

Dec. 9, 1952

R. B. SAALFRANK

2,620,734

CONSTANT DELIVERY PUMP

Filed May 15, 1948

10 Sheets-Sheet 1

Inventor,
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Dec. 9, 1952

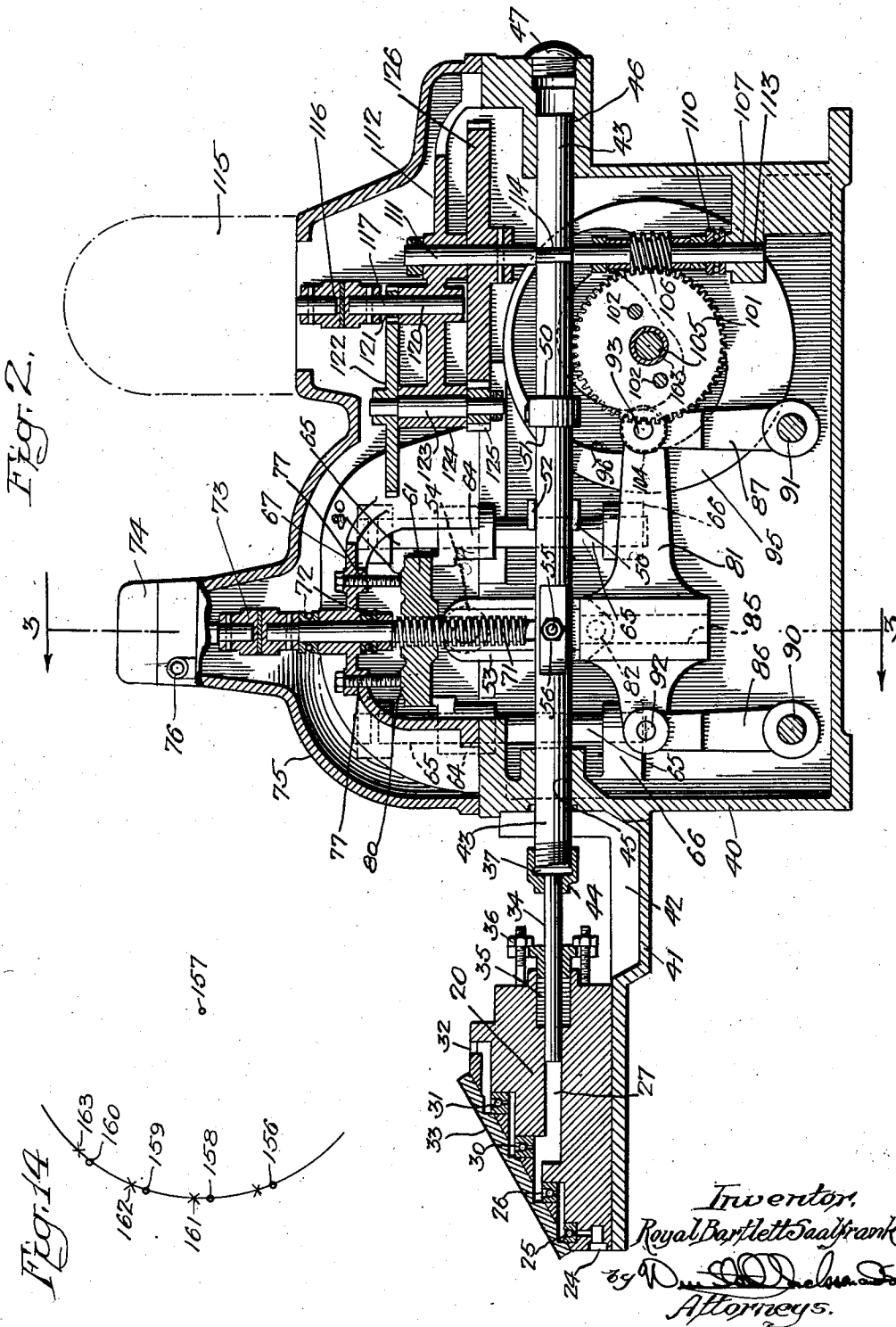
R. B. SAALFRANK

2,620,734

CONSTANT 'DELIVERY' PUMP

Filed May 15, 1948

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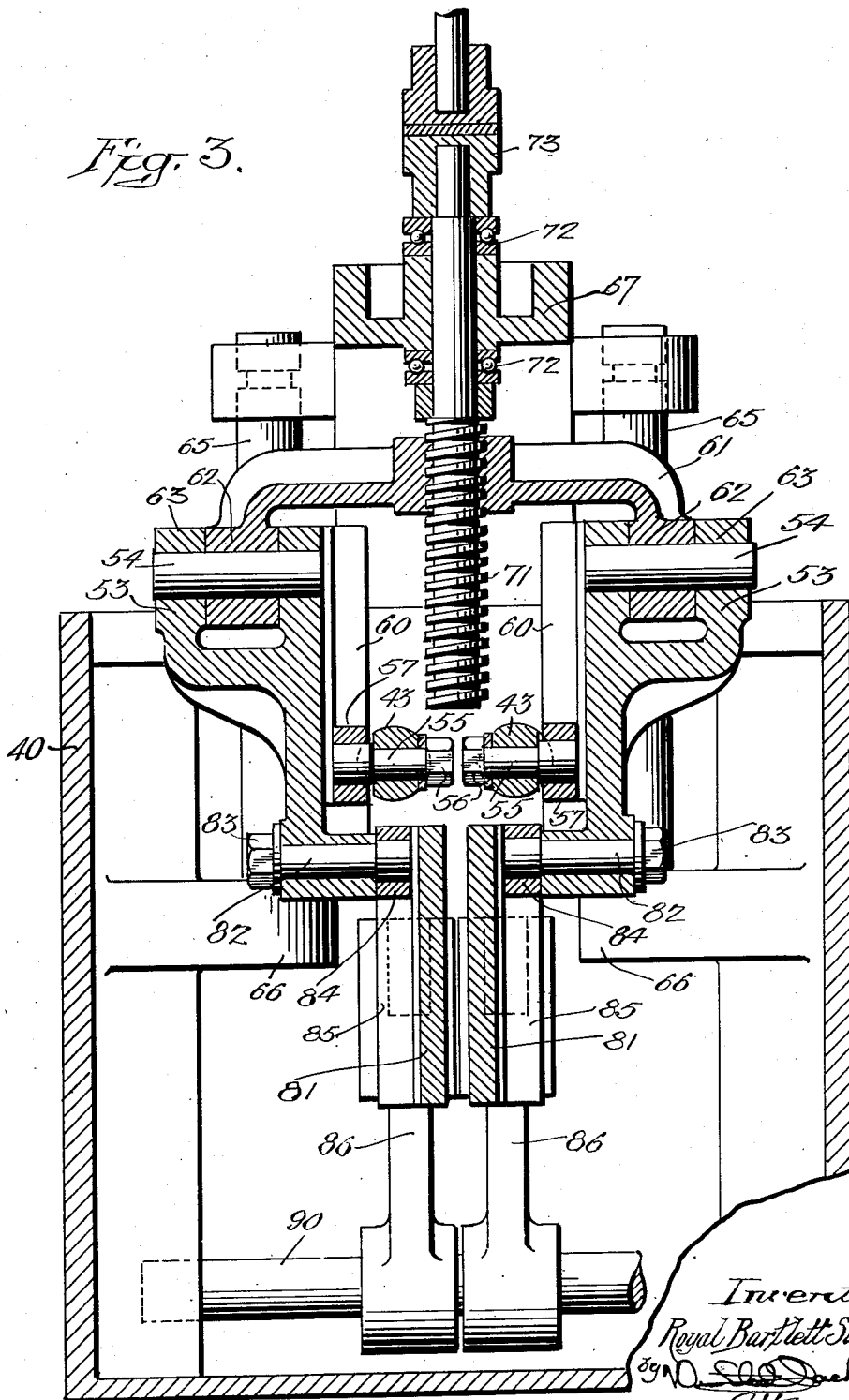
Dec. 9, 1952

R. B. SAALFRANK
CONSTANT DELIVERY PUMP

2,620,734

Filed May 15, 1948

10 Sheets-Sheet 3



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R. B. SAALFRANK
CONSTANT DELIVERY PUMP

2,620,734

Filed May 15, 1948

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Fig. 4.

