Jan. 21, 1947. L. J. GARDAY 2,414,518

FUEL INJECTION PUMP

Filed Dec. 12, 1942 3 Sheets-Sheet 1

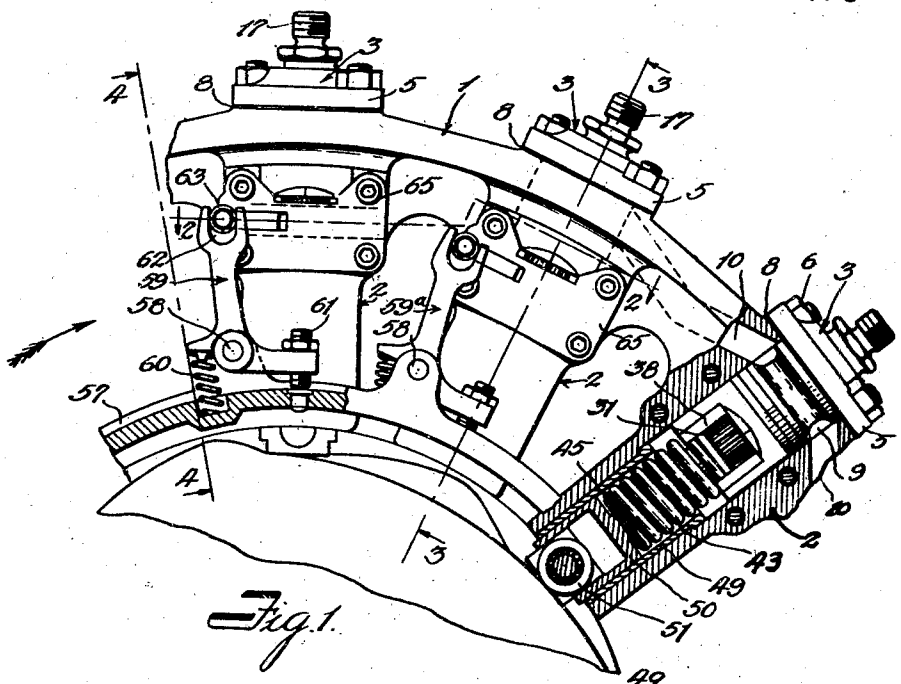

Fig. 1.

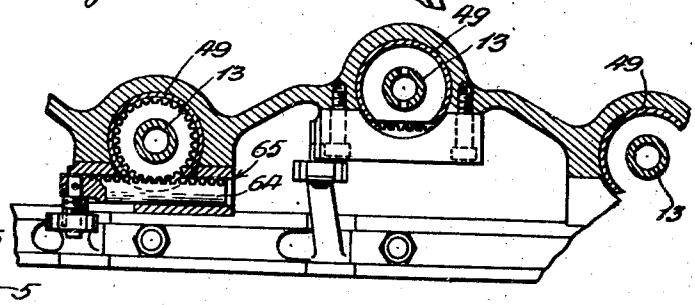

Fig. 2.

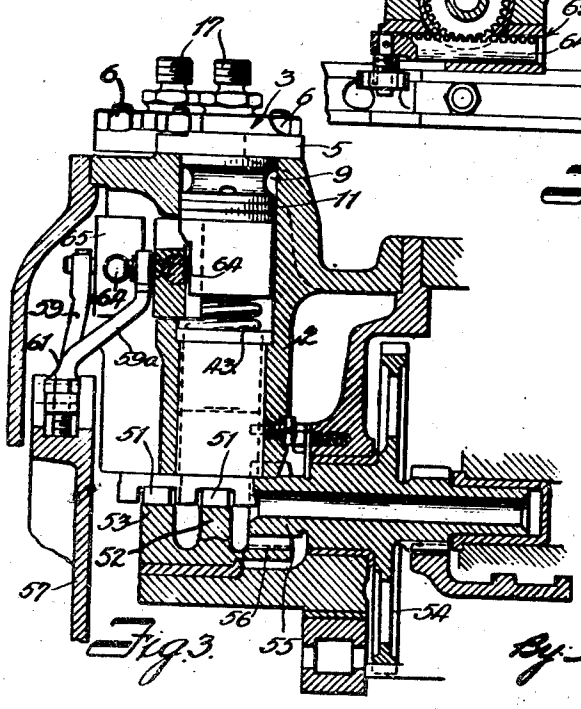

Fig. 3.

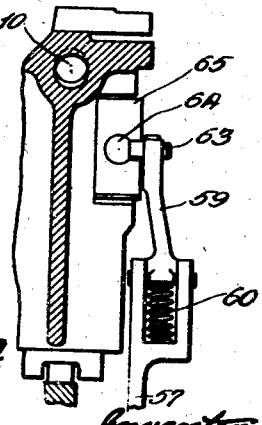

Fig. 4.

Inventor
Louis J. Garday
By Thies, Olson & Mecklenburg
Attys.

