Feb. 1, 1938. C. G. A. ROSÉN 2,106,932

ENGINE

Filed Nov. 7, 1933 5 Sheets-Sheet 1

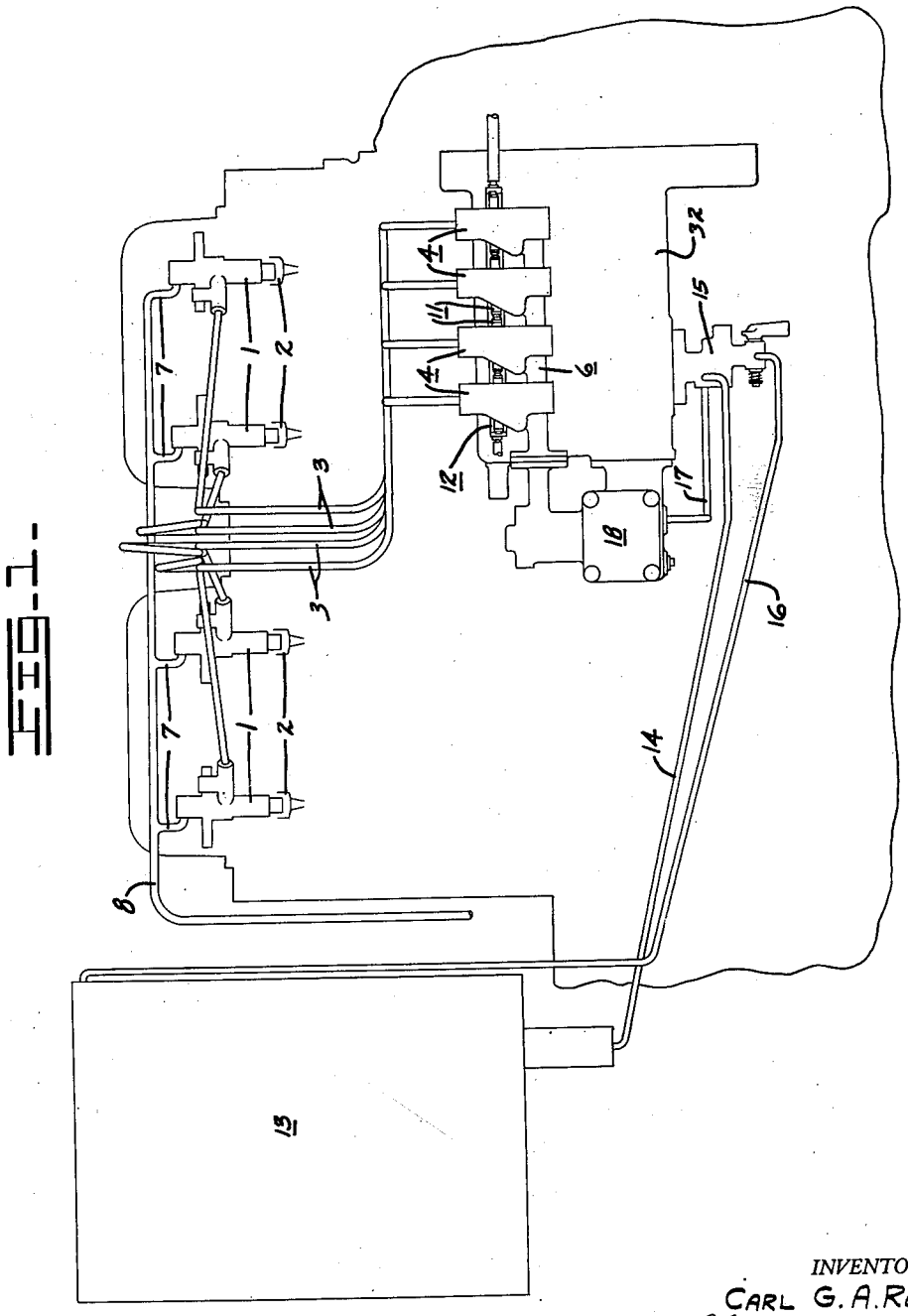


Fig. 1.

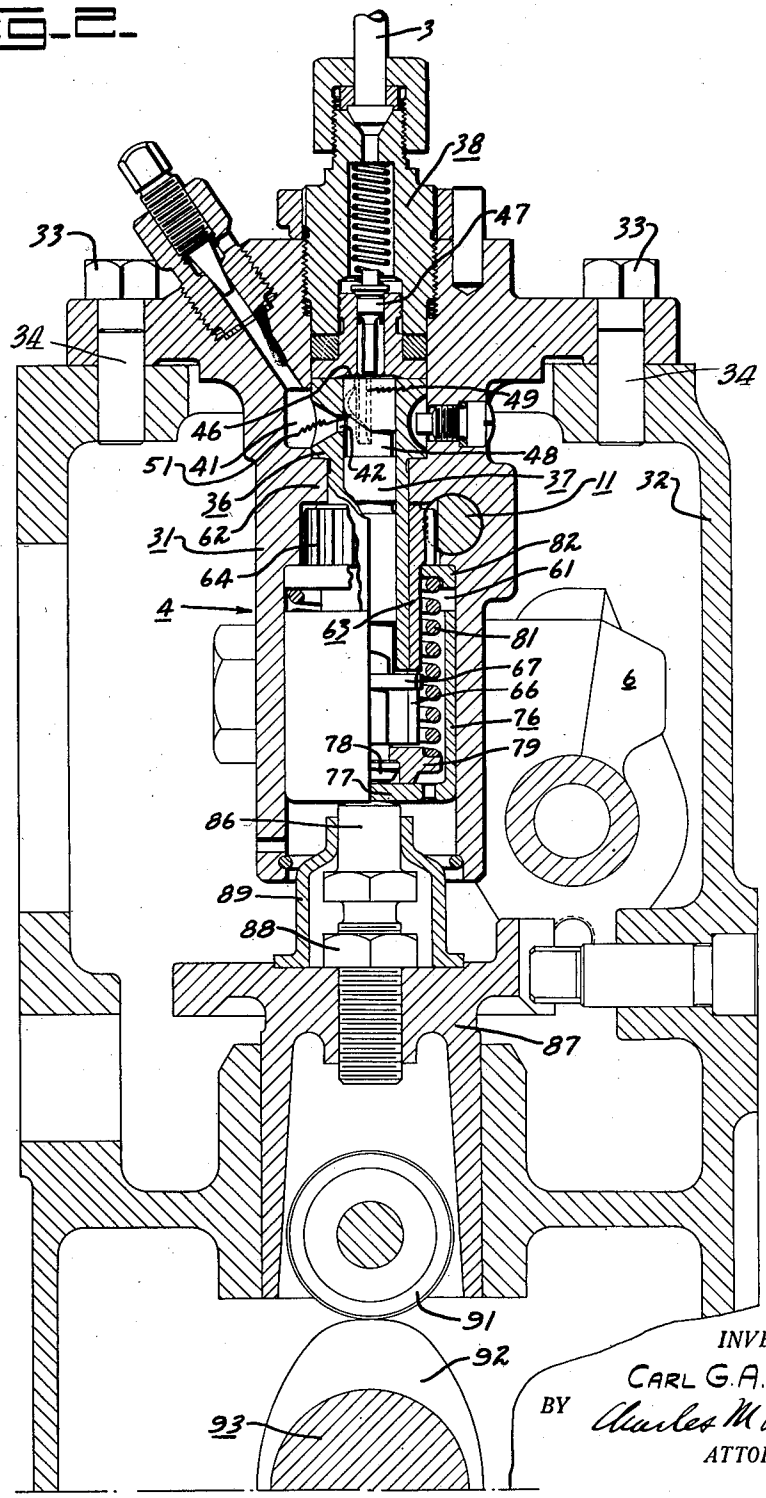
INVENTOR.
CARL G. A. ROSEN
BY Charles M Fryer
ATTORNEY.

