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HYDRAULIC ARTIFICIAL ARM

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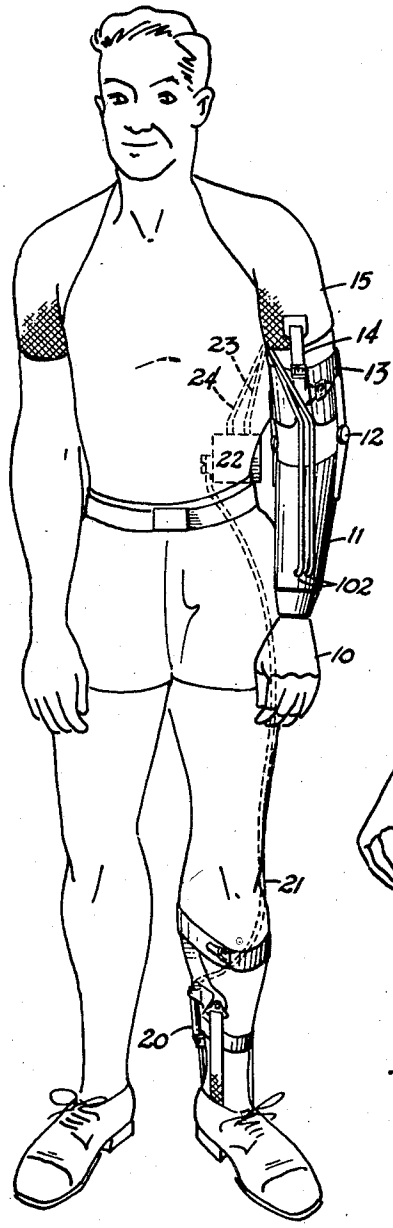

Fig. 1.

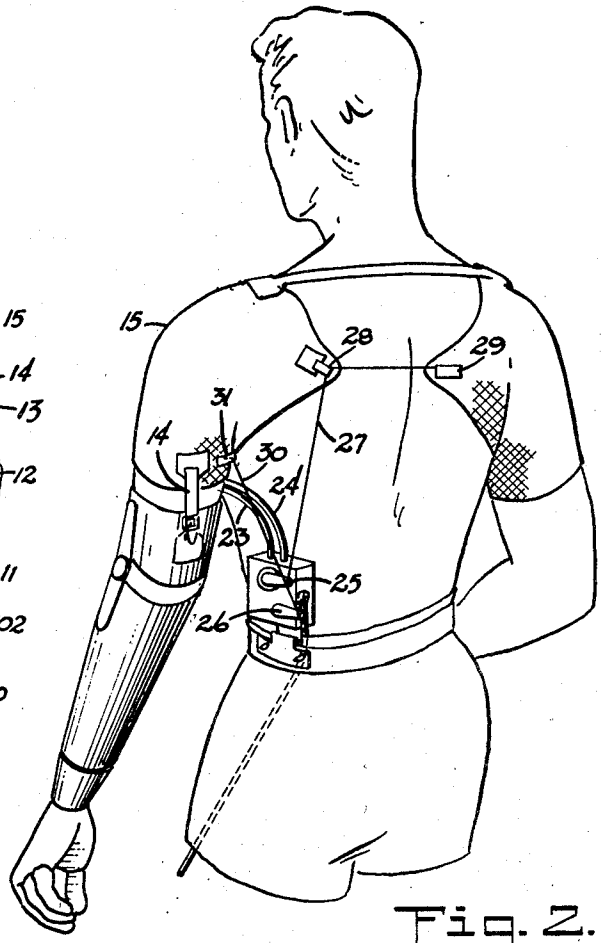

Fig. 2.

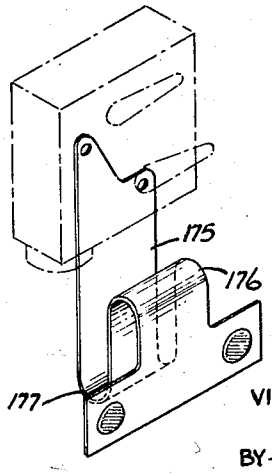

Fig. 3.

