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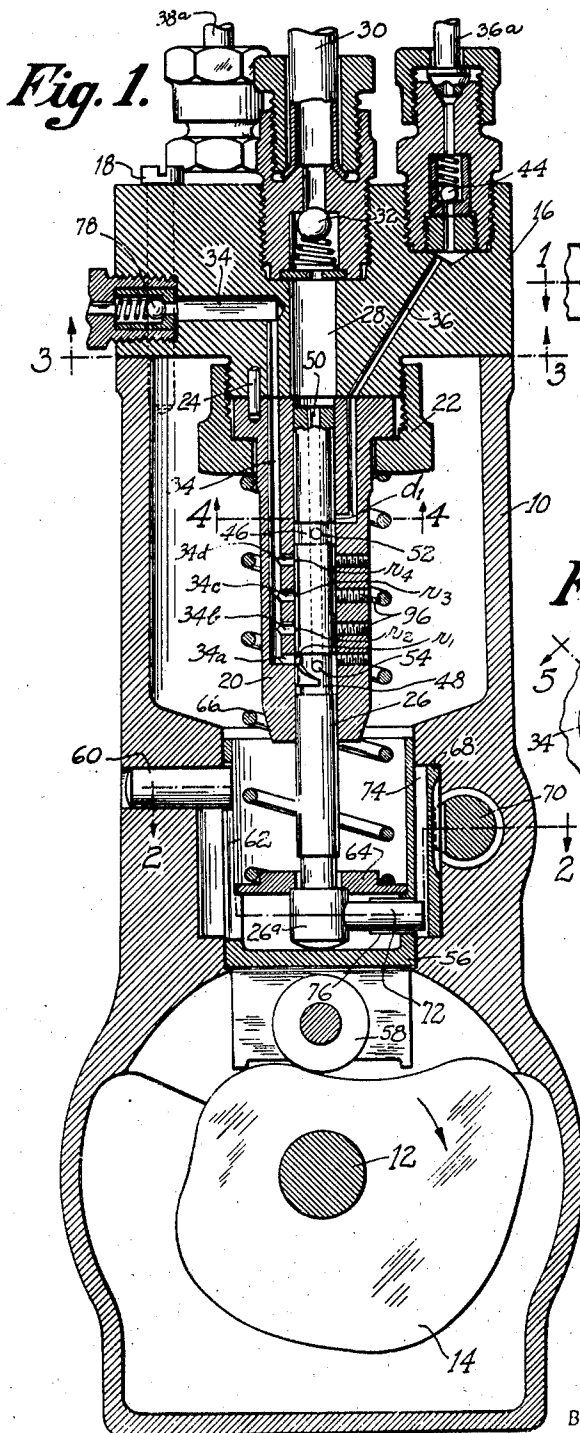
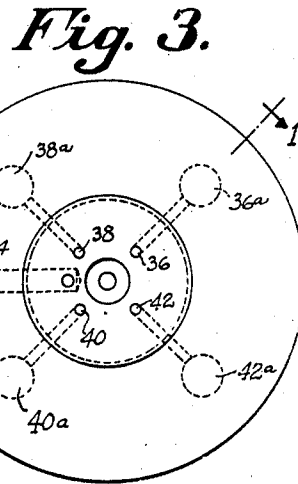
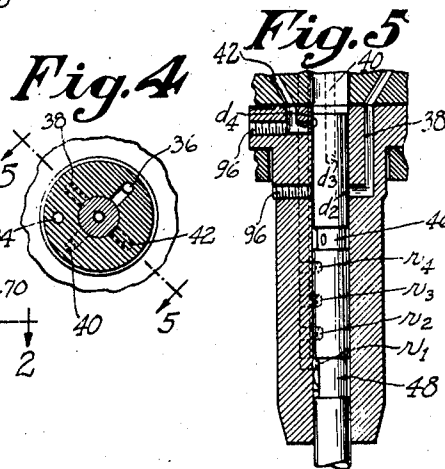
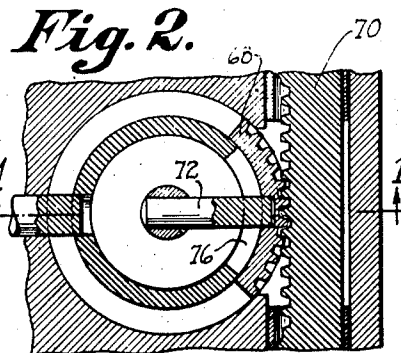
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Filed May 26, 1939

10 Sheets-Sheet 1



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Fig. 6.

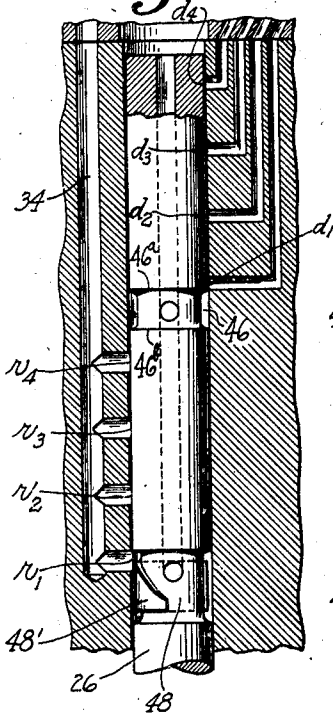


Fig. 7.

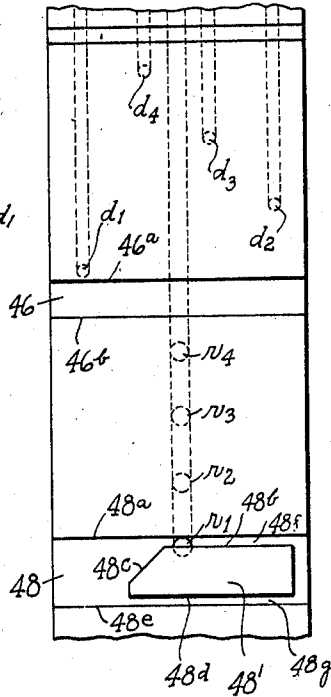


Fig. 12.

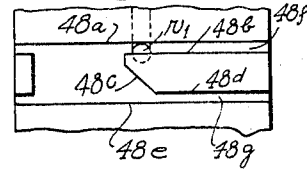


Fig. 13.

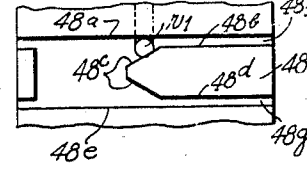
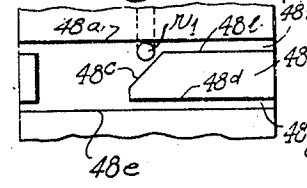


Fig. 11.



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Fig. 8.

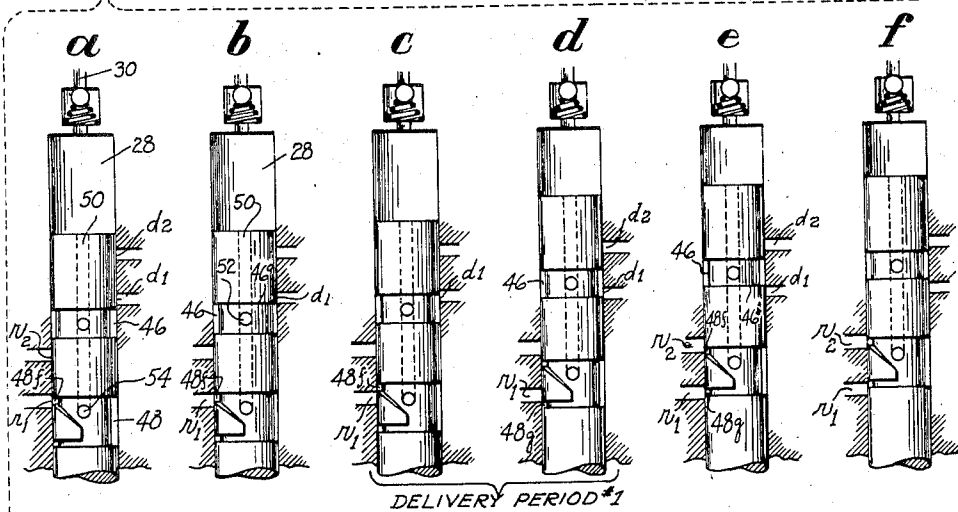
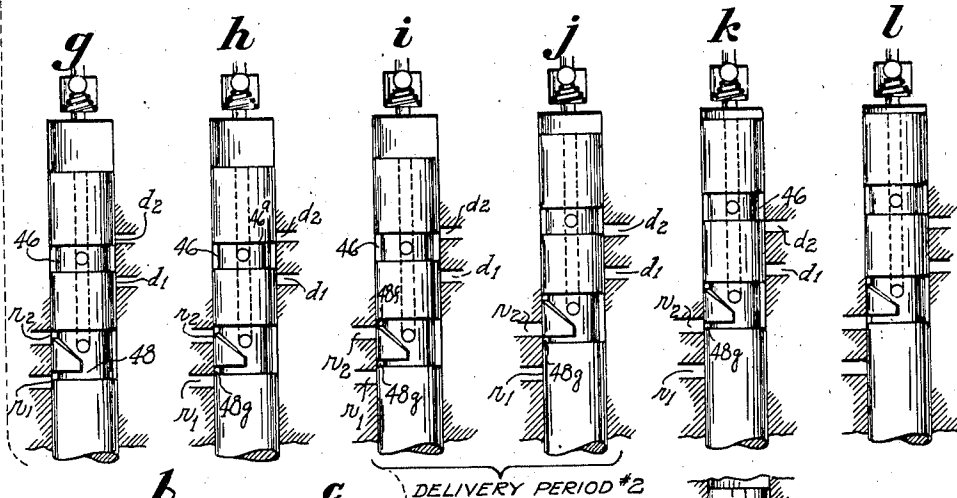
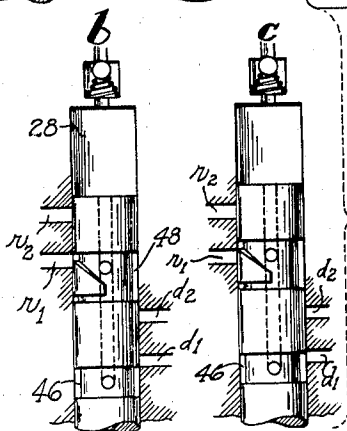


Fig. 9.

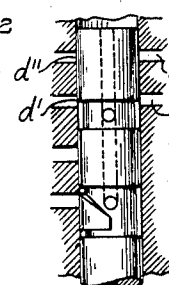


Fig. 10.

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Fig. 18.

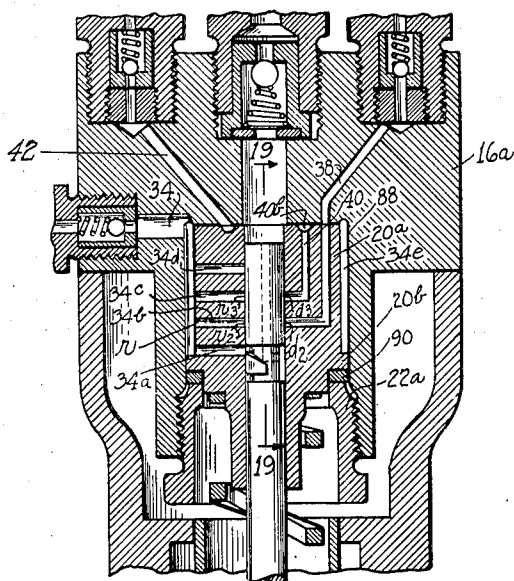


Fig. 24

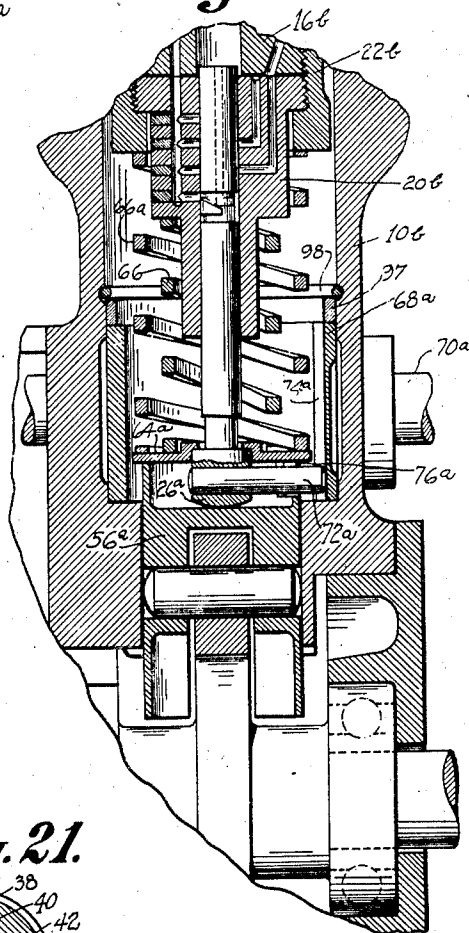


Fig. 20.

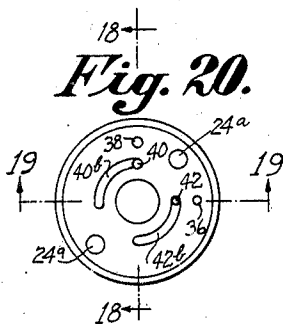


Fig. 19.

