

[54] SYNCHRONIZED PISTON ASSEMBLY

[75] Inventors: **Kenneth H. Meyer; William E. Heese**, both of Akron, Ohio

[73] Assignee: **Hydrapower Inc.**, Wadsworth, Ohio

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Related U.S. Application Data

[63] Continuation of Ser. No. 256,599, May 24, 1972, abandoned.

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[51] Int. Cl. **F15b 11/22**

[58] Field of Search 91/171, 422, 437, 411 A; 92/151; 60/97 E, 546

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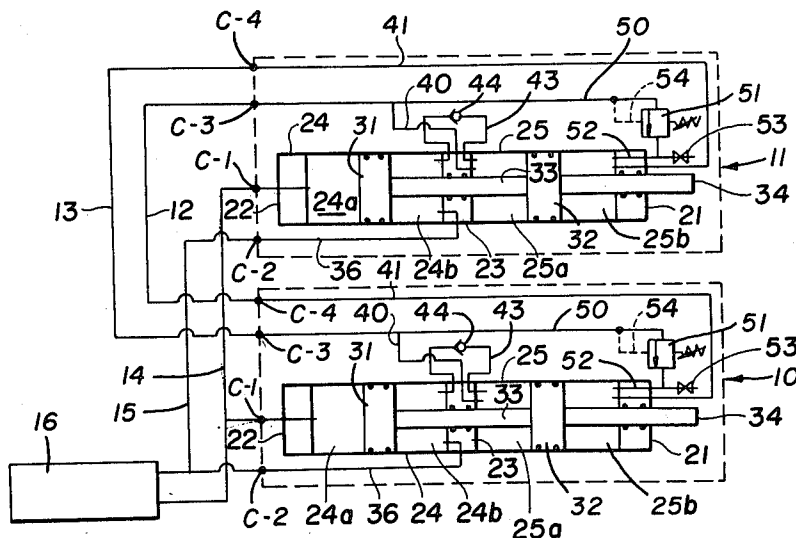
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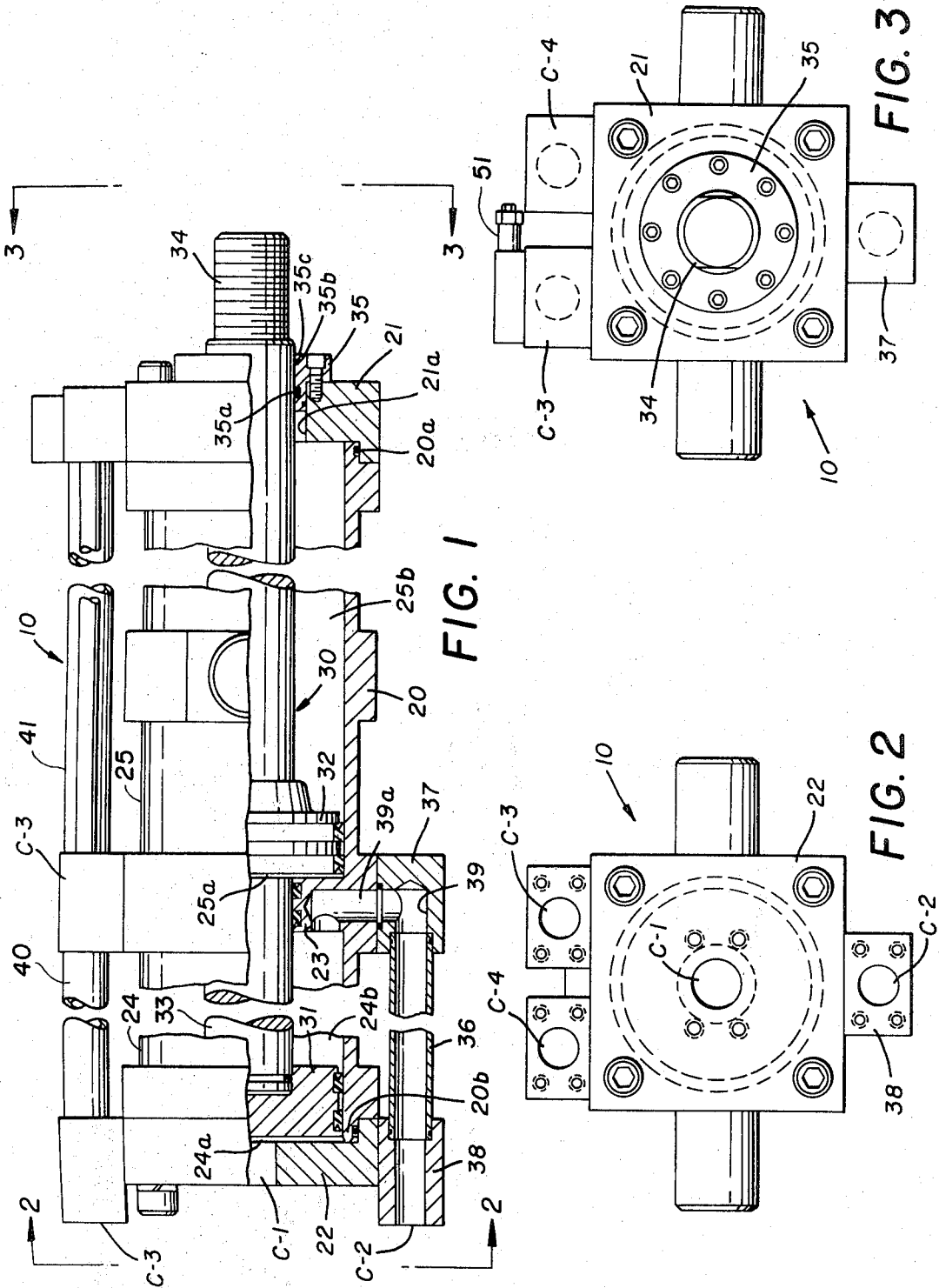
Primary Examiner—Paul E. Maslousky
 Attorney, Agent, or Firm—Donnelly, Maky, Renner & Otto

