

# VETERANS ADMINISTRATION PROSTHETICS CENTER RESEARCH REPORT

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The following presents progress during a 6-month period on a number of research, development, and evaluation projects performed by the VA Prosthetics Center:

## I. PROSTHETICS

### A. Lower Limb

1. Composite Endoskeletal Structures
2. Vacuum Forming Plastic Sockets
3. VAPC Above-Knee Endoskeletal Structures
4. Weber-Watkins Rotator for Lower-Limb Prostheses

### B. Upper Limb

APL Electric Prosthesis

## II. ORTHOTICS

### A. Lower Limb

Vacuum-Formed Ankle-Foot Orthoses

### B. Upper Limb

1. Hosmer Electrically Powered Orthoses
2. Viennatone Orthomot Myoelectric Orthosis
3. Orthosis for Brachial Plexus Injury

## III. SCI REHABILITATION

### A. Mobility Aids and Environmental Controls

1. VAPC Hospital Environmental Control
2. VAPC Home Environmental Control System
3. VAPC Wireless Environmental Control

4. Remote Station Environmental Controls
  5. Battery Monitor for Powered Wheelchairs
  6. Foot Control for Electrically Powered Wheelchairs
  7. Motorized Litters
  8. Microfiche Reader
  9. Breath-Controlled Microfilm Reader
  10. Voice-Operated Environmental Controls
  11. Telescopic Mouth Instrument
  12. Powered Wheelchairs
- B. Clinical Evaluation
1. The Hayes Pneumatic Control for Wheelchairs
  2. The Advanced Wheelchair
  3. Twenty-Four Volt Everest & Jennings Electric Wheelchair
  4. Motorette 24 Volt Power Package for Wheelchairs
  5. Mobilizer
  6. Mercy Lift
  7. Gaymar High Density Fluid (HDF) Support System
  8. Royale Air-Fluidized Bed
  9. Theradyne Marquis Wheelchair
  10. Theradyne Electromatic Wheelchair
  11. Isotorque Ankle Dorsiflexor
  12. Exer-Shoe

#### IV. TESTING

##### A. Standards Development

✓ Hand Controls

##### B. Compliance

Compliance tests were conducted on the following:

- a. Sierra/APRL #44 Voluntary Closing Hand
- b. Sierra/APRL Voluntary Closing Hook

#### I. PROSTHETICS

##### A. Lower Limb

1. *Composite Endoskeletal Structures.* Clinical findings from recent testing of the VAPC above-knee endoskeletal prosthesis (Multiplex) indicated the need for several design changes. The consensus of the clinics was that the shank be substantially reduced in size and all sharp exterior angles designed as flowing curves. The smaller, stream-



FIGURE 1.—Graphite-epoxy shank.

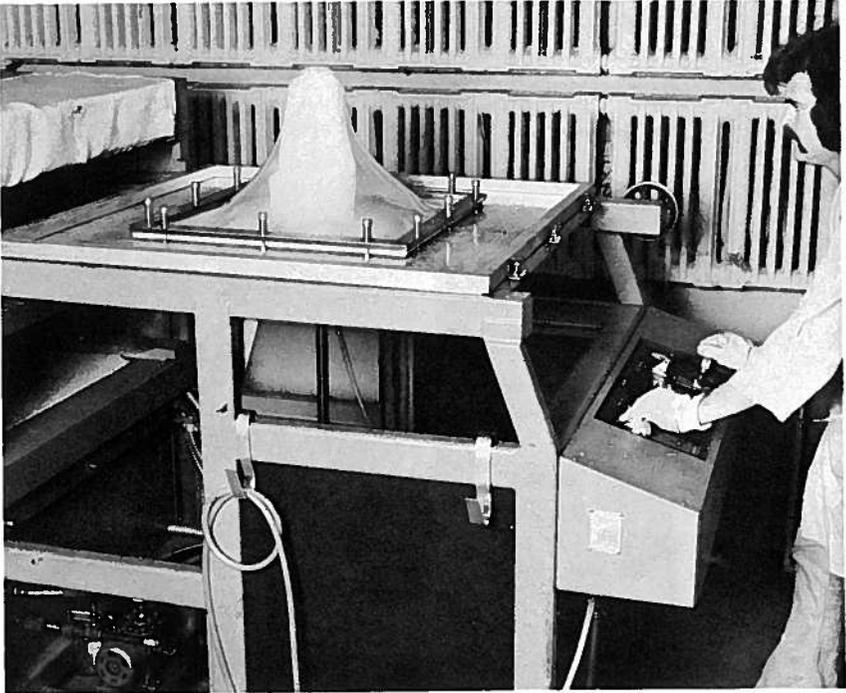


FIGURE 2.—Vacuum-forming plastic sockets.

lined shank will simplify the fabrication of a custom-shaped soft foam cover (Fig. 1).

To implement this approach, a contract has been entered into with the Northrop Corp. of Hawthorne, California. Initially they are to develop an inexpensive manufacturing process for making a graphite-epoxy shank system. The prosthetic knee and foot are to be added later. It is anticipated that great strength and a weight savings of at least 30 percent can be obtained by this process.

2. *Vacuum Forming Plastic Sockets* (Fig. 2). Work continues to develop suitable bonding procedures for joining plastic vacuum-formed sockets to the other components which make up a prosthesis. We are experimenting with textured materials embedded in the outer socket surface to improve the bonding characteristics of the smooth thermo-plastic materials. We are working with two laboratories who specialize in sonic welding of plastic materials to investigate this method for joining the prosthetic components.

