ABSTRACT

A pneumatic lift cylinder for scaffolds and having a plurality of telescopically arranged cylinder members which are extended sequentially in at least three steps of extension from the bottom up and retracted sequentially in at least three steps of retraction from the top down. In extension, after each member extends, it is overpressured, to rigidify the extended member before the next member is extended. In the retraction sequence, each of the cylinders below the retracting cylinder is maintained in an overpressured condition until its turn to retract.

12 Claims, 14 Drawing Figures
PNEUMATIC TELESCOPIC HOIST HAVING THREE OR MORE STEPS OF EXTENSION

BACKGROUND OF THE INVENTION

Hydraulic lift cylinders comprising a plurality of telescoped cylindrical stages, into which oil is pumped to extend the cylinder, have long been in use for hoisting purposes. They have a distinct advantage in that the fluid is incompressible and thus when the cylinder is extended the cylinder is quite rigid and insensitive to variations in loading on the platform. However, a relatively large and heavy storage tank for the elevating fluid is required, which limits the mobility of the hoist. Also, oil leakage is a common occurrence which can be a severe problem when a hoist is to be used indoors or in other places where oil leakage would either be hazardous or hard to clean.

The use of compressed gas, for example, air or carbon dioxide, overcomes these disadvantages. Small air compressors or tanks of compressed gas may be used in place of larger and heavier oil reservoirs. Leakage of gas from the system creates no mess or hazard since such leakage will merely dissipate in the atmosphere. The use of gas does have a drawback because of the compressible nature thereof. If only enough pressure is used to charge the lift cylinders so that the platform and load thereon is fully extended, as would be the case in hydraulic hoists, then the system is very load-sensitive. For example, if another workman steps only to the work platform from a structure adjacent to the platform, the increase in load will cause the gas in the lift cylinder to compress, lowering the scaffold. If several lift cylinders are used to elevate a single platform, movement of the workman on the platform can increase the load on one cylinder, while lightening another cylinder, which will cause the platform to tilt. To avoid this load sensitivity, once the lift cylinders have been fully extended, the cylinders are overpressured with gas so that the internal pressure is far in excess of that required to support the load thereon. This will stiffen the cylinders and render them insensitive to load variations so that the above-mentioned tilting or lowering will not occur. This overpressurization in effect gives the system the feel and results of hydraulically charged cylinders.

It has also been realized that the extension and retraction of a multi-stage pneumatic hoist can be improved by providing for gas connections to the bottom of the outermost cylinder and the top of the innermost cylinder and providing an internal separation between cylinders so that introduction of gas into the outermost cylinder will cause a partial extension of the hoist. Gas pressure can then be built up in the bottom portion of the hoist to rigidify that portion of the hoist. Gas pressure is then introduced into the top of the hoist to cause full extension of the hoist, after which the top portion may be overpressurized.

Such stepwise extension, overpressurization, extension and overpressurization is advantageous in that the height of the hoist acted upon by relatively low-pressure gas to cause an elevation of the platform is reduced, thus decreasing the feeling of mushiness of the ascending platform and decreasing the tendency of the platform to tilt and bind the cylinders.

However, present use of this concept, wherein the hoist is internally divided to separate the lower from upper portion thereof, has been limited to a two-step system, i.e., where only one portion of the hoist can be overpressurized after partial extension.

It is the main object of this invention to provide a pneumatic hoist having a plurality of telescopically arranged cylinders arranged to extend from the bottom up, and in which three or more steps of extension occur, with each extended cylinder being overpressurized before the next extension step. In retraction, each cylinder is overpressurized until its turn to retract. With such an arrangement, only the single cylinder which is extending or retracting is acted upon by a relatively low pressure — all the others therebelow are at a high rigidifying pressure.

It is a further object of the invention to provide control systems for actuating such hoist so as to provide for the desired sequential operation wherein each step of extension is followed by an overpressurization of the extended portion and wherein in retraction the cylinders are maintained in an over pressured condition until it is their turn to be retracted.

