Aug. 16, 1966 H. A. PANISSIDI 3,266,377

PISTON ADDER APPARATUS

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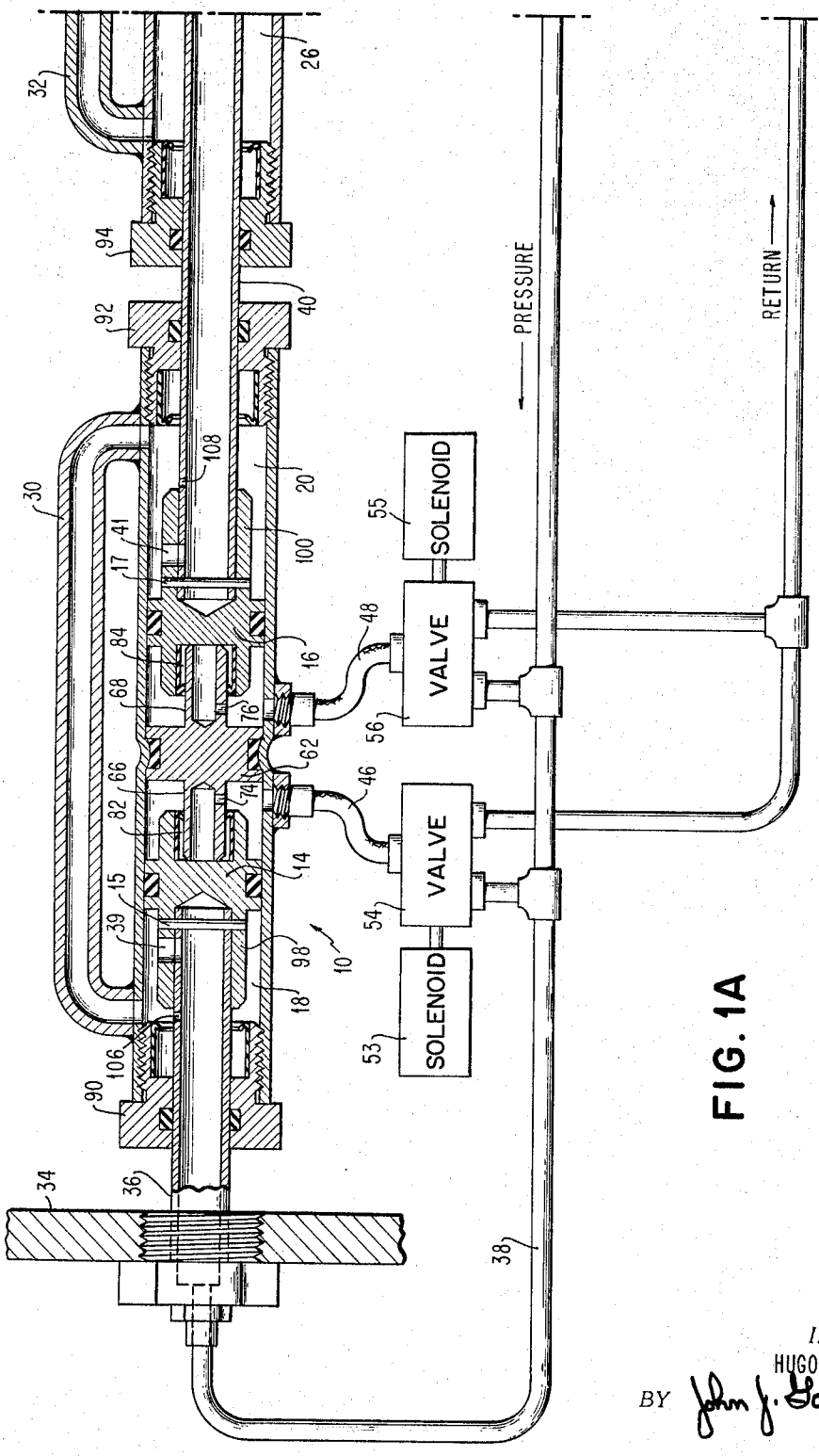


