Dec. 25, 1962 C. E. REGNELL 3,069,692

ARTIFICIAL LEG

Filed July 13, 1959 2 Sheets-Sheet 1

Fig. 1

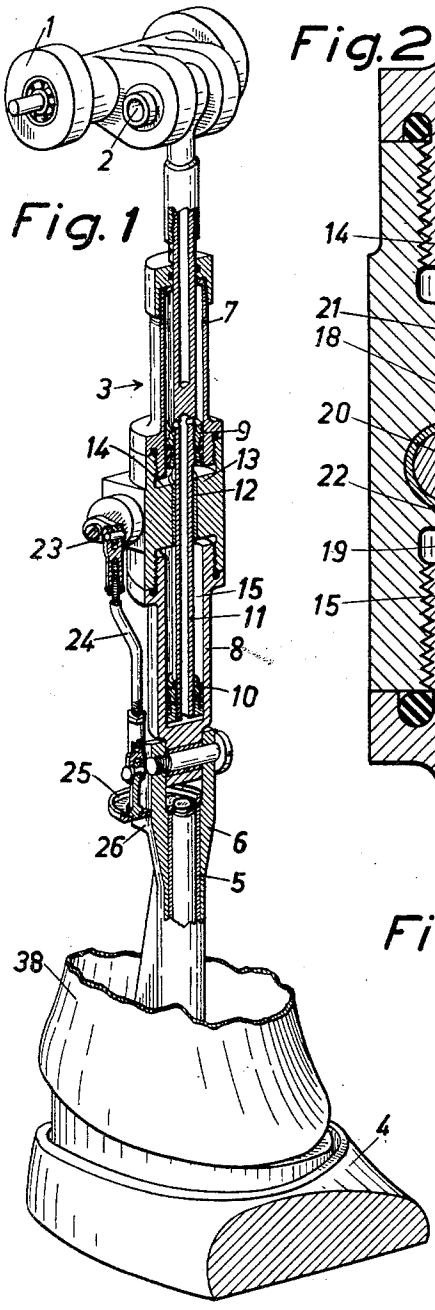


Fig. 2

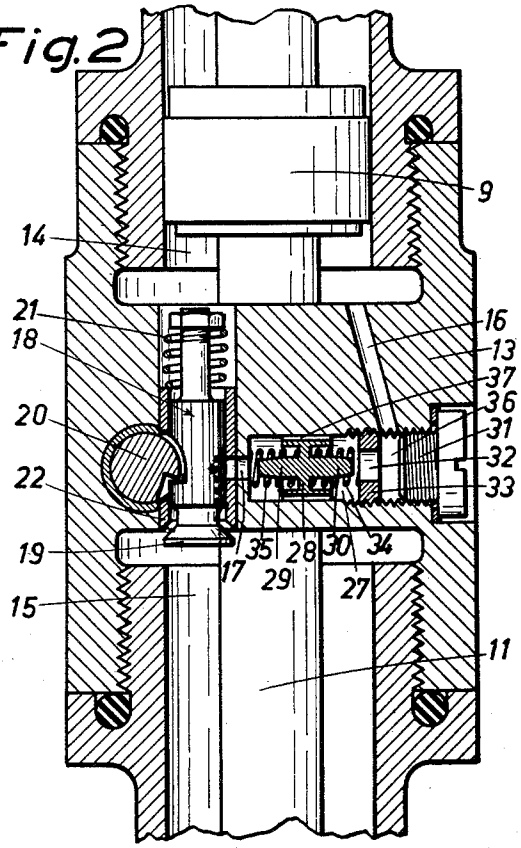


Fig. 3

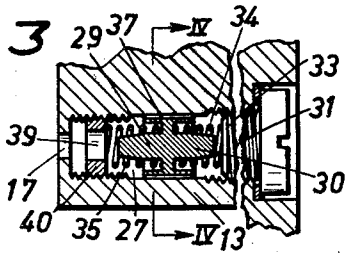
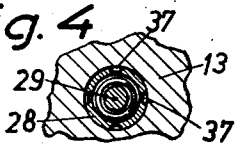