Feb. 1, 1938. C. G. A. ROSÉN 2,106,932

ENGINE

Filed Nov. 7, 1933 5 Sheets-Sheet 2

Fig. 2.



INVENTOR.
CARL G. A. ROSEN
BY Charles M. Dwyer
ATTORNEY.

Feb. 1, 1938. C. G. A. ROSÉN 2,106,932

ENGINE

Filed Nov. 7, 1933 5 Sheets-Sheet 3

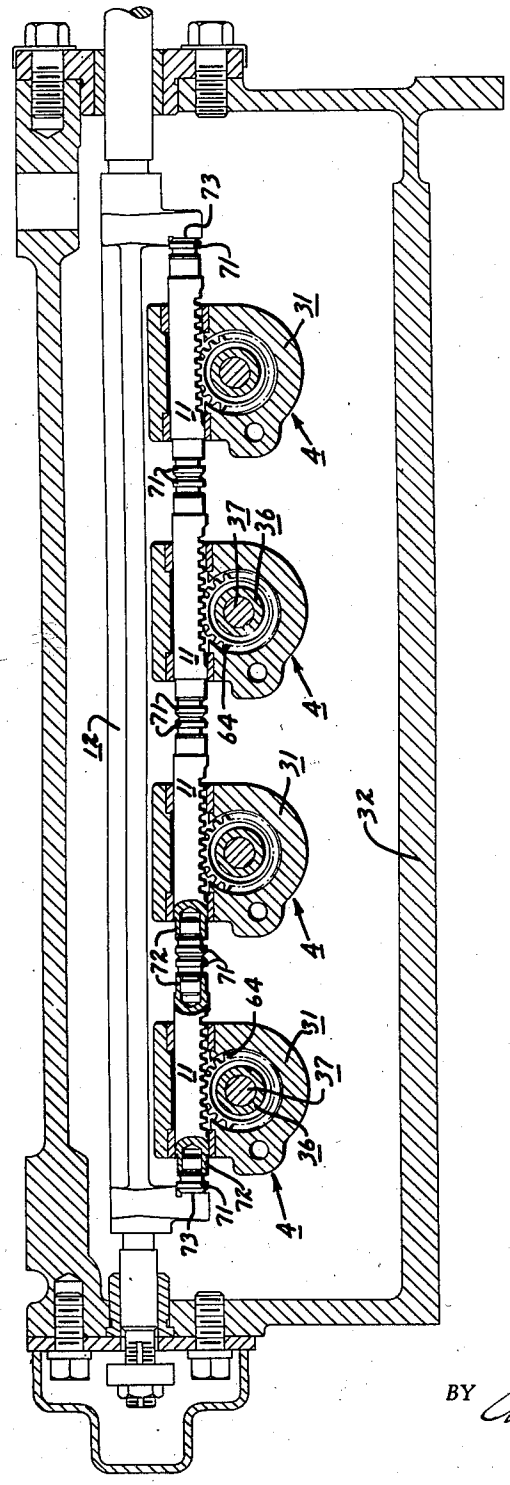


FIG. 3.

INVENTOR.
CARL G. A. ROSEN
BY Charles M. Fryer
ATTORNEY.

