March 3, 1953 R. S. FULLERTON ET AL 2,629,876

HYDRAULIC CONTROL SYSTEM FOR ARTIFICIAL LIMBS

Filed March 4, 1948 3 Sheets-Sheet 1

Fig. 1.

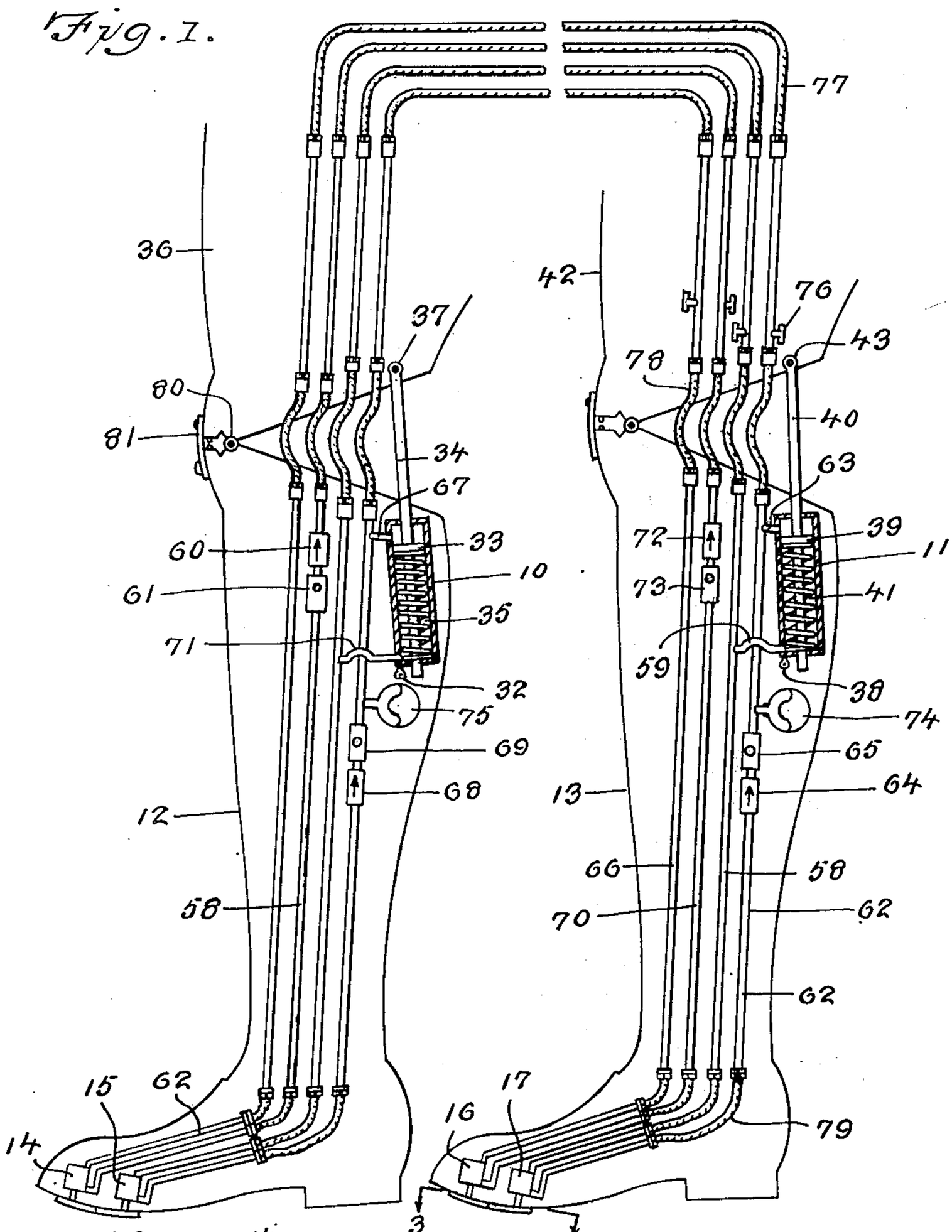

Fig. 2.

Fig. 4.

Fig. 3.

