Jan. 4, 1955 R. A. STRUB 2,698,576

AUTOMATIC CONTROL OF INTERSTAGE PRESSURES IN PUMPS

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Fig. 1.

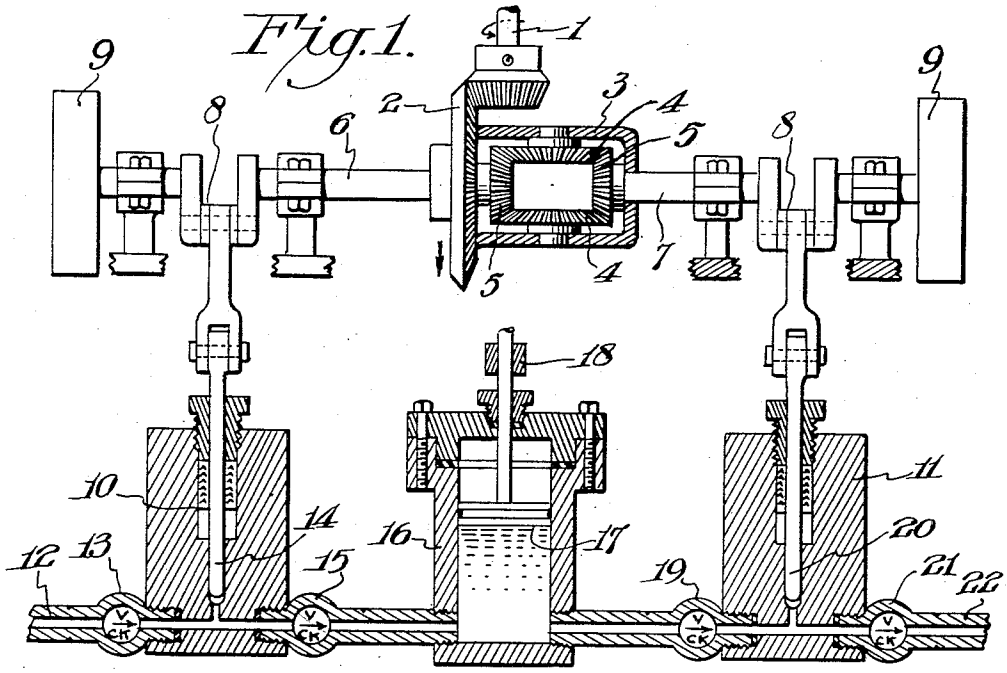
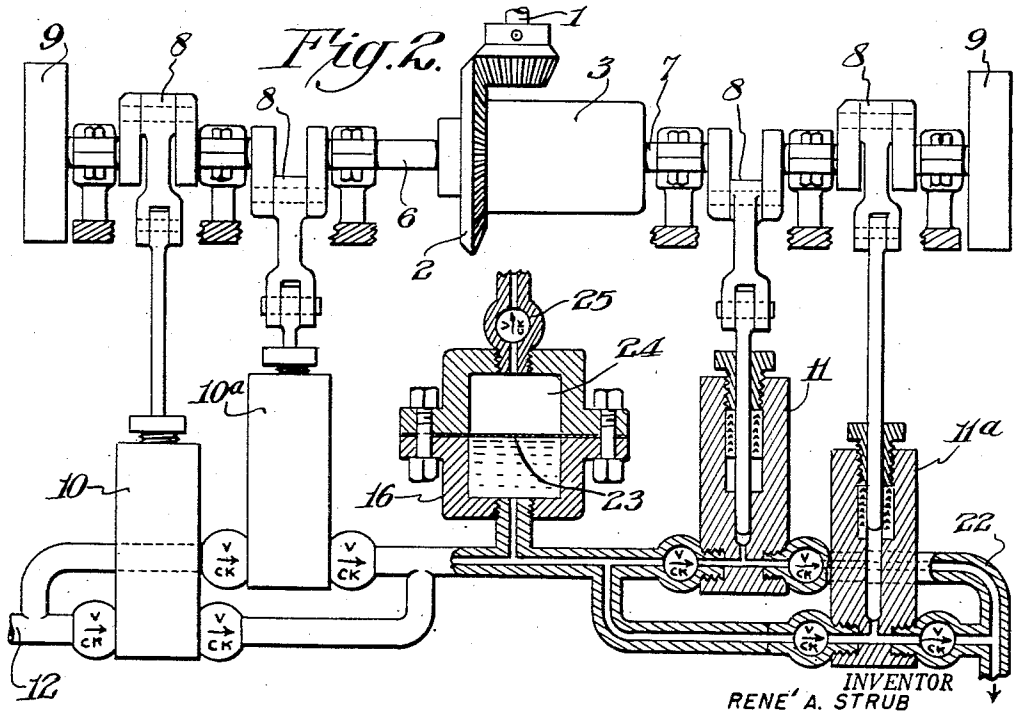


Fig. 2.



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Fig. 3.