Feb. 1, 1938. C. G. A. ROSÉN 2,106,932

ENGINE

Filed Nov. 7, 1933 5 Sheets-Sheet 4

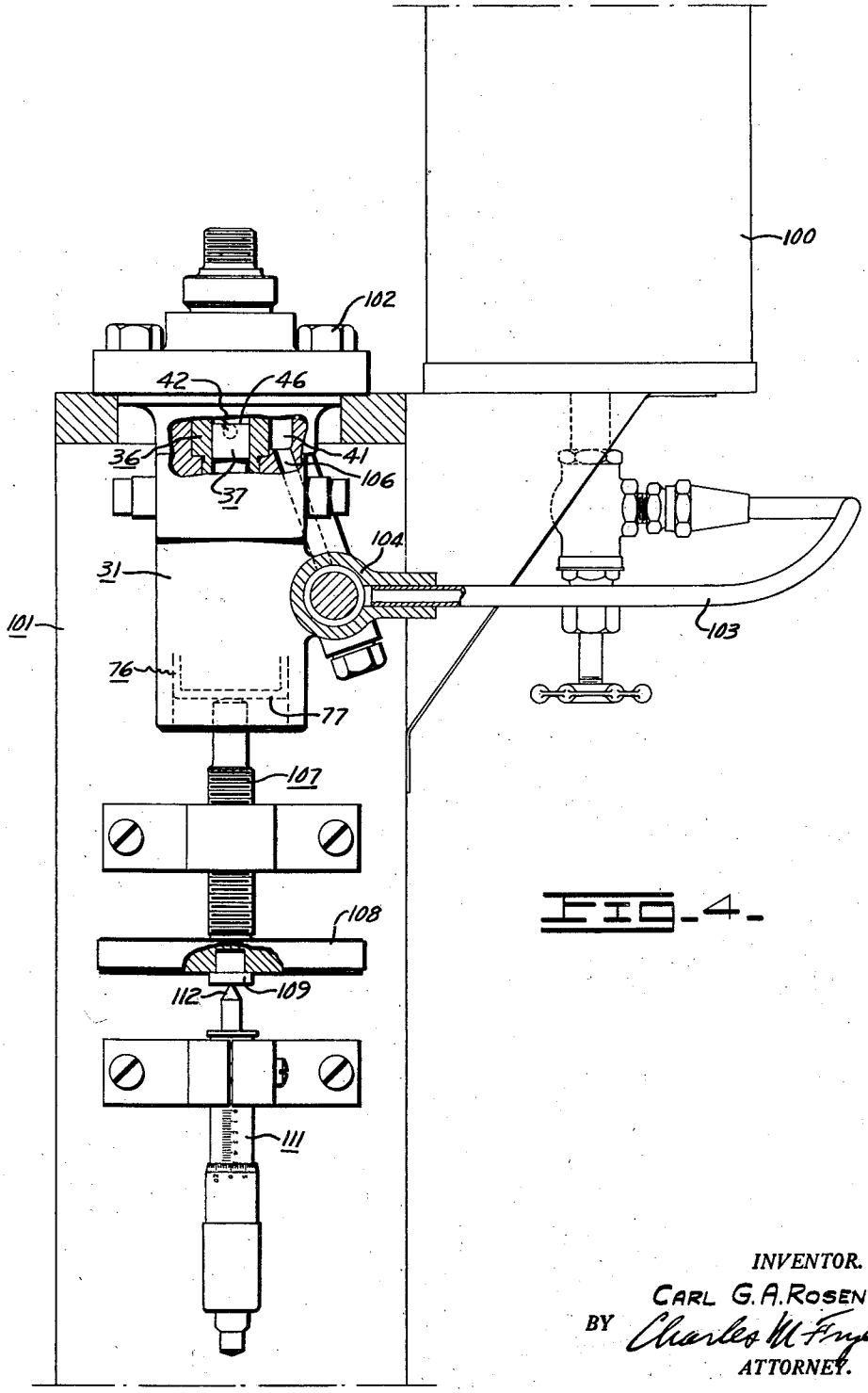


FIG. 4.

INVENTOR.
CARL G. A. ROSEN
BY Charles M. Fryer
ATTORNEY.

Feb. 1, 1938. C. G. A. ROSÉN 2,106,932

ENGINE

Filed Nov. 7, 1933 5 Sheets-Sheet 5

FIG. 6.

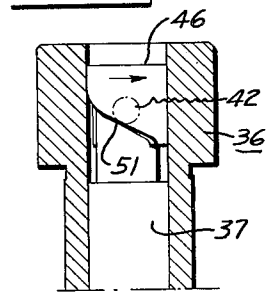


FIG. 5.

INVENTOR.
CARL G. A. ROSEN
BY Charles M. Fryer
ATTORNEY.

Patented Feb. 1, 1938 2,106,932

UNITED STATES PATENT OFFICE

2,106,932

ENGINE

Carl G. A. Rosén, Oakland, Calif., assignor to Caterpillar Tractor Co., San Leandro, Calif., a corporation of California

Application November 7, 1933, Serial No. 696,960

21 Claims. (Cl. 123—139)

Statement of invention

The present invention relates to compression ignition and the like engines especially adapted for use as a power plant of a tractor, and more particularly, to the provision of a fuel injection system therefor, including standardized fuel injection pumps, and to the provision of a method of calibration of such pumps to obtain standardization.

The provision of a suitable fuel injection system for compression ignition and the like engines adapted for use as a power plant of a tractor involves many problems. One of the most troublesome of these problems is the provision of fuel injection pumps which require no servicing or adjustment upon installation thereof on the engine, as replacements must be made by operators who are usually unskilled, due to the fact that tractors are most often used in remote places far away from the facilities of skilled servicemen. The present invention contemplates the provision of fuel injection pumps which are completely interchangeable, and are standardized to obtain uniform operating characteristics. These features enable the replacement of any pump which has become disabled, by another pump without any adjustments or checking, the only necessary operation being the actual mounting of the pump on the engine. The pumps are entirely free from the necessity of any checks or adjustments during operation, and require no attention from the operator; all adjustments and checking being done beforehand at the factory.

Obviously, such adjustments and checking at the factory can be obtained by manufacturing all corresponding parts of the pumps, effecting fuel injection, of exactly the same size. This is commercially unfeasible, because these pump parts are made by the most accurate machining apparatus available; and even with such apparatus slight discrepancies in dimensions obtain among various corresponding parts. Therefore, in order to have corresponding parts of exactly the same size, it would be necessary to do the finishing work on the parts by hand. The cost of this is of course prohibitive, making such hand finishing method highly impractical. My invention allows slight discrepancies to exist in the dimensions of the various parts which are compensated for, as will be hereinafter explained, to provide each and every pump with exactly the same standardized fuel injection characteristics.

It is an object of the invention, therefore, to provide an economical method for the manufacture of standardized, interchangeable fuel injection pumps for compression ignition and the like engines, any one of which can be installed in any engine, either new or old, without requiring any adjustment, and without affecting the operation of the engine.

Another object of the invention is to provide interchangeable fuel injection pumps for compression ignition and the like engines, any one of which can be substituted for another without affecting the timing of the engine.

Another object of the invention is to provide a method of standardizing fuel injection pumps by calibration of certain of the working parts thereof.

Another object of the invention is to provide a method of assembling fuel injection pumps in which certain parts are selected out of preformed groups of such parts having selected, varying dimensions.

Another object of the invention is to provide a method for calibrating fuel injection pumps which insures standardization of the time of beginning and ending of fuel injection by said pumps in operation.

Another object of the invention is to provide, as articles of manufacture, interchangeable standardized fuel injection pumps.

Other objects will appear as the description progresses.

Description of figures

Fig. 1 is a schematic view illustrating a fuel injection system in which the instant invention can be employed.

Figs. 2 and 3 illustrate a fuel injection pump construction in which the instant invention can be employed.

Fig. 2 is a vertical transverse section through a fuel injection pump.

Fig. 3 is a horizontal section through a set of fuel injection pumps for a compression ignition engine.

Figs. 4, 5, and 6 illustrate the method of calibrating a fuel injection pump.

Fig. 4 illustrates the step of standardizing the time of beginning of injection.

Figs. 5 and 6 illustrate the step of standardizing the time of fuel cut off, and the step of adapting a plurality of pumps for interconnection to determine uniform action thereof in controlling fuel injection.

Description of fuel injection system

The fuel system is of the solid injection type,

namely, one in which only fuel—not mixed with air—is injected into the precombustion chamber, in an atomized state by the fuel injection nozzle. The system is designed to preclude air from becoming entrapped with the fuel.

Fig. 1 illustrates, more or less diagrammatically, the fuel injection system. For each cylinder of the engine, a fuel injection nozzle 1 is provided. Each fuel injection nozzle is operated to eject fuel from discharge end thereof, into the precombustion chamber 2 of the cylinder with which the nozzle is associated. Each nozzle 1 is connected by means of a conduit 3 with a fuel injection pump 4, from the discharge end of which, a measured quantity of fuel is forced under pressure into the fuel injection nozzle associated with the pump. All of the pumps contain plungers which are actuated, in timed relationship by means of cams on the camshaft, to measure fuel into the fuel injection nozzles in accordance with the firing order of the cylinders. Also, all of the pumps are connected to fuel manifold 6 to which fuel is supplied from the fuel supply tank, by means to be described. In actual operation, the entire system, including the portion from manifold 6 through the fuel injection nozzles, is always kept full and solid with fuel. Surplus leakage fuel, which collects in the fuel injection nozzles 1, can pass out through pipes 7 into pipe 8 which is open to the atmosphere.