Jan. 21, 1947. L. J. GARDAY 2,414,518

FUEL INJECTION PUMP

Filed Dec. 12, 1942 3 Sheets-Sheet 2

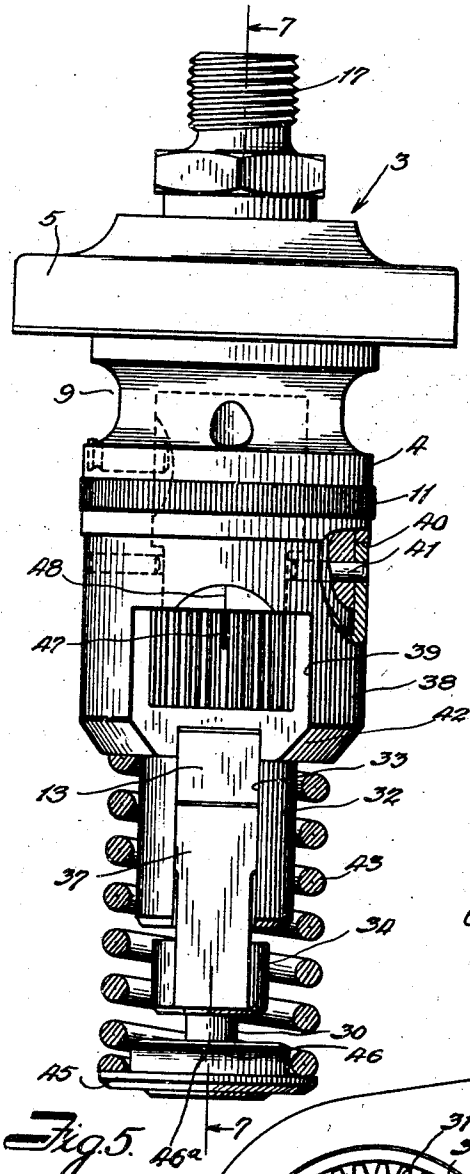

Fig. 5.

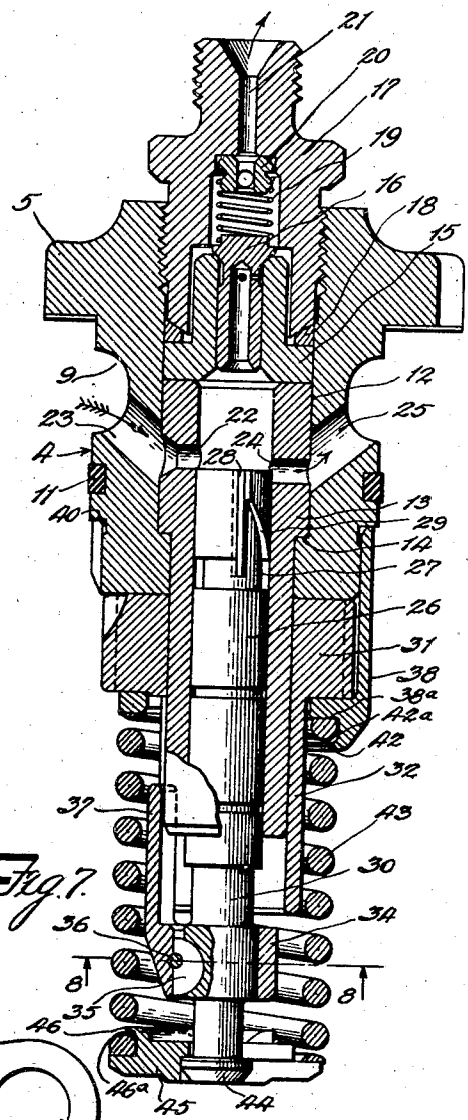

Fig. 7.

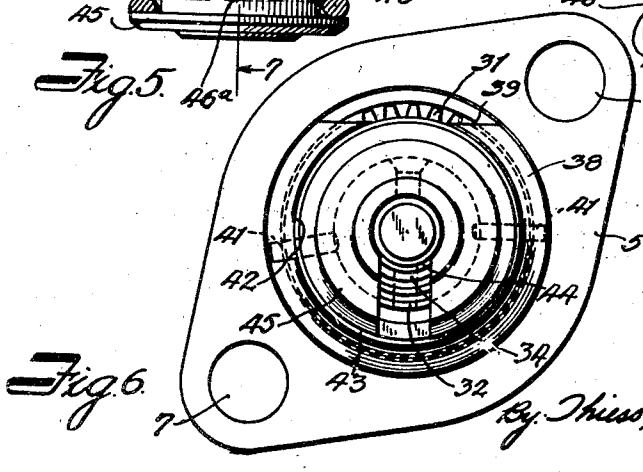

Fig. 6.

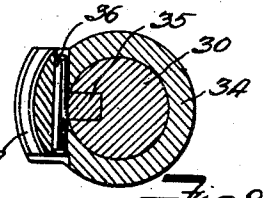

Fig. 8.

Inventor:
Louis J. Garday.
By Thiess, Olson & Mitchell
Attys.

Jan. 21, 1947. L. J. GARDAY 2,414,518

FUEL INJECTION PUMP

Filed Dec. 12, 1942 3 Sheets-Sheet 3

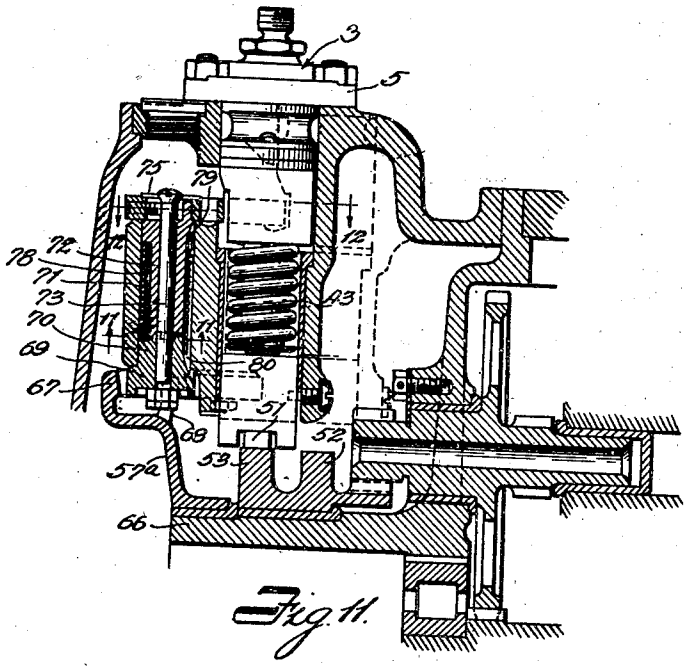

Fig. 11.