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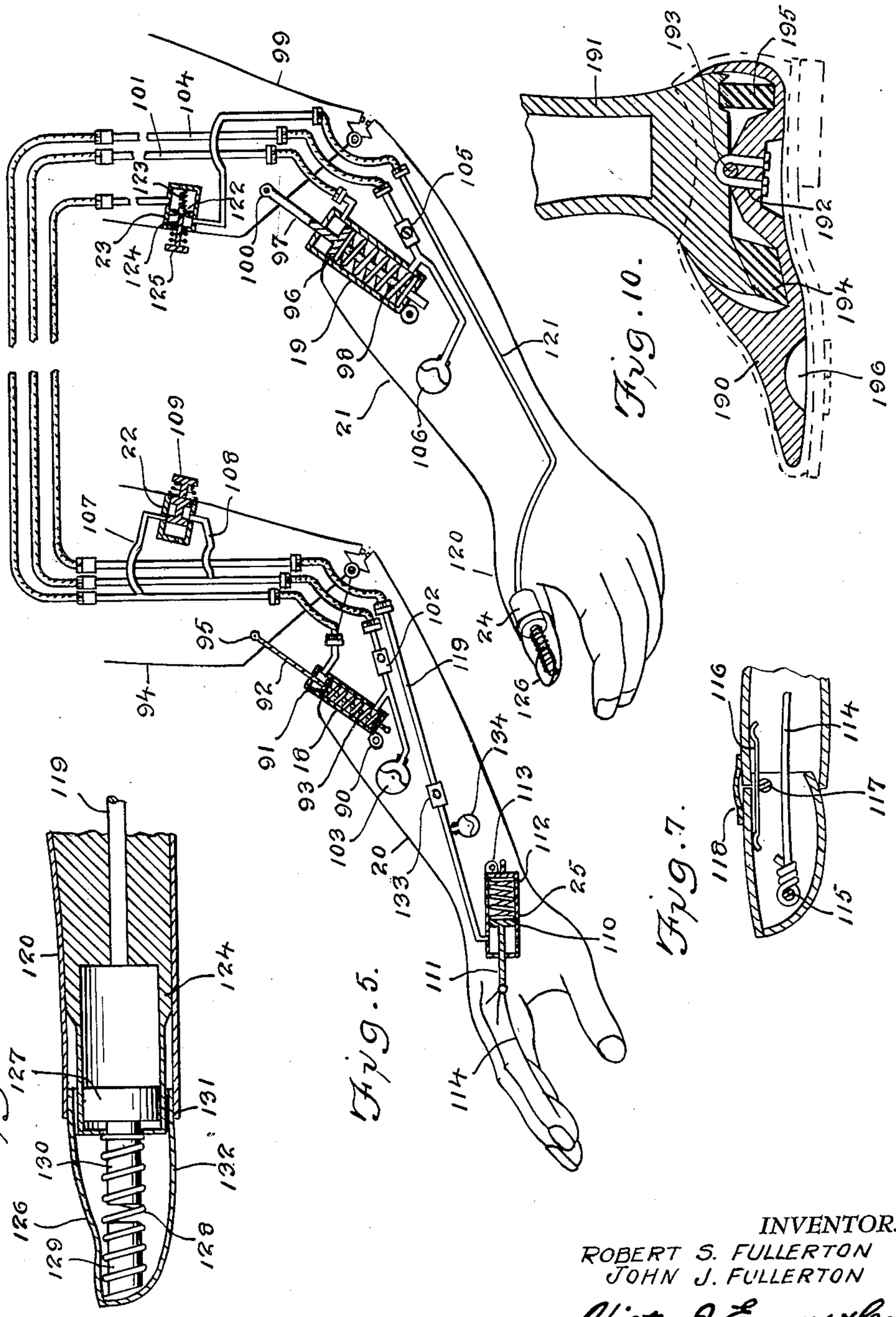

Fig. 10.

Fig. 5.

Fig. 7.

Fig. 6.

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Fig. 8.

