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[54] **FUEL INJECTION PUMP TIMING AND METERING ARRANGEMENT**

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[52] **U.S. Cl.** ....**123/139 AP,** 123/139 BD, 123/139 AB, 123/139 AC, 123/139 AR, 123/139 AD, 123/139 AE

[51] **Int. Cl.** **F02m 39/00**

[58] **Field of Search** ....123/139 R, 139 BD, 139 AP

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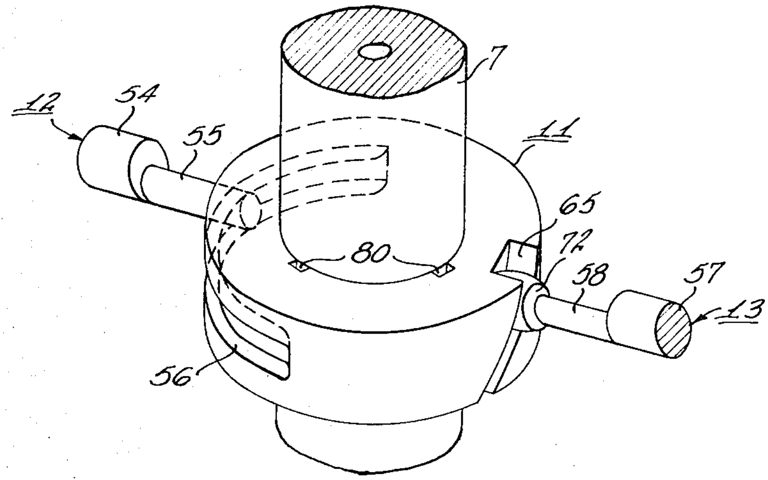
[57] **ABSTRACT**

A fuel injection pump for an internal combustion engine having a control sleeve operated by separate metering and timing control elements.