Fig. 4



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Fig. 6

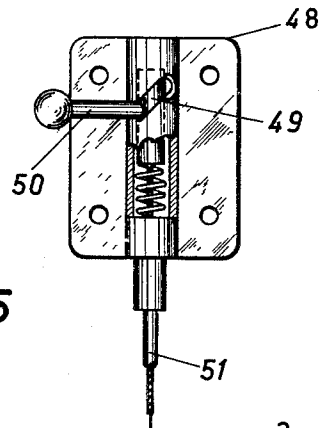


Fig. 5

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3,069,692

ARTIFICIAL LEG

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11 Claims. (Cl. 3—1.2)

This invention relates to artificial legs and more specifically of the kind to be attached to a femural stump. The artificial leg comprises a thigh and a hollow shank journalled to said thigh by means of a knee joint shaft, said shank including an hydraulic unit decelerating the motion of the knee joint, an artificial foot attached to said shank, said hydraulic unit comprising two coaxially arranged cylinders filled with liquid and communicating with each other through a channel, piston means adapted to press liquid from one of said cylinders to the other and vice versa during gait, said piston means arranged on a piston rod, the upper end of said piston rod hinged to said thigh at some distance from said knee joint shaft.

The primary object of the invention is to obtain a control of the swing phase of the shank of an artificial leg of this kind during gait in such a way that the shank is not swung abnormally high reawards and that the swinging movement forwards of the shank is decelerated and further that the performance of a noisy shock just before the complete stretching or extension of the prosthesis is prevented.

The essential feature of the invention resides in the arrangement of a movable slide in the connection channel between said cylinders for decreasing the liquid passage through said channel at sudden pressure impulses in the cylinders on either side of said channel. The device is adapted to function in dependence of the speed of gait of the amputee who uses the artificial leg and as a lower limit could be mentioned the value of 50 steps per minute, preferably however at 65 steps per minute. When put into function the decelerating effect of the device will increase in correspondence to the increase in the gait speed. In such a way the artificial leg is moved with the same cadence as the natural leg and the gait resembles that of a person with two natural legs.

The invention is intended to be applied especially to such artificial legs in which the hydraulic decelerating unit comprises two coaxially arranged cylinders on either side of a valve housing and two pistons parting the said cylinders each in two cylinder chambers, the upper and the lower of these four cylinder chambers interconnected with an axial bore in a piston rod carrying the said pistons and the two intermediate cylinder chambers interconnected with a channel, said piston rod hinged to the thigh, at some distance from the knee joint. The channel is formed in a valve housing between said cylinders, whereas a valve is arranged in said channel, said valve via movable means connected with the artificial foot, said valve being closed by means of a spring when the artificial foot is exposed to a load so as to lock the knee joint, said valve being instantly opened when said load is removed.

According to a further feature of the invention, the device is so constructed as to render possible an adjustment of the swinging of the shank if desired, e.g. for very fast, active walkers, in such a way that said swinging is made more slow at the beginning of the swing phase.

The invention will now be elucidated with reference to the accompanying drawings. In the drawings:

FIG.1 is a perspective view in a partial longitudinal section of an artificial leg according to the invention,

FIG. 2 shows on an enlarged scale a longitudinal section through the valve housing of the prosthesis, said housing provided with a device for the control of the swing phase,

FIG. 3 shows a longitudinal section through the control device according to a somewhat modified embodiment of the invention,

FIG. 4 is a cross section through the valve slide of the control device on the line IV—IV in FIG. 3,

FIG. 5 shows in a longitudinal section similar to that of FIG. 2 a modified embodiment of the valve housing, and

FIG. 6 is a side elevation in a partial longitudinal section of the hydraulic unit according to a modified embodiment of the invention.

