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Henry

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[54] **PRESSURE TRANSFORMER**

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[73] Assignee: **Bertea Corporation,** Irvine, Calif.

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[52] **U.S. Cl.** **417/225,** 417/349, 417/401, 91/477

[51] **Int. Cl.** **F04b 17/00**

[58] **Field of Search** 417/225, 226, 227, 392, 417/401, 339, 349; 91/477, 192

[56] **References Cited**

UNITED STATES PATENTS

3,675,539	7/1972	Zajac et al.	91/477
2,579,670	12/1951	Hjarpe	417/225
2,293,076	8/1942	Ponting	417/225
2,876,704	3/1959	Collion et al.	417/271

Primary Examiner—William I. Freeh
Assistant Examiner—Gregory Paul LaPointe
Attorney, Agent, or Firm—Smyth, Roston & Pavitt

[57] **ABSTRACT**

A pressure transformer including a plurality of pistons. Each of the pistons is driven through a working stroke and a return stroke by fluid under pressure and acts as a fluid motor. Each of the pistons is supplied with fluid, and on the working stroke, the piston increases or decreases the pressure of the fluid supplied thereto. Each of the pistons also serves as a valve to control the movement of one of the other pistons.

16 Claims, 5 Drawing Figures

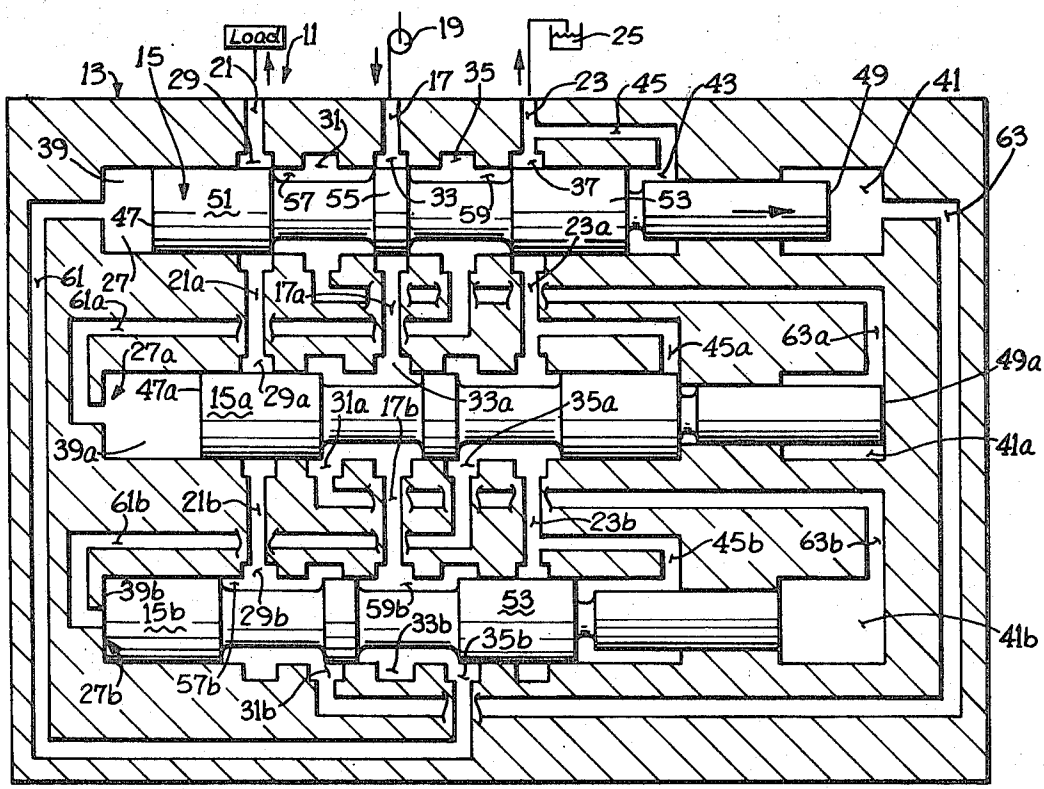
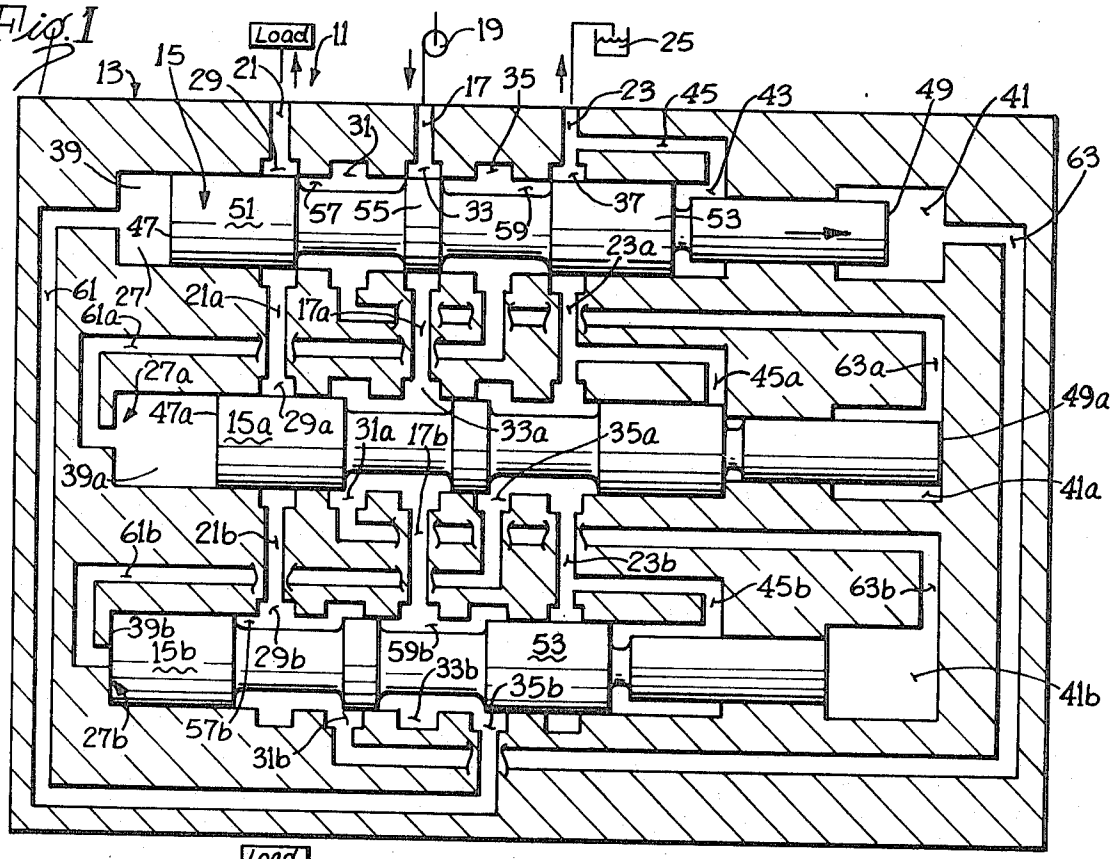


