UC-BL PNEUMATIC SWING-CONTROL UNIT FOR ABOVE-KNEE PROSTHESES

Design, Adjustment, and Installation [a,b]

C. W. Radcliffe, M.S., M.E. [c]
Engineering Coordinator

L. Lamoreux, M. Eng.
Post Graduate Research Engineer

Biomechanics Laboratory
University of California San Francisco Medical Center
San Francisco, California 94122

ABSTRACT

The biomechanics of control of knee flexion during the swing phase of normal level walking is analyzed for the purpose of establishing design criteria for devices which can simulate this control function in an above-knee prosthesis. The benefits of using a double-acting pneumatic damper to simulate the action of the normal knee musculature are discussed; they include a viscous-type resistance characteristic which automatically accommodates to changes in walking speed, the ability to store energy and then return it for an active "kicker" action, a simple valve system—made possible by the inherently nonlinear force/displacement/velocity relationship of the pneumatic damper—and the absence of a damping medium which would be messy in the event of leaks.

The mechanical design of the UC-BL Pneumatic Swing Control is described. The pneumatic cylinder is installed in a special wooden knee block, cast-aluminum upper shank, aluminum tube/pylon lower shank, with a rigid lightweight foam plastic shank cosmetic cover. Adjustment of socket flexion, swing-phase flexion and extension resistance, and overall length allow for the fitting of individual amputees.

Instructions for the assembly, installation, and adjustment of the UC-BL Pneumatic Swing Control are included.

---

[a] Based on work performed under VA Contract V1005M–2075.

[b] Also available as Biomechanics Laboratory Technical Report 57. Address requests to Biomechanics Laboratory, 471–U, University of California San Francisco Medical Center, Third and Parnassus Avenues, San Francisco, California 94122.

[c] Professor of Mechanical Engineering, University of California, Berkeley.

I. INTRODUCTION

A *swing control* is a device to control the swing at the knee of an above-knee prosthesis in the same manner as the neuromuscular system of the quadriceps and hamstring groups acting about a normal knee. This controlling action has several effects that increase the ability of the amputee to walk at various speeds and with a smooth and normal-appearing gait. The functional benefits which result from the use of a swing control have become increasingly important as improvements in fitting and alignment techniques have made it possible for the amputee to exercise more precise physical control over the prosthesis through action of the hip joint and stump.

Numerous substitutes for this particular muscle function have been used in above-knee prostheses. Mechanical friction, in combinations with elastic straps about the knee, has probably been the most common way of controlling the swing of the prosthetic knee joint. Mechanical swing-control devices of this type, when properly adjusted, are in many cases capable of providing good control of the swing phase in walking, but they have several disadvantages: they are effective over a very narrow range of walking speeds, they require frequent adjustments, and they are sensitive to the detrimental effects of dirt and moisture.

In recent years hydraulic swing-control devices have been developed which are capable of providing improved control of the knee during the swing phase and which have fewer functional disadvantages for the amputee than mechanical friction devices. The pneumatic swing control described here is similar to a hydraulic device in its action. However, since air is a compressible fluid with elastic characteristics, the action of the air-filled pneumatic device is somewhat different from that of the oil-filled hydraulic swing control.

Before the functional advantages and construction of the UC-BL Pneumatic Swing Control are described, it will be helpful to discuss some of the aspects of the swing phase of normal level walking.

II. THE SWING PHASE OF NORMAL LEVEL WALKING

Swing phase begins at the instant the toe loses contact with the walking surface, continues through the acceleration, midswing, and deceleration subphases, and ends at the instant the heel makes contact.

Acceleration Subphase—Quadriceps Action

In normal walking, flexion of the knee begins before the toe loses contact, i.e., during the last part of stance phase. Swing phase is initiated as the muscles acting about the hip joint flex the weight-bearing knee into an unstable position.

As knee flexion continues, the knee is brought forward rapidly, causing the toe to leave the walking surface. Prior to toe-off the knee has flexed approximately 40 deg. relative to the fully extended position. Flexion continues as the knee is accelerated forward and the foot swings upward behind it.

Since the knee is brought forward very rapidly, this upward swing of the foot would result in an excessive angle of flexion were it not for the restraining action of the quadriceps muscle group. These are the muscles of the anterior aspect of the thigh, and they act to extend the knee joint. The patella is imbedded in the distal part of the quadriceps tendon, which, together with the patellar ligament, inserts on the tibia at the tibial tubercle. Contraction of the quadriceps muscles, therefore, tends either to extend the knee actively or to decrease the rate of flexion of the knee.

This quadriceps action limits the maximum angle of knee flexion as the knee is accelerated forward.

A schematic graph of the relationship between muscle action and knee-flexion angle in normal level walking is given in Figure 1. For the purposes of this discussion numerical magnitudes are not pertinent, but the curves show in approximately the correct ratio the relative magnitudes of the torque exerted by the two major muscle groups about the knee. Torque values for results of quadriceps action are shown as positive on the graph. Torque values resulting from hamstring action, which tends either to flex the knee or to decrease the rate of extension, are shown as negative values.