10 Claims, 13 Drawing Figures



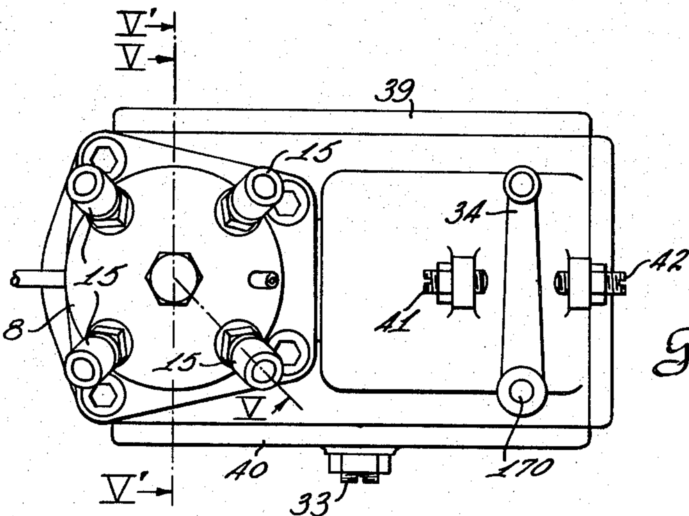


Fig. 1

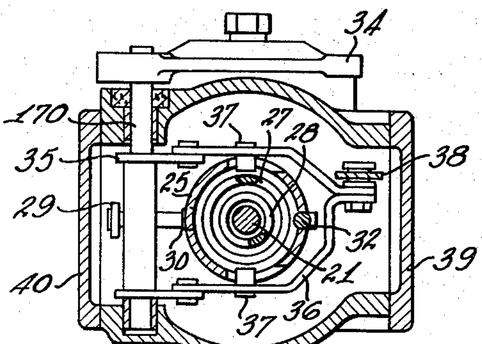


Fig. 4

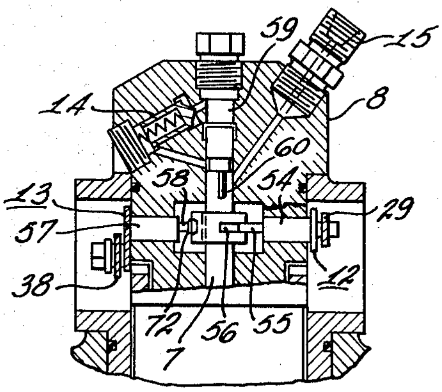


Fig. 5

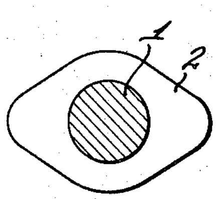


Fig. 6

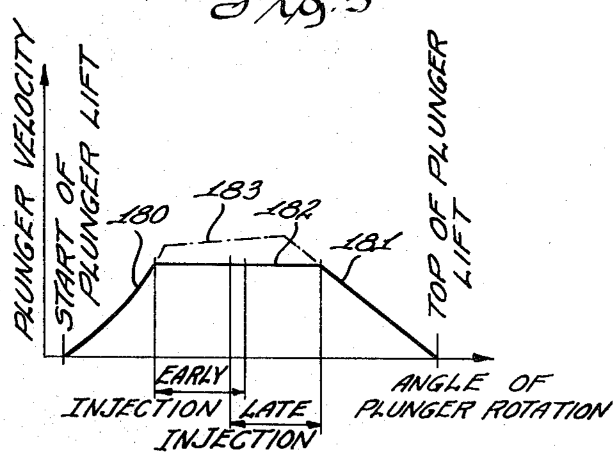


Fig. 11

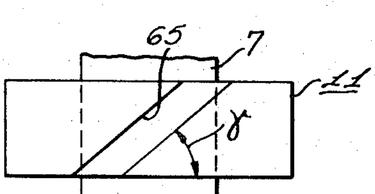


Fig. 13

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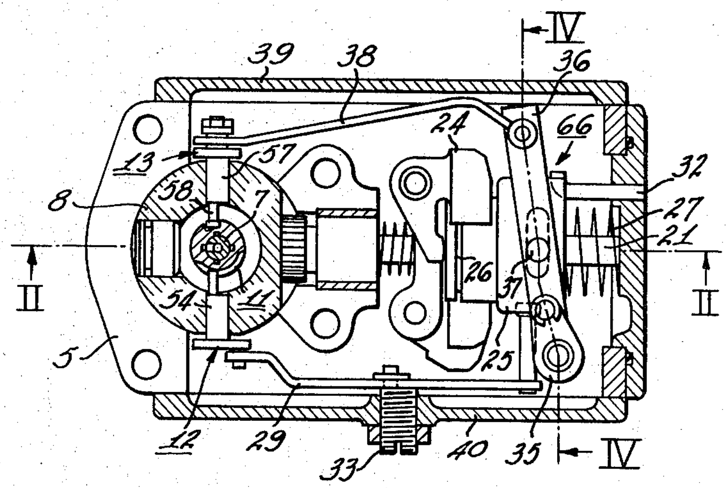