3. *VAPC Above-Knee Endoskeletal Structures*. The clinical study of the endoskeletal above-knee prosthesis (Multiplex) has been terminated. Response from the field stations participating in this study

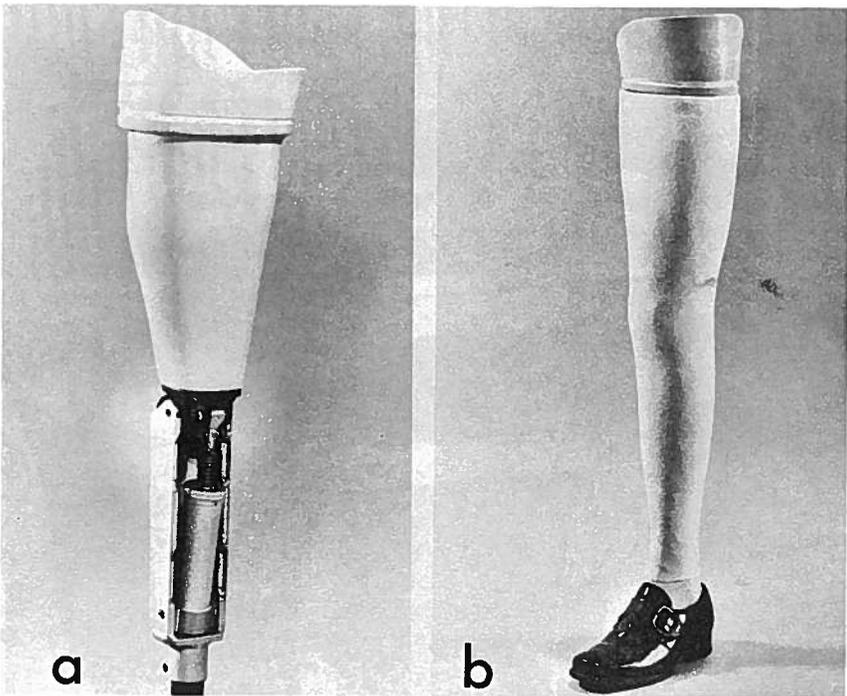


FIGURE 3.—a. VAPC endoskeletal structure, b. cover for endoskeletal structure.

brought out a number of problems. The prosthetists were in unanimous agreement that the knee design did not permit sufficient flexion. They felt that the external angular contours and the size of the shank caused serious difficulty in shaping the cosmetic foam cover. All agreed that the other basic functions were satisfactory (Fig. 3a).

Most of the patients expressed an initial desire for the cosmetic cover but later had reservations about its durability. All were favorably impressed with the light weight and function of the prosthesis. The consensus of the clinics was that the shank size should be reduced and streamlined to facilitate shaping the foam cover (Fig. 3b).

As a result, the basic prosthesis has been modified. The prosthesis shown in the illustration is a further development of the VAPC Multiplex concept (Fig. 4a). It conforms to Veterans Administration needs requiring certain fluid knee controls and other mechanical friction systems to be received in a single structure. Interchangeability of the knee systems makes available to the user the wide range of functional characteristics inherent in many different knee mechanisms even after the prosthesis is completed.

The unit fits into a prefabricated urethane-foam shank cover (Fig. 4b). The cosmetic effect thus obtained is not as desirable as the continuous, custom-shaped foam covering previously used. As an expedient, however, it is inexpensive, durable, and readily available. Although this system is now in production, efforts continue to provide a single-piece cover.

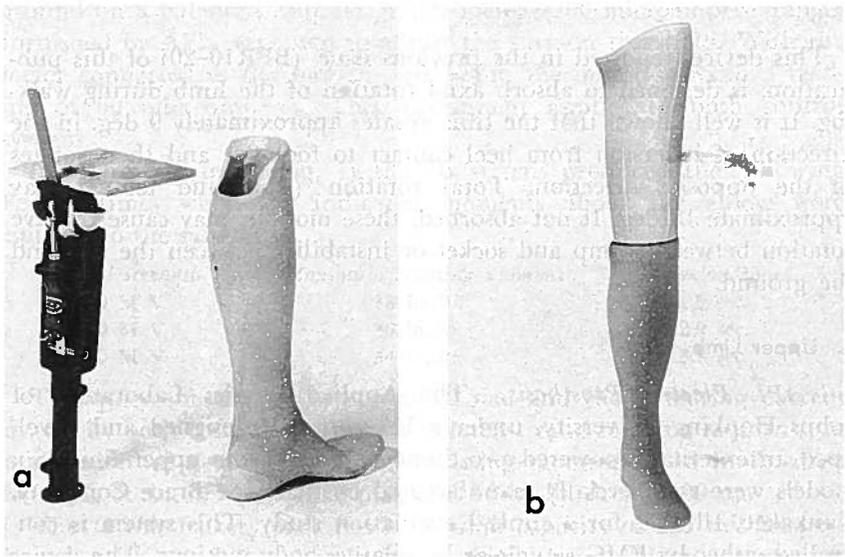


FIGURE 4.—a. VAPC Multiplex concept further developed, b. prefabricated urethane-foam shank cover.

4. *Weber-Watkins Rotator for Lower-Limb Prostheses.* Reports from clinical tests in the field and at the Veterans Administration Prosthetics Center indicate that this pivot joint provides useful function and that it is quite durable. The data were sufficient to warrant its inclusion in the Artificial Limb Contract. However, we will continue to monitor patient reactions to the device to further clarify prescription indications (Fig. 5).

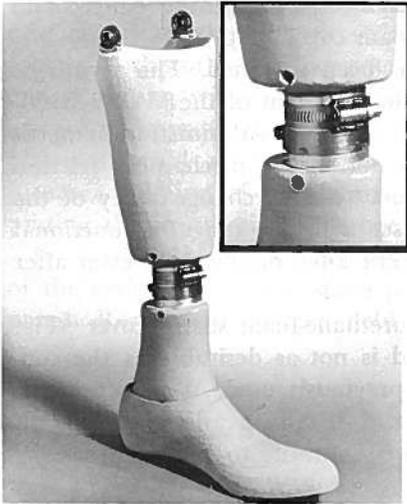


FIGURE 5.—Weber-Watkins Rotator (close-up in inset).

