

July 24, 1951

U. K. HENSCHKE ET AL

2,561,370

ARTIFICIAL LEG WITH CONTROLLED KNEE LOCKING MEANS

Filed July 9, 1948

2 Sheets-Sheet 1

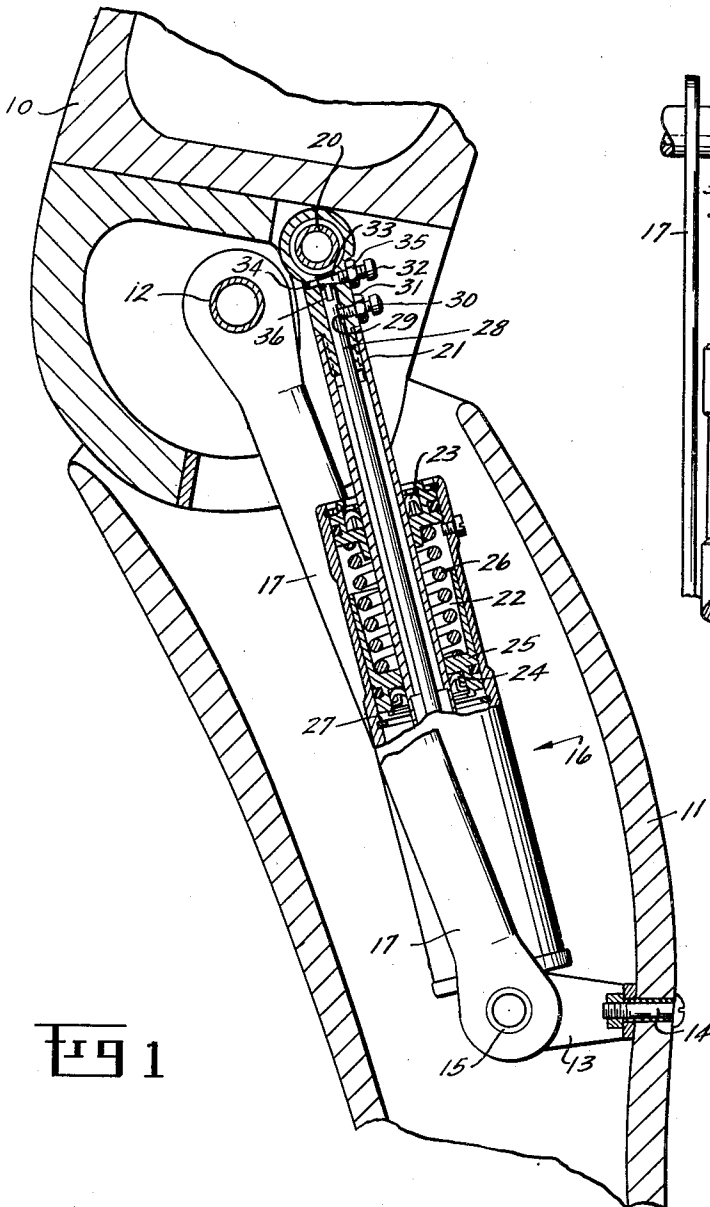


Fig 1

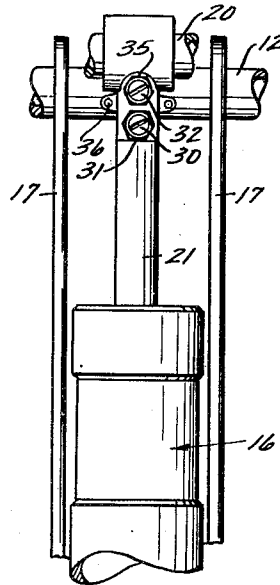


Fig 2

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Fig 3

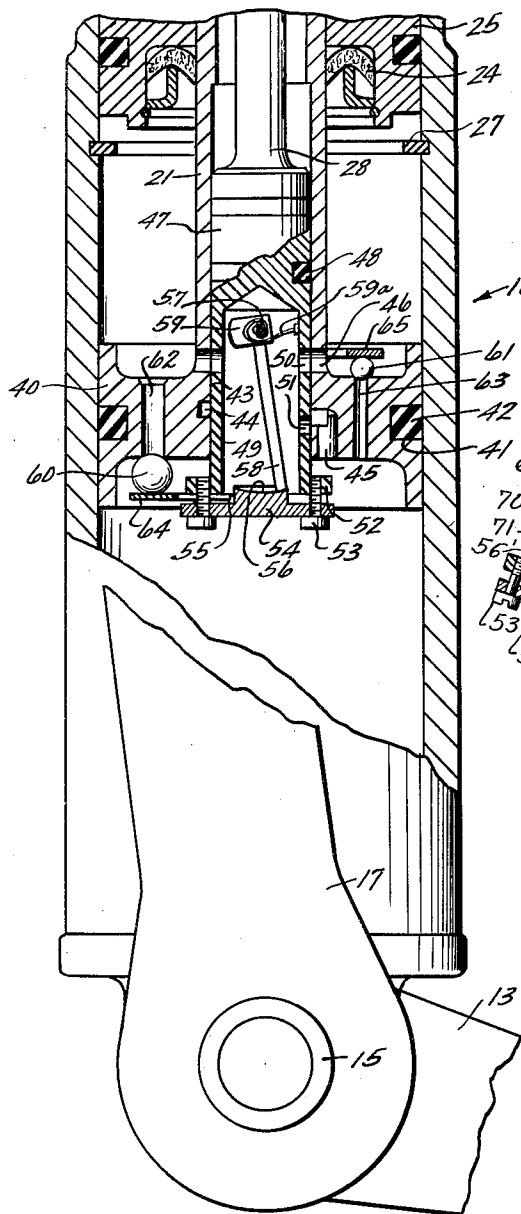
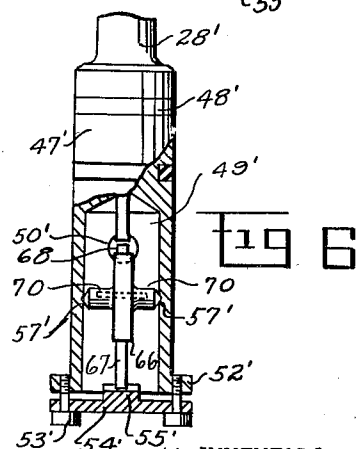
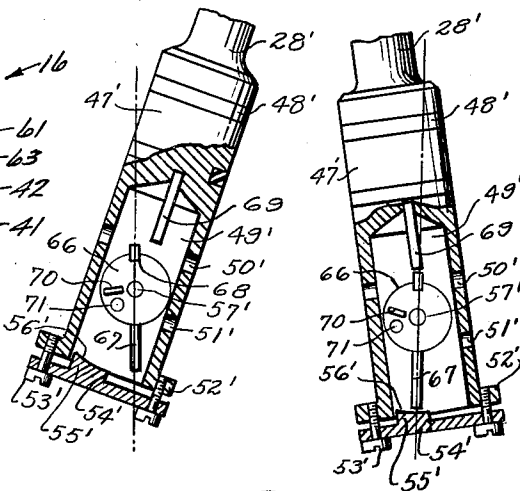


Fig 4 Fig 5



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ARTIFICIAL LEG WITH CONTROLLED KNEE
LOCKING MEANSUlrich K. Henschke and Hans A. Mauch,
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Application July 9, 1948, Serial No. 37,746

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amended April 30, 1928; 370 O. G. 757)

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The invention described herein may be manufactured and used by or for the Government for governmental purposes without payment to us of any royalty thereon.