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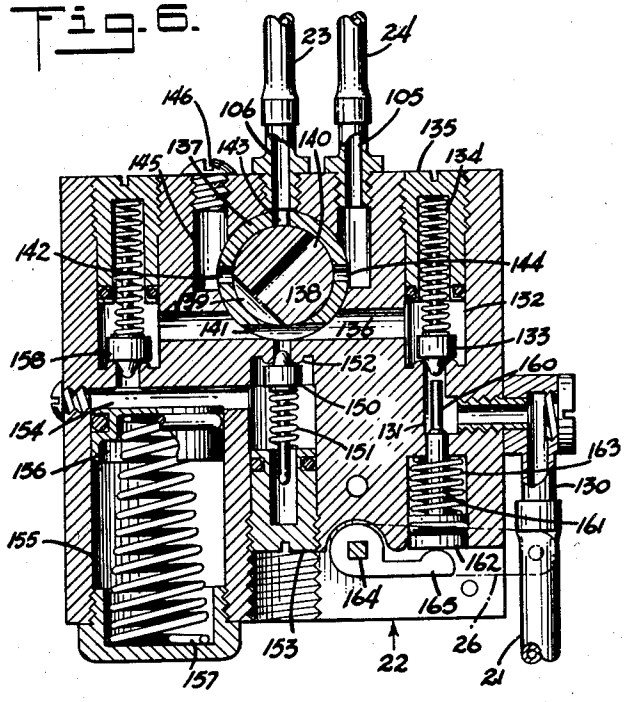
Fig. 6.



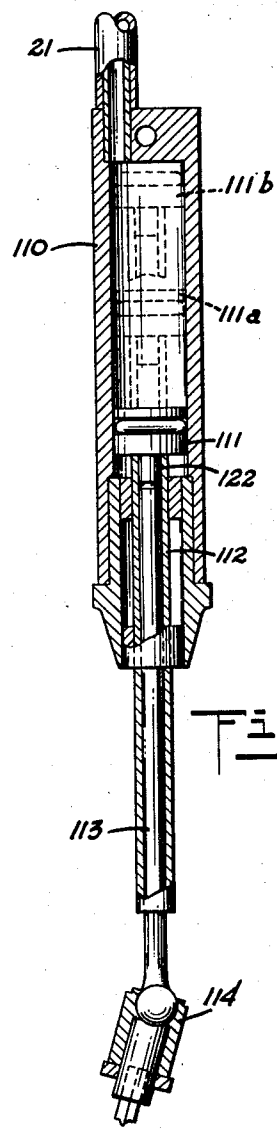


Fig. 5.

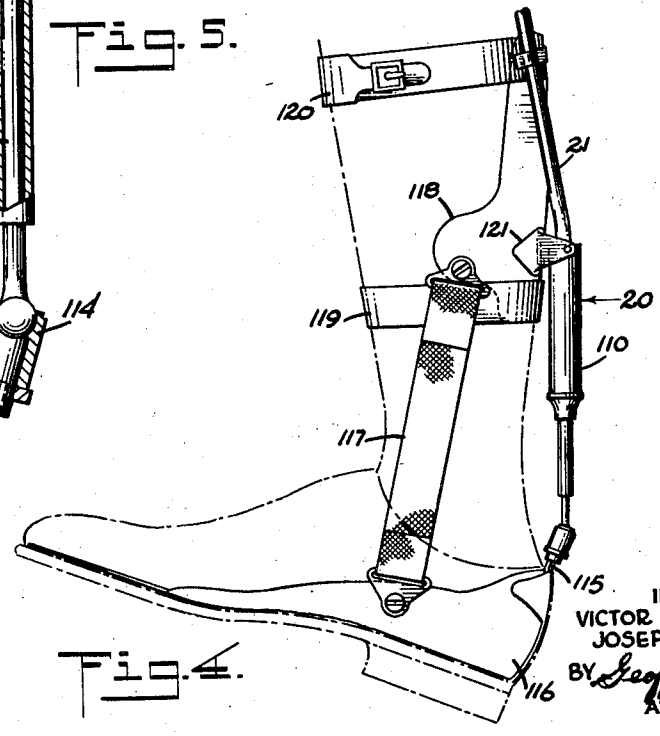


Fig. 4.