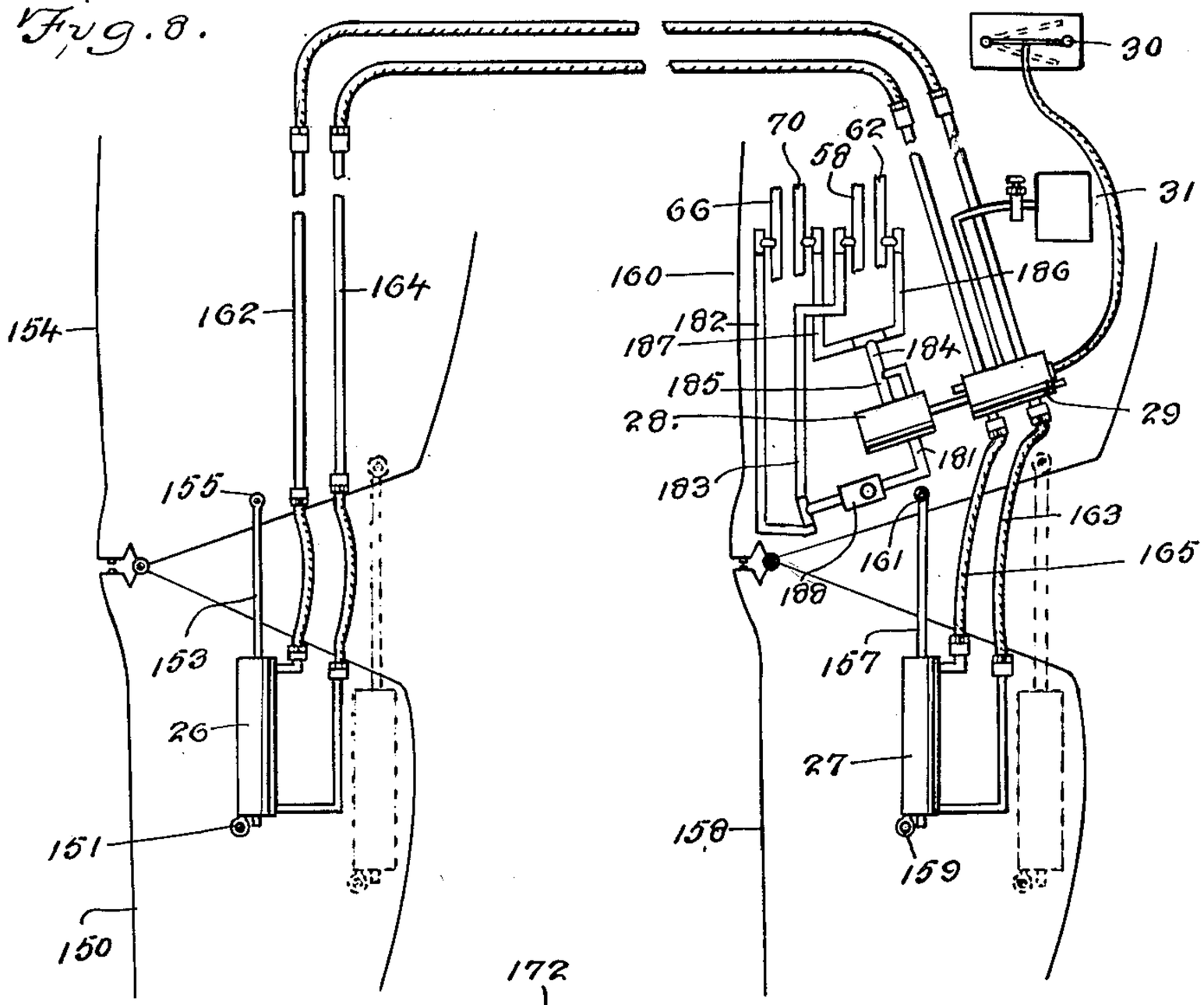
