June 30, 1953 R. WESTBURY ET AL 2,643,613

HYDRAULIC PUMP

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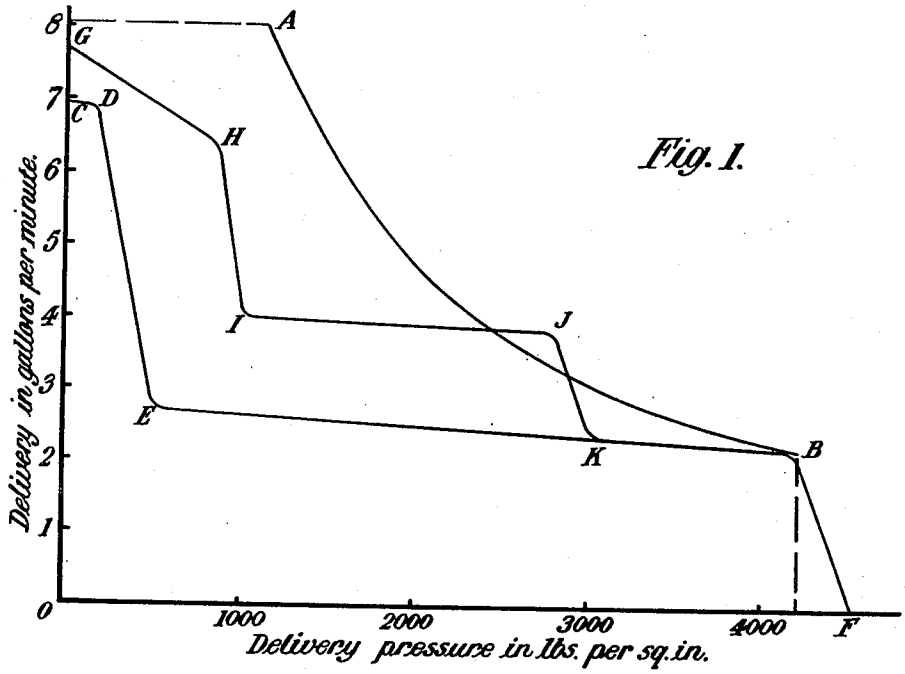


Fig. 1.

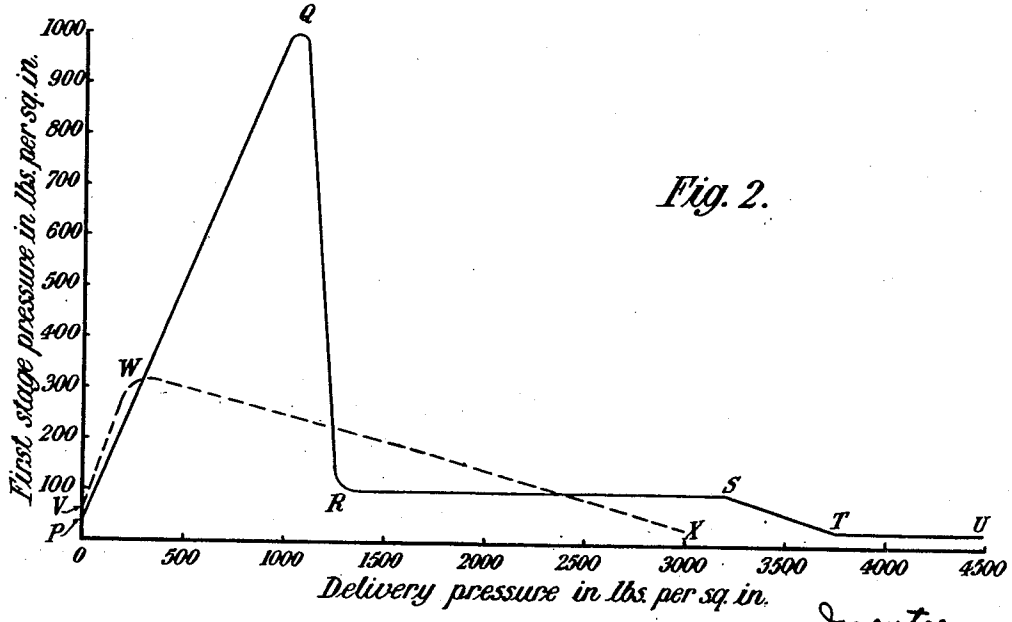


Fig. 2.