Fig. 1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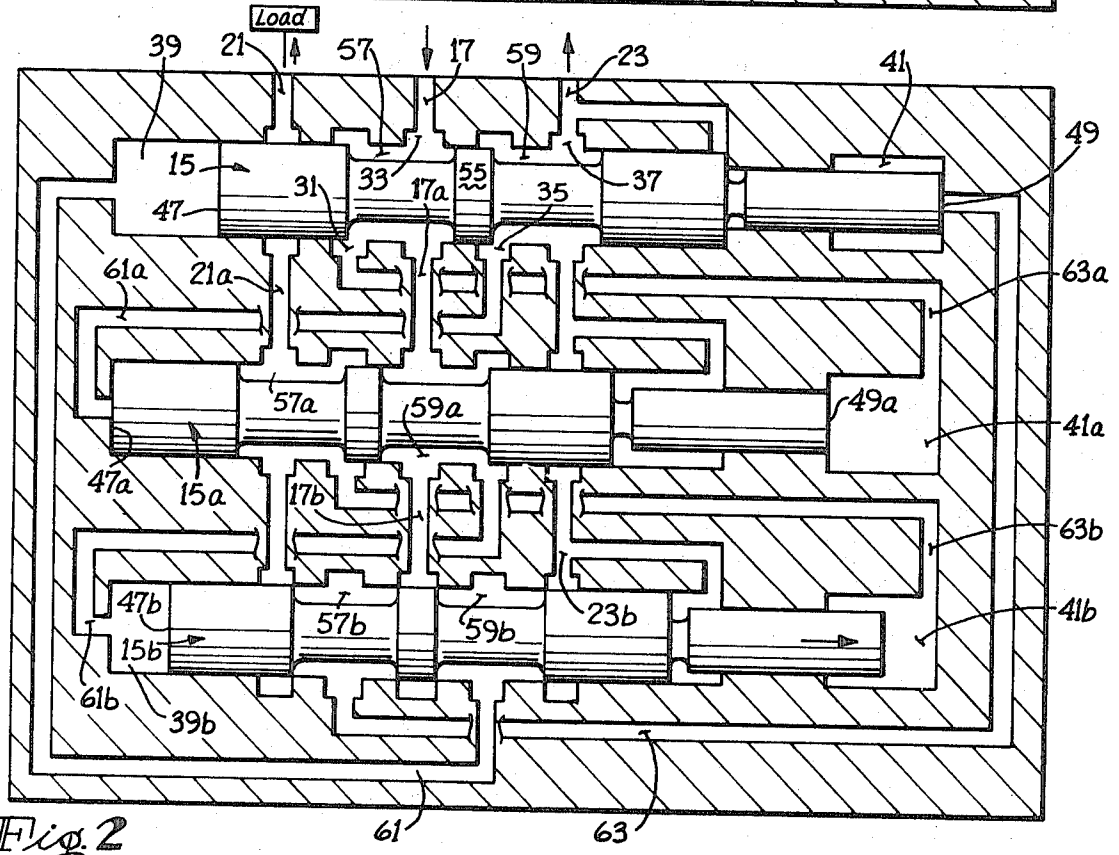
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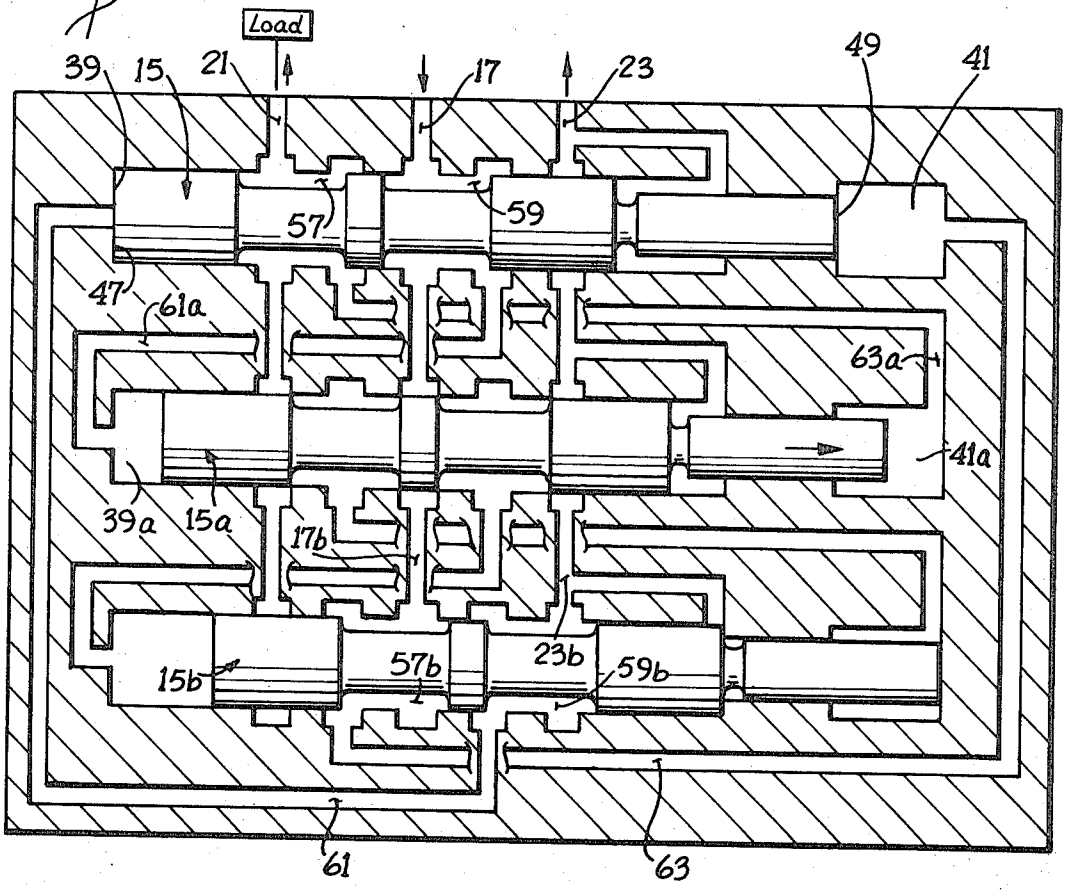
Fig. 2

