

Oct. 29, 1968

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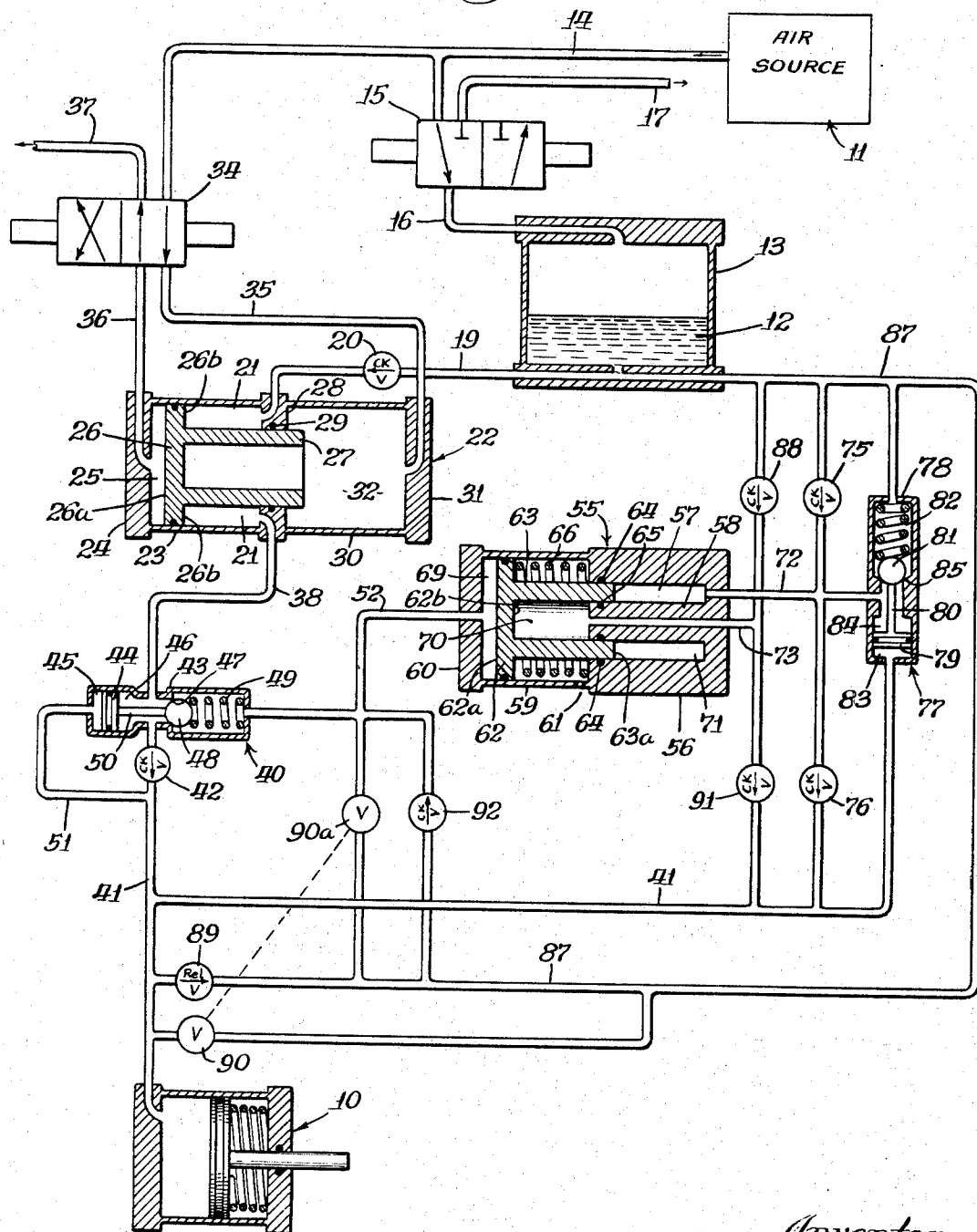
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AIR-HYDRAULIC SYSTEM AND APPARATUS

Filed July 26, 1965

2 Sheets-Sheet 1

Fig. 1.



