ABSTRACT OF SUMMARY REPORT ON RESEARCH AND DEVELOPMENT IN THE FIELD OF ARTIFICIAL LIMBS[a]

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This report discusses progress from July 1, 1970, through June 30, 1971, in the development of lower-extremity prostheses, sponsored by the Veterans Administration, Prosthetic and Sensory Aids Service. Work on three items has been underway: A semi-voluntarily actuated swing- and stance-control knee mechanism (S-N-S System), including development work toward an improved setup; an automatically controlled ankle mechanism, including lateral motion foot control and transverse rotation; and a fully voluntarily actuated swing- and stance-control knee mechanism. The purpose of these developments is to provide as many as possible of the lost muscle functions in the artificial joints involved, without exceeding reasonable limits regarding cost, weight, complexity, and maintenance needs.

The third production run of the *Swing and Stance Control (Type S-N-S) System* is in progress. The demand for this system is still unexpectedly high. It is interesting to note, that by the end of June 1971, 70 bilateral above-knee amputees have been fitted with S-N-S systems.

As a result of experiences from the first two production runs and from systems of the first production run which are coming back from the field for maintenance, a major effort was initiated toward a marked extension of the maintenance-free life of the S-N-S system. The results of this effort are being applied to the third production run.

The improvements arrived at, after extensive testing and theoretical considerations, are designed to reduce the wear of the component parts, to decrease the likelihood of air entering the hydraulic chambers either from the outside or from the reserve oil space inside the system, and to eliminate noises.

The modifications include: the reintroduction of a modified form of

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the original annular (accumulator) piston to reduce cylinder wear, the adoption of a shorter rubber boot for the shortened piston rod to decrease oil consumption, the provision of more clearance between the swing-control damping piston and the surrounding control bushing to reduce abrasion, the modification of the shape of the main spring to eliminate an occasional ("hooting") noise, and the introduction of a flat area on the dashpot circumference, where the lip of the large U-cup comes to rest, in order to prevent the transfer of air from the reserve oil space or from the outside into the hydraulic chambers.

In response to suggestions from prosthetists that we should decrease the minimum swing-phase resistances obtainable within our adjustment range, an extended program was carried out toward this goal which resulted not only in the desired extension of the lower end of the adjustment range but also reduced the influence of viscosity variations of the hydraulic fluid on the swing resistances.

An encouraging finding from the field was that the modified setup for the S-N-S system performed very well: The reduced side play of the knee block combined with tighter radial tolerances of all three bolts eliminated the noises encountered previously.

Substantial progress has been made in the development of the *Hydraulic Ankle Control Unit,* against severe and unexpected difficulties.

Numerous design modifications were included in the system after extensive bench and amputee testing in order to improve the function, reduce wear, and eliminate noises: All the parts inside the unit which slide upon each other under load were made of hardened steel. The weight to be applied by the amputee to initiate the dorsiflexion stop was reduced from 50 to 30 lb. The U-seals on the vane-type piston are now made of a "dry" Buna-N compound which does not shrink or harden in the silicone hydraulic fluid. All the attachment elements for the system inside the shank were redesigned to eliminate noises. For the same purpose, the front end of the unit was equipped with a triangular rubber-lined cup which serves as an attachment element to the prosthetic foot. The most persistent and problematical noise which occurred on toe-off was finally analyzed to be caused by cavitations within the hydraulic fluid between the surfaces of the control bushing and its adjoining design elements. The problem was finally solved by the application of a closely meshed network of grooves on those surfaces of the control bushing and the bolt inside it which separate upon load reversal.

After these modifications, our test amputee wore the system daily for 4 months without incident and with obvious satisfaction. After that wear period, a rubber washer which serves as a cushion between the unit and the heel part of the foot had to be replaced. At that time the

unit was disassembled and it was found that the internal wear was negligible. Based on these results, the second prototype was completed and installed in our test amputee's leg in April. So far no malfunction has occurred. It will now be installed in the prosthesis of a test amputee from New York for further evaluation before starting the shakedown testing of additional systems.

Work on the *Voluntarily Actuated Swing and Stance Control Unit* was resumed in July 1970 on a low priority basis. Good progress has been made in the design work on the prototype hydraulic unit. All the shop drawings for this unit are completed and manufacturing will start in July 1971.

The unit will be shorter than the S-N-S unit, but can still be exchanged for the S-N-S unit in existing legs by attaching an extension part to its cylinder bottom. The space thus obtained can also be utilized for the installation of an elastic member, which enables the amputee to walk in a more natural fashion by locking the unit proper fully but still allowing an elastically limited knee flexion upon heel-contact. In this way the shock-absorbing gait of a natural leg ("double knee bend") would be duplicated for the first time in a prosthesis.

From the present design it appears that the cost of the unit proper will be significantly less than the cost of the S-N-S unit. However, these lower costs do not include the electronic circuitry, including battery, sensor, and feedback elements to be installed in the socket.