Fig. 3

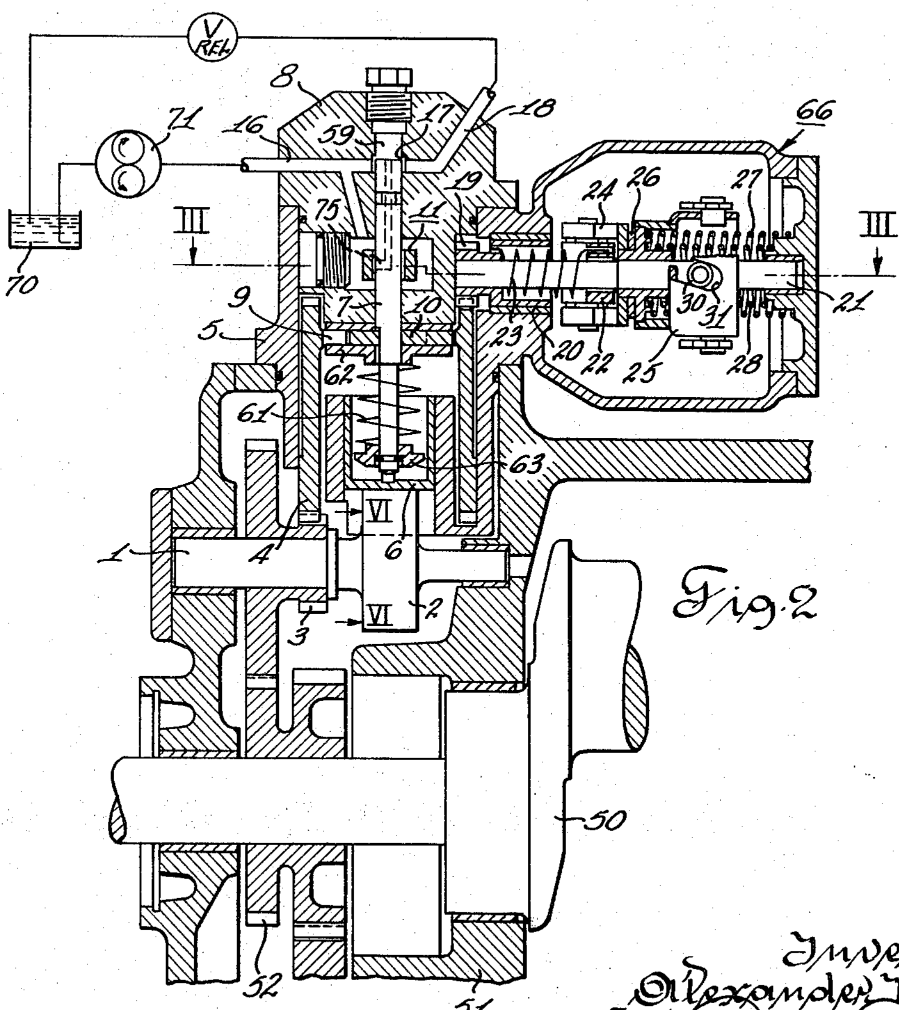

Fig. 2

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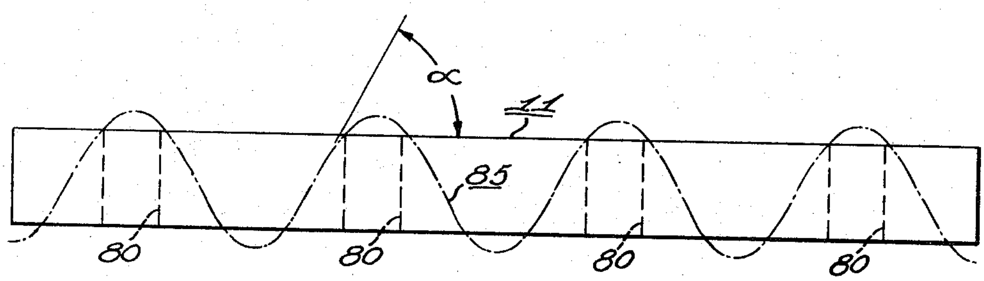