Fig. 3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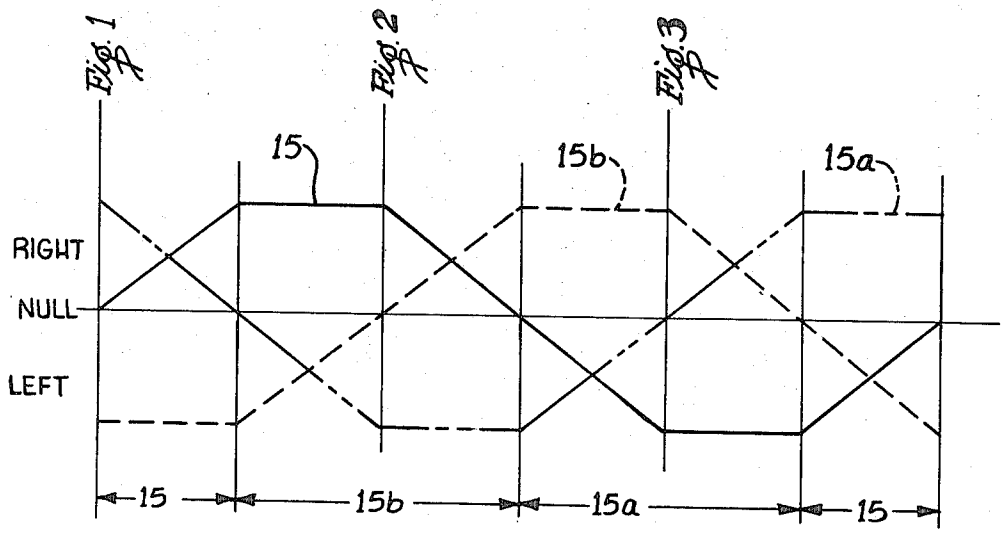
Fig. 1
Fig. 2
Fig. 3
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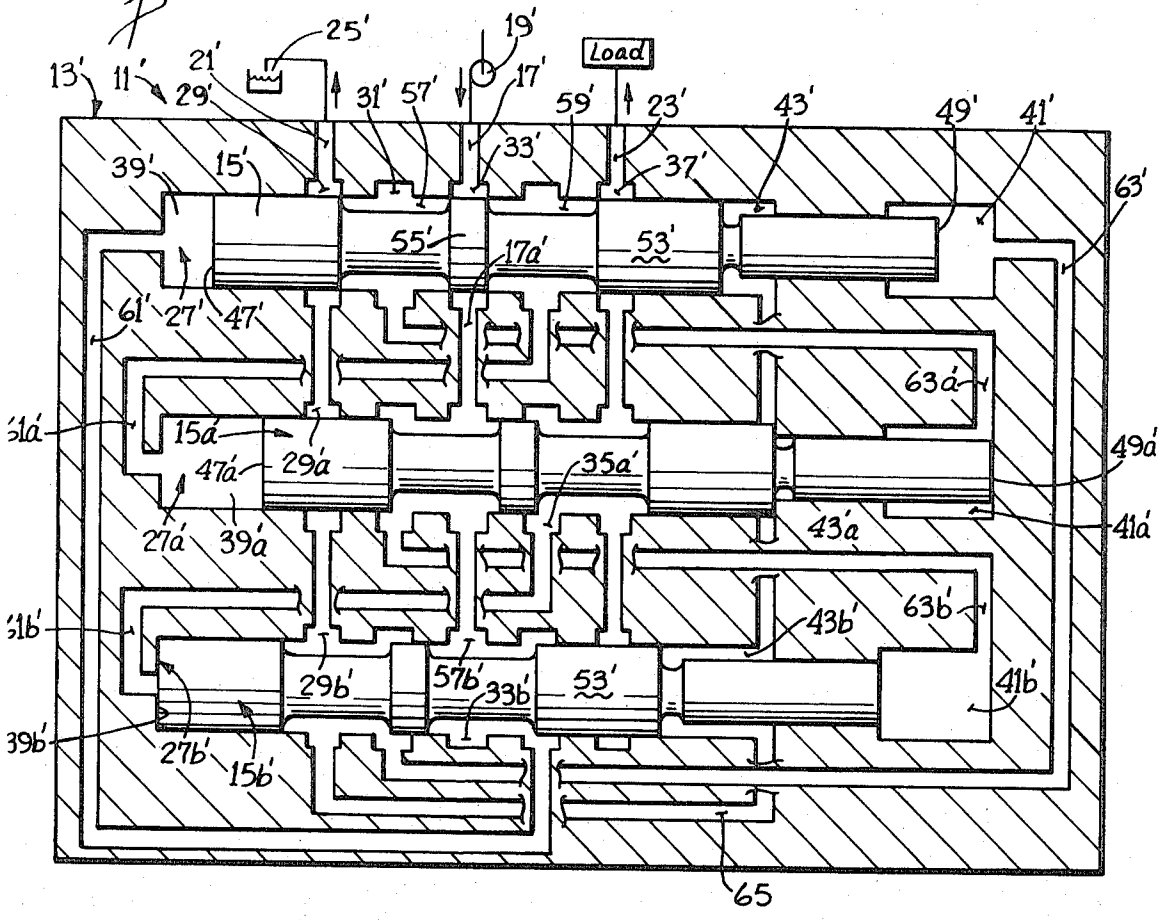
Fig. 4