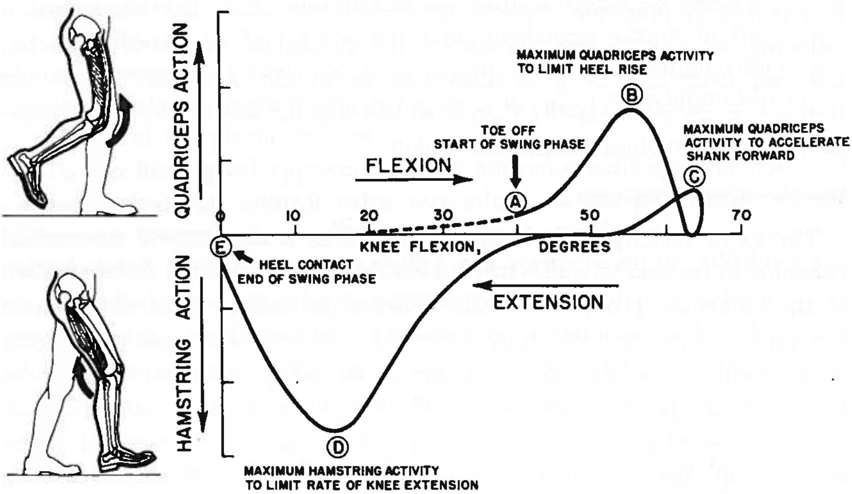


FIGURE 1

Referring to Figure 1, one can see that in normal gait swing phase begins at point *A*, which corresponds to approximately 40 deg. of knee flexion. Quadriceps action has begun earlier with control of flexion of the weight-bearing knee during the final part of stance phase. As the knee is brought forward rapidly by the flexors of the hip, all of the quadriceps muscles increase in activity as they begin to act to limit heel rise. Maximum muscle activity has been observed to occur at about 55 deg. on knee flexion (at point *B* on the graph).

Following this first burst of quadriceps activity there is a momentary lull as the foot continues to swing upward behind the knee to a maximum angle of knee flexion of about 65 deg. (It is interesting to note that this 65 deg. value is something of a universal human constant. Persons of all ages, both sexes, and varying physique, when walking at a comfortable speed, have been observed to maintain a maximum angle of knee flexion which is within a few degrees of the 65 deg. value.)

As the maximum angle of knee flexion is reached there may be a second burst of quadriceps activity which accelerates the shank forward. This second peak, at point *C* on the graph, is typically of a smaller magnitude than the first peak, for at this time, when the knee reaches a maximum angle of flexion, gravitational forces are also providing an appreciable extension torque about the knee, which tends to aid the quadriceps in accelerating the shank forward.

Midswing Subphase

As the shank/foot segment continues to swing forward, the acceleration subphase ends and the midswing subphase begins. The midswing subphase is a period of minimum muscle activity during which the shank/foot is swinging as a pendulum. However, the pendulum action is somewhat different from that of a so-called free pendulum, since the leg swings forward much more rapidly than it would without the accelerating torque provided by previous quadriceps action.

Deceleration Subphase

The extra velocity of the midswing subphase is necessary if the normal person is to be able to walk rapidly. However, if it were not for the action of the hamstring group, which slows down the rate of knee extension as the knee approaches the fully extended position, the rapidly swinging shank would cause the knee to come to an abrupt stop limited only by tension in the posterior ligaments. This would be highly undesirable not only because of possible damage at the knee but also because of interference with the smooth motion of the entire body. The action of the hamstring muscle group prevents this undesirable impact by providing maximum deceleration as the knee swings through a position of about

15 deg. of knee flexion, allowing the knee to approach the fully extended position smoothly.

Most of the muscles of the hamstring group are two-joint muscles, spanning the hip as well as the knee. When these muscles apply forces at their insertions on the shank, they simultaneously apply equal and opposite forces to their origins on the pelvis. Consequently, the muscle action which tends to decelerate the leg tends simultaneously to accelerate the remainder of the body. This dynamic effect has been calculated [d] and, perhaps surprisingly, has been shown to contribute to the forward acceleration of the remainder of the body with an impulse approximately equal to that provided by the opposite foot and ankle during push-off of the opposite leg.

III. THE UC-BL PNEUMATIC SWING CONTROL

In principle, the UC-BL Pneumatic Swing Control simulates in an above-knee prosthesis the effects of normal swing-phase quadriceps and hamstring action. The unit provides no particular advantages during the stance phase except to insure a smooth transition from the swing phase.