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Oct. 29, 1968

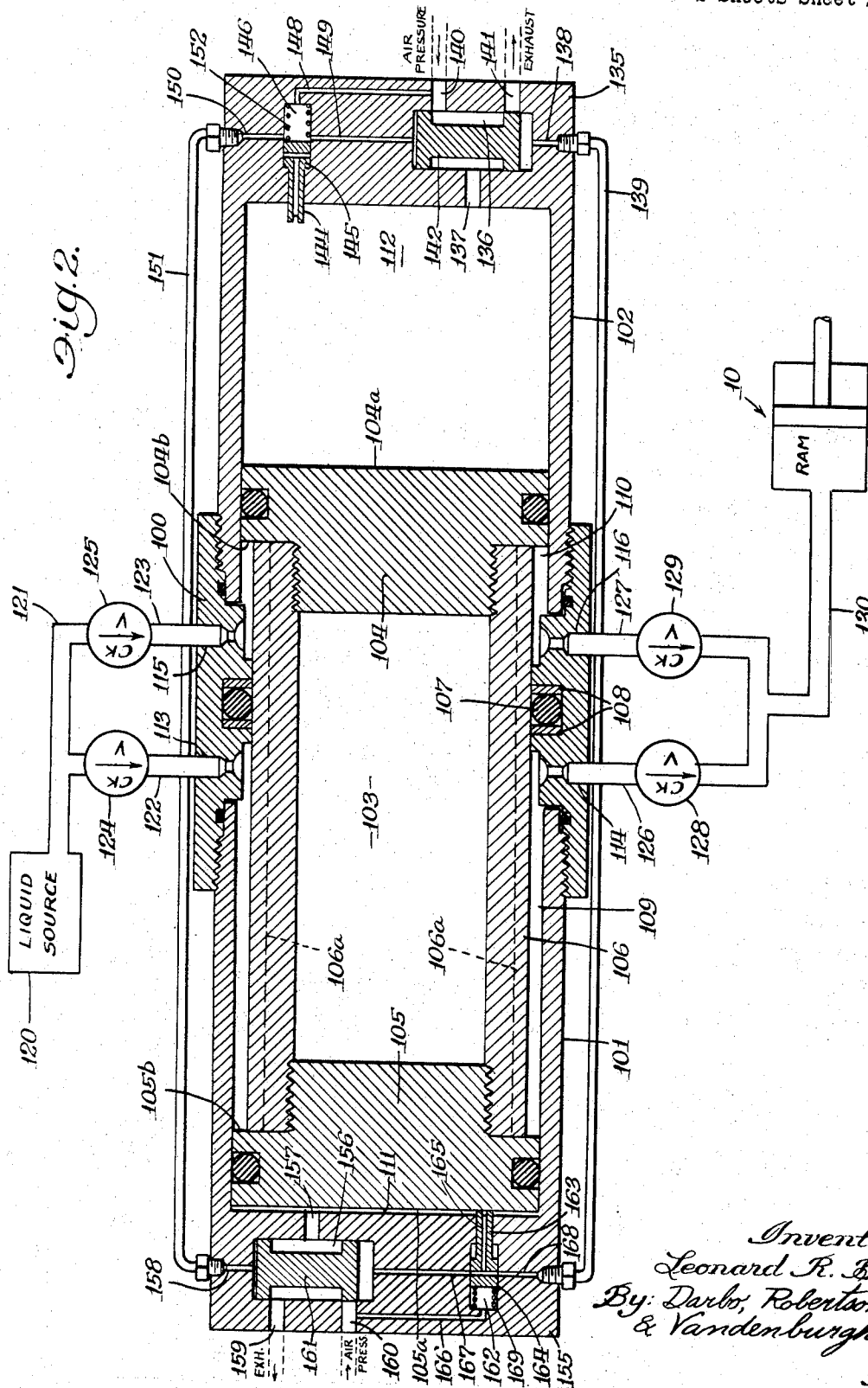
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AIR-HYDRAULIC SYSTEM AND APPARATUS
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Filed July 26, 1965, Ser. No. 474,673

14 Claims. (Cl. 60—54.5)

ABSTRACT OF THE DISCLOSURE

A method and apparatus as provided for operating a fluid actuated ram from a low pressure, high volume fluid source, the normal fluid in the ram being a hydraulic fluid while the normal fluid of the source is air. During the time that the ram meets little resistance the hydraulic fluid is forced directly to the ram by pressure from the air source. As the resistance met by the ram increases, fluid intensifiers are cut into operation to supply low volumes of fluid at comparatively high pressures. Particularly for use with such a system, a fluid intensifier is provided which, by interchanging the piston rod and seals thereabout, may be revised to change the intensification pressures and volumes.

This invention relates to a system and apparatus employed in the air-hydraulic operation of fluid cylinders.

In some instances the supply of hydraulic fluid to a hydraulic cylinder is provided by a continuously rotating pump. However, for many applications the hydraulic liquid, usually an oil, is pressurized for use in the hydraulic cylinder by the application of another fluid, usually air, under pressure to the hydraulic fluid. For the purposes of this application, the latter types of systems and apparatus are designated as an air-hydraulic type.