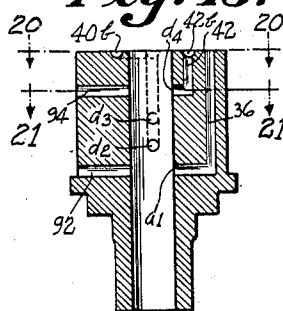
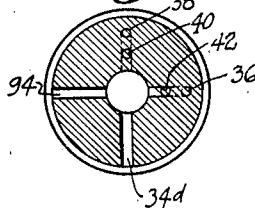


Fig. 21.



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Fig. 22.

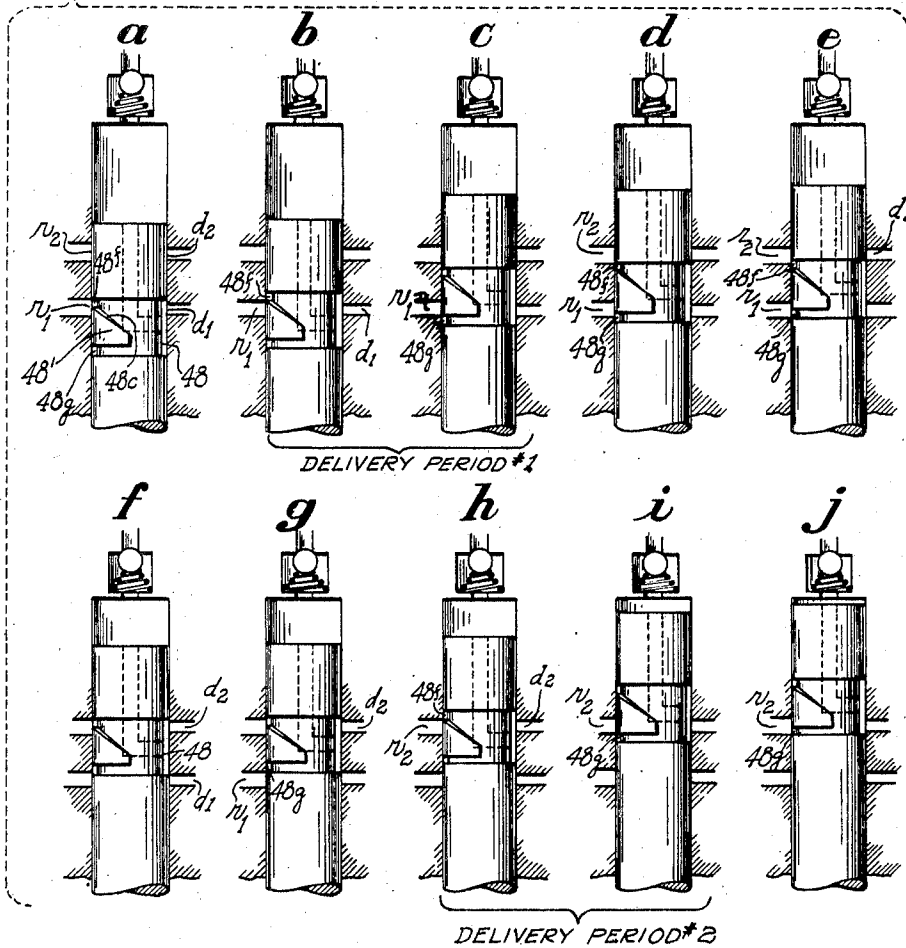


Fig. 23.

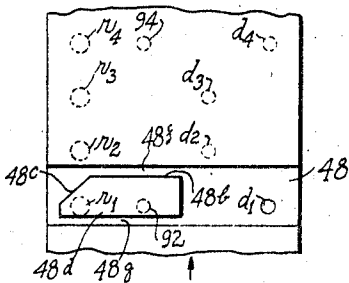
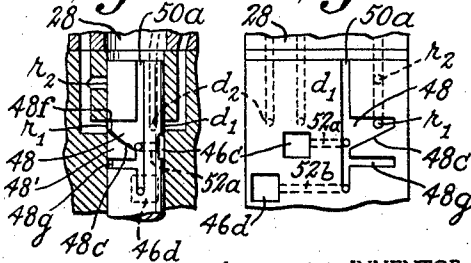


Fig. 37. Fig. 38.



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Fig. 25.

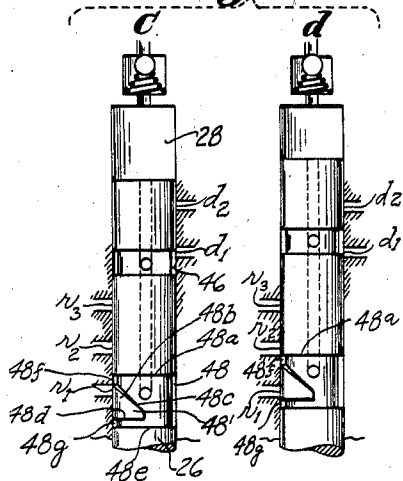


Fig. 26.

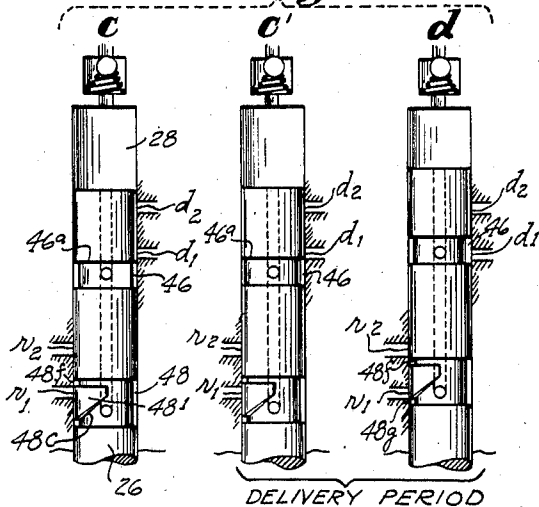


Fig. 27. Fig. 28.

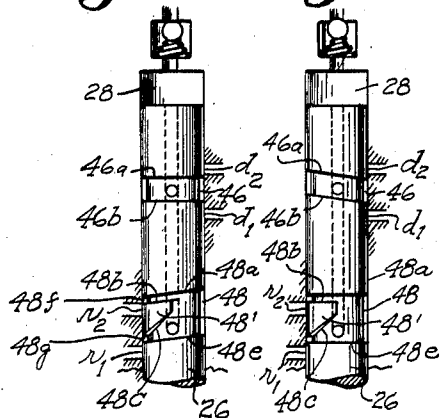


Fig. 29.

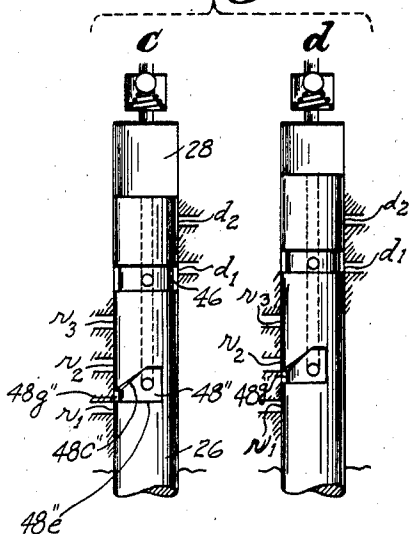
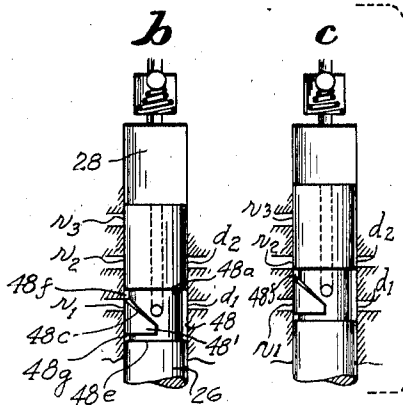


Fig. 30.



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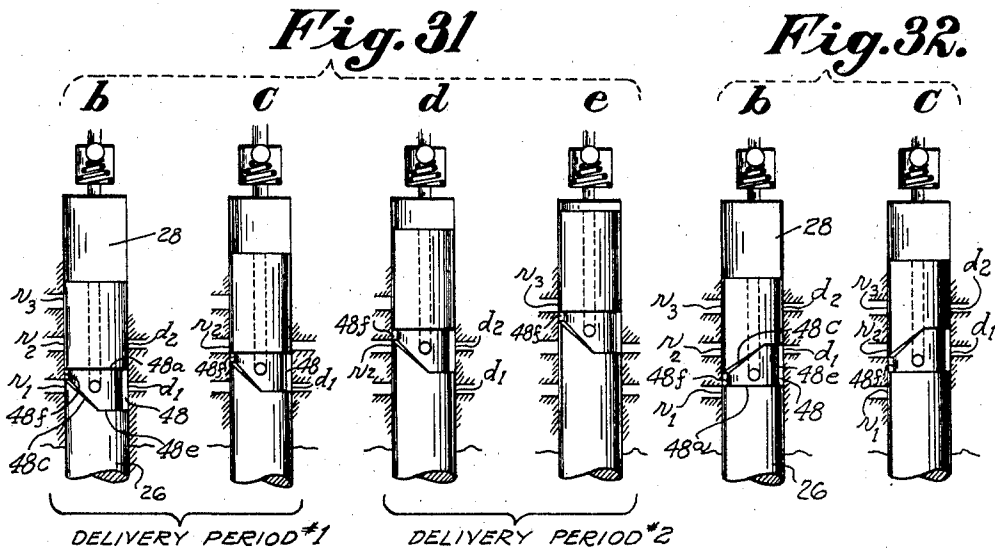


Fig. 33.

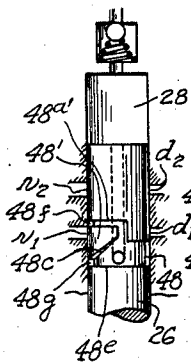


Fig. 34.

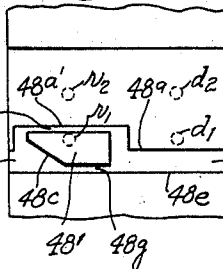


Fig. 35.

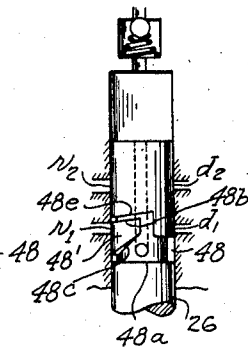
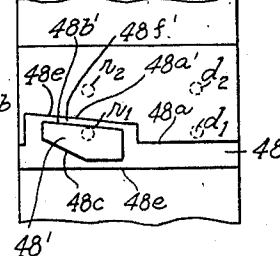


Fig. 36.



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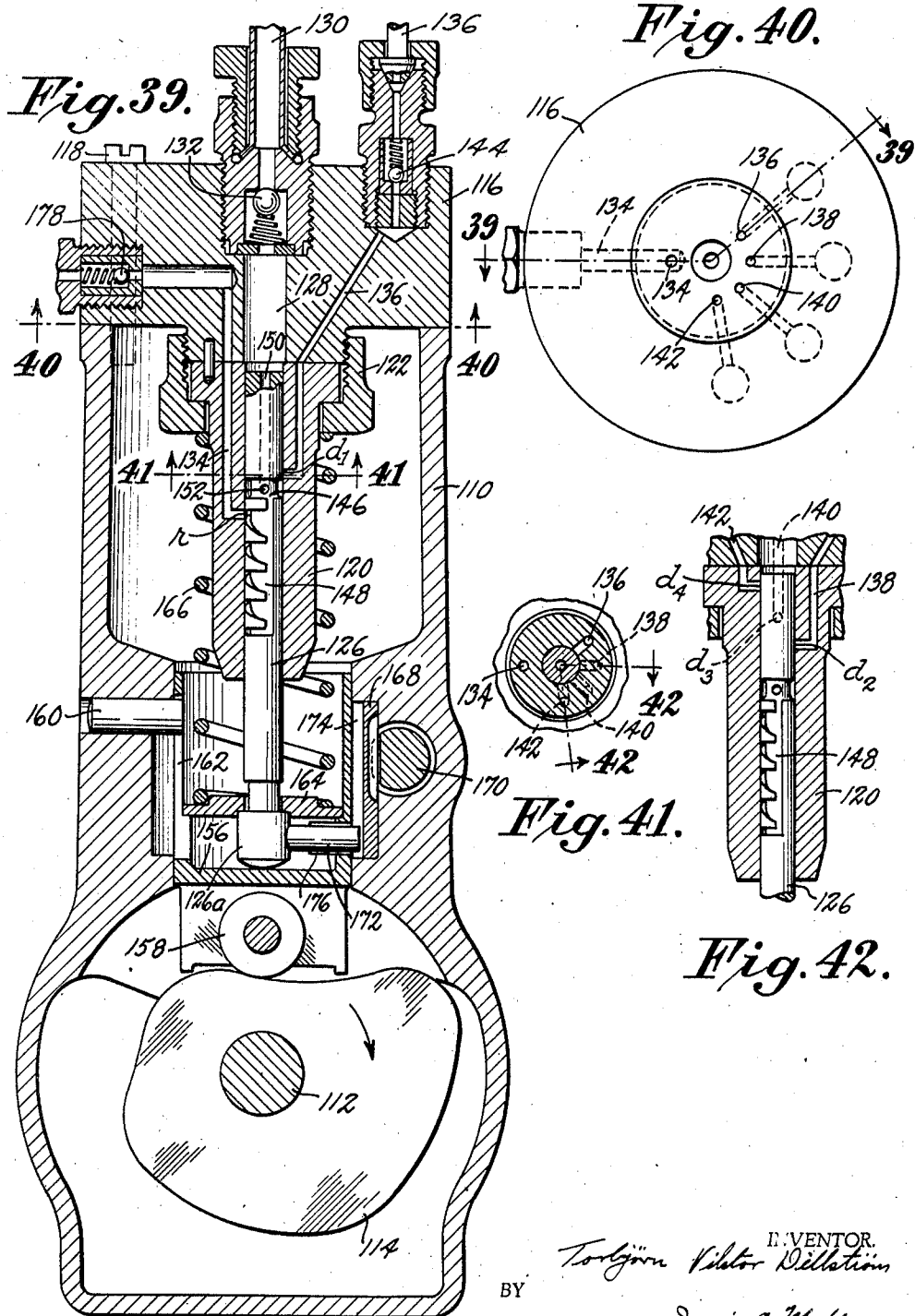
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Fig. 44.