With each fuel injection pump 4 is provided a valve adjusting member 11 (specifically a slidable rack), which is movable to control the quantity of fuel that the fuel injection pump can measure to the fuel injection nozzle 1. In assembling the fuel injection pumps on the engine, all the valve adjusting members 11 are interconnected, and are operated by a movable linkage, indicated generally by reference character 12; and are so set with respect to each other that each of the fuel injection pumps can measure the same quantity of fuel for any position of the linkage. The linkage is connected to the governor, not shown, which automatically shifts the linkage, to control the quantity of fuel measured by the pumps while the engine is running. The linkage is of such character as to move, simultaneously and to the same extent, all of members 11, thereby insuring that changes in quantity of fuel measured by the pumps will be uniform for all of the pumps.

Means is provided for supplying fuel to fuel injection pump manifold 6. In order that the fuel supply shall be adequate for all demands of the fuel injection pumps, an excess quantity of fuel is pumped from a main fuel supply tank, by means of a fuel transfer pump. The excess quantity of fuel above the requirements of the fuel injection pumps, is by-passed back to the fuel tank. In practice, about 10 times the quantity of fuel necessary for the fuel injection pumps, is handled by the fuel transfer pump. The by-passing of the large excess quantity of fuel back to the main tank, provides a line of least resistance, so that entrained air can leave the pressure system and be by-passed back into the main fuel tank.

From main fuel tank 13, fuel flows under a positive head through pipe 14 to the suction side of fuel transfer pump 15. Fuel transfer pump 15, which is driven from the engine, is of such design as to withdraw always an excess quantity of fuel from fuel tank 13, and by-pass said excess quantity through pipe 16 back to main tank 13. From the fuel transfer pump, a portion of the fuel is forced through pipe 17 into fuel filter 18, from which fuel is led to fuel injection pump manifold 6.

Fuel injection pumps 4 force the fuel at a considerably higher pressure into the fuel injection nozzles, than the pressure at which the fuel transfer pump 15 forces the fuel through the fuel filter 18 and into fuel manifold 6. The fuel transfer pump pressure is preferably about 10 to 15 pounds, while that of the fuel injection pump is preferably about 1800 pounds.

I have found that the precombustion chamber type of fuel system, with individual fuel injection pumps for the cylinders, as described above, is the fuel system best adapted for tractor service. As described hereinafter, the fuel injection pumps are completely interchangeable, and can be installed without the necessity of any delicate checks or adjustments, thus providing one of the most necessary characteristics of a successful compression ignition engine adapted for use by unskilled labor throughout the world. The fuel injection pump will now be described with respect to those features necessary to an understanding of the method of calibration thereof to provide standardization.

Description of fuel injection pump

From the description of the fuel injection system, it is seen that the fuel transfer pump insures an adequate supply of fuel for all of the fuel injection pumps 4. Each fuel injection pump 4 is adapted to discharge a measured quantity of fuel to the fuel injection nozzle associated therewith, as controlled by a pump plunger which is reciprocated longitudinally to eject the fuel, and is adjusted about its axis to control the quantity of fuel ejected therefrom.

Each pump 4 (Fig. 2) includes hollow pump casing 31, which is adapted for insertion in pump housing 32, being secured thereto by suitable screws 33; a pair of oppositely positioned dowel pins 34 being employed to align pump casing 31 in a predetermined fixed position, as is also disclosed in my co-pending application Serial No. 691,640, filed September 30, 1933. The pumps are aligned within the casing, as described later, to facilitate simultaneous control thereof from the governor.

The active parts of the pump proper comprise sleeve or barrel 36 forming a pump cylinder, (Fig. 2) and plunger 37 closely fitting therein. Sleeve 36 is insertable through the top of pump casing 31, being held therein by means indicated generally at 38, such securing means providing a fuel passage from the pump to conduit 3. Adjacent the top of sleeve 36, fuel supply chamber 41 is provided in casing 31, said chamber communicating through aperture 42 with the cylinder of the pump. Fuel is supplied to chamber 41 by a suitable passage in casing 31 from fuel manifold 6, such passage not being illustrated in Fig. 2.

It will be noted (Fig. 2) that fuel can pass from chamber 41 into sleeve 36 when the upper end of plunger 37 is below aperture 42. When the plunger is moved upwardly, it is seen that aperture 42 will be closed by upper edge 46 of said plunger at a given point in the upward stroke, and the plunger will thereafter serve to force fuel under considerable pressure past discharge valve 47 suitably disposed in the passage leading to conduit 3. It will be noted that if, at a later point in the upward stroke of the plunger, communica-

tion can be made between chamber 41 and the cylinder within sleeve 36, pressure will be relieved and fuel ejection from the pump will cease. Means, which may be broadly considered as valve means, is provided to perform the preceding described function, solely by virtue of the plunger construction per se.

The upper end surface of the plunger is flat and normal to the plunger axis, to form edge 46. Spaced below the upper surface, annular groove 48 is provided, and slot 49 leads from said groove 48 to the upper surface of the plunger. Leading from adjacent the top of one side of slot 49 is by-pass ledge 51 which has a constant angle slant downwardly to groove 48. By-pass ledge or scroll 51 is adapted to cooperate with aperture 42 to establish communication from the cylinder above the top of plunger 37 through slot 49, annular space 48 and aperture 42 to chamber 41.

Plunger 37 (Fig. 2) is positioned, in normal operation thereof, with slot 49 at one side of aperture 42, so that the surface portion of the plunger between top edge 46 and scroll ledge 51 can shut off aperture 42 as the plunger reciprocates. Assuming that top edge 46 of the plunger is below aperture 42, the following described action will take place on upward movement of the plunger, such upward movement being the discharge stroke. When top edge 46 of the plunger passes the upper edge of aperture 42, aperture 42 is closed by the plunger side surface, and fuel will be forced out past discharge valve 47 under pressure. Valve 47 is spring-pressed so that it yields only under the greater pressure of the pump plunger, but does not yield to the smaller pressure of the fuel transfer pump. Upon continued upward movement of the plunger, slanting ledge 51 uncovers aperture 42 as it passes the lower edge thereof. Thus, communication will be established between chamber 41 and the cylinder in sleeve 36 above the upper end of plunger 37. As a result, pressure will be relieved and ejection of fuel from the pump will cease. Continued upward movement of the plunger will result only in fuel above the plunger being by-passed down slot 49 to annular space 48 and through aperture 42 into chamber 41.

The point at which such pressure will be relieved is determined by the position of scroll ledge 51 with respect to aperture 42. By rotating the plunger in the sleeve and about its own axis, such position can be varied to control the time of pressure relief (hereinafter called by-pass) and thereby control the quantity of fuel ejected from the pump. Upon downward movement of the plunger or on its suction stroke, fuel will be drawn into sleeve 36 from chamber 41 for the succeeding discharge stroke.

Thus far, only the upper portion of the pump construction has been described. The construction of the remaining or lower portion of the pump will now be explained.

From the above description, it is seen that two types of motion must be imparted to the pump plunger, one of these types of motion being longitudinal reciprocation to effect measuring of the fuel and ejection of the measured amount of fuel, and the other type of motion being oscillation or reciprocation of the plunger about its axis to determine the amount of fuel to be measured and ejected. Two trains of members are provided for effecting the two types of motion noted.

