Nov. 29, 1966 R. M. FISHER 3,288,036

MULTIPLE LINEAR ACTUATING CYLINDER

Filed Sept. 12, 1963

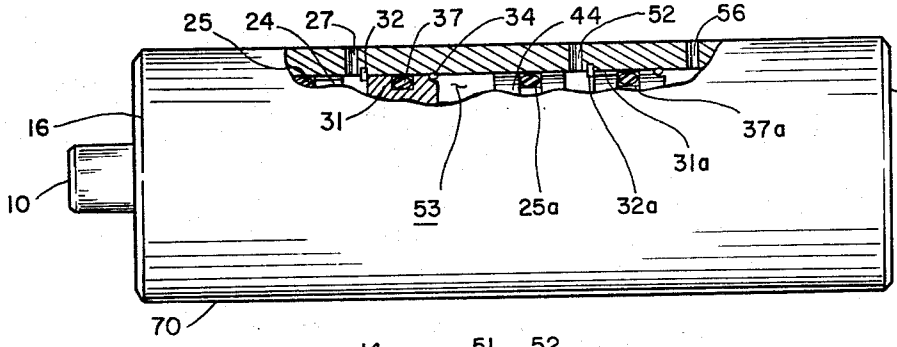


FIGURE 5

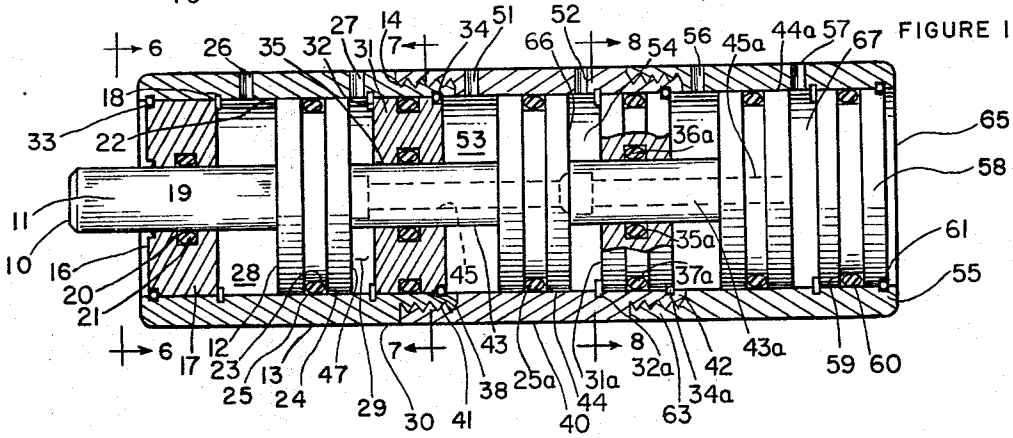


FIGURE 1

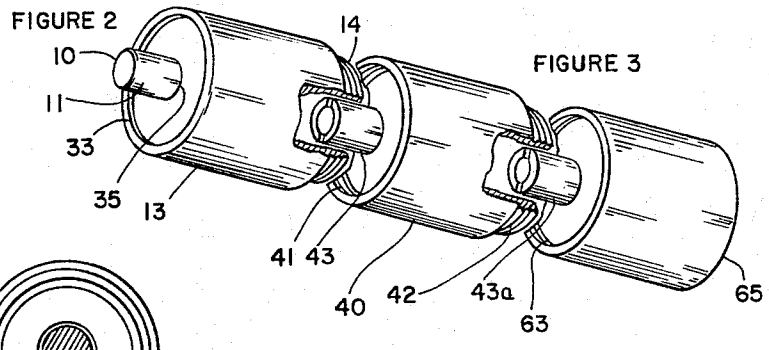


FIGURE 2

FIGURE 3

FIGURE 4

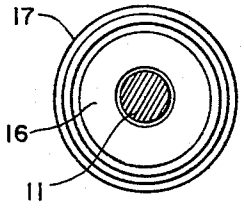


FIGURE 6

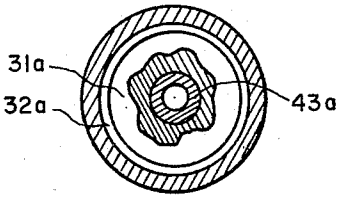


FIGURE 8

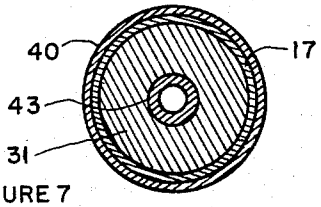


FIGURE 7

ROBERT M. FISHER
INVENTOR.