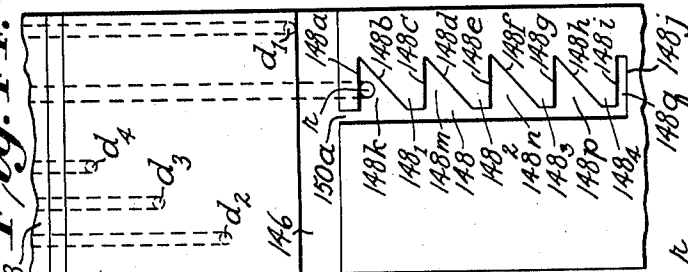


Fig. 43.

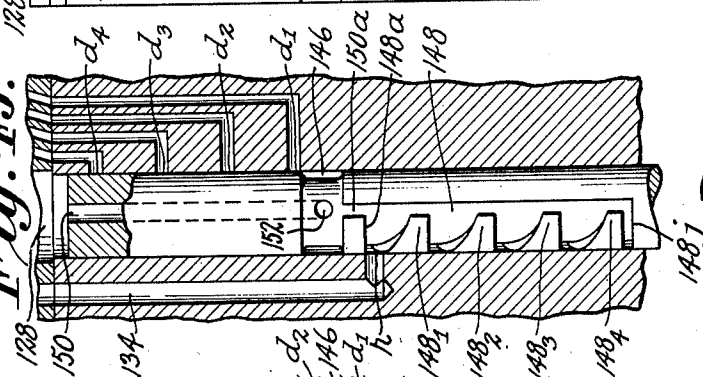


Fig. 46.

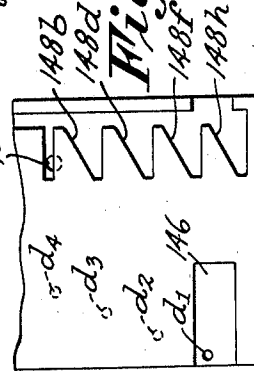
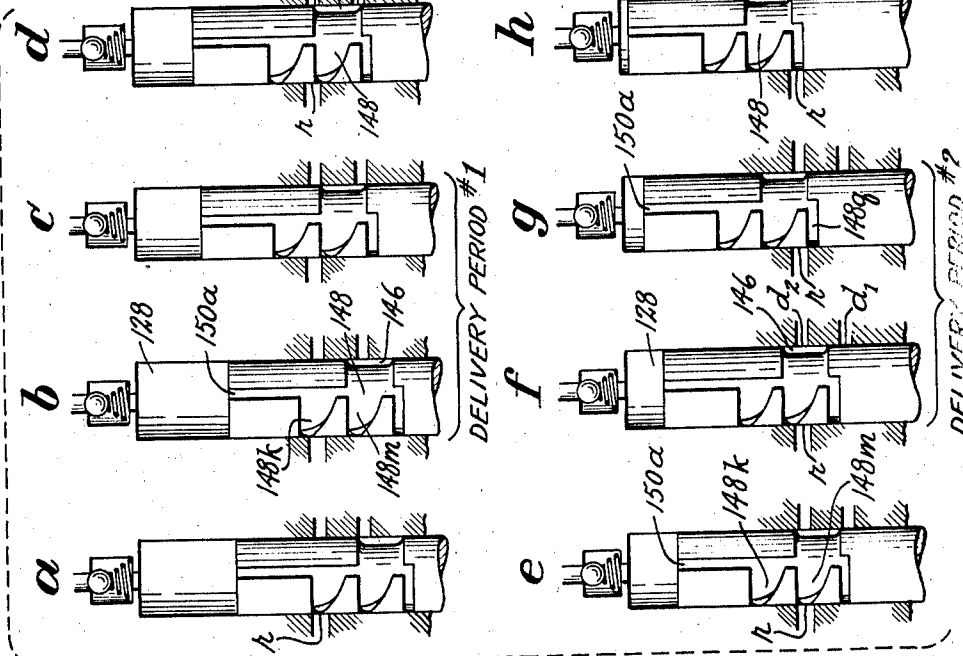


Fig. 45.

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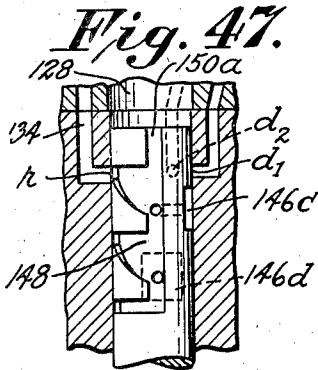
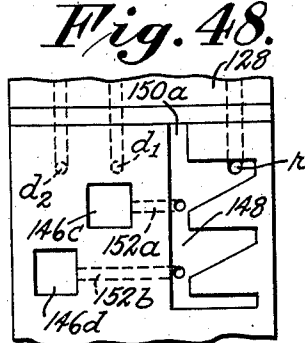
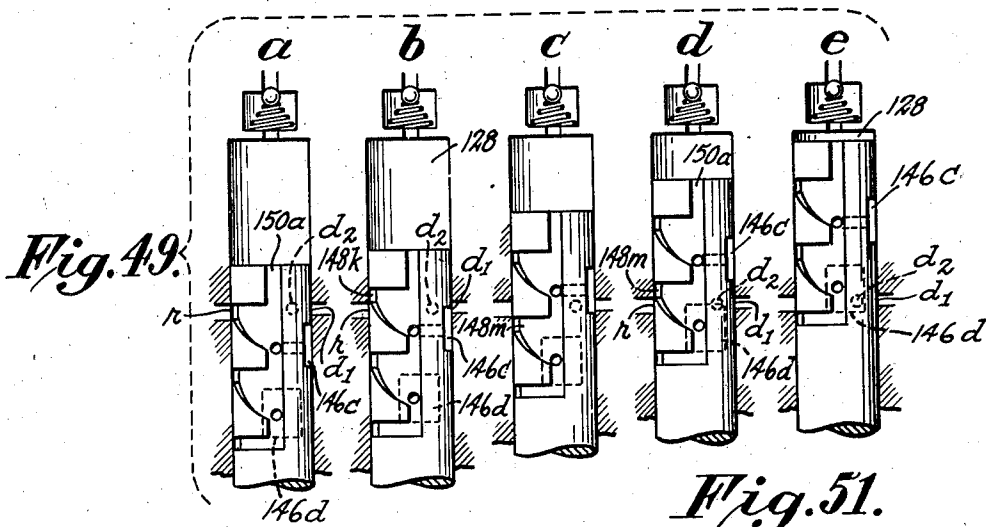
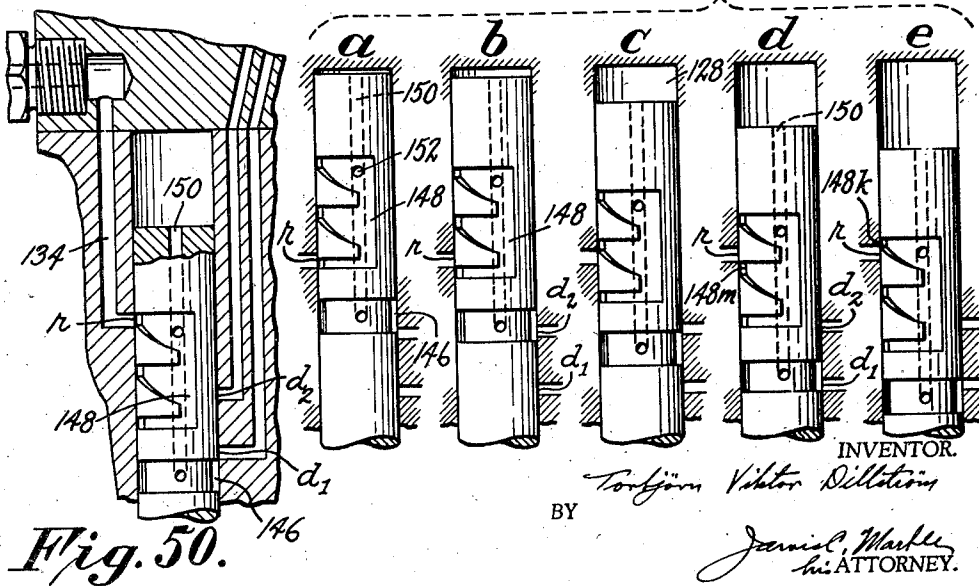
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10 Sheets-Sheet 10



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UNITED STATES PATENT OFFICE

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Application May 26, 1939, Serial No. 275,974
 In Sweden April 6, 1939

20 Claims. (Cl. 103—41)

This application is a continuation in part with respect to my copending application Serial Number 224,211, filed August 10, 1938, and relates back thereto, as to all common subject matter, for all dates and rights incident to the filing thereof and to the filing of corresponding foreign applications.

The present invention relates to plunger pumps for supplying liquid and has particular reference to pumps of this kind for supplying liquid fuel under pressure for injection into the cylinders of internal combustion engines.

The requirements for fuel injection pumps are particularly severe. In order for such pumps to inject fuel in a manner providing satisfactory engine operation they must inject fuel under very high pressure, they must act with extreme accuracy and precision, they must be capable of adjustment to vary the quantity of fuel delivered per cycle of operation and they must, when supplying fuel to a multiple cylinder engine, be capable of delivering, as nearly as possible, precisely the same quantity of fuel to each outlet for any given setting of pump capacity.

In order to meet these extremely rigid requirements, the most satisfactory type of pump arrangement heretofore developed has been that in which a separate cylinder and plunger is provided for each injector or other device to which fuel must be supplied and because of the extreme accuracy with which such pumps must be manufactured and the pressures involved, such pumps have proved to be very expensive to manufacture and also difficult to maintain in proper adjustment over long periods of service so that appreciable variation is not developed, through wear or other causes, in the quantities of fuel delivered to different outlets leading for example to injectors in different cylinders of the same engine.

It is the general object of the present invention to improve upon prior forms of construction of plunger pumps and to provide novel plunger pump structure which will enable liquids such as fuel oil to be supplied to a plurality of points of consumption with great accuracy of control both as to the quantity delivered and the relation of the quantities delivered by the pump to different outlets, while at the same time accomplishing the desired results with pump structure very much more simple and inexpensive than structures heretofore representing the best available for accomplishing the desired purpose.

To this end the invention contemplates the

provision of improved plunger pump structure so constructed that liquid is delivered to a plurality of outlets from a common pump chamber through the action of a single plunger.

The manner in which the above general object, and other and more specific objects of the invention to be hereinafter pointed out, are attained, will best be understood from a consideration of the ensuing portion of this specification, taken in conjunction with the accompanying 10 drawings, in which is described various forms of constructional examples of pump structure for carrying the invention into effect.

In the drawings, Fig. 1 is a transverse section of a pump embodying the invention, taken in 15 part along the line 1—1 of Fig. 2 and in part along line 1—1 of Fig. 3;

Fig. 2 is a fragmentary section taken on the line 2—2 of Fig. 1;

Fig. 3 is a section taken on the line 3—3 of 20 Fig. 1;

Fig. 4 is a section taken on the line 4—4 of Fig. 1;

Fig. 5 is a section taken on the line 5—5 of 25 Fig. 4;

Fig. 6 is an enlarged view of part of the pump plunger and barrel shown in Fig. 1, certain passages being turned into the plane of the drawing for clarity of illustration;

Fig. 7 is a developed view of the plunger and 30 barrel surface of the pump shown in Fig. 1 with the plunger adjusted for maximum delivery;

Fig. 8 is a series of diagrams illustrating various phases of operation during the delivery stroke of the type of pump shown in Fig. 1, only 35 two outlets being shown in the diagrams, however, for the sake of simplicity;

Fig. 9 shows different phases of the delivery stroke of a different form of plunger applicable 40 for use in a pump of the general kind shown in Fig. 1;

Fig. 10 illustrates a different arrangement of outlet openings in a pump of the general kind shown in Fig. 1;

Fig. 11 illustrates in developed form the control 45 portion of the plunger surface shown in Fig. 7, but in partial load position of adjustment;

Fig. 12 is a view similar to Fig. 11 showing a different form of control surface on the pump 50 plunger for effecting a different mode of timing of part load delivery with respect to the timing of the pump actuating mechanism;

Fig. 13 is a view similar to Fig. 12 showing still another form of pump control surface for 55

effecting yet another mode of timing of part load delivery;

Fig. 14 is a diagram illustrating a preferred cycle of movement of the pump plunger, particularly with reference to the delivery stroke;

Fig. 15 is a view showing a form of cam profile for securing the kind of plunger operation shown in Fig. 14;

Fig. 16 is a fragmentary section showing a form of overflow arrangement different from that of Fig. 1;

Fig. 17 is a view similar to Fig. 16 showing still another overflow arrangement;

Fig. 18 is a partial section showing a different form of pump plunger and barrel construction for use in a pump of the kind shown in Fig. 1;

Fig. 19 is a central longitudinal section of the pump barrel of Fig. 18, taken on the lines 19—19 of Figs. 18 and 20;

Fig. 20 is a top plan view taken on line 20—20 of Fig. 19;

Fig. 21 is a section taken on line 21—21 of Fig. 19;