The functional element is a piston/cylinder unit that works in a manner similar to that of an automobile shock absorber or a pneumatic door closer. Flexion of the prosthetic knee causes the bellcrank pivot located at the rear of the knee joint to move distally in the shank and forces the piston into the cylinder. This downward motion of the piston results in compression of the air below the piston and the creation of a partial vacuum above it. The pressure differences thus formed creates a resistance to knee flexion similar to the effect of quadriceps action in the normal knee. Extension of the knee from a resting flexed position results in a similar resistance to extension as the pressure/vacuum relationship on the two faces of the piston reverses.

To provide a good approximation to normal quadriceps and hamstring action, a leak-rate control valve was added to the pneumatic cylinder. This was necessary to modify certain characteristics of its performance which result from the compressibility and elasticity of air. Without such a controlled leak rate, the pneumatic swing-control unit acts as an air spring with a variable rate. This can be demonstrated by closing the connection between upper and lower cylinders. The performance of such a closed system appears in the zero leak-rate characteristic curve

---

[d] Bresler, B., and F. R. Berry: Energy and Power in the Leg During Normal Level Walking. Prosthetic Devices Research Project, Institute of Engineering Research, University of California, Berkeley, Series 11, Issue 15, May 1957. 27 pp. + illus.

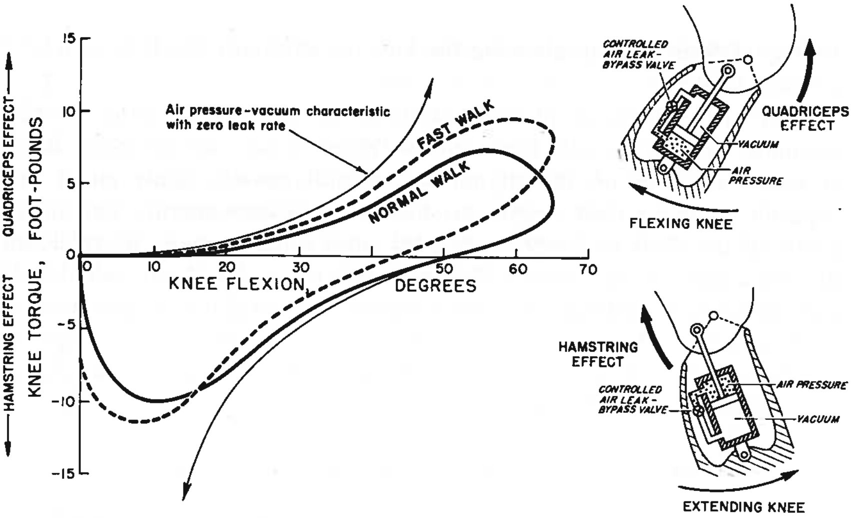


FIGURE 2

(Fig. 2), which shows progressive deviation from the desired normal characteristic curve shown in Figure 1.

In normal walking, during the initial quadriceps action which limits heel rise, all the muscle work about the knee is negative and is dissipated as heat. With the pneumatic swing-control unit acting as a closed system, the work done on the air is stored in the form of elastic energy in the compressed air. When this compressed air expands, accelerating the shank forward, there is an excess of available energy which acts much too forcibly, and a severe impact is unavoidable as the knee reaches full extension.

The addition of a leak rate between upper and lower cylinders, controlled by a needle valve, alters the function of the air spring drastically. Figure 2 shows the characteristic curve for a system with a controlled leak rate. Under these conditions, as the piston moves downward in the cylinder, air immediately begins to move from the high-pressure lower cylinder to the low-pressure upper cylinder, and the pressure difference drops off with time. As a result of this change in the pressure difference, the net torque characteristic created about the knee joint has a curve which always lies below the zero leak-rate (closed system) curve. The modified pneumatic differential pressure tends to reduce the rate of knee flexion in a manner very similar to normal quadriceps action. The rate of knee flexion decreases rapidly as the angle of flexion approaches 65 deg. When properly adjusted to the individual amputee, a small pressure difference will continue to apply an extension torque about the knee as the maximum angle of flexion is reached. This extension torque drops off rapidly as the direction of motion changes.

As extension of the knee continues there is a range of motion of 20 to 30 deg. over which the resisting torque due to the pneumatic action is quite small. Near the end of the forward swing the air-pressure difference builds up in the opposite sense to provide a decelerating torque which resists extension in a manner similar to hamstring action in the normal knee.

In order to provide greater flexibility in adjustment to the needs of individual amputees, separate bypass lines and leak-rate adjustment valves are provided in the unit for the adjustment of the overall resistance *level* (*L* valve) and the adjustment of the *ratio* of maximum flexion resistance to maximum extension resistance (*R* valve).