An elementary type of an air-hydraulic system would be one in which compressed air was fed into a supply tank of hydraulic fluid to force the hydraulic fluid out of the supply tank and into the hydraulic cylinder or ram to operate the same. Such a system is eminently satisfactory for many applications. Yet, for many other applications, which well may be in the majority of the total, this elemental system has disadvantages and drawbacks which are overcome by the present invention.

The latter type of applications to which reference is made would be exemplified by a hydraulic press wherein the maximum load occurs only after the jaws of the press have been brought together on the work. For the majority of the piston stroke little work is performed, usually only that necessary to overcome the weight of the parts, friction and the like. During the period when the maximum force is applied, i.e. after the jaws have been closed, there is only a relatively small (often quite imperceptible) movement of the piston. Thus, while all of the equipment must be designed and fabricated to operate and withstand the high pressures and forces required at the closing of the jaws, despite the fact that for all of the operations except when the jaws are actually closed, nothing like such high pressures and forces are present. Since all of the equipment must be designed to handle the maximum forces and pressures, it is expensive both in first cost and in operating cost when using the elemental system.

This can be illustrated by reference to the air compressor. It must supply air in sufficient quantities to provide the volume necessary for substantial movements of the piston. At the same time, it must be capable of producing pressures (in pounds per square inch) sufficient to achieve the high jaw pressures desired when the jaws are closed. Such a high volume, high pressure, compressor is very expensive as compared to a high pressure, low volume compressor or as compared to a low pressure, high volume compressor. A similar comparison exists as

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to operating costs. The present invention employs a high volume, low pressure air compressor. While it adds other parts to the elemental system referred to, both the initial cost and the operating costs are reduced as compared to an elemental system having the same operational parameters.

An important advantage of the system and apparatus of my invention is its versatility. With simple and minor modifications, the apparatus may be tailor-made to meet the requirements of a particular installation. This is highly important to the manufacturer of such equipment. A large market for air-hydraulic equipment exists in applications, no two of which are alike, figuratively speaking. Large equipment employing hydraulic rams is, in many instances, designed to meet the special requirements of the user of the equipment. The length of stroke required and the maximum pressure which the ram must exert vary from job to job. By employing the system and apparatus of my invention, the widely varying requirements in such respects can be met by a manufacturer from a comparatively limited stock of components.

In this respect, the fluid intensifier that I have devised plays an important role. A fluid intensifier is an apparatus which uses comparatively low pressure fluid to supply comparatively high pressure fluid. Typically, it is a dual piston device wherein the low pressure air acts on a piston of large area which drives a piston of small area to pump the hydraulic fluid. The ratio of the piston areas determines the relationship between the two pressures. The intensifier that I have devised enables the manufacturer, with only a minor interchange of parts, to change the ratio of piston areas and, thus, the ratio of pressures. The majority of the parts of the intensifier remain the same for all ratios. The manufacturer need only stock a nominal quantity of a few replacement parts in order to obtain a variety of ratios of pressures.

The intensifier I have devised has a number of other advantages. The parts are comparatively simple to manufacture. Substantially the same parts may be incorporated into the production of either a single acting or a double acting intensifier. A compact double acting intensifier may be produced as a package unit having all of the controls incorporated therein. The piston rings and seals can be inexpensive, long life, O-rings. Even with a large pressure differential between the driving and driven sides, the O-rings are all relatively large in diameter and thus easy to install and maintain in good condition.

Further objects and advantages will become apparent from the following description taken in conjunction with the drawings, in which:

FIGURE 1 is a diagrammatic representation of a hydraulic system embodying my invention; and

FIGURE 2 is a section longitudinally through a double acting fluid intensifier of my invention.

Although the following disclosure offered for public dissemination is detailed to ensure adequacy and aid understanding this is not intended to prejudice that purpose of a patent which is to cover each new inventive concept therein no matter how others may later disguise it by variations in form or additions or further improvements. The claims at the end hereof are intended as the chief aid toward this purpose; as it is these that meet the requirement of pointing out the parts, improvements, or combinations in which the inventive concepts are found. Various modifications will be apparent to those skilled in the art. For example, the following description, single and double-acting rams and intensifiers will be discussed. It will be apparent to those skilled in the art how they could be constructed and used as double-acting rather than single-acting or as single-acting rather than double-acting.

The system of FIGURE 1 is for the purpose of oper-

ating a single-acting hydraulic cylinder or ram, generally 10, with hydraulic fluid. As a source of power compressed air from an air source, generally 11, is used. Air source 11 normally would be an air compressor and air supply tank. The hydraulic fluid 12 is supplied from a closed tank 13 which is pressurized by air from source 11. The air from source 11 traverses a conduit 14 to valve 15 and then through conduit 16 to tank 13. The position of valve 15 may be changed so that conduit 16 is connected to exhaust line 17.