Fig. 22 is a series of diagrams illustrating different phases of delivery stroke operation of the plunger of the type shown in Fig. 18, only two outlets again being shown in these diagrams for the sake of simplicity;

Fig. 23 is a developed view of part of the barrel and plunger surfaces of the pump shown in Fig. 18;

Fig. 24 is a fragmentary section similar to Fig. 1 showing a pump having the same type of plunger as shown in Fig. 18 combined with a different form of tappet construction;

Fig. 25 is a diagram similar to Fig. 8 showing another form of cylinder porting arrangement;

Fig. 26 is a diagram similar to Fig. 25 showing still another porting arrangement providing pre-compression of fuel before delivery;

Fig. 27 is a diagram similar to Fig. 26 showing an arrangement providing variable degrees of precompression;

Fig. 28 is a diagram similar to Fig. 27 but showing a different variation of precompression with respect to load adjustment of the pump;

Fig. 29 is a diagram illustrating a different form of plunger porting construction;

Fig. 30 is a diagram illustrating the features of Fig. 25 applied to a different form of plunger;

Fig. 31 is a diagram illustrating still another plunger porting arrangement;

Fig. 32 is a diagram similar to Fig. 31 showing a different arrangement for part load control;

Figs. 33 and 34 are diagrammatic sectional and developed views of still another arrangement providing for precompression with a plunger of the general type shown in Fig. 30;

Figs. 35 and 36 are diagrammatic sectional and developed views respectively showing an arrangement providing for variable precompression with a plunger of the type shown in Fig. 33;

Fig. 37 is a fragmentary section similar to Fig. 6 showing a different manner of locating the delivery ports;

Fig. 38 is a developed view of the structure shown in Fig. 37;

Fig. 39 is a view similar to Fig. 1, partly in elevation, showing a type of plunger and cylinder porting different from the preceding embodiments;

Fig. 40 is a section taken on the line 40—40 of Fig. 39;

Fig. 41 is a section taken on the line 41—41 of Fig. 39;

Fig. 42 is a section taken on the line 42—42 of Fig. 41;

Fig. 43 is a fragmentary section on enlarged scale of the pump and barrel arrangement of Fig. 39, certain of the passages being moved into the plane of the section for clarity;

Fig. 44 is a developed view of the plunger and cylinder barrel surfaces shown in Fig. 43;

Fig. 45 is a series of diagrams illustrating a different embodiment of the general type of barrel and plunger structure shown in Figs. 39 to 44, and showing the plunger in various positions on its discharge stroke;

Fig. 46 is a developed view on enlarged scale of plunger and cylinder surfaces of the kind shown in Fig. 45;

Fig. 47 is a section showing a form of pump of the general type shown in Fig. 45 but arranged with the cylinder delivery ports at the same level in the pump barrel;

Fig. 48 is a developed view of the device shown in Fig. 47;

Fig. 49 is a series of diagrams showing the plunger of Fig. 47 in different positions on its discharge stroke;

Fig. 50 is a fragmentary section showing a form of pump in which a pump suction valve is eliminated and the pump chamber filled through the overflow passage; and

Fig. 51 is a series of diagrams showing the plunger of Fig. 50 in different positions during its discharge stroke.

Referring now more particularly to Figs. 1 to 5, the pump illustrated is a single cylinder pump adapted to supply liquid fuel to four separate places of consumption such as fuel injectors. The pump comprises a casing part 10 in the base portion of which there is mounted a cam shaft 12 adapted to be driven from any suitable source of power and carrying cam 14 which may be integral with or fixed to the shaft. At the top of the casing part 10 there is secured a head part 16, which is advantageously removably fixed to part 10 by a number of bolts, one of which is shown at 18.

The pump cylinder or barrel 20 is, in the embodiment illustrated, detachably secured to the head 16 by means of a threaded clamping collar 22 and is prevented from rotating with respect to the pump body by means of a locating pin 24. The pump plunger 26 is reciprocally mounted in the bore of barrel 20 and head 16 is bored out in alignment with the bore of the barrel to provide a pump chamber 28 with which the suction or supply conduit 30 communicates. Between the conduit 30 and the chamber 28 there is located the non-return suction valve which in the form shown is a spring loaded ball valve 32. It is to be noted in this connection that the flow of liquid to the pump chamber from the suction line is through a straight channel substantially unobstructed except for the suction valve. This is of importance as will be explained later.

The pump barrel is provided with a series of longitudinally spaced relief or overflow ports 71, 72, 73 and 74 which as will be noted from Figs. 1 and 5 lie in alignment in a plane passing through the axis of the pump barrel. These ports are connected respectively by branch overflow passages 34a, 34b, 34c and 34d to a common overflow passage 34 formed partially in the barrel and partially in the head part of the pump casing.

The pump barrel is further provided with four outlet or delivery ports located in a zone above

the overflow ports and advantageously distributed so as to open into the bore of the barrel in different axial planes passing through the axis of the bore. These delivery ports, like the relief ports, are distributed in longitudinally spaced relation along the pump barrel. One of these ports d_1 is shown in Fig. 1 and the remaining three ports, d_2 , d_3 , d_4 , appear in Fig. 5.

The ports d_1 — d_4 are connected respectively by delivery passages 36, 38, 40 and 42 to individual delivery conduits 36a, 38a, 40a and 42a. Each of the several delivery passages is provided with a spring loaded discharge valve, the one controlling passage 36 being indicated at 44 in Fig. 1.

In the embodiment illustrated the several delivery ports are displaced peripherally with respect to adjacent ports by 90° and the line of relief ports is also displaced peripherally with respect to two peripherally adjacent delivery ports (see Fig. 3). As will hereinafter more fully appear, the arrangement of the outlet ports peripherally of the barrel may be varied without affecting pump operation.

The pump plunger is provided with two longitudinally separated recesses 46 and 48, both of which are in constant communication with the pump chamber 28 by means of a central longitudinal bore 50 in the pump plunger, which at one end opens into the pump chamber and which is placed in communication with the surfaces of the recesses by one or several transverse bores 52 and 54 respectively.

In the embodiment illustrated, the recess 46 encircles the periphery of the pump plunger while the recess 48 is provided with a special configuration to be described later.

Between the plunger and the cam there is provided a tappet 56 mounted for reciprocation in a suitable bore in the casing part 10 and at its lower end provided with a roller 58 contacting the face of the cam. The tappet is restrained against turning movement in the casing by means of a locating pin 60 the inner end of which engages a suitable vertical slot 62 in the tappet. The upper portion of the tappet is of cup-like form providing a cylindrical recess into which the lower end of the pump plunger extends and against the bottom of which recess the enlarged foot 26a of the plunger rests. The foot 26a advantageously is formed with a convexly curved bottom surface as shown in Fig. 1. The bore of the tappet is shouldered to provide a seat for a retaining washer 64 through which the plunger passes and which engages the upper surface of the foot 26a to prevent axial displacement of the plunger with respect to the tappet. The retainer 64 is held in place by the pump plunger spring 66 which is compressed between this retainer and the collar 22. As will be evident from Fig. 1, spring 66 operates to cause the tappet and the pump plunger to follow the path of travel determined by the profile of cam 14.

Adjustment of the quantity of fuel discharged by the pump is effected by turning the pump plunger about its axis and in order to effect this control, a segment 68 is provided having teeth engaging the rack 70 slidably mounted for movement axially of itself in the pump casing. Rack 70 projects from the pump casing for connection to any suitable control for manual or automatic adjustment of the delivery capacity of the pump. Turning movement imparted to segment 68 by movement of rack 70 is transmitted to the pump plunger by means of a pin 72 fixed at one end in the plunger and at its other end sliding in a

vertical slot 74 in the segment 68. Pin 72 passes through an arcuate slot 76 in the wall of the tappet, which permits the pin to be turned by rack 70 while the tappet remains rotationally stationary.

Referring now more particularly to Figs. 6 and 7, in which the pump cylinder and plunger arrangement shown in Fig. 1 has been shown on enlarged scale and in developed form for clarity, the plunger 26 has been shown in its position of rotational adjustment for full load operation.

Recess 46, which may conveniently be considered as the delivery recess, also constitutes a port in the plunger, defined by edges 46a and 46b, which port is conveniently designated as a plunger delivery port to distinguish it from the delivery ports d_1 — d_4 , which are conveniently designated as cylinder delivery ports.

Recess 48, which may conveniently be considered as the overflow recess, has upper and lower limiting edges 48a and 48e and between and spaced from these edges there is provided a control portion 48' in the form of an island-like projection which extends partially around the circumference of the plunger and the surface of which is in contact with the wall of the cylinder bore. The control portion 48' provides two parallel transverse control edges 48b and 48d which operate, as will hereinafter more fully appear, to control the beginning and ending of full load delivery periods, and a third inclined edge 48c which in the embodiment illustrated merges at one end with edge 48b and operates to control the beginning of the delivery periods during part load operation. By reference to Fig. 7 it will be seen that the space between edge 48a on the one hand and edges 48b and 48c on the other hand provides a channel 48f in constant communication with the pump chamber, which channel constitutes a relief or overflow port in the plunger which is conveniently designated as a plunger overflow port to distinguish it from the cylinder overflow ports r_1 — r_4 . Likewise, a channel 48g, constituting a second plunger overflow port longitudinally spaced from the one formed by channel 48f and also in constant communication with the pump chamber, is formed by the space between edges 48d and 48e.

Referring now more particularly to Fig. 8, which shows the plunger in various positions on its delivery stroke and in which for the sake of convenience only two relief or overflow ports r_1 and r_2 , and two delivery ports d_1 and d_2 , have been shown, it is assumed that the pump chamber 28 is filled with liquid drawn thereinto from the suction conduit 30 by the preceding suction stroke of the plunger.

In position 8a, the plunger is assumed to be at the bottom of its stroke and about to ascend on its delivery stroke. In this position, the recess 46 is not in communication with any delivery port while the channel 48f, forming a part of the recess 48, is in communication with the relief port r_1 so that movement of the plunger on its delivery stroke is permitted by overflow of liquid from the pump chamber through the bores 50 and 54 in the plunger and through the overflow recess 48.

In position 8b, the plunger has moved upwardly until the upper control edge of the delivery recess 46 is just passing the lower edge of the delivery port d_1 , to place port d_1 in communication with the pump chamber by way of bores 50 and 52 in the plunger and the delivery recess. At the time the plunger reaches this po-

sition, channel 48f is still in communication with relief port r_1 so that when edge 46a passes the lower edge of port d_1 to establish delivery communication, delivery does not then take place because of the open overflow connection through the relief port.

When the plunger reaches the position 8c, the delivery port d_1 has been substantially opened and when the plunger reaches this position, delivery commences due to the channel 48f having passed out of communication with the relief port r_1 . This determines the instant of commencement of delivery and with the plunger in the full load position of rotation shown, which corresponds to the position shown in Fig. 7, it will be evident that commencement of injection is determined by the control edge 48b.

Continued movement of the plunger from the position shown at 8c to the position shown at 8d effects delivery through port d_1 which, it will be noted, is in communication with the delivery recess 46 during this period of movement of the plunger. When the plunger reaches the position 8d, the overflow channel 48g comes into communication with the relief port r_1 to terminate the delivery period and again by reference to Fig. 7 it will be evident that the end of the delivery period will be determined by the control edge 48d. Thus the delivery through the port d_1 , which may be termed delivery period No. 1, occurs during movement of the plunger from position 8c to position 8d. Also, it will be noted that the delivery recess 46 is in communication with the delivery port d_1 both immediately before and immediately after the delivery period. Stated in another way, the overflow periods immediately preceding and immediately following the delivery period overlap the terminal portions of the period when the plunger delivery port is in communication with the cylinder delivery port, the actual delivery period being shorter than the period of communication between these two delivery ports. Thus the pump chamber is temporarily placed in simultaneous communication with a delivery passage and an overflow passage just before actual delivery commences and just after it ceases.

In the position 8e, the edge 46b of the delivery recess passes the upper edge of delivery port d_1 , overflow continuing to take place during the movement from position 8d to position 8e by the continued communication between overflow channel 48g and relief port r_1 . Before channel 48g passes out of communication with port r_1 , channel 48f comes into communication with port r_2 , and during continued movement of the plunger through positions 8f and 8g, overflow continues through both ports r_1 and r_2 . When position 8h is reached, the delivery recess 46 is about to come into communication with the delivery port d_2 because of edge 46a passing the lower edge of this port, and relief channel 48g passes out of communication with relief port r_1 .

Between positions 8h and 8i, the delivery port d_2 is brought into communication with the delivery recess 46, but no injection takes place during this movement because of the continued communication of overflow channel 48f with relief port r_2 after the overflow channel 48g has passed out of communication with relief port r_1 . When position 8i is reached, delivery period No. 2 commences, since at this instant the overflow channel 48f passes out of communication with

relief port r_2 and channel 48g is already out of communication with relief port r_1 .

Delivery continues until relief channel 48g comes into communication with relief port r_2 as shown at position 8j, communication between channel 48g and port r_2 continuing until the delivery recess 46 passes out of communication with port d_2 (position 8k) and to the end of the movement of the pump plunger in the direction of its delivery stroke, as shown in position 8l.

It will be noted that in order to secure the desired continuity of overflow between delivery periods the overflow through the two channels 48f and 48g overlaps, resulting at certain periods in simultaneous overflow through both of these channels.

It will be evident from the above that with a larger number of delivery ports and overflow ports arranged in the manner shown in Figs. 6 and 7, the sequence of delivery periods and intervening overflow periods will take place as in the manner just described, the number of delivery periods corresponding to the number of longitudinally spaced delivery ports provided in the pump cylinder.