The manner in which the unit responds to a change in walking speed is also shown schematically in Figure 2. With a particular valve adjustment there will always be a certain time required for the air pressures to rebalance on the two sides of the piston as the air flows from the high-pressure to the low-pressure side after a movement of the piston within the cylinder. This means that, with the unit adjusted for a comfortable walking speed, an increase in speed will be accompanied by 1. a decrease in the time required for the knee to reach 65 deg. flexion and 2. more active use of the stump resulting in an increase in the knee torque required to control heel rise. The pneumatic unit responds automatically under these conditions to provide this required increase. This is a consequence of the fact that as the period of knee flexion is decreased the torque about the knee created by the air-pressure difference more nearly approaches the zero leak-rate characteristic curve. As the maximum knee-flexion angle is reached and the direction of knee motion reverses, an appreciable pressure difference remains which now extends the knee actively, with an increase in available energy as compared with the conditions of the somewhat slower comfortable walk. As the knee comes into extension there may or may not be an increase in terminal impact, depending upon the use of the amputee's stump to control the swing. In general there will have been a smaller volume of air transferred during the flexion-resistance phase, with the result that the extension-resistance phase will be characterized by a modified zero leak rate. During stance phase the air pressures are reestablished in preparation for the next swing phase.

IV. MECHANICAL FEATURES

The UC-BL Pneumatic Swing Control is installed in a knee/shank setup which incorporates a special wooden knee block and an aluminum shank/pylon unit as shown in Figure 3. The shank/pylon unit can be covered with one of several optional cosmetic coverings. The procedure to be described makes use of an oversized rigid polyurethane foam preform which allows the custom shaping of shank contours for the individual

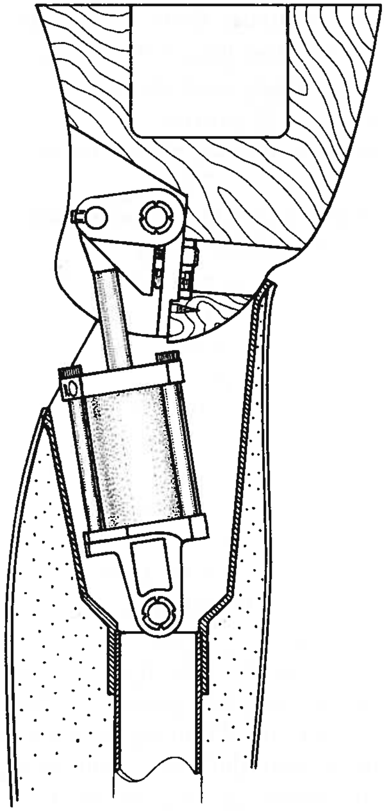


FIGURE 3

patient. A polyester resin/nylon stockinet skin completes the cosmetic cover. If desired, a tinted vinyl leg cover may be used over the rigid foam/polyester skin. The rigid foam cosmetic cover is removable to allow maintenance and repair of the mechanical components of the prosthesis.

Shell-type cosmetic covers of polyester laminate or of PVC may also be used, as well as soft flexible foam units of a standardized shape. In these cases the internal contours of the flexible foam cover must be formed to fit the external contour of the metal shank.

A. Alignment

The dynamic alignment of the socket with the knee/shank unit may be accomplished with either the VAPC alignment coupling or the UC-BL adjustable leg. The temporary use of a constant-friction swing control in the UC-BL adjustable leg has not caused difficulties in achieving optimum alignment of the finished prosthesis containing the pneumatic swing control.

B. Inspection and Disassembly

Before attempting to use the knee/shank unit the prosthetist should acquaint himself with its special mechanical features. This is best accomplished by careful disassembly of the unit.

1. Removal of the Rigid Foam Cosmetic Cover

Loosen the rigid foam cover from the metal shank/pylon by inserting a short length of extra pylon tubing into the distal hole of the cover and tapping lightly with a mallet. Slide the cover off the shank distally. Note that the interior surface of the cover is formed to fit the shank contour; when it is reinstalled, the shank cover must be registered properly.

2. Disassembly of the Wooden Knee/Metal Shank Setup

Loosen, three turns each, the two setcrews which retain the upper pivot pin in the bellcrank. Withdraw the upper pivot pin, using tool number X-48 (Fig. 4) or a long ¼-28 UNF machine screw.

a. *The Removable Knee Bolt.* The knee bolt is a new type which is made of an aluminum alloy with a special hard anodized coating. The knee bolt does not thread into the side straps of the shank but is held in place in the shank by an expanding collar at each end. Remove the knee bolt