A conduit 19 having a check valve 20 therein leads to the driven chamber 21 of a fluid intensifier, generally 22. Intensifier 22 has a cylinder 23, including a head 24, which defines a driving chamber 25. Within cylinder 23 is a piston 26 and piston rod 27. A central hub 28 holds a seal 29 which fits fluid-tight to piston rod 27. A second cylinder 30, including a head 31, is secured to hub 28 and defines an air chamber 32.

Air supply conduit 14 leads to a valve 34. Conduits 35 and 36 lead from valve 34 into cylinders 30 and 23 respectively. Conduit 37 is an exhaust pipe. The position of valve 34 may be as illustrated in FIGURE 1 in which pipes 14 and 35 and 36 and 37 respectively are in communication or the connections may be reversed by a repositioning of the valve. If air pressure is applied to pipe 35 with pipe 36 being connected to exhaust, piston 26 will move to the left. Conversely, with pipe 36 being supplied with air pressure and pipe 35 connected to exhaust, piston 26 will move to the right.

The pressure at which hydraulic fluid is forced from chamber 21 into discharge conduit 38 (for any given air pressure from source 11) is determined by the ratio of the areas of the faces of piston 26 in contact with the two fluids. Thus, piston 26 has a face 26a forming one wall of driving chamber 25 and face 26b forming one wall of driven chamber 21. Assuming, for example, that the area of face 26a is five times as large as the area of face 26b, then the pressure produced in chamber 21 would be substantially five times larger than the air pressure in chamber 25. By changing the external diameter of piston rod 27, the area of face 26b is changed. Of course, the size of seal 29 also would have to be changed to correspond to the changed diameter of piston rod 27.

Conduit 38 leads to a sequence valve, generally 40. A conduit 41 leads from sequence valve 40 to working cylinder 10 with a check valve 42 being interposed in that conduit. Sequence valve 40 comprises a casing 43, one part of which is divided by a piston 44 into an action chamber 45 and a reaction chamber 46. Casing 43 also defines a valve seat 47 against which is positioned a closure member 48 in the form of a ball. Ball 48 is urged against its seat by spring 49. Piston 44 has a piston rod 50 which displaces closure 48 from its seat as a result of a movement of piston 44 to the right. A conduit 51 communicates with conduit 41 downstream of check valve 42 and also communicates with action chamber 45 of the sequence valve. The portion of casing 43 in which closure member 48 is located communicates with a conduit 52.

A second intensifier, generally 55, is a two-stage affair. It comprises a body 56 having an annular opening 57 about a cylindrical boss 58. Secured to body 56 is a cylinder 59 having a head 60. Cylinder 59 has an opening 61 in the wall thereof. In cylinder 59 is a piston 62 having an annular piston rod (and piston) 63. Annular piston rod 63 fits into annular opening 57, with a seal being provided by external and internal O-ring seals 64 and 65 respectively. A spring 66 between body 56 and piston 62 urges piston 62 away from the body.

Thus, intensifier 55 has a driving chamber or cavity 69 and two driven chambers or cavities 70 and 71 respectively. Conduit 52 communicates with chamber 69. A conduit 72 communicates with chamber 71. Conduit 73 communicates with chamber 70. Piston 62 has a face 62a in chamber 69 and a face 62b in chamber 70. It, or actually its piston rod 63 (serving as a piston), has a

face 63a in chamber 71. The combined or total of the areas of faces 62b and 63a is less than the area of face 62a.

Pipe 72 leads to check valves 75 and 76 and to a sequence valve, generally 77. Sequence valve 77 has a casing 78 within which is a piston 79, a piston rod 80, a ball closure member 81 and a spring 82. Casing 78 and piston 79 define an action chamber 83 and a reaction chamber 84. Casing 78 defines a valve seat 85 against which ball 81 is urged by spring 82.

A conduit 87 communicates with that portion of the interior of casing 78 within which closure member 81 is located, as well as with check valve 75, check valve 88, pressure relief valve 89, control valve 90 and the lower part of fluid supply tank 13. Pipe 73 connects to check valves 88 and 91. Pipe 41 connects to check valves 91 and 76 and to chamber 83 of sequence valve 77, relief valve 89 and control valve 90. A manual control valve 90a is connected between pipes 52 and 87 in parallel with a check valve 92. Manual valves 90 and 90a are operated simultaneously.