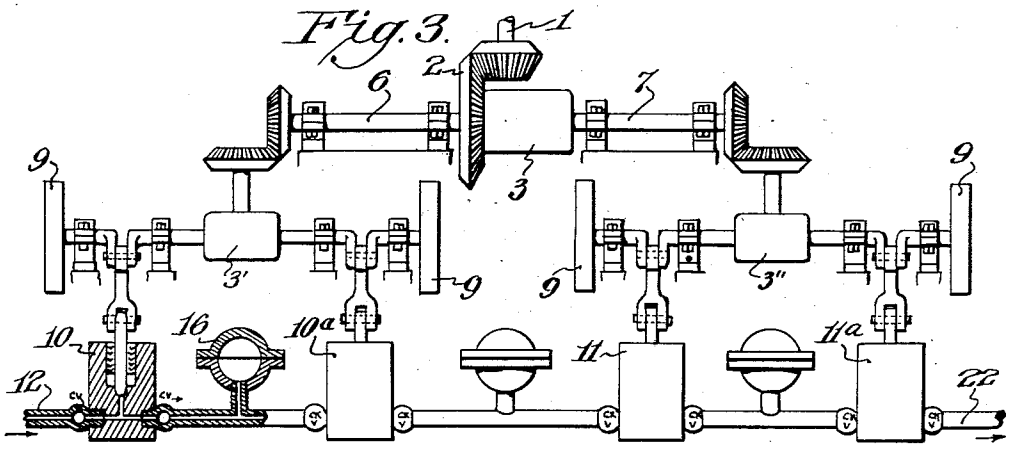


Fig. 4.

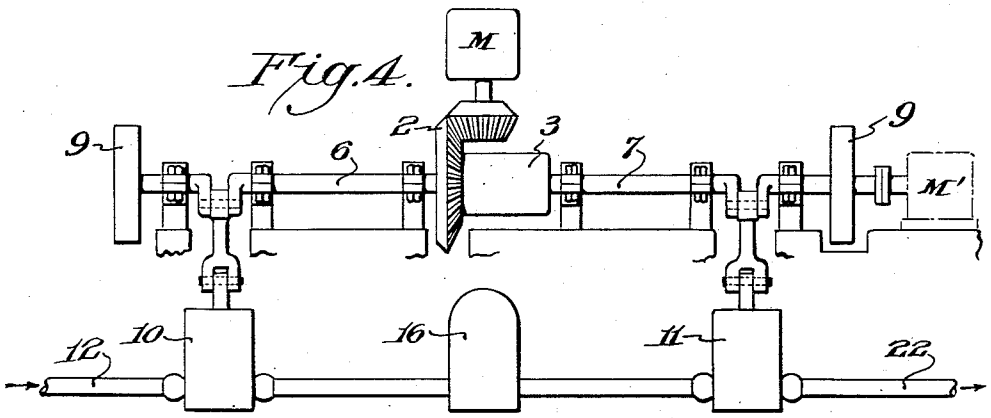


Fig. 5.

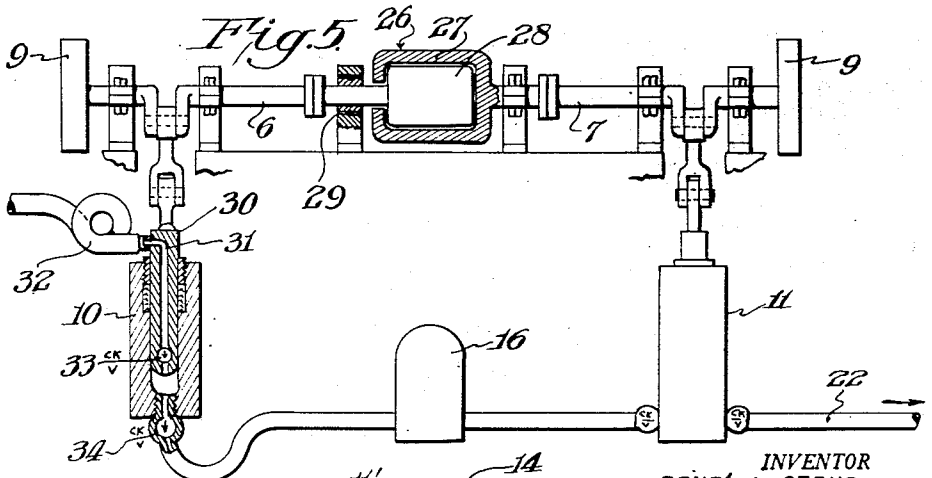
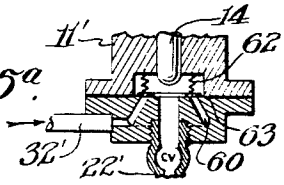


Fig. 5a.



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Fig. 6.