Fig. 5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41b'
39b'
27b'
15b'
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PRESSURE TRANSFORMER

BACKGROUND OF THE INVENTION

A pressure transformer is used to change the pressure of a fluid. A pressure reducer reduces fluid pressure and a pressure intensifier is used to increase fluid pressure when the fluid pressure required is higher than that available from a conventional pumping system. One application for pressure intensifiers is in providing high fluid pressure for hydraulic testing. For example, the test pressure required may be 5,000 psi, and a conventional pumping system may provide only 3,000 psi.

A pressure intensifier may include at least two reciprocable pistons driven by fluid at supply pressure to elevate the pressure of some of the supply fluid to a discharge pressure. To reciprocate the pistons, appropriate valving is provided to control to control the flow of fluid to and from the pistons. The valving is separate from the pistons, but may be mechanically actuated by the pistons as shown for example in U.S. Pat. No. 2,293,076.

SUMMARY OF THE INVENTION

One improvement provided by the present invention is the incorporation of the valving into the piston. With this construction, each of the pistons of a pressure intensifier serves as a fluid motor, a pump for increasing fluid pressure, and valve means for controlling fluid flow to and from the piston and hence for controlling piston movement. Incorporating the valve into the piston eliminates the separate valve structure and the control connection therebetween while retaining the valving function. In addition, the size and weight of the total unit is reduced.

The valve is carried by the piston and is responsive to the position of the associated piston to port fluid to at least one other piston. For example, the valve may take the form of at least one groove and at least one land on the piston, in which event, the piston takes on the characteristics of a valve spool. The valve may be integral with the piston.

If the pistons are to be powered entirely by fluid pressure and solely by valves integral with the pistons, then at least three pistons should be used because two pistons, under these circumstances, may not operate satisfactorily. With the concepts of this invention to provide a constant flow output, the number of pistons employed should be at least three and an odd number or a number which is an even multiple of an odd number greater than one. For example, four pistons will operate satisfactorily except the output will not be a constant flow.

With the present invention, the pistons are automatically reciprocated in a predetermined sequence. For example, movement of the first piston on the working stroke causes the valve means carried thereby to port fluid to the second piston to cause the second piston to move on its return stroke. Movement of the second piston on its return stroke causes the valve means carried thereby to port fluid to the third piston to move the third piston on its working stroke. Movement of the third piston on its working stroke causes the valve means carried thereby to port fluid to the first piston to cause the first piston to move on its return stroke. This sequence is continuously repeated during operation of

the pressure transformer. Each of the pistons dwells at the end of each of its strokes.

To facilitate reciprocating of the pistons, each of the pistons preferably has pressure responsive surface means which includes first and second pressure responsive faces. The valves of a first piston ports fluid at supply pressure to the first pressure responsive face of a second piston and opens the second face of the second piston to a return port to move the second piston on its return stroke. To move the second piston on it working stroke, the second pressure responsive face is connected to fluid at supply pressure and the first fluid responsive face is open to the output or discharge of the pressure intensifier. The second fluid responsive face has a larger effective area than the first face so that fluid at supply pressure can move the piston on its working stroke to increase the pressure of the fluid acting against the first pressure responsive face. With this arrangement, substantially the same fluid which urged the piston on its return stroke is subsequently increased in pressure by the working stroke of the same piston. Another advantage of this invention is that each of the pistons may be identical thereby reducing manufacturing cost.