SUMMARY OF THE INVENTION

The objects of the invention are achieved by the use of a plurality of telescopically arranged cylinders, there being an outermost cylinder, an innermost cylinder and two or more intermediate cylinders. The intermediate cylinders are provided with piston members which divide the interior of the hoist into three or more separate compartments which can be independently overpressurized. A conduit extends from the exterior of the hoist into the bottom of the largest of the cylinders and a conduit extends from the exterior of the hoist into the top of the innermost cylinder, so that the top and bottom compartments of the hoist may be pressurized. In addition, the annular space or spaces between the intermediate cylinders are utilized as flow paths from the middle compartment or compartments to the exterior of the hoist so that the middle compartments can be pressurized or vented independently of the upper or lower compartments.

The control systems for use with the hoist operate so that each compartment, from the bottom up, is sequentially pressurized and overpressurized for sequential stepwise extension of the hoist, and so that each compartment is sequentially vented, first to relieve the overpressure condition therein and then to allow retraction of the cylinder thereabove, from the top down for sequential retraction of the hoist.

Other objects and advantages of the present invention will become apparent in the course of the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings forming a part of this application, and in which like parts are designated by like reference numerals throughout the same,

FIG. 1 is a vertical view, in section, of a multi-stage, telescoping, lift cylinder hoist having four cylinder members and two internally valve pistons, arranged for three steps of extension and overpressurization;

FIGS. 1A, 1B and 1C are schematic views of different control systems usable with the hoist of FIG. 1;

FIG. 2 is a vertical view, in section, of a multi-stage, telescope, lift cylinder hoist having four cylinder members and two internally blocked pistons, arranged for three steps of extension and overpressurization;
FIGS. 2A, 2B, 2C, 2D, 2E and 2F are schematic views of different control systems usable with the hoist of FIG. 2:

FIG. 3 is a vertical view, in section, of a multi-stage, telescoping, lift cylinder hoist having five cylinder members and three internally blocked pistons, arranged for four steps of extension and retraction, and in which one of the cylinder members comprises two telescoped cylinders and another of the cylinder members comprises three telescoped cylinders; FIGS. 3A and 3B illustrate two different control systems usable with the hoist of FIG. 3.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In brief, the multi-stage, telescoping, lift cylinder hoists controlled by the hereinafter-described control systems comprise a plurality of telescopically arranged cylinder members which are connected to a source of compressible fluid whereby the fluid will be introduced into the cylinder members, causing the entire unit to extend. Typically, the hoist is used to raise a working platform, or they may be used as a lift to raise material to a convenient height. The hoist may be used singly, or a group of spaced-apart, parallel hoists may be used to lift a platform in unison.

The control systems all have a common purpose and mode of operation in that they enable the cylinder members to extend, sequentially in at least three steps from the bottom up. After each step of extension, the extended portion is overpressured before the next portion is extended. Thus, the hoist is sequentially rigidified, from the bottom up, during extension. During retraction, the overpressure in the uppermost portion is vented and the uppermost portion allowed to retract, which the rigidifying, overpressure condition in the hoist below the retracting portion is maintained. After retraction of the uppermost portion, the step is repeated with each portion until the entire hoist is retracted.

Referring now to FIG. 1, the hoist, or lift cylinder 10, comprises first, second, third and fourth vertically oriented cylinder members 11, 12, 13 and 14 of decreasing cross-sectional area telescopically arranged within each other. The first cylinder member 11 is supported on a hoist base 15, while a work platform 16 rests on and is secured to the upper end of the innermost cylinder member 14.

The first cylinder member 11 has a closure plug 17 in the lower end thereof, an external pipe 18 being connected to the passage 19 through the closure plug, the pipe 18 and passage 19 forming a conduit from the exterior of the first cylinder member into the lower end thereof.

The second cylinder member 12 has a piston 21 secured to the lower end thereof, piston 21 being in sliding and sealing engagement with the inner wall of the first cylinder member 11. Piston 21 has a downwardly facing surface 23 exposed to fluid pressure therebelow, and a central passage 24 therethrough communicating the interiors of the first and second cylinder members. A valve 25 is disposed in passage 24 for closing this passage against upward flow therethrough. As shown in FIG. 1, valve 25 has an enlarged upper head 26 biased upwardly by spring 27.