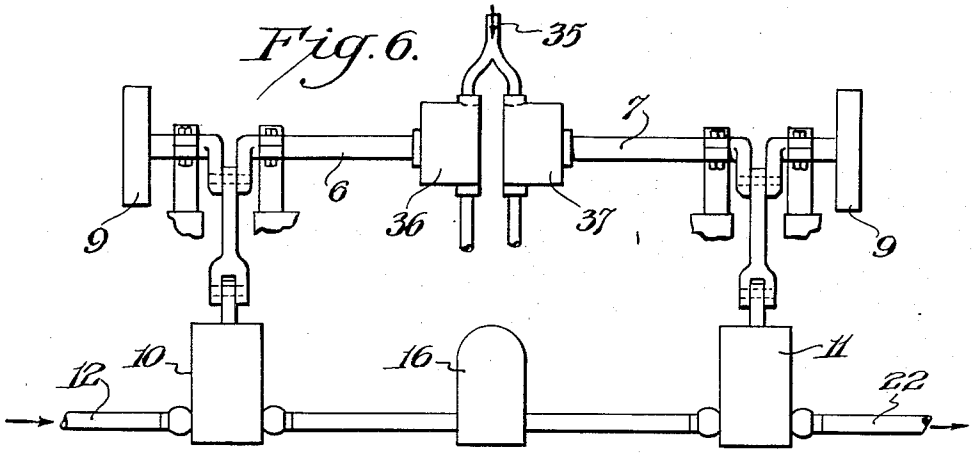


Fig. 7.

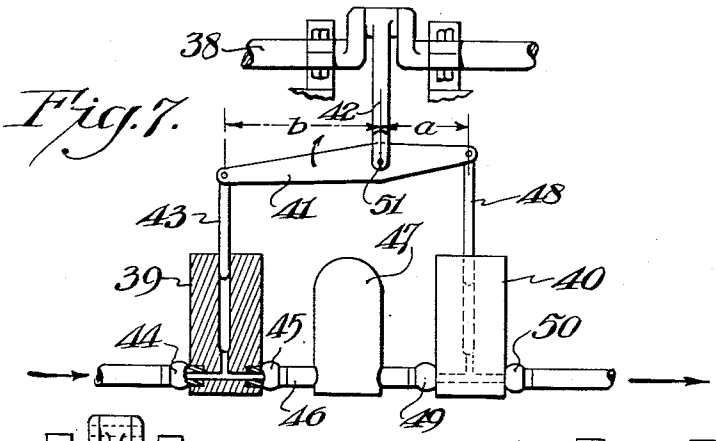
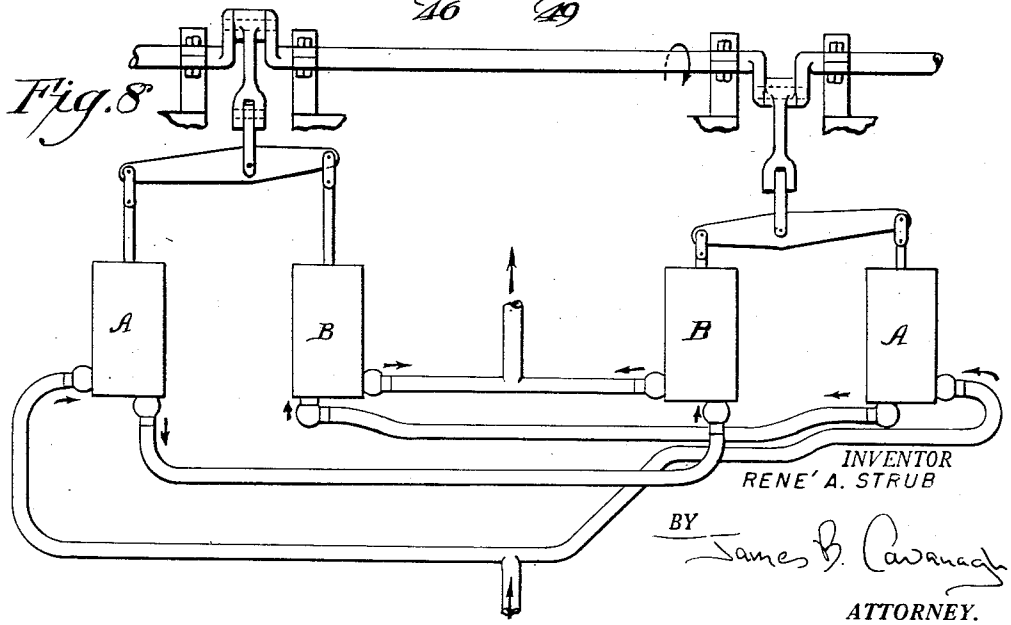


Fig. 8



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AUTOMATIC CONTROL OF INTERSTAGE PRESSURES IN PUMPS

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Application October 6, 1951, Serial No. 250,044

4 Claims. (Cl. 103—5)

This invention relates to multi-stage pumps, particularly adapted for pumping liquids to extremely high pressures.

Many varieties of pumps are available for compressing either liquids or gases to moderately high pressures, as, for example, pressures of 1000 atmospheres or even 1500 atmospheres. Entirely new problems are encountered, however, when one attempts to compress a liquid to even higher pressures, as, for example, pressures of 2000 atmospheres, or 3000 atmospheres, or more, i. e., "superpressures."