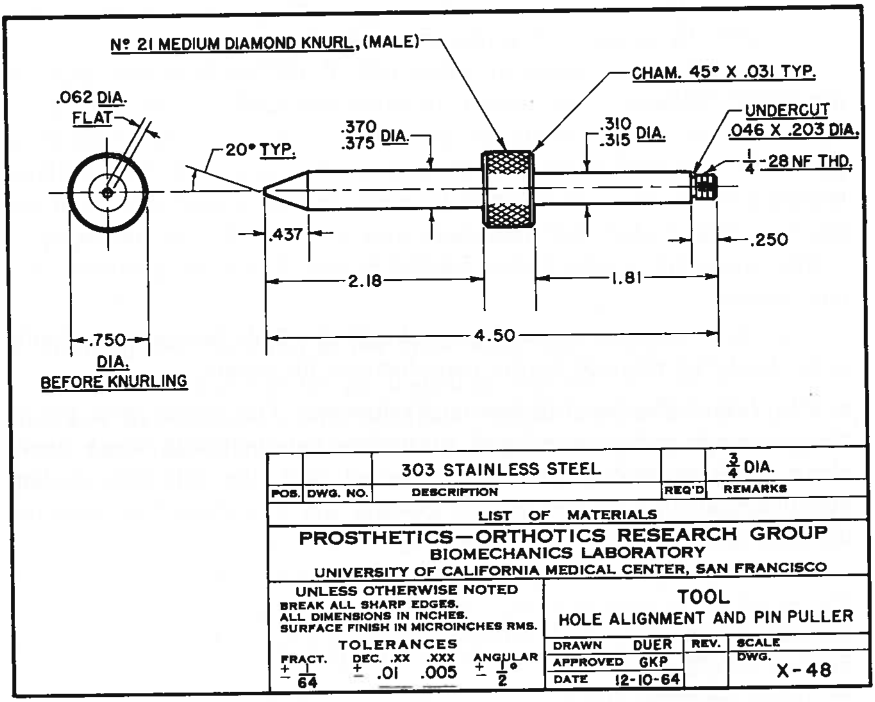


FIGURE 4

by inserting a 5/32 in. hex key into each of the two button-head lock screws on the ends of the knee bolt and loosening each screw approximately one-half turn. If only one screw loosens, remove that screw and the accompanying expansion collar; a slot will then be seen in the end of the knee bolt. Use a *large* screwdriver in this slot to prevent the knee bolt from turning while the second lock screw is loosened. If both lock screws loosen, it is not necessary to remove them or to loosen them more than one-half turn, to remove the knee bolt. When the lock screws are loosened the expansion collars contract sufficiently to allow the knee bolt to slide out either side of the knee/shank setup.

Slide the knee bolt out and separate the knee block from the metal shank.

Loosen, three turns each, the two setscrews which retain the lower pivot pin in the metal shank. Withdraw the lower pivot pin, using tool number X-48 as before. Withdraw the pneumatic unit from the shank and insert the two pivot pins in the end bearings to retain and protect the bearing inserts.

b. *Pneumatic Swing-Control Unit.* Examine the swing-control unit. Note that the piston rod and pivot pins are aluminum, with a special hard anodized coating like that of the knee bolt. The coating is hard but thin, and care should be taken not to allow any metal such as vise jaws, pliers, or wrenches to contact the surfaces of these parts.

The pivot bearing inserts at either end of the swing-control unit are removable Nyliners [e] which should be lubricated with a small quantity of instrument oil. These inserts are assembled for a snug fit over the pivot pins, and care should be taken to keep the inserts in their original locations. The pivot pins should be reinserted to protect and hold the inserts in place when the pneumatic unit is removed from the setup.

The adjustable needle valves labeled *L* and *R* will be discussed in a later section.

Caution: Under no circumstances should the unit be opened! Faulty units should be returned to the manufacturer for repair.

c. *The Initial–Flexion Adjustment Mechanism.* The upper pivot pin of the pneumatic swing-control unit is attached to a bellcrank which pivots about the knee-bearing housing. A second part, the bellcrank anchor, also pivots about the knee-bearing housing but is anchored to the knee block by two Phillips-head screws.

In addition to its swing-phase control function, the pneumatic unit also serves as the extension stop. When the knee approaches full extension the piston contacts a firm rubber bumper located in the cylinder head. Further extension of the knee is then prevented because the bellcrank is

---

[e] Thompson Industries, Manhasset, N. Y., Nyliner Type 6L4FK.

rigidly attached to the bellcrank anchor, which in turn is attached to the knee block. The initial-flexion angle can be adjusted by changing the angle between the bellcrank and the bellcrank anchor. This adjustment does not change the geometry of the linkage which operates the pneumatic unit. It simply rotates the socket slightly relative to this linkage.

The initial-flexion angle is adjusted by using a long 3/16 in. hex key to turn the two screws visible in the slot in the front of the knee block. The lower screw is the adjustment screw which determines the initial-flexion angle. The upper screw is a clamp screw. To increase the initial flexion, loosen the clamp screw, then turn the adjusting screw clockwise. Finally, reset the clamp screw. One full turn of the adjustment screw will result in a 3 deg. change in the initial-flexion angle.

V. FINISHING PROCEDURES

A. Preparation of the Wooden Knee Block for Finishing

The aluminum knee-bearing housing is fitted into a phenolic laminate tube bonded in the knee block. It is held in place by the clamping action of the initial-flexion adjustment screws on the bellcrank and bellcrank anchor. To prepare the knee block for finishing, the following steps are required:

1. Loosen the initial-flexion adjustment clamp (upper) screw. Do not move the adjusting (lower) screw.
2. Remove the two Phillips-head screws which secure the bellcrank anchor to the knee block.
3. Slide the aluminum knee-bearing housing laterally out of the knee block. If the knee-bearing housing is difficult to remove, be sure the initial-flexion adjustment screws are loose and the bellcrank anchor screws are completely removed; then gently tap out the housing with a plastic or wood drift pin.