The third cylinder member 13 has a piston 30 secured to the lower end thereof, piston 30 being in sliding and sealing engagement with the inner wall of cylinder member 12. Piston 30 has a downwardly facing surface 31 exposed to fluid pressure below and a central passage 32 therethrough communicating the interior of the second and third cylinder members. As before, a valve 33 is disposed in passage 32 for closing this passage against upward flow therethrough. Valve 33 has an enlarged upper head 34 biased upwardly by spring 35. Piston 30 is also provided with passages 36 therethrough extending from below the piston upwardly to the annular space between the second and third cylinder members 12 and 13. An annular seal member 37 is mounted at the upper end of cylinder member 12 and is in sliding and sealing engagement with the outer wall of cylinder member 13. A pipe 38 connects through the wall of the second cylinder member 12, just below seal 33, the pipe 38, the annular space between cylinder members 12 and 13 and piston passages 36 forming a conduit from the exterior of the device to below the piston member 30 of the third cylinder member.

The fourth cylinder member 14 has a closure plug 40 at its upper end and a piston 41 secured to its lower end, piston 41 being in sliding and sealing engagement with the inner wall of cylinder member 13 and having a downwardly facing surface 42 exposed to fluid pressure therebelow. A conduit from the exterior of the cylinder member 14 to below piston 41 is formed by exterior pipe 43, plug passage 44, pipe 45 and piston passage 46.

When the cylinder members are in fully retracted position, as shown in FIG. 1, piston 30 engages head 26 of valve 25, and forces it downwardly to open position. Similarly, piston 41 holds valve 33 open against the bias of spring 35.

FIG. 1A illustrates a control system for use with the hoist of FIG. 1, wherein three operator-controlled valves 50, 51 and 52 are provided for sequential extension of the hoist and a single operator-controlled vent valve 53 is provided for automatic sequential retraction of the hoist. These valves are preferably mounted on platform 16 and are provided with foot pedals 54 so that the operator may open or close the valves by stepping on or off the pedals. Throughout the drawings the foot pedals which operate valves causing upward movement of the platform are identified by the letter “U,” and the foot pedals which actuate the vent valves for downward movement of the platform are identified by the letter “D.”

To extend the hoist from its fully retracted position, the workman actuates the first “up” valve 50 so that pressure fluid from source S flows through line 55, valve 50, check valve 56 and line 57 to pipe 18, and thus to the interior of the first cylinder. Source S may be a tank of compressed gas or a compressor, the source being capable of supplying gas at a pressure substantially greater than that required to cause extension of the hoist. As the pressure therein builds up, the second cylinder 12 and all elements thereabove will extend. After full extension of the second cylinder 12, continued build-up of pressure in the first cylinder, below piston 21, will cause an increase of pressure in the second cylinder, since the passage 24 through piston 21 is open. When the pressure in the second cylinder builds up enough to cause the third cylinder to extend, a slight upward movement of the third cylinder piston 30 will allow valve 25 in piston 21 to close. Thereafter, pressure fluid entering the first cylinder.
through pipe 18 will cause the pressure to build up in the first cylinder without affecting the pressure in the second cylinder.

When the desired degree of overpressure has been built up in the first cylinder, the operator releases the first "up" valve 50 and actuates the next "up" valve 51 to allow flow therethrough. Pressure fluid from source S flows through valve 51 and check valve 58 to the intermediate pipe 38, down the annular space between the second and third cylinders and then down through passages 36 in piston 30 to pressurize the interior of the second cylinder. As pressure builds up in the second cylinder the third cylinder 13 will begin to extend, carrying the fourth cylinder 14 and platform 16 upwardly therewith. Continued supply of pressure fluid to the second cylinder will cause full extension of the third cylinder, and then thereafter, because of the opening 32 in the third cylinder piston 30, will cause a build-up of pressure in the third cylinder sufficient to cause a slight extension of the fourth cylinder 14. Such slight extension will then allow valve 33 to close, thereby preventing further upward flow of fluid through piston 30. The "up" valve 51 is then maintained in open position until the desired degree of overpressure has been achieved in the second cylinder.

The operator then releases the "up" valve 51 and actuates the final "up" valve 52 to open position. Opening of this valve allows pressure fluid to flow from source S to the inlet pipe 43 so that the third cylinder is pressurized thereby. The build-up of pressure in the third cylinder will then cause extension of the fourth cylinder 14, and after full extension thereof the third cylinder is overpressured. With all cylinders now overpressured, the hoist is rigidified and insensitive to load variations on the work platform.