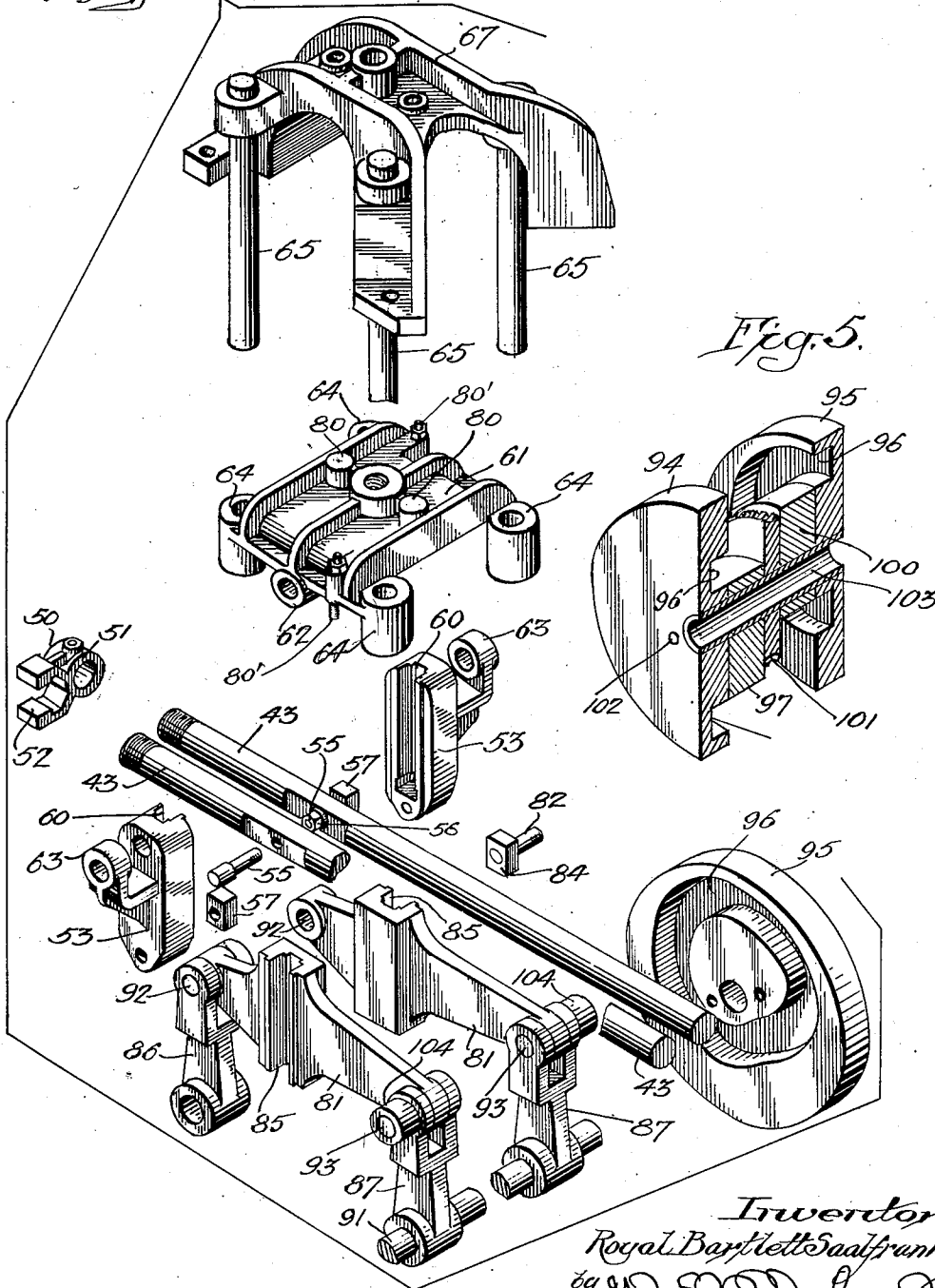


Fig. 5.

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CONSTANT DELIVERY PUMP

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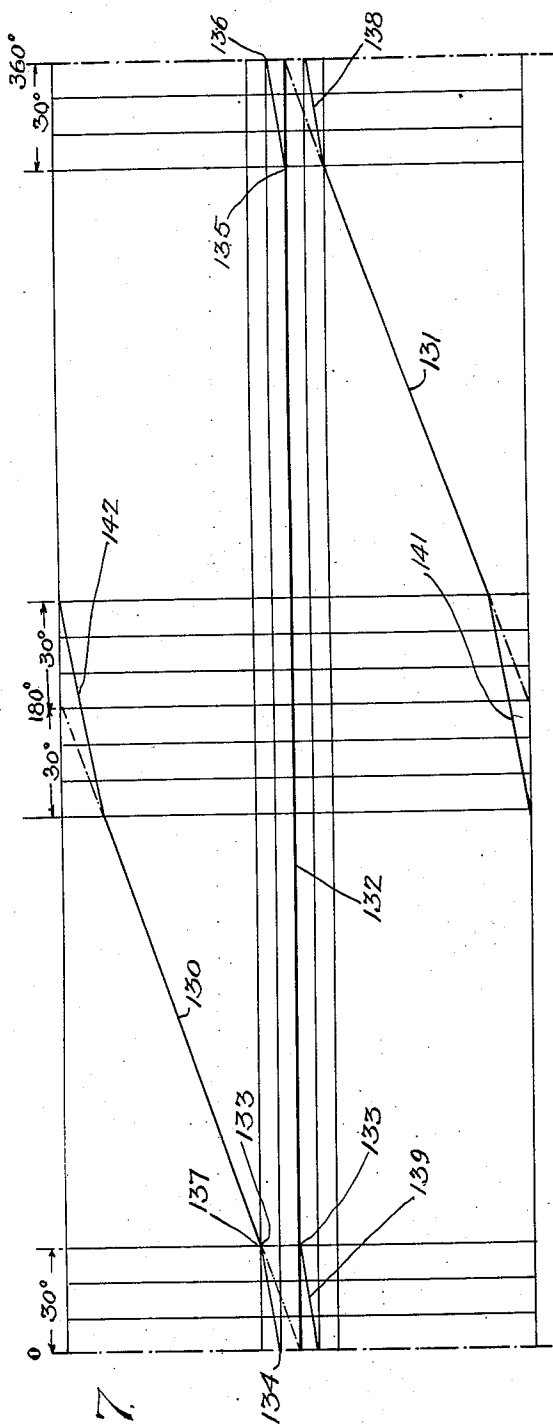


Fig. 7.

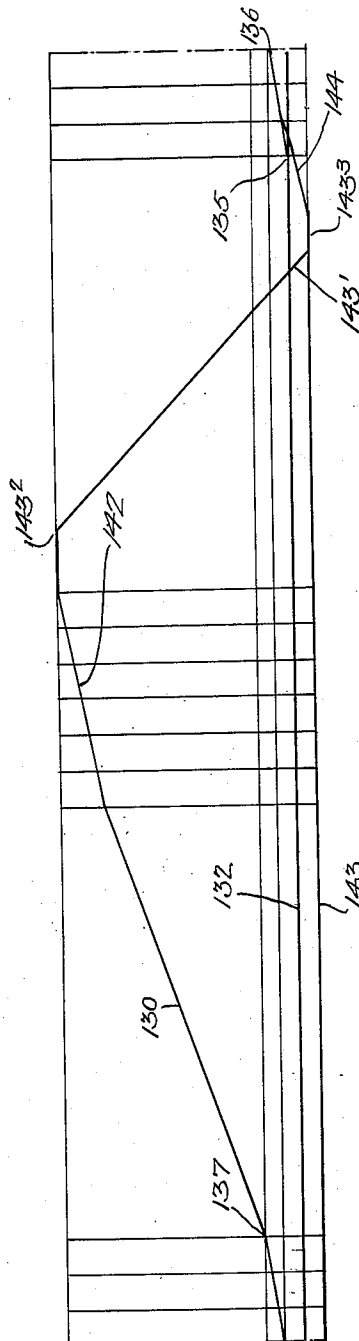


Fig. 8.

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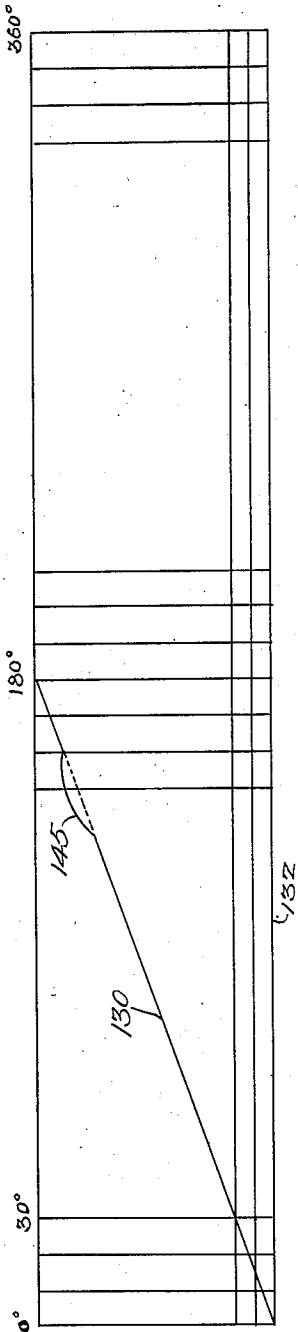


Fig. 9.