The concepts set forth above have been described with reference to a pressure intensifier. However, these concepts are equally applicable to a pressure reducer.

The invention can best be understood by reference to the following description taken in connection with the accompanying illustrative drawing.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic sectional view of a pressure intensifier constructed in accordance with the teachings of this invention with the pistons being in a first relative position.

FIGS. 2 and 3 are views similar to FIG. 1 with the pistons being in other operative positions.

FIG. 4 is diagram illustrating relative piston position and pressure intensifier output.

FIG. 5 is a schematic sectional view of a pressure reducer constructed in accordance with the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 shows a pressure transformer in the form of a pressure intensifier **11** which includes a body **13** and three identical pistons **15**, **15***a* and **15***b*. Although the body **13** is shown as an integral unit housing all three of the pistons **15**, **15***a* and **15***b*, obviously separate housing units could be used for one or more of the pistons, if desired.

The body **13** has an inlet port **17** which is adapted for connection to hydraulic fluid, such as oil, at supply pressure. By way of example, the inlet **17** is illustrated in FIG. 1 as being coupled to a pump **19** capable of providing fluid under pressure, such as 3,000 psi, to the intensifier **11**. Of course, other sources of fluid under pressure may be employed. The body **13** has discharge port **21** through which fluid at discharge pressure is discharged. The fluid at discharge pressure is fed to any suitable hydraulic system or load, and it represents the useful output of the intensifier **11**. The body has a return or exhaust port **23** which is coupled to a return line leading to a sump **25** which may be pressurized or non-pressurized. If there is no need to recover the fluid dis-

charged through the return port 23, then the sump 25 can be eliminated.

The body 13 defines a chamber 27 in which the piston 15 is mounted for reciprocation. The body 13 has annular grooves 29, 31, 33, 35 and 37 all of which open into the chamber 27. The piston 15 cooperates with the chamber 27 to define chamber sections 39 and 41 at opposite ends of the piston 15 and a chamber section 43 intermediate the ends of the piston. A passage 45 in the body 13 provides communication between the chamber section 43 and the return port 23.

The body 13 also defines chambers 27*a* and 27*b* for the pistons 15*a* and 15*b*, respectively. The chambers 27*a* and 27*b* are identical to the chamber 27 and corresponding portions are designated by corresponding reference numerals followed by the letters *a* and *b*, respectively.

The piston 15 has pressure responsive end faces 47 and 49 with the end face 47 having a larger effective area than the end face 49. The piston 15 also includes outer lands 51 and 53 and an intermediate land 55. The lands 51 and 55 are axially spaced to define an annular groove 57 and the lands 53 and 55 are axially spaced to define a groove 59.

The pistons 15*a* and 15*b* are identical to the piston 15 and corresponding portions are designated by corresponding reference numerals followed by the letters *a* and *b*, respectively.

Passage means provide communication from the ports 17, 21 and 23 to the pistons 15, 15*a* and 15*b*. Specifically, a passage 61 provides communication between the chamber section 39 and the annular groove 35*b*. Similarly, passages 61*a* and 61*b* extend between the chamber section 39*a* and the groove 35 and from the chamber section 39*b* to the groove 35*a*, respectively.

A passage 63 provides communication between the chamber section 41 and the groove 31*b*. Similarly, passages 63*a* and 63*b* provide communication between the chamber section 41*a* and the groove 31 and the chamber section 41*b* and the groove 31*a*.

The pistons 15 and 15*a* are also connected by a discharge passage 21*a*, an inlet passage 17*a*, and a return or exhaust passage 23*a*. Similarly, the pistons 15*a* and 15*b* are interconnected by a discharge passage 21*b*, an inlet passage 17*b* and a return passage 23*b*. The body 13 also provides passages 45*a* and 45*b* which correspond to the passage 45 discussed above.

The various passages extending between the pistons 15, 15*a* and 15*b* may be separate tubes, or appropriate grooves, slots, bores, etc. in a one-piece body, or may be formed in any other manner known in the art.

The piston 15 is mounted for reciprocation in the chamber 27. When the piston 15 is moving to the right as viewed in FIG. 1, it is on its working stroke. During the working stroke, the pressure responsive end face 49 compresses fluid in the chamber section 41 to the desired discharge pressure. When the piston 15 is moving to the left as viewed in FIG. 1, it is on its return stroke. The pistons 15*a* and 15*b* are similarly movable through working and return strokes.

In operation, the movement of the piston 15 past null on its working stroke causes the piston 15*a* to move on its return stroke. Movement of the piston 15*a* past null on its return stroke causes the piston 15*b* to move on its working stroke. Movement of the piston 15*b* past null on its working stroke causes the piston 15 to move on its return stroke. Thus, the pistons are sequentially and continuously operated to provide a continuous output.

More specifically, with the pistons 15, 15*a* and 15*b* in the position shown in FIG. 1, fluid at supply pressure from the inlet port 17 passes through the groove 33, the passage 17*a*, the groove 33*a*, the passage 17*b*, the groove 33*b*, and the groove 59*b*. As the groove 35*b* is uncovered by the piston 15*b*, the fluid at supply pressure also flows through the passage 61 to the chamber section 39 to act on the pressure responsive face 47 of the piston 15. As explained more fully hereinbelow with reference to FIG. 3, there is pressurized fluid in the chamber section 41 acting on the pressure responsive face 49. However, because the effective area of the end face 47 exceeds the effective area of the end face 49, the fluid at supply pressure acting on the face 47 urges the piston 15 to the right on its working stroke. Thus, the pressure intensifier 11 utilizes fluid at supply pressure from the inlet port 17 to drive the piston 15 thereby providing a fluid motor.