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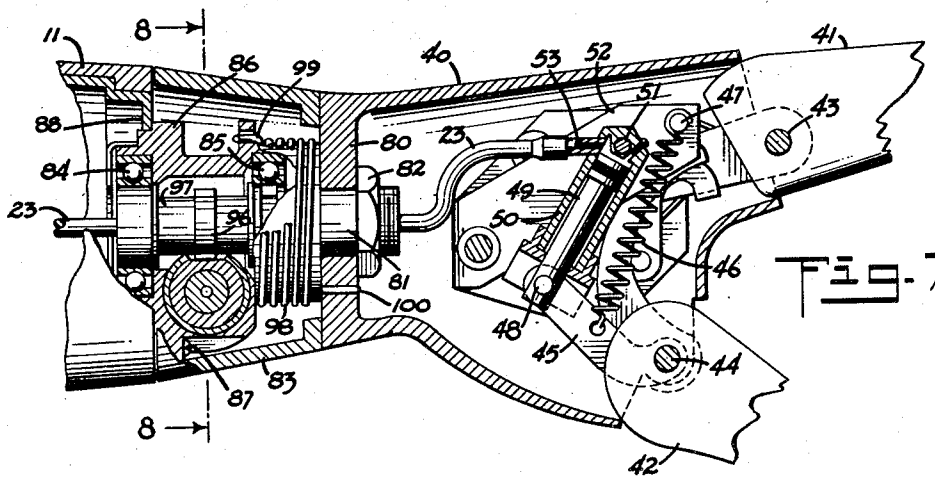

Fig. 7.

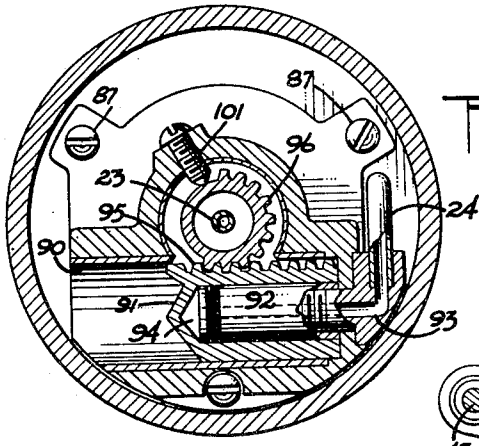

Fig. 8.

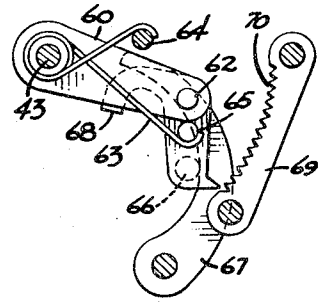

Fig. 10.

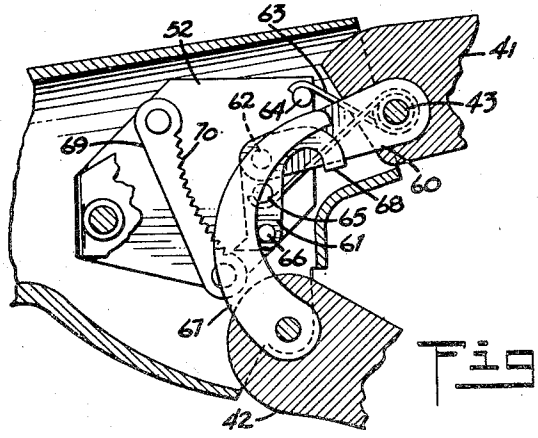

Fig. 9.

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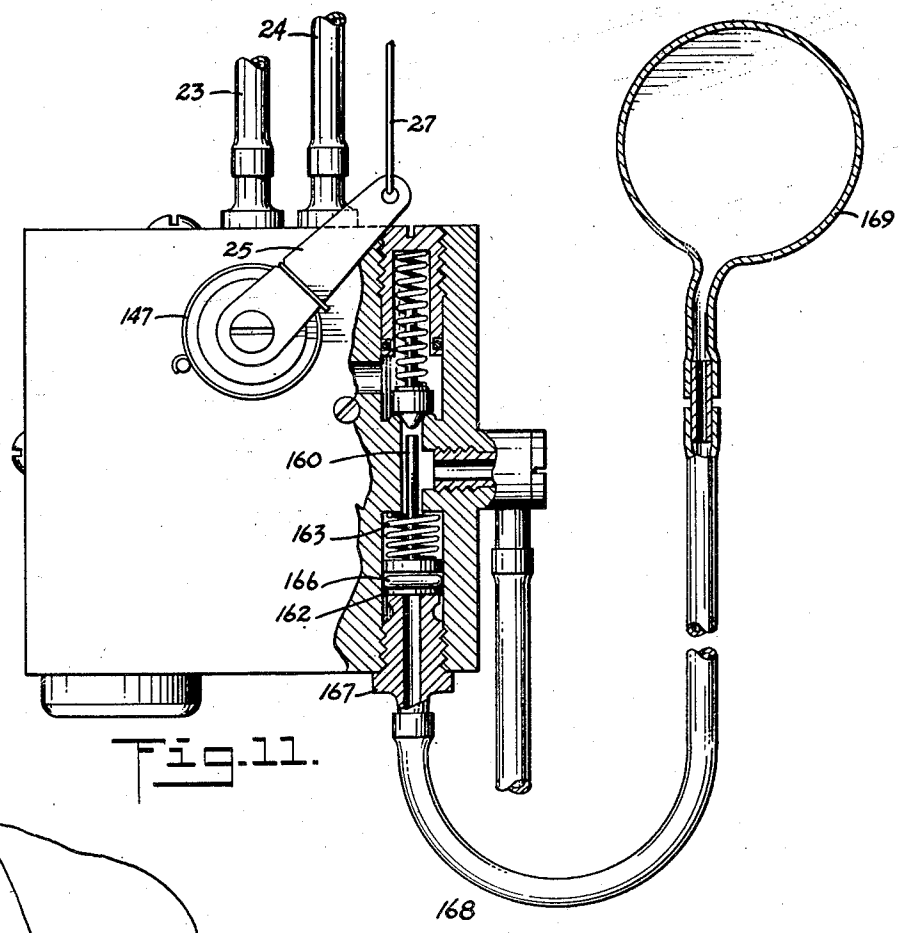