If one attempts to achieve these superpressures in a single stage pump, the metal portions of the pump are subjected to a very great range of stresses. As an example, the cylinder of a reciprocating pump would be subjected, during each cycle, to a pressure of 3000 atmospheres, followed immediately by a pressure of only one atmosphere. Experience has shown that this extreme range of alternating stresses greatly decreases the fatigue life of the metal parts. The metal parts can withstand extremely high pressures over long periods of time, provided the pressure is relatively constant or does not fluctuate over too wide a range, but they cannot withstand changes in stress which are both frequent and extreme. Accordingly, the effective life of such a pump can be very greatly increased if it is possible to employ two or more pressure stages, with only a moderate increase in pressure being produced in any one given stage.

Now, in the case of gases or vapors, it is possible to construct satisfactory multi-stage, superpressure pumps by merely extending the principles employed in constructing multi-stage, moderate pressure pumps. In the case of liquids, however, this is not possible, because of the fundamental difference in the compressibility of gases and liquids. In a gas compressor, if the output of one stage varies somewhat from the design figure, the variation will not upset the entire balance of the pumping system, because the gas is compressible and slight deviations in output are merely absorbed by producing a slightly higher pressure in the compressible gas. In the case of liquids, however, which are relatively incompressible, even the slightest variation in the output of one stage of the pump will drastically upset the pressure balance in the entire system. These difficulties become particularly acute when very high pressures are employed, because of the difficulty of designing pumps which will give a precise output, i. e., pumps which do not leak at these pressures or which do not vary in their output over long periods of time. In pumping a liquid to 3000 atmospheres in a two-stage pump, the first stage should build up a pressure of, say, 1500 atmospheres and the output from this first stage should then be passed to the second stage which would increase the pressure to 3000 atmospheres. Since the liquid is essentially incompressible, any slight leakage around the sealing rings of the first stage will decrease the output of the first stage and this slight decrease in output will in turn greatly reduce the interstage pressure in the pump. The net result will be that the second stage will be doing much more than its share of the work and the entire purpose of having a multi-stage pump to protect the metal parts from extreme ranges of pressure will be defeated.

Accordingly, it is an object of this invention to provide novel multi-stage pumps. Another object of this invention is to provide multi-stage pumps which are particularly adapted for pumping liquids to extremely high pressures. Other objects of this invention will appear hereinafter.

According to this invention, there are provided pumps comprising a plurality of pumping stages connected together in series and all driven from a common source of power through a unit which distributes the power proportionately to the various pumping stages, whereby the amount of work done by one stage is automatically proportioned to the work being done by one or more other stages.

According to certain embodiments of the invention, this automatic proportioning of the work done by the various stages can be achieved by employing various devices such as a differential, a balancing beam, several turbines, or the like.

The invention will be illustrated in certain of its aspects by reference to the drawings.

Figure 1 is a diagrammatic view of a two-stage pump in which the two reciprocating pumps are connected in series and are driven from a common source of power through a differential.

Figure 2 is a diagrammatic view of a two-stage pump in which each stage is made up of two reciprocating pump units connected in parallel, and the two stages are connected in series and driven from a common source of power through a differential.

Figure 3 is a diagrammatic view of a four-stage pump in which the four reciprocating pump units are driven from a common source of power through a combination of three differentials.

Figure 4 is a diagrammatic view of a two-stage pump similar to that shown in Figure 1, except that there is shown an additional motor which assists in the driving of the second pumping stage.

Figure 5 is a diagrammatic view of a two-stage pump driven by an electric motor which is so mounted that both the normally stationary outer casing and the rotor are free to rotate, one pumping stage being connected to the casing and the other to the rotor. In this figure, the feed to the first stage is introduced through the piston itself.

Figure 5*a* is a diagrammatic view of a combination valve assembly which is particularly suitable for use with the pumps described herein.

Figure 6 is a diagrammatic view of a two-stage pump in which two reciprocating pump units are connected in series and are driven from a common source of steam through two steam turbines.

Figure 7 is a diagrammatic view of a two-stage pump in which the two reciprocating pump units are driven from a common source of power through a balancing beam.

Figure 8 is a diagrammatic view of a two-stage pump in which each stage is made up of two reciprocating pump units and all of these reciprocating pumps are driven from a common source of power through two balancing beams.