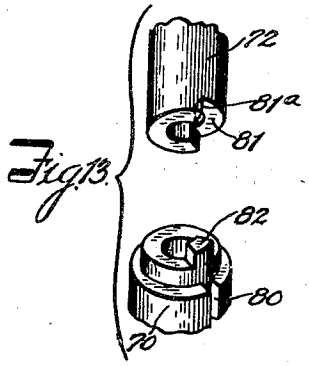

Fig. 13.

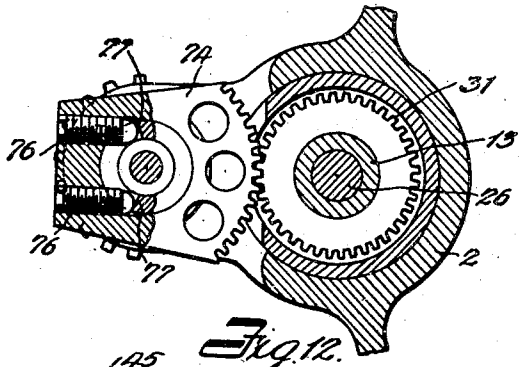

Fig. 12.

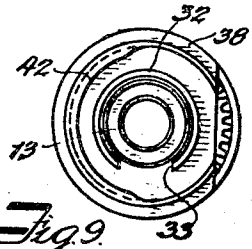

Fig. 9.

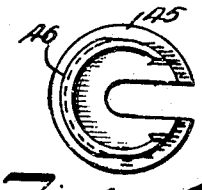

Fig. 10.

Inventor.
Louis J. Garday.
By: Thiess, Olsen & Mecklenburg.
Attys.

Patented Jan. 21, 1947

2,414,518

UNITED STATES PATENT OFFICE

2,414,518

FUEL INJECTION PUMP

Louis J. Garday, Glenview, Ill., assignor to Aircraft & Diesel Equipment Corporation, Chicago, Ill., a corporation of Delaware

Application December 12, 1942, Serial No. 468,772

18 Claims. (Cl. 103—41)

1

This invention relates to fuel pumps and controls therefor, and particularly to pump and control apparatus for the injection of fuel into internal combustion engines, such as Diesel engines and the like.

The invention is especially adapted for use in connection with multiple-cylinder engines of various types, and it will be apparent that modifications may be made by persons skilled in the art to adapt the invention for use in connection with any suitable type of engine without departing from the spirit of the invention.

Any required number of engine cylinders and associated pumps may be used. However, the specific structure shown in the drawings was designed for use on a fourteen-cylinder Diesel engine or the like.

It is an object of the invention to provide an interchangeable precalibrated pumping unit that permits quick removal and replacement of damaged units, that permits individual setting of the units to suitable calibration marks, and in which a single operating control regulates the discharge quantity of all of the pump units with the consequent uniform fuel injection to each cylinder.

In the embodiment shown, a radially positioned casing and pump unit therein is provided for each engine cylinder, and these pumps are so constructed that they may be preassembled as complete units and each unit inserted and secured in its respective casing in position to be individually set to predetermined calibration marks by suitable means provided for this purpose and to automatically be successively operated by suitable cams. Each pump piston is axially movable by a cam lobe for fluid displacement and is retracted by means of a compression spring. All of the pump pistons are simultaneously rotarily settable to predetermine the discharge flow from each pump.

It is another object of the invention to provide a single controlling device for the simultaneous control of the pump pistons wherein the control mechanism includes yieldable means associated with each pump and constructed to permit rotary movement in one or both directions of some of the pistons even though one or more of the pistons abnormally resists rotation. This is an important feature for the reason that an individual piston may sometimes become damaged, or may stick in such a manner that it cannot be moved to the desired position. With the ordinary apparatus for rotating the fuel pump pistons of this type, in the event a piston sticks for any reason, none of the fuel pumps can properly be rotated, and therefore the remaining cylinders

2

of the engine cannot be throttled down or otherwise controlled which may result in serious damage to the engine.

It is also an object of the invention to provide an improved pump construction whereby the entire mechanism of the pump itself, including the compression spring used for the return stroke, may be preassembled as a unit and wherein a number of such single pump units may be installed in a suitable housing, so that the pump units may be inserted, removed or changed around as desired. Also, the pump unit includes sealing means for sealing the unit relative to the pump casing or housing and the fuel intake passageway, which latter is in direct communication with all of the pump units.

Another object is to provide a convenient and accurate calibration means for the pump pistons so that all of the pumps may initially be installed in a manner to provide the same predetermined displacement.

The invention also contemplates various refinements in detail and improvements in construction and relationship of the various elements to facilitate assembly and provide greater efficiency in operation.

Further objects will be apparent from the disclosure herein.