This invention relates to artificial legs and more particularly to means of automatically and voluntarily controlling the knee joint of such legs, and to provisions for controlling the yielding rate of knee bends.

Numerous attempts have been made in the last decades to improve thigh prosthetic devices by incorporating in them a braking or a locking device which brakes or locks the bending motion of the knee joint whenever it seems desirable during various situations occurring in walking, for instance, in order to prevent the amputee from stumbling. The chief difficulty which has to be overcome is not so much the construction of the braking or locking device itself, but the finding and constructing of a satisfactorily working control for the braking or locking device.

Another difficulty which would be desirable to overcome is to vary the locking effect of the braking or locking device. The most desirable should be a control which permits the amputee to vary the locking effect continuously and progressively over the whole range between the unlocked and the fully locked position. Since the realization of such a control is difficult, practical solutions renounce the continuous working principle and confine themselves to the two extreme control positions, the unlocked and the fully locked one. The choice between them is made in walking either automatically or voluntarily, for instance, by toe or heel contact, by some kind of muscle control, etc. These legs protect the amputee against incidental jackknifing or stumbling, but they are of no additional value for other walking situations or necessities. They may even be disadvantageous, for instance, if they prevent desirable jackknifing during walking downstairs or downhill. The present invention aims at the realization of an artificial leg which secures the amputee automatically against stumbling and which enables him in walking downstairs and downhill to use voluntarily a yielding braking action of the knee joint. The invention, furthermore, aims at the realization of such leg without using controlling means outside the braking or locking device proper, such as toe or heel contact or muscle pads, etc.

According to the present invention, those aims are achieved by a thigh prosthesis which contains a braking or locking device—preferably of the hydraulic type—and a control element. The

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control element, according to this invention, is positioned by restoring forces such as gravity, acceleration, springs, or magnetism and by forces produced by the movement of the leg and acts on the knee locking device in such a manner that the latter is placed in its engaged position—in which it adjustably yields under the weight of the amputee—before the beginning of the stance phase and placed in its disengaged position—in which it yields freely—before the beginning of the swing phase of each stride.

The braking or locking device will—in the hydraulic case by use of a check valve—tend to brake or lock the bending motion of the knee joint and offer only slight resistance to the straightening motion. By taking advantage of gravity, acceleration, spring, magnetic or similar restoring forces, singularly or in combination, the control element normally is held in a position in which it keeps the braking or locking device unlocked even for the bending motion of the knee joint—in the hydraulic case by preventing the check valve from closing. During the straightening motion, and for a short period of time after stopping of the straightening motion, the control element will be brought and held, in counteraction to said forces, in a position in which it will permit the engagement of the braking or locking device for the bending motion. In the case of a hydraulic braking or locking device this is effected particularly by using the reversion of the direction of the fluid current during the straightening motion. The maintaining of the locking position of the control element for a short period of time after stopping of the straightening motion, which is a very important feature of the present invention, is achieved preferably by using the inertia of the control element and/or the fluid current.

Since all the stumbling situations, which the wearer of an artificial leg may experience, are chiefly characterized by a sudden reversion of the straightening motion into the bending motion of the knee joint, and since the present invention provides for the maintaining of the locking position of the control element for a short period of time after stopping of the straightening motion, jackknifing of the knee joint in stumbling situations will be prevented. On the other hand, the natural jackknifing, which in normal walking marks the end of the stance phase and the beginning of the swing phase, will be permitted because it occurs late enough after the stopping of the straightening motion to allow that short period of time to elapse.

In the case in which the bending motion has begun before the short period of time has elapsed, as for instance in stumbling, and the braking or locking device, therefore, has become engaged, it should be dangerous as long as any bending tendency of the knee joint exists if the control elements could return to its unlocking position due to the elapsing of that short period of time. The present invention, therefore, provides that the locking position of the control element is maintained beyond the elapsing of that short period of time as long as the bending tendency of the knee joint exists provided this bending tendency has begun before the elapsing of that short period of time. In the case of a hydraulic braking or locking device with a check valve, this is achieved by utilizing the fact that the check valve indicates a bending tendency of the knee joint by moving into its closed position and remaining there as long as the bending tendency lasts. Thus it is only necessary to arrange the control element in such a way that the check valve in its closed position prevents the control element from returning to its unlocking position. Besides the fact that this feature of the present invention makes the stumbling safety complete, it has an additional advantageous consequence. At the ends of the forward swing phase of the artificial leg, before the amputee puts the heel on the floor, the shank part of the leg tends to drop downward due to its own weight. Since this occurs within that short period of time, the braking or locking device will become engaged and prevent the shank from dropping. Since the bending tendency of the knee joint lasts, due to the weight of the shank, as long as the amputee keeps the heel from striking the floor, the knee joint will remain locked also after the elapsing of said short period of time. This means that the amputee has the possibility of choosing the stepping spot carefully without hurry and, moreover, that the leg will not buckle even if he forgets to press his stump backward while putting the heel on the floor. A further advantage of this feature of the invention will become clear as the description proceeds to walking downstairs and downhill.

Before that, one more feature of the invention has to be pointed out. If the holding of the control element in its normal unlocking position is effected or influenced by gravity or acceleration forces, the direction of those forces may change in the course of the walking phases. Apparently the essential moment in which the control element has to be in its normal unlocking position is the end of the stance phase and the beginning of the swing phase. During the swing phase it has to be in its unlocking position too but that can be effected, according to the present invention, despite the eventually changing direction of the gravity and acceleration forces by maintaining the initial position of the control element at the beginning of the swing phase through the whole swing phase. In the case of the hydraulic braking or locking device with a check valve, this can easily be achieved by jamming the control element by the check valve which during the swing phase tends to close under the pressure difference of the passing hydraulic fluid.

For walking downstairs and downhill, an artificial leg, which is designed according to the principles of the invention as described above, offers distinctive advantages. To make use of these possibilities it is only necessary according to the present invention to provide that the braking or locking device in its engaged position does

not lock fully but yields under the weight of the wearer's body at a rate which is convenient for walking downstairs and downhill. In the case of a hydraulic braking or locking device this can be easily effected by the arrangement of a constricted passage parallel to the check valve. The constriction may be adjustable to meet various demands of different amputees. If the amputee, in walking downstairs or downhill after the end of the swing phase, puts the heel on the floor without pressing his stump backward, the artificial leg will yield slowly in a natural manner under the weight of the wearer's body. Also for stumbling prevention, it is better to have the leg yielding instead of fully locking because the former offers a better shock absorption and gives the amputee still enough time to recover his balance.