A second function of the piston 15 is that as it moves to the right on its working stroke, the fluid in the chamber section 41 is pressurized to discharge pressure. This fluid at discharge pressure is transmitted from the chamber section 41, through the passage 63, the grooves 31*b* and 29*b*, the passage 21*b*, the groove 29*a*, the passage 21*a*, and the groove 29 to the discharge port 21. Thus, a second important function of the piston 15 is to provide a pumping action which increases the pressure of the fluid to provide a high pressure fluid output at the discharge port 21.

A third important function of the piston 15 is to provide integral valve means for various purposes including moving the piston 15*a* on its return stroke. In the position shown in FIG. 1, the piston 15 is at a null or centered position, and the piston 15*a* is at an extreme right-hand position and is about to begin its return stroke. The piston 15*b* is at an extreme lefthand position and is the next piston to move on a working stroke. In the null position of the valve 15, it closes off the chamber sections 39*a* and 41*a* from the ports 17, 21 and 23. When the piston 15*a* moves slightly to the right of the position shown in FIG. 1, the land 55 uncovers the groove 33 to provide communication between the inlet port 17 and the groove 57. This causes fluid at supply pressure to flow through the groove 57, the groove 31 and the passage 63*a* to the chamber section 41*a* where it acts on th pressure responsive end face 49*a* of the piston 15*a*. Simultaneously, the land 53 uncovers the groove 37 to open the groove 59 to the return port 23. This in turn provides communication between the chamber section 39*a* and the return port 23 through the passage 61*a* and the groove 35. As the piston 15 moves to the right of the null position, the land 51 continues to block the chamber section 41*a* from communication with the discharge port 21*a*. Thus, fluid at supply pressure acts on the end face 49*a*, and the end face 47*a* is open to the return port 23. Accordingly, the piston 15*a* is moved to the left on its return stroke by this differential fluid pressure notwithstanding the smaller effective area of the end face 49*a*.

Movement of the piston 15*a* to the left on its return stroke provides the necessary valving action to cause movement of the piston 15*b* to the right on its working stroke. In the position shown in FIG. 2, the piston 15 is at the end of its working stroke, the piston 15*a* is at

the end of its return stroke, and the piston 15*b* is at a null or centered position during its working stroke. As shown in FIG. 2, movement of the piston 15*a* on its return stroke provides fluid at supply pressure to the chamber section 39*b* and opens the chamber section 41*b* to the return port 23. Specifically, the groove 59*a* of the piston 15*a* provides communication between the passage 61*b* leading from the chamber section 39*b* and the inlet passage 17*a* whereby fluid at supply pressure is provided to the chamber section 39*b* to act on the end face 47*b*. Similarly, the groove 57*a* provides communication between the passage 63*b* leading from the chamber section 41*b* and the discharge passage 21*a* so that the chamber section 41*b* is connected to the discharge port 21. With this valving operation, the piston 15*b* is moved to the right on its working stroke in the same manner described hereinabove with reference to the working stroke of the piston 15. Thus, the piston 15*b* operates as a fluid motor and a pump to deliver hydraulic fluid at discharge pressure to the discharge port 21.

FIG. 3 shows the pressure intensifier 11 with the piston 15 at the end of its return stroke, the piston 15*a* at a null position during its working stroke, and the piston 15*b* at the end of its working stroke. The piston 15*b* carries valve means which operate to move the piston 15 on its return stroke during the working stroke of the piston 15*b*. Specifically, as the piston 15*b* moves to the right of the null position shown in FIG. 2, the groove 59*b* provides communication between the return passage 23*b* and the passage 61 leading to the chamber section 39. Thus, the pressure responsive face 47 is open to the return port 23. Simultaneously, the groove 57*b* provides communication between the inlet passage 17*b* and the passage 63 leading to the chamber section 41. Thus, fluid at supply pressure acts on the pressure responsive face 49. This moves the piston 15 on its return stroke.

As the piston 15 moves on its return stroke, it provides valving action to move the piston 15*a* on its working stroke. Specifically, the groove 59 allows fluid at supply pressure to flow from the inlet port 17 through the passage 61*a* to the chamber section 39*a*. Simultaneously, the groove 57 provides communication between the passage 63*a* which leads from the chamber section 41*a* to the discharge port 21.

From the foregoing, it should be apparent that each piston, as it moves on its working stroke, provides the necessary valving action to cause one of the other pistons to move on its return stroke. In addition, as each piston moves on its working stroke, it provides the necessary valving action to close off the piston which has just completed its working stroke from the discharge port 21. Each of the pistons as it moves on its return stroke provides the necessary valving action to cause one of the other pistons to move on its working stroke.

In summary, the valve means carried by the piston 15 selectively provides communication between the ports 17, 21 and 23 and the pressure responsive faces 47*a* and 49*a*. Specifically, with the piston 15 to the right of its null position, communication is provided between the ports 17 and 23 and the pressure responsive faces 49*a* and 47*a*, respectively. With the piston 15 to the left of its null position, it provides communication between the ports 17 and 21 and the pressure responsive faces 47*a*, and 49*a*, respectively. The pistons 15*a* and 15*b* similarly operate the pistons 15*b* and 15, respectively.