Hollow cylindrical chamber 61 (Fig. 2) is formed below chamber 41, and is separated therefrom by wall 62 through which sleeve 36 passes. The lower portion of sleeve 36 is of considerably less diameter than that of adjacent chamber 61 to provide space for the reception of pump mechanism. About the lower projecting portion of sleeve 36 is journalled for rotation, a sleeve 63 having teeth formed at its upper end to provide gear 64, which meshes with the teeth on slidably mounted rack 11 (Figs. 2 and 3), whereby movement of rack 11 is adapted to effect rotation of sleeve 63. The lower end of sleeve 63 projects below pump sleeve 36 and is provided with diametrically opposite vertical slots 66 (Fig. 2), only one of which is seen, in which are slidable opposite lugs 67 on pump plunger 37. Slots 66 and lugs 67 provide for axial reciprocation of plunger 37 in any vertically displaced position thereof, and also for transmission of rotation of sleeve 63 to said plunger 37. Consequently, the position of slanting plunger ledge 51 with respect to by-pass aperture 42 can be controlled by movement of rack 11. Thus, the position of rack 11 automatically controls the termination of fuel injection and thereby the amount of fuel ejected from the pump.

As explained generally in describing the fuel injection system, racks 11 of all the pumps are interconnected and are operated by a movable linkage from the governor. The ends of adjacent racks 11 (Fig. 3) contact, and to provide such points of contact or connection, hardened button inserts 71 are fitted in recessed ends 72 of each rack 11. End buttons 71 of the end pumps contact machined faces 73 of throttle control slide bar 12. The function and purpose of button inserts 71 are described hereinafter.

Thus, it is seen that a train of members is provided for controlling the amount of fuel ejected from the pump. The second train of members referred to above provide for longitudinal reciprocation of the pump plunger.

Said second train of members includes cylindrical cup-shaped guide 76 (Fig. 2) having an open upper end, but closed at its lower end by apertured bottom wall 77, said guide 76 being slidably mounted in chamber 61. The upper face of bottom wall 77 is contacted by head 78 formed at the lower end of pump plunger 37, such contact being maintained by keeper 79 and spring 81, said spring being compressed between keeper 79 and retainer ring 82 engaging a face of casing 31 and gear 64. The lower face of bottom wall 77 of guide 76 is engaged by tappet 86 threaded for preadjustment in cross head 87 and having lock nut 88 threaded thereon within bonnet 89. Bonnet 89 is seated in cross head 87 and converges upwardly to engage tappet 86, being placed thereon after preadjustment of said tappet to the proper height, as described hereinafter, said bonnet serving to prevent tampering with the tappet adjustment after it is initially set. Cross head 87 has roller 91 mounted therein and engaging cam 92 on camshaft 93. The function of the preadjustable tappet and of cup-shaped guide 77 in the calibration of the pump to obtain standardization thereof is described hereinafter.

Method of standardization

The method of standardizing each pump to obtain uniformity of action of the pumps comprises generally calibration of the pumps, and the provision, in each of the trains of control members, of a key member (the term "key member" being employed in the sense of meaning a member which is the same part in each train of con-

trol members for all pumps manufactured, and which provides the key leading to economical calibration and standardization of all the pumps). The key member in each train is preselected to compensate for various manufacturing errors in dimension of parts, which must necessarily occur. Preferably, a plurality of sets of each of said key members is provided, each set of members having a dimension which varies a constant amount from the other sets of identical members.

Comparative minute quantities of fuel are ejected from the pumps, so that the control of such amount involves a high degree of accuracy in the finally assembled pump, such accuracy being in the order of .0005 in. This is readily understood when one considers that for one type of engine the amount of fuel injected varies from .0025 cu. in. at idling to .0099 cu. in. at full load. With such an extremely fine limit of accuracy, it is seen that the actual manufacture of the individual parts of the pump to obtain such accuracy would require such an amount of time and effort and expensive equipment as to make the cost of the pumps prohibitive. Further, to provide an adjustable element in each train of the pump for enabling adjustment of the pump to be made upon installation, would mean that such installation could only be made by skilled servicemen, so that replacement of a pump in the field would require a trip by the serviceman, and hence the cost of such replacement would be very high if not prohibitive in certain instances. I have found that by calibrating the pumps on assembly to a uniform standard, the accuracy of manufacture can be placed within reasonable limits and all the pumps can be made completely interchangeable, so that no adjustment of any description is required when the pump is assembled on the engine, either initially, or as a replacement.

To obtain uniform action of the pumps so that each pump will determine the same relative time of beginning of injection in any pump in any engine, it is essential that the over-all length of the pump from its top surface **46** (Fig. 2) when such surface be positioned at the point of closing the aperture **42**, to the bottom surface of the cup-shaped guide **76** which contacts the tappet be substantially the same in all pumps; the limit of error to provide satisfactory operation being not over .001 in. Various factors in manufacture contribute to the errors involved in this distance, such elements for example being the length of the plunger, the thickness of the bottom wall of the cup-shaped guide **76**, the distance of the top edge of the aperture **42** from the seating face of the pump sleeve **36**, and also the relative position of the pump sleeve with respect to the pump body. Accumulated errors of these various elements may place the over-all length, described above, either above or below the desired amount. To compensate for these errors, the bottom wall **77** of cup-shaped guide **76** is utilized as the key member in the train of parts for effecting reciprocation of the pump plunger. A plurality of sets of cup-shaped guides **76** are provided; the bottom wall **77** of each set being manufactured with substantially the same thickness but the thicknesses among the different sets varying in the degree of .0005 in.

For selection of the desired size from among the sets of cup-shaped guides **76**, the pump is assembled with a trial size of guide and placed in a fixture which is designed to provide accurate measurement of the length from the top **46** of the pump plunger when aligned with the top edge of the aperture **42** to the undersurface of bottom **77** of the cup-shaped guide. The measurement determines the actual error in this distance with the trial guide selected and permits the selection from a set of the guides, of a guide of the proper dimensions. To effect this step of the method of calibration, pump casing **31** (Fig. 4) is mounted on fixture **101** by means of screws **102**. Fixture **101** supports a fuel tank **100** from which conduit **103** leads to fitting **104** which is adapted to be attached to pump casing **31** at the station thereon provided to receive the fuel manifold on the engine. A source of supply of fuel is, therefore, provided which is transmitted through passage **106** in pump casing **31** to chamber **41**. Below the pump when positioned on fixture **101**, adjusting screw **107** is provided, having manually operable head **108**; hardened button **109** being mounted in the bottom face of said head. Below adjusting screw **107**, micrometer **111** is provided, said micrometer being adapted to measure to .0001 in.