For walking upstairs or uphill and for other activities in which a stiff leg may be of advantage, the braking or locking device according to the present invention may be locked completely at any knee angle by manually operating a voluntary override. In the case of the hydraulic braking or locking device, this voluntary override closes a valve which is located in series with the check valve.

It is a primary object of this invention to provide a thigh prosthesis which enables an amputee to walk safely on level or slanting ground, and to walk downstairs and downhill in a normal manner.

A further object of this invention is to provide a thigh prosthesis which contains a braking or locking device and a control element, the former tending to brake or lock the bending motion of the knee joint and offering only slight resistance to the straightening motion, the latter normally held by restoring forces, natural and produced, in a position in which it keeps the braking or locking device unlocked even for the bending motion of the knee joint; the latter, furthermore, brought and held in counter-action to said forces during the straightening motion and for a short period of time after stopping of the straightening motion in a position in which it will permit the engaging of the braking or locking device for the bending motion.

It is still a further object of this invention to provide a thigh prosthesis in which the locking position of the control element is maintained beyond the elapsing of said short period of time after stopping of the straightening motion as long as the bending tendency of the knee joint exists, provided this bending tendency has begun before the elapsing of said short period of time.

It is still another object of this invention to provide a thigh prosthesis in which the unlocking position of the control element at the beginning of the swing phase is maintained through the whole swing phase despite the eventual change in restoring forces acting on that control element.

A further object of the invention is to provide a thigh prosthesis in which the braking or locking device in its engaged position is not locked fully but yields under the weight of the wearer's body at a rate which is convenient for walking downstairs and downhill and which may be adjustable.

It is still another object of this invention to provide a thigh prosthesis in which a hydraulic braking or locking device contains a check valve which opens during the straightening motion of the knee joint and tends to close during its bend-

ing motion, both under the influence of the fluid current; the check valve being by-passed by an adjustable constriction and influenced by a control element which in its normal position, maintained by restoring forces, natural and produced, prevents the check valve from closing and which in its displaced position, caused during the straightening motion of the knee joint by the reversed fluid current and maintained for a short period of time after stopping of the straightening motion by the inertia of the fluid current and/or of the control element itself, permits the check valve to close.

One more object of this invention is to provide a thigh prosthesis in which a hydraulic braking or locking device contains a check valve and a control element, the latter having a normal and a displaced position and being in mechanical interaction with the check valve in such a way that the check valve can only close if the control element is in its displaced position, that furthermore, the control element can only return to its normal position if the check valve is open and that finally the control element will be jammed in its normal position by the check valve as long as the latter tends to close under the influence of the fluid current.

These and other objects and advantages will become more apparent as the description proceeds when taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a fragmentary elevational view of the artificial leg of this invention with parts shown in section;

Fig. 2 is a fragmentary elevational view of some of the elements shown in Fig. 1 to illustrate the relation of these parts;

Fig. 3 is a greatly enlarged fragmentary sectional view of the piston and cylinder of the hydraulic cylinder knee brake; and

Figs. 4, 5 and 6 show a modification of the control mechanism in different positions in space.

Referring now more particularly to Figs. 1 and 2, there is shown the lower end of a thigh part 10 which has a socket for receiving the stump of an amputee on the upper end (not shown) and the upper end of a shank 11 which are journaled to provide a knee joint by the pin 12 which may be hollow to reduce weight. Within the shank 11 is preferably a U-shaped bracket 13 which is fastened to the back wall of the shank 11 by bolts 14 or other securing means. The U-shaped bracket 13 supports a cross pin 15 on which is journaled the lower end of a hydraulic cylinder generally referred to by the reference character 16 and later to be more fully described. Two straps 17 are secured on opposite ends to the pins 12 and 15 on opposite sides of the hydraulic cylinder 16 to provide substantial stability to the U-shaped bracket 13 during the periods of applied force by the hydraulic cylinder later to be described. In this manner of construction, the knee is permitted to bend from a straight leg position to a fully bent knee, or sitting position of the prosthesis.

Within the knee portion of the thigh part 10 is a cross pin 20 fixed with respect to the thigh part in a position above and behind as well as parallel with the journal pin 12. Journaled on the cross pin 20 is a tubular piston shaft 21 slidable through the upper hydraulic fluid chamber 22 and sealed against fluid leakage by sealing rings 23 and 24. The lower sealing ring 24 is retained within an annular piston 25 that is bi-

ased downwardly by a spring 26 against a snap ring 27 resting in a groove in the cylinder wall. The fluid, as oil, may be retained in the lower portion of the cylinder under pressure by an amount equal to the force exercised by the spring biasing means 26 in order that the piston, later to be more fully described, is operative in fluid held under pressure as more fully described in our co-pending application Serial No. 37,745 filed July 9, 1943, now Patent Number 2,480,856. Within the tubular piston shaft 21 is a rod 28 having a groove 29 cut partially around the surface near the upper end thereof. A set screw 30 threaded through the tubular piston shaft 21 has the end thereof within the groove 29 but out of contact with the rod 28 to permit the rod to rotate freely for several degrees and to be moved longitudinally a substantial amount without interference from the set screw 30. A jam nut 31 is threaded on the set screw 30 for the purpose of locking the set screw in a suitable position in the well known manner. A second or cammed set screw 32 having a conical portion 33 terminating in a cylindrical pilot portion 34 is threaded in the tubular piston shaft 21 above the set screw 30 such that the conical portion 33 is reciprocable across the top end of the rod 28 which rod is rounded on the top end to establish a substantially point contact with the conical surface 33. By threading the set screw 32 inwardly in the tubular shaft 21, the conical portion 33 of the set screw 32 will force the rod 28 downwardly, and by threading the set screw 32 outwardly, the conical portion 33 is retracted to allow the rod 28 to rise for the purpose later to be described. The cammed set screw also has a jam nut 35 thereon for locking the set screw in adjusted positions. The set screws 30 and 32 are arranged at the top of the tubular piston shaft 21 near the journal pin 20 to make them easily accessible for quick and easy adjustment. A bilateral extension 36 attached to the rod 28 extends through openings in the tubular piston shaft 21 for manual operation preferably by strings or cables attached to opposite ends of the bilateral extension to rotate the rod 28. By pushing the right side of the bilateral extension 36, or by pulling the left side of the bilateral extension by means of the string or cable, rod 28 will be rotated counterclockwise, locking downwardly, and vice versa.

As more clearly shown in Fig. 3, the tubular piston shaft 21 extends downwardly into the hydraulic cylinder and terminates in a piston 40 slidable on the cylinder wall. An annular groove 41 is cut in the piston which retains a sealing ring 42 to cut off the passage of hydraulic fluid in either direction between the piston and cylinder wall. The piston 40 has a central bore 43 that may be a continuation of the hollowed portion of the shaft 21 where the parts 21 and 40 are made integral. However, the piston 40 and stem 21 may be formed of two pieces and threaded or otherwise connected in any well known manner. A groove 44 is cut within the bore 43 and a drilled opening 45 connects this groove to the underside of the piston 40. Laterally drilled openings 46 connect the area above the piston 40 with the bore 43.