This device, reported in the previous issue (BPR10-20) of this publication, is designed to absorb axial rotation of the limb during walking. It is well known that the tibia rotates approximately 9 deg. in the direction of inversion from heel contact to foot flat and then rotates in the opposite direction. Total rotation (tibia and femur) may approximate 18 deg. If not absorbed, these motions may cause relative rotation between stump and socket or instability between the feet and the ground.

## B. Upper Limb

1. *APL Electric Prosthesis.* The Applied Physics Laboratory of Johns Hopkins University, under a VA contract, designed and developed an externally powered prosthetic system for the upper limb. Six models were commercially manufactured by the Pope Brace Company, Kankakee, Illinois, for a clinical evaluation study. This system is controlled either by EMG signals or by relative body motions. The device is an electrically driven cable system for powering elbow flexion and the voluntary opening of terminal devices (Fig. 6). The system con-

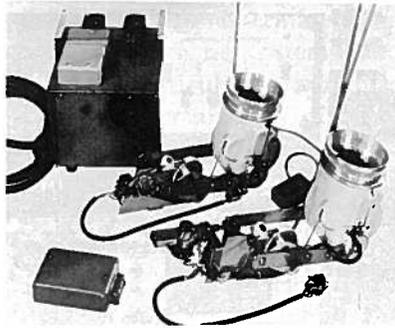


FIGURE 6.—APL Prosthetic System.

sists of a drive motor and gear train, forearm pulley assembly, control mechanism, battery pack, and battery charger. All components except the battery charger are contained within the elbow and forearm assembly.

The system has two methods of control, a myoelectric signal sensor and a body motion displacement transducer. The myoelectric sensor reacts in proportion to the magnitude of an EMG signal. The EMG sensor contains an operational amplifier which provides impedance matching with the body, and preamplification (gain = 67 dB.) of EMG signals. Test signals were introduced at the electrodes with the impedance matched to simulate good skin contact (11,000 ohms to ground on a balanced output). A test meter (200 microampere range) furnished by APL, was used to adjust the turn-on threshold. With the meter connected to the forearm test point, the motor starts at a reading of 60 microamperes. This adjustment applies to both control systems.

In laboratory tests (Fig. 7) 150 Hz signals produced the following flexion times when the indicated moments about the elbow were applied to the system:

<i>Signal strength</i>	<i>Maximum resisting moment</i>	<i>Flexion time</i>
150 M V	18 in.-lb.	1.5 sec.
200 M V	36 in.-lb.	2.9 sec.
200 M V	54 in.-lb.	3.3 sec.

The quiescent current level was 12 ma. and the operating current drawn by both control systems was related to the resisting moments, as expected from a torque motor. A resisting moment of 18 in.-lb. drew 800 ma., 36 in.-lb. drew 1330 ma., and 54 in.-lb. drew 1800 ma.

The 15-volt battery pack has a *nominal* capacity of 225 milliampere hours (mah.) and a pulse discharge capability of 18 ampere-seconds per pulse, for pulse trains of less than 5 seconds, which are distributed over the entire discharge period.

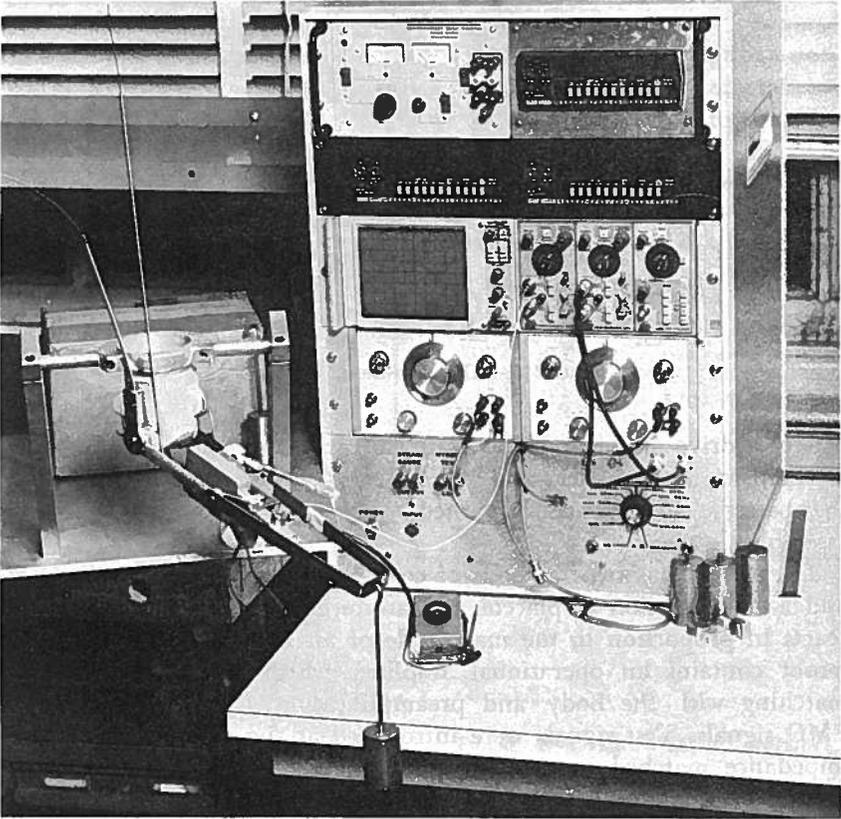


FIGURE 7.—Testing of APL Powered Prosthetic System.

The displacement transducer reacts to body motions similar to those controlling flexion of the elbow joint and the terminal device (Fig. 8). The forces and excursion required are much smaller than in the conventional systems. The force of the cable is transferred from the elbow to the terminal device when the elbow is locked. The system uses a modified Hosmer E-500 outside locking joint which requires conventional body motion for operation.