[57] **ABSTRACT**

A synchronized piston assembly characterized in the provision of at least two hydraulic cylinder units each of which comprises coaxial primary (or drive) and secondary (or synchronizing) cylinders, and a piston unit having interconnected drive and synchronizing pistons axially reciprocable in the respective drive and synchronizing cylinders. The drive cylinders are operatively connected with a fluid pressure control source for simultaneous actuation of said drive pistons, and the synchronizing cylinders are in cross-connected fluid communication with each other to form a closed hydraulic circuit which is effective to synchronize the movements of said piston units upon fluid pressure actuation of the drive pistons thereof despite unequal loading of said piston units. The assembly herein is further characterized in that each cylinder unit has check valve means between the drive and synchronizing cylinders to pressurize the synchronizing circuit and to maintain substantially synchronous operation of said drive pistons despite external fluid loss from the stabilizing circuit, and relief valve means between the ports of the synchronizing cylinder operative to restore the piston units to synchronism at the end of each working stroke or return stroke of said piston units in the event that either piston unit reaches the end of its working stroke or return stroke slightly before the other piston unit due, for example, to leakage in or from the stabilizing circuit.

5 Claims, 5 Drawing Figures





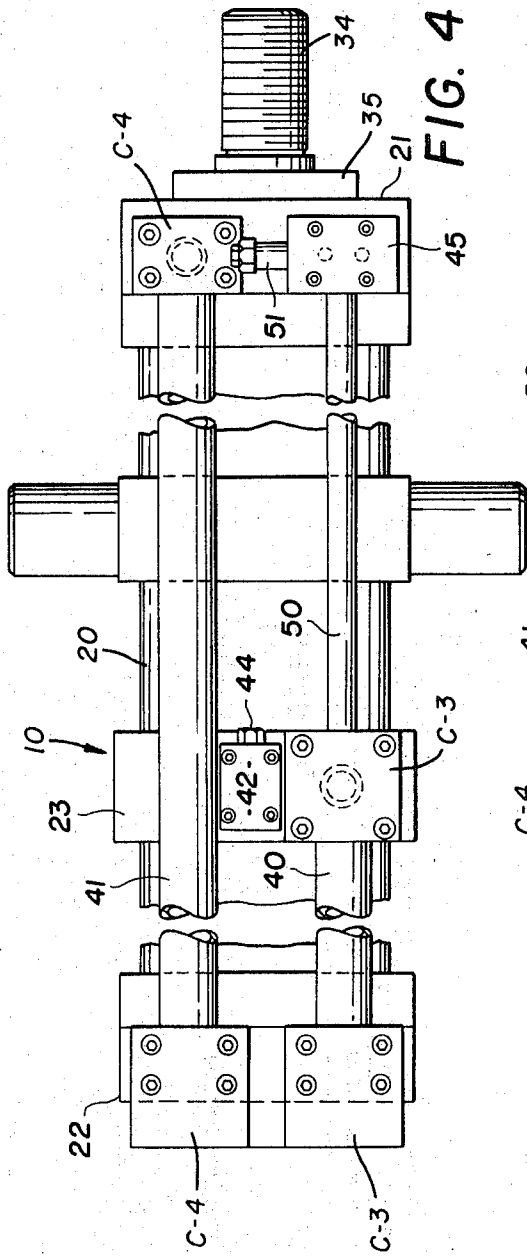


FIG. 4

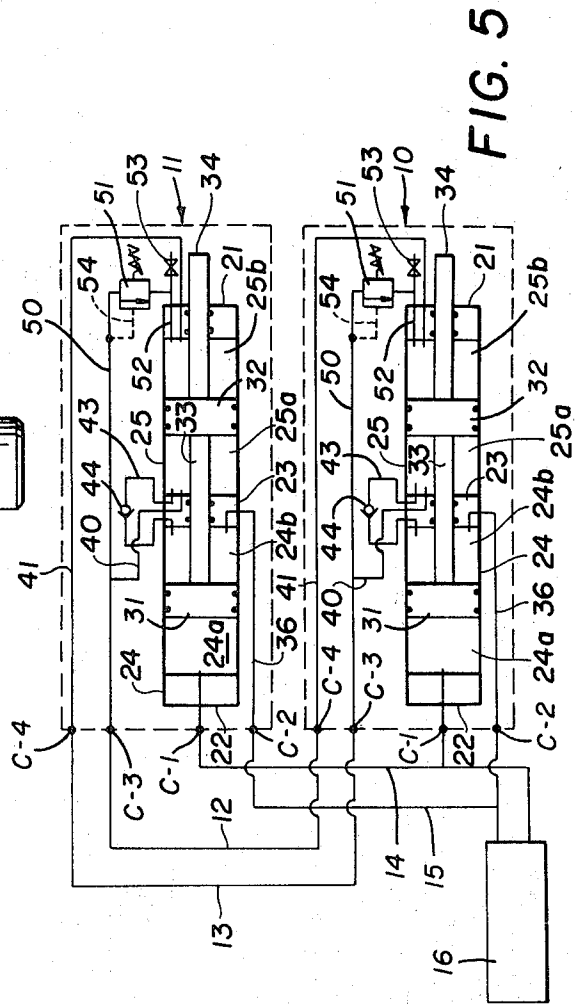


FIG. 5

SYNCHRONIZED PISTON ASSEMBLY

RELATED APPLICATION

This application is a continuation of Ser. No. 5 256,599, filed May 24, 1972 now abandoned.

BACKGROUND OF THE INVENTION

In the hydraulic actuation of the compacting plate of steel coil compacting apparatus, of the lifting platform of lifting apparatus, etc. it is known to employ a plurality of hydraulic cylinders connected in parallel to actuate such plate or platforms. However, in apparatus of the character indicated, the loads on the cylinders may be unequal and hence, the movements of the pistons will not be in synchronism thereby tending to tilt the compacting plate or the lifting platform.