FIG. 1A

*INVENTOR.*
HUGO A. PANISSIDI

BY John J. Goodwin

ATTORNEY

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PISTON ADDER APPARATUS

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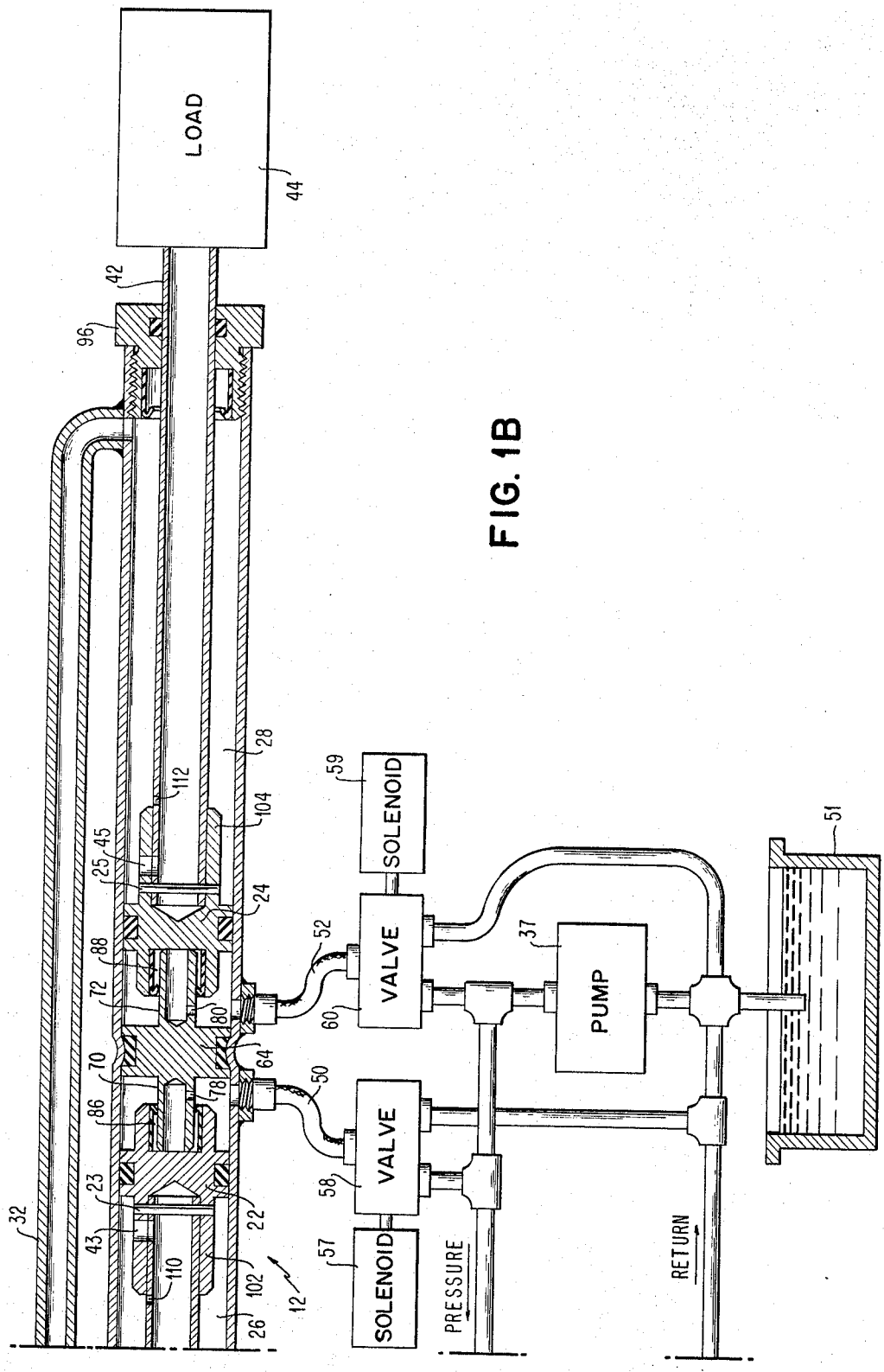


FIG. 1B

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3,266,377

# PISTON ADDER APPARATUS

Hugo A. Panissidi, Peekskill, N.Y., assignor to International Business Machines Corporation, Armonk, N.Y., a corporation of New York

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The present invention relates to fluid piston assemblies and more particularly to a unique fluid piston adder apparatus.