The quiescent and operating currents were measured across a precision milliohm shunt and displayed on the oscilloscope. Delay time and flexion time were simultaneously displayed. A series of moments about the elbow were applied to the system in 18 in.-lb. steps. At the maximum gain setting with a load of 18 in.-lb. in the terminal device and the elbow at 90 deg. flexion, the EMG controlled system has a relatively flat response to 150 input signals of Hz at 200 microvolts\* and higher.

\* All voltages are measured peak-to-peak.

Our evaluation is designed to determine the effectiveness of the Johns Hopkins Powered Prosthetic System for general use among above-elbow and shoulder-disarticulation amputees. It consists of laboratory testing and engineering analyses of the design, construction, and function. Also included are clinical trials in which patients will be fitted to obtain their subjective reactions, prosthetists' experience in fitting, and clinical analyses of performance. Data to be recorded include subjective reactions of patients to the device in comparison with previously worn devices and particularly, to the myoelectric control and electromechanical control. Prosthetists' experience in convenience of installation, fabrication, and maintenance requirements will also be analyzed.

## II. ORTHOTICS

### A. Lower Limb

1. *Vacuum-Formed Ankle-Foot Orthoses.* (Fig. 9) At VAPC, Ankle-Foot Orthoses (AFO) are being routinely vacuum-formed of polypropylene sheets ranging from  $\frac{1}{8}$  in. to  $\frac{1}{2}$  in. thick. Results to date have been excellent. The present equipment has limitations as to the size

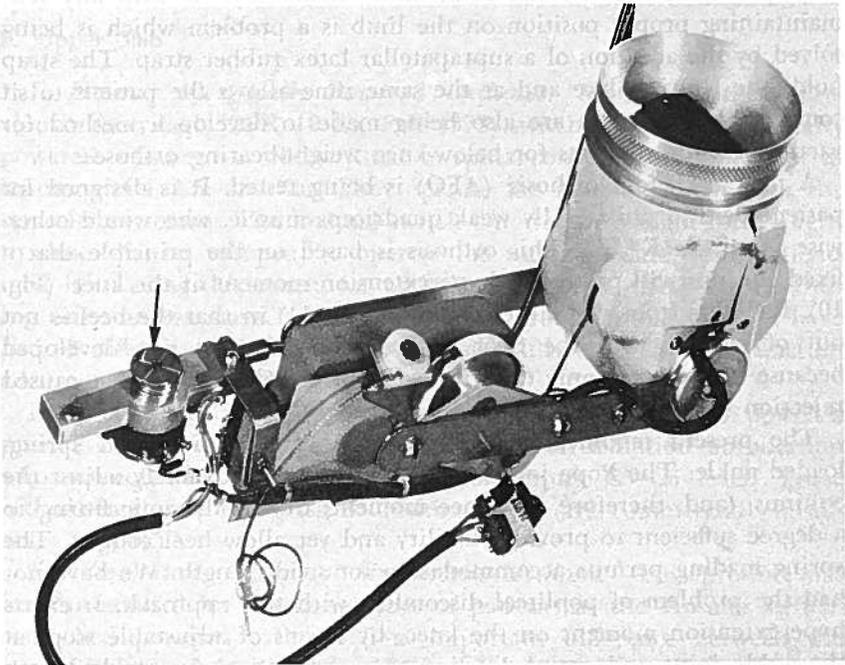


FIGURE 8.—Displacement transducer.

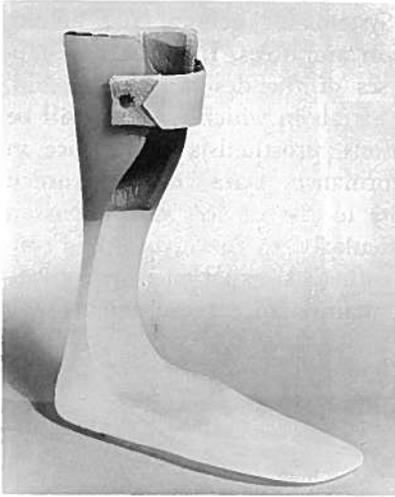


FIGURE 9.—Vacuum-formed ankle-foot orthosis.

of the appliance that can be vacuum-formed. Knee Orthoses (KO) are vacuum-formed as a single mold. Side joints (made of polypropylene or polyethylene) have to be added after vacuum forming over the cast. The quality of the KO has been most satisfactory. As with any KO, maintaining proper position on the limb is a problem which is being solved by the addition of a suprapatellar latex rubber strap. The strap holds the KO in place and at the same time allows the patient to sit comfortably. Attempts are also being made to develop a method for vacuum forming sockets for below-knee weight-bearing orthoses.

A new ankle-foot orthosis (AFO) is being tested. It is designed for patients with a unilaterally weak quadriceps muscle, who would otherwise require a KAFO. This orthosis is based on the principle that a fixed equinus will produce a hyperextension moment at the knee (Fig. 10). It differs from the Saltiel orthosis (Fig. 11) in that the heel is not out of contact with the floor on weight-bearing. It was developed because of the commonly experienced popliteal discomfort that caused rejection of the Saltiel type.

The present modification employs Pope ankle joints and spring-loaded ankle. The Pope joints enable the orthotist to finely adjust the equinus (and, therefore, the knee moment) during dynamic fitting to a degree sufficient to provide stability and yet allow heel contact. The spring loading permits accommodation for stride length. We have not had the problem of popliteal discomfort with this approach. It exerts hyperextension moment on the knee, by means of adjustable stops at the ankle joint and spring loading to accommodate for stride length to assist weak quadriceps during the stance phase of the gait cycle.