To retract the hoist, the operator actuates the single "down" valve 53, which allows the third cylinder to vent through passage 46, pipe 45, passage 44, pipe 43 and vent valve 53 to atmosphere. With the fourth cylinder being extended, internal valve 33 is closed, so that initially only the third cylinder can vent to atmosphere. The overpressure condition in the third cylinder is relieved, followed by a lowering of the fourth cylinder. As the fourth cylinder reaches its fully retracted position, it will engage and open valve 33 to allow the pressure fluid in the second cylinder to flow through passage 32 into the interior of the third cylinder, and then vent to atmosphere as before. At this time, valve 25 in the second cylinder piston 21 is still closed, thus continuing to trap the high pressure in the first cylinder. Venting of the second cylinder dissipates the over pressure condition therein, followed by a retraction of the third cylinder. As the third cylinder reaches a fully retracted position the third cylinder piston 30 will engage and open valve 25 in the second cylinder piston, allowing the high pressure in the first cylinder to flow upwardly through passage 24 and then upwardly and outwardly through the "down" valve 53. Venting of the first cylinder dissipates the high pressure therein and then allows the second cylinder to retract, thus completing retraction of the hoist.

FIG. 1B illustrates another control system usable with the lift cylinder of FIG. 1, utilizing a single "up" valve 60 and a single "down" valve 61. Actuation of the "up" valve 60 allows pressure fluid to flow from source S simultaneously to pipes 18, 38 and 43. Full flow is allowed to pipe 18, but restrictors 62 and 63 permit only a limited rate of flow to pipes 38 and 43 respectively. As before, introduction of pressure fluid through pipe 18 will cause the second cylinder 12 to extend. After the second cylinder has fully extended and the third cylinder has extended sufficiently to allow valve 25 to close, pressure fluid will continue to flow to the interior of the first cylinder through pipe 18 and will also flow to the interior of the second cylinder through restrictors 62 and 63. These restrictors are chosen so that the total flow through both is sufficiently less than the flow through pipe 18 so that the interior of the first cylinder is properly overpressured before full extension of the third cylinder. In due course, the third cylinder becomes fully extended and the fourth cylinder lifts off sufficiently to allow valve 33 to close. At this time the interior of the second cylinder is supplied with pressure fluid through restrictor 62, while the interior of the third cylinder is supplied with pressure fluid through restrictor 63. The sizes of the restrictors 62 and 63 are chosen relative to each other so that a suitably greater flow occurs through restrictor 62, thus allowing the second cylinder to be properly overpressured before full extension of the fourth cylinder. When the fourth cylinder has been fully extended and the interior of the third cylinder has been properly overpressured the operator releases the "up" valve 60.

To retract the device, the operator actuates the "down" valve 61 to open position. Pressure fluid can then flow from pipe 43, through check valve 64 which bypasses the restrictor 63, and then out through the vent valve 61 to atmosphere. A sequential retraction will then take place, as described in connection with FIG. 1A, from the top down, with an overpressure condition existing in each cylinder below the cylinder which is actually retracting.

The control system shown in FIG. 1C provides a single operator-controlled "up" valve 65 and single operator-controlled "down" valve 66. Opening of valve 65 allows pressure fluid to flow through check valve 67 to pipe 214. As described above, this will cause the second cylinder to extend, followed by sufficient extension of the third cylinder to allow the internal valve 25 to close. Continued supply of pressure fluid to the interior of the first cylinder will cause an overpressure condition to be built up therein. When the pressure therein is sufficiently high, the high pressure sensor 68, which is suitably arranged so as to respond to the pressure in the interior of the first cylinder, will cause valve 69 to open, allowing pressure fluid to flow through check valve 70 to pipe 38 and to the interior of the second cylinder. The third cylinder 13 will then extend, after which the interior of the second cylinder is overpressured. When the pressure is sufficiently high, the second cylinder high pressure sensor 71 opens valve 72 so that pressure fluid from source S can now flow to pipe 43 to pressure the third cylinder. The fourth cylinder will now be extended, and the third cylinder is then overpressured. This completes the sequence of extension and the "up" valve 65 is then released.

Retraction of the device by the single operator-controlled "down" valve 66 is accomplished in exactly the same way as described in connection with FIG. 1A.