Piston adder assemblies are mechanical devices operated by fluid pressure. The assemblies conventionally consist of a plurality of separate piston units connected in series via their piston rods. Each piston is enclosed in a separate cylinder which includes two hose connections on either side of the piston such that a relative pressure increase applied through one or the other hose will move the piston to one or the other end of the cylinder.

The piston rod of the first piston in the series is mounted to a stationary reference, and each succeeding piston rod is mounted to the preceding piston cylinder. Each of the piston cylinders is generally of greater length than the preceding piston cylinder. Consider a series of five piston cylinders having lengths of one, two, four, eight, and sixteen units respectively. Thus, with only the first piston actuated the overall apparatus moves one unit. With only the second piston actuated the overall apparatus moves two units, with the first and second pistons actuated the overall apparatus moves three units. It can be seen that by actuating the proper combinations of pistons that the overall apparatus can be made to extend any unit distance from one unit to thirty-one units from the stationary reference. The overall apparatus would consist of five chambers with five pistons. Each chamber would have two hoses for a total of ten hoses. If greater or less distances are required, cylinders may be added or removed according to the situation, however, each cylinder would contain one piston and require two hoses.

An improved piston adder apparatus has been devised which performs the same function as the above-described device, but wherein by unique design much of the mass and complexity of the conventional piston adder apparatus is avoided.

An object of the present invention is to provide a high speed, low mass piston adder apparatus.

Another object of the present invention is to provide an improved piston adder apparatus.

Still another object of the present invention is to provide a multi-cylindered piston adder apparatus having rigid support between cylinders.

Another object of the present invention is to provide a piston adder apparatus wherein the piston rods serve as fluid lines.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of a preferred embodiment of the invention, as illustrated in the accompanying drawings.

In the drawings:

FIG. 1A and 1B combined together show a schematic section of a piston adder apparatus following the principle of the present invention.

In FIGS. 1A and 1B a piston adder apparatus is shown including cylinders **10** and **12**. Cylinder **10** includes pistons **14** and **16** which are free to slide in chambers **18** and **20** respectively and cylinder **12** includes pistons **22** and **24** which are free to slide in chambers **26** and **28** respectively. Chambers **18** and **20** are filled with fluid and are connected via tube **30**, and chambers **26** and **38** also contain



fluid and are connected via tube **32**. Piston **14** is connected to a stationary reference **34** via piston rod **36**. Piston **14** is connected to hollow piston rod **36** by pin **15**. Piston rod **36** is hollow and is joined to a source of constant fluid pressure (pressure compensated pump **37**) via connector tube **38**. The pressure applied by pressure compensated pump **37** into piston rod **36** via connector tube **38** is maintained constant. Piston **16** is connected by pin **17** to a hollow fluid filled piston rod **40** which extends into chamber **26** of cylinder **12** and is connected to piston **22** by pin **23**. Piston **24** is connected by pin **25** to a hollow, fluid filled piston rod **42** which extends out of chamber **28** and may terminate in suitable load **44**. Piston rod **36** and piston **14** include an opening **39** providing a path from the inside of piston rod **36** to the inside of chamber **18**. Likewise, piston rod **40** and piston **16** include a similar opening **41**, piston rod **40** and piston **22** include an opening **43** and piston rod **42** and piston **24** include an opening **45**. Thus, a fluid path exists from pump **37** through tube **38**, through piston rod **36**, through opening **39** into chamber **18**, through tube **30** into chamber **20**, through opening **41**, through piston rod **40** through opening **43** into chamber **26**, through tube **32** into chamber **28**, and through opening **45** into piston rod **42**. Pump **37** maintains the pressure within this fluid path at a constant value.