In the embodiment just described the delivery ports are located in a zone in the pump barrel nearer to the pump chamber end of the barrel than is the zone in which are located the relief ports. It is, however, immaterial which group of ports is nearer the pump chamber end of the barrel and the reverse of the arrangement shown in Figs. 1 to 8 has been indicated in Fig. 9, in which the relief ports r_1 and r_2 are located in a zone nearer to the pump chamber while the delivery ports d_1 and d_2 are located in a zone further from the pump chamber. Obviously, if the positions of the groups of cylinder ports are reversed, the positions of the delivery and overflow recesses in the pump plunger must also be reversed as indicated in Fig. 9. For purposes of illustration the pump plunger in Fig. 9 has been shown in two positions, b and c, corresponding to the positions b and c of Fig. 8 and illustrating the approach to and commencement of the first delivery period.

It will be apparent that any cylinder delivery port may be at any place on a given circumference lying in a plane normal to the axis of the cylinder bore without affecting the timing of delivery through the port. In some instances it may be desirable to provide for simultaneous delivery to two or more outlets, and as will be appreciated from Fig. 10, this may readily be accomplished by placing one or more additional delivery ports, such as d' and d'' , in the same location longitudinally of the cylinder bore as delivery ports d_1 and d_2 , respectively, so that simultaneous delivery may be made through a plurality of delivery ports during each delivery period rather than through a single port.

Referring again to Fig. 7, and having in mind the sequence of operations during the delivery stroke explained in connection with Fig. 8, it will be evident that for any delivery period, as for example the delivery period through port d_1 , the commencement of the delivery period is determined by the control edge 48b closing relief port r_1 and the end of the delivery period is determined by the control edge 48d opening this relief port. With the plunger in the position of rotation shown in Fig. 7, the distance between these control edges is maximum and consequently with the plunger in this position, these edges determine

the maximum period of delivery. Further, as long as the plunger is in any position of rotation where these parallel edges are controlling, the length of the delivery period will be constant and the relation of the beginning and end of the delivery period will not vary with respect to the positions of rotation of the cam shaft of the pump. If, however, the plunger is rotated to bring the control edge 48c to a position where it passes port r_1 , as shown in Fig. 11, it will be evident that the delivery period will be shortened because of edge 48c closing port r_1 only after the plunger has travelled farther on its delivery stroke than the position corresponding to the closing position determined by edge 48b, while the position of the plunger at which the relief port is opened by edge 48d remains unaltered. Stated in terms of fuel injection to an engine, this arrangement operates upon adjustment for part load to commence injection at a later time in the cycle of operation of the pump, and consequently at a later time in the cycle of engine operation, while maintaining the end of the injection period constant with respect to the cycle of pump operation.

For some types of engines it may be desirable to maintain the commencement of injection constant with respect to the engine cycle insofar as adjustment of the pump for variations in load is concerned. In order to accomplish this, the arrangement of the control edges may be as shown in Fig. 12, in which the edge 48c for part load control is inclined oppositely as compared with Fig. 11. With this arrangement, the control edge 48b closes port r_1 with the pump cam in the same position of rotation regardless of load adjustment, however, as shown in Fig. 12, the inclined edge portion opens the relief port earlier in the delivery stroke than would be the case for full load adjustment, in which latter case edge 48d would control the opening of the overflow.

In Fig. 13, still another arrangement of part load control edge is illustrated, which operates to retard the time of closing of the relief port with respect to the pump cycle when part load adjustment is effected, and to advance the time of opening of the relief port with respect to the pump cycle when in this position of adjustment. The arrangement in Fig. 13 in effect combines the arrangement shown in Figs. 11 and 12. From the foregoing it will be evident that in a pump embodying the present invention, substantially any timing variation of part load injection with respect to the operation of the engine to which fuel is being supplied by the pump may be effected by suitable contouring of the part load control edge.

When the pump is to be used to supply fuel for injection to an engine, the delivery stroke of the plunger is advantageously made in a series of steps, each step including a period of acceleration, a period of constant velocity, and a period of deceleration, and the several steps, one for each injection, being separated by intervening periods or dwells when the pump plunger is motionless or substantially motionless.

A curve illustrative of this type of plunger action is shown in Fig. 14, and in Fig. 15 there is illustrated a cam for effecting this type of motion.

Referring to Fig. 14, the ordinates of the diagram represent pump stroke while the abscissae represent cam rotation in degrees. As indicated on the figure, the scale of ordinates to abscissae is approximately three to one and the curve is

for a cam of the kind suitable for a pump having four delivery periods per delivery stroke of the plunger. On the curve illustrated, the four delivery periods occur along the portions A, B, C, and D of the curve while the suction stroke is represented by the dotted line portion E of the curve. The delivery periods are effected respectively by the rising portions A, B, C, and D of the cam, these portions being separated by portions I, II and III of constant radius which provide for the intervals of no plunger movement between the several injection periods. While portions I, II, and III are most advantageously of constant radius, they are not necessarily so. The portion E of the cam profile provides for the suction stroke.

It will be evident that the profile of the cam may be varied to give a curve different in form from that just described, but the curve illustrated has been found to be advantageous for securing good injection characteristics.

As will be observed from Figs. 14 and 15 the portion E of the profile of a cam suitable for effecting a series of delivery periods for each delivery stroke, must be relatively steep, and this results in a high speed suction stroke as well as a suction stroke of greater length than would be required for a plunger effecting but one delivery period. For this reason the arrangement of the pump suction passage of the pump in line with the cylinder bore, to provide for flow of liquid into the pump chamber without abrupt change in direction, is highly advantageous.

It has been found desirable, in order to insure good delivery characteristics, to provide a certain counter pressure or resistance to the overflow from the several relief ports. This may be accomplished in different ways as is illustrated in Figs. 1, 16, and 17. As shown in Fig. 1, a spring loaded valve 78 opening in the direction of overflow is provided to maintain a predetermined pressure load on the liquid overflowing through the passage 34.

In the arrangement shown in Fig. 16, the overflow passage 34 has inserted therein a choke plug 80, the diameter of the orifice of which will of course determine the extent of the counter pressure developed by overflow. In Fig. 17 the overflow passage is restricted by means of an adjustable plug 82, by means of which the value of the resistance to overflow may be varied as desired.

In the arrangements shown in Figs. 16 and 17, the overflow is returned directly to the suction line 30 and when such direct return of the overflow to the suction line is effected, the return line is advantageously provided as shown in these figures with an air or vapor collecting pocket 84 located at a high point in the return line and closed by a removable member such as plug 86 which may from time to time be adjusted or removed to vent any air or incondensable gas that may have collected in the chamber. Obviously, the spring loaded ball valve construction shown in Fig. 1 may be embodied in a direct overflow return passage of the kind shown in Figs. 16 and 17 or the forms of choke shown in the latter figures may be incorporated in an independent overflow line of the kind illustrated in Fig. 1. Also, it will be evident that any individual relief passage may be restricted to provide the desired counterpressure acting on the overflow.

Referring now to Figs. 18 to 21, another form of pump embodying the invention is shown, which differs from the construction shown in Fig. 1 only

with respect to that portion of the pump illustrated in Fig. 18. This embodiment differs principally from that shown in Fig. 1 by the fact that the delivery and relief ports are not disposed in groups located in two longitudinally separate zones in the pump barrel, but are located in the same zone, and different portions of one plunger recess provide both the plunger delivery port and the plunger overflow ports, avoiding the necessity for two longitudinally separated recesses as in the plunger shown in Fig. 1. One principal advantage of the pump shown in Fig. 18 is that the length of the pump barrel and plunger can be made substantially shorter than in the form shown in Fig. 1.

In the present arrangement, passages 34a, 34b, 34c, and 34d, which terminate at their inner ends respectively in the relief ports r_1 to r_4 , are bored directly through from the opposite side of the pump barrel 20a and communicate with an annular relief passage 34e which in turn communicates with the passage 34. The annular passage 34e is provided between the exterior of the pump barrel and the wall of a recess 88 formed in the head portion 16a of the pump casing, the pump barrel being held in position axially by means of a nipple 22a threaded into the recess in the head, and suitably packed against leakage of overflow liquid by packing 80. The barrel is centered by one or more flanges such as the one indicated at 20b and is restrained against turning movement by means of locating pins the recesses for which are shown at 24a in Fig. 20.

In this embodiment the several cylinder delivery ports are at the same height in the pump barrel as the corresponding cylinder relief ports and as will be observed from Fig. 18, the bores 34b and 34c for relief ports r_2 and r_3 are carried through to the opposite side of the bore to provide the corresponding delivery ports d_2 and d_3 which in turn communicate with the delivery passages 38 and 40. Ports d_2 and d_3 thus lie in the same axial plane as the relief ports. Ports d_1 and d_4 , as will be seen more clearly from Fig. 19, lie in a plane at right angles to the plane of ports d_2 and d_3 . Ports d_1 and d_4 and the transverse passages connecting them with their respective outlet passages 36 and 42 are advantageously formed by continuations of auxiliary bores 92 and 94 which provide openings through the barrel directly opposite and in line with these ports. The auxiliary bores 92 and 94 may be closed by plugs in the same manner that the auxiliary bores, the continuations of which form portions of the overflow and delivery passages of Fig. 1, are closed by plugs 96, but as will hereinafter appear, the bores 92 and 94 may be left open without detriment to operation of the pump.

As will be more clearly apparent from Figs. 20 and 21, the delivery passages 36 and 42 lie close together on the same radial line where they emerge from the top of the barrel and passages 38 and 40 lie close together on a second radial line at right angles to the first line, where they emerge from the top of the barrel.

In order to symmetrically locate the pump outlets and to provide room for the several discharge valves, the head portion of the pump casing is advantageously arranged in the same manner as shown in Fig. 3 and the portions of the outlet passages in the head are brought into communication with the portions in the barrel by means of two channels 40b and 42b which respectively provide communication between the portions of channels 40 and 42 in the head and in the barrel

which would otherwise be displaced from each other by 90°.

Turning now to Fig. 22, the operation of the pump on its discharge stroke is illustrated in much the same manner as the operation of the pump of Fig. 1 is illustrated in Fig. 8.

As in Fig. 8 the diagram, for simplicity, shows only two rather than four cylinder delivery ports, and corresponding relief ports. The recess in the pump plunger in the present embodiment is shaped to provide control edges similar in nature and function to the control edges shown in Fig. 7 and need not again be described in detail. In this instance, however, the portion of the recess in line with the cylinder delivery ports d_1 — d_4 provides the plunger delivery port.

In position 22a the recess 48 is in communication with the delivery port d_1 and is also in communication with the relief port r_1 by way of the passage 48f. Upward movement of the plunger does not result in commencement of delivery until position 22b is reached, in which position passage 48f passes out of communication with port r_1 . Delivery continues after position 22b is passed until position 22c is reached, when delivery is terminated by passage 48g coming into registration with port r_1 . As the plunger advances from position 22c through positions 22d, 22e, and 22f, passage 48g passes port r_1 , through which overflow occurs and during this period passage 48f comes into communication with relief port r_2 . By the time position 22g is reached, the recess 48 has passed out of communication with delivery port d_1 and is in communication with delivery port d_2 , but delivery through the latter port does not commence until the plunger has reached the position 22h in which position the channel 48f passes out of communication with relief port r_2 . Passage 48g has passed out of communication with relief port r_1 prior to this time, when the plunger is in position 22g. The second delivery period occurs during movement of the plunger from position 22h to position 22i. When the latter position is reached, channel 48g comes into communication with port r_2 to terminate injection. During the remainder of the plunger stroke, to position 22j, the overflow necessary to permit this continued movement is effected by the continued registration of passage 48g with port r_2 . As in the form described in connection with Fig. 8, it will be apparent that the action just described may be continued for additional cylinder ports placed above those shown in Fig. 22.

In the diagram just described, the plunger is adjusted rotationally for full load operation. For effecting part load operation, the plunger is turned in the same manner as has previously been described in connection with the pump shown in Fig. 1 and the desired timing of part load delivery may be effected in the present embodiment, as in the previously described embodiment, by suitably shaping the part load control edge 48c in any desired way.

It will be remembered that in connection with the construction illustrated in Fig. 19, it was pointed out that the auxiliary bores 92 and 94 for forming the delivery ports d_1 and d_4 might be left open without detriment to operation of the pump. This will be more clearly apparent from a consideration of Fig. 23 showing the ported portion of the pump barrel developed together with the control recess and edge portion of the pump plunger.

As will be seen from this figure, which has

been shown with the plunger adjusted for part load operation after having covered port r_1 and the port formed by the bore 92, the control edge 48b covered bore 92 before edge 48c covered relief port r_1 to start delivery through port d_1 . From the figure it will further be apparent that bore 92, which would if open act as a relief channel, will not be opened on further movement of the pump plunger before the relief port r_1 is opened, since edge 48d will pass both of these ports at the same time. If the plunger is turned to full load position, that is, moved to the left in Fig. 23 so that the edge 48b is in line with the line of relief ports, it will be evident that this edge will close port 92 as soon or sooner than the relief port r_1 . Stated in another way, the bore 92 will, in all positions of adjustment of the pump plunger, be covered for a period as long or longer than the period when relief port r_1 is covered, so that bore 92 can never have any effect on or in any way interfere with the timing of the delivery period through port d_1 , regardless of the position of adjustment of the plunger with respect to load. Likewise, port 94 can in no way affect the delivery period through port d_4 , which is controlled by the covering and uncovering of the relief port r_4 .