FIG. 2 illustrates another form of multi-stage lift cylinder hoist 75. Hoist 75 is substantially the same as hoist 10 of FIG. 1 and corresponding elements are
identified by the same reference numerals. Hoist 75 differs, however, in that the second cylinder piston 76 is solid and blocks communication at all times between the interiors of the first and second cylinders. Similarly, the third cylinder piston 77 is solid and blocks communication at all times between the interiors of the second and third cylinders. Piston 77, however, does have passages 36 therethrough so that the interior of the second cylinder is in fluid communication with the annular space between the second and third cylinders and with pipe 38.

FIG. 2A illustrates a control system usable with the lift cylinder of FIG. 2, in which three operator-controlled “up” valves 80, 81 and 82 are provided and wherein three operator-controlled “down,” or vent, valves 83, 84 and 85 are provided. Opening of the first “up” valve 80 allows pressure fluid from source S to flow to pipe 18, causing the interior of the first cylinder to be pressured so that the second cylinder 12 is extended. After full extension, the interior of the first cylinder is overpressured. The operator then opens the next “up” valve 81, to supply pressure fluid to pipe 30 and, by way of passages 36, to the interior of the second cylinder, so that the third cylinder 13 is extended, followed by an overpressurization of the second cylinder.

The operator then opens the last “up” valve 82 to supply pressure to pipe 43 and the interior of the third cylinder to extend the fourth cylinder 14. After the fourth cylinder is fully extended the interior of the third cylinder is overpressured.

In retraction, the operator opens the first “down” valve 83, allowing the overpressure condition in the third cylinder to dissipate, followed by a retraction of the fourth cylinder. The operator then opens the next “down” valve 84 to vent the overpressure in the second cylinder to atmosphere followed by a retraction of the third cylinder. Finally, the operator opens the last “down” valve 85 to vent the first cylinder to atmosphere. After the overpressure condition therein has dissipated, the second cylinder will retract to complete the retraction.

The control system of FIG. 2B utilized a single operator-controlled “up” valve 90 which when opened allows pressure fluid to flow simultaneously to pipes 18, 38 and 43, but with flow to pipes 38 and 43 being restricted by restrictors 91 and 92, respectively. Restrictor 91 is chosen so that the flow to pipe 38 is sufficiently less than the flow to pipe 18 so that the interior of the first cylinder is suitably overpressured before full extension of the third cylinder. Likewise, restrictor 92 is chosen so that the flow to pipe 43 is sufficiently less than the flow to pipe 38 so that the interior of the second cylinder is suitably overpressured before full extension of the fourth cylinder. As with the control system of FIG. 2A, three operator-controlled “down,” or vent, valves 93, 94 and 95 are provided by which the operator can sequentially relieve the overpressure in the cylinders and allow th cylinder thereaboe to retract. Restrictor 91 and 92 are bypassed by check valves 96 and 97 to allow unrestricted vent flow therehrough.

In the FIG. 2C control, actuation of the single operator-controlled “up” valve 100 allows pressure fluid to flow to pipe 18 and the interior of the first cylinder. After the second cylinder has elevated and the first cylinder has been overpressured, the high pressure sensor 101 actuates valve 102 to open position, allowing pressure fluid to then flow to pipe 38 to pressure the interior of the second cylinder. After the third cylinder has extended and the second cylinder has been overpressured, the high pressure sensor 103 opens valve 104 so that the pressure fluid can then flow to pipe 43 and thus to the interior of the third cylinder. Three operator-controlled “down” valves 105, 106 and 107 allow the operator to retract the device in a manner as described in connection with FIG. 2A.

In the control system of FIG. 2D, three operator-controlled valves 110, 111 and 112 are provided, by which the operator can sequentially extend and overpressurize the cylinder in the same manner as described in connection with FIG. 2A. In retraction, a single operator-controlled “down” valve 113 is used. When this valve is open, the third cylinder can vent from pipe 43 through check valve 114 and vent valve 113 to atmosphere. Upon full or substantial retraction of the fourth cylinder, the pressure in the third cylinder will be sufficiently low to cause the third cylinder low pressure sensor 115 to actuate valve 116, allowing the interior of the second cylinder to vent through valve 116, check valve 117 and “down” valve 113 to atmosphere. Subsequently, the pressure in the second cylinder will decrease to a point where the second stage low pressure sensor 118 will actuate valve 119 to open position so that the first cylinder vents to atmosphere to complete the retraction.