Referring now to FIG. 1, it is obvious that the thigh attachment **1**, i.e., the knee joint, is connected to an hydraulic knee locking unit **3** by means of a lever extending forwards from said thigh attachment **1** for rendering possible a swing movement of the shank relative to the thigh attachment within an angular range of at least 90°. The hydraulic unit **3** is connected to an artificial foot **4** which may be articulated in relation to the shank **38** (shown only partially in FIG. 1) and further is movable vertically in relation to said shank as the artificial foot is hinged to a guide rod **5** which is axially movable in the lower end portion **6** of the unit.

The hydraulic unit **3** for locking the knee joint is arranged in the shank **38**. Said unit **3** comprises two coaxially over each other arranged cylinders **7** and **8** filled with liquid, and in each one of said cylinders there is arranged a piston **9** and **10**. These pistons are fixed to a common piston rod **11** extending through a bushing **12** in a valve housing **13**, situated between the cylinders **7** and **8**, and up to the shaft **2**.

There is a channel **16, 17** arranged in the valve housing **13** which channel constitutes the connection between the cylinder chambers **14** and **15** and in the channel **16, 17** there is a valve **18** the valve disk **19** of which by means of a valve lifter **20** can be removed from its seat **22** against the action of a helical spring **21** thereby creating a connection between said cylinder chambers **14** and **15**. The valve lifter **20** is turnable in the valve housing **13** and is at its outer end provided with a valve arm **23** which by means of a rod **24** is hinged to a disk **25** at the upper end of the guide rod **5**. In the position of the lifter **20** shown in FIG. 1, the disk **25** rests on a surface **26** of the portion **6**.

In an oblong cylinder space **27** in the channel **16, 17** is axially movable a slide **28** having conical end portions **29, 30**. In the outer end of the cylinder space **27** which is closed by a screw **31**, there is screwed a nut **33** having a flow opening **32** for the liquid. A spring **34** is inserted between the nut **33** and one end of the slide **28** and there is a similar spring **35** inserted between the opposite end of the slide **28** and the inner end of the cylinder space **27**. The channel **16** terminates in a space **36** outside the nut **33**. The slide **28** is in its mantel surface provided with by-pass grooves **37** for the liquid.

When the artificial leg is swung from the position according to FIG. 1 and rearwards (i.e. to the left according to the drawing) liquid is pressed from the cylinder chamber **15** around the valve body **19**, through the channel **17** and into the cylinder space **27**, further through the by-pass groove **37**, the flow opening **32** in the nut **33** and through the channel **16** into the cylinder chamber **14**. If the swing movement is performed rapidly, the slide **28** will, due to the pressure impulse occurring when liquid flows rapidly through the channel **17** and into the cylinder space **27**, be moved against the action of the spring **34** with its end more or less into the flow opening **32** in the nut **33** and diminish the flow area of this opening, the swing of the shank thereby being decelerated. In the same way, the movement of the shank is decelerated when swung in opposite direction, liquid then being pressed from the cylinder chamber **14** through the channel **16**

and the flow opening **32** into the cylinder space **27**, further through the by-pass grooves **37** and the channel **17** in the valve body **19** into the cylinder chamber **15**. When the shank **38** is swung rapidly in the direction in question, i.e. forwards (to the right according to FIG. 1) the slide **28** is forced by the pressure impulse to the left according to FIG. 2 and with its conical end **29** it is pressed against the action of the spring **35** more or less into the channel **17** thereby diminishing the flow opening of the same which gives as a result a deceleration of the swing of the shank.

A certain adjustment of the deceleration could be obtained by tightening and loosening the nut **33**, whereby the distance between the conical end **30** of the slide **28** and the flow opening **32** of the nut **33** is adjusted and also the tension of the springs **34**, **35**.

The cross section of the by-pass grooves **37** and also of the channels **16**, **17** and of the flow passage **32** is to be chosen in such a way that there is obtained the deceleration of the shank necessary for a normal gait. Any notable movement of the slide **28** should thus occur only at a rapid gait when the deceleration of the swing movement of the shank described here above is necessary.