Referring now to Figure 1, power is delivered to the assembly through drive shaft **1** from a suitable motor or engine, not shown. The power is transmitted to bevel gear **2** of a differential, which may be any one of several types of differentials ordinarily employed, for instance, in automobiles. The bevel gear **2** is rigidly attached to the frame **3**, and through the frame to the gears **4**, which are free to rotate independently of each other. The gears **4** transmit power to the gears **5**, which in turn transmit the power to shafts **6** and **7**, respectively. These shafts are connected to the piston rods by a suitable device for converting rotary motion into reciprocating motion, such as that shown at **8**, and have flywheels **9** mounted at the ends thereof in order to insure an even flow of power. Shaft **6** is connected to the reciprocating pump unit which is generally designated as **10**, and which constitutes the first stage of the overall pump. Shaft **7** is connected to the reciprocating pump unit which is generally designated as **11**, and which constitutes the second stage of the overall pump assembly. The pump units are provided with suitable fluid seals, which may be packing, or rings, or the like. Liquid is introduced from line **12** through check valve or non-return valve **13** on the upstroke of piston or plunger **14**. On the downstroke of the plunger,

the pressure on the liquid is built up to an intermediate level and the liquid passes out through the check valve **15**. A reservoir, consisting of a pressure accumulator or surge vessel **16**, is placed along the intermediate pipe in order to smooth out pulsations and produce an even interstage pressure. This vessel contains a piston **17** which is free to move up and down in the vessel. If desired, this piston may be guided by a piston rod which runs through one or more bushings designated generally as **18**. This piston may be held in position by a spring at the top of the piston rod, or by a suitable vapor pressure in the top of the vessel. Alternatively, the liquid in the vessel may itself be so compressible that an additional elastic medium is superfluous. The liquid which is now at the interstage pressure passes into the second pumping unit through check valve **19** on the upstroke of piston **20**. The liquid is built up to the ultimate pressure on the downstroke of piston **20** and passes out through check valve **21** into the outlet line **22**.

In operation, the effect of the differential is to transmit the same amount of force to each of the shafts **6** and **7**. Assuming that the first stage is building up a pressure of 1500 atmospheres and that the second stage is then increasing the pressure to 3000 atmospheres, each of the two stages is then contributing an equal increase in pressure, and the operation of the differential will be such that the gears **4** are not turning on their axes and the rotational force of the frame **3** is being transmitted directly and equally to shafts **6** and **7**. Now let us assume that the first stage develops a slight leak, so that its output drops off to some extent. This will have the effect of decreasing the interstage pressure and the load on the second stage will thus be momentarily increased. At this point, however, the differential will automatically increase the speed of shaft **6** and decrease the speed of shaft **7**, so that the outputs of the two stages will be brought back to the point where they are equal. This difference in the rotational speeds of shafts **6** and **7** is made possible by the fact that the gears **4** are free to rotate on their axes. One of the gears **4** will rotate in one direction, while the other gear **4** will rotate in the opposite direction, thus making it possible for the shafts **6** and **7** to rotate at different speeds.

During operation it will be understood that, if the high pressure cylinder **11** receives the liquid being pumped from reservoir **16** at, for example, 1500 atmospheres, the liquid will do work on piston **20** during its upstroke, i. e., suction stroke, and will thereby slightly accelerate right-hand flywheel **9**, storing energy therein. Due to the action of the differential, acceleration of right-hand flywheel **9** will be accompanied by an equal deceleration of the left-hand flywheel **9**. On the downstroke of piston **20**, right-hand flywheel **9** will deliver its increment of stored energy to piston rod **20**, thus decelerating proportionately and simultaneously accelerating left-hand flywheel **9** in the same amount. When first stage piston **14** commences its downstroke, left-hand flywheel **9** will decelerate and right-hand flywheel **9** will accelerate an equal amount, this cycle repeating for each pumping cycle, the equal torque-distributing action of the differential enabling shaft **1** to supply energy to each pump sufficient to make up for frictional or other losses encountered in each stage while, at the same time providing equal pumping torques to each stage in the amount necessary for each to increase the pressure on the liquid in process by 1500 atmospheres. Accordingly, on the pumping stroke driving shaft **7** will only have to supply the energy, and therefore the average torque, necessary for increasing the pressure on the liquid from 1500 atmospheres level to 3000 atmospheres level. Similarly, shaft **6** is required to supply energy to increase the pressure on the liquid from atmospheric pressure to 1500 atmospheres, making the average torque demands of shafts **6** and **7** equal, the peak loads being taken for each of the stages by their respective flywheels **9**. Thus, there exists a constant exchange of energy between the flywheels and the crankshafts during each cycle of operation, and the net torques acting on each of the shafts **6** and **7** are always equal and constant. Pump **10** necessarily has the same output as pump **11**, hence their cycle speeds are likewise equal.

Referring now to Figure 2, the two shafts **6** and **7** are driven through differential **3**, which in turn is driven from a single source of power through shaft **1**. The shafts **6** and **7** are each connected to two reciprocating pump units,

as shown at **8**, and each have flywheels **9** mounted at the ends thereof. Reciprocating pumps **10** and **10***a* are so connected to shaft **6** that they are out of phase with one another, and when one of the pistons is on the upstroke, the other is on the downstroke. These two units are connected in parallel to the inlet line **12**. The fact that the two units are out of phase with one another results in a more uniform torque and in a more even flow of liquid into the interstage area. More than two units can be used in order to obtain a better uniformity of flow and torque. A vessel **16** is shown, which serves to smooth out the interstage pressure. This vessel is provided with a diaphragm **23**, which is backed up by air or other gas under pressure as shown at **24**. The gas can be introduced through valve **25** under pressure. Alternatively, other types of surge vessels can be employed, without using gas cushions. The second stage consists of the two reciprocating pump units, **11** and **11***a*. These two units are also connected in parallel and are so mounted that they operate out of phase with one another and discharge the liquid at the ultimate pressure into outlet line **22**. Each of these pumping units is equipped with suitable check valves, as shown.