With the passages in the pump barrel disposed as above described, it will be apparent that all of the transverse passages for both delivery and overflow may very easily and readily be made by drilling operations which result in the formation of no bores which must subsequently be plugged in order to provide an operative barrel structure. This results in cheap production of cylinder barrels by a minimum of simple drilling operations and aids in one of the objects of the invention which is to produce a satisfactory pump for the purpose intended which may be manufactured at substantially lower costs than pumps heretofore available.

In Fig. 24 there is shown another form of tappet construction which for purposes of illustration has been applied to a pump of the general type shown in Fig. 18 in which the relief and delivery ports are located in the same zone along the length of the barrel. It is of course equally applicable to the type of pump shown in Fig. 1. In this embodiment, the barrel 20b is clamped to the head portion 16b of the pump casing by means of a threaded collar 22b. In the present arrangement, the means for turning the plunger are located above rather than around the tappet structure as in the form shown in Fig. 1 and this means comprises a ring member 68a seated in a suitable bore in the casing portion 10b and having teeth meshing with the load control rack 70a. The ring 68a is held against longitudinal displacement by a bearing ring 97 which is in turn maintained in position by a snap ring 98 seating in a suitable circular recess in the casing. The tappet 56a is extended at its upper end to form only a shallow cup-like recess for the reception of the plunger head 26a which is held in position by the retaining washer 64a. The tappet is restrained against turning by any suitable means such for example as a locating pin working in a vertical slot in the tappet, or by a lower skirt embracing the sides of the cam, and turning movement is imparted to the plunger by means of the pin 72a fixed at one end in the foot of the plunger and at its other end sliding in slot 74a in ring 68a. Pin 72a passes through an arcuate slot 76a in the tappet in the same

manner as in the construction shown in Figs. 1 and 2.

The tappet and plunger are in this instance loaded by means of two heavy helical springs 66 and 66a concentrically arranged between the retaining washer and shouldered portions of the barrel structure. The use of the additional and comparatively large diametered spring 66a is made possible in the present instance because of the fact that the turning means for the plunger is located above rather than around the tappet so that the springs do not have to extend downwardly into the tappet and consequently have available a space of larger diameter than would be the case with the construction shown in Fig. 1 and with a tappet of equal cross-sectional dimensions. Thus, in the form shown in the present figure, a more powerful spring loading can be obtained without having to enlarge this portion of the pump structure.

From the foregoing description it will be evident that in accordance with the present invention a single barreled pump structure can be provided which is relatively cheap to manufacture as compared with multiple plunger pumps and which will at the same time be capable of supplying fuel accurately and in an accurately adjusted quantity to a plurality of separate outlets. Because of the fact that control of the timing of the beginning and ending of each delivery period is effected by a single plunger cooperating with definitely positioned ports, the possibility of variation between the quantities delivered to any two different outlets is substantially eliminated, regardless of the position of adjustment of the plunger with respect to load and also regardless of wear on the pump. If the pump cylinder and barrel wears, the tendency of such wear is to affect all deliveries to the same extent, which is not true of multiple cylinder pumps where wear of unequal magnitude frequently occurs as between different pump plungers and cylinders. Furthermore, since one pump plunger and cylinder assembly serve to effect a multiplicity of deliveries, the manufacture of each pump and cylinder assembly is facilitated because of the fact that the exactness of the matching of the dimensions of cylinder bore and plunger diameter, required for the different pump units of a multiple pump, is not required.

In Figures 25 to 36, inclusive, further different forms of plunger and barrel construction are illustrated, which provide for regulation of the delivery of the fuel from the pump chamber to the delivery conduits in various different manners from that which has been described. In order to illustrate these different forms of pump plunger and barrel arrangements, diagrams similar to those of Figs. 8 to 10, 22 and 23 have been employed, since the remainder of the pump construction may be the same as shown in Figs. 1, 18 or 24. For the sake of simplicity, only so much will be described in detail with reference to the additional figures as differs from the structures heretofore described.

The arrangement shown in Fig. 25 differs from the previously described embodiments in the location and arrangement of the relief or overflow ports in the barrel, with respect to the plunger overflow ports. Referring now to the figure it will be observed that the plunger 26 is of the form illustrated in Fig. 8 in which a separate plunger delivery recess 46 and a plunger overflow recess 48 are provided. In the present instance two delivery ports d_1 , d_2 are shown, and three

overflow ports r_1 , r_2 , and r_3 are provided. The plunger has been shown in two positions c and d corresponding to positions c and d of Fig. 8 and illustrating respectively the commencement and termination of a delivery period.

As will be observed from position 25c, the delivery period through port d_1 is about to commence, since the upper control edge 48b of the control projection 48' is just passing out of communication with the overflow port r_1 to terminate overflow by way of the plunger overflow port 48f. In this position the delivery recess 46 has already moved into communication with port d_1 . As the plunger moves from the position c to the position d , delivery is effected in the manner previously described in connection with Fig. 8 but the delivery period through port d_1 is, in the present instance, terminated when the plunger reaches position d by the control edge 48a of the recess 48 passing the lower edge of the relief port r_2 so that overflow takes place due to communication between the plunger overflow port 48f and the overflow port r_2 . This takes place before the plunger overflow port 48g comes into communication with port r_1 .

It will be evident that by similar action, delivery through port d_2 will be commenced by plunger port 48f passing beyond overflow port r_2 and will be terminated by port 48f coming into communication with port r_3 .

As will be seen from the above, this arrangement differs from the arrangement illustrated in Fig. 8 by the fact that commencement and termination of a delivery period is in the present case determined by the action of a single plunger overflow port in conjunction with two cylinder overflow ports, whereas in the arrangement shown in Fig. 8 commencement and termination of a delivery period are determined by the action of two different plunger overflow ports acting in conjunction with the same cylinder overflow port. In some cases the present arrangement has proved useful rather than the arrangement illustrated in Fig. 8.

In the arrangement shown in Fig. 26, the location of cylinder delivery ports and cylinder overflow ports with reference to each other and to the plunger ports is such as to provide a certain degree of precompression of the fuel in the pump chamber before delivery is commenced so that for each delivery period, high pressure delivery from the very instant of commencement of the delivery period may be insured.

Referring now to Fig. 26, the plunger is of the general form shown in Fig. 8 but with the inclination of the part load overflow control edge 48c the same as in Fig. 12. The arrangement further is similar to that shown in Fig. 8 in that the commencement and ending of the delivery periods is effected by plunger ports 48f and 48g cooperating with the same overflow port rather than by the arrangement shown in Fig. 25. In Fig. 26 positions c and d have also been shown corresponding, in so far as termination and ending of overflow are concerned, to positions c and d of Fig. 8. As will be observed from position 25c, the plunger overflow port 48f has just passed out of communication with the relief port r_1 so that the liquid is at this point trapped in the pump chamber 28. In the present arrangement it will be noted, however, that the plunger delivery port 46 is not yet in communication with the delivery port d_1 and consequently compression of the trapped liquid is effected by movement of the plunger from position c to position

c' . In the latter position the upper edge 46a of the plunger delivery port passes the lower edge of port d_1 to commence the delivery period, and delivery continues through port d_1 until overflow is again established by registry of plunger port 48g with overflow port r_1 .

In similar manner, precompression for the delivery period through port d_2 is effected by port 48f passing out of communication with port r_2 before the plunger delivery port 46 comes into communication with port d_2 .

In the embodiment illustrated in Fig. 26, the amount of precompression is constant regardless of the rotational position of the plunger for load adjustment. Variation of the degree of precompression with variations in load adjustment may, however, be readily accomplished as illustrated in Figs. 27 and 28.

In the form shown in Fig. 27 the upper and lower control edges 46a and 46b respectively of the plunger delivery recess 46 are in planes normal to the axis of reciprocation of the plunger 26, as in the forms previously described, and consequently communication between the plunger overflow port and any given delivery port will be established and cut off in the same stroke positions of the plunger regardless of its position of rotation.

Unlike the previous embodiments, however, the present form provides inclined edges 48a, 48b, 48d, and 48e so that the channels providing the plunger overflow ports 48f and 48g are inclined. With these ports thus inclined it will be evident that any given overflow period will be commenced and terminated in different stroke positions of the plunger for different positions of rotational adjustment thereof. In the figure, the plunger is illustrated with the overflow port 48f just passing out of communication with the overflow port r_2 to start precompression prior to registration of port 46 with port d_2 . It will be seen from the figure that if the plunger is turned to reduce the quantity delivered, that is, so that the control edge 48c moves to the left from the position shown in the figure, the plunger port 48f will pass out of communication with the overflow port r_2 in a lower stroke position of the plunger than the position shown in the drawing. This evidently will result in a higher degree of precompression of the fuel before delivery through the port d_2 can take place since the pump plunger must travel a greater distance during the interim between the cut-off of overflow and the registration of the delivery ports.

Thus it will be seen that with this arrangement, the degree of precompression increases with adjustment for decrease in load and decreases with adjustment for increase in load.

Variation in the degree of precompression for different load values may also be accomplished as shown in Fig. 28 in which figure the overflow control edges 48a, 48b, 48d, and 48e are in planes normal to the axis of reciprocation of the plunger so that the times of beginning and ending of the overflow periods remain constant with respect to the stroke position of the plunger regardless of the rotational position of adjustment of the latter. In the present instance control edges 46a and 46b of the delivery port 46 are inclined, and in order to illustrate the different ways in which the relation between degree of precompression with respect to load may be varied, the edges of the delivery port have in this form been illustrated as inclined in such manner as to produce increase in the value of

precompression upon adjustment to increase the load, which is the reverse of the variation obtained with the form shown in Fig. 27. In Fig. 28 the plunger is again shown with the overflow through port r_2 just being terminated to start the precompression period, the position of adjustment of the plunger being for full load. If now the plunger is turned to bring the control edge $48c$ into play, it will be evident that a higher portion of the control edge $46a$ will be in axial alignment with the delivery port d_2 and consequently less plunger movement will be required after overflow ceases in order to bring the delivery port 46 into communication with the cylinder port d_2 . This obviously will result in less precompression.

It will be evident from the embodiment shown in Figs. 27 and 28 that increase in the degree of precompression with either increase in load or decrease in load may be obtained as desired by proper sloping, in either case, of the control edges of either the plunger delivery port or the plunger overflow ports, or both. In the forms illustrated in Figs. 27 and 28, the shape of the control projection $48'$ is such as to provide for constant commencement and variable termination of injection with respect to the pump cycle in the manner previously described in connection with Fig. 12, but this obviously may be varied.

The character of overflow control effected by means of the island-like control projection $48'$, described in the previously discussed embodiments, can also as readily be obtained by means of a recess in the pump plunger as illustrated by the embodiment shown in Fig. 29. In this embodiment the plunger is provided with an overflow recess $48''$ and an inclined control edge $48c''$ and a lower control edge $48e''$. These edges between them provide an overflow channel $48g''$. The positions of the plunger shown at c and d correspond respectively to positions c and d of Fig. 25 and illustrate the commencement and termination of an injection period. In position c the plunger overflow port is just passing out of communication with overflow port r_1 to start the delivery period through port d_1 . This delivery period is terminated when position d is reached, in which position port $48g''$ comes into communication with the overflow port r_2 .

In the embodiments illustrated in Figs. 30 to 34, the various features illustrated in Figs. 25 to 29 are shown applied to pumps having plungers of the type shown in Fig. 18, which have but one recess, the general action of which pumps has been described in detail in connection with Figures 18 and 22.

Fig. 29 illustrates the action with this type of plunger when a single plunger overflow port, acting in conjunction with two cylinder overflow ports, determines the commencement and ending of a delivery period. Position b of Fig. 30 shows the plunger in the position where delivery through port d_1 is commencing due to port $48f$ passing out of communication with port r_1 , and position c illustrates the termination of this delivery period which is caused by port $48f$ coming into communication with port r_2 .

Fig. 31 illustrates a variation in which a single plunger overflow port $48f$ is provided rather than two spaced ports $48f$ and $48g$ as in the previously described embodiment. In position b the port $48f$ has just passed out of communication with overflow port r_1 to commence delivery through port d_1 , this delivery period being terminated by port $48f$ registering with port r_2 ,

as shown in position c . By the time port $48f$ has closed port r_2 by passing out of communication with this port as illustrated by position d , the plunger port is in communication with the delivery port d_2 and the second delivery period commences, continuing until the position e is reached when port $48f$ comes into communication with overflow port r_2 . It will be evident that turning the plunger to bring the inclined control edge $48c$ into action will vary the duration of the delivery periods in the same general manner previously described.

Fig. 32 shows a construction producing action corresponding to that produced by the form shown in Fig. 29. In Fig. 32, position b again shows delivery commencing through port d_1 due to port $48f$ passing out of communication with port r_1 , and position c shows the ending of the delivery period, caused by port $48f$ coming into communication with port r_2 . The action taking place in Fig. 32 as compared with that taking place in Fig. 31 is different in that in Fig. 32 termination of the delivery period is varied with respect to the pump cycle with different load adjustments of the plunger whereas in Fig. 31 the commencement of the delivery period is varied with respect to the pump cycle as the position of the pump plunger is adjusted for different loads.

In the embodiment illustrated in Figs. 33 and 34, an arrangement is shown for producing precompression with a plunger having a single recess and functioning similarly to the arrangement illustrated in Fig. 26. Fig. 33 shows the plunger and barrel in diagrammatic section while Fig. 34 shows the surfaces developed into a plane view. In this arrangement the bottom edge $48e$ of the plunger recess 48 is in a plane normal to the axis of reciprocation of the plunger while the upper edge $48a$ is provided with an offset portion $48a'$ into which the control projection $48'$ extends, so that the plunger overflow port $48f$ is at a different level from that of the delivery port provided by the main portion of the recess 48 . As will be evident from Fig. 33, the control port $48f$ passes out of communication with the overflow port r_1 before the edge $48a$ reaches the delivery port d_1 , thus providing for a period of precompression before the latter port is uncovered. Evidently the same action will take place on the next delivery period when the control projection $48'$ will cover the port r_2 before the edge $48a$ uncovers the delivery port d_2 .