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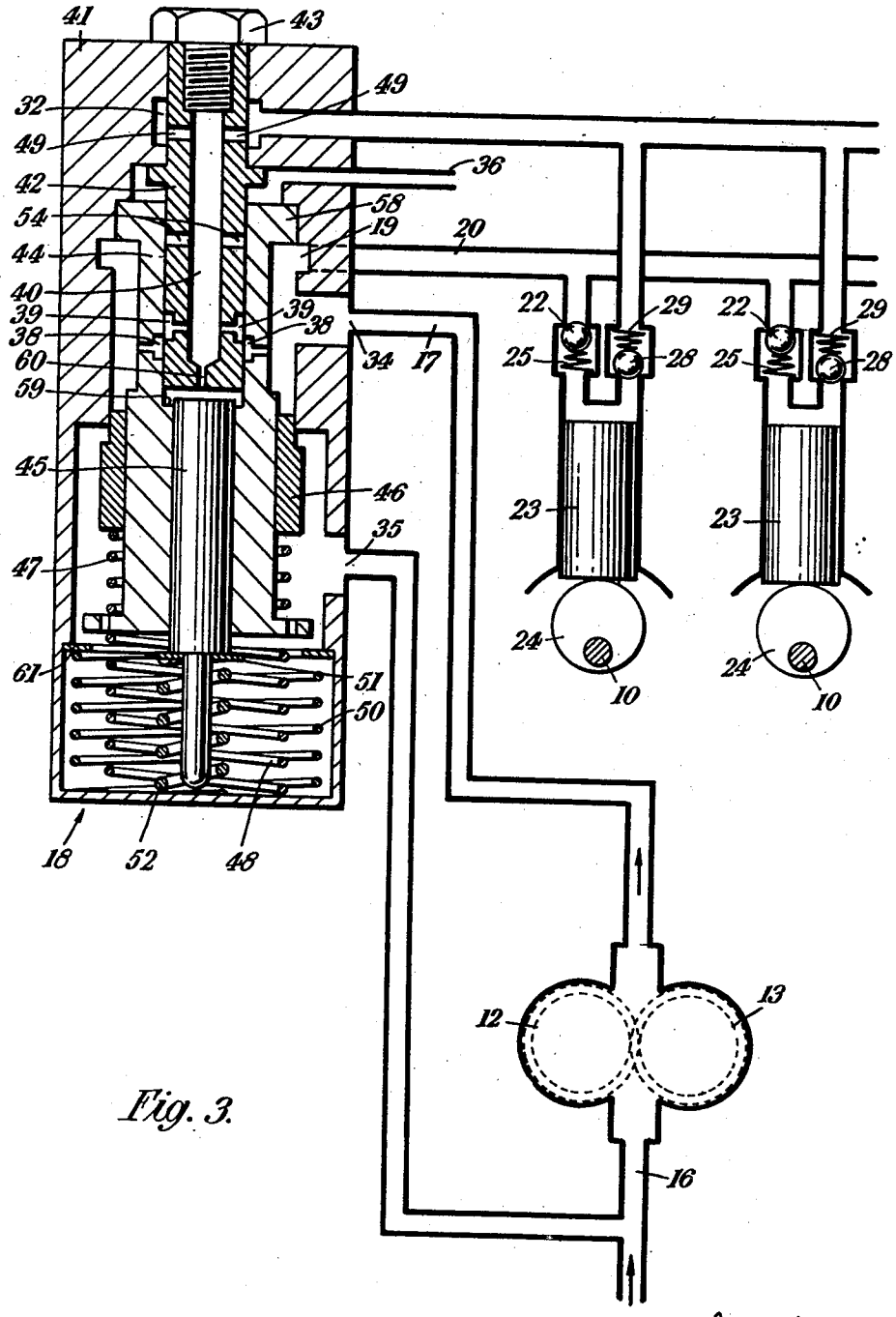


Fig. 3.