With the pump assembled on the fixture and connected to the source of fuel, the following operations are performed in the order described. With pump plunger **37** below aperture **42**, and the discharge valve of the pump disabled, fuel is admitted to the pump and will flow from chamber **41** through aperture **42** into sleeve **36** above plunger **37**, and out through the discharge passage. Adjusting screw **107** is then manipulated to raise guide **76** and thereby plunger **37** until the flow of fuel out of the pump is cut off, that is, until upper edge **46** of plunger **37** is in substantial alignment with the top edge of aperture **42**, as shown in Fig. 4. Thereafter, micrometer **111** is adjusted until point **112** thereof contacts the lower face of button **109**. Fixture **101** and the positions of pump **31**, screw **107** and micrometer **111** are so situated that the reading of the micrometer in the position shown in Fig. 4 determines the error in the length from the bottom face of wall **77** to top plunger edge **46** in the position shown, from the standard dimension for such length. As the operator knows the size guide **76** which is in the pump, he can then select the proper size of guide **76** from another set to compensate for the error present with the trial size of guide. Having this reading, the pump is removed from fixture **101**, the trial size of guide **76** is removed, and the proper size of said guide is installed. It is to be noted that positioning the pump plunger at top of the aperture **42** for calibration thereof compensates for manufacturing dimensional errors in the pump sleeve and casing, as well as for the plunger and operating guide therefor. The pump is thus calibrated so that it can be placed in engagement with any tappet in any engine and upon reciprocation of the pump plunger ejection of fuel from the pump will start at the same time. This is true because, as explained above, all of the tappets **86** (Fig. 2) are preadjusted to the same height from the operating cam, such preadjusting being made upon assembly and never disturbed thereafter; the bonnet **89** preventing tampering with the preadjustment of tappet **86**. Preferably, the preadjustment of the tappet is made with the cam positioned to engage the operative pumping portion thereof with the associated roller.

After the above-described step of calibration, the pump is conditioned for the second step of calibration which serves to standardize the train

of members which controls the amount of fuel measured by the pump. In considering the second phase of the method of calibration, it is important to note what such phase must accomplish. One of the results must be, that for any axially adjusted position of the plunger, the distance from the top edge 46 (Fig. 6) of the plunger to the scroll ledge 51 must be the same within the permissible limits of error; secondly, the points of connection of the adjusting rack 11 (Fig. 3) to adjacent racks and the control linkage therefor must be such that the pump can be installed in any engine; and, lastly, the relative position of the control rack to the scroll ledge must be such that, when the pump is assembled in a set of pumps, the relative positions of the racks of all the pumps to the scroll ledges thereof are the same. These results are accomplished by first positioning the pump plunger to determine the beginning of fuel injection; thereafter raising the plunger an arbitrary selected amount which would serve to cause injection of a given amount of fuel; and determining the proper size of button inserts to be placed in ends of the rack to obtain the desired over-all length of the rack, by rotating the plunger to position the scroll ledge to determine by-passing of fuel after the said given amount would be ejected.

To accomplish these purposes, pump casing 31 (Fig. 5) is mounted in fixture 121, by suitable screws 122, between micrometers 123 mounted on said fixture 121, and above plunger 124 adapted to contact the under surface of bottom 77 of guide 76. Any suitable means, such as aligning dowels, corresponding to dowels 34 (Fig. 2), are employed to position casing 31 in the same predetermined relative position on fixture 121 as on pump housing 32 on the engine. Plunger 124 is slidably mounted in boss 126 fixed on slidable plate 127; the lower face of said plunger being adapted to contact cam 128 on shaft 129. Shaft 129 has handle 131 to provide for oscillation thereof; and both the shaft and its handle are also fixed on plate 127 for slidable movement therewith. Brackets 130 fixed to plate 127 provide a journal for shaft 129. Below cam 128 and aligned with plunger 124, pin 132 is fixedly mounted in boss 133 fixed on plate 127, and adapted for engagement with adjusting screw 134 suitably mounted on fixture 121. A source of fuel supply is mounted on fixture 121, comprising pressure tank 136 adapted for connection with pump 31 by conduit 137 and fitting 138.

With the above-described structure, the following operations are performed in the sequence described.

The pump is positioned on fixture 121 and conduit 137 is connected thereto. Cam 128 is so rotated by handle 131 as to cause the lower end of plunger 124 to rest on the lowermost point of cam 128, namely, when cam 128 is turned 180° from the position shown in Fig. 5. Plate 127, with plunger 124 and cam 128 movable therewith, is then moved upwardly by means of screw 134 until plunger 124 contacts the bottom surface of guide 76. With the fuel supply connected to the pump, adjusting screw 134 is next turned to lift plate 127, and, consequently, plunger 124 until the flow of fuel ceases, i. e., until pump plunger 37 reaches the position shown in Fig. 4, where top edge 46 of plunger 37 has closed aperture 42 to determine beginning of injection. Thereafter, shaft 129 is oscillated by means of handle 131 to place cam 128 in the position shown in Fig. 5, thereby serving to lift the pump plunger 37 (without moving plate 127) an amount equal to the rise of cam 128. The movement imparted to pump plunger 37 by the cam 128 can be arbitrarily selected at any value. However, to obtain the best results, the amount of lift should be selected to correspond to the distance from top edge 46 of pump plunger 37 to approximately a midpoint of scrool ledge 51. Such upward movement of the pump plunger serves to maintain the supply of fuel shut off so that no flow occurs out of the top of the pump. The rotated position of plunger 37 in sleeve 36 is initially adjusted roughly by means of suitable aligning marks on the parts as they are assembled; such rough adjustment placing ends 72 of rack 11 projecting substantially equal distances from pump casing 31. Thereafter, respective micrometers 123 are adjusted to rotate the plunger through movement of rack element 11, in the direction of the arrow in Fig. 6 until a flow of fuel is observed at the discharge of the pump; such flow being caused by the uncovering of the lower edge of aperture 42 by scroll ledge 51. Because of a fuel pressure of about 15 pounds in tank 136, the exact moment of crossing of the lower edge of aperture 42 by scroll ledge 51 can be accurately determined.

The reading of micrometers 123 when this condition obtains discloses the exact amount of length which must be added at each end of the rack to obtain the desired over-all length of the rack and the proper points of abutting end to end connection of adjacent racks and the control linkage, while the position of the rack with respect to a given axial adjustment of the plunger to determine identical metering of fuel by all pumps for said given adjustment has been determined.

Thereafter, the pump is removed from fixture 121 and the operator selects the proper length of insert 71 (Fig. 3) which must be placed in each end of rack 11 to obtain the desired results. As with respect to guide 76, inserts 71 are manufactured in sets of varying sizes, and serve as key members in the train of control members for effecting rotation of the pump plunger. It is seen, therefore, that in any set of pumps for an engine, the length of the button inserts from their outer face to the point of contact with the end of the rack proper will vary while the over-all length of the entire rack is substantially constant, such length being maintained by the above method within .0005 in.