Fig. 7

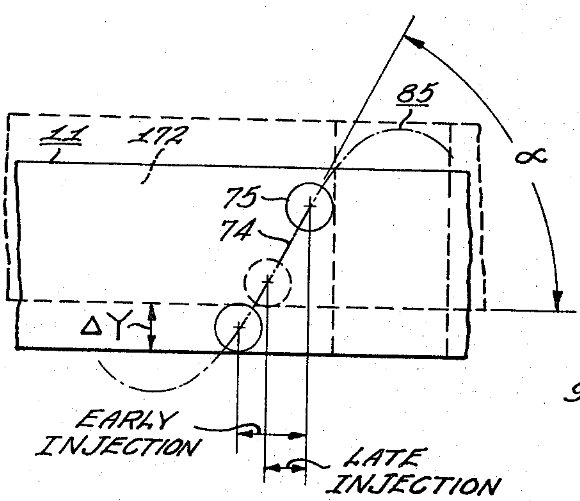

Fig. 8

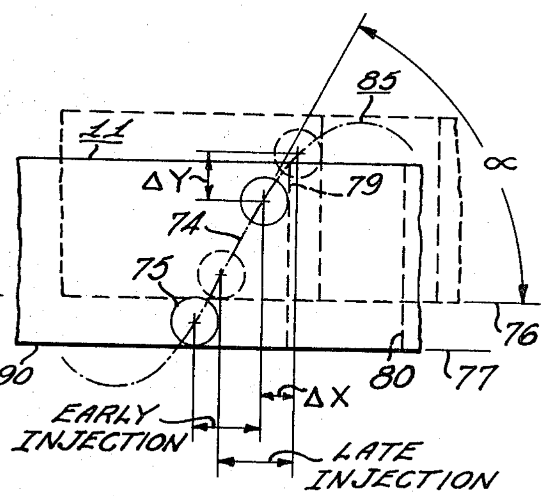

Fig. 10

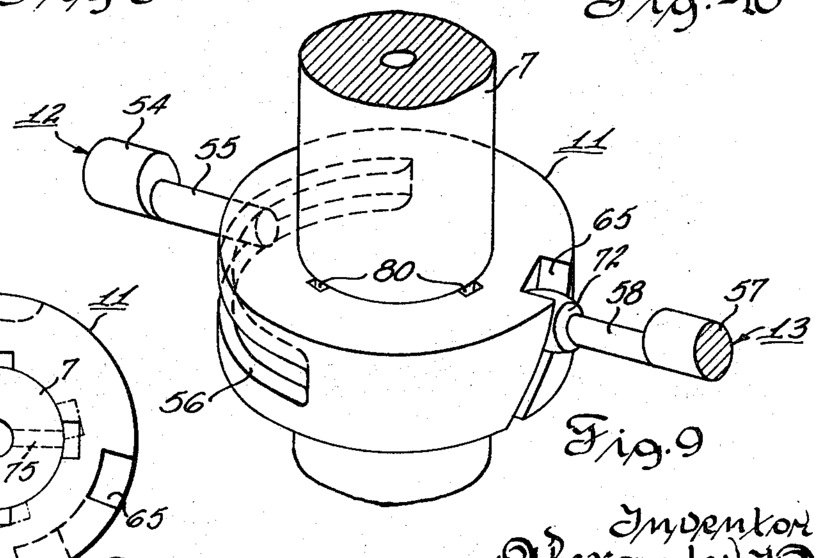

Fig. 9

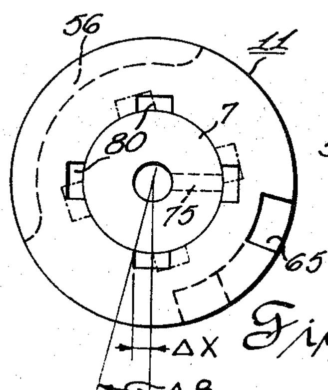

Fig. 12

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FUEL INJECTION PUMP TIMING AND METERING ARRANGEMENT

This invention relates to a fuel injection pump and more particularly to means providing individual metering and timing control levers to operate the control sleeve whereby movement of one lever effects a control without changing the effect of the other control lever.

Distributor type fuel injection pumps of the type which utilize a reciprocating plunger which reciprocates within the pump housing usually in response to a cam action while simultaneously being rotated for selective communication with delivery passages to the engine, normally use a control sleeve to sequentially close and open communication between a fuel supply chamber and a high pressure injection chamber. The closing of a port initiates fuel injection while opening of the port permits the spill of pressurized fluid to terminate fuel injection.

The conventional control mechanism for the control sleeve raises or lowers the control sleeve on the plunger whereby lowering of the sleeve advances timing of fuel injection while the raising of the sleeve retards the timing of fuel injection. A rotation of the control sleeve controls the quantity of fuel injected by metering the quantity of fuel to each combustion chamber. Generally, controlling of timing and quantity of fuel is through a single rod. The timing control varies either the start or the end of fuel injection and in the conventional fuel injector this also varies the effective stroke. This has disadvantageous effects since it is not necessarily desirable to increase the quantity of fuel with an advance in the timing of the fuel injection and accordingly this invention provides a means whereby the timing is completely independent of the quality of fuel injection. This is accomplished by using axial grooves on the inner periphery of the control sleeve which will spill pressurized fluid on termination of fuel injection. The port on the plunger sequentially communicates with the spill groove. The path of the spill port of the plunger defines a wavy curve due to the rise and fall of the cam follower reciprocating the plunger while the plunger is simultaneously rotated. The constant velocity portion of the curve defines an angle on the inner periphery of the control sleeve. If the slot receiving an element of the quantity control linkage positioned on the external periphery of the control sleeve is positioned at a properly selected angle, the effective length of the pumping stroke of the plunger can be kept constant for any retardation or advance of the fuel injection cycle.

Accordingly it is an object of this invention to provide a fuel injection pump having separate metering and timing control elements connected to the control sleeve.

It is another object of this invention to provide a fuel injection pump having a control sleeve to control the timing and metering with individual levers connected to the control sleeve through control slots on the external periphery on the control sleeve.

It is a further object of this invention to provide a distributor type fuel injection pump having a control sleeve receiving a pumping plunger whereby the outer perimetry of the control sleeve forms a horizontal slot to receive a timing control element and an inclined slot to receive a quantity control element, the angle being such as to maintain the vertical distance between port closing and port opening and isolate the effect of timing changes applied to the control sleeve so that a timing change does not vary the quantity setting and vice versa.