Fig. 11.

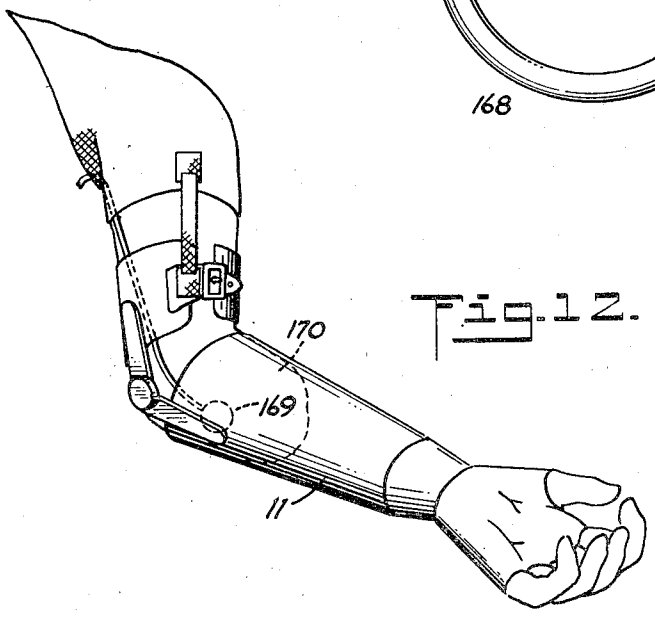

Fig. 12.

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2,528,464

HYDRAULIC ARTIFICIAL ARM

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Application April 4, 1947, Serial No. 739,318

11 Claims. (Cl. 3—12)

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This invention relates to an artificial hand and arm and its general object is to provide a device of this kind which will imitate closely the principal movements of a natural hand and arm.

A particular object of the invention is to provide a device of the kind described including a gripping means actuated by a foot motion.

A further object is to provide an artificial hand and arm including means for pronation and supination of the hand.

A still further object is to provide an artificial hand and arm having a plurality of different kinds of motions, the power therefore being supplied by foot motion, and the kind of motion being selected by shoulder shrugging.

Another object is to provide an artificial hand and actuating means therefore including locking means to maintain the hand in gripping position without further muscular exertion.

A still further object is to provide a hydraulically operated artificial hand and arm including safety means to prevent excessive pressure in the system.

Other objects of the invention will be pointed out in the following description and claims and illustrated in the accompanying drawings, which disclose, by way of example, the principle of the invention and the best mode, which has been contemplated, of applying that principle.

In the drawings:

Fig. 1 is a full length front view of an amputee, illustrating the method of attachment of the artificial hand and arm and its operating means.

Fig. 2 is a partial rear view of the same.

Fig. 3 is a perspective view of a clip for securing a part of the apparatus to the belt of the amputee.

Fig. 4 is a side elevation of the foot operated pump and harness therefore.

Fig. 5 is a longitudinal section of the pump.

Fig. 6 is a vertical section through the valve mechanism.

Fig. 7 is a longitudinal section of the hand.

Fig. 8 is a cross section on the line 8—8 of section 7.

Fig. 9 is a sectional view of a portion of a mechanism shown in Fig. 7, taken in a plane behind that of Fig. 7. It shows the mechanical locking means of the gripping mechanism.