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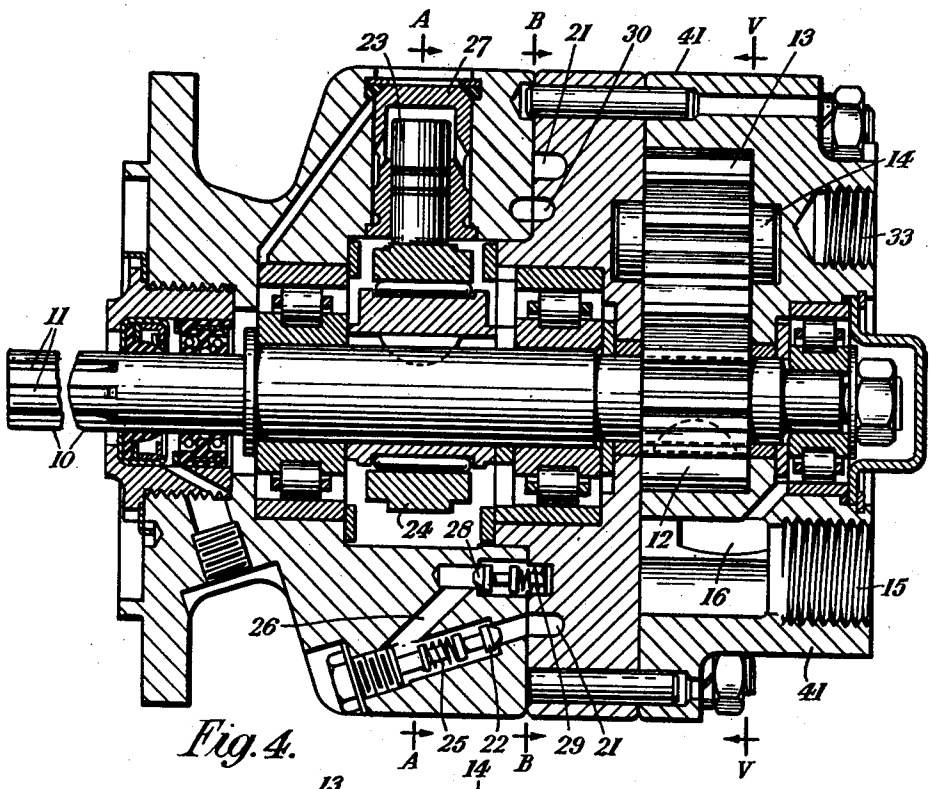


Fig. 4.

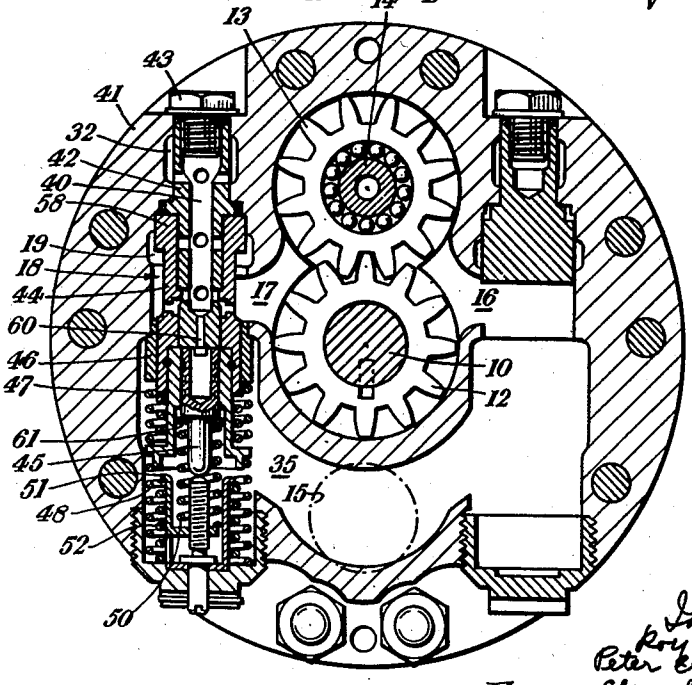


Fig. 5.

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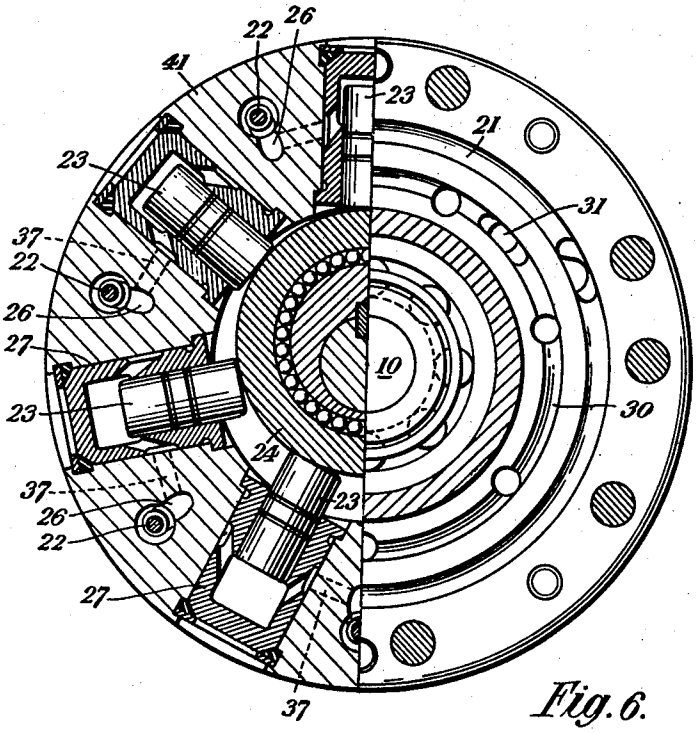


Fig. 6.