In the drawings:

Fig. 1 is a front elevation partially in section of a plurality of pump and control elements in assembled relation and illustrated as mounted on an engine frame;

Fig. 2 is a sectional view through a plurality of pumps and is taken on a line substantially corresponding to line 2—2 of Fig. 1;

Fig. 3 is a transverse sectional view taken on a line substantially corresponding to line 3—3 of Fig. 1, and includes a portion of the driving mechanism and the cams for operating the pumps;

Fig. 4 is a detail sectional view taken on a line corresponding to line 4—4 of Fig. 1;

Fig. 5 is a side elevation of one of the pump units completely assembled and ready for mounting in a pump housing, and the compression spring for returning the pump piston and a portion of the housing are shown in section for purposes of illustration;

Fig. 6 is a bottom view of the pump embodiment shown in Fig. 5;

Fig. 7 is an axial sectional view through the pump unit assembly and is taken on a line corresponding to line 7—7 of Fig. 5;

Fig. 8 is a detail sectional view through the piston stem and through the piston-aligning

bushing or guide secured thereto and is taken on a line corresponding to line 8—8 of Fig. 7;

Fig. 9 is a bottom plan view of the pump unit shown in Fig. 5 with the spring and piston removed more clearly to illustrate the constructional details;

Fig. 10 is a top plan view of the spring-supporting washer shown in Figs. 5 and 6;

Fig. 11 is a sectional view similar to Fig. 3, but illustrates a slightly modified form of pump control mechanism;

Fig. 12 is a transverse sectional view taken on a line substantially corresponding to line 12—12 of Fig. 11; and

Fig. 13 is a fragmentary perspective view of certain of the cooperating elements shown in Fig. 11.

Referring to the drawings in detail, the embodiment illustrated in Figs. 1 to 4, inclusive, comprises an annular pump frame 1 mounted on or forming a part of the frame of a suitable internal combustion engine. The annular pump frame 1 is, in the present embodiment, concentric with the axis of a fuel pump cam which has several lobes suitable for operating the pumps in a manner which will be described later.

The annular pump frame 1 comprises a plurality of radially disposed pump casings 2. Each pump casing 2 is provided with a radial bore therethrough to receive a pump unit 3, which latter comprises a body 4 (Fig. 7). The body 4 supports all of the various elements of the pump unit and is provided at its upper end with a flange 5 whereby the unit may be secured in position in any one of the casings 2 by means of bolts 6 inserted through the holes 7 in the flange (Fig. 6) and secured in the casing. A suitable gasket 8 may be provided for sealing the upper end of the pump unit against the end of the casing.

Each pump body 4 is provided with an annular groove 9 and, when the pump units are inserted in their respective casings, all of the grooves 9 communicate with connecting fuel supply passageways 10 extending between the casings, so that all of the pumps may continuously be supplied with liquid fuel from a supply in the usual manner.

As previously stated, the present embodiment is designed for use in connection with a fourteen-cylinder engine and therefore fourteen pump casings and pump units are provided. The pump casings and units therein are arranged radially in two adjacent annular series with seven pumps in each series. The units in each row or series are equally spaced radially and are staggered with respect to the units in the adjacent row, so that all of the units are equally spaced one from the other and axially positioned on radial lines around a cam shaft.

The body 4 of each unit 3 is provided with a sealing ring or other suitable packing 11 below the groove 9, so that the fuel passageway is effectively sealed when the unit is inserted in the casing. The body 4 is provided with an axial bore 12 in which is mounted a pump cylinder 13, which latter is provided with a shoulder 14 for engaging a complementary shoulder on the body 4. The pump cylinder 13 extends materially below the bottom of the body 4 and is closed at its upper end by means of a bushing 15 (Fig. 7) having an axial valve 16 slidably mounted therein. The bushing 15 is retained and sealed in position by means of a packing nipple 17 threaded into the body 4 and the connection is effectively sealed by means of a suitable packing 18. The valve 16 is normally held in closed position by means of a compression spring 19, and a valve stop 20 is provided to limit the movement of the valve 16. The nipple 17 is provided with an outlet passage 21 and the nipple is externally threaded as shown and connected to a suitable conduit, not shown, leading to the associated engine cylinder.

The pump cylinder 13 is provided adjacent its upper end with an inlet port 22 which communicates with the annular fuel supply groove 9 through an inlet passage 23. The cylinder is also provided with an overflow passage 24 communicating with the annular groove 9 through a passage 25. These ports are preferably oppositely disposed, as shown, with the overflow passage slightly below the transverse plane of the inlet port.

A piston 26 is mounted for longitudinal movement in the cylinder 13 and is provided adjacent its upper end with an annular groove 27, which groove communicates with the pressure space in the upper end of the cylinder through a longitudinal peripheral groove 28. The groove 27 has an upper inclined or helical edge 29 intersecting the vertical groove 28 and is so related to the overflow port 24 that the effective delivery stroke of the piston may be regulated as required by rotarily positioning the piston in the cylinder to thereby vary the point in the delivery stroke in which the overflow port 24 is placed in communication with the pressure chamber through the grooves 27 and 28. By this arrangement, the pump displacement through the outlet passage 21 leading to the engine cylinder begins as soon as the piston, on its displacement stroke, covers the ports 22 and 24, and the fuel delivery stops as soon as the inclined portion of the annular groove 27 communicates with the overflow port 24 to thereby relieve the pressure in the pump cylinder.