To achieve synchronized movements of a plurality of hydraulic cylinders it has been proposed heretofore to connect the cylinders in series but among the principal drawbacks of such series arrangement of cylinders are: that the first cylinder must provide the entire compacting or lifting forces with the succeeding cylinder or cylinders merely following whereby each cylinder must be of size sufficient to handle the full load; that if one of the cylinders goes out of synchronism due to leakage of fluid all of the remaining ones will be moving out of synchronism to a progressively worsening degree; that the series system is difficult to properly fill; that the series system does not make up for fluid losses; and that the series system is not self-correcting.

It has also been proposed heretofore to employ flow control valves in a parallel arrangement of hydraulic cylinders to obtain synchronous actuation of the cylinders by equalizing the flow of fluid to the respective cylinders but, as evident, such systems are complex and expensive and moreover, flow control valves are not sensitive to small departures from the desired equal flows.

SUMMARY OF THE INVENTION

In contradistinction to the foregoing, the synchronized piston assembly herein is characterized in that each of a plurality of hydraulic cylinder units comprises coaxial drive and synchronizing cylinders, and a piston unit which has interconnected drive and synchronizing pistons reciprocable in the respective drive and synchronizing cylinders, said drive cylinders having ports for connection with a fluid pressure control source for hydraulic actuation of said drive pistons, and said synchronizing cylinders having ports which are cross-connected to form a closed synchronizing circuit effecting synchronous actuation of said drive pistons irrespective of differences in the loads thereon.