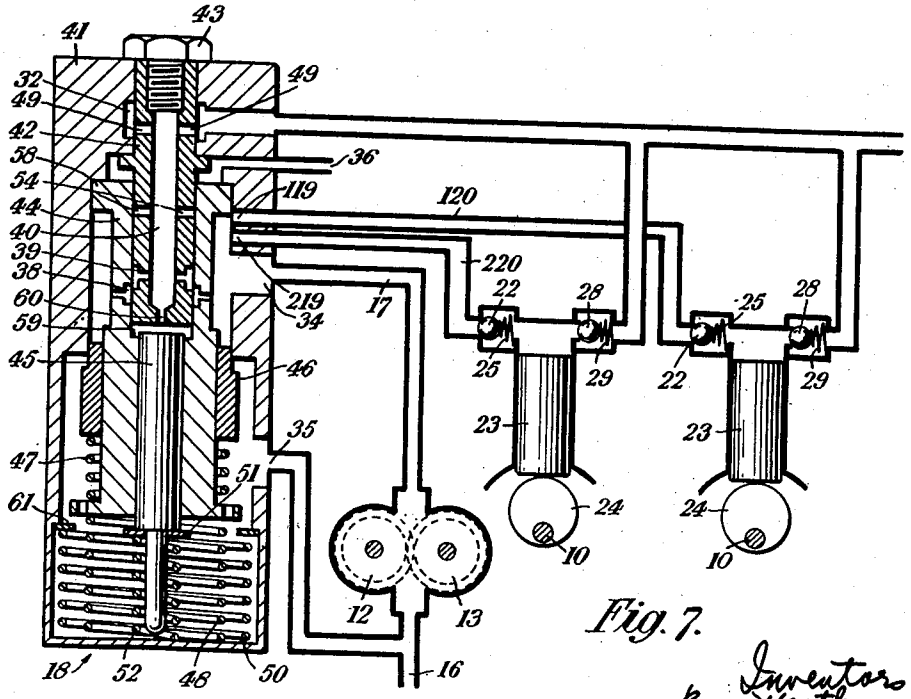


Fig. 7.

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Patented June 30, 1953

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UNITED STATES PATENT OFFICE

2,643,613

HYDRAULIC PUMP

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Application May 31, 1950, Serial No. 165,276
In Great Britain June 2, 1949

8 Claims. (Cl. 103—5)

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In hydraulic systems in which a pump is arranged to supply pressure fluid to one or more jacks, it is seldom possible to arrange for the jacks to operate through their full range of movement at substantially constant pressure. For instance, in retracting certain types of aircraft undercarriages a very low pressure may suffice for the early stages of retraction and the normal working pressure of the system may be necessary only when approaching the fully retracted position. In other cases there may be a pronounced pressure peak at one point in the jack movement, the operating pressure over the bulk of the travel being substantially less than this peak.

Variable delivery pumps are known having an off-loading valve for automatically regulating the delivery so as to maintain a constant pressure between zero and maximum delivery. When the pump is delivering fluid to a service, however, the pressure is determined, not by the characteristics of the pump, but by the restriction in the output circuit to the load operated by the jack and this pressure, during much of the operating cycle, will be lower than the pump working pressure. Under these circumstances the delivery remains constant at the maximum value and the power output of the pump, determined by its delivery and pressure, is less than the desired maximum. Since the pump shaft drive, whether mechanical or electrical, has to be designed to provide the peak working power, it is obviously not being used efficiently under these conditions.

The object of this invention is to provide a hydraulic pump which will give a performance approximating to the theoretical requirement that, over a given range of pressures, the pump will operate at constant power while at pressures below the lower limit of the range, the delivery should remain at the maximum value corresponding to the lower limit of pressure and, at the upper limit of the pressure range, the delivery should fall to zero at constant pressure. A typical example of this theoretical requirement is indicated by the curve AB in Fig. 1 of the accompanying drawings, the working range of pressures being between 1000 and 4200 lbs./sq. in., and the curve AB being a rectangular hyperbola.

The present invention relates to two stage hydraulic pumps of the kind comprising two pumping units arranged in tandem, the second stage pumping unit being a piston pump having a number of radial cylinders whose pistons are operated on their working stroke by a cam or eccentric, with which they are held in contact only by the liquid supplied to them by the first stage pumping unit, and an off-loading valve, subject to the delivery pressure of the second stage, for automatically controlling the delivery of the pump by relieving the first stage pressure back

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to the inlet side of the pump as the delivery pressure rises.