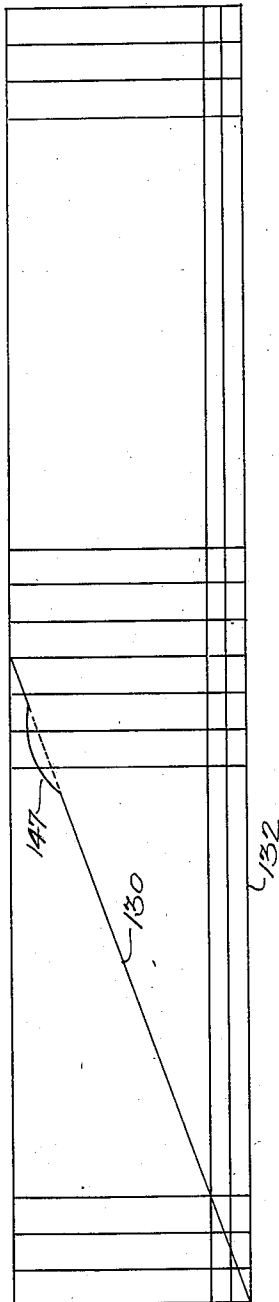
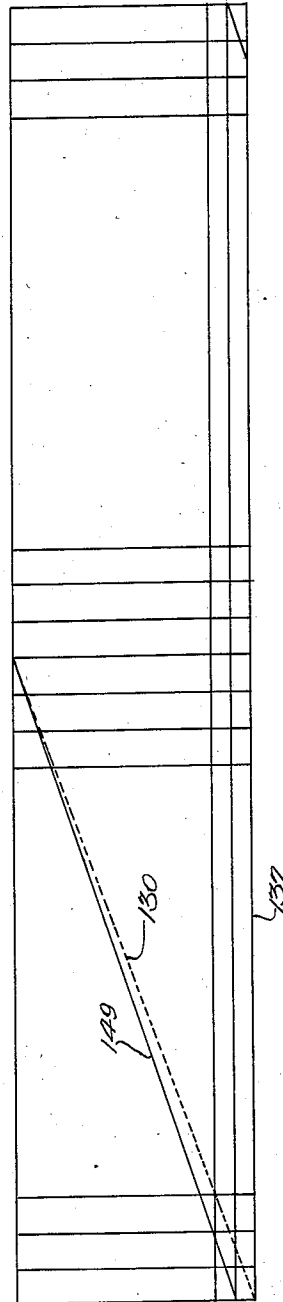


Fig. 10.

Fig. 11.



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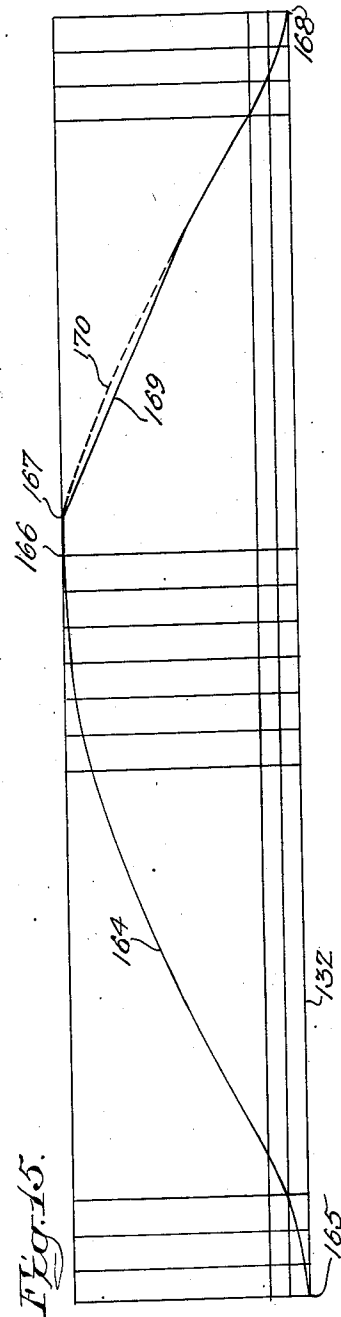
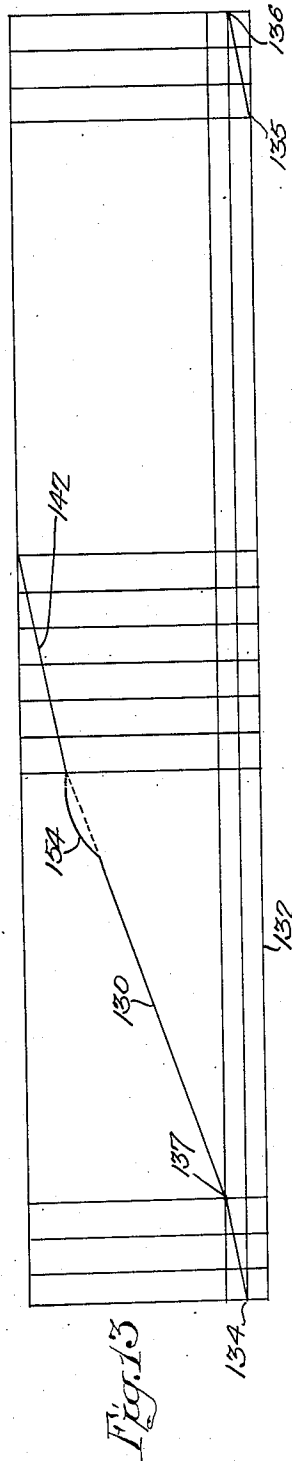
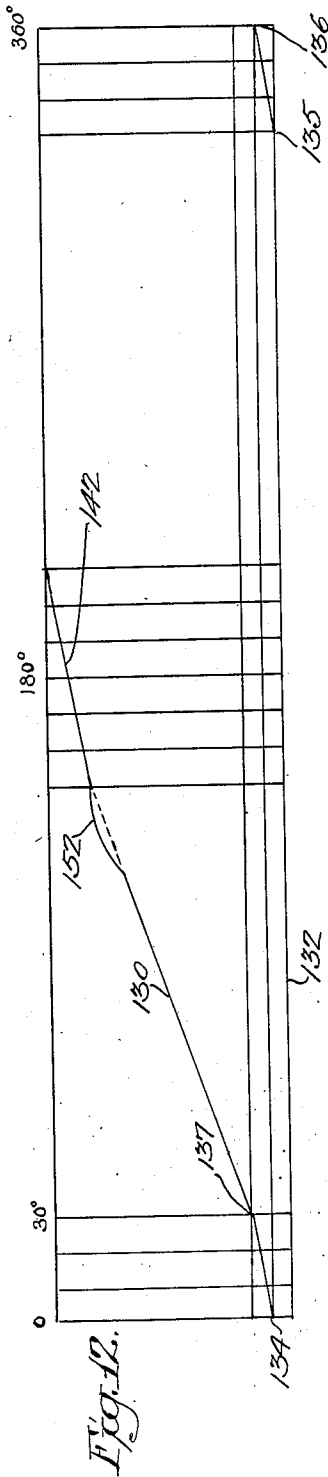
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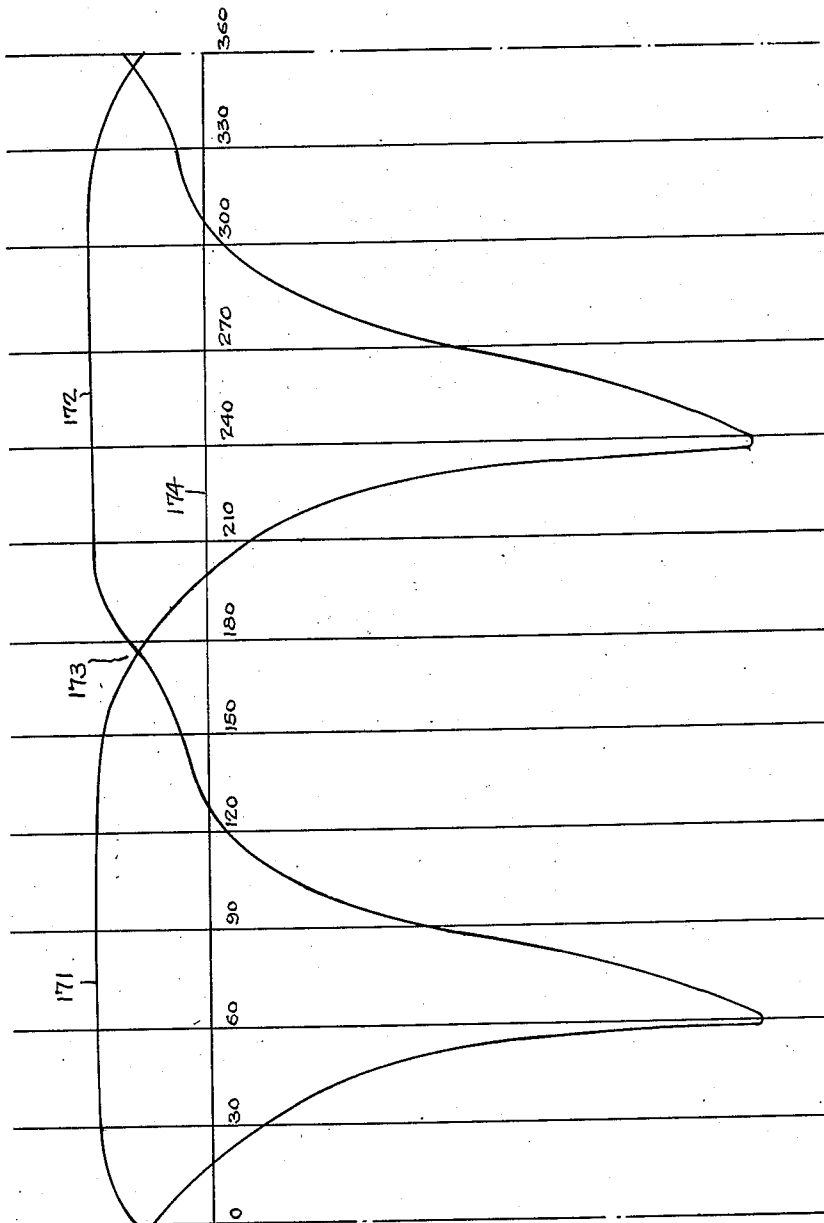