Although the second cylinder low pressure sensor 118 will cause the first cylinder vent valve 119 to be open during the extension phase while pressure fluid is supplied by valve 110 to pipe 18, the pressure fluid will not flow and escape through valve 119 since the “down” valve 113 is closed and the check valves 114 and 117 prevent flow to pipes 38 and 43. Similarly, even though the second cylinder vent valve 116 is open during the time that pressure fluid is being supplied to pipe 38, such pressure fluid will not escape through vent valve 116 because the “down” valve 113 is closed and check valve 114 prevents flow therethrough to pipe 43.

The control system of FIG. 2E utilizes a single operator-controlled “up” valve 120, high pressure sensors 121 and 122 which actuate valves 123 and 124 to provide for an automatic sequence of cylinder member extension and overpressurization as described in connection with the extension portion of the control system of FIG. 2C. In addition, the control system of FIG. 2E utilizes a single operator-controlled “down” valve 125, low pressure sensors 126 and 127 which operate vent valves 128 and 129 in the same way as described in connection with the retraction portion of the control system of FIG. 2D. Check valves 120a and 120b prevent flow of pressure fluid from the interiors of the cylinders 11 and 12 respectively, so that these cylinders can only be exhausted through valves 129 and 128 respectively and then through vent valve 125. Thus, after cylinder 11 has been pressured to raise cylinder 12 and then overpressurized to cause the high pressure sensor 121 to open valve 123, check valve 120a will maintain the overpressure condition in cylinder 11 during the elevation of the third and fourth cylinders 13 and 14 and until such time as valve 129 is opened during the retraction sequence. Similarly, after cylinder 12 has been pressured to extend cylinder 13 and then overpressurized, check valve 120b will maintain the overpressure in cylinder 12 during extension of cylinder 14 and until valve 128 is opened during the retraction sequence.
In the control system of FIG. 2A, a single operator-controlled "up" valve 135 is again used, together with high pressure sensors 136 and 137 to actuate valves 138 and 139 to provide for a fully automatic sequence of extension stages, again as described in connection with FIG. 2C. A single operator-controlled "down" valve 140 is provided, which when actuated to open position will vent pipes 43, 38 and 18 to atmosphere simultaneously. Pipe 43 will vent through check valve 141, while pipe 38 vents through check valve 142 and restrictor 143 and pipe 18 vents through check valve 144 and restrictor 145. Restrictor 143 is chosen in size so that the flow rate therethrough is sufficiently less than the flow rate from pipe 43 so the fourth cylinder will be substantially fully retracted before the overpressure condition in the interior of the second cylinder is relieved. Similarly, restrictor 145 is chosen in size so that the flow rate therethrough is sufficiently less than the flow through restrictor 143 so that the third cylinder will be substantially fully retracted before the overpressure condition in the interior of the first cylinder is relieved.

In the lift cylinders of FIGS. 1 and 2, each of the first, second, third and fourth cylindrical members 11, 12, 13 and 14 comprises only a single cylinder. However, the invention is not limited thereto, since any or all of these cylindrical members may themselves comprise two or more telescopic cylinders. Likewise, the invention is not limited to a hoist having three steps of extension and retraction, but may be used with hoists having an additional step or steps of extension and retraction.

Referring now to FIG. 4, the hoist 210 shown therein comprises a first cylindrical member made up of three telescoping cylinders 211a, 211b and 211c, a second cylindrical member having two telescoping cylinders 212a and 212b, a third cylindrical member 213, a fourth cylindrical member 214 and a fifth cylindrical member 215. These cylinders have, respectively, pistons 216 to 223 secured to the lower end thereof, each piston being in sealing and sliding engagement with the inner wall of the next larger cylinder. A pipe 225 communicates with the interior of the outermost cylinder 211a, and pipe 226 communicates, by way of plug passage 227, pipe 228 and piston passage 229, with the interior of the fourth cylinder member 214 below piston 223. Pistons 217, 218 and 220 have central passages therethrough, whereas pistons 219, 221 and 222 are blocked pistons. Piston 221 has passages 231 therethrough from below piston 221 to the annular space between cylinders 212a and 213, external pipe 232 being connected at the upper end of cylinder 212b to this annular space. Similarly, piston 222 has passages 233 therethrough from below piston 222 to the annular space between cylinders 213 and 214, external pipe 234 being connected at the upper end of cylinder 213 to this annular space.