BY Norman L. Chalfin
agent

United States Patent Office 3,288,036 Patented Nov. 29, 1966

3,288,036
MULTIPLE LINEAR ACTUATING CYLINDER

Robert M. Fisher, 20966 Las Flores Mesa Drive, Malibu, Calif.

Filed Sept. 12, 1963, Ser. No. 308,529
3 Claims. (Cl. 92—62)

This invention relates to piston actuating cylinders and more particularly to a novel in-line array of actuating cylinders the elements of which may be added together to increase the resultant actuating pressure without an increase in the cross-sectional diametral area of the piston rod elements.

A particular feature of the invention is the incorporation of three types of unit elements which can be assembled in-line in various combinations or which can be used individually. The number of the unit elements of the invention which can be added together is limited only by Euler's formula for long columns which establishes the buckling limit.

Each of the elements of the invention when added to another, or group of preceding elements in the linear column increases the linear output pressure capability of the actuator formed thereby in response to an applied pressure by a factor of between .8 and .9 times per unit added.

This may be expressed as:

$$F_1=P_i(A_iknA_2)$$

where

F_1=linear force in pounds per square inch (output);
P_i=input pressure in pounds per square inch (p.s.i.);
A_1=area of piston on which input pressure is applied;
A_2=area of piston applying pressure to load or succeeding elements;
k=increase factor provided by each added element; and
n=number of elements in the linear multiple actuator assembly.

The three types of elements which can be combined in the practise of this invention are a front or forward section, a middle section, and a rear or end section.

If only two elements of the invention are used to form a linear actuator assembly in one form of use of the invention a forward and a rear section are assembled together in line on a common axis. If more than two elements are used together in a linear actuating cylinder as conceived in this invention, then one or more middle sections are inserted between the front and rear sections to make up the multiple piston actuating cylinder.

The front section is threaded at its input end only and the end section at its output end only so that the front and end sections may be fitted together to form a unitary linear actuator. The threads in one are internal and in the other external so that the ends which are threaded may be mated together. A middle section is threaded at either end, one end to mate with end sections or the opposite end of other middle sections and the other end to mate with forward sections or the opposite end of other middle sections.

It is accordingly a principal object of this invention to provide a multiple piston linear actuating cylinder comprising a number of sections through which the linear force applied at the input end thereof is multiplied by a factor times the number of sections assembled together in line to produce a corresponding increase in the linear output force without an increase in the cross-sectional area of the piston employed.

This and other objects of the invention will become more clear from the specification which follows taken together with the appended claims in view of the accompanying drawings in which:

FIGURE 1 is a drawing partially in cross-section showing an assembly of one of each of the piston actuator elements of this invention in a linear actuator in one of the forms in which the invention may be used;

FIGURE 2 is a typical front or forward section, according to the invention;

FIGURE 3 is a typical middle section according to the invention;

FIGURE 4 is a typical end or rear section according to the invention;

FIGURE 5 is a representative unitary cylinder assembly embodying another form of the use of the invention;

FIGURE 6 is a cross-section through 6—6 of FIGURE 1;

FIGURE 7 is a cross-section through 7—7 of FIGURE 1; and

FIGURE 8 is a cross-section through 8—8 of FIGURE 1.

Referring now to FIGURE 1 there may be seen in partial cross section an assembly of the multiple piston linear actuator elements as used in one embodiment of the invention. The individual elements are shown in FIGURES 2, 3 and 4.

A piston assembly **10** includes piston rod **11** and piston head **12** and is assembled into a cylindrical body **13**. Body **13** is the type used for a forward section according to the invention, and is threaded at the output end **14** thereof with external threads. Within body **13** at the input end **15**; thereof a cap **16** is fitted tightly. Cap **16** may either be threaded on its outer circumference with appropriate matching threads provided in the inner top surface of the body wall of body **13** or cap **16** may be press-fitted into body **13** tightly sealed thereby against the inner walls **22** and retained by ring **17** in groove **18** provided therefor and held down by a ring **33**.