Variation of precompression for different load adjustments of the pump may also readily be accomplished with this general arrangement as illustrated by the embodiment shown in Figs. 35 and 36. This arrangement is the same as described in connection with Figs. 33 and 34 except that the edges $48a'$ and $48b'$ are inclined to provide between them an inclined overflow port passage $48f'$. As will be clearly evident from Fig. 6, rotational movement of the plunger will operate to vary the amount of plunger travel required between the position when an overflow port is covered by the projection $48'$ and the position when the next cylinder delivery port is opened.

While in Figs. 35 and 36 the slope of the port $48f'$ has been shown such that a greater degree of precompression is effected as adjustment is made for lower load, it will be obvious that the inclination of this port may be made in the opposite direction to produce the opposite relationship between the degree of precompression and value of load adjustment.

In all of the embodiments hereinbefore described, the several overflow ports have all been illustrated as being in the same axially extending plane, and cooperating with a plunger which in any given position of load adjustment travels axially without any turning movement. This arrangement is to be preferred but it will be apparent that the line of overflow ports might be arranged otherwise, for example, spirally and in cooperation with a plunger to which a corresponding spiral motion is imparted by means of an inclined guide slot in the plunger adjusting ring.

Also, while the preferred form of ports has been described and illustrated, in which the cylinder delivery ports are circular and the plunger delivery ports are elongated, it will be evident that the same function is readily obtainable by utilizing circular plunger delivery ports and elongated cylinder delivery ports.

In all of the previously described embodiments, the cylinder delivery ports are longitudinally spaced, but a longitudinal spacing of the delivery ports is not required in order to provide an operative pump embodying the principles of the invention.

The cylinder delivery ports may be circumferentially spaced at the same level but when this is done modification of the form of the plunger is required in order to secure the proper cooperative action between the ports.

In order to illustrate how the cylinder delivery ports may be placed at the same level, Figs. 37 and 38 show in section and developed view, respectively, an arrangement of this kind. Referring now to these figures, which for the sake of simplicity show only two delivery outlets, the cylinder delivery ports d_1 and d_2 are circumferentially spaced but at the same level in the pump barrel. The cylinder overflow ports r_1 and r_2 are longitudinally spaced as in the previously described embodiments, and in the present instance the plunger is provided with a recess 48 in which is located the projection 48' providing an inclined control edge 48c and plunger overflow ports 48f and 48g. The construction of this part of the pump plunger is similar to that shown and described in Fig. 22. In the present instance, however, the recess 48 does not extend circumferentially around the plunger but is instead provided with two circumferentially offset and longitudinally spaced delivery port recesses 46c and 46d. Port 46c is located to be in alignment with the cylinder delivery port d_1 and port 46d is located to be in alignment with delivery port d_2 . The recess 48 is in communication with the pump chamber 28 through the slot 50a and the plunger delivery port 46c is placed in communication with the pump chamber by way of the transverse bore 52a which communicates with the recess. Port 46d is placed in communication with the pump chamber by the transverse bore 52b which also communicates with the recess 48.

In the position of the parts shown in Fig. 37 the overflow ports r_1 and 48f are in communication and by the time these ports have passed out of communication, the delivery port 48h will have been brought into communication with the delivery port d_1 . As the plunger moves upwardly, delivery will take place through port d_1 until registration between overflow ports 48g and r_1 takes place. During this delivery period no delivery will be effected through the delivery port d_2 since port 46c is circumferentially offset from port d_2 . By the time the plunger overflow

port 48f has passed out of registration with port r_2 to commence a second delivery period, port 46c will have passed out of communication with port d_1 and port 46d will be in registration with port d_2 . The second delivery period is thus effected through the latter port. It will be apparent that more than two cylinder delivery ports may be placed in circumferentially spaced relation at the same level and the action just described be secured for more delivery periods by providing the requisite number of separate longitudinally spaced and circumferentially offset delivery ports in the plunger.

Regulation of the quantities supplied to the various delivery ports is effected in the same manner as in the previously described embodiments, by turning the plunger so that the control edge cuts off the overflow at different points in the plunger stroke. From Fig. 38 it will be evident that the plunger delivery ports 46c and 46d must have sufficient width in peripheral direction to register with their respectively cooperating cylinder delivery ports in any position of rotation of the plunger within the range of turning movement required of it to effect the desired regulation.

As will be apparent from Figs. 37 and 38, the construction just described requires a more intricate form of plunger than the previously described embodiments, but in some instances this form of construction may be preferable to one in which the delivery ports are longitudinally spaced.

Referring now to the pump shown in Fig. 39 and related figures, the type of pump illustrated differs from the various forms hereinbefore described principally in the construction of the plunger and the porting arrangements provided by the plunger and barrel for effecting the desired character of operation. This difference consists principally in the fact that instead of having a plurality of cylinder overflow ports in the barrel, a single cylinder overflow port is employed with which a plurality of plunger overflow ports having control edges come into communication in sequence during the discharge stroke of the plunger to provide for overflow periods, the timing and duration of which determine the timing and duration of the delivery periods.

Since the general organization of pump construction, aside from the form of the plunger and the porting arrangements, may be the same as in the embodiments previously described, the description of this form of the pump will be confined to the portions thereof embodying the parts different from those previously described, it being understood that in so far as the present construction is concerned any of the various features of cam and tappet construction, plunger control, overflow resistance, and special modes of boring the barrel to provide the desired porting thereof, which have previously been described, may be incorporated.

As shown in Fig. 39, the pump barrel 120 is secured to the pump head 116 by means of the cap nut 122 and is provided with delivery ports d_1 , d_2 , d_3 , and d_4 connecting respectively to the discharge passages 136, 138, 140, and 142.

The delivery ports are longitudinally spaced in the barrel and circumferentially offset from each other. The barrel is further provided with an overflow or relief passage 134, which passage terminates in a single relief port r .

The plunger in this instance is provided with a circumferentially extending recess 146 which

is placed in constant communication with the pump chamber 128 by means of the longitudinal bore 150 in the plunger which connects with the recess through one or more transverse bores 152.

5 The recess 46 provides the necessary plunger delivery port means for placing the cylinder delivery ports in communication with the pump chamber. The plunger is further provided with an overflow recess designated generally at 148, 10 which recess is placed in constant communication with the pump chamber in the present embodiment by means of a passage 150a.

The recess 148 is limited by top and bottom control edges 148a and 148j, respectively, and between these edges there are provided the control edges 148b, 148c, 148d, 148e, 148f, 148g, 148h, 15 and 148i, alternating ones of which are inclined and at right angles to the axis of reciprocation. These alternating inclined and transverse control 20 edges provide a series of four control projections 148i, 148j, 148k, and 148l located to pass successively the overflow port r as the plunger advances on its discharge stroke. By virtue of these projections, the recess 148 provides a series of 25 plunger overflow ports 148k, 148m, 148n, 148p, and 148q.

In the position of the parts shown in Figs. 43 and 44, the plunger overflow port 148k is in registration with the cylinder overflow port r and as 30 the plunger advances on its discharge stroke, with overflow taking place through these ports, the plunger delivery recess 146 comes into communication with the cylinder port d₁. Delivery through port d₁ commences as soon as the control 35 edge 148b passes port r and continues until the overflow port is opened by registry with the plunger overflow port 148m. The second delivery period commences when the overflow port r is closed by the control edge 148d and by the time 40 the plunger has reached the height necessary for this to occur, the plunger delivery port 146 has passed out of communication with cylinder port d₁ and into communication with cylinder port d₂. The second delivery consequently takes 45 place through port d₂ and continues until port r is opened by the plunger port 148n coming into communication with port r. Similarly, the third and fourth delivery periods are effected through ports d₃ and d₄ respectively.

50 It will be apparent that the duration of the delivery periods will be controlled by the position of rotation of the plunger in the barrel. In the embodiment illustrated, adjustment of the plunger operates to vary the timing of commencement 55 of the delivery periods with respect to the cycle of operation of the pump while the timing of the ending of the delivery periods remains constant for all positions of rotational adjustment of the plunger.

60 Referring now more particularly to Fig. 45, another embodiment of the same general type of plunger and barrel is shown, only two delivery passages being illustrated for the sake of simplicity. In the present arrangement the recess 65 148 is placed in communication with the pump chamber 128 by means of a groove 150a and the plunger recess provides not only the plunger overflow ports 148k and 148m, but also the plunger delivery port 146.

70 It is believed that in view of the preceding description, the action of this form of plunger will be clear from the several diagrams of Fig. 45. In the position shown in Fig. 45a, overflow is occurring through port r, the first delivery 75 period occurs between positions 45b and 45c and

overflow through ports r and 48m takes place until position 45f is reached, when the second delivery period commences. Before this latter period commences, the delivery port 146 has 5 passed out of communication with port d₁ so that the second delivery takes place through port d₂ and continues until the final overflow occurs by communication between port 148q and port r, as shown at 45g.

As in the embodiment shown in Figs. 43 and 44, 10 rotational adjustment of the plunger varies the timing of the commencement of the delivery periods, but variation of the timing of the ends of the delivery periods rather than the commencement thereof may readily be provided if 15 desired. An arrangement for effecting this is shown in Fig. 46 in developed view wherein the plunger recess is shaped in the same general manner as in the form shown in Fig. 45, but in which the inclined control edges 148b, 148d, 148f, and 20 148h are on the lower rather than the upper sides of the respective control projections. From the figure it will be apparent that as the plunger is moved to different rotational positions, the inclined control edges will come into registry with 25 the overflow port r in different positions of reciprocation of the plunger to terminate deliveries at different times in the cycle of operation of the pump.

Referring now to Figs. 47 and 48, still another 30 arrangement employing a single cylinder overflow port r and multiple plunger overflow ports is illustrated, this arrangement differing from that shown in Fig. 45, for example, by the fact that the cylinder delivery ports d₁ and d₂ are circumferentially spaced at the same level in the pump barrel. In this embodiment separate 35 plunger delivery ports 146c and 146d are provided, which ports are circumferentially offset and longitudinally spaced on the surface of the plunger. These ports are connected by transverse passages 152a and 152b, respectively, to the 40 overflow recess 148 which is in communication with the pump chamber 128 by way of the groove 150a.

As will be observed from Fig. 49, which shows 45 the plunger of this embodiment in different positions on its discharge stroke, port 146c comes into communication with port d₁ at the time the first delivery period is commenced by the passage of 50 port 148k out of communication with the overflow port r. At this time the delivery port 146d is out of communication with the delivery port d₂ as will be apparent from Fig. 49b. Delivery 55 takes place through port d₁ until port 148m comes into communication with port r to effect overflow, as shown at 49c. The second delivery commences at the position shown in 49d when port 148m passes out of communication with port r and in 60 this position of the plunger the delivery port 146c has already passed out of communication with port d₁ and port 146d has been brought into communication with port d₂. Delivery through 65 this latter port continues until the position 49e is reached, when final overflow takes place.

As has been previously pointed out, the relatively long stroke of the plunger required to deliver to a plurality of different outlets during a single discharge stroke usually involves high 70 linear speed on the suction stroke. In some instances, however, the service may be such that even with relatively long stroke, a fairly low speed of travel on the suction stroke can be obtained. Where this is the case, it may be possible to dispense with a separate suction valve, 75

the pump chamber being filled by reverse flow through the pump overflow. An arrangement of this kind is illustrated in Figs. 50 and 51 and in the embodiment illustrated, a plunger and cylinder arrangement is shown which is in general similar to that illustrated in Figs. 43 and 44 except that in this instance the plunger delivery recess 146 is placed below rather than above the plunger overflow recess 148.

In Fig. 51 the plunger is shown in various positions on its suction stroke and as will be apparent from this figure, liquid can flow into the pump chamber from the overflow port *r* by way of the overflow recess 148 and the bores 152 and 150 until the port *r* is closed by the control projection as shown in position 51*b*. During movement from position 51*b* to position 51*c*, flow of liquid into the pump chamber is prevented and vacuum is created in this chamber which will be relieved when the overflow port 148*m* passes port *r* as the plunger moves from position 51*c* to position 51*d*. A second vacuum will be produced in the pump chamber as the second control projection closes the port *r* and this will again be relieved as soon as the overflow port 148*k* comes into communication with port *r*.

Ordinarily, when the cycle of operation of the pump permits the suction valve to be dispensed with, there will be time available between delivery strokes to enable the plunger to dwell an appreciable length of time at the bottom of its stroke, with overflow ports in communication, so that ample time is available with the plunger in this position to insure complete filling of the pump chamber before the next discharge stroke of the plunger takes place.

Obviously, if the suction valve is dispensed with and the pump chamber is filled by reverse flow through the overflow, any means for producing resistance in the overflow line which is in the form of a check valve, as shown for example in Fig. 1, must be dispensed with and in most instances it will be preferable to omit means for creating resistance in the overflow line.

It will be understood that the same principles providing for dwell of the pump plunger between delivery periods are advantageously applied regardless of whether the plunger and barrel construction employs a plurality of cylinder overflow ports or a plurality of plunger overflow ports.

As will be apparent from the drawings, the type which employs a plurality of cylinder overflow ports also provides the simplest form of plunger. It is to be noted, however, that in this type it is essential to the accuracy of distribution effected by the pump that the cylinder overflow ports be of precisely the same diameter and exactly in line with the line of reciprocation of the plunger overflow ports. In commercial manufacture the desired accuracy of diameters and alignment of these ports may be difficult to maintain and if the ports as bored have slightly different diameters or are slightly out of alignment, the inaccuracy cannot be corrected and the barrel must be scrapped.