A pump of this kind has the performance indicated by the graph CDEBF in Fig. 1. Over the range CD the first stage pumping unit, which is preferably a gear pump, is effective. At the point D, the off-loading valve opens and the delivery falls, as shown by DE. Over the range EB there is sufficient gear stage pressure to impart full stroke to the pistons of the piston stage, and the pump operates at substantially constant delivery, the slight reduction in delivery from E to B being due to reduction in volumetric efficiency. At the point B the gear stage pressure has fallen to a value such that the inlet valves to all of the pistons of the piston stage are not fully opened, and the delivery falls rapidly to zero over the range BF due to progressive reduction in the stroke imparted to all of the pistons of the piston stage. As will be seen, the performance of this pump is far from the theoretical ideal represented by the line AB. The variation in gear stage pressure with delivery pressure in the case of this known pump is indicated by the line VWX in Fig. 2.

The present invention provides a hydraulic pump of the above kind in which, at a predetermined delivery pressure, one or more of the pistons of the piston stage are automatically rendered completely inoperative while the other pistons are permitted to operate at full stroke.

Thus, in contradistinction to the known pump, in which all the pistons are rendered inoperative together, the pistons of the pump according to the invention are rendered inoperative in stages.

This result may be achieved by differential loading of the inlet valves for admitting pressure from the first stage pumping unit to the cylinders of the second stage or by closure of a port to cut off completely the first stage pressure from those cylinders of the second stage which are to be rendered inoperative.

Thus, in the case where the piston stage has seven cylinders, and three of the inlet valves are loaded by strong springs and the other four inlet valves are loaded with light springs, the pump will control the flow over three ranges. In the first range, the first stage pumping unit will be effective, in the second range the piston stage will be effective with all the pistons operating and in the third range the piston stage will be effective with only four pistons operating, and the capacity of the pump will thus be reduced.

Two alternative forms of pump according to the invention will now be described in detail, by way of example, with reference to the accompanying drawings, in which—

Fig. 1, to which reference has already been made, shows graphs indicating the relationship between the delivery of the pump in gallons per

minute and the delivery pressure in lbs./sq. in., graph AB showing the theoretical ideal, graph CDEBF showing the performance of the known pump above referred to and graph GHIJKBF the performance of the pump according to the invention,

Fig. 2, to which reference has already been made, shows graphs illustrating the relationship between first stage pressure and the delivery pressure of the known pump and of that according to the invention,

Fig. 3 is a diagrammatic lay-out of the first form of pump,

Fig. 4 is a longitudinal section through a practical form of the pump shown diagrammatically in Fig. 3,

Fig. 5 is a section on the line V—V in Fig. 4,

Fig. 6 is a section, the left hand side of the figure being taken on the line A—A in Fig. 4 and the right hand side on the line B—B in Fig. 4, and

Fig. 7 is a diagrammatic lay-out, similar to that of Fig. 2, of the second form of pump.

Like reference numerals designate like parts throughout the figures.

Referring first of all to Figs. 4–6, and to the accompanying diagrammatic Fig. 3, the pump comprises a drive shaft 10, having splines 11 by means of which it may be driven, and carrying a gear wheel 12, meshing with a gear wheel 13 on a shaft 14. The gear wheels 12, 13 constitute the first, or gear, stage of the pump and are fed with liquid from an inlet 15 through a passage 16 (Fig. 5). The liquid is fed under pressure from the gear stage of the pump via a passage 17 (Fig. 5) to an off-loading valve 18. Initially, the liquid passes, as later described, through the off-loading valve 18 to an annulus 19 and thence, through a passage 20 (Fig. 3) to an annular channel 21 (Figs. 4 and 6), whence it has access to the inlet valves 22 of the piston stage of the pump.

The piston stage comprises seven radially arranged pistons 23 which are successively given outward, or discharge, strokes by an eccentric 24 mounted on the pump shaft 10. Normally, on the inlet stroke of each piston, the gear stage pressure in the annulus 21 lifts the associated inlet valve 22 against its spring 25, and allows liquid to enter a passage 26 (Figs. 4 and 6) and to pass thence into the associated pump barrel 27 through a passage 37 (Fig. 6). The gear stage pressure thus serves to return the pistons on the suction stroke.