Alternatively, cap **16** may be machined as an integral part of cylinder body **13** forming a unitary end piece. In any event cap **16** has a central aperture or bore **19** to receive piston rod **11** slidably but tightly therein. An O-ring **21** is fitted in bore **19** in a rectangular groove **20** therein to seal piston rod **11** against outside pressure and leakage from within cylinder **13**.

The head **12** of piston **10** is provided with a rectangular groove **23** about the periphery **24** thereof to receive another O-ring **25** to seal piston head **12** off from outside pressure.

Piston head **12** and rod **11** forming piston assembly **10** can be seen to be an integral solid structure. In cylinder wall **22** two relief or intake ports **26** and **27** are provided. Relief port **26** is provided to permit exhaust of pressure from the space **28** above head **12** on extension of piston **10**. Extension is movement of the piston in the direction of piston rod **11**. Retraction is movement in the direction of head **12** into the cylinder. Pressure is normally applied to move rod **11** in the direction away from its associated piston head **12**.

Intake port **27** is the principal pressure port **27** which acts as an intake for fluid from external sources port during extension of piston **10** while, as above described, pressure is exhausted through port **26**. Port **26**, on the other hand can be pressurized by external means to retract rod **10** by acting on the upper surface of head **12**. When piston is being retracted in this manner the relief of pressure out of space **29** is through port **27** as will be more clear from the description below when ports **27** and **26** are being used as inlet or relief ports then either ports **51** and **56** or **52** and **57** must be closed off dependent upon whether extension or retraction is being employed.

At the input end **30** of cylinder **13** a cap **31** similar to cap **16** (when used as a separate element in one of the forms of the invention above described) is inserted against a retaining ring **32**, similar to retaining ring **17**,

within the inner wall **22** of cylinder body **13**. Lock rings **33** and **34** holds caps **16** and **31** against their respective retaining rings **17** and **32** in cylinder **13**.

In cap **31** a bore **35** is provided similar to bore **19** and similarly equipped with an O-ring **36**. Bore **35** is provided to receive the piston rods of successive elements connected to cylinder **13** as hereinafter described. Cap **31** is provided with an external O-ring **37** in a groove **38** cut into the periphery thereof.

The components hereinabove described and fitting within cylinder **13** comprise a front or forward unit of the linear actuator of this invention.

The components of a middle section of the invention are incorporated in cylinder section **40** which has an internal thread **41** at the output end thereof and an external thread **42** at the input end thereof. Within cylinder **40** piston assembly **43–44** is inserted. Piston **43–44** is similar in construction to piston element **11–12** except that piston **43–44** has a central aperture **45** therethrough. When cylinder **40** is screwed to cylinder **13** by the mating of threads **14** with threads **41** piston shaft **43** butts against the bottom surface **47** of piston head **12** so that any pressure on piston head **12** due to the application of pressure thereto from external fluid or pneumatic sources at intake port **27** will move piston rod **11** outwardly. Continued application of pressure at inlet **27** results in the passage of the pressure fluid through aperture **45** in rod **43** to fill space **54** and continuing through aperture **45***a* to fill space **67**. Pressure is thus applied both to piston head **44** and **44***a*, the former causing rod **43** to butt against head **12** and the latter to cause rod **43***a* to butt against head **44**, the respective pressures adding according to the formula F_a given below. In the input end of cylinder **40** a cap **31***a* is provided which matches in every respect cap **31** and is held in place by stop rings **32***a* and **34***a*, and includes inner and outer O-rings **36***a* and **37***a* and the central bore **35***a* to receive the piston rod from a subsequent middle section or from a rear or end section. The cylinder wall **40** of the middle section unit includes a relief port **51** which permits exhaust of pressure from the space **53** on extension of piston assembly **43–44** and alternate exhaust or pressure port **52** is similar to port **27** in its function and which permits intake of pressure from external sources if port **52** is to be used as the inlet port whereupon ports **27** and **57** must be closed off.