Within the bore 43 is a cylindrical piston member 47 which is shown integral with the rod 28 but may be made separable if so desired. The piston 47 has one or more sealing rings 48 placed in the groove near the upper portion thereof to seal against leakage of hydraulic fluid upwardly

and outwardly around the rod 28. The piston 47 has a blind bore 49 directed centrally and upwardly from the bottom with ports 50 near the upper end of this bore adapted to be placed in or out of registry with the drilled openings 46 by manipulating the handle extension 36 (Fig. 1) to rotate the rod 28 and consequently the piston 47. Also through the wall of the piston 47 is a graduated port 51 that may take a triangular or tear-drop form that is in the region adjacent the groove 44 of the piston 40 such that the communication through the port 51, groove 44, drilled openings 45 may be graduated from a fully closed to a fully open position by the longitudinal movement of the piston 47 in accordance with the adjustment made by the set screw 32 (Fig. 1). The bottom end of piston 47 is flanged as shown at 52. The flanged portion is tapped to receive three or more cap screws 53 which loosely support a check valve head 54 on the heads thereof. When the check valve head 54 is resting on the heads of the cap screws 53, the check valve is open and there is free communication between the two sides of the piston 40 through the blind bore 49 and drilled openings 46, 50 in the position of the parts shown in Fig. 3. When the check valve 54 is closed, it is in its upward position against the flanged end of the piston 47 and any flow across the piston 40 must then be through the restricted passage 45, 44, 46, 50, 51.

The top side of the check valve head 54 has a raised portion 55 of a considerably reduced diameter compared to the diameter of the blind bore 49. The top surface of the raised portion 55 is spherically concave as shown at 56 having the center of curvature at the point near the upper end of the blind bore 49 which is herein designated as the point 57. Suspended at the point 57, by a universal knuckle joint of any well known type that does not permit relative rotational movement and is low in friction, is a pendulous member 58 the lower end of which just clears the convex surface 56 when the check valve 54 is open. Whenever the pendulous element 58 is pivoted such that the lower end engages the wall of the blind bore 49, which amounts to a position on the surface of a cone whose base is the diameter of the blind bore and the angle of the apex is at least 30 degrees, the check valve 54 will be permitted to close since the annular space between the blind bore 49 and the raised portion 55 is sufficient to hold the lower end of the pendulous element 58. The pendulous element 58 is counter weighted on the front side at 59 in a relation to the length of the pendulous element such that the lower end thereof is just over the center point of the raised portion 55 of the check valve head 54 when the shank is in the slightly forward inclined position as it occurs at the beginning of the swing phase.

The two ball valves 60 and 61 are merely relief valves to relieve unusual and excessive pressure which might occur on the piston and cylinder elements to avoid any damage to the leg parts. Each ball valve 60, 61 controls a passage 62, 63, respectively, through the piston 40 the relief pressure being determined by the compressive forces of the respective springs 64 and 65 and the effective area on the balls.

In the operation of this artificial leg, it is assumed that the cylinder 16 has been filled with hydraulic fluid approximately up to the upper rim of the annular piston 25 in Fig. 1. It is further assumed, of course, that a complete artificial

leg incorporating the elements and features just described is positioned on an amputee for walking. Upon the amputee carrying his good leg forward shortly before beginning a step with the artificial leg, the check valve head 54 is down and the lower end of the pendulous element 58 is well over the raised portion 55 since the shank at the beginning of the swing is at a considerable angle posterior to the body and free flow of fluid is permitted upward across the piston 40 to allow the knee to bend freely in which event the foot is well above the floor in the forward carrying movement of the stump. The flowing fluid presses the check valve head 54 against the lower end of the pendulous element 58 jamming it so that it can not change its position regardless of what the further direction of the gravity and acceleration forces may be. As the stump is decelerated in its forward movement preparatory to taking the step, the shank is swung forward pivoting at the knee joint. This releases the fluid pressure on the check valve head 54 and the hydraulic fluid now flows through the passage 46, 50 downward. The cylindrical inside shape of the bore 49 causes the fluid to rotate about the cylinder axis forming an eddy. By this eddy rotary forces are exerted on the pendulous element 58 which therefore rotates likewise. The centrifugal forces press the pendulous element against the wall of the bore 49. This rotation continues for a short period of time due to inertia, even if the forward movement of the shank is interrupted for instance by stumbling. The check valve head 54 will therefore close, as soon as the current of the fluid begins to reverse. The leg can not jackknife and the amputee is able to recover his balance.

To achieve the optimum function of the leg, it may be expedient according to the invention to modify the movements of the pendulous element 58 by spring or other forces in order to obtain changes in its characteristics, for instance, arranged in a manner shown by spring 59a in Fig. 3. When, in continuation of the description of the normal step, the foot is set on the floor preparatory to transferring body weight to it, the knee may be biased in a bending direction, but the downward movement of the piston 40 causing a direction of fluid flow upward across the piston 40 immediately closes the check valve head 54 and locks the knee against sudden jackknifing. The same thing happens in walking downstairs or downhill. In the event the handle extension 36 is positioned as shown in Fig. 1, the knee will bend gradually in accordance with the leak of hydraulic fluid across the piston through its restricted passage 45, 44, 46, 50 and 51. The rate of knee yielding, as has been mentioned before, can be adjusted by the set screw 32 that adjusts the longitudinal position of the rod 28 and piston 47 which determines the flow area of the graduated port 51 over the groove 44. If at any time the wearer wishes the knee to be positive and unyielding, it is merely necessary to rotate the rod 28 by the hand lever 36 until the ports 50 are out of registry with the drilled openings 46.

Ordinarily, for walking upstairs step over step the amputee will want the knee brake to be unyielding; but, for walking on level ground or downhill and downstairs, the amputee will want the knee brake to yield. The set screw 30 serves as a stop which limits the rotation of the rod 28 by the hand lever 36 opening the ports 46, 50 thus determining the fluid resistance through

passage 46, 50 and thereby the slight braking effect on the shank movement during the swing phase.

When the knee is locked by the check valve head 54 and weight is placed on the leg, as above stated, for instance, in walking downstairs, the amputee can pass his body over the leg in a normal manner and the pendulous element 53 is incapable of opening the check valve regardless of the gravity forces acting to bring it over the raised portion 55. After the leg has gone through the stepping phase and the body weight is lifted from it which lets the check valve 54 open, the knee brake is released for the forward swing of the leg as before. In the event the amputee stumbles during walking situations other than the swing phase and the artificial leg is jerked quickly to rest the foot on the floor, the jerk accelerates the shank causing the end of the pendulous element to be held against the wall of the bore 49 to allow the hydraulic system to brake the knee movement in order that the fall may be averted. Since the pendulous element is universally suspended from the point 57, a fall in any direction will operate to permit the check valve 54 to close wherein the knee brake is effective. The operation of the by-pass during conditions for falling or stumbling will not jeopardize the amputee's chances of recovering since the knee brake yields slowly enough to allow the amputee to regain his attitude. During the periods of standing, the amputee can place a part or all of his weight on the artificial limb, with the by-pass passage 46, 50 cut off, and remain standing at any angle of the knee joint as long as he wishes without the leg jackknifing.