In other words, even though the lengths of the inserts projecting beyond the ends of the rack element proper of each pump (i. e. the distance between the outer faces of each of such inserts and the associated end of the rack element proper) will vary in accordance with the size of such inserts which are chosen as a result of the testing or calibrating steps, nevertheless the over-all length of each of the rack means on each pump which includes the rack proper as well as the projecting portions of the inserts, will be substantially the same for all of the pumps thus calibrated. At the same time, for any given angular or rotated position of the pump plunger determining a fixed quantity of fuel for injecting, the distance between one end of each of the rack means and the axis of the pump plunger will be substantially the same for all pumps, while the distance between the opposite end of each of the rack means and such axis will also be substantially the same for all pumps. As a result, the sizes of the inserts

chosen from the testing or calibrating of the pumps under conditions corresponding to actual fuel injection conditions of the pumps on the engine, enables uniform timing or standardization for all pumps, and also complete interchangeability of the pumps inasmuch as the over-all length of the rack means is the same in all the pumps.

From the foregoing description, it is seen that the provision of a key member of preselected size in each train of control members for a pump, together with the various calibration steps performed to determine the actual size of key member required, provide a ready and accurate method to obtain standardization in size and in performance for all pumps manufactured. The advantages resulting from such standardization are believed obvious, as the saving in cost of manufacture, assembly and replacement is material. Such standardization has enabled the use of compression ignition engines for tractors and in power plants situated in various remote parts of the world, thousands of miles from any place where service could be obtained, as no delicate checks or adjustments are necessary upon installation. In addition, such standardization means that an unskilled operator can replace a defective pump in a compression ignition engine as easily as he can change a spark plug in a spark ignition engine. All he has to do is to order a new pump from a dealer or from the factory, remove the defective pump, and replace the defective pump by the new pump without making any adjustments whatsoever; it being recalled that tappets **86** are all preadjusted when the engine is built. Since all pumps are exactly of the same calibrated standard, the timing of the engine will be unaffected by the substitution. Other advantages, such as the reduced cost of manufacture, are believed obvious.

I, therefore, claim as my invention:

1. The method of standardizing fuel injection pumps of the type adapted to eject measured amounts of fuel therefrom, so as to obtain uniform action thereof and interchangeability, each pump having a train of members including a pump plunger member adapted for movement to determine the beginning of fuel injection and a second member associated with said plunger member; which comprises the steps of providing a plurality of sets of said second members, the members of each set having a dimension in the motion transmitting line thereof varying by a constant amount from the corresponding members of another set, said constant amount being less than the permissible error in the dimension of the plunger member in a standardized pump, determining the size of the second member which most accurately satisfies the conditions for a given pump, and mounting a second member of the determined size in said pump.

2. The method of standardizing fuel injection pumps of the type adapted to eject measured amounts of fuel therefrom, so as to obtain uniform action thereof and interchangeability, each pump having a part adapted to transmit movement to the fuel metering means of the pump; which comprises the step of providing a plurality of sets of said parts, said parts of a set having a constant dimension in the motion transmitting line, said dimension varying among sets by amounts less than the permissible error in the dimension of said part which is adapted to transmit movement to the fuel metering means of the pump.

3. The method of standardizing fuel injection pumps of the type adapted to eject measured amounts of fuel therefrom, so as to obtain uniform action thereof and interchangeability, each pump having a part adapted to transmit movement to the fuel metering means of the pump; which comprises the steps of providing a plurality of sets of said parts of varying dimensions, placing a trial size of said parts in the pump to determine its dimensional deficiency under conditions simulating actual operating conditions, and from this deficiency determining the correct dimension of said part to be finally assembled in said pump.

4. The method of standardizing fuel injection pumps of the type adapted to eject measured amounts of fuel therefrom, each pump having a train of members including a plunger member adapted for movement to effect fuel injection and a second member for transmitting movement thereto; which comprises the steps of moving said plunger member of a pump to the position thereof determining a fixed phase of the fuel injection period, determining a size of said second member necessary for providing a standard dimension of said train of members in said relative position, then employing a second member of the properly selected size, and performing the same steps for the standardizing of all pumps.

5. The method of constructing a plurality of standardized fuel metering pumps of fuel injection systems for compression ignition and the like engines, each pump having a train of members adapted to transmit movement to the fuel metering member thereof, which comprises determining the dimensional deficiency in the combined length of the members of the train of each pump, and altering the effective dimension of one of said members in said train of each pump to cooperate in determining uniform beginning and ending of fuel injection in all pumps.

6. In the method of constructing standardized fuel injection pumps for compression ignition and the like engines, each of which pumps has fuel metering means and a movable train of members for controlling said metering means, comprising the steps of utilizing the same member of each train as a part providing a key member leading to standardization, testing each pump under conditions corresponding to actual fuel injection conditions of the pump on an engine, to determine in said test the size of each key member of each pump train necessary to provide standardization of effective dimension of an element of said trains, and employing in each pump a premanufactured key member of the proper size as determined in said test.

7. A set of fuel injection pumps for compression ignition and the like engines, each pump comprising fuel metering means and means including a key part adapted to control said fuel metering means, the corresponding key parts of said pumps each being of a size sufficient to obtain standardization and resulting uniformity in pumping characteristics among the individual pumps.

8. A fuel injection pump having a plunger mounted for reciprocation to effect fuel injection, and members associated with said plunger for transmitting movement thereto and providing with said plunger a train of reciprocating elements, one of said members of said train being of a size determined by testing of said pump under conditions corresponding to actual fuel injection conditions of the pump on an engine to

provide a key member for supplying any dimensional deficiency in said train of elements, to obtain standardized operation of said pump.

9. In a compression ignition and the like engine, a plurality of interchangeable standardized unitary fuel injection pumps, each pump having a movable train of members including a plunger for controlling fuel injection, any one of said trains of members of said plurality of pumps being characterized by one member which is the same operating part occurring in all of said trains and which is a key member of a size determined by testing of said pump under conditions corresponding to actual fuel injection conditions of the pump on said engine for imparting to said any one train substantially the same fuel control characteristics as the remaining trains on said engine.

10. The method of standardizing each of a plurality of unitary interchangeable fuel injection pumps for compression ignition and the like engines to impart like fuel metering characteristics to said pumps; each unitary pump being of the type having a plunger and a cylinder mounted for relative reciprocatory and rotary movements to control fuel injection, the relative position of rotation between said plunger and said cylinder determining the quantity of fuel injection, means on each pump to provide for said relative reciprocatory movement, and mechanism on each pump adapted for connection with similar mechanism of other pumps to provide for said relative rotary movement; comprising testing each pump under conditions corresponding to fuel injection conditions of the pump on an engine, to determine the deficiencies in said mechanism which prevent standardized operation of each of said pumps, and thereafter adjusting said mechanism to cure said deficiencies and obtain substantially identical fuel pumping characteristics in said unitary pumps.

11. The method of standardizing each of a plurality of unitary fuel injection pumps for compression ignition and the like engines to impart like fuel metering characteristics to said pumps; each pump being of the type having a plunger and a cylinder mounted for relative reciprocatory and rotary movements to control fuel injection, the relative position of rotation between said plunger and said cylinder determining the quantity of fuel injection, means on each pump to provide for said relative reciprocatory movement, and mechanism on each pump adapted for connection with similar mechanism of other pumps to provide for said relative rotary movement; comprising testing each pump under conditions corresponding to fuel injection conditions of the pump on an engine by effecting relative linear movement between said plunger and said cylinder to a position corresponding to a fixed point determining the same timing of the beginning of fuel injection for all of said pumps, effecting additional relative linear movement between said plunger and said cylinder of each pump for a predetermined fixed distance from said point to a second point, while at said second point effecting relative rotary movement between said plunger and said cylinder of each pump to a position determining a fixed quantity of fuel injection for each pump for said predetermined fixed distance of said additional relative linear movement, and then providing the proper adjustment of said mechanism to obtain similar operating characteristics of the various pumps when in operation.