The objects of this invention are accomplished by providing in a distributor type fuel injection pump a cam operated plunger having means for rotating the plunger simultaneously with its reciprocation. A horizontal slot in the external periphery of the control sleeve is connected to a speed responsive device to control the timing of fuel injection of the pump. The path of the port on the plunger which sequentially opens and closes as it reciprocates and rotates in the sleeve forms a wavy curve having a constant velocity portion of the curve which defines a predetermined angle. The metering slot on the external periphery of the control sleeve is formed at an angle duplicating the lead of the constant velocity portion of the port curve. Accordingly any change in timing due to raising and lowering in the sleeve does not change the effective length of the pumping stroke for fuel injection. Accordingly the metering control is independent of the timing control and each control separately controls its function of timing and metering.

Referring to the drawings:

FIG. 1 is a top view of the fuel injection pump and governor assembly;

FIG. 2 is a cross section view of the fuel injection pump and governor assembly mounted on an engine taken on line II—II of FIG. 3;

FIG. 3 is a cross section view taken on line III—III in FIG. 2;

FIG. 4 is a cross section view taken on line IV—IV on FIG. 3;

FIG. 5 is a cross section view with the upper portion taken on line V—V and the lower portion taken on line V′—V′ of FIG. 1;

FIG. 6 is a cross section view taken on line VI—VI of FIG. 2;

FIG. 7 is a view showing the development of the control sleeve with fragmentary views showing control elements on the external peripheral grooves;

FIG. 8 is an illustration of a sleeve movement for a sleeve having a vertical quantity control slot;

FIG. 9 is a three dimensional view of the control sleeve;

FIG. 10 is an enlarged portion of the development;

FIG. 11 is a plunger velocity control graph;

FIG. 12 is an illustration of relationship of dimensional and angular rotation of the control sleeve;

FIG. 13 is a front view of the quantity control slot in the control sleeve.

Referring to FIG. 2 the engine crankshaft **50** is rotatably mounted in the housing **51** and carries the drive gear **52** which drives a pump drive gear **3**. The pump drive gear **3** is carried on the camshaft **1** and drives the cam **2** at engine speed.

The cam is a double lobe cam for operation with a four cylinder, four stroke cycle engine.

A pinion of the pump drive gear **3** engages the lower face gear of the cup gear **4** which is guided axially in the pump housing **5**. It also contains a coaxially guided flat cam follower **6**. The pump plunger **7** is fitted into the pump head **8**. In addition to the reciprocal movement imparted by the cam **2** the plunger **7** is rotated by the cup gear **4** through the inwardly extending prongs **9** which engage slots in the drive plate **10**. The drive plate **10** has a D-shaped opening in its center cooperating with the plunger outside diameter which has a flat on one side.

A control sleeve **11** is rotatably and slidably positioned on the intermediate portion of the plunger **7**. The metering and timing mechanism for operating the control sleeve includes 2 levers, one for each function. The timing control is introduced into the control sleeve **11** by the crank **12**. The crank arm **12** has a cylindrical portion **54** which is journaled in the head **8** and has an eccentric pin **55** extending into a substantially horizontal slot **56** on the external periphery of the control sleeve **11**. As the crank **12** is rotated in response to a movement of the lever **29**, the control sleeve is moved upwardly or downwardly on the plunger which controls the timing function of the fuel injection pump.

Angular dephasing of the sleeve **11** provides the metering function of the control sleeve. The crank **13** also has a cylindrical portion **57** which is journaled in the pump head **8** and has an eccentric pin **58**. The crank **13** is connected to the lever **38** and provides quantity control. The pin **58** is equipped with a spherical end **72** engaging the slanted slot **65** in the control sleeve. Angular rotation or counterrotation of the control sleeve regulates the quantity of fuel injected.

The plunger **7** reciprocates in the head **8** and pumps by pressurizing fuel in the high pressure chamber **59**. The pump head is equipped with a conventional delivery valve **14** and four outlet fittings **15** which are sequentially connected through distribution slot **60** on the plunger **7** to delivery valve

14. Fuel is supplied from supply pump **71** through the passage **16** and goes around the plunger by the annulus **17** and out through the passage **18** to a pressure relief valve, and back to the tank **70**. It is understood that only surplus fluid is returned to the tank and that during the pumping cycle fuel is pressurized and delivered through the delivery valve to a combustion chamber (not shown).