On the other hand, when multiple plunger overflow ports are employed and slight inaccuracies as between different control edges are found to exist in the plunger as originally cut, such inaccuracies can be corrected so that in the finished plunger all control edges are exactly alike. Thus in this type while the plunger form is more complex, initial inaccuracies can be corrected and saving thereby effected by reducing

the number of parts that must be rejected for inaccuracy.

It will be apparent, particularly from a consideration of the several developed surface views such as those shown in Figs. 7, 11 to 13, 34, 36, 44, 46, and 48, that in so far as the shaping of the delivery and overflow ports and the provision of control edges is concerned, the cooperating parts may be made in a manner the reverse of that shown in the several embodiments herein described. In other words, the various irregularly shaped control recesses provided in the plunger in the embodiments herein shown may be formed in the surface of the cylinder bore, and the ports provided by round bores in the cylinders herein described placed in the plunger surface to cooperate with the irregularly shaped ports in the cylinder surface.

It will be apparent, however, that in most instances it will be much more convenient and cheaper to form the irregularly shaped ports on the convex surface of the plunger rather than to form these ports in the relatively inaccessible concave internal surface provided by the cylinder bore.

The several modifications hereinbefore described clearly illustrate the fact that the invention may be carried out in many different specific ways which are capable of producing different delivery characteristics. It is to be noted, however, that it is characteristic of all modifications that pump overflow permits advancement of the pump plunger on its delivery stroke between spaced delivery periods. This permits separate injections of fuel to different cylinders of an engine to be made by the pump where the number of engine cylinders and the timing of the injection periods for the engine are such that time intervals must elapse between the termination of one injection period and the commencement of injection to the cylinder next to be supplied with fuel.

It is further to be noted that a highly advantageous characteristic is that the delivery ports are arranged so that full delivery communication is established for each delivery period before the preceding overflow period is terminated, and that full communication between cooperating delivery ports is maintained until the delivery period has been terminated by the next succeeding overflow period. By doing this the duration of the delivery periods is accurately and completely controlled by beginning and ending of overflow periods and pressure differentials between the pump chamber and the delivery passages due to wire drawing through the delivery ports is avoided.

The above characteristic of spacing of the ports is clearly illustrated for example in Fig. 45, from which figure it will further be apparent that this characteristic of spacing ordinarily operates to produce a condition in which at least two cylinder delivery ports are in communication with the pump chamber simultaneously with communication of a cylinder overflow port with the pump chamber. This condition is shown in position 45*d*.

While for the purposes of this specification the pump structures embodying the invention have been described principally in connection with use as fuel injection pumps for engines, it will be apparent that the pump is applicable to other uses as for example as an oil pump for supplying lubricating systems and the like.

It will be apparent that many changes and modifications may be made in the several em-

bodiments hereinbefore described, and that certain features may be employed to the exclusion of others, without departing from the principles of the invention, and the invention is accordingly to be understood as limited in its scope only by the scope of the appended claims when they are construed as broadly as is consistent with the state of the prior art.

The several species of structure embodying multiple cylinder overflow ports are not specifically claimed herein, claims directed to the species characterized by this feature constituting the claimed subject matter of my copending application Serial No. 224,211, with respect to which this application is a continuation-in-part.

What is claimed is:

1. A pump including a cylinder and a pump plunger reciprocably mounted therein to provide a pump pressure chamber in which delivery pressure is created by movement of said plunger in said cylinder, said plunger and said cylinder being constructed to together provide a plurality of cooperating delivery ports for placing the pump chamber in communication with different delivery outlets in different positions of reciprocation of the plunger, overflow means for diverting a part of the contents of the pump chamber therefrom between successive delivery periods during the same discharge stroke of the plunger, and means for regulating the ratio between the deliveries to each of the several outlets and the quantity of liquid diverted from the pump chamber.

2. A pump including a cylinder and a pump plunger reciprocably mounted therein to provide a pump pressure chamber in which delivery pressure is created by movement of said plunger in said cylinder, said plunger and said cylinder being constructed to together provide a plurality of cooperating delivery ports for placing the pump chamber in communication with different delivery outlets in different positions of reciprocation of the plunger, overflow means for diverting a part of the contents of the pump chamber therefrom between successive delivery periods during the same discharge stroke of the plunger, and means for controlling said overflow means to vary by substantially like amounts the liquid delivered to each of the several outlets.

3. A pump including a cylinder and a pump plunger reciprocably mounted therein to provide a pump pressure chamber in which delivery pressure is created by movement of said plunger in said cylinder, said plunger and said cylinder being constructed to together provide a plurality of cooperating delivery ports for placing the pump chamber in communication with different delivery outlets in different positions of reciprocation of the plunger, overflow means for diverting a part of the contents of the pump chamber therefrom between successive delivery periods during the same discharge stroke of the plunger, said overflow means being constructed and arranged to cause substantially like amounts of fuel to be successively delivered to different outlets during successive delivery periods and means for controlling said overflow means to vary by substantially like amounts the liquid delivered to each of the several outlets.

4. A pump including a cylinder and a pump plunger reciprocably mounted therein to provide a pump pressure chamber in which delivery pressure is created by movement of said plunger in said cylinder, said plunger and said cylinder being constructed to together provide a plurality of delivery ports arranged to communicate in sequence

during one discharge stroke of the plunger and a plurality of overflow ports arranged to communicate in sequence during the same discharge stroke of the plunger to determine the duration of the periods of delivery through said delivery ports, said ports further being arranged to provide alternating overflow and delivery periods during said stroke, and means for varying the duration of the overflow periods to control the duration of the intervening delivery periods.

5. A pump having a plurality of delivery outlets including a cylinder, a plunger mounted for reciprocation in the cylinder, said cylinder and plunger together being provided with a plurality of delivery ports arranged to communicate in sequence during one discharge stroke of the plunger, a plurality of overflow ports in the plunger, an overflow port in the cylinder, said plunger overflow ports being arranged to pass the cylinder overflow port in sequence during the same discharge stroke of the plunger to provide alternating overflow and delivery periods during said stroke, and means for varying the duration of communication of the plunger overflow ports with the cylinder overflow port to control the duration of the intervening delivery periods.

6. A pump having a cylinder provided with a plurality of delivery ports leading to different pump outlets and a plunger in said cylinder, said plunger and cylinder being constructed to together provide a plurality of cooperating overflow ports located to establish overflow from the pump chamber through a different path of flow in each of a plurality of positions of reciprocation of the plunger on its discharge stroke and said plunger further being ported to provide communication between the pump chamber and different ones of said cylinder delivery ports in each of a plurality of other positions of reciprocation of the plunger when overflow from the pump chamber is cut off.

7. A pump having a cylinder provided with a plurality of delivery ports leading to different pump outlets, a plunger mounted for reciprocation and turning movement in said cylinder, said plunger and cylinder being constructed to together provide a plurality of cooperating overflow ports located to establish overflow from the pump chamber through a different path of flow in each of a plurality of positions of reciprocation of the plunger on its discharge stroke, at least one of said overflow ports providing an inclined edge for altering the duration of the periods of overflow from said chamber when the plunger is turned and said plunger further being ported to provide communication between the pump chamber and different ones of said cylinder delivery ports in each of a plurality of other positions of reciprocation of the plunger when overflow from the pump chamber is cut off, means for reciprocating the plunger and means for turning the plunger to different positions of rotation.

8. A pump having a cylinder provided with a plurality of delivery ports leading to different pump outlets, a plunger mounted for reciprocation and turning movement in said cylinder, said plunger and cylinder being constructed to together provide a plurality of cooperating overflow ports located to establish overflow from the pump chamber through a different path of flow in each of a plurality of positions of reciprocation of the plunger on its discharge stroke, at least one of said overflow ports providing an inclined edge for altering the duration of the periods of overflow from said chamber when the

- plunger is turned and said plunger further being ported to provide communication between the pump chamber and different ones of said cylinder delivery ports in each of a plurality of other positions of reciprocation of the plunger when overflow from the pump chamber is cut off, means for reciprocating the plunger comprising a cam having a face providing a dwell in the discharge stroke of the plunger between each two successive delivery periods and means for turning the plunger to different positions of rotation.
9. A pump including a cylinder having a plurality of delivery ports and an overflow port, and a cooperating plunger having a delivery port and a plurality of overflow ports arranged to place cooperating delivery and overflow ports alternately and successively in communication with the pump chamber.
10. A pump including a cylinder having a plurality of longitudinally spaced delivery ports and an overflow port, and a cooperating plunger ported to place the pump chamber in communication with different longitudinally spaced delivery ports at different times during the delivery stroke, said plunger further being ported to place said overflow port in communication with the pump chamber at a plurality of other times during said stroke.
11. A pump including a cylinder having a plurality of circumferentially offset delivery ports located at substantially the same level in the cylinder, a cooperating plunger having a plurality of circumferentially and longitudinally offset delivery ports each located to register with a different one of the cylinder ports in a different position of reciprocation of the plunger, and overflow port means for establishing overflow from the pump chamber between the periods of delivery therefrom.
12. A pump including a cylinder having a plurality of circumferentially offset delivery ports located at substantially the same level in the cylinder, a cooperating plunger having a plurality of circumferentially and longitudinally offset delivery ports each located to register with a different one of the cylinder ports in a different position of reciprocation of the plunger, an overflow port in the cylinder and a plurality of longitudinally spaced overflow ports in the plunger for establishing overflow from the pump chamber a plurality of times in the plunger stroke.
13. A pump including a cylinder having a plurality of spaced delivery ports and an overflow port and a cooperating plunger having a delivery port and at least one overflow port both of which are in constant communication with the pump chamber, said ports being located and spaced relative to each other to place at least two cylinder delivery ports and an overflow port in communication with the pump chamber simultaneously during a portion of the discharge stroke of the plunger.
14. A pump including a cylinder and cooperating plunger providing a pump chamber, a plurality of delivery ports and at least one overflow port in said cylinder, cooperating port means in said plunger providing a plurality of alternating delivery and overflow periods from said chamber during one discharge stroke of the plunger, said cylinder ports providing the sole outlets from said chamber, and said chamber being filled on the suction stroke of the plunger by reverse flow of liquid through the overflow port means during a plurality of periods corresponding to the overflow periods effected during a discharge stroke.
15. A pump including a plunger recessed to provide a delivery port and an overflow recess both in constant communication with the pump chamber, said overflow recess extending longitudinally of the plunger and one side wall thereof providing a plurality of longitudinally spaced inclined control edges, a cylinder having a plurality of spaced delivery ports located to be passed successively by the plunger delivery port and an overflow port located to be passed successively by said control edges on a discharge stroke of the plunger, means for reciprocating the plunger in the cylinder and means for turning the plunger to different positions of rotational adjustment in the cylinder.
16. A pump including a cylinder and a plunger having cooperating delivery and overflow ports to provide a delivery period preceded and followed by overflow periods during the same discharge stroke of the plunger, said plunger being rotationally adjustable and said overflow ports being shaped and located to vary the length of plunger travel between successive overflow periods in different positions of rotational adjustment of the plunger and said overflow ports further being shaped and located with respect to the delivery ports to require a predetermined amount of plunger travel after the termination of a preceding overflow period and before the commencement of a succeeding delivery period in at least certain positions of rotational adjustment of the plunger.
17. A pump including a cylinder having a first delivery port, a second delivery port axially spaced from said first port and an overflow port, a ported plunger having a delivery port located to pass said cylinder delivery ports in sequence as the plunger advances on its discharge stroke and further having an overflow port located to pass said cylinder overflow port as the plunger advances on the same stroke to establish an overflow period, the beginning of said overflow period determining the ending of delivery through said first delivery port and the ending of said overflow period determining the beginning of delivery through said second delivery port.
18. A pump including a cylinder and plunger cooperatively ported to deliver liquid from a common pump chamber to different pump outlets during different delivery periods occurring at different times in the same delivery stroke of the plunger and to permit liquid to overflow from said chamber during different overflow periods at other times during said stroke, and a cam for moving said plunger on its discharge stroke, said cam having a plurality of spaced rising sections separated by sections of substantially constant radius, and said cam being arranged so that each section of substantially constant radius operates to provide a dwell in the plunger discharge stroke when overflow ports are in registry to provide an overflow period.
19. A plunger pump including a cylinder having a delivery port and an overflow port, said ports opening into the bore of the cylinder intermediate its ends, and a recessed plunger in said bore providing a delivery port and two axially spaced overflow ports, all of said ports being located intermediate the ends of the plunger and in communication with the pump chamber, the plunger delivery port being located to pass the cylinder delivery port at an intermediate position of the plunger on its delivery stroke and the

plunger overflow ports being located to communicate with the cylinder overflow port to establish overflow periods through the cylinder overflow port immediately before and immediately after delivery is effected through said cylinder delivery port, the commencement of said delivery period being determined by movement of the first of said plunger overflow ports out of communication with the cylinder overflow port and the termination of the delivery period being determined by movement of the second of said plunger overflow ports into communication with the cylinder overflow port.

20. A pump including a cylinder and a pump plunger reciprocally mounted therein to provide

a pump pressure chamber in which delivery pressure is created by movement of said plunger in said cylinder, said plunger and said cylinder being constructed to together provide a plurality of cooperating delivery ports for placing the pump chamber in communication with different delivery outlets in different positions of reciprocation of the plunger, and overflow means for diverting a part of the liquid from the pump chamber between successive delivery periods during the same discharge stroke of the plunger, said overflow means including means for creating resistance to flow therethrough.

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