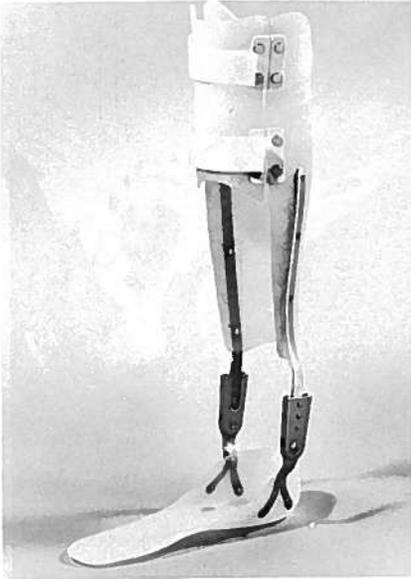


FIGURE 10.—Ankle-foot orthosis (with springs at the ankle joint).

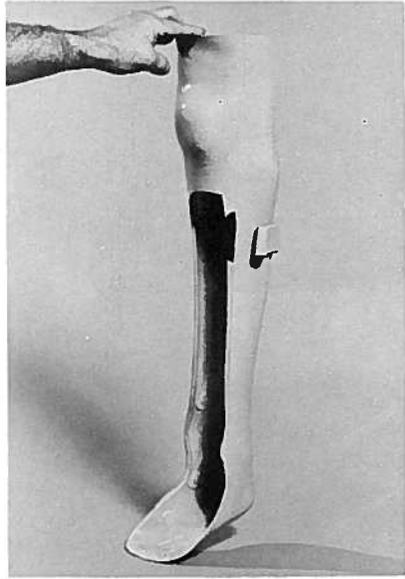


FIGURE 11.—Salties orthosis.

## B. Upper Limb

1. *Hosmer Electrically Powered Orthoses.* Several of these previously described (BPR 10-20, Fall 1973) switch-controlled electrically powered orthoses have been fitted to spinal-cord-injured patients with lesions at C4, C5, and C6. They operate the manual switch with the opposite extremity. The manual switch only requires slight force (light to close—harder to open) to operate the unit. To date, four patients have been using this system for periods of 4 months to 1½ years. During this time, we have had no mechanical problems and patients have had no difficulty in learning its functions. Fully charged units function adequately for a full day.

In an unusual application, this device has been used to power a prosthetic hook for a patient with a wrist-disarticulation amputation who subsequently sustained a spinal-cord-injury C5-C6 level. These orthoses are now being issued routinely and are commercially available (Fig. 12).

2. *Viennatone Orthomot Myoelectric Orthosis.* This product has been prescribed for the same types of patients as the Hosmer switch-controlled powered orthosis. The important difference between the two units is that the Orthomot is myoelectrically controlled while the Hosmer unit is switch-controlled. In most cases it frees the opposite

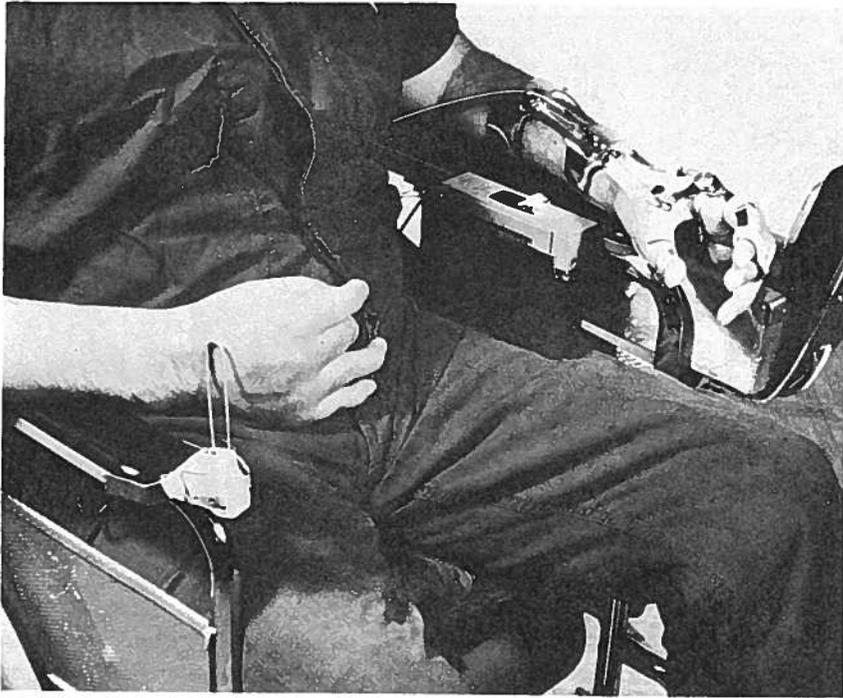


FIGURE 12.—Hosmer electrically powered upper-limb orthosis.

limb for motions required in activities of daily living. Three patients have been using the myoelectric orthoses for periods of 4 months to 1 year. Two of the patients are using the upper portions of the trapezius muscle and one patient is using the biceps muscle as EMG control sites. Operation is sequential: contraction of these muscles will close the orthosis, recontraction of the same muscles will open the orthosis.

To operate the device EMG signal strength must be of sufficient magnitude to exceed an adjustable threshold. In a few patients with inadequate EMG signal strength the unit functioned erratically. Reeducation of the muscles of SCI patients may be quite time consuming. In these cases, we employ the Hosmer switch-controlled orthosis, giving them earlier use of their orthosis. Fully charged overnight, the units function adequately for a full day.