The plunger **7** is seated on the cam follower **6** and the spring **61** on the upper spring seat **62** biases the lower spring seat **63** on the lower end of the plunger **7** downwardly to make a firm seating between the plunger and the cam follower **6**. The cam **2** biases the plunger upwardly against the force of the spring **61** during the pumping operation.

The face gear cut in the upper portion of the cup gear **4** engages the governor drive pinion **19** which is positioned in sleeve bearing **20** and has a sliding fit with a governor shaft **21**. The weight spider **22** is pressed onto the splined portion of the governor shaft **21**. The weight spider is driven through the low frequency torque spring **23**, connected between the gear **19** and the weight spider assembly **22**. The governor weight **24** transmits centrifugal force through the shifter assembly **25** through the thrust bearing **26**. Springs **27** and **28** balance the axial vector of the centrifugal forces produced by the governor weights **24**. The axial movement of the shifter assembly **25** is thus a function of the governor speed which in turn is in direct relationship to engine speed.

The timing advance and retard motion is initiated by the shifter assembly and is transmitted by the timing lever **29** to the timing crank **12**. The timing lever **29** has a spherical end **30** which is engaged to a helical slot **31** in the cup end of the shifter **25**.

The shifter assembly **25** is guided axially by a fixed pin **32** which registers in an axial slot in the cup of shifter assembly **25**. Initial adjustment of the pump timing, which for the purpose illustrated is at port closing, is made from the outside adjusting screw **33** which moves an eccentric pin serving as a fulcrum for the timing lever **29**.

The metering function provides a rotational movement of the control sleeve **11**. The metering movement is transmitted through a conventional floating fulcrum arrangement from the throttle lever **34** through the fulcrum assembly **35**, governor yoke **36**, which engages the shifter by means of pins **37**, through the lever **38** to the metering crank arm **13**. Any other control arrangement such as torque limiter, starting boost, pressure compensator or other modifying sensors can be mounted on the covers **39** and **40** for convenient interaction with the basic governor mechanism. Exterior adjustments **41** and **42** are respectively high idle and low idle stops.

FIG. 7 illustrates the development of the control sleeve and the curve produced by the path of the port **75** in the plunger **7** as it simultaneously reciprocates and rotates within the control sleeve **11**. The spill slots **80** are shown in FIGS. 7 and 8 and their relationship with the curve formed by the movement of the port in the plunger. In a conventional timing control of distributor type pump, a timing change varies either start or ending of fuel injection. This also varies the effective stroke length which is undesirable. This invention however provides a means whereby the effective pumping stroke remains constant with timing variations. With the separate cranks controlling the timing and metering as shown in FIGS. **7**, **8**, **9** and **10**, crank arm **12** changes timing by moving the control sleeve **11** up and down. Crank arm **13** changes the quantity of fuel injected by moving the sleeve in a horizontal plane in a clockwise or a counterclockwise rotation. The slot **65** engaging the crank arm **13** for quantity control is slanted. When the slot **65** engaging the end **72** of crank arm **13** is positioned to the same lead as the angle formed by the constant velocity portion of the curve **85**, the effective stroke remains constant notwithstanding timing variations. Accordingly the timing control and the metering or quantity control provide control of the control sleeve which is unaffected by the movement of the other control lever.

FIG. **11** shows the plunger movement generated by a typical cam profile in an injection pump subdivided into three portions. The first portion **180** is needed to accelerate the plunger and shows a rising velocity. The last portion **181** shows the movement caused by the nose of the cam over which the plunger decelerates, and comes to rest momentarily at the top of the stroke; and the intermediate portion **182** which is used essentially for the injection itself. This intermediate portion is made typically with either a constant velocity, as shown in solid line on FIG. **11** or a somewhat variable velocity shown by the dotted line **183** in FIG. **11** which can be approximated by an average constant value. If we look at the trace of the port against the inside diameter of the sleeve this curve is approximately sinusoidal, or preferably termed a wavy curve.

Referring again to FIG. **11**, an early injection is shown at the beginning of the constant velocity portion of the cam and a late injection during the later part of this portion. Because both injections are at constant velocity and have the same duration or the same angle of plunger rotation, both will have the same effective stroke and will deliver equal quantities of fuel.

The control sleeve of the type referred to in the description always has the injection controlled by a horizontal sleeve edge and a slot edge. Either edge can be used to start or end an injection. In the following figures the lower edge of the sleeve controls port closing and the left hand edge of vertical slot controls port opening.