As previously stated, the pump cylinder 13 extends a material distance beyond the lower end of the body 4, and the piston 26 is provided with an elongated stem 30 which stem extends below the end of the cylinder 13.

A gear 31 is mounted for rotation on the protruding end of the cylinder 13 and snugly adjacent the body 4. The gear 31 is provided with an elongated skirt 32 having a longitudinal slot 33 therein as shown particularly in Fig. 5. The piston stem 30 is provided with a collar 34, which collar is secured against rotation and against longitudinal movement by means of a Woodruff key 35 (Fig. 7). The key 35 prevents relative rotary movement between the piston stem 30 and the collar 34, and a pin 36 is transversely inserted through the collar and the Woodruff key, as shown, so that the elements are securely locked together to prevent relative movement in any direction.

By the above described arrangement of the key 35 and the transverse pin 36, relative to the stem 30 and the collar 34, the collar may be accurately positioned on the stem even though this stem is hardened. Drilling of the stem after hardening, or hardening the stem after drilling the hole, is impractical due to the accuracy which must be maintained with respect to the final location of the pin 36 therein and of the collar 34 associated with the pin. If the collar also is hardened a transverse hole may be formed therein prior to hardening, and the key only is drilled

after assembly to provide a properly aligned hole for the pin 36.

The collar 34 is provided with an upwardly extending arm 37 which is slidably engaged in the slot 33 in the gear skirt 32. This provides a slidable aligning means between the piston and the gear 31. The gear 31 is retained in position against the body 4 by means of a gear cover or sleeve 38. This sleeve is cut away at 39 to expose one side of the gear 31. The sleeve is secured in position on the reduced lower end of the body and against a shoulder 40 thereof by means of headless pins 41, which pins are pressed through suitable holes in the cover or sleeve 38 and into complementary holes in the body 4. Thus the gear 31 is securely and accurately positioned for rotation and the gear cover 38 may be removed from the unit by first removing the cylinder 13 and associated piston and then pushing the pins 41 either inwardly or outwardly to release the cover.

A suitable spring 43 for operating the piston 26 is provided, as shown, and is adapted to surround the stem 30 of the piston, the skirt 32 of the gear 31, and the cooperating arm 37. In order to retain all of the elements of the pre-calibrated unit in assembled relation, the opposite ends of the spring 43 are squared and ground in the usual fashion, and the gear cover or sleeve 38 is provided adjacent its lower end with an inturned lip 42 which extends only part way about the periphery of the cover or case, as shown best in Fig. 9, and which is spaced from a shoulder 38a (Fig. 7) to provide a groove 42a. When the upper end of the spring 43 is inserted into the sleeve 38 and rotated, a portion of the first turn or round on the spring will be threaded into the groove 42a and may be wedged or tightened between the shoulder 38a and the lip 42 so as firmly to secure the spring to the sleeve 38 without interfering with the compression and extension of the spring.

Similarly, a slotted washer 45, which engages an enlarged head or flange 44 on the stem 30 of the piston, is provided with an outturned lip 46 (Figs. 7 and 10) extending partially about the circumference to define a groove 46a into which the first turn or round on the lower end of the spring may be threaded and tightened. Thus all of the cooperating and relatively movable elements of the unit are retained in assembled relation with the spring 43 relaxed and the piston in its retracted position, the arm 37 being of sufficient length to maintain its engagement in the slot 33 throughout the normal range of extension of the spring 43.

The gear 31 and body 4 are relatively calibrated by means of a vertical slot 47 in the face of one of the gear teeth and a calibration line 48 on the pump body 4 (Fig. 5). The elements are so constructed and the calibration lines are so related thereto that, when these calibration lines are in alignment, the pump will deliver a predetermined output; also, rotary movement of the gear in either direction will correspondingly vary the pump output.

One of the pump casings 2 is shown in section in Fig. 1 with the pump unit installed therein. The casing 2 is provided at its lower end with a bushing 49 in which is slidably mounted a tappet 50 having at its lower end a cam follower comprising a roller 51. The lower end of the pump piston is pressed against this follower by the spring 43 so as to retain the follower in contact with its respective cam surface.

In order to operate the two series of pump units, a cam drum is provided comprising a cam 52 for operating the inner series of pumps and a cam 53 for operating the outer series. This cam drum is rotatably mounted and may be driven from the engine crank shaft through a gear 54 in suitable bearings and a pinion 55 fixed to the gear 54 and in mesh with a gear 56 on the cam drum. In the present embodiment, the cams 52 and 53 are four-lobe cams with the lobes staggered in accordance with the alternate staggered position of the pump units in the two series. Therefore, in the particular construction disclosed, the cams are rotated at one-eighth of the crank shaft speed and in the same direction as the crank shaft, thereby properly timing the fuel injection. It will, of course, be understood that suitable cams and gear ratios may be provided in order to conform to the engine design and the number of engine cylinders used.

In order to simultaneously control all of the pumps to provide a predetermined output, a control mechanism, as disclosed in Figs. 1 to 4, inclusive, is provided. This control mechanism comprises a ring or disc-like member 57 on which is pivoted at 58 a series of control elements or bell cranks 59 and 59a. These bell cranks are spring-pressed in one direction by means of a compression spring 60, and the short arm of the bell crank is provided with an adjustable stop screw 61 which engages against the ring 57 to limit the movement of the bell crank in one direction. The other arm of each bell crank is slotted at 62 to receive a roller 63, which latter is secured on a longitudinally slidable rack 64 in mesh with the pump gear 31. One side of the pump gear is exposed through an opening in the casing 2, and this opening is covered by means of a plate 65, which latter provides a bearing for the rack 64, so that the rack may be longitudinally moved to rotate the pump piston 26 when the control ring 57 is moved in either direction. The stop screws 61 may all be adjusted to accurately set the control elements or bell cranks 59 and 59a so that the pump calibration marks on the associated pumps will occupy the desired aligned positions.