B. Shaping and Finishing of the Knee Block and Socket

The knee block and socket are shaped as required for a natural appearance and finished with plastic laminate. Before lamination, all openings in the knee block must be sealed with strips of resin-impregnated glass-fiber cloth, or an equivalent material. The edges of the sealing patches are sanded to blend smoothly into the contours of the knee blocks. After the finished lamination has cured, the knee-bolt holes, the posterior slot, the slot for the anterior adjusting screw, and the access hole for the pivot pin are reopened with a small, pointed knife.

C. Lamination of Plastic Skin on Rigid Foam Cosmetic Cover

Before laminating plastic skin on the rigid foam cosmetic cover, be sure that the dynamic alignment of the prosthesis is satisfactory, with

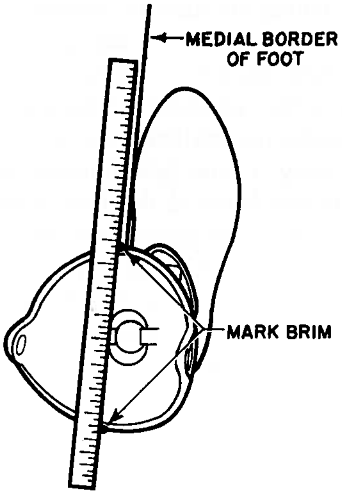


FIGURE 5

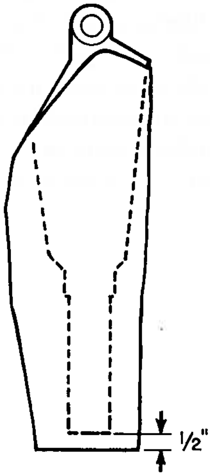


FIGURE 6

particular attention to the overall length of the prosthesis and the toe-out of the foot with respect to the knee bolt.

1. Record the toe-out of the foot in the following manner: Place a straight-edge along the medial border of the foot and project this line upward to the brim of the shank casting. Mark the intersection of this line (as viewed from above) with the anterior and posterior brim of the shank unit. The procedure is reversed when the foot is reinstalled after the cosmetic cover is finished (Fig. 5).

2. Remove the foot by loosening the foot-attachment plug from the bottom of the foot and sliding the foot and plug out of the shank pylon tubing.

3. Slide the foam cover over the shank and seat firmly against the shank casting. Be sure the cover is registered to fit the shank casting contours accurately.

4. Cut the foam cover at right angles to and approximately ½ in. longer than the pylon tubing. The extra length is required to accommodate the added thickness of the flange of the foot-attachment plug (Fig. 6).

5. Carve a recess in the end of the foam cover to accommodate the foot-attachment plug. The plug should fit snugly into the recess and seat firmly against the cut end of the pylon tubing.

6. Slip the lower half of the foot-attachment plug into its recess and carefully plane or sand the distal end of the foam cover parallel to the top surface of the SACH foot to be used. Either a flat Surform file or a disk sander may be used to form this foot-attachment surface (Fig. 7).

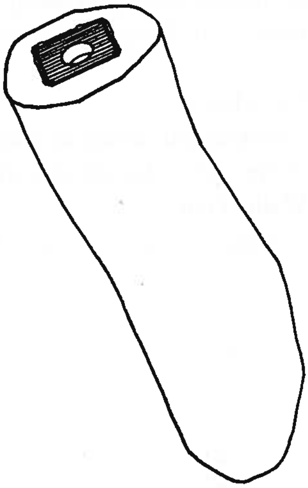


FIGURE 7

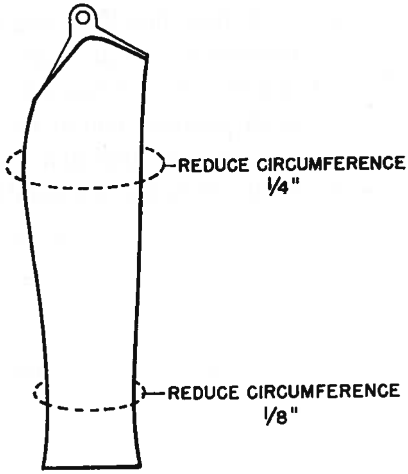


FIGURE 8

7. Reinstall the foot with toe-out checked against the two marks established in Step 1. Be sure the pylon tubing and the flange of the foot-attachment plug are in contact.

8. Shape the external contours of the shank as desired. The calf circumference should be reduced 1/4 in. and the ankle circumference 1/8 in. to allow for the thickness of the laminate skin. The contour at the ankle junction should also be reduced slightly to allow for the external finish. The flange on the shank brim should be exposed, with the foam plastic shaped to fair smoothly in the brim area (Fig. 8).