3. *Orthosis for Brachial Plexus Injury.* We are developing a myoelectrically controlled shoulder/elbow/wrist/hand orthosis (SEWHO) for a brachial plexus injury which results in a completely flail limb. These patients are ambulatory, requiring miniaturization of components to allow the orthosis to be carried by the patient. The fabrica-

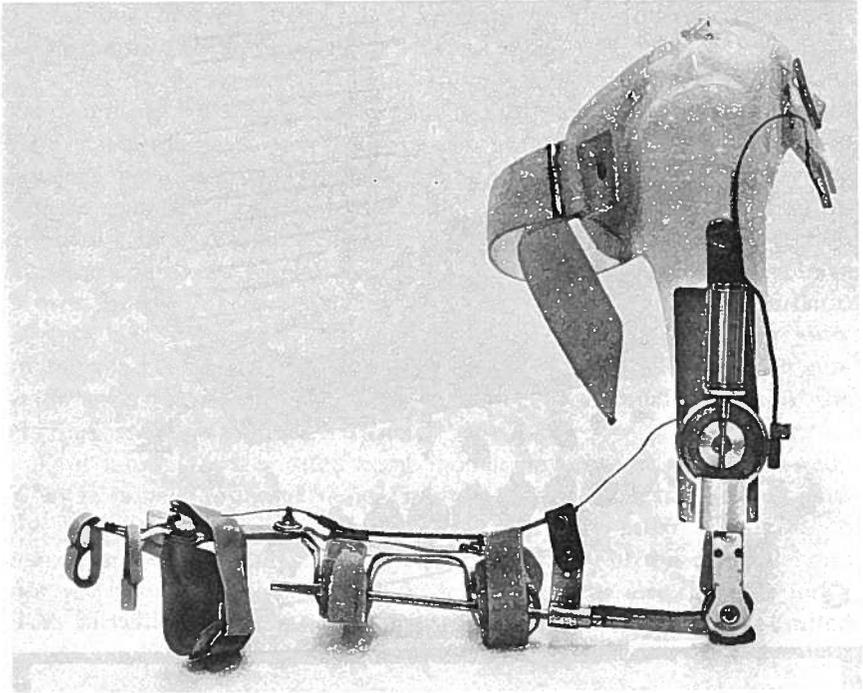


FIGURE 13.—Myoelectrically controlled shoulder/elbow/wrist/hand orthosis (SEWHO).

tion of one unit is now in progress. Using only one cable it will operate both the elbow and the hand (Fig. 13).

### III. SCI REHABILITATION

#### A. Mobility Aids and Environmental Controls

1. *VAPC Hospital Environmental Control.* The *VAPC Hospital Environmental Control* is now commercially available from Teleoperators, Inc., P.O. Box 3584, Los Amigos Station, Downey, Calif. 90242 (Fig. 14a). The deployment of approximately 25 units at Spinal Cord Injury Services throughout the VA Hospital system has shown that the device is a very useful aid to the severely physically handicapped. The current design provides a total of 12 channels: four 110-volt a.c. grounded outlets, six 12-volt a.c. momentary outlets for operating remote switching systems, and two shorting jacks which provide simple switching operations. The power and control section has also been improved for greater reliability (Fig. 14b). With the completion of an extensive evaluation program, information regarding the description and availability of the device has been circulated through the

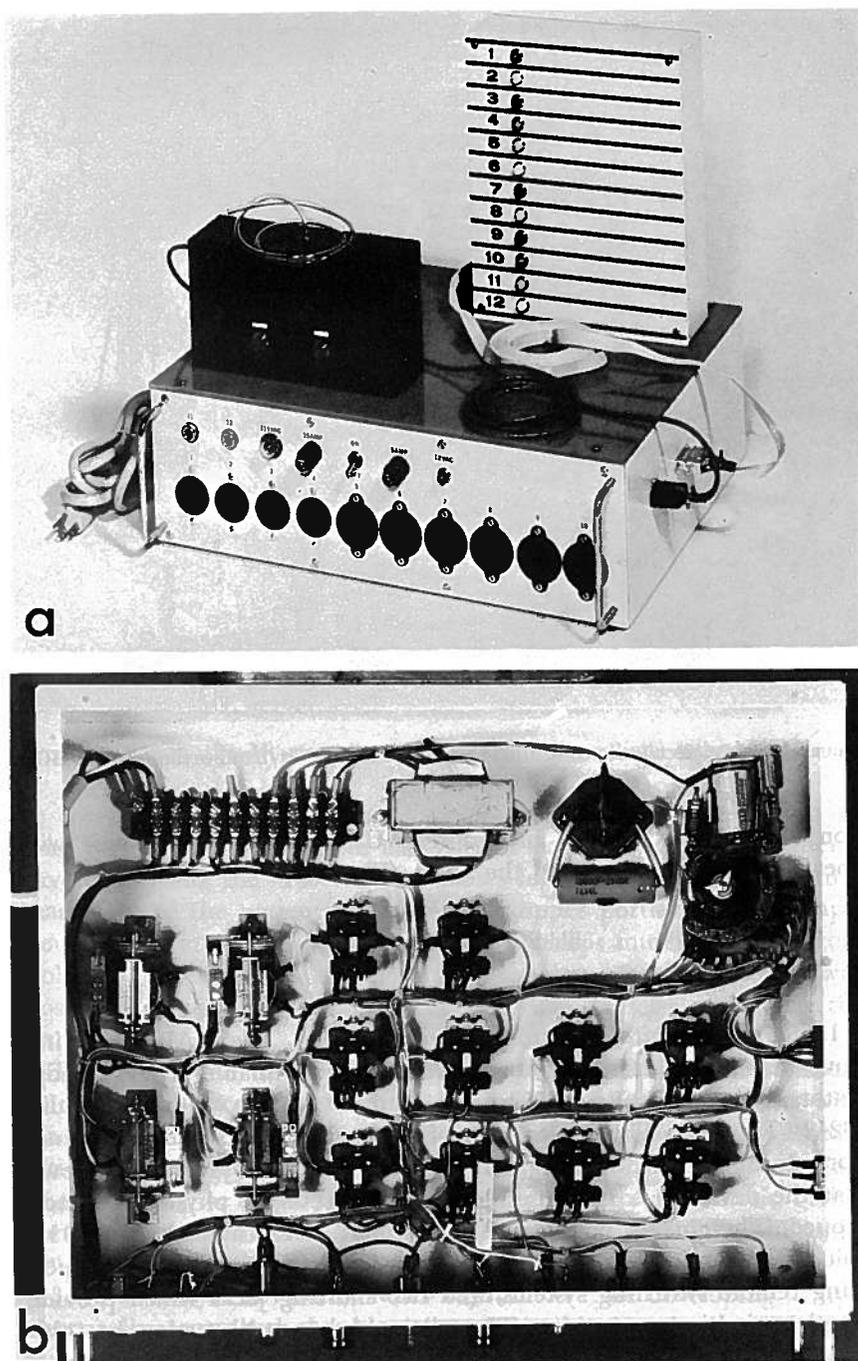


FIGURE 14.—a. VAPC Hospital Model Environmental Control System, b. inside view of power and control section.