FIG. 4 is a diagram showing the sequence of operation of the pistons 15*a*, 15*b* and 15*c*. The ordinate represents the position of the pistons with respect to null and the abscissa represents time.

The lines designated 15, 15*a* and 15*b* represent the movement of the pistons 15, 15*a* and 15*b*, respectively. The slope of each of these lines represents the direction and rate of movement of the associated piston. Specifically, a positive slope represents the working stroke and a negative slope represents the return stroke. A zero slope represents dwell.

FIG. 4 also illustrates which of the pistons is providing a work output during each time interval with the designations 15, 15*a* and 15*b* along the abscissa. Generally, each of the pistons provides a work output for substantially the full working stroke thereof as shown in FIG. 4.

As each of FIGS. 1–3 represents the relative positions of the pistons at one point in time, each of these points can be located with reference to FIG. 4. Accordingly, the vertical lines designated FIG. 1, FIG. 2, and FIG. 3, respectively, in FIG. 4 correlate FIGS. 1–4.

FIG. 5 shows a pressure transformer in the form of a pressure reducer 11′. The pressure reducer 11′ is identical to the pressure intensifier 11 (FIGS. 1–3) in all respects not specifically shown or described herein. Portions of the pressure reducer 11′ corresponding to portions of the pressure intensifier 11 are designated by corresponding primed reference characters.

Functionally, the pressure reducer 11′ differs from the pressure intensifier 11 in that it reduces, rather than increase, the pressure of the fluid supplied to it. The pistons reduce the pressure of the fluid supplied thereto on the working stroke. Secondly, the pistons 15′, 15*a*′ and 15*b*′ move on their working stroke as they move to the left as viewed in FIG. 1 and on their return strokes as they move to the right.

In terms of fluid flow paths, the pressure reducer 11′ differs from the pressure intensifier 11 in that the port 21′ is the return port and the port 23′ is the discharge port. Thus, the port 21′ is coupled to the sump 25′, and the useful output of the pressure reducer 11′ discharged through the port 23′. The port 17′ is the inlet port for fluid under pressure.

The chamber sections 43, 43*a*, and 43*b* of the pressure intensifier 11 are placed in communication with the return port 23 by passages 45, 45*a*, and 45*b*, respectively. With the pressure reducer 11′, it is still necessary to provide a fluid flow path between the chamber sections 43′, 43*a*′, and 43*b*′ and the return port. However, because the discharge and return ports have been reversed, it is necessary to eliminate the passages 45, 45*a* and 45*b* and substitute therefor a passage 65 which extends from the chamber section 43′ to the chamber section 43*a*′ to the chamber section 43*b*′ and from there to the groove 29*b*′. The groove 29*b*′ is always in communication with the return port 21′. Thus, by this simple change, the chamber sections 43′, 43*a*′, and 43*b*′ are placed in communication with the report port for all positions of the pistons 15′, 15*a*′ and 15*b*′.

In the position shown in FIG. 5, the piston 15′ is at its null position and is moving to the right on its return stroke. The piston 15*a*′ is at an extreme righthand position and is about to begin its working stroke, and the

piston 15b' is at the extreme lefthand position and is the next piston to move on a return stroke.

The chamber section 39' is in communication via the passage 61' with fluid at supply pressure from the inlet port 17'. The chamber section 41' is in communication via the passage 63' with the return port 21'. Accordingly, the greater fluid pressure on the face 47' forces the piston 15' to the right on its return stroke.

As the piston 15' moves to the right of its null position, the land 55' uncovers the groove 33' to port fluid through the passage 63a' to the chamber section 41a'. Thus, fluid at relatively high supply pressure acts on the pressure responsive face 49a'. Simultaneously, the land 53' uncovers the groove 37' to thereby provide communication between the chamber section 39a' and the discharge port 23'. Although the pressure responsive face 47a' is of greater effective area than the face 49a', the discharge port 23' is coupled to a load having a pressure less than the pressure of the fluid supplied to the reducer 11' through the inlet 17'. Accordingly, by maintaining an appropriate relationship between the relative effective areas of the faces 47a' and 49a' and between supply and discharge pressures, the piston 15a' can be caused to move to the left on a working stroke to discharge fluid from the chamber section 39a' through the discharge port 23' at a lower pressure than supply pressure.

Movement of the piston 15a' to the left causes the piston 15b' to move the right which in turn causes the piston 15' to move to the left. Thus, the pistons 15', 15a' and 15b' move in the same manner as described hereinabove with reference to the pressure intensifier 11.

When the piston 15' is to the left of its null position, fluid at supply pressure is ported from the inlet port 17' to the chamber section 39a', and the chamber section 41a' is open to the return port 21'. Thus, the piston 15a' is moved to, or held in, the right-hand position. Thus, the location of the piston 15' with respect to null controls the direction of movement of the piston 15a'. The operation of the pressure reduceer 11', except to the extent noted above, is identical to the operation of the pressure intensifier 11.

Although exemplary embodiments of the invention have been shown and described, many changes, modifications and substitutions may be made by one having ordinary skill in the art without necessarily departing from the spirit and scope of this invention.

I claim:

1. A pressure intensifier adapted for connection to fluid at a first pressure level and to return wherein the pressure intensifier can increase the pressure of the fluid from the first level to a second level, said pressure intensifier comprising:

a plurality of pistons including first and second pistons;

body means for mounting said pistons for movement through working and return strokes;

means defining fluid passages extending between said first and second pistons;

each of said pistons having surface means responsive to exposure to fluid under pressure for driving the piston on said working and return strokes, each of said pistons increasing the fluid pressure to said second level on the working stroke thereof;

said first piston porting fluid under pressure to the surface means of the second piston during at least a portion of one of the working and return strokes of said first piston to move said second piston on the other of its working and return strokes whereby the second piston is moved on said other stroke during at least a portion of said one stroke of said first piston; and

valve means for controlling the fluid pressure applied to said surface means of said first piston to move the first piston on the working and return strokes thereof.