9. Remove the foot and the foot-attachment plug. Seal the entire distal cut surface of the foam cover with a minimum of 1/8 in. of firm sponge rubber (Kemblo or equivalent). The sponge-rubber material has a dual purpose: to protect the vulnerable sharp edge of the rigid foam and to provide a final trim line such that the laminate skin forms a smooth transition with the matching ankle contour of the foot.

10. Invert the combined aluminum shank/foam cosmetic cover over a padded pipe or pipe with padded wooden plug mounted in the laminating bench vise. A vacuum source is highly desirable.

11. Pull a well-fitted and moistened PVA bag with smooth lap joint over the shank/cover combination and tie off top and bottom. The PVA bag prevents excessive resin absorption by the foam plastic and protects the metal shank parts. Tie off this bag and trim excess material distal to the tie. The plastic skin will not be bonded to the foam cover (Fig. 9).

12. Pull one or two layers of nylon stockinet (depending upon weight of material used) over this PVA bag and laminate with 300 gm. of a 50-50 mixture of polyester resin as follows:

a. Pull a second PVA bag over the nylon stockinet.

b. Tie off proximal end of the external PVA bag in order to allow a vacuum between inner and outer bags (Fig. 10). Tie off the distal end of the PVA bag temporarily with a slip knot.

c. Draw a low vacuum on the nylon stockinet between the two PVA bags, to remove entrapped air.

d. Pour resin above the slip knot, then remove tie and allow the vacuum to draw the resin downward into the stockinet. Strip resin downward, then tie off excess at the upper (distal) end.

e. Allow vacuum to continue to act and force the laminate firmly against the foam cover and the flange on the proximal socket brim.

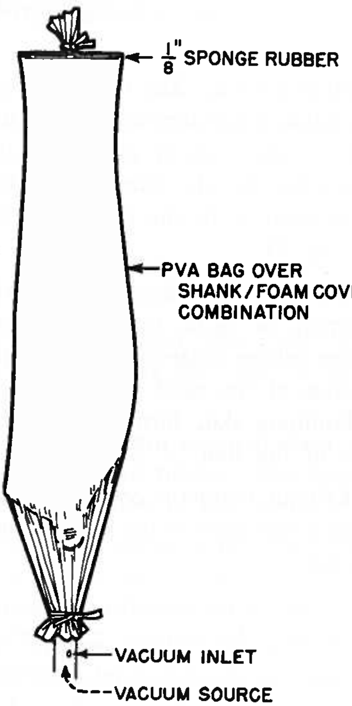


FIGURE 9

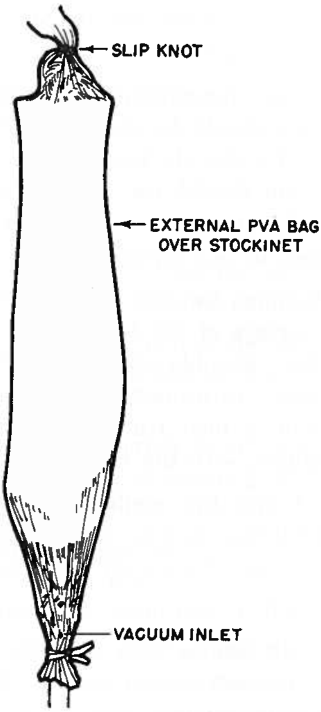


FIGURE 10

f. After the plastic laminate has cured, trim the proximal brim area such that the metal flange is covered by a thin layer of plastic, and trim the distal surface for a smooth junction with the foot.

g. The cosmetic cover may be removed at any time by sliding it off the shank casting distally.

VI. REASSEMBLY

A. Holding the bellcrank assembly in place in the knee block, slide the bearing housing into place until equal amounts of the ends are exposed. If the housing is too tight in the knee block to assemble by hand, be sure that the bellcrank assembly is not binding and use a plastic or wooden drift and a mallet to tap the housing into place.

B. Install the wood screws which secure the bellcrank anchor to the knee block and tighten securely. Note: To avoid binding of the bearing housing upon assembly, do not install the wood screws until the bearing housing is in place.

C. Tighten the knee-flexion adjustment clamp screw (the upper screw in the anterior slot of the knee block).

D. Install the Nyliner knee bearings. Oil the Nyliners lightly with instrument oil.

E. Oil the pivot bearings on the pneumatic swing-control unit lightly with instrument oil and insert the unit into the shank cavity. Install the lightly oiled lower pivot pin into the distal hole in the shank casting and through the lower bearing of the unit, using tool X-48. Tighten both setcrews securely with a 3/32 in. hex key, making sure that the setcrews seat on the flats of the pin.

F. Slide the ears of the shank over the flanges of the Nyliner bearings and slide the lightly oiled knee bolt into place.