12. The method of standardizing each of a plurality of unitary fuel injection pumps for compression ignition and the like engines to impart like fuel metering characteristics to said pumps; each pump being of the type having a plunger and a cylinder mounted for relative reciprocatory and rotary movements to control fuel injection, the relative position of rotation between said plunger and said cylinder determining the quantity of fuel injection, means on each pump to provide for said relative reciprocatory movement, and mechanism on each pump adapted for connection with similar mechanism of other pumps to provide for said relative rotary movement; comprising testing each pump under conditions corresponding to fuel injection conditions of the pump on an engine by effecting relative linear movement between said plunger and said cylinder to a position corresponding to a fixed point determining the same timing of the beginning of fuel injection for all of said pumps, from said position determining and correcting for dimensional deficiencies to render the plunger of each pump of substantially the same effective length as the others, effecting additional relative reciprocatory movement between said plunger and said cylinder of each pump for a predetermined fixed distance from said point to a second point, while at said second point effecting relative rotary movement between said plunger and said cylinder of each pump to a position determining a fixed quantity of fuel injection for each pump for said predetermined fixed distance of said additional relative linear movement, and then providing the proper adjustment of said mechanism to obtain similar operating characteristics of the various pumps when in operation.

13. The method of standardizing each of a plurality of unitary fuel injection pumps for compression ignition and the like engines to impart like fuel metering characteristics to said pumps; each pump being of the type having a plunger and a cylinder mounted for relative reciprocatory and rotary movements to control fuel injection, the relative position of rotation between said plunger and said cylinder determining the quantity of fuel injection, means on each pump to provide for said relative reciprocatory movement, and rack mechanism on each pump adapted for end to end abutting connection with similar mechanism of other pumps to provide said relative rotary movement and including a rack proper; comprising testing each pump under conditions corresponding to fuel injection conditions of the pump on an engine by effecting relative linear movement between said plunger and said cylinder to a position corresponding to a fixed point determining the same timing of the beginning of fuel injection for all of said pumps, from said position providing said means of each pump of substantially the same length, effecting additional relative linear movement between said plunger and said cylinder of each pump for a predetermined fixed distance from said point to a second point, while at said second point effecting relative rotary movement between said plunger and said cylinder of each pump through movement of said rack to a position determining a fixed quantity of fuel injection for each pump for said predetermined fixed distance of said additional relative linear movement and then providing projections of predetermined length on each end of the rack proper to extend the same to an equal distance to either side of the

plunger axis and obtain an over-all length of the rack mechanism the same for each pump.

14. A unitary fuel injection pump having a plunger and a cylinder mounted for relative rotary adjustment about an axis to control fuel injection, and control mechanism therefor adjusted under conditions corresponding to fuel injection conditions of the pump on an engine to give to said unitary fuel injection pump fuel pumping characteristics substantially identical to those of similarly constructed and adjusted pumps.

15. A fuel injection pump having a plunger and a cylinder mounted for relative rotary adjustment about an axis and for relative reciprocatory movement to control fuel injection, means providing for said relative reciprocatory movement, and mechanism providing for said relative rotary movement, said means being of a standardized length determined by testing of said pump under conditions corresponding to actual fuel injection conditions of the pump on an engine, and said mechanism having a standardized dimensional relationship with respect to said axis of said pump also determined by testing of said pump under conditions corresponding to fuel injection conditions of the pump on an engine, whereby said pump will be interchangeable with other pumps of similar standardized relationships.

16. A fuel injection pump having a plunger and a cylinder mounted for relative rotary adjustment about an axis to control fuel injection; and control mechanism therefor including an element mounted for reciprocation along an axis normal to said first mentioned axis, and means projecting beyond the ends of said element of predetermined lengths sufficient to extend the effective length of said element to a standardized dimension and adapted for end to end contact with similar means of like pumps.

17. A fuel injection pump having a plunger and a cylinder mounted for relative rotary adjustment about an axis and for relative reciprocatory movement to control fuel injection, means providing for said relative reciprocatory movement, and mechanism providing for said relative rotary movement, said means being adjusted to a standardized length determined by testing of said pump under conditions corresponding to actual fuel injection conditions of the pump on an engine; and said mechanism including an element mounted for reciprocation along an axis normal to said first mentioned axis, and means projecting sufficiently beyond the ends of said element to provide predetermined operating characteristics in said pump, the lengths of said means being determined by operating of said pump under conditions corresponding to fuel injection conditions of the pump on an engine said means being formed for end to end contact with similar means of like pumps.

18. In a compression ignition and the like engine, a plurality of individual interchangeable standardized fuel injection pumps; each pump having a plunger and a cylinder mounted for relative rotary adjustment about an axis and for relative reciprocatory movement to control fuel injection, means providing for said relative reciprocatory movement, and mechanism providing for said relative rotary movement, each of said means being of a common length as determined by operation of each pump under conditions corresponding to fuel injection conditions of the pump on an engine, and each mechanism being preadjusted under similar conditions to obtain a standardized pumping characteristic in each of said individual pumps prior to its installation in said engine, whereby any one of said individual pumps may be interchanged with a similarly standardized pump.

19. A fuel injection pump having a cylinder and a plunger mounted for relative angular movement therein to control fuel injection, control means for varying the relative angular position between said cylinder and said plunger in response to load conditions of an engine in which said pump may be installed whereby the quantity of fuel supplied per injection will vary with the angular position as determined by said load conditions, said pump having its control mechanism preadjusted to obtain a standardized pumping characteristic prior to its installation in an engine, whereby most efficient operation of an engine may be maintained by mere interchange of individual fuel pumps with similarly preadjusted pumps.

20. A fuel injection pump having a cylinder and a plunger mounted for relative angular movement therein to control fuel injection, control means for varying the relative angular position between said cylinder and said plunger in response to load conditions of an engine in which said pump may be installed whereby the quantity of fuel supplied per injection will vary with the angular position as determined by said load conditions, said pump having its control mechanism preadjusted under operating conditions simulating those existing in an engine in the field, to obtain a standardized pumping characteristic prior to its installation in an engine, whereby most efficient operation of an engine may be maintained by mere interchange of individual fuel pumps with similarly preadjusted pumps.

21. In a compression ignition engine or the like, a pump housing, a plurality of individual pumps, each having its own control mechanism associated therewith, said individual pumps and associated control mechanisms being preadjusted to a common standard and mounted in said housing in freely disengageable contact with each other, whereby said individual pumps may be readily interchanged with similar preadjusted pumps without impairing operation of said engine.

CARL G. A. ROSÉN.