The bell crank springs 60 and the bell cranks are mounted relative to the ring 57, so that when the ring is rotated in the direction of the arrow (Fig. 1) the pump output will be decreased, and when moved in the opposite direction the output will be increased. Also, in case one or more of the pumps should stick or for any reason abnormally resist rotary movement, lost motion will occur between the associated bell crank and the control ring. By this construction a defective or stuck pump will not interfere with the proper control of the remaining pumps. Any suitable means may be provided to enable operation of the control ring 57, either manually or by suitable servo-motor mechanism.

Fig. 11 is a sectional view similar to Fig. 3, and is taken through one of the pump casings and the control mechanism thereof. This view illustrates a slightly modified embodiment of the control mechanism as adapted to the same pump unit and casing construction, as previously described.

In this embodiment a control ring or disc 57a is rotatably mounted on a bearing 66 and in axial alignment with the pump operating cams 52 and 53. The control ring 57a is provided with a plurality of outer beveled gear segments 67, each of which is adapted to control an associated one of the outer series of pumps through a suitable

lost motion mechanism. The ring 57a is also provided with a plurality of inner beveled gear segments 68, which latter are similar to the gear segments 67, but are positioned to control the inner series of pump units through similar lost motion mechanisms.

The lost motion mechanism for each pump unit comprises a pinion segment 69 having a hub 70 rotatably mounted in a vertical bore 71 in the pump casing and parallel with the axis of the pump. A lost motion element 72 is also rotatably mounted in the bore 71 and is secured to the segment pinion 69 by means of a bolt or shaft 73, so as to permit relative rotary movement of the control elements to provide lost motion therebetween in one direction while at the same time retaining them in assembled relation.

A gear segment 74 is secured for rotary movement on the upper end of the element 72 by means of the bolt 73 and a suitable washer 75. This gear segment 74 is in mesh with the pump unit gear 31 as illustrated in Fig. 12. The gear segment 74 may be rotarily adjusted with respect to the lost motion element 72 by means of set screws 76 which engage shoulders 77 on the member 72.

The lower portion of the element 72 is reduced in diameter and a coiled torsion spring 78 is mounted thereon. The upper free end of this spring is bent upwardly and engaged in a slot 79 in the side of the element 72 and adjacent the upper end thereof, and the lower end of the spring is engaged in a slot 80 in the side of the hub of the segment pinion 69. The lower end of the lost motion element 72 is cut away at 81 (Fig. 13) and an upwardly extending lug 82 on the pinion segment 69 is engaged in the slot formed by the cutaway portion 81. This lug 82 is normally tensioned against one of the shoulders 81a of the member 72 by means of the spring 78, so that in case the valve should stick for any reason, a lost motion in one direction is provided between the control ring 57a and the pump in substantially the same manner as in the embodiment previously described.

As previously stated, each pump is precalibrated and marked by means of the calibration slot 47 and line 48; also, the control devices may be adjusted for uniform operation of the pumps by means of the set screws 76 for adjusting the gear segment 74 to conform with the pump calibration.

While I have shown particular embodiments of my invention, it will be understood, of course, that I do not wish to be limited thereto since many modifications may be made, and I, therefore, contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

Having thus described my invention, what I claim and desire to secure by Letters Patent is:

1. In a fuel injection pump of the type having a plurality of cooperating cylinders and pistons, the pistons being axially displaceable to provide a pumping effect and being rotatable to control the pumping effect, the combination of individual means associated with each cylinder and operable to rotate the corresponding piston, a common movable operating element, and individual connecting means between said element and each of said individual means for normally effecting simultaneous rotation of all of said pistons upon movement of said element, each of said connecting means including yieldable means for permitting movement of said element to rotate some of said pistons even though one or more of said pistons abnormally resist rotation.

2. In a fuel injection pump of the type having a plurality of cooperating cylinders and pistons, the pistons being axially displaceable to provide a pumping effect and being rotatable to control the pumping effect, the combination of individual means associated with each cylinder and operable to rotate the corresponding piston, a common movable operating element, connecting means between said element and each of said individual means for normally effecting simultaneous rotation of all of said pistons upon movement of said element, said connecting means including yieldable means for permitting movement of said element to rotate some of said pistons even though one or more of said pistons abnormally resist rotation, and means for individually adjusting each of said connecting means initially to rotarily position said piston relative to said operating element.

3. In a fuel injection pump of the type having a plurality of cooperating cylinders and pistons, the pistons being axially displaceable to provide a pumping effect and being rotatable to control the pumping effect, the combination of individual means associated with each cylinder and operable to rotate the corresponding piston, a common movable operating element, connecting means between said element and each of said individual means for normally effecting simultaneous rotation of all of said pistons upon movement of said element, said connecting means including lost motion connections for positively driving said individual means in one direction and yieldable means normally preventing relative movement in said lost motion connections for driving said individual means in the opposite direction, said yieldable means and lost motion connections permitting movement of said element to drive some of said pistons in said opposite direction even though others thereof abnormally resist rotation.