Professional Services Letter of the Veterans Administration Department of Medicine and Surgery, dated November 23, 1973.

2. *VAPC Home Environmental Control System.* The VAPC Home Environmental Control System provides 20 channels for operation of electrical appliances. Included are two switching channels, three 110 volts a.c. grounded outlets, 12 momentary low voltage outlets for operation of remotely located switches, and three channels for operating an automatic dialing telephone (Fig. 15). The power and control section also incorporates a special outlet that provides a constant low voltage source for an intercom system. As discussed in the previous Bulletin of Prosthetics Research (BPR 10-20), the home model has an automatic channel sequencing circuit which is actuated by developing constant negative pressure on the air tube or by manually pressing the channel select push button switch.

Four laboratory-fabricated home models have been deployed to date. They have been found extremely useful for the special needs of patients living in the home. They seem to perform very reliably; almost no maintenance has been required. The full capacity of the controller has not yet been used, since auxiliary devices such as electric door locks, T.V. surveillance systems, etc., are still under development. A limited

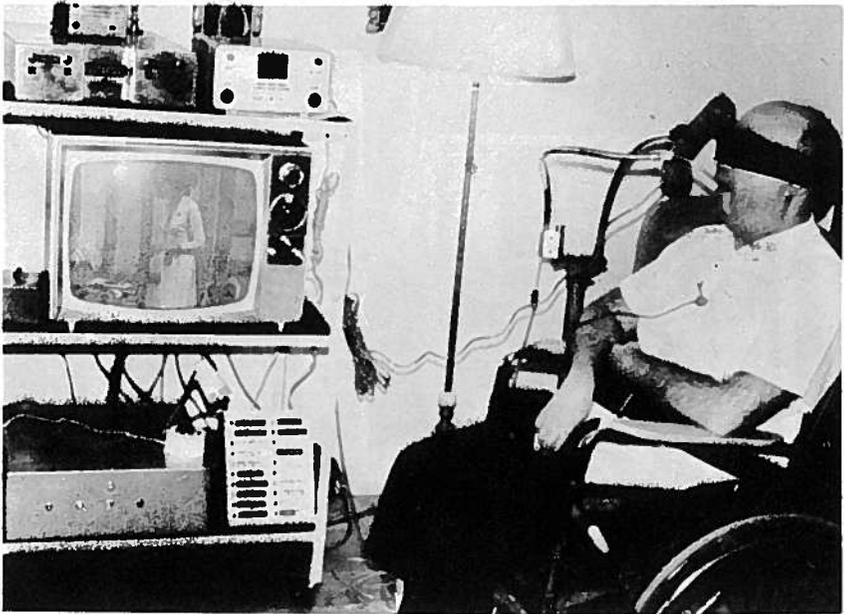


FIGURE 15.—VAPC Home Model Environmental Control operates telephone dialer, special channel changing T.V., and VAPC E.C. Radio.

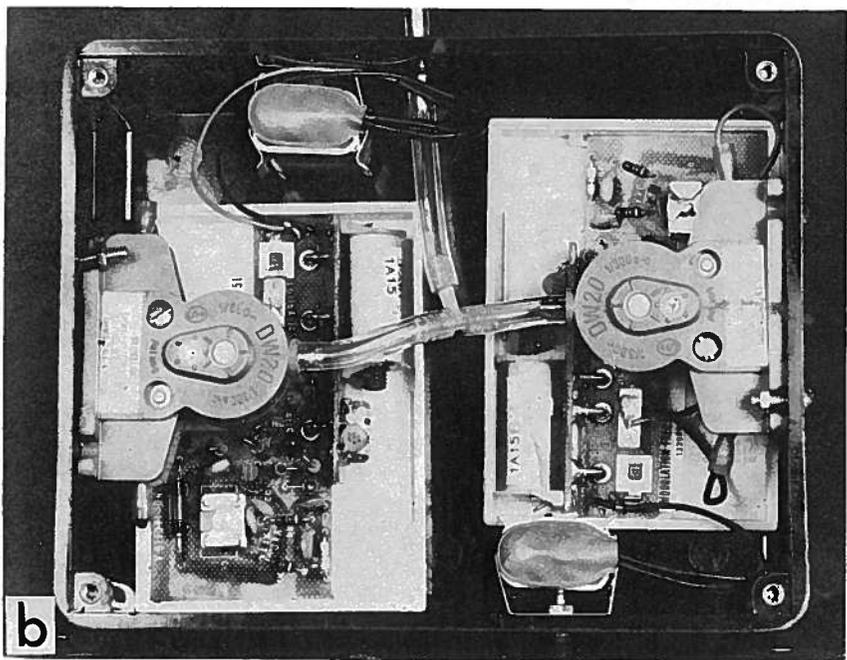
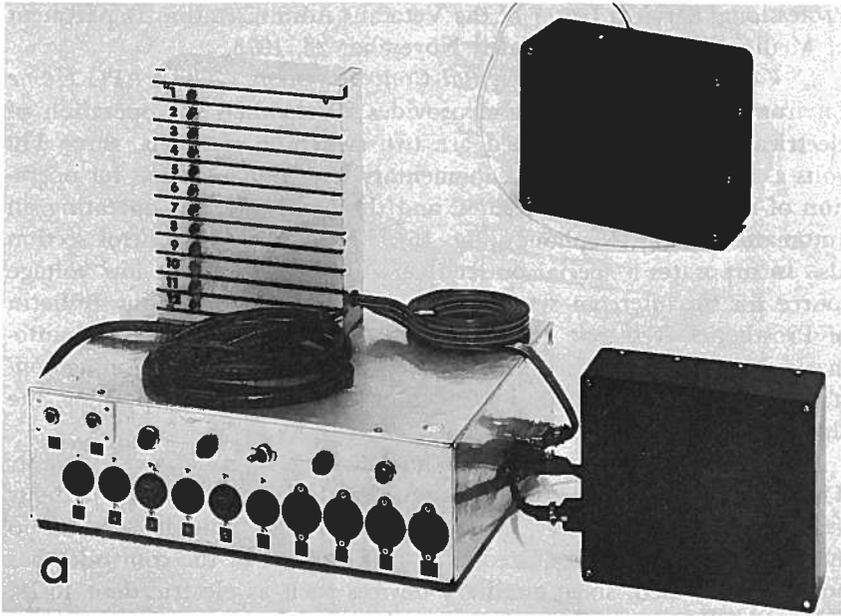