Fig. 10 is a detail view of the mechanical locking means shown in Fig. 9, looking at the same from the side opposite of that of Fig. 9.

Fig. 11 is a side elevation, with parts in section, of a modified, bulb-operated form of releasing means for the hydraulic locking means.

Fig. 12 is a perspective view of an artificial arm

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showing the method of associating the bulb therewith.

The illustrative embodiments of the invention are hydraulically operated devices designed for an amputee still having a part of his forearm. A hand 10 is rotatively mounted upon a supporting sleeve 11 adapted to slip over the forearm stump. The sleeve 11 is connected by hinged straps 12, providing an elbow joint, to a band 13 adapted to be buckled around the upper arm. The band 13 is connected by straps 14 to a shoulder harness 15.

The system includes a foot operated pump 20 connected to the hand mechanisms by conduit means including a tube 21, a valve unit 22, and two tubes 23 and 24. The valve mechanism has an arm 25 for operating the valve which places the tube 21 in communication with either of the tubes 23 or 24. A second arm 26 controls a check valve which hydraulically locks the hand actuating mechanism, in a manner to be described later. The arm 25 is connected by a cord 27 passing through a loop 28 to a tab 29 on the right shoulder portion of the harness 15. The arm 26 is connected by a cord 30 to a tab 31 on the left sleeve of the shoulder harness. It will be seen presently that the system provides for grasping movements and wrist turning movements, which can be executed successively in such a way that an object can be grasped and then the hand can be turned at the wrist while the grasp is retained.

The details of the construction of the hand are shown in Figs. 7 to 10. A hollow palm member 40 has two grasping elements jointed to it, namely, a finger element 41 and a thumb element 42. The finger element is jointed to the palm member by a pivotal connection 43 and the thumb member by a pivotal connection 44. Any suitable material may be used for these parts, but a flesh colored plastic material which can be molded to the proper shape is preferable. The finger element can be replica of the four fingers, molded in one block.

The thumb has rigid therewith a lever arm 45 to which is connected a spring 46 anchored at 47, which normally holds the thumb in open position. The end of the lever arm 45 is pivotally connected at 48 to a piston 49 operating in a cylinder 50. The head of the cylinder is rotatably mounted by a pivot pin 51 upon a bracket 52 secured to the inside of the palm member 40. The tube 23 is connected to a nipple 53 communicating with the space within the cylinder 50. When the pressure fluid is forced into the cylinder the

thumb will rock on its pivot 44 toward the finger element 41, tensioning the spring 46. When the pressure fluid is released the spring will return the thumb to the position shown in Fig. 7.

The finger block 41 has rigid with it a lever arm 60 (see Fig. 9) at the end of which a dog 61 is pivoted upon a pin 62.

A spring 63 coiled upon the pivot 43 of the finger block is anchored at one end upon a stationary pin 64 on the bracket 52, while its other end bears upon a pin 65 on the dog 61. Another pin 66 on the dog 61 rides upon a cam lever 67 rigidly fastened to the thumb 42. The dog 61 has a lug 68 engaging the lever arm 60 to limit the rocking of the dog in one direction. An anchoring member 69 is riveted to the bracket 52 and is provided with teeth 70 adapted to be engaged by the pointed end of the dog 61, in a manner to be described.

The spring 63 tends to rock the dog 61 clockwise about its pivot 62, but the spring 46 is stronger than the spring 63 and the cam lever 67, upon which the cam follower 66 rides, normally holds the dog 61 in the counterclockwise limit of its rocking movement in relation to the lever arm 60 and, furthermore, rocks the finger block 41 to its normal open position. When the thumb 42 is rocked, by hydraulic pressure fluid, toward the finger block, to grasp an object, the cam lever 67 rocks toward the wrist and allows the cam follower 66 to move outwardly along it, thereby permitting the finger block to be rocked by the spring 63 toward the thumb. When the finger block strikes the object and its rocking is stopped, further movement of the thumb allows the dog 61 to turn on its pivot 62, under the influence of spring 63, and engage the teeth 70 of the anchoring device 69. This locks the finger block against movement away from the thumb. In effect, the finger block becomes rigid with the palm member, against the grasping force of the thumb. When the hydraulic pressure is released and spring 46 moves the thumb outward, the cam lever 67 first rocks dog 61 out of engagement with anchoring member 69, then, when lug 68 strikes lever arm 60, rocks the finger element toward open position.