2. A pressure intensifier as defined in claim 1 wherein said one stroke is the working stroke and said other stroke is the return stroke.

3. A pressure intensifier as defined in claim 1 wherein said one stroke is the return stroke and said other stroke is the working stroke.

4. A pressure intensifier as defined in claim 1 wherein said surface means of said second piston includes first and second faces of different effective areas, said fluid passages communicating with both of said faces, said first piston having a position in which it provides communication between said first and second faces and fluid at the first pressure level and return, respectively, to thereby move said second piston on said other stroke thereof.

5. A pressure intensifier connectible to fluid at supply pressure and to return for increasing the pressure of the fluid supplied thereto, said pressure intensifier comprising:

a plurality of pistons including first, second, and third pistons;

body means for providing first, second and third chambers in which said first, second and third pistons can be reciprocated, each of said first, second and third pistons having a working stroke for increasing the pressure of the fluid supplied to the pressure intensifier and a return stroke;

means for defining fluid passages between said first, second and third chambers;

first valve means carried by said first piston and responsive to at least a portion of the working stroke thereof to port fluid through said passage means to said second piston to move the second piston on its return stroke; and

second valve means carried by said second piston and responsive to at least a portion of the return stroke of said second piston for porting fluid through said fluid passage means to said third piston to move the third piston on its working stroke.

6. A pressure intensifier as defined in claim 5 wherein said pressure intensifier has an outlet through which the fluid having increased pressure can be discharged, said second valve means including means for opening said third piston to said outlet during at least the working stroke of said third piston.

7. A pressure intensifier as defined in claim 5 wherein the second valve means is responsive to at least a portion of the return stroke of the second piston to port fluid to said third piston to drive said second piston on its working stroke.

8. A pressure intensifier as defined in claim 6 wherein said second piston includes a first pressure responsive face, said pressure responsive face and said body means defining a chamber section, said first valve means porting fluid to said chamber section to act against said first pressure responsive face to move said second piston on its return stroke, said pressure responsive face acting

against said fluid in said chamber section on the working stroke of said second piston to increase the pressure thereof.

9. A pressure intensifier as defined in claim 5 including third valve means carried by said third piston responsive to at least a portion of said working stroke of said third piston for porting fluid at supply pressure to said first piston to move the first piston on its return stroke.

10. A pressure intensifier as defined in claim 5 wherein there are three of said pistons.

11. A pressure intensifier as defined in claim 2 wherein the number of said pistons is at least three and an odd number or a number which is an even multiple of an odd number greater than one.

12. A pressure transformer for changing the pressure of fluid from a first pressure level to a second pressure level comprising:

a plurality of pistons including first and second pistons;

body means for mounting said pistons for movement through working and return strokes, said body means having an inlet port for receiving fluid at the first pressure level, a discharge port through which fluid can be discharged at a second pressure level, and an exhaust port through which fluid can be exhausted from the body means;

means defining fluid passages extending from said ports to said first and second pistons whereby each of said first and second pistons can be supplied with fluid at the first pressure level;

each of said pistons having surface means responsive to exposure to fluid at the first pressure level for driving the piston on said working and return strokes, each of said pistons changing at least some of the fluid at the first pressure level supplied to said second pressure level thereto on the working stroke thereof;

first valve means carried by said first piston and responsive to the first piston being in a first position to port fluid at the first pressure level through said passage means to said second piston and to open a path through said passage means form the second piston to one of exhaust and discharge ports whereby the second piston is moved on one of its strokes; and

valve means for controlling the fluid pressure applied to said surface means of said first piston to move the first piston on the working and return strokes thereof.

13. A pressure transformer as defined in claim 12 wherein said first pressure level is higher than said second pressure level.

14. A pressure transformer as defined in claim 12 wherein said first valve means is responsive to said first piston being in a second position to port fluid at the first pressure level through said passage means to said second piston and to open a path through said passage means from said second piston to the other of said exhaust and discharge ports whereby the second piston is moved on the other of its strokes.

15. A pressure transformer comprising:

a plurality of pistons including first and second pistons, each of said first and second pistons having at least first and second pressure responsive faces;

body means for mounting said pistons for reciprocating movement, each of said pistons having a null position, said body means having first, second and third ports;

means defining fluid passages extending from said ports to said first and second pistons;

said first and second pressure responsive faces of said first and second pistons being exposable to fluid to reciprocate the first and second pistons; and

first valve means carried by said first piston and responsive to the first piston being on one side of its null position for providing communication through said passage means between said first and second faces of the second piston and the first and second ports, respectively, while blocking communication between the third port and said first and second faces of the second piston, said first valve means being responsive to the first piston being on the other side of its null position for providing communication through said passage means between said first and second faces of the second piston and said second and third ports, respectively, while blocking communication between said first port and said first and second faces of the second piston.

16. A pressure transformer as defined in claim 15 wherein said plurality of pistons includes a third piston, said third piston having at least first and second pressure responsive faces, said second piston including valve means carried thereby for controlling the communication between said ports and said first and second faces of said third piston, and said third piston including valve means carried thereby for controlling the communication between said ports and said first and second faces of said first piston.

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