On the delivery stroke, each piston 23 discharges liquid from its respective barrel 27 into the associated passage 26 and thence, through an outlet valve 28 which opens against a spring 29, into an annular channel 30. The channel 30 communicates, via an outlet 31, with an annular port 32 associated with the off-loading valve 18, and also with an outlet 33 (Fig. 4) from which the liquid delivered by the pump is discharged.

Referring now to Fig. 3, the off-loading valve 18 controls, in three steps, the flow from the pump. The off-loading valve comprises a valve stem 42, rigidly secured in the pump housing 41 by a bolt 43. Slidably mounted on the valve stem 42 is a sleeve 44, which is also a close fit in the housing 41, and in the sleeve 44 is fitted a floating piston 45, of slightly smaller diameter than the valve stem 42. A further sleeve 46 is slidably mounted on the sleeve 44, the upper end of sleeve 46 also being a close fit in the housing 41.

The valve 18 controls the following ports in the pump housing: An inlet port 34 to which the output of the gear stage is applied via the passage 17, a low pressure return port 35, the annular port 32 leading to the high pressure output from the piston stage, and a return port 36 to the tank. The annular groove 19 communicates, by the passage 20, with the inlet to the piston stage. Springs 47, 48, 50 and 52 initially hold the parts in the position illustrated in Fig. 3.

The operation of the valve 18 is as follows:

Step 1

In the initial position liquid from the gear stage can flow directly to the piston stage, from the inlet port 34, via the annular groove 19 and passage 20, and also, via overlapping annular grooves 38, 39 in the parts 44 and 42, an axial bore 40 in the part 42, holes 49 and outlet port 32 directly to the pump outlet. As the delivery pressure rises, as shown by the line GH in Fig. 1, it acts, through a hole 60 in the base of the bore 40, on the small differential cross-sectional area 59 between the two bores of the sleeve 44, and at 1000 lbs./sq.in. is sufficient to overcome the loading of the spring 48. The sleeve 44 will then slide downwards until stopped by a washer 61 loaded by the spring 50. During the first part of this action the overlapping grooves 38, 39 in the parts 44 and 42 are brought out of register and the surplus gear stage liquid is relieved to the port 35 by the sleeve 46 sliding downwards against the spring 47. During the latter part, the spring 47 expands again, finally reducing the gear stage pressure to 100 lbs./sq.in. The piston stage of the pump is then effective as indicated by the line IJ in Fig. 1.

In Fig. 2, the graph drawn in full lines indicates the relationship for this pump between gear stage pressure and delivery pressure. The gear stage pressure is initially the same as the delivery pressure and it rises, as indicated by PQ to a value of 1000 lbs./sq.in. Then the valve 18 responds, as just described, to cause the gear stage pressure to fall, as indicated by QR, to 100 lbs./sq.in.

Step 2

When the delivery pressure rises to 3200 lbs./sq.in., the gear stage pressure remaining at 100 lbs./sq.in., the delivery pressure acts, through the port 32, the holes 49, and the bore 40, on the differential area 59 of the sleeve 44 to overcome the load of spring 50, and the sleeve 44 will slide downwards until stopped by a washer 51 and the spring 52. During this action the spring 47 will expand further, thus reducing the gear stage pressure to 30 lbs./sq.in. as indicated by ST in Fig. 2. The inlet valves 22 to the pistons are spring loaded, three with strong springs 25, and four with light springs 25, and this action will have the effect of preventing the opening of the three strongly sprung valves 22. Pumping will therefore continue at a reduced capacity as indicated by the line KB in Fig. 1.

Step 3

When the delivery pressure rises to 4200 lbs./sq. in., the gear stage pressure remaining at 30 lbs./sq. in. as indicated by TU in Fig. 2, the load of spring 52 is overcome, and the sleeve 44 will slide down until its head 53 closes the annular groove 19 connecting the gear stage to the piston stage. At this point the pistons receive no further supply, and the pump is fully off-loaded, as indicated by BF in Fig. 1. Any fur-

ther movement of the sleeve 44 downwards will result in relief holes 54 being uncovered to open communication between the ports 32, 36, thus preventing excessive pressure from developing.

As will be clear from Fig. 1, the change in delivery pressure in three steps provides a reasonably close approximation to the theoretical requirement shown by the line AB.

As an alternative to arranging for one group of three pistons to be rendered inoperative before the other group of four pistons by reason of differential loading of the inlet valves 22, the sleeve 44 may, as indicated in Fig. 7, be arranged to control two ports 119, 219, for conducting liquid from the gear stage of the pump to the inlet valves 22 of the piston stage. The port 119 communicates via a passage 120 with the inlet valves 22 of three of the pistons and the port 219 communicates via a passage 220 with the inlet valves 22 of the other four pistons. When, at point J, Fig. 1, the sleeve 44 moves downwards against the action of the spring 50 into contact with the washer 51, the sleeve 44 closes the port 119 and so renders three of the plungers inoperative by depriving them of gear stage pressure. Thereafter, at the higher delivery pressure represented by the point B, Fig. 1, the sleeve 44 will move down further against the spring 52 to close the port 219 and render the remaining four pistons inoperative.