Each of the chambers **18**, **20**, **26**, and **28** has a hose **46**, **48**, **50**, and **52** respectively connected thereto. Each of the hoses is connected to its respective one of chambers **18**, **20**, **26**, and **28** on the side of each of the associated pistons **14**, **16**, **22**, and **24** which is opposite to the side to which the piston rods are connected. The hoses **46**, **48**, **50**, and **52** are respectively connected to a separate three way valve **54**, **56**, **58**, and **60**. When valves **54**, **56**, **58**, and **60** are in one position the associated hoses **46**, **48**, **50**, and **52** are connected to pump **37**. When valves **54**, **56**, **58**, and **60** are in their other position the associated hoses **46**, **48**, **50**, and **52** are connected to reservoir **51**. When valves **54**, **56**, **58**, or **60** are in their reservoir position no pressure is applied through associated hoses **46**, **48**, **50**, or **52**, however, when valves **54**, **56**, **58**, or **60** are in their pump position, a fluid under pressure P is applied through associated hoses **46**, **48**, **50**, or **52**. Cylinder **10** includes a separator **62** separating chambers **18** and **20** and cylinder **12** includes a separator **64** separating chambers **22** and **24**. Separators **62** and **64** respectively include hollow rods **66**, **68**, **70**, and **72** which protrude from each side thereof. Hollow rods **66**, **68**, **70**, and **72** each respectively contain an orifice **74**, **76**, **78**, and **80**. Piston **14** contains a cavity **82** into which rod **66** fits when piston **14** is in its unextended position. Likewise, piston **16** contains a cavity **84** into which fits rod **68**, piston **22** contains a cavity **86** into which fits rod **70**, and piston **24** contains a cavity **88** into which fits rod **72** when pistons **16**, **22**, and **24** are in their unextended position. The unextended positions of pistons **14**, **16**, **22**, and **24** are when they are proximate to separators **62** and **64**. End caps **90** and **92** of cylinder **10** and end caps **94** and **96** of cylinder **12** also contain cavities into which fit snubber diameters **98**, **100**, **102**, and **104** which protrude from the piston rod sides of pistons **14**, **16**, **22**, and **24** respectively, when pistons **14**, **16**, **22** and **24** are in their extended positions.

When piston **14** is moved from its unextended position shown in the drawing to its extended position (to be later described), snubber diameter **98** will enter the cavity in end cap **90** and the fluid trapped therein will bleed through orifice **108** in piston rod **36**. Thus, a damping effect occurs reducing the impact of the stroke. When piston **14** is returned to the unextended position on the return stroke, hollow rod **66** enters into cavity **82** and

the fluid trapped therein bleeds through orifice **74** also causing damping and reducing impact. The same is true of piston **16** and bleeder orifices **76** and **108**, piston **22** and bleeder orifices **78** and **110**, and piston **24** and bleeder orifices **80** and **112**.

The piston rods **36**, **40**, and **42** have cross-sectional areas equal to one-half the cross-sectional area of the piston to which they are connected, thus with constant fluid pressure in the piston rods, only one-half the amount of such pressure need be applied to the other side of the pistons to equalize the force.

Actually, valves **54**, **56**, **58**, and **60** being connected to pump pressure when they are in their pressure position, when any valve is in its pressure position, fluid under pressure P is applied to the side of the associated piston opposite to the piston rod. Since the force on the piston rod side of the piston is $P \cdot A$ and the force on the other side of the piston is equal to $P \cdot 2A$, the associated piston will move toword its extended position. When the valve is moved back to its reservoir position the pressure falls to zero and the force equal to $P \cdot A$ applied through the piston rod returns the piston to its unextended position.

In the drawing the piston adder is in its completely retracted position, and the load **44** is at its initial position. In such case valves **54**, **56**, **58** and **60** are in their reservoir position. When valve **54** is actuated to its pressure position pump fluid under pressure P is applied from valve **54** via hose **46** and the resulting force which is equal to $P \cdot 2A$ will be greater than the $P \cdot A$ force applied by piston rod **36**, causing cylinder **10** to move to the right until snubber diameter **98** is in the orifice in end cap **90**. The distance that cylinder **10** moves in such instance is designed to be one unit. Thus, cylinder **12** and load **44** being mechanically connected to cylinder **10** also move one unit to the right. When chamber **18** moves to the right with respect to piston **14**, the pressure in the piston rod side of chamber **18** increases and the fluid therein is forced through opening **39** in rod **36** and is conveyed through tube **38** through valve **54** and through hose **46** into the right side of chamber **18**, thereby occupying a portion of the resultant increased volume due to the movement of chamber **18** to the right. The additional displaced volume is made up by the pump. The pressure in piston rod **36** and the pressure through hose **46** is thus maintained at P. When valve **54** is reset to its reservoir position the pressure applied through hose **46** falls to zero and the force which is equal to $P \cdot A$ in piston rod **36** causes chamber **18** to move to the left with respect to piston **14**, thereby returning cylinder **10**, cylinder **12**, and load **44** to their initial positions.