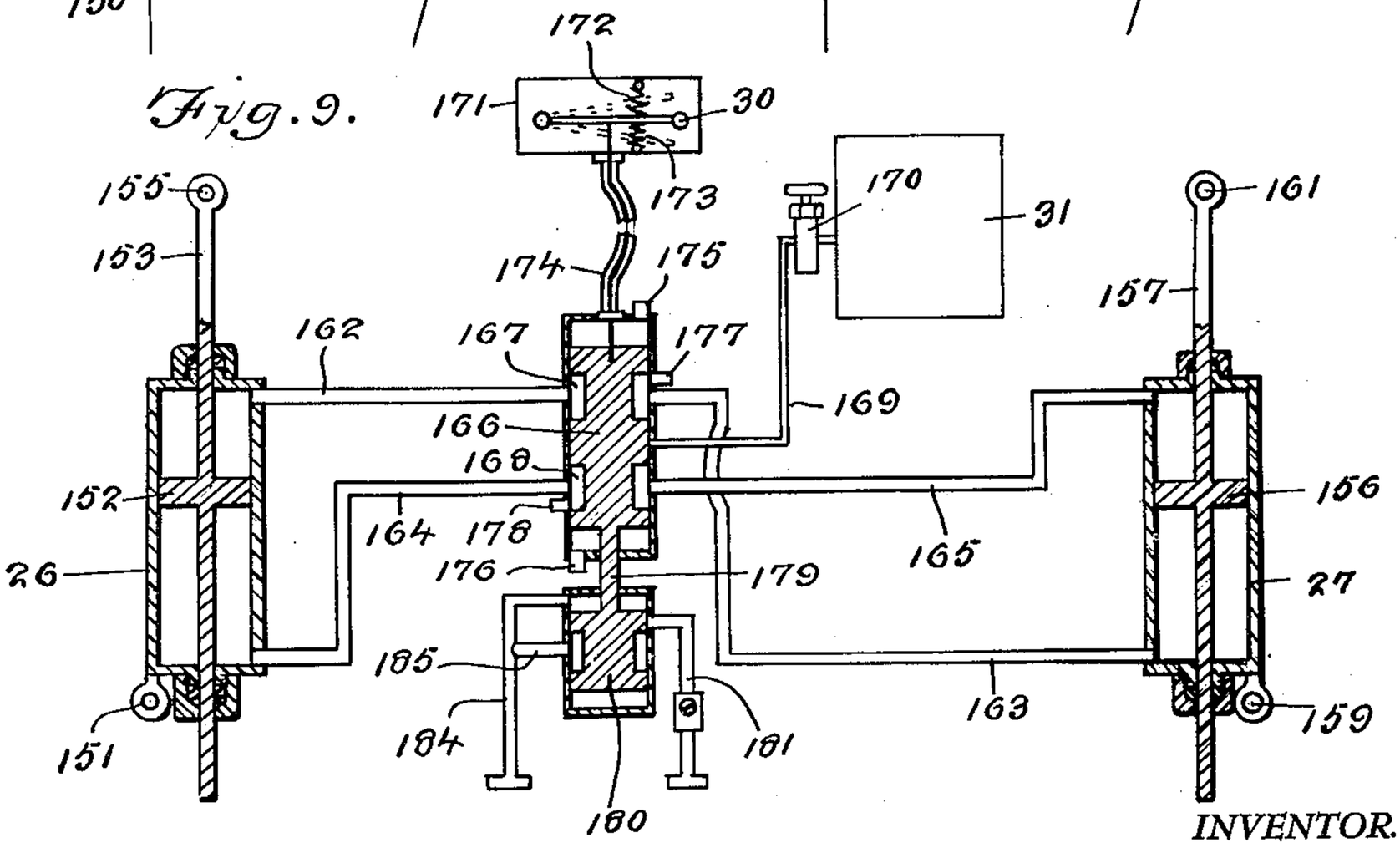