At the start of a cycle of operations, control valves 90 and 90a are closed. Air from source 11 is applied to tank 13 to pressurize hydraulic fluid 12 and cause it to flow into all parts of the system. With the system full of hydraulic fluid, air is applied to driving chamber 25 of intensifier 22. This applies a first stage pressure to the fluid in driven chamber 21, which fluid flows to the working cylinder 10 through conduit 38, check valve 42 and conduit 41. This flow continues until the resistance to the movement of the piston of working cylinder 10 approaches the maximum that can be supplied by intensifier 22 from an air source 11 of given characteristics. At this point sequence valve 40 cuts in the second stage, as follows. The fluid pressure in pipes 38 and 41 is also exhibited in chambers 45 and 46 of sequence valve 40. Here the fluid acts upon the two sides of piston 44 as well as upon the exposed portion of closure 48. Of these exposed areas upon which the oil acts, the major amount is so disposed as to cause the hydraulic fluid to urge the piston and closure to the right in FIGURE 1. These forces, however, are resisted by spring 49 until the limit of the capabilities of the intensifier 22 in driving working cylinder 10 in the first stage is reached. When this predetermined limit pressure is reached, spring 49 permits piston 44 and closure 48 to move to the right and allowing hydraulic fluid to flow into pipe 52. The predetermination is controlled by the strength of spring 49.

When the sequence valve is thus opened, the hydraulic fluid flows into driving chamber 69 of intensifier 55. In turn, it applies an increased pressure to the hydraulic fluid in chambers 70 and 71 of the intensifier 55. This is the second stage pressure. The hydraulic fluid in chambers 70 and 71 flows through conduits 72 and 73, check valves 76 and 91, and conduit 41 to hydraulic cylinder 10. Of course, if at any stage piston 26 moves to the right end of its travel, valve 34 is reversed to move piston 26 back to its original position and then reoriented to cause piston 26 to again commence moving to the right in FIGURE 1.

When the capability of the second stage to deliver hydraulic fluid to cylinder 10 is reached, i.e. the pressure in driving chamber 69 is as great as can be achieved with intensifier 22 and air source 11, sequence valve 77 opens and a third pressure stage is achieved. The opening of the sequence valve is achieved by reason of the fact that the pressures on the piston 79 and closure 81 offset the force of spring 82 so that closure 81 moves away from its seat 85. This permits the hydraulic fluid from chamber 71 and conduit 72 to return to tank 13. Thus, chamber 71 is unloaded and only the fluid pressure in driven chamber 70 is resisting the fluid pressure in driving chamber 69. In such a situation, a given force in driving chamber 69 can apply an increased pressure to the fluid in driven chamber 70, as compared to what had been achieved

before chamber 71 was unloaded. Intensifier 55 thus can continue to supply hydraulic fluid to working cylinder 10 until the desired jaw pressure of the device operated by working cylinder 10 is achieved. To return the system to its original condition, valves 90 and 90a are opened, whereupon the hydraulic fluid returns to supply tank 13. Relief valve 89 is employed as a safety precaution in the event that the fluid pressure in pipe 41 exceeds the safe maximum.

FIGURE 2 illustrates an intensifier ideally suited for use in an air hydraulic system because of the ease with which the ratio of the input to output pressures may be varied. It comprises a central hub 100, two end cylinders 101 and 102 and a piston assembly 103. Piston assembly 103 comprises two pistons 104 and 105 threaded into opposite ends of a cylindrical piston rod 106. Hub 100 has a central seal fitting about piston rod 106 and comprising an O-ring 107 held between two relatively rigid washers 108. The structure defines two driven chambers 109 and 110 for the hydraulic fluid, and two driving chambers 111 and 112 for the driving fluid, usually air. Hub 100 has two connections 113 and 114 communicating with chamber 109 and two connections 115 and 116 communicating with chamber 110. Air supply ports in the cylinder heads, hereinafter described in detail, communicate with air chambers 111 and 112.

A source of hydraulic fluid 120 is connected to connections 113 and 115 by conduits 121, 122 and 123 and check valves 124 and 125. Conduits 126 and 127 lead from the output connections 114 and 116 to check valves 128 and 129. From check valves 128 and 129, the hydraulic fluid is conducted through a conduit 130 to the point at which it is to be used as, for example, a working cylinder or ram 10.

As piston assembly 103 is moved back and forth by alternately applying air pressure to the two driving chambers 111 and 112, hydraulic fluid is drawn into driven chambers 109 and 110 and from there pumped out through conduit 130. The pressure at which the hydraulic fluid is pumped out (in relation to the driving air pressure) is determined by the relationship that the area of faces 104a and 105a bears to the area of faces 104b and 105b. Thus, for example, if the external diameter of piston rod 106 is reduced to the size indicated by dotted lines 106a, the area of faces 104b and 105b will be substantially increased. This, of course, would change the ratio of the area of face 104a to face 104b. In turn, this would substantially reduce the output pressure in pipe 130 for a given air pressure used to drive the intensifier. At the same time, the volume of hydraulic fluid pumped would be correspondingly increased.