4. In a fuel injection pump of the type having a plurality of cooperating cylinders and pistons, the pistons being axially displaceable to provide a pumping effect and being rotatable to control the pumping effect, the combination of individual means associated with each cylinder and operable to rotate the corresponding piston, a common movable operating element, connecting means between said element and each of said individual means for normally effecting simultaneous rotation of all of said pistons upon movement of said element, said connecting means including lost motion connections for positively driving said individual means in one direction and yieldable means normally preventing relative movement in said lost motion connections for driving said individual means in the opposite direction, said yieldable means and lost motion connections permitting movement of said element to drive some of said pistons in said opposite direction even though others thereof abnormally resist rotation, and means for individually adjusting said lost motion connections initially to rotarily position said pistons in predetermined operative relationship to said operating element.

5. In a fuel injection pump of the type having cooperating cylinders and pistons, the pistons being axially displaceable to provide a pumping effect and being rotatable to control the pumping effect, the combination of individual means associated with each cylinder and operable to rotate the corresponding piston, a common movable op-

erating element, a plurality of arms pivotally mounted on said operating element and respectively connected to said individual means, spring means tending to rotate each of said arms about its pivot, and abutment means on each arm engaging said element to limit the pivotal movement of said arms by said spring means, said spring means normally retaining said abutment means in engagement with said element whereby said arms effect rotation of said pistons in accordance with movements of said member in either direction, said spring means being yieldable to permit pivotal movement of the associated arm when a corresponding piston abnormally resists rotation, whereby said element may be moved in one direction to rotate the remaining pistons even though said corresponding piston is not rotatable.

6. In a fuel injection pump of the type having cooperating cylinders and pistons, the pistons being axially displaceable to provide a pumping effect and being rotatable to control the pumping effect, the combination of individual means associated with each cylinder and operable to rotate the corresponding piston, a common movable operating element, a plurality of arms pivotally mounted on said operating element and respectively connected to said individual means, adjustable abutment means on each of said arms for engaging said element in predetermined adjusted positions of said arms relative to said elements, and spring means for normally retaining said arms in said adjusted positions whereby movement of said element effects movement of all of said arms simultaneously to rotate said pistons, said spring means being yieldable to permit pivotal movement of the associated arm from said adjusted position when a corresponding piston abnormally resists rotation.

7. In a fuel injection pump of the type having a cylinder and a hardened piston therein including an extending end portion, said piston being axially displaceable in said cylinder to provide a pumping effect and being rotatable to control said pumping effect, the combination of an operating member for effecting rotation of said piston including a collar adapted to encircle said extending end portion of said piston, said portion having an axially extending slot in the external surface thereof, a key having a portion thereof disposed in said slot and restrained against axial and transverse movement by the end and side walls of said slot, said collar having a slot in an internal surface thereof open at one end for receiving said key when said collar is axially pressed onto said piston, whereby said key locks said collar and piston against relative rotation, and a locking pin extending transversely through said collar and said key to lock said collar against relative axial movement on said piston.

8. In a fuel injection pump of the type having a cylinder and a hardened piston therein including an extending end portion, said piston being axially displaceable in said cylinder to provide a pumping effect and being rotatable to control said pumping effect, the combination of an operating member for effecting rotation of said piston including a collar adapted to encircle said extending end portion of said piston, said portion having an axially extending slot in the external surface thereof, a key having a portion thereof disposed in said slot and restrained against axial and transverse movement by the end and side walls of said slot, said collar having a slot in an internal surface thereof open at one end for receiving said key when said collar is axially pressed onto said piston, whereby said key locks said collar and piston against relative rotation, said collar and said key having a hole drilled transversely therethrough after assembly on said piston, and a locking pin in said drilled hole for locking said collar and said piston against relative axial movement.

9. In a fuel injection pump of the type having a cylinder and a hardened piston therein including an extending end portion, said piston being axially displaceable in said cylinder to provide a pumping effect and being rotatable to control said pumping effect, the combination of an operating member for effecting rotation of said piston including a collar adapted to encircle said extending end portion of said piston, said portion having an axially extending slot in the external surface thereof, a key having a portion thereof disposed in said slot and restrained against axial and transverse movement by the end and side walls of said slot, said collar having a slot in an internal surface thereof open at one end for receiving a projecting portion of said key when said collar is axially pressed onto said piston, whereby said key locks said collar and piston against relative rotation, and a locking pin extending transversely through said collar and through said projecting portion of said key for locking said piston and collar against relative axial movement.

10. In a fuel injection pump having a cylinder and a hardened piston therein including an extended end portion, said piston being axially movable for pump displacement and rotarily adjustable to vary pump displacement, the method of rigidly securing on said piston in precision relation thereto an operating member having an unhardened collar adapted to encircle said hardened portion, which method comprises forming an axially extending slot in said piston prior to hardening said piston, hardening said piston, inserting into said slot a portion of an unhardened key, forming an internal slot in said collar, axially assembling said collar onto said piston with said collar slot receiving said key, transversely drilling said collar and key after assembly to provide a hole therethrough at one side of said piston, and inserting a locking pin into said hole to lock said piston and collar in precision relation to each other.

11. In a fuel injection pump having a cylinder and a hardened piston therein including an extended end portion, said piston being axially movable for pump displacement and rotarily adjustable to vary pump displacement, the method of rigidly securing on said piston in precision relation thereto an operating member having a collar adapted to encircle said hardened portion, which method comprises forming an axially extending slot in said piston prior to hardening said piston, hardening said piston, inserting into said slot a portion of an unhardened key, forming an internal slot and an intersecting transverse hole in said collar, axially assembling said collar onto said piston with said collar slot receiving said key, transversely drilling said key to provide a hole through said collar and key at one side of said piston, and inserting a locking pin into said hole to lock said piston and collar in precision relation to each other.