Fig. 9.



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HYDRAULIC CONTROL SYSTEM FOR ARTIFICIAL LIMBS

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Application March 4, 1948, Serial No. 12,985

2 Claims. (Cl. 3—2)

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This invention relates to controlling and actuating devices for artificial arms and limbs wherein the actuating devices are incorporated in the arms and limbs, and in particular spring actuated liquid filled cylinders incorporated in the elbow and knee joints with connecting tubes extending around the shoulders and hips and with control valves for the cylinders positioned in the fingers and toes.

The purpose of this invention is to provide hydraulic control means for artificial arms and limbs of bilateral amputees which provide smooth, graceful, and at the same time positive action, that makes it possible to travel up and down steps, and that eliminates unsightly hooks and the like.

Artificial limbs and other parts of the human body have been made in different forms and provided with various types of control and actuating devices but it is difficult to simulate the natural movements of the human body with artificial means and therefore, arms and limbs in particular, provided with mechanically operating instrumentalities are not completely successful. With this thought in mind this invention contemplates joints for artificial members which are hinged at one side and provided with cylinders having pistons and springs therein connected by tubes and the cylinders and tubes are filled with liquid, and with the cylinders mounted in one member and the pistons connected by rods to the other member, and with the movement of the pistons controlled by valves positioned at convenient points.

The object of this invention is, therefore, to provide suitable elements for holding joints straight by hydraulic means.

Another object of the invention is to provide actuating means for artificial hands whereby the hands may be used for eating, grooming, and the like.

Another object of the invention is to provide operating instrumentalities in artificial limbs whereby one limb may be controlled by a toe or finger of the other limb.

Another object of the invention is to provide hydraulically actuated instrumentalities in artificial limbs whereby the limbs are adapted for ascending and descending stairs.

Another object of the invention is to provide emergency power elements for artificial arms and limbs which insure absolute control of the members under all conditions.

A further object of the invention is to provide hydraulically actuated instrumentalities for artificial arms and limbs which are of comparatively simple and economical construction.

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With these and other objects and advantages in view the invention consists of the new and novel combination, construction, and arrangement of parts as hereinafter more fully described, set forth in the claims appended hereto, and disclosed in the accompanying drawings, forming part hereof, wherein:

Figure 1 is a view illustrating the hydraulic control elements incorporated in a pair of artificial limbs with parts broken away and parts in section and with the limbs indicated in outline.

Figure 2 is a detail showing a section through a toe actuated control valve that is installed in a toe of a foot of one of the limbs.

Figure 3 is a detail taken on line 3—3 of Figure 1 showing cover plates for the toe operated valves with the valve stems shown in section.

Figure 4 is a detail showing a safety lock or latch that is positioned on the outer surface of the knees.

Figure 5 is an assembly view similar to that illustrated in Figure 1 showing the device as applied to the arms and hands.

Figure 6 is a longitudinal section through a thumb of one of the hands shown in Figure 5.

Figure 7 is a longitudinal section through the outer end of a finger of one of the hands shown in Figure 5.

Figure 8 is a view illustrating an emergency power assembly adapted to be used in combination with the control elements shown in Figure 1 to facilitate ascending and descending stairways and the like.

Figure 9 is an enlarged detail with parts shown in elevation and parts in section showing the control elements of the device illustrated in Figure 8.

Figure 10 is a detail on an enlarged scale showing a longitudinal section through a foot adapted to be used on the limbs shown in Figure 1 with a shoe indicated in dotted lines thereon and with part of the limb broken away.

Referring now to the drawings wherein like reference characters denote corresponding parts the artificial limb hydraulic control system of this invention includes cylinders 10 and 11 in lower limbs 12 and 13 with control valves 14 and 15 in the toe of the limb 12 and 16 and 17 in the toe of the limb 13, and also cylinders 18 and 19 in forearms 20 and 21, respectively, with valves 22 and 23 in the upper arms, a thumb actuated cylinder 24, and a finger actuating cylinder 25. The invention also includes emergency power

units including cylinders 26 and 27 with control valves 28 and 29, a manual control 30, and a fluid pressure supply chamber 31, and also suitable connecting tubes with restricting and check valves therein.

The cylinder 10 is pivotally mounted in the limb 12 by a pin 32 and the cylinder is provided with a piston 33 on a rod 34 with the piston held upward by a spring 35 and with the upper end of the rod pivotally attached to the thigh 36 by a pin 37. The cylinder 11 is similar to the cylinder 10 being pivotally mounted in the limb 13 by a pin 38 and provided with a piston 39 on a rod 40 with the piston held upward by a spring 41 and with the upper end of the rod pivotally attached to the thigh 42 by a pin 43. The valves 14, 15, 16 and 17 which are positioned just behind the toe or under the metatarsus of the foot are similar, and each is formed as illustrated in Figure 2 with a partition 44 having an orifice 45 therein with a valve seat 46 at the upper end and a ball 47 resiliently held against the seat by a spring 48. The valve is opened by a pin 49 having a head or button 50 thereon and the pin, which is provided with a collar 51 and extends through a packing gland 52 is held outward by a spring 53, with the head or button 50 at the surface of a member in which the valve is incorporated. The heads 50 of the pins 49 may be of any suitable shape, however, as it is desired to prevent the heads turning the head of one pin may be provided with a tongue 54 and the head of the pin of the adjoining valve may be provided with a recess 55 to receive the tongue, as shown in Figure 3, in which the pins are indicated by the numerals 56 and 57.