As soon as the prosthesis with its foot abuts against the ground, the guide rod **5** with the disk **25** and the rod **24** is moved upwards while provoking a turning of the lifter **20** in a counterclockwise direction according to FIG. 2 whereas the spring **21** closes the valve **18**, and there will not any longer be any connection between the cylinder chamber **15** and the cylinder chamber **14**. It is then possible for the amputee to rest on the artificial leg without any risk for the same to collapse.

In FIG. 3 there is shown an embodiment which differs from the embodiment disclosed in FIG. 2 only thereby that there is at the inner end of the cylinder space **27** arranged a nut **40** having a flow opening **39** resembling the nut **33** at the outer end of said cylinder space **27**. Such an arrangement provides for an even better precision of the device as then the flow openings **32** and **39** of the two nuts **33** and **40** as well as the conical ends **29** and **30** could be easily ground.

In FIG. 5 there is shown an embodiment of an artificial leg to be used by a person having a rather long and strong femural stump, as some of those persons do not need or do not want to have a valve controlled by the foot as they themselves can control the knee joint and lock it by pressing rearwards the lower end of the thigh thereby preventing the prosthesis from collapsing. In FIGS. 2 and 5 corresponding parts have been given corresponding reference letters and these parts will therefor not be described once again. In the cylinder space **27** there is according to FIG. 5 arranged a nipple **41** having a flow channel **42** which constitutes a continuation of the channel **17** from the cylinder chamber **15**. The nipple **41** fits into the cylinder space **27** with practically no play and forms an abutment for one end of the spring **35** which with its opposite end surrounds one of the conical ends **29** of the slide **28**. In the opposite end of the cylinder space **27** there is arranged a spring **34** clamping in the same manner as the spring **35** the conical end **30** of the slide **28** and a nipple **43** with its outermost coils. The slide **28** differs in this embodiment from the one shown in FIG. 2 in that it has no by-pass grooves but has a flange **44** having a diameter which is smaller than the diameter of the cylinder space **27** by an amount such that there is provided a clearance between said flange **44** and the wall of the cylinder space **27** having about the same area as the flow opening **42**. The nipple **43** is pressed against the inner end of a screw **45** closing the opening of the cylinder space **27** and being provided at its inner end with a flow channel **46** corresponding to the flow opening in the nipple **43**. The screw **45** can be loosened or tightened by means of a hexagon key inserted in a hexagon notch **47** in said screw head.

When at the swinging of the artificial leg pressure arises

for instance in the cylinder chamber **14**, liquid is forced through the channels **16** and **46**. If the pressure arises suddenly, as the case is at a quick walking, the jet of liquid from the orifice in the nipple **43** will press the slide **28** in the direction towards the nipple **41** at the inner end of the cylinder space **27**. Thereby, the stream of liquid is diminished not only by the conical end **29** which is moved more or less towards the orifice in the nipple **41** but there is also a decelerating effect obtained by the coils of the spring **35** which are pressed closer to each other while preventing liquid from passing through the spaces between them. As obvious, also in this case the swing phase control according to the invention involves the same advantages as in the embodiment where the artificial leg was provided with a valve controlled by its foot.

In FIG. 6 there is shown an hydraulic device in a view corresponding to the view shown in FIG. 1 and in these two figures corresponding parts have been given same reference letters. The action of the device is principally the same as that of the device according to FIG. 1 but as there is no valve controlled by the foot the liquid in this hydraulic unit is streaming as described in connection with the valve housing shown in FIG. 5. In the device according to FIG. 6 there is, however included an attachment plate **48** having a turning rod **49** which plate is to be fixed to the thigh of the prosthesis. In the bed for the turning rod **49** there is arranged a guide rod **50** with a handle which turning rod **49** is connected to a Bowden-wire **51** or the like. By swinging the turning rod **49** with the handle a valve **52** is moved from an opened to a closed position or vice versa under intermediary of a valve arm **53**. This valve **52** serves for closing the channel between the cylinder chambers **14** and **15** so as to lock the knee joint when the amputee intends to be standing for a while and he does not want to have to think of locking the knee joint himself by pressing the lower end of the thigh rearwards. The plate **48** is to be placed in such a way that the rod **49** can be easily reached by the amputee for instance through the pocket so as to render it possible to manipulate the rod **50** as inappreciably as possible.

