seem that the weight alone of present systems would make voluntary control impractical, and thus any project in this area should begin anew.

At present, very little work seems to be going on in the area of voluntary control systems. Some work at the Massachusetts Institute of Technology has been reported for nearly a decade. More recently, the REC at Moss Rehabilitation Hospital started a project where pattern recognition techniques are used to obtain subconscious control of a knee mechanism by EMG signals about the hip joint, which shows a good deal of promise.

Perhaps what we need most at this point is more information concerning the contribution of each variable, such as swing-phase control, stance-phase control, ankle action, weight, and weight distribution, singly and in combination, for designers of the next generation of above-knee legs. With the technology now available to us, this appears to be possible as well as practical.

Physical Therapy and Hydraulic Knee Units

Bernice Kegel R.P.T.*

Without a thorough understanding of the principles of operation and functional benefits engineered into the sophisticated hydraulic knee mechanisms, the therapist will be unable to help the amputee gain maximum benefits and to use the system effectively. It is important that the prosthetist ascertain that the therapist knows what adjustability is incorporated into the prosthesis. Much of the adjustment will be done during dynamic alignment at the prosthetic facility, but modifications will need to be made as the patient gains confidence and his ambulation pattern improves.

An understanding of the fundamental differences between hydraulic control and mechanical friction will help in training the amputee to take full advantage of the flexibility of hydraulic mechanisms. Amputees can walk over a wide range of cadences instead of being limited as with mechanical friction. There are two reasons for this. First, hydraulic friction increases with speed to just balance the increase in kinetic energy of the prosthesis while mechanical friction remains essentially constant. The programmed hydraulic characteristics give little frictional resistance during initial extension and flexion, but build to a peak at terminal flexion and extension. This helps to provide a natural appearing gait regardless of cadence. The stability of hydraulic systems permits alignment nearer the trigger point and thus results in less energy expenditure required for walking. If a patient has previously used a mechanical knee, he needs to be reminded that no exaggerated residual limb motion is necessary to gain adequate flexion and extension of his hydraulic prosthesis.

For purposes of brevity I will limit my discussion to gait training with one knee unit—the Mauch S-N-S (Figure 1). The Mauch S-N-S knee unit can be set to provide 3 functions:

1. Swing and Stance phase control.
2. Swing phase control only.
3. Manual knee lock.

A stirrup shaped lever near the top of the piston rod operates as a selector switch. When the lever is in the down position, swing and stance control are both operative. This would be the adjustment chosen for normal walking. The major advantage of stance control is that it offers the patient stumble recovery. If