With the parts arranged in this manner it will be noted that as the step is started with the left foot 13 the weight of the body on the ball of the foot will first open the valve 17 and release fluid in the lower end of the cylinder 11 so that the piston may move downward to bend the knee. A tube 58 connects the upper part of the valve 17 with the lower part of the valve 14 and this tube is provided with a connection 59 to the lower part of the cylinder 11, and also with a check valve 60 that permits upward flow only of fluid in the limb 12, and a restricting or control valve 61. A tube 62 connects the lower part of the valve 17 to the upper part of the valve 14 and this tube is provided with a connection 63 to the upper part of the cylinder 11 above the piston 39, and also a check valve 64 that permits upward flow only of fluid in the limb 13, and a restricting or control valve 65. The restricting valves 61 and 65 will control the speed of the bending action of the knee wherein the knee will bend to compensate for the upward movement of the ankle as the foot rises on the toe or ball thereof.

As the forward action continues the valve 16 will be opened and this will release the fluid above the spring 35 in the cylinder 10 of the right limb 12 so that the spring will straighten the knee of the right limb. The upper part of the valve 16 is connected by a tube 66 to the lower part of the valve 15 and the tube 66 is provided with a connection 67 to the upper part of the cylinder 10 above the piston 33, a check valve 68 that permits upward flow only of fluid in the right limb 12, and a control valve 69. The lower part of the valve 16 is connected by a tube 70 to the upper part of the valve 15 and the tube 70 is provided with a connection 71 to the lower part of the cylinder 10, a check valve 72 that permits upward flow only of fluid in the left limb 13,

and a control valve 73. The valve 73 restricts the flow of fluid in the tube 70 and thereby controls the speed of the straightening action of the right limb. The check valve 72 will prevent return flow of the fluid and hold the right limb 12 straight as weight is applied thereto. As the weight is shifted to the right limb the left limb remains bent, the fluid being retained by the check valve 64, so that the left limb is carried through without scuffing on the pavement or the like. In the next step the right limb controls the left limb in the same manner.

The tubes 62 and 66 may be provided with accumulator bells 74 and 75, respectively, to absorb variations in volume of the fluid due to changes in temperature, and all of the tubes may be provided with connections 76 for a booster system if desired. The tubes may be provided with flexible connections 77 that may extend over the hips or around the waist, and similar connections 78 and 79 may be provided in the knees and ankles respectively.

The limbs are connected at the knees by hinges 80 and safety latches 81 are pivotally mounted on the lower sections and positioned to lock over pins 82 on the thighs, as shown in Figure 4.

In the arm control device illustrated in Figures 5, 6 and 7 the cylinder 18 is pivotally mounted in the forearm 20 by a pin 90, and the cylinder is provided with a piston 91 on a rod 92 with a spring 93 for urging the piston upward, and the outer end of the rod is pivotally connected to the upper arm 94 by a pin 95. The cylinder 19 is somewhat larger in diameter than the cylinder 18 and this is provided with a piston 96 on a rod 97 with a spring 98 below the piston and with the upper end of the rod pivotally attached to the upper arm 99 by a pin 100. The upper end of the cylinder 19 is connected to the lower end of the cylinder 18 by a tube 101 and the tube is provided with a control valve 102 and an accumulator bell 103. The lower end of the cylinder 19 is connected to the upper end of the cylinder 18 by a tube 104 and this tube is also provided with a control valve 105 and an accumulator bell 106. With the left arm 21 slightly bent the hand thereof may be placed on a table and by bending the body forward the weight will bend the elbow forcing the cylinder 19 upward and thereby forcing the fluid below the piston into the cylinder 18 above the piston which will move the cylinder 18 upward bending the elbow of the right arm. As the cylinder 18 is smaller than the cylinder 19 the right hand will travel further than the left and with greater speed, the movement being controlled by the position of the valve 102. If the weight is removed from the left arm the pressure will be relieved and the spring 93 will straighten the right arm, the movement also being restricted by the valve 102. The right arm will also force the left arm upwardly in the same manner.