Referring now to Figure 3, power is provided from shaft **1** to the main differential **3**, which drives shafts **6** and **7**. These shafts in turn drive differentials **3'** and **3''**, respectively. Flywheels **9** are mounted on the ends of the output shafts from differentials **3'** and **3''**. Each of the output shafts drives a reciprocating pump unit. Such an assembly might, for instance, take liquid at atmospheric pressure from line **12**, and increase the pressure thereon by 1000 atmospheres in each of the four stages, so that liquid at 4000 atmospheres pressure will be pumped out through outlet line **22**. Suitable devices for evening out the interstage pressures are shown. The effect of the three differentials arranged as shown is to automatically compensate for the changes in the output in any one of the reciprocating pump units, with the result that the pressure increase in each unit will be kept equal to that in every other unit.

Referring now to Figure 4, a two-stage assembly is depicted which is very similar to the two-stage assembly depicted in Figure 1. The parts which correspond to those shown in Figure 1 are identified by the same numbers as are employed in Figure 1. The assembly shown in this figure differs from that shown in Figure 1 only in that, in addition to the main motor M, an extra motor M' is provided, which assists differential **3** in driving shaft **7**. As the result of this additional power added to shaft **7**, the second pumping stage **11** can do more work than the first pumping stage **10**. Accordingly, the interstage pressure, which might normally be about halfway between the inlet pressure at **12** and the outlet pressure at **22**, will now tend to level out at a pressure which is closer to the inlet pressure **12** than it is to the outlet pressure **22**. In place of a motor attached to shaft **7**, one may attach a motor to shaft **6**, which will tend to raise the interstage pressure until it is closer to the outlet pressure **22**. Instead of placing a motor on one side of the differential, the same type of effect can be achieved by placing a consumer of power, such as a generator or the like, on the opposite side of the differential. In these ways, the interstage pressure may not only be controlled automatically, but the level at which it is controlled may be chosen at will.

Figure 5 shows an embodiment of the invention which involves the use of an electric motor to drive the two pumping stages. The electric motor, designated generally as **26**, is mounted in such a way that both the normally stationary outer casing **27** and the rotor or armature **28** are free to rotate. This may be accomplished, for instance, by mounting the motor on bearings **29**. The rotor and the casing are each attached to one of the drive shafts **6** and **7**. When electric power is supplied to the motor, from a source not shown, the casing will rotate in one direction while the rotor rotates in the opposite direction, and the power produced by the motor will be automatically apportioned between the two shafts.

There is also shown in Figure 5 a different arrangement for introducing the feed into one of the pumping stages. In this instance, the first pumping stage, designated generally as **10**, consists of a piston or plunger

30 mounted to reciprocate in a cylinder. The plunger is provided with an internal passage 31, which is connected to a flexible hose 32, or the like, through which the feed is introduced. The check valve 33, mounted within the plunger, opens on the upstroke to permit the flow of fluid into the cylinder. On the downstroke of plunger 30, check valve 33 closes and fluid is forced out past check valve 34 into the interstage area 16, and thence through the second pumping stage 11 to the outlet line 22. The advantage of this arrangement, whereby the feed is introduced through the piston or plunger, lies in the fact that it makes it possible to eliminate cross-bores in the cylinder, thus eliminating a frequent source of failures in high pressure cylinders. This type of pump, known as a uniflow pump, is designed in such a way that the fluid flows through the pump in a uniform direction and there are no sharp corners around which the fluid must flow. Such a design has very great advantages when working with either gases or liquids at very high pressures.

Figure 5a shows a combination valve which can be used in connection with any of the individual reciprocating pumping units shown herein. A piston 14 is mounted to reciprocate in cylinder block 14'. On the upstroke of piston 14, fluid is drawn in from feed line 32', through an annular passage 60, and past the check valve 63, which is in the form of an annular ring, and which raises up against the force of the spring 62. On the downstroke of piston 14, the spring 62 closes the check valve 63, and the fluid is forced out under pressure through the check valve 22'. This kind of valve eliminates the cross-bores which are usually present in high pressure, reciprocating pumps, and thus eliminates a frequent cause of failures. The valve can be employed with any one of the various pumping stages, but its greatest utility is in those instances in which the feed being introduced through this valve is already under considerable pressure. In such a case, the pressure within the annular passage 60 is at all times pushing in on the adjacent metal and helps the metal to withstand the even greater pressure which exists on the downstroke within the main bore of the cylinder. In place of the annular passage 60, one may provide a number of slots, or merely a single slot. Such a design would provide for a greater amount of metal to support the pressure within the main bore, and would thus be more useful when the suction pressure is low and furnishes no appreciable support itself. It is understood, of course, that neither this valve nor any of the other units shown herein need to be operated only in the positions shown. For example, the entire valve shown in Figure 5a could be turned upside down, so that the compression stroke of the piston would actually be an upward stroke.