Fig. 16.

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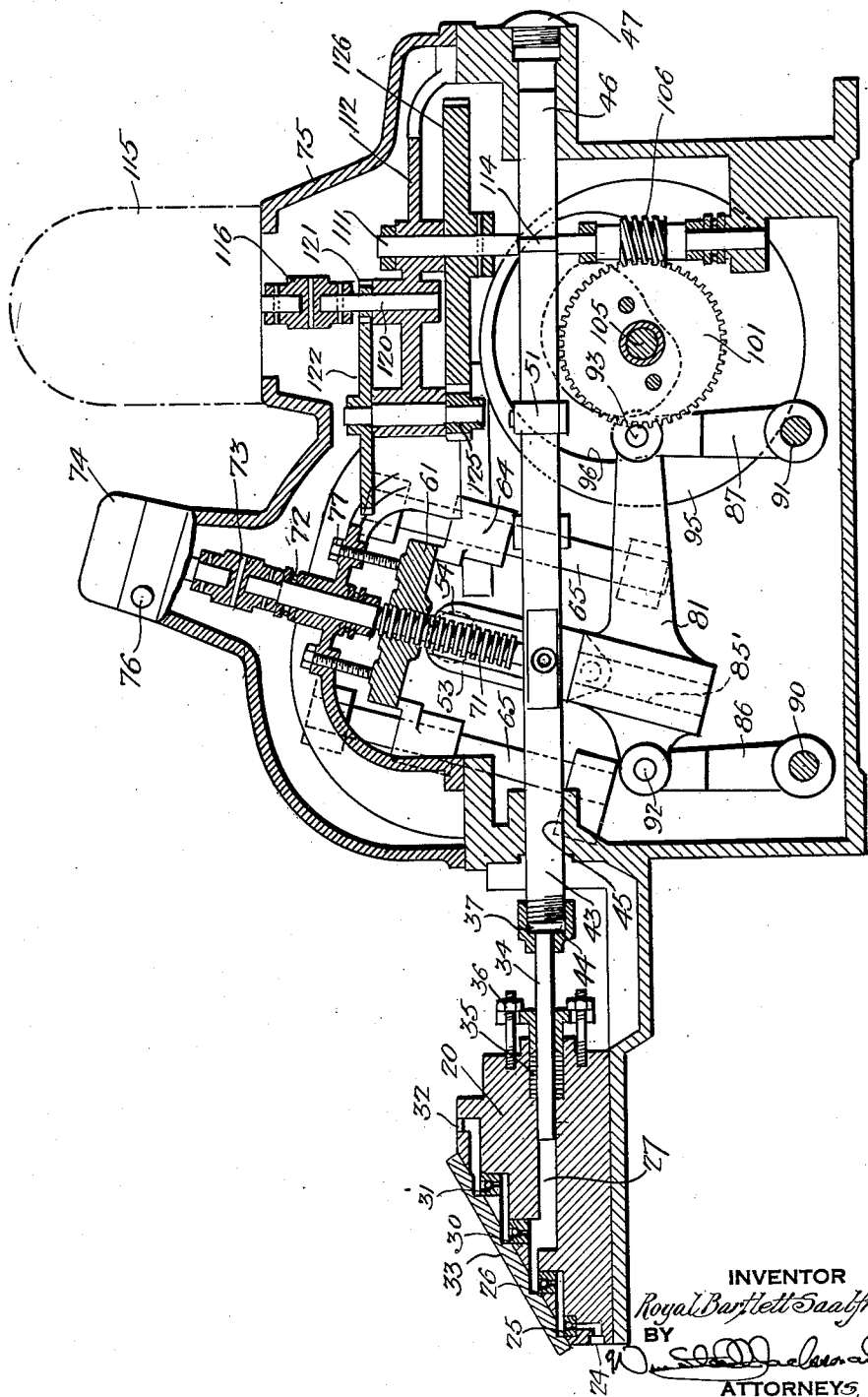
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Fig. 17.



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Fig. 18.

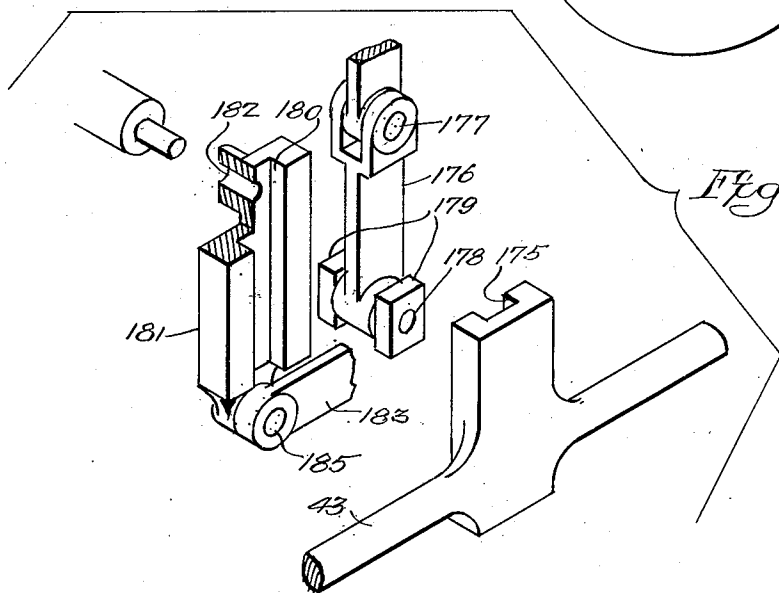
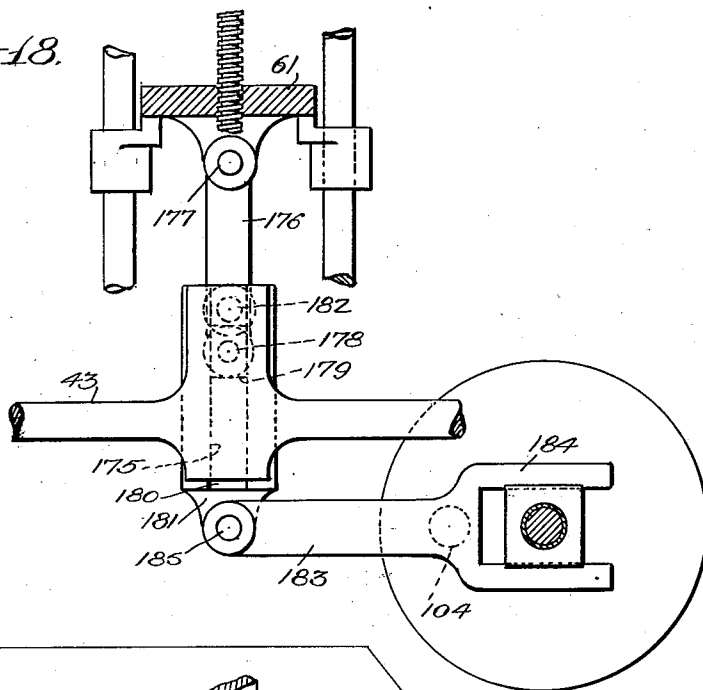


Fig. 19.

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UNITED STATES PATENT OFFICE

2,620,734

CONSTANT DELIVERY PUMP

Royal Bartlett Saalfrank, Gulfport, Fla., assignor
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corporation of Pennsylvania

Application May 15, 1948, Serial No. 27,294

9 Claims. (Cl. 103—38)

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The present invention relates to constant delivery pumps.

A further purpose of the invention is to simplify and improve the construction of constant delivery pumps in which a plurality of pumps in out-of-phase relationship are pumping from the same inlet to the same discharge, and provisions are made for variation in the flow rate while maintaining uniformity at any given flow rate.