The components cap **31***a* and its associated stop rings **32***a*, **34***a* and O-rings **36***a*, **37***a* and piston **43–44** within cylinder body section **40** comprise a middle section of the elements of this invention. When a middle section assembled in cylinder body **40** is screwed by means of its inside threaded end **41** to the outside threaded end **14** of cylinder body section **13**, rod **43** of piston **43–44** is tightly fitted in bore **35** of end cap **31** of the front section and butts against the end **47** of the head **12** of piston rod **10** in the upper or front section.

The end or rear section unit of the invention is contained in a cylinder body **55** having apertures **56** and **57** which function in the same manner as similar apertures **26**, **27** and **51**, **52** in the front and middle sections, respectively. Cylinder body **55** is closed off at the bottom by bottom end cap **58** which has a rectangular groove **59** to accommodate an O-ring **60**.

End cap **58** may be machined as an integral part of body **55** in the same manner as cap **16** may be an integral machined part of body **13** previously described. End cap **58**, when a separate part, is held in place by stop rings **61** and **62**. O-ring **60** forms a seal against outside pressure. Within body section **55** a piston assembly **43***a*–**44***a* is fitted, which corresponds exactly to piston **43–44** in the middle section. The output end **63** of the bottom section of cylinder body **55** is threaded internally to mate with the external threaded portion **42** of cylinder body **40** of the middle section. When end section **55** is assembled to middle section **40** the piston rod **43***a* of end section **55** butts against the bottom **66** of piston head **44**.

It may be seen therefore that three sections, respectively, in cylinder bodies **13**, **40** and **55** may be assembled together to form a multiple linear actuating cylinder. The outside threaded end **14** of cylinder body **13** may mate with the inside threads **41** of a middle section or with the inside threads **63** of a bottom section so that either a combination of two sections **55** and **13** may be assembled together or a combination of three sections **13**, **40** and **55** may be assembled together. It should also be clear to those skilled in this art that additional middle sections **40** may be interposed end to end between a front section **13** and an end section **55** to provide a multiple element actuator according to this invention wherein a total of 4 or more sections are employed. The limit is only that which may be computed from Euler's formula for long columns which may be found in any text on strength of materials. One such reference is on p. 465 in the Mechanical Engineers' Handbook, Fifth Edition, edited by Lionel S. Marks and published by McGraw-Hill Book Co., New York, 1951.

When a typical assembly such as that illustrated in FIGURE 1 is made and incorporates a front section **13**, a middle section **40** and an end section **55**, for a piston head cross-sectional area (of piston heads **12**, **44** and **44***a*) of one square inch and a piston rod cross-sectional area (of piston rods **10**, **43** and **43***a*) of one-tenth square inch, the total pressure applied by end cap **10** will be 2.8× the applied pressure for an applied pressure of one unit of pressure on piston head **12** from pressure at inlet **27**, inlets **52** and **57** being closed off.

This is computed on the basis of the following formula:

$$F_a = 1 + (n-1)(A_1 - A_2)$$

where

F_a=force area
A_1=piston area
A_2=piston rod area
n=total number of sections

In the example given

$$F_a = 1 + 2(1.0 - 0.1) = 2.8$$

F_a may properly be called the multiplication factor or "enhancement factor".

If more middle sections are added as, for example, there were three middle sections and a front and an end section, the total pressure applied by end **65** of the linear actuator will be based on the factor $N-1$ or $1+(5-1)(1.0-0.1)$ times the applied pressure or, 4.6 times, the pressure applied to piston rod **10**.

It may be further seen that the same piston assembly **43–44** (**43***a*–**44***a*) may be used in both middle and end sections. It may also be seen that the same end caps **31** or **31***a* may be used in front and middle sections so that considerable economy of assembly is possible in the manufacture and exploitation of multiple sectional linear actuator assembles according to this invention. The individual components which are stocked would include the following:

*Front section top cap **16**
*Front section cylinder **13**
*Middle section cylinder **40**
*Rear section cylinder **55**
*Front section piston **12–11**
Middle and rear section piston **43–44/43***a*–**44***a*
Front and middle section input cap **31/31***a*
End stop rings **33**, **34**, **34***a*, **61**
End stop ring (flat type) **18**, **32**, **32***a*, **62**
External O-ring **25**, **37**, **37***a*
Internal O-ring **21**, **36**, **36***a*
*Rear end cap **58**

From the asterisked items it may be seen that six of the components are used individually and the remainder may be used alternatively in different elements as needed. If cap elements **16**, **31** and **31***a* should be integral with

their respective cylinders the end stop rings, of course, would not be required.