Figure 6 shows an embodiment of the invention wherein steam under pressure is passed at a given rate of speed through line 35 to a Y or T connection, and thence into two separate steam turbines 36 and 37. These two steam turbines drive shafts 6 and 7, respectively, each of which is provided with a flywheel 9. The first stage of the assembly consists of a reciprocating pump unit 10, which is driven from shaft 6, and the second stage of the assembly consists of reciprocating pump unit 11, which is driven from shaft 7. Vessel 16 is provided to smooth out the interstage pressure. The arrangement is such that the same amount of power is provided to the two steam turbines 36 and 37. If one of the pumping units should be doing more than its share of the work, the resistance on that turbine wheel would be increased, with the result that its speed would tend to diminish and the work done by the two units would then be brought back to the same level. The device may or may not include speed regulators for the turbines. The work done by the overall assembly can be controlled by providing a throttling device in line 35, or the proportion of work done by each of the pumping units can be altered by providing throttling devices in the individual lines leading to each of the two turbines. By following this latter technique, it is possible to distribute the load on the two pumping units in any ratio which may be desired, rather than having the load distributed equally between the two units. In any event, however, once the assembly is set up, any changes in the output of either one of the pumping units would be automatically compensated for by the operation of the turbines connected in the manner shown.

Referring now to Figure 7, crank shaft 38 drives two pumps 39 and 40 working in series. These pumps are connected through the lever or balancing beam 41 to the drive rod 42. On the upstroke of the drive rod 42, piston rod 43 will tend to move upwardly and will draw liquid into the first stage through check valve 44. This liquid will then be compressed and forced out through check valve 45 into the interstage line 46. Vessel 47 serves to smooth out the interstage pressure. On the upstroke of piston rod 48, the liquid flows through check valve 49 into cylinder 40. On the next downstroke of piston rod 48, the liquid is forced out through check valve 50 at the ultimate pressure. The balancing beam 41 is mounted on drive rod 42 at fulcrum 51. The amount of work done by the two individual pumping units will be determined by the ratio of the distances *a* and *b* as measured along the balancing beam 41. If the balancing beam is mounted off-center, one of the pumps will do more work than the other. The operation of the balancing beam is such that, if one of the units is doing more than its share of the work, the effective stroke of the piston in that unit will automatically be decreased by the operation of the balancing beam, and the system will thus automatically come back into equilibrium. With this arrangement, the pump will develop equal pressure ratios in the two stages. If desired, stops may be provided at the ends of the balancing beam to limit the stroke of the piston at either the upper or the lower end. Alternately, stops may be provided at the point where the drive rod 42 is attached to the balancing beam 41, in order to prevent the balancing beam from getting too far removed from its normal position which is perpendicular to the drive rod.

Referring now to Figure 8, there is depicted a two-stage pump in which each of the two stages consists of two reciprocating pump units connected in parallel. All of the pump units are driven from a single crank shaft through two balancing beams which are so mounted on the crank shaft that one balancing beam is on the upstroke, while the other is on the downstroke. This arrangement results in a very even flow of liquid and any changes in the output in any single pump is automatically compensated for by the operation of the balancing beams. The arrangement is such that the downstroke in a first stage unit A corresponds with the upstroke of a second stage unit B, so that there is a minimum change in the interstage volume. If desired, surge vessels may be provided to even out the interstage pressure.

The pump assemblies of the present invention involve, as an essential feature, the use of a single or common source of power to drive several pumping units which are connected in series, the several pumping units being driven through a device which permits the output of one unit to be proportioned automatically to the output of another unit. As illustrated in the drawings, such a device may be a differential, a combination of several different differentials, a balancing beam, an electric motor, a combination of turbines, or the like. Differentials of the type using either bevel gears or straight spurs or of any of the other types known to the art may be employed. Alternately, it is possible to employ two or more electric motors which are connected in parallel to a single source supplying a constant amount of electric power. In such an arrangement, if the load becomes unduly heavy on the motor which is driving one of the pumps, it will slow down, thus diminishing the output of the pump connected to that motor. As still another alternative, one may employ two or more water wheels or Pelton wheels connected to a single source of water, in the manner illustrated in Figure 6. One might also employ a turbine, such as a Ljungstrom type turbine, in which the casing itself is free to rotate, the casing driving one shaft and the rotor the other, in the manner illustrated in Figure 5.

The arrangements depicted in the drawings may be modified, for instance, by introducing a set of gears into one or more of the crank shafts, so as to step up or step down the speed of rotation of the shaft and shift the intermediate pressure between the two pumps in series. It is also possible to either introduce power into, or remove power from, one or more of the individual pumping units by means of an independent source of power or an independent consumer of power. For example, by attach-

ing an additional motor to the drive shaft 6 shown in Figure 1, one would increase the pumping capacity of the first stage, with the result that the amount of pressure increase which was added by the first stage would be greater than the pressure increase added in the second stage. The same effect could be obtained by attaching a generator, or another pumping unit, or a brake to the shaft 7 shown in Figure 1, whereby some of the power output of shaft 7 would be tapped off for other uses. The brake may take the form of a supplementary pump discharging fluid to atmospheric pressure through a throttle. It will thus be apparent that a wide variety of combinations of machines either producing or absorbing energy can be employed.