The valve 22 under the right arm pit is provided with a connection 107 to the tube 104 and a connection 108 to the tube 101 and by pressing the button 109 thereof inward the connections will be in communication through the valve and the pressure will be equalized so that both arms will settle to any desired position at which time the button may be released.

In the design shown the right hand is also provided with a cylinder 25 having a piston 110 therein with the piston mounted on a rod 111 and held outward by a spring 112. The cylinder is pivotally mounted on a pin 113 and the end

of the rod 111 is connected to a cord 114 that extends through the forefinger and is connected to a pin 115 at the end thereof. With the joints of the finger formed as illustrated in Figure 7 with springs 116 held by pins 117 on the inside and caps 118 on the outside the finger may be flexed or actuated to gripping position by drawing on the cord. The cylinder 25 is connected by a tube 119 to a check and release valve 23 in the upper arm 99, and the valve 23 is connected to the cylinder 24 in a thumb 120 of the left hand by a tube 121. The valve 23 is formed with a ball 122 held against a valve seat by a spring 123 and adapted to be opened by a pin 124 with a button 125 on the outer end, and as the tip 126 of the thumb is pressed inward a piston 127 in the cylinder 24 will force fluid through the tubes 121 and 119 and through the valve 23 into the forward end of the cylinder 25 so that the piston will move backward and draw the cord 114 which will bend the finger into gripping position. The ball 122 which functions as a check valve will hold the finger in this position until it is released by pressing on the button 125 so that objects may be positively held by the finger. The tip 126 of the thumb is resiliently held outward by a spring 128 the ends of which are held on pins 129 and 130 and the outward movement thereof is limited by a projection 131 that extends into a groove 132 in the under surface of the tip. The tube 119 is also provided with a control valve 133 and an accumulator bell 134. It will be noted that as the button 125 is pressed inward the valve 23 will be opened and the fluid will be forced back to the cylinder 24 by the spring 112 and the finger will be released.

The elbows are connected by hinges 135 and the tubes through the arms are provided with flexible connections 136 that may extend upward across the shoulders, and also flexible connections 137 in the elbows.

The limbs may also be provided with an auxiliary booster system or emergency power unit to facilitate ascending and descending stairways and the like, and this system as illustrated in Figures 8 and 9 includes the auxiliary power cylinders 26 and 27 with the control valves 28 and 29 and the manual control lever 30 and pressure supply chamber 31.

The cylinder 26 which is pivotally mounted in the limb 150 on a pin 151 is provided with a piston 152 on a rod 153 and the upper end of the rod is pivotally attached to the thigh 154 by a pin 155. A similar cylinder 27 with a piston 156 on a rod 157 is pivotally mounted in the limb 158 on a pin 159 and the end of the rod is pivotally attached to the thigh 160 by a pin 161. The upper end of the cylinder 26 is connected by a tube 162 to the upper part of the valve 29 and the opposite side of the valve is connected by a tube 163 to the lower part of the cylinder 27. The lower part of the cylinder 26 is connected by a tube 164 to the lower part of the valve 29 and the opposite side of the lower part of the valve is connected by a tube 165 to the upper part of the cylinder 27. The valve 29 is formed with a slide valve 166 having annular recesses 167 and 168 therein and the pressure chamber 31 for CO_2 or other suitable gas, is connected to an intermediate point of the valve 29 by a tube 169 which has a regulating valve 170 therein.

The control lever 30 which is pivotally mounted on a base 171 and provided with equalizing springs 172 and 173, may be positioned in a pocket or under a garment and the lever is connected

to the slide valve 166 by a flexible shaft 174. The slide valve is illustrated in the neutral position and as the lever 30 is pressed downward the valve member 166 is forced downward so that the connection 169 is in communication with the tubes 162 and 163 wherein pressure is applied to the upper end of the cylinder 26 to bend the knee of the right limb, and to the lower end of the cylinder 27 so that the knee of the left limb will straighten; and if the lever is moved upward the pressure will be applied to the opposite ends of the cylinders wherein the action will be reversed.