G. Lock the knee bolt in place by simultaneously tightening both button-head lock screws with two 5/32 in. hex keys. The ears of the shank will often be too tight against the flanges of the knee bearings because the expansion collars draw the ears together as they are tightened. This tightness can be relieved by loosening either one of the button-head lock screws, pulling one ear of the shank away from the knee block slightly, and retightening the cap screw. Always check for excessive mediolateral looseness, which may result in noise.

H. Slide the rod-end bearing on the piston rod of the pneumatic unit between the ears of the crank and insert the pivot pin with tool X-48. Lock the pin in place with two setcrews, making sure that they bear on the flats of the pin.

I. Slide the finished cosmetic cover on the shank and seat it firmly against the proximal flare of the shank casting. Orient the foot coupling on the foot with "ANT." Facing the toe, insert the coupling into the pylon tube, align the foot, seat it firmly against the pylon tube, securely tighten the foot coupling.

J. Check the static alignment of the assembled prosthesis and readjust the initial-flexion setting as required to provide the desired alignment stability at the knee.

VII. ADJUSTMENT PROCEDURE

A. Initial Flexion Adjustment

Initial flexion adjustment procedures are described in detail in Section IV.B.2.c.

B. Needle Valve Adjustment

The level valve (*L*) setting affects both the flexion and extension resistance levels of the unit. If the ratio valve (*R*) is closed completely, the system operates as a single-valve unit which is adjusted by the level valve only. The ratio valve is in series with a check valve and is open during extension only. When opened it reduces extension resistance without affecting flexion resistance.

C. Adjustment

Figure 11 is a schematic diagram showing the manner in which the level and ratio valves control the air flow in the pneumatic system in such a way as to provide individually adjustable resistance to flexion and extension of the prosthetic knee joint. The function of the level and ratio valves will be illustrated by a description of the method of adjustment for a typical amputee. The procedure is as follows:

1. Close both the level and the ratio valves by turning clockwise until the needle valves are seated lightly.

2. Open the level (*L*) valve 2½ turns counterclockwise. The resistance level will be very low with this setting.

3. Ask the amputee to attempt walking slowly and then gradually to increase his speed. The low resistance level set in Step 2 will usually be insufficient for normal walking speeds, so that an impact is to be expected as the knee swings into full extension.

4. Gradually increase the resistance level by partially closing the level valve—turn it clockwise ¼ turn for each trial. Continue to increase the resistance level until the impact as the knee extends is barely noticeable at a comfortable walking speed.

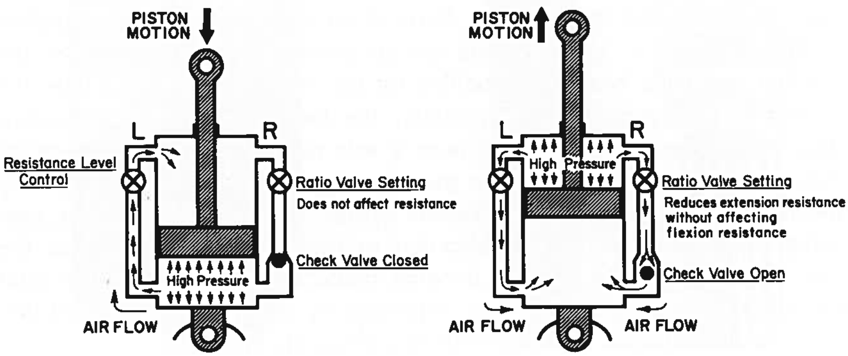
At this point in the adjustment procedure all air flow in both directions is passing through the level valve, with the ratio valve closed. The valve unit is functioning as a single-valve system.

5. Ask the amputee to attempt walking at a higher speed. With only the level valve open the amputee will usually have difficulty in preventing excessive heel rise. Attempts to control heel rise by an increase in overall resistance level will result in an undesirable "bounce-back" as the knee comes into full extension.

6. If more flexion resistance is required, close the level valve ¼ turn (clockwise) but open the ratio valve ¼ turn (counterclockwise) to compensate. This procedure will maintain the extension resistance at the previous setting but increase the flexion resistance.

7. Proper adjustment of the level and ratio valves will allow the amputee to walk at a comfortable speed without excessive heel rise and with a barely noticeable impact as the knee comes into full extension. This slight impact is desirable as an indication that the knee is in a position which will be stable at the beginning of stance phase. After a period of wear the amputee will learn to control the severity of the impact by use of his stump and an improved sense of timing.

Precaution: Do not overadjust the control valves by working one adjustment against the other. When in doubt, reset the valves as described in Steps 1 and 2 and repeat the adjustment procedure. Every effort should be made to achieve the desired swing control with a minimum resistance level.



a– AIR FLOW CORRESPONDING TO KNEE FLEXION

The pneumatic unit will resist flexion (or cause extension) as long as high pressure air is below piston.

b – AIR FLOW CORRESPONDING TO KNEE EXTENSION

The pneumatic unit will resist extension (or cause flexion) as long as high pressure air is above piston.

FIGURE 11