In the embodiment of FIG. 6 there is arranged a pin **56** projecting upwards from the bottom **54** of the outer, lower cylinder chamber **55** of the cylinder **8**, i.e. the cylinder chamber situated on the outside of the piston **10**, said pin **56**, the upper end of which preferably is conical, projects into the cylinder chamber **55** and is arranged in such a way that it enters into the downwards widening mouth of a central bore **57** in said piston rod **11** in the lower end position of the latter. When the shank is swung forwards, the piston rod **11** with the pistons **9** and **10** is pressed downwards, liquid then streaming from the lower cylinder chamber **55** upwards through the central bore **57** in the rod **11** until the mouth of a bore is put over the pin **56** which, as the mouth widens conically in the direction downwards, continuously closes said mouth more and more until it, before the lower end of the pistons rod **11** strikes against the bottom **54** of the cylinder chamber **55**, completely or almost completely closes said mouth and prevents further movement downwards of said rod **11**. The pin **56** thus provides for a smooth and effective stopping of the movement downwards of the rod **11** and thus also of the swing forwards of the shank whereby is prevented a noisy shock when the rod **11** reaches the bottom **54** and also is ensured a longer life of the knee joint. By using a suitable steel material in the pin **56** the latter will be exposed to practically no wearing especially as oil will be used as hydrualic medium.

The pin **56** could of course be used with the same advantage in the embodiment shown in FIG. 1. Practical tests have proved that the pin **56** renders impossible even a voluntary damage of the knee joint by hard swinging of the shank.

The shown and described embodiments are to be regarded only as examples and the different details of the prosthesis could be constructively changed in many ways within the scope of the invention. There could thus be arranged a further valve in a special, narrow conduit between the cylinder chambers **14** and **15** to be opened by the amputee when walking down stairs or on uneven ground so as to create a connection between said cylinder chambers when the channel **16**, **17** between them is closed due to load on the foot. This regards of course only the embodiment according to FIGS. 1 and 2.

What I claim is:

1. An artificial leg to be attached to a femural stump and comprising a thigh and a hollow shank journalled to said thigh by means of a knee joint shaft, said shank including an hydraulic unit decelerating the motion of the knee joint, an artificial foot attached to said shank, said hydraulic unit comprising two coaxially arranged cylinders filled with liquid and communicating with each other through a channel, piston means adapted to press liquid from one of said cylinders to the other and vice versa during gait, said piston means arranged on a piston rod, the upper end of said piston rod hinged to said thigh at some distance from said knee joint shaft, a valve housing arranged between said cylinders, said channel arranged in said housing with the ends opening into said cylinders and a valve arranged in said channel, movable means connecting said valve with the artificial foot, a spring arranged to close said valve in order to lock the knee when said artificial foot is exposed to load and to open said valve when there is no load, a slide arranged in said channel between the ends thereof and having a cross sectional area slightly less than the cross sectional area of said channel for partially obstructing flow through said channel, and resilient means in said channel bearing on said slide urging it into position in said channel intermediate the ends of said channel, said slide being movable from an intermediate position in either direction against said resilient means at pressure impulses in either of said cylinders for decreasing the cross sectional area of the flow path in said channel for decreasing the passage of liquid through said channel, said slide provided with conical end portions, said channel having reduced cross sectional areas on both sides of said slide into which said conical end sections move depending on the liquid pressure.