A particular object of the invention is to provide pronation and supination movement of the hand. The construction shown in Figs. 7 and 8 accomplishes this result. A barrel 81, is clamped to the base portion 80 of the palm member by a nut 82. The barrel extends through a wrist section 83 of the supporting sleeve 11, being mounted therein by ball bearings 84 and 85 seated in a bearing housing 86 secured by screws 87 to a transverse partition 88 of the sleeve 11. The lower part of the bearing housing contains a bushing 90 in which travels a cylinder 91. Within the cylinder is a piston 92 rigidly mounted on the bearing housing and having a bore 93 through it. Pressure fluid is supplied through tube 24 to the end space 94 of the cylinder 91. The upper side of the cylinder is provided with rack teeth 95, which are exposed through an opening in the bushing 90, to mesh with a sector of teeth 96 on the mid-section 97 of the barrel 81. A spring 98 surrounding a cylindrical portion of the bearing housing has one end 99 anchored in a hole in the bearing housing and the other end 100 extending into a hole in the base portion 80 of the palm member 40. In the normal condition of the spring the hand is in the prone position shown in Figs. 1 and 2. When pressure fluid is forced into the cylinder 91 and moves the latter to the left in Fig. 8, the hand rotates to a supine position, its movement being limited by a screw 101 extending through the bearing housing into the gap between the ends of the sector of teeth 96. The tube 23 extends through the hollow of the barrel member 81, into the hollow space of the sleeve 11. The tubes 23 and 24 turn out through holes 102 in sleeve 11 and run along the outside of the sleeve, curving under the arm pit to connect with nipples 105 and 106 (Fig. 6) on the valve unit 22.

Turning now to Figs. 4 and 5, the foot operated pump 20 comprises a cylinder 110 in which travels a piston 111. The piston has rigidly secured thereto a sleeve 112 slidably receiving a rod 113, the lower end of which rod has a ball and socket connection 114 to a fastener 115 secured to a heel plate 116. The heel plate 116 is connected by a strap 117 to an ankle plate 118 attached to the leg by straps 119 and 120. The cylinder 110 is pivotally supported at its upper end by a bracket 121 on the plate 116. Within the tube 112 is a short rod 122 fixed to the piston 111. The rod 122 normally rests upon the end of the rod 113, and holds the piston 111 in the dotted line position 111*a* in Fig. 5, when the foot is in the normal position. The piston can move down to the full line position, when the foot is cocked up to the angle shown in Fig. 4, or it can be moved up to the dot and dash line position 111*b*, by pointing the toe downward. The operation of the pump will be described a little later.

The tube 21 is connected to a nipple 130 (Fig. 6) on the valve unit 22, which leads into a chamber 131. At the exit from the chamber 131 into a chamber 132 is a valve seat upon which a check valve 133 is pressed by a spring 134. The spring 134 is held down by a screw cap 135. The chamber 132 is in communication with a cross channel 136 at the center of which is located a valve bushing 137. A valve 138 in said bushing has ducts 139 and 140 providing selective communication between a port 141 in the valve bushing, which lies within the cross channel 136, and any one of three ports 142, 143 and 144. The port 142 opens into a filling hole 145 closed by a screw 146. The port 143 communicates with nipple 106, to which is attached the tube 23. The port 144 opens into a chamber communicating with the nipple 105, to which is attached the tube 24. When the pressure fluid is forced by the pump 20 through the tube 21 and past the check valve 133, it is directed by the valve 138 either through the tube 23 to the cylinder 50 in the palm of the hand, which actuates the grasping elements, or it is directed through the tube 24 to the cylinder 91 in the wrist, which rotates the hand to the supine position. The angular position of the valve 138 is controlled by the arm 25, which is tilted upward to the position shown in Fig. 11, by shrugging the right shoulder and thereby pulling the cord 27. The valve 138 is restored by a spring 147 to a normal position in which the fluid is forced through the tube 23 to execute the grasping action. When the right shoulder is shrugged and the foot pump is operated, the fluid is forced through the tube 24 to rotate the hand. Fig. 6 shows the valve in the filling position, to which it can be turned by rocking the arm 25 down from a horizontal position.

When the pressure fluid is forced into either of the cylinders 50 or 91, the check valve 133 locks the fluid in them. Means are provided to release the check valve, to permit the pressure fluid to return out of the cylinders 50 or 91. For

this purpose a plunger 160 is slidably mounted in the valve casing, in position to be pressed against the valve 133, to raise it from its seat. The plunger 160 is normally held down by a spring 161 inserted between the head 162 of the plunger and the top of the chamber 163 containing the spring. A lever rockably mounted by its shaft 164 in the valve casing has an arm 165 bearing against the plunger head 162. The arm 26 is fixed to the shaft 164 and can be rocked by shrugging the left shoulder and pulling the cord 30, to press the plunger 160 up and release the check valve 133. The head of the plunger is sealed against the wall of the chamber 163 by a ring 166.