FIG. **8** shows effect of retarding the start of injection when the sleeve is lifted by the amount ΔY without rotation of the sleeve. Port closing occurs later by this amount of effective stroke, while the port opening is still at the same point as before.

FIG. **10** shows what happens if, in addition, we rotate the sleeve moving it to the right by the amount ΔX. This amount is chosen in such a way as to add ΔY to the effective stroke so that the total effective stroke remains unchanged. The amount ΔX by which we rotated the sleeve corresponds to an angle of rotation of $\Delta\beta$. This angle $\Delta\beta$ is required to maintain constant effective stroke when we lift the sleeve by the amount ΔY.

Assuming that the slope of the constant velocity portion of the cam continues indefinitely, then a rotation of the sleeve 360° will raise the sleeve by the amount Y, maintaining the original total effective stroke. By an analogy with a screw and nut this is known as the lead or the amount by which a nut advances axially when rotated a complete turn. Therefore, the inclined control slot on the outside of the sleeve makes an angle with the horizontal which has the same lead as the angle which the path of the port makes on the inside of the sleeve. Mathematically it is expressed as follows:

Y = constant. Where Y = lead.

On the inside diameter of the sleeve:

$$\tan\alpha = \Delta Y/\Delta X = Y/\pi d \qquad \text{I}$$

where d = inside diameter of sleeve

$$Y = \pi d \tan\alpha \qquad \text{II}$$

On the outside of this sleeve at the diameter D on which the quantity control knob (**72**) contacts the inclined slot, we have:

$$\tan\alpha = Y/\pi D \quad \text{(see FIG. 5)}$$

or, substituting from II

$$\tan\alpha = d/D \tan\alpha \qquad \text{III}$$

Therefore, the correct statement is: the control slot angle with horizontal is equal to angle α on the sleeve inside diameter multiplied by the ratio of the diameters d/D.

The operation of this device is described in the following paragraphs. When the engine is in operation the engine crankshaft **50** carrying the drive gear **52** drives the pump drive gear **3**. The drive gear **3** drives the cup gear **4** which in turn is connected to the drive plate **10** which rotates the plunger **7**. Simultaneously with rotation of the plunger **7** the camshaft **1** carrying the cam **2** is rotated. The cam **2** is a double lobe cam and it rotates at engine speed. The plunger **7** is reciprocated simultaneously with its rotation causing port **75** to define curve as shown in FIGS. **7** and **9**. The governor **66** is also driven by the cup gear **4** which drives the governor drive pinion **19**. The flyweight spider **22** is driven through the torque spring **23** thereby producing an axial movement of the shifter assembly **25** in response to speed of rotation of the flyweight. This in turn produces the axial movement of the shifter assembly which controls the timing and metering function supplied to the fuel injection pump.

The control sleeve **11** is rotatably and reciprocably mounted on the plunger **7**. The control of timing is provided through the timing lever **29** which is connected to the shifter assembly **25**. As the speed increases the flyweights **24** move radially outward shifting the shifter assembly to the right as shown in FIG. **3**. This in turn causes the spherical end **30** to move in the slot **31** causing the pivoting of the shifter lever **29** on its fulcrum screw **33**. With an increase in engine speed the lever moves to lower the control sleeve **11** which advances timing of the fuel injection. A reverse function produces a lifting of the control sleeve which in turn retards the timing of the fuel injection.

The throttle lever **34** is a manually controlled lever which moves the throttle assembly and the throttle arm **35**. The throttle arm **35** is pivoted on the shaft **170** which in turn pivots the end of the lever **36**. This in turn moves the metering lever **38**, crank arm **13**, and rotates the control sleeve **11**. The shifting movement of the shifter assembly to the right with increased engine speed causes rotation of the lever **36** and the metering lever **38** and rotation of the control sleeve. This in turn will cause the control sleeve to rotate counterclockwise or shift to the right as viewed in FIG. **10** permitting the path of the port in the plunger to move through a larger segment of the land **172**, thereby increasing the time which the port is closed. The reverse situation is produced when the sleeve is rotated in the opposite direction aNd the quantity of fuel is decreased. Consequently the port is closed for a shorter length of time and the fuel injection duration is for a shorter period. This is shown in FIG. **8** by moving the path of the port **75** to the right to cause a shorter duration of the closed port and consequently reduce quantity of fuel injection.