Introduction of gas under pressure into pipe 225 will cause sequential extension of cylinders 211a, 211b and 211c. With piston 219 being blocked, pressure can be built up therebelow without causing further extension of the remaining cylinders. When the pressure below piston 219 has built up to the desired degree for rigidification, pressure fluid is then introduced into pipe 232, thereby causing extension of cylinders 212b and 213. When these are fully extended, the blocked piston 221 allows rigidifying pressure to be built up therebelow, again without causing any further extension. Pressure fluid is now introduced into pipe 234 to extend cylinder 214. After the rigidifying pressure has been built up, pressure fluid is introduced into pipe 226 to extend the first cylinder member 215. Sequential contraction is achieved by venting, in order, pipes 226, 234, 232, and 225.

The control systems of FIGS. 2A through 2F can be modified to provide for the additional extension and retraction step of hoist 210. As for example, the four-step control system of FIG. 3A is essentially the same as the three-step control system of FIG. 2A, with an additional "up" valve and an additional "down" valve being added. The four-step control system of FIG. 3B corresponds to the fully automatic control system of FIG. 2E, with an additional high-pressure sensor, an additional low pressure sensor and valves actuated thereby to provide for the additional step of extension and retraction. It is believed that the operation of the FIGS. 3A and 3B control systems is fully apparent in light of the previous descriptions of the corresponding three-step control system.

The internally valved hoist 10 of FIG. 1 can similarly be modified to provide several cylinders per cylindrical member or to add further cylindrical members. As for example, the hoist shown in FIG. 3 could be made with internally valved pistons, i.e., as pistons 21 or 30 of FIG. 1, in place of the blocked pistons 219, 231 and 233. With internally valved pistons, the sequential venting from top to bottom will take place automatically, with but a single external vent valve connected to the uppermost pipe 226. As a consequence, the control systems of FIGS. 1A, 1B or 1C can be used with such a hoist, with suitable additional valves and/or restrictors to provide for the additional step of extension.

Having thus described our invention, we claim:

1. A compressible fluid-operated multi-stage hoist for operating up to a given load limit comprising:
   a. a first, second, third and fourth vertically oriented cylin- 
   dindrical members of decreasing cross-sectional area telescopically 
   arranged within each other, said 
   first cylinder member being closed at the lower end thereof, 
   said second cylinder member having a piston member 
   secured thereto in sliding and sealing engagement 
   with said first cylinder member and extending 
   across the interior of said second cylinder member, 
   and having a downwardly facing surface exposed 
   to fluid pressure therebelow, said piston member 
   being closed to passage therethrough from the interior 
   of said first cylinder member to the interior of 
   said second cylinder member during at least the 
   major portion of extension and retraction of said 
   third cylinder member,
   said third cylinder member having a piston member 
   secured thereto in sliding and sealing engagement 
   with said second cylinder member and extending 
   across the interior of said third cylinder member, 
   and having a downwardly facing surface exposed 
   to fluid pressure therebelow, said piston member 
   being closed to passage therethrough from the interior 
   of said second cylinder member to the interior of 
   said third cylinder member during at least the 
   major portion of extension and retraction of said 
   fourth cylinder member,
   said fourth cylinder member having a piston member 
   secured thereto in sliding and sealing engagement