2. An artificial leg to be attached to a femural stump and comprising a thigh and a hollow shank journalled to said thigh by means of a knee joint shaft, said shank including an hydraulic unit decelerating the motion of the knee joint, an artificial foot attached to said shank, said hydraulic unit comprising two coaxially arranged cylinders filled with liquid, and further comprising a wall between said two cylinders, said wall having a channel therethrough with the ends of said channel opening into said cylinders, said cylinders being in communication with each other through said channel, piston means adapted to press liquid from one of said cylinders to the other and vice versa during gait, said piston means arranged on a piston rod, the upper end of said piston rod hinged to said thigh at some distance from said knee joint shaft, a slide arranged in said channel between the ends thereof and having a cross sectional area slightly less than the cross sectional area of said channel for partially obstructing flow through said channel, and resilient means in said channel bearing on said slide urging it into position in said channel intermediate the ends of said channel, said slide being movable from an intermediate position in either direction against said resilient means at pressure impulses in either of said cylinders for decreasing the cross sectional area of the flow path in said channel for decreasing the passage of liquid through said channel, said slide provided with conical end portions, said channel having reduced cross sectional areas on both sides of said slide into which said conical end portions move in dependence of the liquid pressure.

3. An artificial leg as claimed in claim 2 in which said slide has at least one groove in the peripheral surface thereof for reducing the cross sectional area thereof.

4. An artificial leg as claimed in claim 2 in which the diameter of said slide is slightly less than the diameter of channel.

5. An artificial leg to be attached to a femural stump and comprising a thigh and a hollow shank journalled to said thigh by means of a knee joint shaft, said shank including an hydraulic unit decelerating the motion of the knee joint, an artificial foot attached to said shank, said hydraulic unit comprising two coaxially arranged cylinders filled with liquid, and further comprising a wall between said two cylinders, said wall having a channel therethrough with the ends of said channel opening into said cylinders, said cylinders being in communication with each other through said channel, piston means adapted to press liquid from one of said cylinders to the other and vice versa during gait, said piston means arranged on a piston rod, the upper end of said piston rod hinged to said thigh at some distance from said knee joint shaft, a slide arranged in said channel between the ends thereof and having a cross sectional area slightly less than the cross sectional area of said channel for partially obstructing flow through said channel, and resilient means in said channel bearing on said slide urging it into position in said channel intermediate the ends of said channel, said slide being movable from an intermediate position in either direction against said resilient means at pressure impulses in either of said cylinders for decreasing the cross sectional area of the flow path in said channel for decreasing the passage of liquid through said channel, said slide provided with conical end portions, said channel having reduced cross sectional areas on both sides of said slide into which said conical end portions move in dependence of the liquid pressure, at least one of said passage openings being in a nut, said wall having a cylindrical chamber therein for said slide, said chamber being part of said channel and said nut threaded into said chamber.

6. An artificial leg to be attached to a femural stump and comprising a thigh and a hollow shank journalled to said thigh by means of a knee joint shaft, said shank including an hydraulic unit decelerating the motion of the knee joint, an artificial foot attached to said shank, said hydraulic unit comprising two coaxially arranged cylinders filled with liquid and piston means adapted to press liquid from one of said cylinders to the other and vice versa during gait, said piston means comprising two pistons dividing the said cylinders each in two cylinder chambers, a piston rod carrying said two pistons and having an axial bore interconnecting the upper and the lower of these four cylinder chambers and said hydraulic unit having a channel interconnecting the two intermediate cylinder chambers, the upper end of said piston rod hinged to said thigh at some distance from said knee joint shaft, a slide arranged in said channel between the ends thereof and having a cross sectional area slightly less than the cross sectional area of said channel for partially obstructing flow through said channel, and resilient means in said channel bearing on said slide urging it into position in said channel intermediate the ends of said channel, said slide being movable from an intermediate position in either direction against said resilient means at pressure impulses in either of said cylinders for decreasing the cross sectional area of the flow path in said channel for decreasing the passage of liquid through said channel, said slide provided with conical end portions, said channel having reduced cross sectional areas on both sides of said slide into which said conical end sections move depending on the liquid pressure and a damper means in one of said cylinders for preventing the performance of a sudden

shock at the full extension of the artificial leg, said damper means comprising a pin projecting axially upwards from the bottom of the lowermost cylinder chamber, said pin being arranged to almost fully close the lower end of said bore at the end of the downward movement of said piston rod at the gait.