A further characterizing feature of this invention is that the aforesaid drive-synchronizing piston units are automatically maintained in substantial synchronism during actuation or are automatically resynchronized at the end of the working stroke or return stroke thereof in the event of minute non-synchronous movement due, for example, to fluid losses in or from the synchronizing circuit.

Other objects and advantages will appear from the ensuing description.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevation view, partly in cross-section,

of one of a plurality of hydraulic cylinders constituting the present synchronized piston assembly;

FIGS. 2 and 3 are end elevation views as viewed along the respective lines 2-2 and 3-3, FIG. 1;

FIG. 4 is a top plan view as viewed from the top of FIG. 1; and

FIG. 5 is a schematic piping diagram showing the power and synchronizing circuits respectively for actuation of the drive pistons of two hydraulic cylinders embodying the present invention and for synchronizing the actuation of said drive pistons.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now in detail to the drawings and in particular to FIG. 5, a pair of cylinder units 10 and 11 interconnected by fluid lines 12 and 13 to provide a synchronizing circuit and are interconnected by fluid lines 14 and 15 with a fluid power source 16 to provide a drive or actuating circuit which, as well known in the art, may comprise a tank, a pump, and a directional control valve, the latter in the case of double acting cylinders usually being of the four-way type so that fluid under pressure may be directed to the cylinder units 10 and 11 through either fluid line 14 or 15 with fluid being returned to the tank via the four-way directional control valve through the other fluid line 15 or 14. The cylinder units 10 and 11 are of the same construction and therefore only one of them, namely cylinder 10, has been shown in detail in FIGS. 1-4.

Referring now in detail to FIGS. 1-4, each cylinder unit 10 and 11 comprises a main cylinder 20 which has cylinder heads 21 and 22 at its opposite ends and which has between its ends a dividing wall 23 which constitutes a common cylinder head for the coaxial drive and synchronizing cylinders 24 and 25.

Reciprocable in the main cylinder 20 is a piston unit 30 comprising a drive piston 31 reciprocable in the drive cylinder 24 and dividing the same into chambers 24a and 24b, and a synchronizing piston 32 reciprocable in the synchronizing cylinder 25 and dividing the same into chambers 25a and 25b, said drive and synchronizing pistons 31 and 32 being interconnected by a piston rod 33 which is slidably sealed in the bore of the common head 23. In addition, the piston unit 30 has a piston rod 34 which passes through a suitable rod packing unit 35 including packing rings 35a and 35b and scraper 35c in the cylinder head 21 and which is threaded for connection with the machine part or parts which it is desired to hydraulically actuate by means of a plurality of cylinder units 10 and 11. The drive cylinder ports are designated C-1 and C-2 and have fluid communication with the respective drive cylinder chambers 24a and 24b, the latter communication being effected through a tube and fitting assembly 36, 37, and 38 as best shown in FIG. 1 with the dividing wall 23 having a passage 39a leading into the chamber 24b and communicating with a passage 39 in the fitting member 37.

The cylinder head 22 has thereon C-3 and C-4 fittings which provide the synchronizing cylinder ports C-3 and C-4 which communicate by way of conduits 40 and 41 with the synchronizing motor chambers 25a and 25b respectively via C-3 and C-4 fittings on heads 23 and 21. The common head 23 has thereon a fitting 42 which provides the passage 43 which intercommunicates the drive cylinder chamber 24b with the syn-

chronizing cylinder chamber 25a via the check valve 44. The cylinder head 21 has thereon a fitting 45 which is connected by conduit 50 to the C-3 fitting on head 23 and which contains the relief valve 51. The inlet side of the relief valve 51 is communicated with the synchronizing chamber 25a by way of passages 40 and 50 (see FIG. 5) and the outlet side of the relief valve 51 has a passage 52 which communicates with the synchronizing chamber 25b. The passage 52 also has associated therewith a bleed valve 53 by means of which the air in synchronizing chambers 25b may be bled from the synchronizing system.

When, for example, two cylinder units 10 and 11 have their piston rods 34 connected to members (not shown) which are to be actuated in synchronism, the C-3 synchronizing port of the cylinder unit 10 is connected by way of conduit 13 to the C-4 port of the other cylinder unit 11 and the C-4 port of the cylinder unit 10 is connected by way of conduit 12 to the C-3 port of the other cylinder unit 11 whereby the synchronizing cylinders 25 are cross-connected whereby, when the drive pistons 31 are actuated, they must move in synchronism despite different loads which may be imposed on the piston rods 34.