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with said third cylinder member and extending across the interior of said fourth cylinder member and having a downward facing surface exposed to fluid pressure therebelow,
means forming a first conduit from the exterior of said first cylinder member into the lower end thereof,
means forming a seal between the upper end of said third cylinder member and the upper end of said second cylinder member,
means forming a second conduit from the exterior of said second cylinder member into the upper end thereof, said second conduit extending down between said second and third cylinder members and extending through and terminating below said piston member of said third cylinder member,
means forming a third conduit from the exterior of said fourth cylinder member into the upper end thereof, said third conduit extending through and terminating below said piston member of said fourth cylinder member,
a source of compressible fluid at a pressure substantially greater than that required for the extended hoist to support said given load limit,
control means for supplying compressible fluid from said source to said first, second and third conduits to cause sequential extension of said second, third and fourth cylinder members and for maintaining the interior of said first cylinder member at a pressure greater than the interior of said second cylinder member during extension of said third cylinder member, and for maintaining the interior of said second cylinder member at a pressure greater than the interior of said third cylinder member after extension of said third cylinder member and during extension of said fourth cylinder member,
vent means for venting compressible fluid and pressure from said first, second and third conduits to cause sequential retraction of said fourth, third and second cylinder members and for maintaining the pressure in said second cylinder member higher than the pressure in said third cylinder member during retraction of said fourth cylinder member, and for maintaining the pressure in said first cylinder member higher than the pressure in said second cylinder member during retraction of said third cylinder member.
2. A hoist according to claim 1 in which the interior of said first cylinder member is always separated from fluid communication with the interior of said second cylinder member by said piston member of said second cylinder member, in which the interior of said second cylinder member is always separated from fluid communication with the interior of said third cylinder member by said piston member of said third cylinder member and in which said vent means vents the interior of said third, second and first cylinders through said third, second and first conduits respectively.
3. A hoist according to claim 1 in which said control means comprises:
first, second and third flow lines from said source to said first, second and third conduits respectively, an operator-controlled valve in said first flow line and having an open position to allow fluid to flow from said source to said first conduit and a closed position to prevent such flow,
means in said second flow line for allowing flow of said compressible fluid to said second conduit to cause extension of said third cylinder member after the pressure in said first cylinder member has built up to a pressure greater than that required to extend said second cylinder member,
means in said third flow line for allowing flow of said compressible fluid to said third conduit to cause extension of said fourth cylinder member after the pressure in said second cylinder member has built up to a pressure greater than that required to extend said third cylinder member.
4. A hoist according to claim 3 in which said second and third flow lines are connected to said source through said operator-controlled valve, and in which said means in said second and third flow lines comprise restrictors for passing fluid through said second flow line at a rate less than that at which said fluid can flow through said first flow line and for passing fluid through said third flow line at a rate less than that at which said fluid can flow through said second flow line.
5. A hoist according to claim 3 in which said means in each of said second and third flow lines comprises a valve having an open and a closed position.
6. A hoist according to claim 5 and further including means responsive to a predetermined high pressure in said first cylinder member for operating the valve in said second flow line to open position, and means responsive to a predetermined high position in said second cylinder member for operating the valve in said third flow line to open position.
7. A hoist according to claim 1 in which said vent means includes an operator-controlled vent valve exteriorly of said cylinder members, said vent valve having its inlet in fluid communication with said third conduit, said vent valve having an open position to allow fluid flow therethrough and a closed position to prevent such flow.
8. A hoist according to claim 7 in which said vent means includes a second vent valve for controlling the venting of said second cylinder member and a third vent valve for controlling the venting of said first cylinder member.
9. A hoist according to claim 8 in which said piston member of said third cylinder member has a passage therethrough communicating the interiors of said second and third cylinder members, in which said second valve is disposed in said passage and normally closes said passage to flow upwardly therethrough, said fourth cylinder member having a valve actuator thereon for opening said second vent valve in response to substantial retraction of said fourth cylinder member into said third cylinder member, in which said piston member of said second cylinder member has a passage therethrough communicating the interiors of said first and second cylinder members, in which said third vent valve is disposed in said last-named passage and normally closes said passage to flow upwardly therethrough, said third cylinder member having a valve actuator thereon for opening said third vent valve in response to substantial retraction of said third cylinder member into said second cylinder member.
10. A hoist according to claim 8 in which said second and third vent valves are exterior of said cylinder members and have their inlets in fluid communication with said second and third conduits, respectively.
11. A hoist according to claim 10 and wherein said vent means further includes means responsive to a predetermined low pressure in said third cylinder member for opening said second vent valve to flow therethrough and means responsive to a predetermined low pressure in said second cylinder member for opening said third vent valve to flow therethrough.

12. A hoist according to claim 7 in which said vent means includes a flow line said second conduit to the inlet of said vent valve and a restrictor in said flow line for venting said second conduit at a slower rate than from said first conduit when said vent valve is open, and a flow line from said first conduit to the inlet of said vent valve, and a restrictor in the last-mentioned flow line for venting said first conduit at a slower rate than from said second conduit when said vent valve is open.