The same operation is true for each of the other chambers and pistons when their associated valves are actuated except that each of the succeeding chambers are greater in length. Thus, when valve **56** is moved to its pressure position the pressure in hose **48** is raised to P and piston **16** is extended two units of lengths with respect to chamber **20** and cylinder **12** and the load **44** consequently move two units of distance. When piston **16** moves, the fluid in the right side of chamber **20** is forced back through tube **30** into the left side of chamber **18**, through opening **39**, into piston rod **36** and finally through tube **38** back through valve **56**.

Chamber **26** is four units in length so that when valve **58** is moved to its pressure position the pressure in hose **50** is increased to P and chamber **26** (and consequently load **44**) is ultimately moved four distance units to the right and chamber **28** is eight units in length so that when valve **60** is moved to its pressure position the pressure in hose **52** is increased to P and ultimately the load **44** is moved eight distance units to the right.

The valves **54** through **60** may be actuated in combinations so that the pressures in some or all the hoses **46**, **48**, **50**, **52** are increased at the same time. By selecting the combinations, the load **44** can be moved from one to fifteen units of length. The combinations and resultant distances are set forth as follows:

| Actuated valve: | Distance load is moved |
|---|---|
| **54** | One unit. |
| **56** | Two units. |
| **54, 56** | Three units. |
| **58** | Four units. |
| **54, 58** | Five units. |
| **56, 58** | Six units. |
| **54, 56, 58** | Seven units. |
| **60** | Eight units. |
| **54, 60** | Nine units. |
| **56, 60** | Ten units. |
| **54, 56, 60** | Eleven units. |
| **58, 60** | Twelve units. |
| **54, 58, 60** | Thirteen units. |
| **56, 58, 60** | Fourteen units. |
| **54, 56, 58, 60** | Fifteen units. |

When more than one of the valves **54**, **56**, **58**, or **60** is actuated to its pressure position a greater amount of fluid will be displaced in the associated chambers, however this fluid will be fed back through the fluid path into tube **38** and be returned via the actuated valves. If the volume of fluid displaced when piston **14** moves with respect to chamber **18** is V, then the volume displaced when piston **16** is moved with respect to chamber **20** is 2V, the volume displaced from chamber **26** is 4V and the volume displaced from chamber **28** is 8V. For example, if valves **54** and **58** were actuated to their pressure positions load **44** would move five distance units and a volume of fluid V from chamber **18** plus a volume 4V from chamber **26** would be transferred into tube **38**. However, the volume of the right side of chamber **18** is now increased by a volume greater than V and the volume of the right side of chamber **26** is now increased by a volume greater than 4V so that the 5V volume of fluid fed through tube **38** is returned through valves **54** and **58** to chambers **18** and **26** in a V and 4V division with additional fluid being supplied by the pump **37**.

The valves **54**, **56**, **58**, and **60** may be actuated by means of solenoid or relays, etc. such as solenoids **53**, **55**, **57**, and **59** connected to a source of binary input signals (not shown). Valve **54** would be responsive to binary signals representative of the value $2^0$, valve **56** responsive to the $2^1$ signal value, valve **58** responsive to the $2^2$ signal value, and valve **60** responsive to the $2^3$ signal value.

It is obvious that if another cylinder were included in the piston adder having chambers with lengths of sixteen and thirty-two units, the load **44** could be moved up to sixty-three units of length. Thus, the piston adder of the present invention is not limited to any particular number of stages. It is also obvious that the lengths specified in the present embodiment may be changed depending on the application of the piston adder. End caps **74**, **76**, **78**, and **80** are shown mounted on cylinders **10** and **12** by threaded connections sealed with thread sealant so that fine adjustments in length may be made.

It is to be noted that the piston adder of the present invention uses only half the flexible pressure hoses as required by conventional piston adders. Since the pressure hoses must move with the adder a significant saving in weight, drag and inertia is realized. By having the piston rods also serve as hydraulic lines and by arranging the pistons back-to-back in a single cylinder a saving in material, weight and unnecessary length is effected. Further, since the pin connections between pistons and piston rods are inside the cylinders, a more rigid cylinder to cylinder connection results, therefore requiring no external guides or supports. These advantages become more significant as more stages are included in the piston adder.