Referring especially to FIG. 5, it can be seen that when the fluid power control source 16 is actuated to conduct fluid under pressure into the fluid line 14 fluid under pressure admitted into the drive cylinder chambers 24a will cause the drive pistons 31 to move toward the right and the fluid displaced from the chambers 24b will be returned to the tank of the control source 16 via the fluid lines 36 and ports C-2 and fluid line 15 to the tank associated with the control source 16 as previously explained. Despite unequal loads on the piston rods 34, the drive pistons 31 will move in synchronism because of the cross-connection of the synchronizing cylinders 25, that is, in the condition of the parts as explained the fluid from the chamber 25b of the unit 10 is conducted by way of passages 41 and 12 to the chamber 25a of the unit 11 via the port C-3 of the unit 11 and passage 40. At the same time, the fluid displaced from the synchronizing chamber 25b of the unit 11 is displaced into the synchronizing chamber 25a of the unit 10 via the fluid lines and passages 41 and 13 and port C-3 and passage 40 of unit 10.

When the control source 16 is actuated to supply fluid pressure via the fluid lines 15 to the C-2 ports of the units 10 and 11, the drive pistons 31 will be actuated thereby to the left as viewed in FIG. 5 by fluid under pressure admitted into the drive cylinder chambers 24b and the fluid displaced from the drive cylinder chambers 24a will be returned to the tank in the control source 16 via the ports C-1 and fluid lines 14 when the drive pistons 31 are thus actuated toward the left. By reason of the cross-connection of the synchronizing cylinder chambers 25a and 25b as previously explained, the piston units 30 are constrained to move in synchronism.

As evident from the foregoing, the cross-connection of the synchronizing chambers 25a and 25b as above indicated will maintain the drive pistons 31 in synchronism to uniformly actuate the elements to which the piston rods 34 are connected irrespective of the fact that the loads on said piston rods 34 may be of different magnitude.

In the event of fluid loss from the synchronizing circuit as by leakage, the piston units 30 may tend to move

out of synchronism but this is prevented by opening of one or both of the check valves 44 to permit flow of make-up fluid from the drive cylinder chambers 24b into the synchronizing chambers 25a. The check valves 44 also serve to pressurize the synchronizing circuit to guarantee synchronization accuracy.

The synchronization system herein is self-correcting at the end of the working stroke and at the end of the return stroke should one piston unit 30 reach such stroke end slightly before the other piston unit 30 due, for example, to fluid leakage in the synchronizing circuit. Assuming that the piston unit 30 of the cylinder unit 10 reaches the righthand end of its working stroke before the piston unit 30 of the cylinder unit 11, the flow of fluid from the chamber 25b of unit 10 to the chamber 25a of unit 11 will stop and, of course, no fluid can flow from the chamber 25b of unit 11 to the chamber 25a of unit 10. Hence, pressure will build up in the chamber 25b and passage 41 of unit 11 and in the fluid line 13 and in the fluid line 50 and pilot line 54 of unit 10 to open the relief valve 51 of unit 10 for flow transmission of high pressure from said chamber 25b of unit 10 via the fluid lines 41, 12 and 50 to the pilot line 54 of the relief valve 51 of unit 11. High pressure fluid can then flow from chamber 25b of unit 11 into chamber 25a of unit 11 via fluid line 52, open relief valve 51, and lines 50 and 40. This permits the piston unit 30 of unit 11 to complete its working stroke so as to be in synchronized position with the piston unit 30 of unit 10. In the event that the piston unit 30 of the unit 11 reaches the end of its working stroke before the piston unit 30 of assembly 10, the relief valves 51 will operate in the manner just described to permit the piston unit 30 of unit 10 to complete its working stroke.