As a further extension of the use of the invention there is illustrated in FIGURE 5 an assembly of elements such as shown in FIGURE 1. The elements **13**, **40** and **55** of FIGURE 1 however are formed as a single cylinder **70** into which the various pistons, centering rings, caps, and so on are dropped to build up a multiple piston actuating cylinder. The internal components of the article illustrated in FIGURE 5 are identical with those illustrated in FIGURE 1 and bear corresponding reference characters. The operation of the article in FIGURE 5 is the same as above described for that shown in FIGURES 1 through 4.

Cylinders such as **70** are provided in different lengths to accommodate different numbers of linear actuator piston elements in line therein. The same formula for output actuating pressure multiplication applies to the single cylinder assembly of multiple pistons as to the assembly of several screwed together sections.

What is claimed as new is:

1. A linear actuating cylinder comprising:

a plurality of interfitting cylindrical guides; and

a plurality of pistons positioned end-to-end, each of said pistons being assembled in one of said interfitting cylindrical guides, respectively, forming thereby a section;

the upper one of said plurality of pistons being solid, the remaining pistons each having a central aperture for pneumatic or fluid flow transfer therethrough;

the bottom of each of said pistons being normally positioned at the top of each succeeding piston whereby the pressure applied to the top most of said pistons is multiplied by a factor between .8 and .9 times the number of said sections assembled together in-line on a common axis.

2. A multiple linear piston actuator assembly comprising:

a first piston element having a piston rod and a piston head, said head being larger in diameter than said rod, said rod and head being an integral solid structure;

a second piston element including a piston rod and a piston head identical in external configuration to said first piston element and having a central aperture axially therethrough;

at least a third piston element similar to said second piston element; apertured separation means; and

a cylindrical housing being solidly capped at the bottom end thereof and having an apertured cap for closing the top thereof;

said first, second and third pistons being assembled, end for end in said housing to form a linear axial assembly, said separation means being interposed between said first and said second, and between said second and said third pistons, respectively, so as to provide a seal for said piston rods while permitting slidable motion of said pistons within said housing in response to pressure applied to said first piston, said pressure being magnified at the third piston thereof due to the series accumulation of force down the axis of the linear actuator assembly.

3. A multiple piston linear actuating assembly comprising:

a plurality of similar interfitting body sections;

one of said plurality having a solid piston rod and head assembly movable therein;

the others of said plurality having piston and rod assemblies movable therein and said piston and rod assemblies of said others including a central aperture;

the respective piston and rod assemblies of said one and said others being in alinement on a common axis, the rod of each of said others abutting the respective pistons above it; and

apertures in each said body sections on either side of said pistons therein, each said body sections having end caps through which the respective rods project and interfit into respective section above, the topmost section having a projection of said rod therein, the bottommost section being closed at the bottom thereof,

whereby pressure applied to one aperture beneath one piston forces piston to move and proceeds through said central apertures to the other pistons, the pressures on the totality of pistons being cumulative in proportion to the product plus one of their number less 1 and the difference between the diameters of said rods and pistons.

References Cited by the Examiner

UNITED STATES PATENTS

825,866	7/1906	Rogers	91—411 X
1,031,528	7/1912	Cole	92—151
1,210,179	12/1916	Lewis	92—151
2,361,130	10/1944	Simpson	91—411
2,383,082	8/1945	Rossmann	91—376
2,946,314	7/1960	Nast	92—151
2,983,256	5/1961	Seeloff	92—151

MARTIN P. SCHWADRON, *Primary Examiner.*

RICHARD B. WILKINSON, SAMUEL LEVINE, *Examiners.*

H. G. SHIELDS, *Assistant Examiner.*