Thus, it will be seen that by merely changing the external diameter of piston rod 106 and the internal diameter of the sealing assembly comprising O-ring 107 and washers 108, one can change the characteristics of the intensifier of FIGURE 2. In some instances, the whole central hub assembly would be changed with a change in the piston rod diameter, rather than merely changing the seals. In any event, the pistons 104 and 105 would be the same for all units as would be the cylinders 101 and 102. By way of illustration, assume that the diameter of the pistons 104 and 105 was 1.500 inches. For piston rod diameters of 1.3125, 1.3750 and 1.4375 inches, the ratio of the piston areas is 4.26 to 1, 6.26 to 1 and 12.26 to 1 respectively. Since the pistons and cylinders always remain the same size, there is a great simplification in manufacturing procedures as well as a reduction in the required finished stock necessary to meet demands. Furthermore, the alignment of the whole apparatus, and particularly the piston assembly 103 in cylinders, is always maintained correctly by the pistons themselves. The piston rod need not be relied upon to maintain a correct alignment of parts as is the case with some prior art devices.

The embodiment of FIGURE 2 also incorporates fea-

tures to make it a self-contained double-acting unit. Cylinder 102 has a head 135 within which is a cylindrical cavity 136. A port 137 connects cavity 136 to chamber 112. A port 138 is used for connection to pipe 139. Ports 140 and 141 connect to sources of air pressure and exhaust respectively. A valve spool 142 is slidably received in cavity 136.

A valve member having a stem 144 and a head 145 is received in opening 146 in head 135. The valve member has a T-shaped passageway 147 therein. A passage 148 connects opening 146 and port 140. A passage 149 connects opening 146 with cavity 136. A port 150 is used to connect opening 146 with pipe 151. A spring 152 urges the valve member 144, 145 to the left.

Cylinder 101 has a head 155 with a corresponding construction. There is a cavity 156 having ports 157, 158, 159 and 160. Spool 161 is in cavity 156. The valve member in opening 162 has a stem 163, a head 164 and a T-shaped passageway 165. Connecting to opening 162 are passages 166 and 167 and port 168. A spring 169 urges the valve member to the right.

The two valve members are urged toward chambers 112 and 111 by springs 152 and 169. When in the position to which they are urged, the air pressures at opposite ends of spools 142 and 161 are balanced. Thus, air under pressure flows through passage 148 and opening 146 to the top of spool 142 through passage 149, and to the top of spool 161 through port 150, pipe 151 and port 158. Similarly, air under pressure enters passage 166 to opening 162 and, thence, to the bottom of spool 161 through passage 167 and to the bottom of spool 142 through port 168, pipe 139 and port 138 (assuming that the left valve member has not been displaced as illustrated).

However, with the displacement of valve member 164, 165 as illustrated, the air is exhausted from below spools 142 and 161. This is accomplished by reason of the fact that chamber 111 is exhausted (through ports 157 and 159) and passageway 165 is in communication both with chamber 111 and with passage 167 and port 168. Thus, having arrived at the situation illustrated in FIGURE 2, spools 142 and 161 would be moved downwardly by reason of the fact that the space therebelow is connected to exhaust and the space thereabove is connected to air pressure.

When spool 161 moves down, ports 157 and 160 are brought into communication so that air under pressure is applied to chamber 111. When spool 142 moves down, it places ports 137 and 141 into communication so that chamber 112 now is connected to exhaust. Air pressure still exists in pipe 151 (as previously described) and by reason of the foregoing, air pressure is now supplied to passageway 165 so that the pressures at opposite ends of the spools again are balanced. Even when piston 105 moves away from valve member 164, 165, and that valve member shifts to the right under the urging of spring 169, the pressure remains balanced since the communication between passage 166 and passages 167 and 168 is restored.

When the piston assembly 103 moves to the other, right hand, end of its stroke, it shifts valve member 144, 145, so that the space above spools 142 and 161 is connected to exhaust through chamber 112. Thus, the pressures at opposite ends of the spools are unbalanced and the two spools shift back to the position illustrated in FIGURE 2. This restores air pressure to chamber 112 and connects chamber 111 to exhaust so that the piston assembly 103 commences moving to the left toward the position illustrated in FIGURE 2. Thus, it will be seen that the embodiment of FIGURE 2 is a self-contained double-acting intensifier, which, for example, could replace intensifier 22 and valve 34 of FIGURE 1.