An alternative means for releasing the check valve is the hydraulic device shown on Figs. 11 and 12. A plunger 160 having a head 162, spring 161, and ring 166, is provided, as before. In this case the chamber 163 is capped by a nipple 167 connected by a tube 168 to a bulb 169. As shown in Fig. 12, the bulb can be located within the sleeve 11, for example, in position to be squeezed by the forearm stump 170. The bulb 169 and tube 168 are filled with fluid which presses up the plunger 160 to release the check valve.

Means are provided to prevent excessive pressure of the fluid on the tubes. Relief valve 150 is pressed by a spring 151 against a valve seat 152, the aperture of which communicates with the cross channels 136. The spring 151 is compressed by a screw cap 153. The fluid passing through the valve 152 escapes through a duct 154 into a cylinder 155 containing a piston 156 held up by a spring 157, the piston being displaced accordingly. When the pressure in the system is released by operation of the check valve 133, the spring operated piston 156 forces the liquid past an overflow valve 158 back into the cross channel 136.

The valve unit is provided with a clip 175 of the form shown particularly in Fig. 3. The upward fold 176 of the clip can be fitted over the belt, while the downward fold 177 provides space for the shirt to be tucked in, the valve unit being hidden inside the shirt.

The operation of the apparatus is as follows:

Assume that the amputee is standing with his foot flat on the ground and that he wishes to grasp an object. The piston of the foot pump at this time is in the position 111*a* and the valve 138 is in the position with the arm 25 horizontal and the port 140 providing communication between the channel 136 and the tube 23. The check valve 133 is released by shrugging the left shoulder and the foot is cocked to the position shown in Fig. 4. This draws the rod 112 down and allows the piston 111 to descend to the full line position of Fig. 5, the top of the cylinder 110 being filled with fluid entering through the pipe 21 from the upper part of the system.

The left shoulder is now dropped to the normal position, allowing the check valve 133 to close and the foot is moved down toward the horizontal position. This forces fluid from the cylinder 110 through the valve unit and tube 23 to the cylinder 50 in the palm of the hand. The thumb and finger elements rock toward each other and by continued movement of the foot after first contact is made with the object, the grasping pressure can be made as strong as desired, up to the limit allowed by the overflow device in the valve unit. If the foot is moved still further, overflow liquid passes into the cylinder 155, depressing the piston 156 against the force of spring 157. The check valve 133 locks the pressure fluid in the cylinder 50 and maintains the grasp without further effort by the foot.

If it is now desired to move the hand to the supine position, the right shoulder is shrugged and the valve 138 is rocked to the position in which channel 139 connects cross channel 136 with the port 144, which communicates with the tube 24. Rotation of the hand at the wrist will now occur in response to the fluid flowing out of the reservoir cylinder 155 through the valve and tube 24, into the cylinder 91. Further rocking of the foot may be required to supply enough pressure fluid to complete the desired movement of the hand. The check valve again locks the pressure fluid in the cylinder 91 and maintains the hand in the supine position, against the force of the spring 98.

If the amputee now wishes to walk, he points his toe downward, forcing the piston 111 up to the position 111*b* in Fig. 5, the excess fluid passing into the overflow cylinder 155 and being locked therein by the check valve 133. The foot is now free to execute all the movement required in walking, the rod 113 simply sliding in and out of the tube 112, while the piston 111 remains at the upper end of the cylinder 110.

The hand can be restored to the prone position by shrugging both shoulders at once, thereby connecting the tube 24 through the valve unit with the tube 21 and releasing the check valve 133 at the same time. The grasp can be released by shrugging the left shoulder alone, whereby the check valve 133 is opened while the tube 23 is placed in communication with the tube 21 through the valve unit. As the pressure fluid flows out of the hand operating cylinders into the pump cylinder 110, the piston 111 moves down as far as permitted by the position of the rod 113 at the time.

The movements of the hand are derived from limited movements of the foot. It is desirable to reduce as far as possible the demands of the grasping movements of the thumb and finger elements on the pressure fluid supplied from the pump. This is accomplished, in accordance with the present invention, by the construction of the grasping mechanism, which utilizes the force of a spring to move the finger block up to the point where it makes contact with the object to be grasped, the pressure fluid being used only to move the thumb. If the hydraulic mechanism in the palm were required to operate the finger element directly, in addition to the thumb, it would consume a considerable amount of the limited fluid supply, to perform this work, which, in accordance with the invention, is performed by the spring 63.