7. An artificial leg as claimed in claim 6 in which the lower end of the bore of said piston rod increases in width in the downward direction where said pin enters said bore.

8. An artificial leg as claimed in claim 6 in which said pin decreases in diameter in the upward direction.

9. An artificial leg to be attached to a femural stump and comprising a thigh and a hollow shank journalled to said thigh by means of a knee joint shaft, said shank including an hydraulic unit decelerating the motion of the knee joint, an artificial foot attached to said shank, said hydraulic unit comprising two coaxially arranged cylinders filled with liquid and communicating with each other through a channel, piston means adapted to press liquid from one of said cylinders to the other and vice versa during gait, said piston means arranged on a piston rod, the upper end of said piston rod hinged to said thigh at some distance from said knee joint shaft, a valve housing arranged between said cylinders, said channel arranged in said housing with the ends opening into said cylinders and a manually operated valve arranged in said channel, a slide arranged in said channel between the ends thereof and having a cross sectional area slightly less than the cross sectional area of said channel for partially obstructing flow through said channel, and resilient means in said channel bearing on said slide urging it into position in said channel intermediate the ends of said channel, said slide being movable from an intermediate position in either direction against said resilient means at pressure impulses in either of said cylinders for decreasing the cross sectional area of the flow path in said channel for decreasing the passage of liquid through said channel, said slide provided with conical end portions, said channel having reduced cross sectional areas on both sides of said slide into which said conical end sections move depending on the liquid pressure.

10. An artificial leg to be attached to a femural stump and comprising a thigh and a hollow shank journalled to said thigh by means of a knee joint shaft, said shank including an hydraulic unit decelerating the motion of the knee joint, an artificial foot attached to said shank, said hydraulic unit comprising two coaxially arranged cylinders filled with liquid and communicating with each other through a channel, piston means adapted to press liquid from one of said cylinders to the other and vice versa during gait, said piston means arranged on a piston rod, the upper end of said piston rod hinged to said thigh at some distance from said knee joint shaft, a valve housing arranged between said cylinders, said channel arranged in said housing with the ends opening into said cylinders and a valve arranged in said channel, said valve manually operated by means of a handle connected to said valve by means of a Bowden-wire, a slide arranged in said channel between the ends thereof and having a cross sectional area slightly less than the cross sectional area of said channel for partially obstructing flow through said channel, and resilient means in said channel bearing on said slide urging it into position in said channel intermediate the ends of said channel, said slide being movable from an intermediate position in either direction against said resilient means at pressure impulses in either of said cylinders for decreasing the cross sectional area of the flow path in said channel for decreasing the passage of liquid through said channel, said slide provided with conical end portions, said channel having reduced cross sectional areas on both sides of said slide into which said conical end sections move depending on the liquid pressure.

11. An artificial leg to be attached to a femural stump and comprising a thigh and a hollow shank journalled to said thigh by means of a knee joint shaft, said shank including a hydraulic unit decelerating the motion of the knee joint, an artificial foot attached to said shank, said hydraulic unit comprising two coaxially arranged cylinders filled with liquid and further comprising a wall between said two cylinders, said wall having a channel therethrough with the ends of said channel opening into said cylinders, said cylinders being in communication with each other through said channel, piston means adapted to press liquid from one of said cylinders to the other and vice versa during gait, a piston rod on which said piston means are mounted, the upper end of said piston rod hinged to said thigh at some distance from said knee joint shaft, an obstruction member arranged in said channel and obstructing the flow passage through said channel to reduce it to an area which is small compared to the cross sectional area of the channel for automatically increasing the resistance of the oil flow through the channel at fast walking with the artificial leg, and a damper means comprising a pin projecting axially upwards from the bottom of the lowermost cylinder, said lowermost piston having a bore therein, said pin being arranged to almost fully close the lower end of said bore at the end of the downward movement of said piston at the gait for preventing the performance of a sudden shock at the full extension of the artificial leg.

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