanism for a fuel injection pump on an engine as set forth in claim **1** wherein said hydraulic system defines a lubrication oil system on said engine.

7. An automatic hydraulic timing mechanism for a fuel injection pump on an engine as set forth in claim **1,** wherein said fuel injection pump defines a unit fuel injector, a cam follower, a cam in said pump operating

mechanism for driving said follower, means connecting said cam follower to said hydraulic timing cylinder for operating said fuel injection pump, a spring spacer positioned between said follower spring and said auxiliary spring, said follower spring producing a substantially greater spring force than said auxiliary spring and extending to a free length, said auxiliary spring collapsing upon expansion of said hydraulic timing cylinder during the phase of cam rotation when said cam follower is operating on the base circle of the cam to thereby advance fuel injection timing.

8. An automatic hydraulic timing mechanism for a fuel injection pump on an engine as set forth in claim **1** wherein said hydraulic system includes an engine, means connecting said hydraulic pump to said engine for operating responsive to engine speed, a cam, a push rod and rocker arm driving said fuel injection pump, a rocker arm shaft and said rocker arm in said pump actuating means defining passage means in communication with said hydraulic system, a radial port in said rocker arm shaft intermittently in communication with the passage means in said rocker arm to intermittently supply hydraulic pressure in said hydraulic timing cylinders when said cam follower is operating on the base circle of said cam.

9. An automatic hydraulic timing mechanism for a fuel injection pump on an engine as set forth in claim **1** including a spring spacer positioned between said follower spring and said auxiliary spring.

10. An automatic hydraulic timing mechanism for a fuel injection pump on an engine as set forth in claim **1** wherein said follower spring produces a substantially greater force than said auxiliary spring and extends to a free length.

* * * * *