The casing of the valve 29 is provided with vents 175 and 176 at the ends and 177 and 178 in the sides, as shown in Figure 9, and the slide valve 166 is connected by a stem 179 to an equalizing or dump valve 180 in the valve casing 28. One side of the valve casing 28 is connected by a tube 181 to booster connections 76 on the tubes 66 and 58 by tubes 182 and 183, respectively, and the other side is connected by a tube 184 with a bypass 185 to the booster connections of the tubes 62 and 70 by tubes 186 and 187. The tube 181 is provided with a regulating valve 188, and with the tubes connected to the valve as shown upward movement of the valve 180 will dump or equalize the pressure in the cylinders 10 and 11; and when lever 30 is pressed downward a reverse action takes place in cylinders 26 and 27 although the valve 180 still dumps or equalizes the pressures in the cylinders 10 and 11. When the lever 30 is in the neutral position and the system is functioning the pressure chamber is shut off at the valve 29, and the cylinders 26 and 27 are vented to the atmosphere. With the lever 30 in the neutral position the valve 28 also holds the system pressures wherein normal action is controlled by the valves 14 to 17 in the toes of the feet.

The emergency power system in combination with the actuating devices shown in Figure 1 facilitates bending the knees particularly when rising from chairs, and ascending and descending stairways and the like.

The feet of the artificial limbs are substantially rigid, and these may be formed as illustrated in Figure 10 wherein elements 190 are pivotally attached to the lower ends of limbs 191 by U-bolts 192 and pins 193. Resilient blocks 194 and 195 are provided on opposite sides of the U-bolt and a recess 196 may be provided in the metatarsus for the valves 14 to 17 inclusive. It will be understood that feet of any type or design may be used.

It will also be understood that modifications may be made in the design or arrangement of the parts without departing from the spirit of the invention.

What is claimed is:

1. In combination, an artificial right leg and an artificial left leg, each of said legs including an upper limb and a lower limb hingedly connected together, said lower limbs having their lower portions terminating in feet, a cylinder mounted in each of said lower limbs, a pair of spaced valves mounted in the foot portion of said lower limbs, a pin pivotally mounting said cylinders in said limbs, a piston reciprocably arranged in each of said cylinders, a rod extending upwardly from each of said pistons, a coil spring positioned in each of said cylinders and circumposed on said rods for normally urging said pistons to their raised position, a pin pivotally connecting the upper end of said rods to said upper limbs, each of said valves comprising

a partition provided with a central orifice therein providing a valve seat, a spring pressed ball mounted for movement into and out of bridging relation with respect to said valve seat, a pin extending through said orifice and having its inner end engaging said ball, a button arranged exteriorly of said foot and secured to the outer end of said rod, and a coil spring circumposed on said rod and abutting said button, tongue and groove means for preventing rotation of said buttons, a plurality of conduits connecting the valves in one foot with the valves in the other foot, each of said conduits including an upper flexible section, and tubes connecting the ends of said cylinders to said conduits.

2. In combination, an artificial right member and an artificial left member, each of said members including an upper limb and a lower limb hingedly connected together, said lower limbs having their lower portions terminating in terminal portions, a cylinder mounted in each of said lower limbs, a pair of spaced valves mounted in the terminal portions of said lower limbs, a pin pivotally mounting said cylinders in said limbs, a piston reciprocably arranged in each of said cylinders, a rod extending upwardly from each of said pistons, a coil spring positioned in each of said cylinders and circumposed on said rods for normally urging said pistons to their raised position, a pin pivotally connecting the upper end of said rods to said upper limbs, each of said valves comprising a partition provided with a central orifice therein providing a valve seat, a spring pressed ball mounted for movement into and out of bridging relation with respect to said valve seat, a pin extending through said orifice and having its inner end engaging said ball, a button arranged exteriorly of said terminal portion and secured to the outer end of said rod, and a coil spring circumposed on said rod and abutting said button, tongue and groove means for preventing rotation of said buttons, a plurality of conduits connecting the valves in one terminal portion with the valves in the other terminal portion, each of said conduits including an upper flexible section, and tubes connecting the ends of said cylinders to said conduits.

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