A further purpose is to avoid the extremely high tolerances and expensive machining which have been required in the production of constant delivery pumps, while improving the accuracy and reliability of the mechanisms.

A further purpose in a constant delivery pump employing a plurality of pumps each having a cylinder, a piston in the cylinder and an inlet and outlet connection to the cylinder, with common fluid connections to the inlets and outlets to all cylinders, is to provide a link or the like for controlling the motion of each piston, which link bears the same angular relation to each piston and is pivotally supported.

A further purpose is to drive the links for the respective pistons by cams out of phase with one another, and to the pumping stroke of another link, and to mechanically connect each link to its piston by an adjustment.

A further purpose is to adjust the mechanical connection between each link and its piston with respect to the pivotal support of each link, and preferably to adjust all links in unison to vary the throw of all pistons in unison.

A further purpose is to pivot the links each at a plurality of spaced points.

A further purpose is to provide an adjustment slot in each link, and means for varying the mechanical connection with the adjustment slot along a line which maintains the same angular relation with respect to the piston for any adjustment at at least one position in the stroke and which at corresponding positions maintains the same angular relation with respect to each piston.

A further purpose is to provide an approach portion at the beginning of the pumping stroke on each cam which is added to the uniform motion curve (and desirably also add to the dwell) and to correspondingly subtract from the uniform motion curve of the end of the pumping stroke on each cam (and desirably also subtract from the dwell) and to overlap the cam portions so as to give gradual acceleration and gradual deceleration of the pistons and other moving parts.

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A further purpose is to provide correction for lost motion by lowering the base line of the cam.

A further purpose is to add a correction for valve slippage, for stroke length below optimum, for piston speed below optimum, and for piston diameter below optimum, on the pumping stroke.

A further purpose is to add a correction for fluid compressibility throughout the pumping stroke of each cam.

A further purpose is to retard the retraction stroke on each cam to avoid volatilization of the liquid pumped when pumping volatile liquids as compared to the retraction stroke when pumping non-volatile liquids.

A further purpose is to drive through face cams preferably mounted and rotating as a single unit.

A further purpose is to drive through a rocker parallelogram having equal parallel rockers and an intermediate link which follows a cam and transmits the motion.

A further purpose is to employ plunger type crossheads in prolongation of the pump pistons, and to inter-relate the crossheads to one another during motion to prevent rotation.

A further purpose is to drive a constant delivery pump from a cam to a rocker parallelogram, from the rocker parallelogram by a sliding pivot, movable transversely to the piston line of motion, to the swinging end of an adjustment rocker having a pivot movable toward and away from the line of piston motion, and by a sliding pivot on the adjustment rocker to the piston crosshead.

A further purpose is to provide common and coaxial support for the adjustment rockers of a plurality of pumps.

A further purpose is to provide coaxial pivot support for the end rockers of the rocker parallelograms for a plurality of pumps.

A further purpose is to carry the piston to the same position at the end of the stroke in each pump regardless of variation in stroke length, to correct for compressibility of liquid, preferably by inclining the adjustment slot in each link at an angle to the piston which corresponds with the angle of the adjustment rocker at the end of the stroke, and making the adjustment along a line corresponding to the line of the adjustment rocker at the end of the stroke.

A further purpose is to operate a rocker by a link from a cam for each piston, to connect an adjustment slot on the rocker to the free end of an adjustment rocker and to connect the free end of the adjustment rocker to a transverse slot on the piston plunger.

Further purposes appear in the specification and in the claims.

In the drawings I have chosen to illustrate a few only of the embodiments in which this invention may appear, choosing the forms shown from the standpoints of convenience in illustration, satisfactory operation and clear demonstration of the principles involved.

Figure 1 is a top plan view of a constant delivery pump of the present invention with the cover removed.

Figure 2 is a longitudinal section on the line 2—2 of Figure 1.

Figure 3 is a transverse section on the line 3—3 of Figure 2.

Figure 4 is a fragmentary exploded perspective showing the operating mechanism.

Figure 5 is an axial sectional perspective of the cam unit.

Figure 6 is a diagram of the inlet and discharge.

Figure 7 is a cam diagram showing the cam throw or follower motion on the pumping stroke as the ordinate, plotted against angle of rotation of the cam as the abscissa. This diagram shows the correction for gradual acceleration and deceleration of the pistons.

Figure 8 is a cam diagram corresponding to Figure 7 showing the correction for lost motion. This and the remaining diagrams of this type show only a single cam track, whereas Figure 7 shows the tracks of both cams, which are out-of-phase opposite counterparts.

Figure 9 is a cam diagram corresponding to Figure 7 showing the correction for valve slippage.

Figure 10 is a cam diagram corresponding to Figure 7 showing the correction for stroke length below optimum.

Figure 11 is a cam diagram corresponding to Figure 7 showing the correction for fluid compressibility.

Figure 12 is a cam diagram corresponding to Figure 7 showing the correction for piston diameter below optimum.

Figure 13 is a cam diagram corresponding to Figure 7 showing the correction for speed below optimum.

Figure 14 is a circle diagram illustrating diagrammatically the correction for the arc of the rockers which support each link.

Figure 15 is a cam diagram similar to Figure 7 showing the change in the return stroke when pumping a volatile liquid.

Figure 16 is a pair of overlapped curves showing the volume of discharge from the two pumps plotted against angle of cam motion.

Figure 17 is a view corresponding to Figure 2 showing a modification of the form of Figures 1 to 6 inclusive.

Figures 18 and 19 illustrate a further modification of the form of Figures 1 to 6, Figure 18 being an elevation of the mechanism for the operation of one pump, and Figure 19 being an exploded perspective of such mechanism.

Except for the features modified the device of Figure 17 and the device of Figures 18 and 19 correspond to the device of Figures 1 to 6 inclusive.

Describing in illustration but not in limitation and referring to the drawings:

The present invention is a further development and improvement of the subject matter of patent application Serial No. 778,316, filed by me jointly with Milton Roy Sheen, deceased, and Robert T. Sheen, for Constant Delivery Pump,

filed October 7, 1947, now abandoned, which is incorporated herein by reference and made a part hereof.

In constant delivery pumps, in order to obtain a delivery curve which is constant within a high degree of accuracy with variation in discharge, it has been necessary in the past to employ mechanism which entails expensive and complicated machining, with high tolerances throughout, and which is necessarily expensive to produce and difficult to maintain. By the present invention the mechanism required is greatly simplified, the machine operations are markedly reduced both in number and complexity, and the difficulty through maintenance is minimized, without, however, departing from the high accuracy previously obtained, and in fact with improvement in both accuracy and reliability.

By the present invention it is possible to obtain very accurate adjustment without employing mechanical devices such as constantly sliding power transfer members which are difficult to produce and likely to be subject to wear. A suitably pivoted member such as a link is preferably employed for driving each piston of a plurality of pumps which have a common inlet connection and a common outlet connection (the connections may be internal or external). The link or other pivoted member is movable in a path which bears the same angular relation to each piston, and the respective links for the different pistons are cam operated out of phase with respect to one another and with the pumping stroke of one link displaced with respect to the pumping stroke of another link.

A mechanical connection extends from each link to its piston, and this connection is adjustable with respect to the pivotal support of the link, the adjustment being preferably common for all links and capable of varying all links in unison. The links are preferably mounted on pivoted rockers at spaced points. The adjustment preferably includes an adjustment slot and an adjustment in the slot which accomplishes adjustment on a line which maintains the same angular relation with respect to the piston for any adjustment at at least one position in the stroke and which line at corresponding positions maintains the same angular relation with respect to the corresponding piston. It is therefore possible to make linear or uniform adjustment and to record the same on a dial or the like reading linearly, without necessity for numerous dial corrections or for non-uniform dials. And a remote control or other automatic device can linearly change the adjustment as required.

The present device in the preferred embodiment transmits cam motion through a rocker parallelogram whose link maintains parallelism with the line of piston motion, and which preferably makes sliding pivot connection with the swinging end of an adjustment rocker whose pivot is moved toward and away from the line of piston motion, and which in turn makes sliding pivot connection with a plunger-type crosshead in prolongation of and connected with the piston.

The cams are preferably separate cams for each pump which are united together as a cam unit.

As shown in Figures 1 to 5 inclusive, the pumps comprise a pair of separate reciprocating piston pumps 20 and 21 having common inlet at 22 (Figure 6) and common outlet at 23. Inlet 24 to each individual pump occurs through passages containing a plurality (preferably two) ball check valves 25 and 26 on seats and arranged in

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series and discharging into a pump cylinder 27. Discharge in the individual pump from the pump cylinder takes place through passages containing a plurality (preferably two) successive ball check valves 30 and 31 on seats and connecting to an individual discharge 32 from each pump. Access to the balls and seats of the respective check valves is conveniently provided through a removable cover plate 33 fastened and gasketed in any suitable way not shown. In each pump cylinder is located a piston 34 extending through packing 35 compressed by a packing gland 36. The piston preferably has an enlarged attachment head 37 for connection to operating mechanism.