12. In a fuel injection pump of the type having a piston axially displaceable in a cylinder for pump displacement and rotatable to vary displacement, a precalibrated sub-assembly comprising a body having a longitudinal bore, a cylinder in said bore and having an end projecting out-

wardly from said body, a piston having a portion thereof extending beyond the projecting end of said cylinder, a sleeve having a longitudinal slot therein, means rotatably mounting said sleeve on the projecting portion of said cylinder, a finger on said piston extending parallel to the axis of said piston in spaced relation thereto and engaged in said slot to provide a longitudinally slidable connection between said sleeve and said piston, and resilient means cooperating between the extending end of said piston and said sleeve to retain all of said elements in assembled relation.

13. In a fuel injection pump of the type having a piston axially displaceable in a cylinder for pump displacement and rotatable to vary displacement, a precalibrated sub-assembly comprising a body having a longitudinal bore, a cylinder in said bore and having an end projecting outwardly from said body, a piston having a portion thereof extending beyond the projecting end of said cylinder, a sleeve having a longitudinal slot therein, means rotatably mounting said sleeve on the projecting portion of said cylinder, a finger on said piston extending parallel to the axis of said piston in spaced relation thereto and engaged in said slot to provide a longitudinally slidable connection between said sleeve and said piston, resilient means cooperating between the extending end of said piston and said sleeve to retain all of said elements in assembled relation, said finger and slot being proportioned to maintain said slidable connection throughout the entire range of movement of said resilient means.

14. In a fuel injection pump of the type wherein a piston is axially reciprocable in a cylinder for pump displacement and rotatable in the cylinder to vary displacement, a precalibrated sub-assembly comprising a pump body having a longitudinal bore, a fixed cylinder member in said bore and projecting therefrom, a piston in said cylinder and projecting therefrom, a control element rotatable on said projecting cylinder, a longitudinally slidable connection between said piston and said control element to maintain radial alignment and prevent relative rotation therebetween, a spring for axially displacing said piston in an outward direction, means securing one end of said spring to said piston, and means on said body for securing the other end of said spring and said control element in longitudinally fixed relation to said body, said slidable connection maintaining said piston and said control element aaginst relative rotation throughout the entire range of extension of said spring whereby said sub-assembly is maintained in properly assembled relation.

15. In a fuel injection pump of the type wherein a piston is axially reciprocable in a cylinder for pump displacement and rotatable in the cylinder to vary displacement, a precalibrated sub-assembly comprising a pump body having a longitudinal bore, a fixed cylinder member in said bore and projecting therefrom, a piston in said cylinder and projecting therefrom, a control element rotatable on said projecting cylinder, a longitudinally slidable connection between said piston and said control element to maintain radial alignment and prevent relative rotation therebetween, a spring for axially displacing said piston in an outward direction, means securing one

end of said spring to said piston, and means on said housing for securing the other end of said spring and said control element in longitudinally fixed relation to said housing, said slidable connection maintaining said piston and said control element against relative rotation throughout the entire range of extension of said spring whereby said sub-assembly is maintained in properly assembled relation, a calibration mark on an accessible external surface of said control element, and a cooperating calibration mark on said body, said calibration mark being related to predetermine an initial displacement of said pump.

16. A precalibrated sub-assembly unit for a fuel injection pump comprising a body adapted to be mounted in a pump casing, said body having a pump cylinder projecting therefrom, a piston axially movable in said cylinder for pump displacement and rotatable to vary said displacement, a control element rotatably mounted on said projecting cylinder, a longitudinally slidable connection between said piston and said control element to prevent relative rotary movement therebetween, a spring for axially displacing said piston in an outward direction, means for securing one end of said spring to said piston, and means carried by said body for securing said control element and the other end of said spring in axially fixed relation to said body, so that all of the elements of said unit are held in assembled relation.

17. A precalibrated sub-assembly unit for a fuel injection pump comprising a body adapted to be mounted in a pump casing, said body having a pump cylinder projecting therefrom, a piston axially movable in said cylinder for pump displacement and rotatable to vary said displacement, a control element rotatably mounted on said projecting cylinder, a longitudinally slidable connection between said piston and said control element to prevent relative rotary movement therebetween, a spring for axially displacing said piston in an outward direction, means for securing one end of said spring to said piston, a cup shaped member having the upper end thereof secured to said body for supporting said control element in longitudinally fixed relation, said cup shaped member having an aperture in the bottom wall thereof through which said piston and a portion of said control element extends, and means for securing the other end of said spring to said cup shaped member to maintain said sub-assembly in assembled relation.

18. A precalibrated sub-assembly unit for a fuel injection pump comprising a body adapted to be mounted in a pump casing, said body having a pump cylinder projecting therefrom, a piston axially movable in said cylinder for pump displacement and rotatable to vary said displacement, a control element rotatably mounted on said projecting cylinder and comprising a gear portion having a reduced sleeve portion extending therefrom, a longitudinally slidable connection between said piston and said sleeve portion, and a cup shaped member surrounding said gear portion and secured to said body for supporting said control element in axially fixed relation to said body, said cup shaped member having an aperture through which said sleeve portion extends.

LOUIS J. GARDAY.