A number of different types of pumping units may be employed satisfactorily in connection with the overall assembly of the present invention. Reciprocating pumps are preferred, but these may be replaced, if desired, by centrifugal pumps or other types of positive displacement pumps such as gear pumps. It is also possible to employ several different types or sizes of pumps in a single assembly. It may be advantageous to employ as the last unit in the series a relatively smaller pump which operates with a relatively faster stroke, in order to make the flow more nearly even and to make the design of the highest pressure portion of the pump easier. There is no limit to the number of stages which may be connected together in series, although, as a practical matter, not much advantage is gained by including more than four stages, when working with reciprocating pumps. Any one pumping stage may be made up of a number of individual pumping units connected together in parallel. The use of several such pumping units connected in parallel results in a very much smoother flow of liquid from a given stage and greatly decreases the problem of maintaining an even output pressure. The use of flywheels is important when working with reciprocating pumps, especially when a given stage of the pumping assembly consists of only one reciprocating pump. When working with centrifugal pumps, however, the use of a flywheel is not nearly so essential. The weight of the flywheels should be taken into consideration. For instance, the two flywheels shown in the assembly of Figure 1 should preferably be of the same weight.

Ordinary air or gas chambers may be employed to smooth out pulsations and insure that the interstage pressure remains fairly even, but it is preferred to employ vessels in which the gas under pressure is kept out of direct contact with the liquid, as by means of a diaphragm or a plunger. Similar means may also be employed to smooth out the pressure fluctuations in the final outlet line. At superpressures, liquid chambers are often sufficiently elastic in themselves to smooth out undesirable pressure fluctuations and may therefore be used.

The use of the principles described herein leads to very great advantages in connection with the pumping of any relatively incompressible liquid to a high pressure. Liquids which may be pumped by these pumps include not only the relatively non-viscous liquids such as water, but a wide variety of organic liquids or oils, some of which may be very viscous. As the result of the ability of the pumps described herein to automatically maintain a given ratio of pressure increase in the various individual stages, one is not nearly so frequently troubled by slight changes in the output of any single stage of the pump. This is of the very greatest importance when working at extremely high pressures where it is impossible, as a practical matter, to construct a pump which will not leak or vary in its output.

One of the main advantages of the present invention is that it makes possible the elimination of the extreme range of stresses to which individual pumping units must be subjected. In order to make sure that the full advantages of this feature are realized, it is often desirable to include in the pumping assembly a device which will automatically shut off the pump in the event that any one of the pumping units should seize and stop pumping. Referring to Figure 1, if the first stage should seize, the interstage pressure would drop to 1 atmosphere, whereas if the second stage should seize, the interstage pressure would rise to the final output pressure. Accordingly, one could provide a safety device which would shut off the entire pump whenever the interstage pressure varied too much, either upwardly or downwardly, from its normal level.

Since many changes and modifications in the pumps described herein can be made by those skilled in the art without departing from the spirit and scope of the invention, it is not intended that the invention should be limited in any way other than by the claims.

I claim:

1. A pump for pumping liquids comprising a plurality of pumping stages connected together in series with a pressure accumulator disposed in the line of liquid flow between each of the several stages, check valves connected in said line of liquid flow at the inlet and discharge sides of each of said several stages, a power supply means provided with two power delivery shafts and adapted to apportion the output torque of said power supply means in accordance with a preselected ratio to each of said two power delivery shafts, power transmitting means connected between each of said power delivery shafts and adjacent ones of said stages, and a flywheel mounted on each of said power delivery shafts.

2. A pump in accordance with claim 1 in which said pumping stages consist of reciprocating pumps.

3. A pump for pumping liquids comprising a plurality of pumping stages connected together in series with a pressure accumulator disposed in the line of liquid flow between each of the several stages, each of said pumping stages comprising an equal but multiple number of pumping units connected in parallel flow relationship, check valves connected in said line of liquid flow at the inlet and discharge sides of each of said pumping units, a power supply means provided with two power delivery shafts and adapted to apportion the output torque of said power supply means in accordance with a preselected ratio to each of said two power delivery shafts, power transmitting means connected between each of said power delivery shafts and the pumping units of adjacent ones of said stages, and a flywheel mounted on each of said power delivery shafts.

4. A pump for pumping liquids comprising a plurality of pumping stages connected together in series with a pressure accumulator disposed in the line of liquid flow between each of the several stages, check valves connected in said line of liquid flow at the inlet and discharge sides of each of said several stages, a power supply means consisting of a differential, power transmitting means connected between each of the two power delivery shafts of said differential and adjacent ones of said stages, and a flywheel mounted on each of said power delivery shafts.

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