Each pump will desirably be of the character set forth in Milton Roy Sheen U. S. Patents Nos. 2,263,429 for Pump, issued November 18, 1941, and 2,367,893 for Liquid Pump, issued January 23, 1945. It will be understood that other suitable pumps may be employed.

In order to accomplish constant delivery, a plurality of pumps are connected to the same inlet and the same discharge, and are arranged out of phase so that generally when one pump is on the exhaust, another pump is on the discharge stroke. In the preferred embodiment of the invention, two pumps will be used, although some higher number might be employed, and with two pumps the pumps will preferably be 180° out of phase. The pumps will be arranged adjacent to one another with the line of travel of the pistons in the preferred embodiment parallel and the pistons extending out of the open ends of the cylinders, preferably in the same direction (not in opposite directions). The driving and adjusting mechanism is contained in a housing 40 which is provided with a bracket extension 41 on which the pumps are mounted. The extension has a well 42 which is carried up as high as desired to provide for catching of leakage or for holding a liquid sealing bath, if this be desired.

Extending in prolongation of each piston is one of two duplicate plunger-like driving crossheads 43, united to the corresponding piston by a locking collar 44 around the attachment head 37. While each crosshead 43 is of circular shape and resembles a plunger, it is guided to perform a crosshead function. The crossheads 43 are guided at the forward or pump end of the housing at 45 and at the opposite or rear end at 46, for sliding motion back and forth on the axis of each piston. The wide spacing of the guides makes high tolerance in the guides unnecessary. A plug 47 closes the guiding opening at 46.

In order to prevent undesired rotation of the crossheads, each crosshead carries a crosshead interlocking guide 50 having a collar portion 51 provided with a set screw for locking on one crosshead, and guiding fingers 52 for extending around the other crosshead. Thus the crossheads can slide back and forth freely without being permitted to turn.

Motion is submitted to each crosshead by an adjustment rocker 53. Each rocker is pivotally supported at 54 coaxial with respect to the other adjustment rocker, the axis being located at one side of the lines of motion of the pump pistons and the axis extending transversely to the lines of motion of the pump pistons and in a direction to permit the rocker ends to swing back and forth with the crossheads. The adjustment rockers are as shown opposite counterparts of equal length, and toward their outer or rocking ends each adjustment rocker makes sliding pivot

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contact with a pivot pin 55 in a crosshead. The positions of the pivot pins 55 with respect to the crossheads are the same distance from the piston for each crosshead. Each pivot pin is conveniently secured as by a nut 56, and carries at its end toward the adjustment rocker a pivot block 57 which turns on the pin 55. Each block 57 slides in a slot or guideway 60 extending longitudinally of each adjustment rocker. Thus each adjustment rocker maintains a driving connection with the corresponding crosshead through the sliding connection made by the guideway 60, the block 57 and the pin 55 for each pump.

The adjustment rocker pivots are mounted on a support 61 having bearings 62 which are preferably surrounded on each side by cooperating bearings 63 on the adjustment rockers, the bearings 62 and 63 receiving pivot pins at 54. The adjustment support 61 is guided for motion transversely to the line of motion of the piston and toward or away from the same to change the volume of discharge of the constant delivery pump by sliding bearings 64 (preferably at the four corners) which engage guide rods 65 mounted at the bottom in lugs 66 on the inside of the housing and mounted at the top in a spider 67 which is fastened as by bolts 70 to the interior of the housing.

The support 61 moves up and down in its guides under the action of an adjusting screw 71 journaled in bearings 72 in the spider and provided with driving connection, preferably through a dog-type clutch 73 driven manually or mechanically from an adjustment drive 74 supported on a cap 75 of the housing. The adjustment drive may be manual or mechanical, direct or remote, as later explained, but here is shown as a manual adjustment through gearing of well known character operated by a crank handle 76. A suitable dial not shown may indicate the adjustment position.

The range of motion of the support 61 away from the lines of piston motion under the action of the screw 71 is limited by adjustable stop screws 77 on the spider which engage abutments 80 on the support. Motion in the opposite direction of adjustment is limited by the contact of the adjusting screws 80' on the support 61 against the lug 80² on the housing.

The rocker motion of the adjustment rockers is caused by a sliding connection made with a rocker parallelogram. Preferably located on the outer end of each adjustment rocker, and therefore on a greater radius than the sliding connection with the corresponding crosshead, is a sliding pivot connection with a link 81 by means of a pin 82 secured by a nut 83 and making pivotal connection to a block 84 sliding in a slot or guideway 85 extending transversely to the line of piston motion in each link 81. Thus as the adjustment rocker pivots are moved toward and away from the line of piston motion the effective rocker arm of the adjustment rockers acting on the crossheads changes equally for each pump, while the effective rocker arm by which each adjustment rocker is driven by its link 81 of the rocker parallelogram remains unchanged, since the guideways 85 are transverse to the direction of motion of the links.

The links 81 maintain a direction parallel to the direction of the pistons during the motion of the links due to the action of parallelogram rockers 86 and 87, at the ends of each link. The rockers 86 and 87 are of equal length. Within each rocker parallelogram, the rockers are par-

allel to one another. In the two parallelograms (one for each pump) the rockers 85 are preferably coaxial and the rockers 87 are preferably coaxial. The rockers 86 turn freely about shaft 90 extending across the housing and the rockers 87 similarly turn freely about shaft 91 similarly supported. The shafts 90 and 91 are preferably supported at their extreme ends so that slight variations in the supporting positions will make little difference in the accuracy of positioning of the rockers. The shafts 90 and 91 as shown are at equal distances from the line of piston motion. Each link 81 makes pivot connection with a rocker 86 at 92 and with a rocker 87 at 93 near the ends of the link.

Thus it will be seen that the link and rockers of each set make in effect a parallelogram, since the center distance between the rocker shafts 90 and 91 are the same as the center distances between the link pivotal connections 92 and 93 and the rocker arms of the two rockers are equal.

Although the links move out of phase with one another, each link in the preferred embodiment always moves in a direction parallel with the axis of its piston.

The motion of the rocker parallelograms is imparted by cams which are preferably face cams arranged and operating as a single unit. As best seen in Figure 5, cams 94 and 95 have cam tracks 96 preferably facing inwardly and are separated by spacers 97 and 100 and by a driving gear 101 between the spacers. The entire unit is united by pins 102 and has an internal bearing sleeve 103. Each cam track 96 cooperates with a cam follower 104, conveniently arranged on the pivot connection 93 between the link and rocker 87 so that the parallelogram moves back and forth in response to the cam track.

The cam unit is conveniently driven from an electric motor through a speed reducer and worm drive. For this purpose the gear 101 will suitably be a worm wheel. The worm wheel and cam unit turns on shaft 105 (which is itself stationary) transverse to the axis of the pistons. A worm 106 on a shaft 107 intermeshes with the worm wheel 101. The thrust from the worm is taken by a thrust bearing 110 (Figure 2) and the shaft 107 is suitably journaled at one end 111 in a spider 112 supported from the housing and at the other end in a lug 113 on the interior of the housing. The shaft 107 is reduced in section at 114 to clear the crossheads. Drive to the shaft 107 is accomplished in any suitable way, conveniently from an electric motor 115 on a vertical axis supported in the top 75 of the housing, driving by a convenient separable dog type clutch 116 to a stub shaft 117 journaled at 120 in the spider 112 and carrying a pinion 121. The pinion 121 meshes with a gear 122 on a shaft 123 journaled at 124 in the spider and carrying at its opposite end a pinion 125. The pinion 125 meshes with a gear 126 on the worm shaft 107.

The gear spider 112 is conveniently made removable and the gears are themselves readily removable so that gears can be changed as required to vary the speed reduction from the motor.

It will be noted that the rear end of the crossheads is carried back beyond the speed reduction to provide widely spaced sliding support for the crossheads, so that a slight variation in the centers of the crossheads will not produce a serious error and excessively high tolerances in the boring of the guides will not be required. Throughout the mechanism where possible widely spaced

points of shaft support are provided on critical components.

Wear can be reduced to a minimum by running the mechanism in oil, which fills the interior of the housing suitably up to a level above the speed reduction gears.

It will be evident that in the preferred embodiment the shafts are stationary, and supported at widely spaced points, so that a slight tolerance variation in the support location will not seriously affect the mechanism. Except for the pistons and crossheads, no sliding parts in constant motion are employed.

It will be understood that the pair of face cams provide a unit which can be replaced whenever different operating cam characteristics are required. Thus if desired, the cam rocker parallelogram can be employed with variation in the cams if required for operation by the pump on markedly different liquids.

The cams include the fundamental uniform motion, which is laid out on each cam substantially 180° out of phase.