The technical realization of the control mechanism can be achieved, according to the present invention, in various ways. One modification is shown in Figs. 4 to 6 in different positions in space wherein like elements of like reference characters and corresponding elements of the reference characters are primed. All three figures show the cylindrical piston member 47'. In Fig. 4 this member is in a spatial position as it would be when the artificial leg has just completed the swing phase and the amputee is going to put the heel on the floor. Fig. 5 shows the cylindrical member 47' in a spatial position in which it would be at the beginning of the swing phase when the amputee is going to bend the leg. Both Fig. 4 and Fig. 5 are seen from the left side of the amputee partially elevated and partially in section. Fig. 6 is the member 47' in the position as in Fig. 5 but seen from the rear, also partially in section. In all three figures parts 48' through 53', inclusive, are the same as in Fig. 3. Check valve head 54' has a little different design. Its raised portion 55' extends at its left side in Fig. 4 and in Fig. 5 nearly to the inner wall of the blind bore 49' and at its right side only about to the center of that bore. It extends laterally, as shown in Fig. 6, to both sides only so far that its width is about one-third of the inside diameter of that bore. The top surface of the raised portion 55' is spherically concave as shown at 56' having the center of curvature at a point near the half height of the blind bore 49' which is herein designated as the point 57'. Supported at the point 57', by a low friction joint of any well known type, is a disk-shaped member 66. This member has a lower extension 67 which serves as a locking means for the raised portion 55' of the check valve head 54'. Member 66, furthermore, has

on its top an insert 68 of iron or another material which may be attracted by a permanent magnet 69 which is threadedly fixed in the upper wall of the blind bore 49' to be adjustable in its distance from the insert 68 in order to vary the magnetic attractive force. This member 66 additionally has on its left side, in Figs. 4 and 5, flat lateral extensions 70 as more clearly to be seen in Fig. 6 in dotted lines. These two extensions serve as impact plates for the downward flowing hydraulic fluid which produces a counterclockwise torque on the disk-shaped member 66. The unbalances which are caused by the lower extension 67, the insert 68 and the lateral extensions 70 on the disk-shaped member 66, are compensated for by drilling holes at suitable spots through the disk member 66 like the hole 71 which is shown in Figs. 4 and 5. Thus the only force which tends to keep the disk member 66 in the position as shown in Fig. 5, is the magnetic attractive force between permanent magnet 69 and insert 68. The force which tends to bring and hold disk member 66 in the position as shown in Fig. 4 is the impact of the downward flowing hydraulic fluid during leg extensions acting on the lateral extensions 70. After stopping of this downward flowing fluid current, disk member 66 will return from its position as shown in Fig. 4 to the position as shown in Fig. 5 under the influence of the magnetic forces only with some time delay due to its own inertia. The interaction between the lower extension 67 and the raised portion 55' of the check valve head 54' occurs just in the same way during the various phases of walking as explained for the corresponding parts of Fig. 3. It may be noted that in the control arrangement as shown in Figs. 4 and 5 no gravity or acceleration forces are used. The permanent magnet may be replaced by a spring.

In Figs. 1, 2 and 3, the pendulous control element 58 is positioned by the normal forces of the spring (if used), gravity, and acceleration or deceleration forces acting on it; while in Figs. 4, 5 and 6, the control element 57 is positioned by magnetic forces. These forces act on the controlling element as restoring forces which tend to maintain the controlling element in a predetermined related position with respect to the check valve 54, or 54', in opposition to other acting forces caused by the hydraulic fluid current or mechanical engagement of associated parts.

It may also be noted that by different shaping of the surfaces 56 and 56' numerous different functioning patterns and throttling effects can easily be achieved.

While many changes and modifications may be made without departing from the spirit and scope of this invention we desire to be limited only by the scope of the appended claims.

We claim:

1. An automatically and voluntarily controlled thigh prosthesis having an upper leg part and a lower leg part connected by an artificial knee joint, a compressible and expansible first hydraulic chamber mechanically connected between said upper and lower leg parts to be compressed by knee bending motions and expanded by knee extending motions occurring during the walking movements of the prosthesis, said hydraulic chamber adapted to contain a hydraulic fluid, a second hydraulic chamber to receive hydraulic fluid from said first hydraulic chamber displaced by knee bending motions, and fluid flow passage means

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in communication with said chambers such that fluid is forced through said passage means upon rotation of said knee joint in knee bending and extension movements respectively, said fluid flow passage means including means for varying the cross-sectional area of the fluid flow passage means, said means for varying said cross-sectional area being movable between at least two predetermined positions, one position permitting a substantially free flow of fluid from said expansive chamber and free articulation of the leg members about the knee joint during knee bending and extension movements and a second position causing resistance to free flow of fluid from said expansive chambers and thereby resisting articulation of said leg members during knee bending movements about the knee joint due to loads applied by the weight of the amputee, and control means for said last named means responsive to a condition of leg operation for changing the effective area of the flow resistance passage means from said one position to the said second position, said condition of leg operation being bending articulation of said knee joint within a predetermined short time period immediately following knee extending movement.

2. An automatically and voluntarily controlled thigh prosthesis having an upper leg part and a lower leg part connected by an artificial knee joint, a compressible and expansible first hydraulic chamber mechanically connected between said upper and lower leg parts to be compressed by knee bending motions and expanded by knee extending motions occurring during the walking movements of the prosthesis, said hydraulic chamber adapted to contain a hydraulic fluid, a second hydraulic chamber to receive hydraulic fluid from said first hydraulic chamber displaced by knee bending motions, fluid passage means connected between said two hydraulic chambers for the conduit of said displaced fluid, fluid throttling means located in said fluid passage means to control the rate of said fluid displacement from said first hydraulic chamber to said second hydraulic chamber, a valve contained in said fluid throttling means, said valve being shiftable between a first position in which it leaves a comparatively large opening for said fluid displacement and a second position in which it leaves only a predetermined small opening for said fluid displacement, retarding in the latter position sufficiently said fluid displacement out of said first hydraulic chamber to permit only slow compression of said first hydraulic chamber and slow bending motion of said knee joint under the weight of the amputee, a control element for said valve normally biased to prevent movement of the valve from the first position to the second position and means responsive to walking motions occurring in said leg parts for actuating said control element between the beginning of said extending motion and the beginning of said bending motions of the knee joint and for shifting said valve from said first position to said second position.