The construction just referred to also eliminates the need for a driving ratio change device to be operated by the other hand.

It will be observed that the system enables the wearer to perform such an operation as to grasp a suitcase handle, lift it, and walk with it, because of the check valve which maintains the grasping pressure, while the foot is freed from the pump by the sliding connection between the rod 113 and the piston assembly 111, 112. It is also possible, with this device, to grasp an object and then to turn the hand from a prone to a supine position while the grasp is maintained by the locking of the pressure fluid in the tube 23 by the valve 138. Moreover, the maintenance of grasping pressure is not dependent upon contin-

ued muscular exertion, but is taken care of by the check valve or the control valve.

While there have been shown and described and pointed out the fundamental novel features of the invention as applied to two preferred embodiments, it will be understood that various omissions and substitutions and changes in the form and details of the device illustrated and in its operation may be made by those skilled in the art, without departing from the spirit of the invention. It is the intention, therefore, to be limited only as indicated by the scope of the following claims.

What is claimed is:

1. In an artificial hand, a palm member, two grasping elements jointed thereto, expansible hydraulic means anchored at one end to said palm member and at its other end to one of said grasping elements, for rocking the latter, impositive means for rocking the second of said grasping elements toward said first grasping element, and means for locking said second grasping element to said palm member.

2. An artificial hand as described in claim 1, wherein means are provided to control the movement of said second grasping element in accordance with the position of said first grasping element.

3. An artificial hand as described in claim 1, wherein means are provided to control the movement of said second grasping element in accordance with the position of said first grasping element, said last means including means to render said locking means effective when said second grasping element is stopped by abutment with an object, while said first grasping element continues to rock.

4. In an artificial hand system, a hand comprising parts articulated for a plurality of different kinds of movements, a plurality of hydraulic actuating means for said parts to cause said different kinds of movements respectively, foot actuated fluid pumping means, conduit means connecting said pumping means to said hydraulic actuating means including a valve for directing pressure fluid selectively to said hydraulic actuating means, and manipulative means for controlling said valve.

5. An artificial hand system as described in claim 4, wherein said manipulative means comprises a shoulder harness and means connecting the latter to said valve.

6. An artificial hand system as described in claim 5, wherein the hydraulic actuating means for said hand members includes spring return means, said conduit means including a check valve for locking the pressure fluid against the action of said spring return means, and manipulative means for releasing said check valve.

7. In an artificial hand and arm, a supporting sleeve, a hand including grasping means, means rotatively mounting said hand upon said sleeve to provide pronation and supination of said hand, separate hydraulic actuating means for rotating said hand and for operating said grasping means respectively, a foot actuated pump, a conduit means for conducting a fluid from said pump to said hydraulic actuating means, said conduit means including a valve for directing the pressure fluid to either of said hydraulic actuating means, and manipulative means for controlling said valve.

8. An artificial hand as described in claim 7, wherein said pump includes a cylinder, a piston therein, and an actuating rod having only a pushing contact with said piston.

9. An artificial hand as described in claim 8, wherein the manipulative means for releasing said check valve comprises a hydraulically operated releasing device, and a tube and bulb containing a fluid connected to said hydraulic releasing device, whereby said bulb can be positioned for application of pressure thereto to exert a hydraulic pressure on said hydraulically operated releasing means.

10. In an artificial hand and arm, a supporting sleeve, a hand including grasping means rotatively mounted on said sleeve to provide pronation and supination movement of said hand, hydraulic actuating means for rotating the hand in one direction, yieldable means for rotating said hand in the opposite direction, fluid pumping means, and conduit means connecting said pumping means with said hydraulic actuating means, including a check valve to lock the fluid in said hydraulic actuating means against the force of said yieldable means.

11. In an artificial hand system, a mechanical hand including grasping means, hydraulic actuating means for the said grasping means, pumping means consisting of a cylinder and a piston freely movable therein, a foot-operated element for moving said piston to force pressure fluid into said hydraulic actuating means, and conduit means interconnecting the said actuating means with the said pumping means including a check valve for maintaining pressure therebetween, the said conduit means including a storage device having a spring-operated piston and cylinder into which fluid can be forced on passing said valve by travel of the foot-operated element to an extreme position whereby the pressure fluid is locked by the said check valve.

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