I claim:

1. A fluid intensifier adapted to be used with a source of fluid under pressure to pressurize a second fluid, said

intensifier including: a fluid cylinder having a longitudinal axis; a piston in said cylinder for axial movement therein and dividing said cylinder into two chambers; a plurality of interchangeable piston rods usable one at a time, said one piston rod being in one chamber, extending parallel to said axis and releasably secured to one side of said piston, said piston rod covering a predetermined portion of said side whereby the area of remaining part of said one side bears a given relationship to the area of the other side of the piston, the remaining piston rods being releasably securable to said one side of said piston in place of said one piston rod and when so secured covering other predetermined portions of said side whereby the area of the remaining part of said one side bears other given relationships to the area of the other side of the piston; a first seal between the piston and the cylinder; a plurality of interchangeable second seals, one for each of said piston rods and usable one at a time, said one second seal being between the cylinder and the piston rod; a fluid connection with one chamber for said second fluid; and means to connect the other chamber to said source; whereby the ratio of said areas may be changed by changing the piston rods and the second seals are changed to correspond to the piston rod being used.

2. A fluid intensifier adapted to be used with a first source of fluid under pressure to pressurize a second fluid from a source thereof and to deliver the pressurized second fluid to a utilization device, said intensifier including: a unitary casing defining two fluid cylinders having a common axis; pistons in each cylinder for axial movement therein, each piston dividing its cylinder into two chambers; a piston rod rigidly connecting said pistons; a seal between said casing and said piston rod intermediate said two cylinders; means including first fluid connections communicating with the cylinders at each side of the seal and between the seal and the adjacent side of the pistons and to connect to said source of said second fluid and to said utilization device; and means including second fluid connections communicating with the cylinders at the opposite side of the pistons and to connect to said first source to drive said pistons.

3. A fluid intensifier as set forth in claim 2, wherein said casing includes a hub and two cylinder parts about said axis, said parts being connected to said hub by threads, said first two connections and said seal being in said hub, said piston rod being connected to said pistons by threads.

4. An air-hydraulic booster for use with a source of pressurized air, a source of hydraulic liquid and a hydraulic ram, said booster including: a unitary casing defining two fluid cylinders having a common axis; pistons in each cylinder for axial movement therein, each piston dividing its cylinder into two chambers; a piston rod rigidly connecting said pistons; a seal between said casing and said piston rod intermediate said two cylinders; first fluid connections communicating with the cylinders at each side of the seal and between the seal and the adjacent side of the pistons; unitary directional flow means connecting said first connections with said source of liquid and with said ram to permit liquid to flow from the source thereof to the booster and from the booster to the ram; fluid ports communicating with the cylinders at the opposite sides of the pistons; and air control means connected to the ports and to the source of air to apply the air alternately to the two ports and to alternately permit the other of the two ports to exhaust.

5. A booster as set forth in claim 4, wherein said air control means includes valve means having two positions of rest, at one of said positions one port communicating with the air source and the other port with exhaust and at the other of said positions said other port communicating with the air source and said one port with exhaust, valve actuator means connected to the valve means and having two actuating members, one member being effective to change said valve means from one position to

the other and the other member being effective to change said valve means from the other position to the one position, said members being in the ends of the cylinders respectively to change the position of the valve means as the piston approaches the end of the respective cylinder.

6. A booster as set forth in claim 5, wherein said valve means comprises a fluid actuated spool valve, said spool normally being urged equally in both directions with air under pressure, said member each including a second valve which is opened, as the respective member is contacted by the respective piston, to remove the pressure from one side of the spools and to exhaust that side of the spools whereby the spools are unbalanced and moved to another position.

7. A booster as set forth in claim 6, wherein said member and second valve includes a stem projecting through the wall at the end of the respective cylinder, said stem having an end within the cylinder and a passageway communicating with said end, said stem being movable parallel to said axis between two positions, in one of said positions said end projecting farther into said cylinder than in the other of the positions, said passageway being in communication with the valve means when said stem is in the other position.

8. Apparatus for supplying hydraulic fluid to a hydraulic ram from a pressurized source of hydraulic fluid and using air under pressure from a source thereof, said apparatus comprising: first fluid intensifier means connected to the source of hydraulic fluid to receive fluid therefrom and to said source of air to be driven by the air to deliver said fluid at an output under increased pressure; a conduit connecting said output and said ram; a check valve in said conduit to permit flow only from the output to the ram; normally closed, fluid operated sequence valve means connected to said conduit upstream of said check valve, said valve means having a discharge opening communicating with said conduit only when said valve means is open, said valve means being also connected to said conduit downstream of said check valve to be opened when the pressure downstream of the check valve exceeds a certain value; second fluid intensifier means connected to the source of hydraulic fluid to receive fluid therefrom and to said discharge opening to be driven by fluid from said opening to deliver said fluid from said source to a second output under increased pressure; and a second conduit connecting said second output and said ram.