It will be appreciated that, if desired, the cylinders of the piston stage may be divided into more than two groups which are rendered successively inoperative on increase of the delivery pressure, either by appropriate differential loading of their inlet valves or by the provision of more than two ports, one communicating with each group of cylinders, which are successively closed by the off-loading valve.

What we claim as our invention and desire to secure by Letters Patent is:

1. A two stage hydraulic pump, comprising a first pumping unit, a second pumping unit including a plurality of radial cylinders, pistons in said cylinders, inlet and outlet valves associated with each of said cylinders, and positively driven means for reciprocating said pistons in said cylinders to cause them to discharge liquid under pressure through said outlet valves, a conduit for supplying liquid under pressure from the first pumping unit to the inlet valves of the second pumping unit, an outlet for receiving the discharge from the outlet valves of the second pumping unit, a connection between said conduit and said outlet, and an off-loading valve, responsive to the delivery pressure in said outlet, for controlling the hydraulic pressure in said conduit and also controlling communication between said conduit and said connection, said off-loading valve comprising a spring loaded member controlling a port for initially allowing liquid to flow from said conduit into said connection, said member being arranged to close said port in response to increase in the delivery pressure to a first predetermined value, a pair of spring loaded washers constituting successive abutments for said member, as it moves in response to further increase in the delivery pressure, said abutments yielding successively at predetermined higher values of the delivery pressure, to permit of stepwise movement of the member, and a spring-loaded sleeve surrounding said member and serving, in response to movement thereof, to effect progressive opening of a relief port to reduce, in steps, the hydraulic pressure prevailing in said conduit.

2. A two stage hydraulic pump as claimed in claim 1, comprising weak springs loading certain of said inlet valves and stronger springs loading the rest of said inlet valves, the pressure in said conduit being reduced, on yielding of said first abutment, to a value such that the inlet valves with the stronger springs will remain closed, and said spring loaded member being arranged, on yielding of said second abutment, to close said conduit and thereby render the rest of the inlet valves inoperative.

3. A two stage hydraulic pump as claimed in claim 1, comprising a first port, controlled by the spring-loaded member and affording communication between said conduit and certain of said inlet valves, and a second port, controlled by said spring-loaded member and affording communication between said conduit and others of said inlet valves, said spring-loaded member being arranged, on yielding of said first abutment, to close said first port and, on yielding of said second abutment, also to close said second port.

4. A two stage hydraulic pump, comprising a first pumping unit, a second pumping unit including a plurality of radial cylinders, pistons in said cylinders, inlet and outlet valves associated with each of said cylinders, and positively driven means for reciprocating said pistons in said cylinders to cause them to discharge liquid under pressure through said outlet valves, a conduit for supplying liquid under pressure from the first pumping unit to the inlet valves of the second pumping unit, an outlet for receiving the discharge from the outlet valves of the second pumping unit, and an off-loading valve, responsive to the delivery pressure in said outlet, for controlling the hydraulic pressure in said conduit, said off-loading valve comprising a slidable member exposed to the delivery pressure in said outlet, spring means balancing said slidable member against said delivery pressure and arranged to yield in stages in response to increase in the delivery pressure to certain predetermined values, and means responsive to movement of said slidable member for effecting a step wire reduction in the hydraulic pressure in said conduit from an initial high value first to a lower value sufficient to maintain all the pistons of the second pumping unit effective and thereafter to a still lower value at which certain only of the pistons of the second pumping unit are effective, the other pistons being inoperative.

5. A two stage hydraulic pump, comprising a first pumping unit, a second pumping unit including a plurality of radial cylinders, pistons in said cylinders, inlet and outlet valves associated with each of said cylinders, and positively driven means for reciprocating said pistons in said cylinders to cause them to discharge liquid under pressure through said outlet valves, a conduit for supplying liquid under pressure from the first pumping unit to the inlet valves of the second pumping unit, an outlet for receiving the discharge from the outlet valves of the second pumping unit, and an off-loading valve, responsive to the delivery pressure in said outlet, for controlling the hydraulic pressure in said conduit, said off-loading valve comprising a first slidable member exposed to the delivery pressure in said outlet, spring means balancing said slidable member against said delivery pressure and arranged to yield in stages in response to increase in the delivery pressure to certain predetermined values,