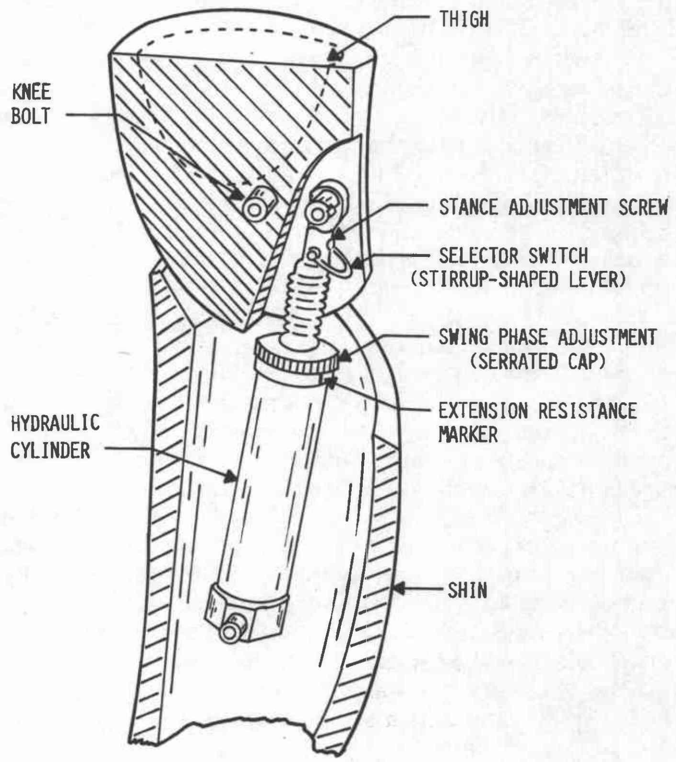

Figure 1. Cutaway diagram of the Mauch Unit

the prosthetic knee buckles, it will give way slowly enough that the patient should be able to regain his balance before falling. When training a patient with a conventional knee unit, he is taught to forcefully contract his hip extensors late in swing phase to accelerate the shank forward (with resulting terminal impact) to ensure extension of the knee at heel strike. Amputees wearing fluid-controlled mechanisms need not do this. The amputee should be instructed to swing his thigh forward, decelerate it, and end the movement with the residual limb pointing to the point on the ground where the heel should strike. The shank, aided by the built-in extension bias will swing forward smoothly, and at heel strike will be in

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full extension. With the stance phase control engaged, the prosthetic knee will be stable in the initial portion of stance phase without forceful extension of the hip musculature being necessary. The feature makes gait training markedly easier.

It is extremely important during the end of stance phase on the prosthetic side that the hip be ahead of the knee and weight on the ball of the foot. This hyperextension moment is necessary to disengage the stance phase control momentarily and allow the knee to bend freely in swing phase. If the amputee does not exert this hyperextension for 1/10th of a second, he might experience difficulty in flexing the knee to begin swing phase. When walking on soft ground, it is even more important to exert this hyperextension moment.

The benefits of stance control are also used when walking down stairs and ramps in a step-over-step manner. This ability to walk down steps in a step-over-step manner rather than one step at a time or by jack-knifing is one of the key advantages of the Mauch knee unit. The patient needs to be taught to place his prosthetic heel on the lower step with the forefoot extending beyond the edge of the step (Figure 2). He is then told to flex his hip forward while simultaneously putting weight on the prosthetic leg. This will cause a controlled bending of the prosthetic knee. As the prosthetic knee yields, the sound leg is brought forward and placed on the lower step. If the

Figure 2. Correct placement of the prosthetic heel

patient has to wait for the prosthetic knee to bend, then stance phase resistance is too high and should be reduced. This activity is probably the most difficult to teach an amputee, expecially if he has used a conventional knee unit in the past. This same technique is used for going down ramps. When walking up steps and ramps the same techniques are used as in conventional training.

When sitting down in a chair, the patient can either use the weight bearing resistance of the S-N-S unit to control the rate of sitting, or release the stance phase control and use the sound leg to control sitting rate in the same fashion as with a conventional knee unit.

How quickly the knee bends under weight is determined by the stance adjustment screw, which is turned with a 22mm Allen wrench (Figure 3). The adjustment is *extremely* sensitive with a range of only 120 degrees. Slowest bending and maximum stability is obtained with a full clockwise adjustment. Most patients like to start with a high degree of stability.