9. An apparatus as set forth in claim 8, wherein one of said intensifiers includes a fluid cylinder having a longitudinal axis; a piston in said cylinder for axial movement therein and dividing said cylinder into two chambers; a piston rod in one chamber, extending parallel to said axis and secured to one side of said piston, said piston rod covering a predetermined portion of said side whereby the area of remaining portion bears a given relationship to the area of the other side of the piston; a first seal between the piston and the cylinder; a second seal between the cylinder and the piston rod; a fluid connection with one chamber; and a fluid connection with the other chamber.

10. Apparatus for supplying hydraulic fluid to a hydraulic ram from a pressurized source of hydraulic fluid and using air under pressure from a source thereof, said apparatus comprising: first fluid intensifier means adapted to be connected to the source of hydraulic fluid to receive fluid therefrom and to said source of air to be driven by the air to deliver said fluid at an output under increased pressure; a conduit connecting said output and said ram; a check valve in said conduit to permit flow only from the output to the ram; normally closed fluid operated sequence valve means connected to said conduit upstream of said check valve, said valve means having a discharge opening communicating with said conduit only when said valve means is open, said valve means

being also connected to said conduit downstream of said check valve to be opened when the pressure downstream of the check valve exceeds a given value; second fluid intensifier means having a driving cavity and two driven cavities each with a piston face, the piston faces of the driven cavities having a total area smaller than that of the piston face of the driving cavity, said driving cavity being connected to said discharge opening to receive fluid under pressure therefrom, said driven cavities being adapted to be connected to said source of hydraulic fluid to receive fluid therefrom; a second conduit connecting one of the driven cavities with the ram; a second check valve in said second conduit to permit flow in said conduit only from the cavity to the ram; a second normally closed fluid operated sequence valve means connected to said second conduit upstream of said check valve, said second valve means having a discharge opening communicating with said second conduit only when said valve means is open, said second valve means being also connected to said second conduit downstream of said second check valve to be opened when the pressure downstream of the second check valve exceeds a value greater than said given value, said opening of said second valve means being adapted to be connected to said source of hydraulic fluid; and a third conduit connecting the other driven cavity and the ram.

11. Apparatus as set forth in claim 10, including valve means connected to said ram, said driving cavity of the second intensifier means and adapted to be connected to said source of fluid to permit fluid to flow from said source to said ram and driving cavity while normally preventing fluid flow in the reverse direction, and being operable to selectively permit fluid flow in said reverse direction.

12. Apparatus for supplying hydraulic fluid to a hydraulic ram from a pressurized source of hydraulic fluid and using air under pressure from a source thereof, said apparatus comprising: first intensifier means; second intensifier means; sequencing valve means; and conduit means connected to the intensifier means, said sources, the ram and the valve means; said first intensifier means, said sources, the ram and the valve means; said first intensifier means being connected to be actuated by air from the source thereof and to receive fluid from said source thereof and to deliver said fluid at an increased pressure to said valve means, said valve means directing said increased pressure fluid to said ram until the pressure at said ram exceeds a certain value and thereafter to direct said fluid to the second intensifier means to actuate the latter, said second intensifier means being connected to said ram and to said fluid supply to receive fluid from the supply and when actuated to deliver said

fluid under pressure greater than said increased pressure to said ram.

13. An apparatus as set forth in claim 12, wherein said second intensifier means comprises piston means having a large pressure face on one side and two concentric secondary pressure faces on the opposite side, said two secondary faces having a total area less than the area of the main face, means defining three pressure chambers of which said faces define a wall thereof respectively, and fluid connections communicating with each chamber; a second sequencing valve means connected to the two secondary chambers and to the ram to deliver fluid from both chamber to the ram until the fluid pressure at the ram reaches a given value and to thereafter only deliver fluid from one secondary chamber to the ram with the fluid from the other secondary chamber being returned to the source of fluid.

14. The method of operating a hydraulic ram with fluid from a pressurized source of hydraulic fluid and using air under pressure from a source thereof, and two fluid intensifiers, said method including the steps of: feeding fluid from said source thereof to the two fluid intensifiers, intensifying the pressure of the fluid in one intensifier by using air from said source to produce fluid of increased pressure, feeding said increased pressure fluid to the ram to operate the ram up to a given load thereof, thereafter feeding the fluid of increased pressure to the second intensifier, intensifying the fluid originally in the second intensifier by using the fluid of increased pressure to produce fluid of greater than said increased pressure, and feeding said fluid of greater than increased pressure to the ram to operate it above said given load.

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