It can also be seen that if the sleeve is moved upwardly or downwardly in response to the timing function that the duration of fuel injection is not changed since the lead of the slot **65** is substantially the same as the constant velocity portion **74** of the curve **85**. The port closes at the point where the port passes under the lower edge **90** of sleeve **11** in FIG. **10** and opens when the port passes over the edge **79** of the groove **80**. Regardless of whether the lower edge of sleeve **11** is in retarded position at **76** or in advanced position at **77**, the duration of the closed port condition during fuel injection remains substantially constant. Accordingly, a timing change does not affect duration of fuel injection.

The preferred embodiments of this invention have been illustrated and described.

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

1. A fuel injection pump for an internal combustion engine comprising, a pump housing defining a cylindrical bore and a plunger received in said bore defining a fuel injection pumping chamber and a fuel supply chamber, means simultaneously reciprocating and rotating said plunger to define a predetermined angular motion of the plunger during fuel injection, said housing and said plunger defining a fuel supply passage and a fuel discharge passage in communication with said pumping chamber, a control sleeve in said supply chamber receiving said plunger, said sleeve defining a sleeve edge and a spill groove on the inner periphery of said sleeve, said plunger defining passage means and a spill port connected to said pumping chamber and selectively and alternatively passing over said sleeve edge and said spill groove to control fuel injection, said control sleeve defining a horizontal peripheral timing slot and a diagonal peripheral metering slot on the external periphery of said control sleeve with said diagonal slot defining a predetermined constant relationship to the angular motion of said plunger, a speed responsive device, a timing control linkage connected between said speed responsive device and said control sleeve for engaging said sleeve in said timing slot for controlling the timing of said fuel injection pump, a fuel quantity control linkage connected between said speed responsive device and said control sleeve for engaging said sleeve in said metering slot for controlling the metering of said fuel injection pump.

2. A fuel injection pump for an internal combustion engine as set forth in claim 1 wherein said means simultaneously reciprocating and rotating said plunger moves said spill port in said plunger through a curve having constant velocity portion defining a predetermined axial advance per degree rotation of said plunger, said metering slot defines an axial advance per degree rotation of said sleeve substantially equal to the axial advance defined by the constant velocity portion of said curve to thereby permit the quantity fuel setting to remain constant when injection timing is changed.

3. A fuel injection pump for an internal combustion engine as set forth in claim 1 wherein said control sleeve includes a vertical spill groove on the internal periphery of said control sleeve to spill pressurized fluid from said pumping chamber for termination of fuel injection during operation of said fuel injection pump.

4. A fuel injection pump for an internal combustion engine as set forth in claim 1 wherein said means reciprocating and rotating said plunger include a face gear rotating said plunger and a cam reciprocating said plunger to thereby cause the spill port of said plunger to define approximately a sinusoidal path.

5. A fuel injection pump for an internal combustion engine as set forth in claim 1 wherein said plunger defines an axial passage means in communication with said pumping chamber and a radial passage means defining said spill port connected to said axial passage means in said plunger.

6. A fuel injection pump for an internal combustion engine as set forth in claim 1 wherein said means reciprocating and rotating said plunger includes a cam and gear driving said plunger to cause said spill port to define a curve having a constant velocity portion forming an angle of a predetermined lead on the internal periphery of said control sleeve, said sleeve defines said metering slot on its external periphery at another angle having substantially equal lead to the angle of the constant velocity portion of said curve, said control sleeve defines said horizontal timing slot on its external periphery connected to said timing control linkage to thereby provide metering and timing function of said fuel injection pump.

7. A fuel injection pump for an internal combustion engine as set forth in claim 1 wherein said control sleeve defines a plurality of vertical spill grooves on its inner periphery.

8. A fuel injection pump for an internal combustion engine as set forth in claim 1 wherein said control sleeve defines at least one substantially vertical spill groove on its internal periphery and said metering slot means includes a helical slot on its external periphery.

9. A fuel injection pump for an internal combustion engine as set forth in claim 1 wherein said control sleeve defines at least one vertical land and groove defining said spill groove on its inner periphery, said means simultaneously reciprocating and rotating said plunger causes said spill port in said plunger to define a diagonal path across a portion of said land whereby movement of the spill port over the lower edge of said sleeve initiates injection and movement to the edge of said groove terminates fuel injection.

10. A fuel injection pump for an internal combustion engine as set forth in claim 9 wherein said timing and quantity control linkages include means axially moving said sleeve on said plunger to control timing and rotatably moving said sleeve on said plunger to control quantity of fuel injection.

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