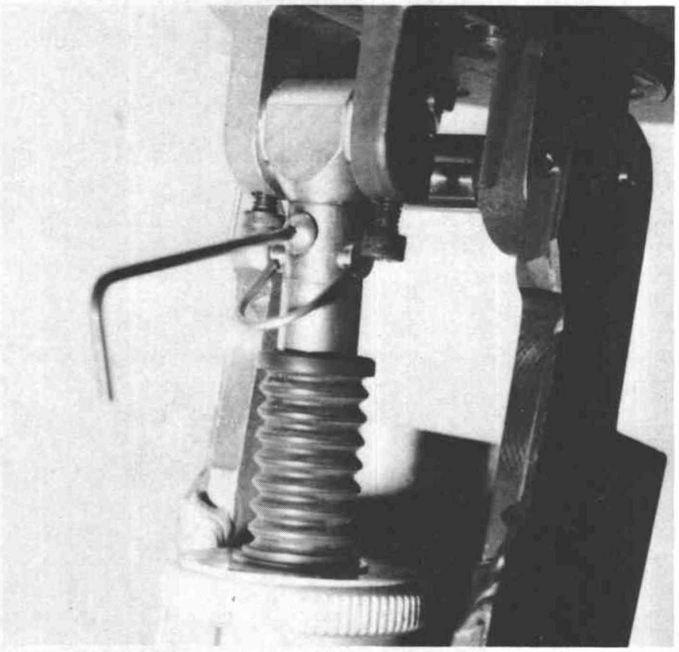

Figure 3. Allen wrench inserted into the stance adjustment screw.

To eliminate stance phase control the patient is told to stand with his prosthetic leg behind his sound leg. With weight on the toe of his prosthesis, he pulls the selector switch lever up (Figure 4). This mode would be used for bicycling and other activities needing a free swinging leg. Swing resistance is adjusted by moving the serrated cap. The verticle black line under the serrated cap is the extension resistance marker. When the black line is all the way to the right (4 o'clock) extension resistance is lowest, and all the way to the left (8 o'clock) is the maximum setting. A good resistance for beginning walking would be at 5 o'clock (Figure 5).

The same serrated cap that adjusts extension resistance also adjusts flexion resistance. When the "H" in the word HYDRAULIC is over the line marker (regardless of the position of the line marker), flexion resistance is lowest. "K" over the marker indicates maximum resistance. A good resistance for beginning walking is at the "D" position (as shown in Figure 5).


Figure 4. Eliminating the stance phase control.

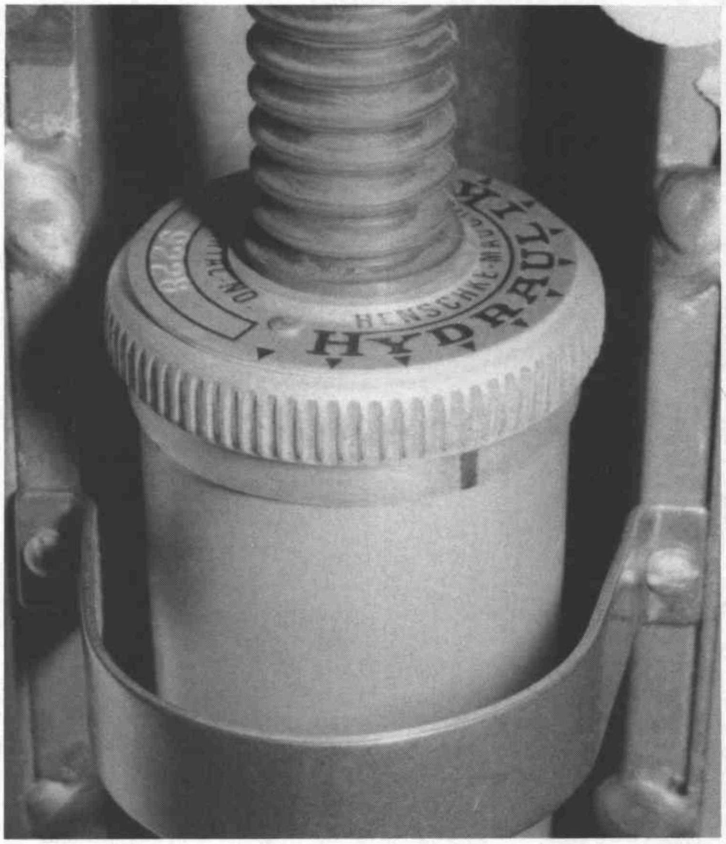

Figure 5. Good resistance settings for beginning walking.


Figure 6. Engaging the knee lock.

To engage the knee lock, the selector switch is pulled into up position with the knee flexed and bearing no weight (Figure 6). The knee may now be extended from this flexed position, but increased flexion is not possible.

A right-legged amputee might choose to lock the prosthetic knee while driving and pressing the pedal by a forward motion of the hip. For standing at work for any length of time or while standing on a bus, the amputee could be taught to lock his knee.