While the invention has been particularly shown and described with reference to a preferred embodiment thereof, it will be understood by those skilled in the art

that various changes in form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. A piston apparatus comprising at least one piston cylinder,

said piston cylinder including first and second fluid filled chambers separated by a center member;

a first piston movably mounted in said first chamber and a second piston movably mounted in said second chamber;

a first piston rod connected through the end of said first chamber to said first piston, said first piston rod being a fluid filled tube, said first piston rod having an orifice therein providing a fluid path to said first chamber;

a second piston rod connected through the end of said second chamber to said second piston, said second piston rod being a fluid filled tube, said second piston rod having an orifice therein providing a fluid path to said second chamber;

a fluid filled connecting tube connecting said first and second fluid filled chambers;

and means connected to said piston cylinder for selectively moving said first piston and said second piston.

2. A piston apparatus comprising a plurality of separate piston cylinders,

each of said piston cylinders including first and second fluid filled chambers separated by a center member;

a first piston in said first chamber and a second piston in said second chamber of each of said piston cylinders;

a separate first piston rod connected through the end on said first chamber to each of said first pistons, said first piston rods being fluid filled hollow tubes;

a separate second piston rod connected through the end of said second chamber to each of said second pistons, said second piston rods being fluid filled tubes;

the second piston rod of each said piston cylinders and the first piston rod of the successive one of said piston cylinders being a common fluid filled rod, said plurality of piston cylinders thereby forming a serially connected array of cylinders;

a fluid filled connecting tube connecting said first and second fluid filled chambers of each of said piston cylinders;

and means connected to each of said piston cylinders for selectively moving said first piston and said second piston in each of said piston cylinders.

3. A piston apparatus according to claim 2 wherein said first piston rod of said first piston cylinder in said series is maintained stationary, and wherein the movement of each piston from said first position proximate said associated center member to said second position at the end of said associated chamber produces an equal movement of said successive ones of said piston cylinders in said series.

4. A piston apparatus according to claim 3 wherein the movement of said second piston rod of the last piston cylinder in said series array is the cumulative addition of the movements of each of the pistons in each of the piston cylinders in said series array.

5. A piston apparatus according to claim 4 wherein the length of each of said second chambers of each of said piston cylinders is twice as long as the length of said first chamber therein, and wherein the length of each of said first chambers in each of said piston cylinders is twice as long as the length of the second chamber of the preceding piston cylinder in said series array.

6. A piston adder apparatus comprising at least one piston cylinder,

said piston cylinder including first and second fluid filled chambers separated by a center member;

a first piston movably mounted in said first chamber and a second piston movably mounted in said second chamber;

a first piston rod connected through the end of said first chamber to said first piston, said first piston rod being a fluid filled tube, said first piston rod having an orifice therein providing a fluid path to said first chamber;

a second piston rod connected through the end of said second chamber to said second piston, said second piston rod being a fluid filled tube, said second piston rod having an orifice therein providing a fluid path to said second chamber;

a fluid filled connecting tube connecting said first and second fluid filled chambers;

a fluid pump connected to said first piston rod for maintaining said fluid in said first piston rod, said first chamber, said connecting tube, said second chamber, and said second piston rod at a given constant pressure;

a first hose connected between said first chamber and said pump;

a second hose connected between said second chamber and said pump;

a first valve connected to said first hose for selectively controlling the pressure from said pump through said first hose to said first chamber between said given constant pump pressure and zero pressure such that when said given constant pressure from said pump is applied to said first chamber said first piston moves from a first position proximate said center member to a second position proximate to the end of said first chamber opposite said center member, and when zero pressure is applied to said first chamber and said first piston is in said second position, said first piston will return to said first position proximate said center member;

and a second valve connected to said second hose for selectively controlling the pressure from said pump through said second hose to said second chamber between said given constant pump pressure and zero pressure such that when said given constant pressure from said pump is applied to said second chamber, said second piston moves from a first position proximate said center member to a second position proximate to the end of said second chamber opposite said center member, and when zero pressure is applied to said second chamber and said second piston is in said second position, said second piston will return to said first position proximate said center member.

7. A piston adder apparatus according to claim 6 wherein the length of said second chamber is twice the length of said first chamber.