In the event that the piston units 30 move slightly out of synchronism during their return strokes to the left as viewed in FIG. 5, the flow from chamber 25a of one unit 10 or 11 to chamber 25b of the other unit 10 or 11 will cease. When that occurs pressure builds up in the chamber 25a of the unit 10 or 11 in which the piston unit 30 has not reached the end of its return stroke and opens its relief valve 51 for flow of fluid into its chamber 25b to permit continued movement of said piston unit 30 to the end of its return stroke.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A synchronized piston assembly comprising at least two cylinder units each comprising: a drive cylinder having ports adapted for connection with a fluid power control source and a synchronizing cylinder having ports which are cross-connected with respect to the ports of the other synchronizing cylinder; and a piston unit in each cylinder unit having interconnected drive and synchronizing pistons axially reciprocable in the respective cylinders whereby hydraulic actuation of said drive pistons in the respective drive cylinders actuates the respective synchronizing pistons in the respective synchronizing cylinders so that fluid displaced from one end of each synchronizing cylinder to the other end of the other synchronizing cylinder synchronizes the actuation of said drive pistons despite unequal loads on said piston units; each cylinder unit having relief valve means operative to intercommunicate the synchronizing circuit chambers on opposite sides of the synchronizing piston for fluid pressure equalization therein and for continued movement thereof and its

drive piston to the end of one stroke in the event that the other piston unit previously reaches the end of one stroke, and to intercommunicate the synchronizing chambers on opposite sides of the synchronizing piston of said other piston unit to equalize fluid pressures therein each relief valve means being opened by pilot pressure buildup in its decreasing synchronizing chamber during such continued movement of its piston unit to the end of its retract stroke; said pilot pressure opening said other relief valve means for fluid pressure equalization of the synchronizing chambers on opposite sides of the synchronizing piston in said other piston unit.

2. A synchronized piston assembly comprising at least two cylinder units each comprising: a drive cylinder having ports adapted for connection with a fluid power control source and a synchronizing cylinder having ports which are cross-connected with respect to the ports of the other synchronizing cylinder; and a piston unit in each cylinder unit having interconnected drive and synchronizing pistons axially reciprocable in the respective cylinders whereby hydraulic actuation of said drive pistons in the respective drive cylinders actuates the respective synchronizing pistons in the respective synchronizing cylinders so that fluid displaced from one end of each synchronizing cylinder to the other end of the other synchronizing cylinder synchronizes the actuation of said drive pistons despite unequal loads on said piston units; each cylinder unit having relief valve means operative to intercommunicate the synchronizing circuit chambers on opposite sides of the synchronizing piston for fluid pressure equalization therein and for continued movement thereof and its drive piston to the end of one stroke in the event that the other piston unit previously reaches the end of one stroke, and to intercommunicate the synchronizing chambers on opposite sides of the synchronizing piston of said other piston unit to equalize fluid pressures therein, each relief valve means being opened by pilot pressure buildup in its decreasing synchronizing chamber which opens the other relief valve means for fluid pressure equalization as aforesaid and for transmission of such pilot pressure to open the first-mentioned relief valve means for fluid pressure equalization in its decreasing and increasing synchronization chambers and for flow of fluid into the increasing synchronizing chamber during such continued movement of its piston

unit to the end of its extend stroke.

3. A synchronized piston assembly comprising at least two cylinder units each comprising: a drive cylinder having ports adapted for connection with a fluid power control source and synchronizing cylinder having ports which are cross-connected with respect to the ports of the other synchronizing cylinder; and a piston unit in each cylinder unit having interconnected drive and synchronizing pistons axially reciprocable in the respective cylinders whereby hydraulic actuation of said drive pistons in the respective drive cylinders actuates the respective synchronizing pistons in the respective synchronizing cylinders so that fluid displaced from one end of each synchronizing cylinder to the other end of the other synchronizing cylinder synchronizes the actuation of said drive pistons despite unequal loads on said piston units; each cylinder unit having relief valve means opened by pilot pressure to intercommunicate the synchronizing chambers on opposite sides of the synchronizing piston for continued movement thereof and its drive piston either to the end of its extend stroke or its retract stroke in the event that the other piston unit previously reaches the end of either of the corresponding strokes, and to intercommunicate the synchronizing chambers on opposite sides of the synchronizing piston in said other piston unit to equalize fluid pressures therein.

4. The assembly of claim 3 wherein such continued movement toward the end of the retract stroke builds up pilot pressure in the decreasing synchronizing chamber to open its relief valve means for flow into the increasing synchronizing chamber; and wherein such continued movement toward the end of the extend stroke builds up pilot pressure to open the other relief valve means for fluid pressure equalization as aforesaid and for transmission of pilot pressure to open the first-mentioned relief valve means for flow of fluid through the latter in the opposite direction from the then decreasing synchronizing chamber to the then increasing synchronizing chamber.

5. The assembly of claim 4 wherein each cylinder unit has check valve means to communicate the power circuit with the synchronizing circuit for supply of makeup fluid to compensate for fluid loss in the synchronizing circuit thus to maintain substantially synchronous actuation of said drive pistons.

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