The Mauch S-N-S units have also been successfully used by bilateral amputees. The two units are likely to be adjusted differently because different residual limb lengths call for different resistance settings.

The patient should be taught that the hydraulic unit may require servicing every one to two years. He should also be told that small amounts of air in the hydraulic system are no reason for concern. An automatic selfbleeding feature will eliminate the air after he walks a few steps, or if he bends the knees several times before applying the prosthesis. The leg should be stored upright with the knee fully extended so that air does not enter the hydraulic spaces.

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Hydraulic/Pneumatic Knee Control Units A Prosthetist's Point of View

Charles H. Pritham, CPO*

As Mr. Wilson has demonstrated, the use of hydraulic and pneumatic control units had its genesis in the post World War II R & D effort. The objective, of course, was to fit the returning veteran AK amputee with the best prosthesis technology could provide. Such amputees were young and physically fit, prime candidates to benefit from the advantages of advanced control units. The prime advantage, usually cited, is cadence responsiveness. As the patient walks at different rates, the control unit automatically adjusts to control heelrise and terminal swing impact. Constant friction knees can not duplicate this feature. All hydraulic and pneumatic units provide this feature and one, the Mauch S-N-S, provides stance phase control as well. This means that the unit provides enhanced knee stability in the early portion of stance phase to increase the patient's safety.

In this mode, the S-N-S unit can be said to function in a fashion analogous to that of a conventional safety knee. In another mode, the function of the S-N-S can be likened to that of a simple manually locking knee. Two other knee control units, variants of Kingsley's Hydranumatic and USMC's Dynaflex, function in a similar fashion.

The Hydracadence, in addition to swing phase control, also provides heel height adjustability and toe pick-up. Otto Bock has recently introduced a modular knee that includes a hydraulic swing phase control.

As can be seen then, these are just a few of the variations available to the prosthetist and his patient. The principle advantages claimed for such control units are enhanced cosmesis and performance, and lower energy expenditure. Against these advantages the disadvantages must be weighed. Bulk, size, and weight of some of the units preclude their use by many patients. The considerable expense of most, if not all, hydraulic and pneumatic control units rules out others. Moreover, the control units have shown to be unreliable. Some patients derive satisfactory service from their units while other patients using the same brand unit are constantly having them replaced and repaired. As most of the units need to be factory serviced, the delay and expense of maintaining a unit under such circumstances can engender considerable frustration.

Given these circumstances, the pool of available amputees for whom such advanced control units are suitable is a small proportion of the total AK population, and most closely resembles the patients for whom they were originally developed: young traumatic males; i.e. veterans. It must be borne in mind that this pool today represents a less important proportion of the amputee population than it did some 25 years ago. Statistics demonstrate that the majority of civilian amputees in the Western World are geriatrics who lose a leg due to arteriosclerosis and are as often as not female. Indeed, the very amputees who were originally provided hydraulic units by the VA are not getting any younger. The day will come for each of them when they, and the clinic teams who attempt to address their needs, must make a reappraisal of their prescription. So, the use of hydraulic/pneumatic control units for a considerable portion of the amputee population can be ruled out. Not only that, but it is possible to be very skeptical in considering the suitability of such units for patients for whom it is theoretically ideally suited.

Young, active traumatic amputees are probably, children aside, the hardest on their prostheses. Given the expense of purchasing and maintaining such a unit, does it make sense to fit an amputee with one if he is going to have more than average maintenance problems? Can he afford the time lost from work, interruptions in his daily life, and expense of repairs? Given the disproportionately rising cost of health care today, can society? Gait studies demonstrate that AK amputees walk slower than normal subjects and BK amputees because of increased energy expenditure. If this is so, is the prime advantage cited for hydraulic/pneumatic units, cadence response, relevant and worth the additional expense and problems? In another vein, given the aging nature of the population should further effort and money be devoted to developing newer and more sophisticated knee control units?

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