In accordance with the invention, the cams permit correction for stroke length, working pressure, speed, volume, and fluid viscosity. A gradual approach curve to the pumping stroke is permitted to reduce harshness of operation and permit greater speed. Adjustment for a low operating pressure angle is also made on the cams. The cams likewise permit compensation for lost motion in the mechanism, overlap of pistons due to valve slippage, and correction for compressibility of the residual volume of fluid. Likewise the cams permit adjustment of the working plunger for any "suck back" through the valve seat by the returning plunger. There is thus a full range of adjustment, and different sets of cams may be used whenever any one of the factors changes.

It is very desirable to keep the pressure angle below 25°. The most difficult condition is created at the inception of the pressure stroke on the cam. Each cam is adjusted at this point to give an acceleration approximately equal to the acceleration of gravity. It is necessary to add stroke increments to one side of a cam equal to stroke increments removed from the other side of the cam and to orient the two cams 180° out of phase so that a uniform pump delivery will be produced.

This correction can be distributed over 60°, that is 30° on one cam to the point where the pressure angle would become too high (exceed 25°), plus 30° to adjust the matching slope on the opposing cam. As seen in Figure 7, curve 130 plots cam rise against angle of rotation for uncorrected uniform motion on the pressure stroke only for one cam, and curve 131 does the same for the other cam, the dividing line between the plots for the two cams being at 132, which is the base line for the cam depicted by curve 130.

With uncorrected uniform motion, the throw at the point where the correction would end is 133. An amount of motion one-half of this requirement is established at 134 at the original zero point on rotation of one cam, and a new zero point 135 is established 30° behind the original zero and on the dwell. A modified cam surface is now run from 135 to 136, which coincides with 134, and then to 137, where it intersects the uniform uncorrected motion curve 130. This correction gives a gradual acceleration of

the piston comparable to that of gravity, over an angle of 60° from the new zero 135.

The amount of throw added to cam curve 130 at the beginning of the pumping stroke is subtracted from cam curve 131 at 138 and 139 on the same slope and over the same 60° angle at the end of its stroke. Similarly at the beginning of cam curve 131 the same 60° correction is added at 141, and a corresponding correction is subtracted at 142 at the end of the pumping stroke on cam curve 130.

Thus the opposite cam has amounts of motion added to its uniform motion increments equal and opposite to those subtracted from the uniform motion increments of the high side of the other cam. This has the effect of gradually slowing down the motion of the piston at the end of the stroke, since the partial load is picked up by the other piston at an earlier point.

Correction is also made for lost motion inherent in the parts. This correction is determined experimentally to be 0.002 inch per bearing or 0.015 inch total in the device. The stroke is increased by this amount by lowering the radius of the low dwell 132 to 143 in Figure 8 and slightly varying the slope of the corrective curve 144 at the beginning of the pumping stroke, with the same corrective curve 143¹ added at the end of the return stroke of the same cam. Dwells are shown at 143² and 143³.

An additive correction 145 for valve slippage is included on the pumping stroke opposite the valve slippage point as shown in Figure 9. A similar additive correction is applied on the other cam. As shown in Figure 10, an additive correction 147 is made on the pumping stroke for stroke length below optimum, with a similar additive correction on the other cam not shown.

For fluid compressibility, an additive correction 149 (Figure 11) is made progressively decreasing all along the stroke. There is a similar additive correction on the other cam.

In Figures 9 to 11, the corrections shown on Figure 7 are omitted for convenience.

As shown in Figure 12, an additive correction 152 is made for piston diameter below optimum on the pumping stroke opposite the point of valve operating in the other cylinder. A similar additive correction is made on the other cam, not shown.

Figure 13 shows another additive correction 154 on the pumping stroke, in this case for speed below optimum. The opposite cam has a similar additive correction.

As well known in the mechanical arts, the fact that in the preferred embodiment the cam followers are on rockers rather than moving truly radially to the cam center necessitates another correction in the cam which is purely geometrical in its purpose. Thus if on a cam path 156 turning about a center 157 a radial follower would at certain times reach points 158, 159 and 160, but the particular rocker follower would be at points 161, 162, and 163, the cam path is modified in any well known way to move the follower to points 161, 162 and 163 when the angular position corresponds to following of points 158, 159 and 160. The time increment of motion is stretched out to allow the follower to reach points 161, 162 and 163.

Figure 15 shows a cam path 164 for the full stroke having a pressure stroke from 165 to 166, a dwell from 166 to 167 and a suction stroke from 167 to 168. For nonvolatile liquids the cam suction stroke drops off rapidly at first at

169, but for volatile liquids, to avoid flashing into vapor, the drop of the cam path is made more gradual at 170.

Figure 16 indicates the characters of the discharge curves 171 and 172 for the two pumps. At the point of overlap, 173, the ordinate above neutral line 174 beneath curve 171, plus the ordinate above neutral line 174 beneath curve 172 is always equal to the ordinate above neutral line 174 under curve 171 or 172 at a point where there is no overlap.

In the preferred form when the various corrections are applied, all increments in pumping stroke due to a given piston give equal speeds of delivery, and all increments of overlapped pumping strokes of two or more pistons give combined total delivery which equals all other increments.

By these various corrections it has been found in practice that the flow curve at the discharge is extremely uniform and no appreciable indication is obtained of variation corresponding to the end of one cycle and the beginning of another.

In operation at any given adjustment position, the motor drives through the speed reduction to the worm and worm wheel, which turns the cam unit so that (with exception of the short angular period of overlap) one pump is always on discharge when another one is on suction. Each cam manipulates its follower to move the rocker parallelogram of the corresponding pump back and forth, keeping the rocker motion always parallel to the piston axis and keeping the adjustment slot of the particular rocker always transverse to the piston axis.

Each parallelogram link moves the end of its adjustment rocker back and forth and carries the corresponding interconnected crosshead and piston through the pumping cycle, the stroke being determined by the position of the pivot pin 55 on each crosshead with respect to the pivot 54. In other words, if the pivot 54 is down close to the pivot pin 55, the stroke will be short and the volume of delivery in each pump will be low, although the adjustment rocker for each pump always moves back and forth through the same angle for a given cam unit. To change the stroke of the adjustment rocker it is necessary to replace the cam unit by another cam unit, and this can readily be done. To change the timing of the cycle, the motor speed or the speed reduction will be changed.

For any given motor speed, speed reduction and cam unit, a wide variation in the volume of delivery can be accomplished during the operation of the pump without stopping the mechanism or interfering with delivery. To do this it is merely necessary to move the adjustment rocker pivots 54 closer to the pivot connections 55 to the crossheads to shorten the stroke and reduce the volume of delivery, or farther from such pivot connections 55 to increase the stroke and increase the delivery. This adjustment is conveniently made by turning the screw by hand or power and directly or by remote control. Any suitable electric, pneumatic, hydraulic or other remote drive may be used to move the screw up or down and obtain the required length of stroke. It will be understood, of course, that both pumps are adjusted simultaneously and to the same extent by adjustment of the screw.

It will be evident that by the present invention in the preferred embodiment the adjustable stroke drive of a plurality of pumps having a common inlet and a common discharge is controlled by cam means which operates a plurality

of rocker parallelograms, and that each rocker parallelogram by its link or bridge manipulates an adjustment rocker which interconnects with the piston crosshead over a variable rocker arm length which can be controlled by moving the adjustment rocker pivots closer to or farther from the piston axes.

It will be evident that in any case the adjustment support will be moved on a line which maintains the same angular relation with respect to each piston for any adjustment at at least one position in the stroke and which at that position reached at different times in different pumps bears the same angular relation to the corresponding piston.

Figure 17 shows a modification of Figure 2 in which the adjustment slots 85' are on an angle to the piston which corresponds with the angle of each adjustment rocker 53 with its piston at the forward end of its stroke. The adjustment support 61 and its guide rods 65 are canted on the same angle, so that all adjustment takes place along this line. By this device the piston is always held at the same forward position in the cylinder at the end of the stroke, whether the stroke is long or short (even at zero stroke). This gives predetermined and very much reduced compressibility of liquid at the end of the stroke, and variation in such compressibility of the liquid with stroke change may cause an error at very high pressures.

It will be evident that in this form the angle of the adjustment rocker in the forward position, the angle of the adjustment slot, and the angle of the parallelogram rockers in rear position equals in each case the angle of the line of adjustment, with respect to the piston.

In the form shown in Figures 18 and 19, each piston plunger 43 carries suitably transverse thereto a slot 175. An adjustment support 61 suitably adjusted as in the other forms pivotally mounts an adjustment rocker 176 pivoted at 177 and carrying a stud 178. On one side the stud 178 pivotally connects to a sliding block 179 which adjustably moves in the slot 175 of the piston plunger. At the other end the stud 178 carries a similar adjustment block which pivotally connects in an adjustment slot 180 of a rocker 181 having a fixed pivot at 182 and pivotally connected by a link 183 to the cam follower 104. The link 183 carries a yoke 184 which rides the cam pivot and is pivotally connected to the rocker 181 at 185.