3. An automatically and voluntarily controlled thigh prosthesis having an upper leg part and a lower leg part connected by an artificial knee joint, a compressible and expansible first hydraulic chamber mechanically connected between said upper and lower leg parts to be compressed by knee bending motions and expanded by knee extending motions occurring during the walking movements of the prosthesis, said hydraulic

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chamber adapted to contain a hydraulic fluid, a second hydraulic chamber to receive said hydraulic fluid from said first hydraulic chamber displaced by knee bending motions, fluid passage means connected between said two hydraulic chambers for the conduit of said displaced fluid, fluid throttling means located in said fluid passage means to control the rate of said fluid displacement from said first hydraulic chamber to said second hydraulic chamber, a valve contained in said fluid throttling means, said valve being shiftable between a first position permitting a substantially free fluid displacement and a second position causing resistance to said fluid displacement out of said first hydraulic chamber to resist compression of said first hydraulic chamber and resist bending motion of said knee joint under the weight of the amputee, a control element carried by said prosthesis consisting of a movably supported mechanical part capable of moving through at least two positional ranges and located suitably within the prosthesis to permit positioning interaction with said valve, said control element in its first positional range producing by said positioning interaction on said first position of said valve, said control element in its second positional range producing by said positioning interaction said second position of said valve, motion transmitting means located between said control element and said leg parts for positioning said control element in said positional ranges in response to the motions occurring in said leg parts incident to said walking movements of the prosthesis, said control element being put thereby in its second positional range incident to knee extending motions, biasing means between the control element and the prosthesis to urge said control element to its first positional range, and means to delay for a predetermined short period of time the return of said control element in its first positional range after stopping of said knee extending motions.

4. An automatically and voluntarily controlled thigh prosthesis having an upper leg part and a lower leg part connected by an artificial knee joint, a compressible and expansible first hydraulic chamber mechanically connected between said upper and lower leg parts to be compressed by knee bending motions and expanded by knee extending motions occurring during the walking movements of the prosthesis, said hydraulic chamber adapted to contain a hydraulic fluid, a second hydraulic chamber to receive said hydraulic fluid from said first hydraulic chamber displaced by knee bending motions, fluid passage means connected between said two hydraulic chambers for the conduit of said displaced fluid, fluid throttling means located in said fluid passage means to control the rate of said fluid displacement from said first hydraulic chamber to said second hydraulic chamber, a valve contained in said fluid throttling means, said valve being shiftable between a first position in which it leaves a comparatively large opening for said fluid displacement and a second position in which it leaves only a predetermined small opening for said fluid displacement, retarding, thus, in the latter position sufficiently said fluid displacement out of said first hydraulic chamber to permit only slow compression of said first hydraulic chamber and slow bending motion of said knee joint under the weight of the amputee, a control element carried by said prosthesis consisting of a movably supported mechanical part capable of moving

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through at least two positional ranges and located suitably within the prosthesis to permit positioning interaction with said valve, said control element in its first positional range producing by said positioning interaction said first position of said valve, said control element in its second positional range producing by said positioning interaction said second position of said valve, and motion transmitting means located between said control element and said leg parts for selectively positioning said control element in response to the motions occurring in said leg parts incident to said walking movements of the prosthesis, said control element being put thereby in its second positional range between beginning of knee extending motions and beginning of knee bending motions and being kept during a knee bending motion in the positional range in which it was at the beginning of said knee bending motion.

5. An automatically and voluntarily controlled thigh prosthesis having an upper leg part and a lower leg part connected by an artificial knee joint, a compressible and expansible first hydraulic chamber mechanically connected between said upper and lower leg parts to be compressed by knee bending motions and expanded by knee extending motions occurring during the walking movements of the prosthesis, said hydraulic chamber adapted to contain a hydraulic fluid, a second hydraulic chamber to receive said hydraulic fluid from said first hydraulic chamber displaced by knee bending motions, fluid passage means connected between said two hydraulic chambers for the conduit of said displaced fluid, fluid throttling means located in said fluid passage means to control the rate of said fluid displacement from said first hydraulic chamber to said second hydraulic chamber, a valve contained in said fluid throttling means, said valve being shiftable between a first position in which it leaves a comparatively large opening for said fluid displacement and a second position in which it leaves only a predetermined small opening for said fluid displacement, retarding, thus, in the latter position sufficiently said fluid displacement out of said first hydraulic chamber to permit only slow compression of said first hydraulic chamber and slow bending motion of said knee joint under the weight of the amputee, a control element carried by the prosthesis consisting of a movably supported mechanical part capable of moving through at least two positional ranges and located suitably within the prosthesis to permit positioning interaction with said valve, motion transmitting means located between said control element and said leg parts for selectively positioning said control element in response to the motions occurring in said leg parts incident to said walking movements of the prosthesis, and means for manually blocking said fluid passage means rendering the knee voluntarily locked at any desired bending angle, overriding the function of said control element.

6. An automatically and voluntarily controlled thigh prosthesis having an upper leg part and a lower leg part connected by an artificial knee joint, a compressible and expansible first hydraulic chamber mechanically connected between said upper and lower leg parts to be compressed by knee bending motions and expanded by knee extending motions occurring during the walking movements of the prosthesis, said hydraulic chamber adapted to contain a hydraulic fluid a second hydraulic chamber to receive said

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hydraulic fluid from said first hydraulic chamber displaced by knee bending motions, fluid passage means connected between said two hydraulic chambers for the conduit of said displaced fluid, fluid throttling means located in said fluid passage means to control the rate of said fluid displacement from said first hydraulic chamber to said second hydraulic chamber, a valve contained in said fluid throttling means, said valve being shiftable between a first position permitting a substantially free fluid displacement and a second position causing resistance to said fluid displacement out of said first hydraulic chamber to resist compression of said first hydraulic chamber and resist bending motion of said knee joint under the weight of the amputee, and a control element carried by said prosthesis consisting of a movably supported, gravitationally unbalanced mechanical part capable of moving through at least two positional ranges in response to the changes in the direction of the gravity and acceleration forces occurring in the prosthesis during walking movements and located suitably within the prosthesis to permit positioning interaction with said valve.

7. An automatically and voluntarily controlled thigh prosthesis having an upper leg part and a lower leg part connected by an artificial knee joint, a compressible and expansible first hydraulic chamber mechanically connected between said upper and lower leg parts to be compressed by knee bending motions and expanded by knee extending motions occurring during the walking movements of the prosthesis, said hydraulic chamber adapted to contain a hydraulic fluid, a second hydraulic chamber to receive said hydraulic fluid from said first hydraulic chamber displaced by knee bending motions, fluid passage means connected between said two hydraulic chambers for the conduit of said displaced fluid, fluid throttling means located in said fluid passage means to control the rate and said fluid displacement from said first hydraulic chamber to said second hydraulic chamber, a check valve contained in said fluid throttling means, said check valve being shiftable between a first position permitting substantially free fluid displacement and a second position causing resistance to said fluid displacement out of said first hydraulic chamber to resist compression of said first hydraulic chamber and resist bending motion of said knee joint under the weight of the amputee, said check valve being arranged regarding its response to fluid flow in such a way that fluid flow from said first hydraulic chamber to said second hydraulic chamber tends to put said check valve in its second position, a control element carried by said prosthesis consisting of a movably supported mechanical part capable of moving through at least two positional ranges and located suitably within the prosthesis to permit positioning interaction with said check valve, said control element in its first positional range locking said check valve in its first position despite possible tendencies of said check valve to shift into its second position in response to fluid flow, said control element in its second positional range not obstructing the shifting of said check valve into its second position, and motion transmitting means between said control element and said leg parts for positioning said control element in response to the motions occurring in said leg parts during said walking movements of the prosthesis.