a second slidable member, subject to the hydraulic pressure in said conduit, a relief port controlled by said second slidable member, a spring between said first and second slidable members and acting on said second slidable member in opposition to the hydraulic pressure in said conduit, said spring maintaining said relief port closed at low delivery pressure but permitting, in response to movement of said first slidable member on increase in the delivery pressure, of movement in stages of said second slidable member to reduce the hydraulic pressure in said conduit first to a lower value sufficient to maintain all the pistons of the second pumping unit effective and thereafter to a still lower value at which certain only of the pistons of said second pumping stage are effective, the other pistons being inoperative.

6. A two stage hydraulic pump, comprising a first pumping unit, a second pumping unit including a plurality of radial cylinders, pistons in said cylinders, inlet and outlet valves associated with each of said cylinders, and positively driven means for reciprocating said pistons in said cylinders to cause them to discharge liquid under pressure through said outlet valves, a conduit for supplying liquid under pressure from the first pumping unit to the inlet valves of the second pumping unit, an outlet for receiving the discharge from the outlet valves of the second pumping unit, a connection between said conduit and said outlet, and an off-loading valve, responsive to the delivery pressure in said outlet, for controlling the hydraulic pressure in said conduit and also controlling communication between said conduit and said connection, said off-loading valve comprising a slidable member exposed to the delivery pressure in said outlet, spring means balancing said slidable member against said delivery pressure and arranged to yield in stages in response to increase in the delivery pressure to certain predetermined values, said slidable member maintaining said connection open so long as the delivery pressure in said outlet is below a predetermined value, but being effective, when the delivery pressure reaches said predetermined value to close said connection and means responsive to movement of said slidable member for effecting a stepwise reduction in the hydraulic pressure in said conduit from an initial high value first to a lower value sufficient to maintain all the pistons of the second pumping unit effective and thereafter to a still lower value at which certain only of the pistons of the second pumping unit are effective, the other pistons being inoperative.

7. A two stage hydraulic pump, comprising a first pumping unit, a second pumping unit including a plurality of radial cylinders, pistons in said cylinders, inlet and outlet valves associated with each of said cylinders, springs loading said inlet valves, one group of inlet valves having weaker loading springs than another group of inlet valves, and positively driven means for reciprocating said pistons in said cylinders to cause them to discharge liquid under pressure through said outlet valves, a conduit for supplying liquid under pressure from the first pumping unit to the inlet valves of the second pumping unit, an outlet for receiving the discharge from the outlet valves of the second pumping unit, a connection between said conduit and said outlet, and an off-loading valve, responsive to the delivery pressure in said outlet, for controlling the hydraulic pressure in said conduit, said off-loading valve comprising a slidable member exposed to the delivery pressure in said outlet, spring means balancing said slidable member against said delivery pressure and arranged to yield in stages in response to increase in the delivery pressure to certain predetermined values, said slidable member maintaining said connection open so long as the delivery pressure in said outlet is below a predetermined value, but being effective, when the delivery pressure reaches said predetermined value to close said connection, and means responsive to movement of said slidable member for effecting a step-wise reduction in the hydraulic pressure in said conduit from an initial high value first to a lower value sufficient to maintain all the pistons of the second pumping unit effective and thereafter to a still lower value at which the group of inlet valves with the stronger loading springs will remain closed and the other group of outlet valves alone will be effective to admit liquid to their respective cylinders.

8. A two stage hydraulic pump, comprising a first pumping unit, a second pumping unit including a plurality of radial cylinders, pistons in said cylinders, inlet and outlet valves associated with each of said cylinders, and positively driven means for reciprocating said pistons in said cylinders to cause them to discharge liquid under pressure through said outlet valves, a conduit for supplying liquid under pressure from the first pumping unit to the second pumping unit, a first port leading from said conduit to certain of said inlet valves, a second port leading from said conduit to others of said inlet valves, and an off-loading valve, responsive to the delivery pressure in said outlet, for controlling the hydraulic pressure in said conduit and also controlling the flow of liquid from said conduit through said ports, said off-loading valve comprising a slidable member exposed to the delivery pressure in said outlet, spring means balancing said slidable member against said delivery pressure and arranged to yield in stages in response to increase in the delivery pressure to certain predetermined values, and means responsive to movement of said slidable member for effecting a step-wise reduction in the hydraulic pressure in said conduit, said slidable member being arranged to close said first port when the delivery pressure attains a predetermined value and to close said second port when the delivery pressure attains a second and higher predetermined value.

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