In operation the rocker 181 moves back and forth under the action of the link 183. The motion transmitted by the link 181 to the piston varies with the position of the stud 178 as the adjustment rocker carries the stud up and down.

In view of my invention and disclosure variations and modifications to meet individual whim or particular need will doubtless become evident to others skilled in the art, to obtain all or part of the benefits of my invention without copying the structure shown, and I, therefore, claim all such insofar as they fall within the reasonable spirit and scope of my claims.

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

1. In a constant delivery pump, a plurality of pumps each having a cylinder, a piston in the cylinder, and an inlet and outlet connection including check valves to the cylinder, there being a common fluid connection to the inlets and a common fluid connection to the outlets of the

cylinders, a link for each piston movable in a path which bears the same angular relation to each piston, pivotal support for each link, cam means for driving the links out of phase with respect to one another and with the pumping stroke of one link displaced with respect to the pumping stroke of another link, and a mechanical connection from each link to its piston adjustable with respect to the pivotal support for each link in linear proportion between the adjustment and the change in the piston throw.

2. In a constant delivery pump, a plurality of pumps each having a cylinder, a piston in the cylinder, and an inlet and outlet connection including check valves to the cylinder, there being a common fluid connection to the inlets and a common fluid connection to the outlets of the cylinders, a link for each piston movable in a path which bears the same angular relation to each piston, pivoted rockers supporting each link at a plurality of spaced points, cam mechanism for driving the links out of phase with respect to one another and with the pumping stroke of one link displaced with respect to the pumping stroke of another link, a mechanical connection from each link to its piston, and an adjustment common to all links and varying in unison the throw of all pistons by the mechanical connections by varying the position of each mechanical connection to the rocker pivots of each link in linear proportion between the common adjustment and the change in the piston throw.

3. In a constant delivery pump, a plurality of pumps each having a cylinder, a piston in the cylinder, and an inlet and outlet connection including check valves to the cylinder, there being a common fluid connection to the inlets and a common fluid connection to the outlets of the cylinders, a link for each piston movable in a path which bears the same angular relation to each piston, pivotal support for each link, walls forming an adjustment slot in each link, cam means for driving the links out of phase with respect to one another and with the pumping stroke of one link displaced with respect to the pumping stroke of another link, a mechanical connection between the adjustment slot of each link and the corresponding piston, and means for adjusting each connection in each adjustment slot in linear proportion between the adjustment and the change in piston stroke along a line which maintains the same angular relation with respect to the piston for any adjustment at at least one position in the stroke and which at corresponding positions maintains the same angular relation with respect to each piston.

4. In a constant delivery pump, a plurality of pumps each having a cylinder, a piston in the cylinder, and an inlet and outlet connection including check valves to the cylinder, there being a common fluid connection to the inlets and a common fluid connection to the outlets of the cylinders, a link for each piston movable in a path which bears the same angular relation to each piston, pivoted rockers supporting each link at a plurality of spaced points, walls forming an adjustment slot in each link generally crosswise with respect to the link motion, cam means for driving the links out of phase with respect to one another and with the pumping stroke of one link displaced with respect to the pumping stroke of another link, an adjustment support, adjustment rockers pivotally mounted on the adjustment support and at their outer ends each engaging in

the adjustment slot of one of the links, means for moving the adjustment support in linear proportion to the change in piston stroke on a line which maintains the same angular relation with respect to each piston for any adjustment at at least one position in the stroke and which at that position bears the same angular relation to all pistons, and means for interconnecting each adjustment rocker and its piston while permitting adjustment of each rocker.

5. In a constant delivery pump, a plurality of reciprocating piston pumps arranged with the pistons adjacent, parallel and facing in the same direction, common fluid inlet and discharge connections including check valves to the pumps, crossheads connected to the pistons and extending in prolongation thereof, guides for the crossheads for motion in the direction of the piston axes, a rocker parallelogram comprising two rockers and a link for each crosshead, the parallelogram rockers at each end having fixed pivots which are common for all parallelograms and are located transversely to the line of piston motion and at one side thereof, with pivotal interconnection between the parallelogram rockers and the link of each parallelogram, all rockers of the parallelograms being equal and parallel within each parallelogram and the rockers of all parallelograms being equal, adjustment rockers, one for each parallelogram, having a common pivot transverse to the lines of piston motion and at one side thereof, a sliding connection between each link at a point intermediate its pivotal connections with the parallelogram rockers and the end of one of the adjustment rockers remote from its pivot, a sliding connection between each crosshead and one of the adjustment rockers intermediate between its pivot and the sliding connection with the link, means for moving the adjustment rocker pivots toward and away from the crossheads in linear proportion to the change in piston stroke and means for moving the links back and forth in a position generally out of phase with one another.

6. In a constant delivery pump, a plurality of reciprocating pumps each having a piston and respectively adjacent with the pistons moving in parallel lines and facing in the same direction generally out of phase with one another, common fluid inlet and discharge including check valves to the pumps, crossheads secured to the pistons and extending in prolongation thereof and in parallel relation to one another, guides for the crossheads on the lines of piston motion, a drive, a cam unit having cams pivoted for rotation on an axis transverse to the lines of motion of the pistons and at one side thereof and driven by the drive, the respective cams being secured in out-of-phase relation to one another, a rocker parallelogram adjoining each cam and including a pair of spaced equal parallel rockers on axes located to one side and transversely to the line of piston motion and a link making pivotal connection to the ends of the rockers and maintaining parallelism with the lines of piston motion, a follower for each cam interconnected with one of the links, an adjustment support, guides for moving the adjustment support transversely to the lines of piston motion from a position at one side thereof, an adjustment for moving the support along the guides, pivots on the adjustment support on a common axis transverse to the lines of motion of the pistons, equal adjustment rockers, one for each piston, pivoted one on each pivot, a sliding pivot connection be-

tween the swinging end of each adjustment rocker and one of the parallelogram links extending transversely to the direction of motion of the links, and a sliding pivotal connection between each crosshead and one of the adjustment rockers extending longitudinally of the rocker at a position on the crosshead which is the same distance from each piston.

7. In a constant delivery pump, a plurality of reciprocating pumps having pistons which are adjacent, parallel and face in the same direction, common fluid inlet and outlet connections including check valves to the pumps, a crosshead extending in prolongation of each piston, guides for the crossheads permitting motion in the line of the pistons, sliding interconnections between the crossheads preventing rotation of each crosshead, a drive, a face cam unit having face cams secured to one another on opposite faces of the unit, respectively generally out of phase and mounted for rotation by the drive at an axis to one side of and transverse to the lines of motion of the pistons, a follower on each face cam, a rocker parallelogram for each piston including equal spaced parallel rockers pivoted transversely to the lines of the pistons and each at the same distance from its piston at either end of the stroke, and including a link connected with the follower of one of the face cams and making pivotal connection to the rockers at the ends, and adjustable means interconnecting each link with one of the crossheads adjustable in linear proportion to the change in piston stroke.

8. In a constant delivery pump, a plurality of reciprocating pumps having pistons which are adjacent, parallel and face in the same direction, common fluid inlet and outlet connections including check valves to the pumps, a crosshead extending in prolongation of each piston, guides for the crossheads permitting motion in the line of the pistons, a drive, a face cam unit having face cams secured to one another on opposite faces of the unit, respectively generally out of phase and mounted for rotation by the drive at an axis to one side of and transverse to the lines of motion of the pistons, a follower on each face cam, a rocker parallelogram for each piston including equal spaced parallel rocker arms pivoted transversely to the lines of the pistons and each at the same distance from its piston at either end of the stroke, and including a link connected with the follower of one of the face cams and making pivotal connection to the rockers at the ends, the rocker pivots at each end of all parallelograms being coaxial, an adjustment support positioned at one side of the crossheads, guides for the adjustment support permitting it to move transversely to the lines of piston motion toward and away from the crossheads, pivots on the support on a common pivot axis transverse to the lines of motion of the pistons and transverse to the line of motion of the support, equal adjustment rockers pivotally mounted one on each pivot, a sliding pivot connection of each adjustment rocker with one of the links extending transversely of the lines of the piston motion, and a sliding pivot connection between each crosshead at the same distance from its piston and one of the adjustment rockers extending longitudinally of the adjustment rocker.

9. In a constant delivery pump, a plurality of pumps each having a cylinder, a piston in the cylinder, inlet and outlet connections to the cylinder, there being a common fluid connection to the inlets and a common fluid connection to the

outlets of the cylinders, including check valves in the connections, cam followers, one for each pump, mechanical means for interconnecting each cam follower with one of the pistons, and cam means for driving the followers out of phase with respect to one another and with the pumping stroke of one piston displaced with respect to the pumping stroke of another piston, there being an overlap at the beginning and end of the respective pumping strokes of the pistons and there being a cam correction for gradual acceleration and deceleration of the pistons added in the beginning of each pumping stroke and subtracted at the end of each pumping stroke.

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