8. An automatically and voluntarily controlled

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thigh prosthesis having an upper leg part and a lower leg part connected by an artificial knee joint, a compressible and expansible first hydraulic chamber mechanically connected between said upper and lower leg parts to be compressed by knee bending motions and expanded by knee extending motions occurring during the walking movements of the prosthesis, said hydraulic chamber being adapted to contain a hydraulic fluid, a second hydraulic chamber to receive said hydraulic fluid from said first hydraulic chamber displaced by knee bending motions, fluid passage means connected between said two hydraulic chambers for the conduit of said displaced fluid, fluid throttling means located in said fluid passage means to control the rate of said fluid displacement from said first hydraulic chamber to said second hydraulic chamber, a check valve contained in said fluid throttling means, said check valve being shiftable between a first position permitting substantially free fluid displacement and a second position causing resistance to said fluid displacement out of said first hydraulic chamber to resist compression of said first hydraulic chamber and resist bending motion of said knee joint under the weight of the amputee, said check valve being arranged regarding its response to fluid flow in such a way that fluid flow from said first hydraulic chamber to said second hydraulic chamber tends to put said check valve in its second position, a control element carried by the prosthesis consisting of a movably supported mechanical part capable of moving through at least two positional ranges and located suitably within the prosthesis to permit positioning interaction with said check valve, said control element in its first positional range locking said check valve in its first position despite possible tendencies of said check valve to shift into its second position in response to fluid flow, said control element in its second positional range not obstructing the shifting of said check valve into its second position, motion transmitting means between said control element and said leg parts for positioning said control element in response to the motions occurring in said leg parts during said walking movements of the prosthesis, said control element being put thereby in its second positional range incident to knee extending motions, biasing means between said control element and the prosthesis to urge said control element to its first positional range and means to delay for a predetermined short period of time the return of said control element in its first positional range after stopping of said knee extending motions.

9. An automatically and voluntarily controlled thigh prosthesis having an upper leg part and a lower leg part connected by an artificial knee joint, a compressible and expansible first hydraulic chamber mechanically connected between said upper and lower leg parts to be compressed by knee bending motions and expanded by knee extending motions occurring during the walking movements of the prosthesis, said hydraulic chamber adapted to contain a hydraulic fluid, a second hydraulic chamber to receive said hydraulic fluid from said first hydraulic chamber displaced by knee bending motions, fluid passage means connected between said two hydraulic chambers for the conduit of said displaced fluid, fluid throttling means located in said fluid passage means to control the rate of said fluid displacement from said first hydraulic chamber to

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said second hydraulic chamber, a check valve contained in said fluid throttling means, said check valve being shiftable between a first position permitting substantially free fluid displacement and a second position causing resistance to said fluid displacement out of said first hydraulic chamber to resist compression of said first hydraulic chamber and resist bending motion of said knee joint under the weight of the amputee, said check valve being arranged regarding its response to fluid flow in such a way that fluid flow from said first hydraulic chamber to said second hydraulic chamber tends to put said check valve in its second position, a control element carried by said prosthesis consisting of a movably supported mechanical part capable of moving through at least two positional ranges and located suitably within the prosthesis to permit positioning interaction with said check valve, said control element in its first positional range locking said check valve in its first position despite possible tendencies of said check valve to shift into its second position in response to fluid flow, said control element in its second positional range not obstructing the shifting of said check valve into its second position, and motion transmitting means between said control element and said leg parts for positioning said control element in response to the motions occurring in said leg parts during said walking movements of the prosthesis, said control element being put thereby in its second positional range between beginning of knee extending motions and beginning of knee bending motions and being kept during a knee bending motion in the positional range in which it was at the beginning of said knee bending motion.

10. An automatically and voluntarily controlled thigh prosthesis having an upper leg part and a lower leg part connected by an artificial knee joint, a compressible and expansible first hydraulic chamber mechanically connected between said upper and lower leg parts to be compressed by knee bending motions and expanded by knee extending motions occurring during the walking movements of the prosthesis, said hydraulic chamber adapted to contain a hydraulic fluid, a second hydraulic chamber to receive said hydraulic fluid from said first hydraulic chamber displaced by knee bending motions, fluid passage means connected between said two hydraulic chambers for the conduit of said displaced fluid, fluid throttling means located in said fluid passage means to control the rate of said fluid displacement from said first hydraulic chamber to said second hydraulic chamber, a check valve contained in said fluid throttling means, said check valve being shiftable between a first position in which it leaves a comparatively large opening for said fluid displacement and a second position causing resistance to said fluid displacement out of said first hydraulic chamber to resist compression of said first hydraulic chamber and resist bending motion of said knee joint under the weight of the amputee, said check valve being arranged regarding its response to fluid flow in such a way that fluid flow from said first hydraulic chamber to said second hydraulic chamber tends to put said check valve in its second position, and a control element carried by said prosthesis consisting of a movably supported, gravitationally unbalanced mechanical part capable of moving through at least two positional ranges in response to the changes in the direction of the gravity and acceleration forces occurring in the prosthesis during walking move-

ments and located suitably within the prosthesis to permit positioning interaction with said check valve, said control element in its first positional range locking said check valve in its first position despite possible tendencies of said check valve to shift into its second position in response to fluid flow, said control element in its second positional range not obstructing the shifting of said check valve into its second position.

11. An automatically and voluntarily controlled thigh prosthesis having an upper leg part and a lower leg part connected by an artificial knee joint, a compressible and expansible first hydraulic chamber mechanically connected between said upper and lower leg parts to be compressed by knee bending motions and expanded by knee extending motions occurring during the walking movements of the prosthesis, said hydraulic chamber adapted to contain a hydraulic fluid, a second hydraulic chamber to receive hydraulic fluid from said first hydraulic chamber displaced by knee bending motions, fluid passage means connected between said two hydraulic chambers for the conduit of said displaced fluid, fluid throttling means located in said fluid passage means to control the rate of said fluid displacement from said first hydraulic chamber, to said second hydraulic chamber, a valve contained in said fluid throttling means, said valve being shiftable between a first position permitting a substantially free fluid displacement and a second position causing resistance to said fluid displacement out of said first hydraulic chamber to resist compression of said first hydraulic chamber and resist bending motion of said knee joint under the weight of the amputee, a control element carried by the prosthesis consisting of a movably supported, gravitationally unbalanced mechanical part capable of moving through at least two positional ranges in response to the changes in the direction of the gravity and acceleration forces occurring in the prosthesis during walking movements and located suitably within the prosthesis to permit positioning interaction with said valve, and motion transmitting means between said control element and said leg parts for positioning said control element in response to the motions occurring in said leg parts during said walking movements of the prosthesis.