8. A piston adder apparatus comprising a plurality of separate piston cylinders,

each of said piston cylinders including first and second fluid filled chambers separated by a center member;

a first piston movably mounted in said first chamber and a second piston movably mounted in said second chamber of each of said piston cylinders;

a separate first piston rod connected through the end on said first chamber to each of said first pistons, said first piston rods being fluid filled hollow tubes;

a separate second piston rod connected through the end of said second chamber to each of said second pistons, said second piston rods being fluid filled tubes;

the second piston rod of each said piston cylinders and the first piston rod of each successive one of said piston cylinders being a common fluid filled rod, said plurality of piston cylinders thereby forming a serially connected array of cylinders;

a fluid filled connecting tube connecting said first and second fluid filled chambers of each of said piston cylinders;

a fluid pump connected to said first piston rod of the first piston cylinder in said series array for maintaining said fluid in said first piston rod, said first chamber, said connecting tube, said second chamber, and said second piston rod of each of said piston cylinders at a given constant pressure;

a separate first hose connected between said first chamber of each of said piston cylinders and said pump;

a separate second hose connected between said second chamber of each of said piston cylinders and said pump;

a separate first valve connected to each of said first hoses for selectively controlling the pressure from said pump through each of said first hoses to each of said first chambers between said given constant pump pressure and zero pressure such that when said given constant pressure from said pump is applied to each of said first chambers, each of said first pistons therein moves from a first position proximate said center member to a second position proximate to the end of said first chamber opposite said center member, and when zero pressure is applied to each of said first chambers and said first piston there is in said second position, said first piston will return to said first position proximate said center member;

and a separate second valve connected to each of said second hoses for selectively controlling the pressure from said pump through each of said second hoses to each of said second chambers between said given constant pump pressure and zero pressure such that when said given constant pressure from said pump is applied to each of said second chambers, each of said second pistons moves from a first position proximate said center member to a second position proximate to the end of said second chamber opposite said center member, and when zero pressure is applied to each of said second chambers and said second piston therein is in said second position, said second piston will return to said first position proximate said center member.

**9.** A piston adder apparatus according to claim **8** wherein said first piston rod of said first piston cylinder in said series is maintained stationary, and wherein the movement of each piston from said first position proximate said associated center member to said second position at the end of said associated chamber produces an equal movement of said successive ones of said piston cylinders in said series.

**10.** A piston adder apparatus according to claim **9** wherein the movement of said second piston rod of the last piston cylinder in said series array is the cumulative addition of the movements of each of the pistons in each of the piston cylinders in said series array.

**11.** A piston adder apparatus according to claim **10** wherein the length of each of said second chambers of each of said piston cylinders is twice as long as the length of said first chamber therein, and wherein the length of each of said first chambers in each of said piston cylinders is twice as long as the length of the second chamber of the preceding piston cylinder in said series array.



**12.** A piston adder apparatus according to claim **11** further including a load connected to the second piston rod of the last piston cylinder in said series array;

and wherein said first and second valves connected to said first and second hoses are selectively actuated to selectively apply said given constant pump pressure to selected ones of said first and second piston chambers for moving the associated ones of said first and second pistons from their first position to their second position, thereby moving said load a distance equal to the cumulative value of the lengths of said selected ones of said first and second piston chambers.

**13.** A piston apparatus comprising a plurality of piston cylinders each having first and second chambers linearly disposed and separated by a center member;

first and second pistons respectively movably mounted in said first and second chambers and adapted to move in opposite directions away from said center wall to the respective end of each first and second chamber,

each of said second pistons of said piston cylinders connected to the first piston of another of said piston cylinders by common piston rods to form a serial array of said piston cylinders;

a second piston rod connecting said second piston of the last piston cylinder in said serial array to a load means;

said first piston rod, said second piston rod, and said common piston rods containing fluid and said first and second chambers in each of said piston cylinders containing fluid;

means for applying pressure to said fluid in said first, second and common piston rods and to said fluid in each of said first and second chambers,

and means connected to each of said piston cylinders for selectively moving said first and second pistons in each of said piston cylinders.

**14.** A piston apparatus according to claim **13** wherein said means for applying pressure includes valve means for controlling said pressure applied to said first and second chambers in each of said piston cylinders for selectively moving each of said first and second pistons therein.


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MARTIN P. SCHWARDON, *Primary Examiner.*

SAMUEL LEVINE, *Examiner.*

P. T. COBRIN, *Assistant Examiner.*