12. An automatically and voluntarily controlled thigh prosthesis having an upper leg part and a lower leg part connected by an artificial knee joint, a compressible and expansible first hydraulic chamber mechanically connected between said upper and lower leg parts to be compressed by knee bending motions and expanded by knee extending motions occurring during the walking movements of the prosthesis, said hydraulic chamber adapted to contain a hydraulic fluid, a second hydraulic chamber to receive hydraulic fluid from said first hydraulic chamber displaced by knee bending motions, and to deliver hydraulic fluid back to said first hydraulic chamber during knee extending motions, fluid passage means connected between said two hydraulic chambers for the conduit of said hydraulic fluid, fluid throttling means located in said fluid passage means to control the rate of said fluid displacement from said first hydraulic chamber to said second hydraulic chamber, a valve contained in said fluid throttling means, said valve being shiftable between a first position permitting a substantially free fluid displacement and a second position causing resistance to said fluid displacement out of said first hydraulic chamber to resist compression of said first hy-

draulic chamber and bending motion of said knee joint under the weight of the amputee, a control element carried by said prosthesis consisting of a movably supported mechanical part capable of moving through at least two positional ranges and located suitably within the prosthesis to permit positioning interaction with said valve, said control element in its first positional range producing by said positioning interaction said first position of said valve, said control element in its second positional range producing by said positioning interaction said second position of said valve, said control element being arranged within said fluid passage means to be moved by the fluid flowing through said passage means in response to knee motions, said control element being put thereby in its second positional range during knee extending motions, biasing means between the control element and the prosthesis to urge said control element to its first positional range, and means to delay for a predetermined short period of time the return of said control element in its first positional range after stopping of said knee extending motions.

13. An automatically and voluntarily controlled thigh prosthesis having an upper leg part and a lower leg part connected by an artificial knee joint, a compressible and expansible first hydraulic chamber mechanically connected between said upper and lower leg parts to be compressed by knee bending motions and expanded by knee extending motions occurring during the walking movements of the prosthesis, said hydraulic chamber adapted to contain a hydraulic fluid, a second hydraulic chamber to receive said hydraulic fluid from said first hydraulic chamber displaced by knee bending motions, and to deliver hydraulic fluid back to said first hydraulic chamber during knee extending motions, fluid passage means connected between said two hydraulic chambers for the conduit of said hydraulic fluid, fluid throttling means located in said fluid passage means to control the rate of said fluid displacement from said first hydraulic chamber to said second hydraulic chamber, a check valve contained in said fluid throttling means, said check valve being shiftable between a first position permitting substantially free fluid displacement and a second position causing resistance to said fluid displacement out of said first hydraulic chamber to resist compression of said first hydraulic chamber and resist bending motion of said knee joint under the weight of the amputee, said check valve being arranged regarding its response to fluid flow in such a way that fluid flow from said first hydraulic chamber to said second hydraulic chamber tends to put said check valve in its second position, and a control element carried by said prosthesis consisting of a movably supported mechanical part capable of moving through at least two positional ranges and located suitably within the prosthesis to permit positioning interaction with said check valve, said control element in its first positional range locking said check valve in its first position despite possible tendencies of said check valve to shift into its second position in response to fluid flow, said control element in its second positional range not obstructing the shifting of said check valve into its second position, said control element being arranged within said fluid passage means to be moved by the fluid flowing through said passage means in response to knee motions.

14. An automatically and voluntarily controlled thigh prosthesis having an upper leg part and a lower leg part connected by an artificial knee joint, a compressible and expansible first hydraulic chamber mechanically connected between said upper and lower leg parts to be compressed by knee bending motions and expanded by knee extending motions occurring during the walking movements of the prosthesis, said hydraulic chamber adapted to contain a hydraulic fluid, a second hydraulic chamber to receive said hydraulic fluid from said first hydraulic chamber displaced by knee bending motions, and to deliver hydraulic fluid back to said first hydraulic chamber during knee extending motions, fluid passage means connected between said two hydraulic chambers for the conduit of said hydraulic fluid, fluid throttling means located in said fluid passage means to control the rate of said fluid displacement from said first hydraulic chamber to said second hydraulic chamber, a check valve contained in said fluid throttling means, said check valve being shiftable between a first position in which it leaves a comparatively large opening for said fluid displacement and a second position causing resistance to said fluid displacement out of said first hydraulic chamber to resist compression of said first hydraulic chamber and resist bending motion of said knee joint under the weight of the amputee, said check valve being arranged regarding its response to fluid flow in such a way that fluid flow from said first hydraulic chamber to said second hydraulic chamber tends to put said check valve in its second position, and a control element carried by the prosthesis consisting of a movably supported mechanical part capable of moving through at least two positional ranges and located within the prosthesis to permit positioning interaction with said check valve, said control element in its first positional range locking said check valve in its first position despite possible tendencies of said check valve to shift into its second position in response to fluid flow, said control element in its second positional range not obstructing the shifting of said check valve into its second position, said control element being arranged within said fluid passage means to be moved by the fluid flowing through said passage means in response to knee motions, said control element being put thereby in its second positional range incident to knee extending motions and being maintained in said second positional range for a predetermined short period of time after stopping of knee extending motions.

15. An automatically and voluntarily controlled thigh prosthesis having an upper leg part and a lower leg part connected by an artificial knee joint, a compressible and expansible first hydraulic chamber mechanically connected between said upper and lower leg parts to be compressed by knee bending motions and expanded by knee extending motions occurring during the walking movements of the prosthesis, said hydraulic chamber adapted to contain a hydraulic fluid, a second hydraulic chamber to receive said hydraulic fluid from said first hydraulic chamber displaced by knee bending motions, and to deliver hydraulic fluid back to said first hydraulic chamber during knee extending motions, fluid passage means connected between said two hydraulic chambers for the conduit of

said hydraulic fluid, fluid throttling means located in said fluid passage means to control the rate of said fluid displacement from said first hydraulic chamber to said second hydraulic chamber, a valve contained in said fluid throttling means, said valve being shiftable between a first position permitting a substantially free fluid displacement and a second position causing resistance to said fluid displacement out of said first hydraulic chamber to resist compression of said first hydraulic chamber and resist bending motion of said knee joint under the weight of the amputee, and a control element carried by the prosthesis consisting of a movably supported, gravitationally unbalanced mechanical part capable of moving through at least two positional ranges in response to the changes in the direction of the gravity and acceleration forces occurring in the prosthesis during walking movements and located suitably within the prosthesis to permit positioning interaction with said valve, said control element being arranged within said fluid passage means to be moved by the fluid flowing through said passage means in response to knee motions.

16. An automatically and voluntarily controlled thigh prosthesis having an upper leg part and a lower leg part connected by an artificial knee joint, a compressible and expansible first hydraulic chamber mechanically connected between said upper and lower leg parts to be compressed by knee bending motions and expanded by knee extending motions occurring during the walking movements of the prosthesis, said hydraulic chamber adapted to contain hydraulic fluid, a second hydraulic chamber to receive said hydraulic fluid from said first hydraulic chamber displaced by knee bending motions, and to deliver hydraulic fluid back to said first hydraulic chamber during knee extending motions, fluid passage means connected between said two hydraulic chambers for the conduit of said hydraulic fluid, fluid throttling means located in said fluid passage means to control the rate of said fluid displacement from said first hydraulic chamber to said second hydraulic chamber, a third chamber containing hydraulic fluid for replenishing such fluid lost from said first and second hydraulic chambers, a movable wall separating said third chamber from the two other chambers, biasing means acting on said movable wall to produce a slight superatmospheric pressure in the fluid in said first and second chamber, and check valve means by-passing said movable wall to permit hydraulic fluid to pass from said third chamber to said two other chambers.

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