FIGURE 16.—a. VAPC Wireless Environmental Control power and control section and monitoring section are electrically connected. Actuator is wireless. b. VAPC Wireless Environmental Control actuator showing pneumatic switches and transmitter.

number of production units is being fabricated and will be deployed at selected sites.

3. *VAPC Wireless Environmental Control.* A prototype wireless environmental control (Fig. 16a) permits high lesion level quadriplegics, and similarly disabled individuals, to operate electrical appliances while in bed or from a remote location in a powered wheelchair. The wireless actuator (Fig. 16b) is housed in a support bracket on the wheelchair (Fig. 17). It may also be supported in a bracket adjacent to the bed.

Although wireless control may not offer substantial improvements over hard-wired controls in the hospital, great advantages are anticipated in the home use. In the hospital, at least in the bedside environment with the patient relatively static in bed and operating one array of devices in a console or in brackets around the bed where connections may not be highly inconvenient or hazardous, wireless control may not be as important. Nevertheless, even in this milieu, radio or sonic control eliminating wires would provide greater flexibility in the placement of appliances, in improved neatness around the bed area, and in reduced hazard related to falling and tripping over wires. On

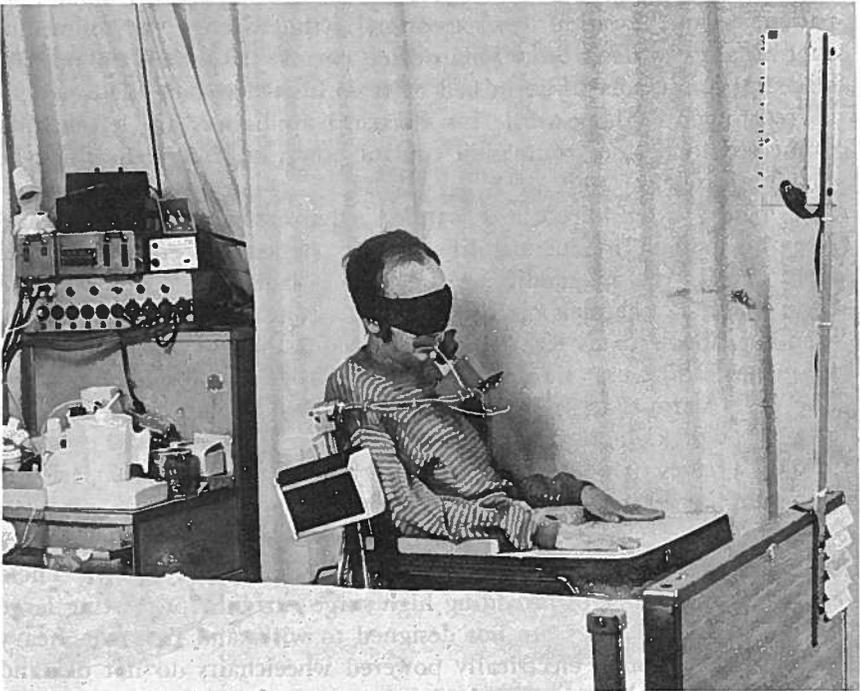


FIGURE 17.—VAPC Wireless Environmental Control actuator mounted on wheelchair.

the other hand, in a home, telemetry may permit the operation of several different arrays of appliances in several different locations with the patient capable of moving into and out of different appliance "sets."

The wireless system operates in a manner similar to the conventional VAPC Hospital Environmental Control. The main difference is that constant sucking on the air tube activates an automatic channel changing circuit. When the desired channel is displayed the patient stops sucking. By blowing into the air tube he then actuates the selected T.V. channel.

The first laboratory model was installed at the Castle Point VA Hospital for evaluation. The early reactions of a quadriplegic patient corroborate our thinking to some extent. He suggests that the wireless system offers a certain limited utility in the hospital, but we believe it would be an extremely useful tool in the home environment. More experience on the need for and use of telemetry systems in the home environment will be obtained.

4. *Remote Station Environmental Controls.* Enabling a seriously handicapped individual to operate different groups of electrical appliances located throughout his home may fulfill important patient needs. All currently available environmental control systems confine the patient to one location; an exception is the wireless environmental control already described. This device permits a patient to operate electrical appliances while in bed or from his wheelchair. The patient is free to move about while his electrical appliances are left behind connected to the environmental control power section with which he communicates by radio.

A logical extension of the wireless environmental control should permit a patient to operate different sets of appliances as he moves about freely. We are modifying the wireless control system to actuate each of the 12 channels of the VAPC Environmental Control System. The air tube actuates RF transmitter circuits that operate at different frequencies. The user simply selects the desired function, but its actuation is by radio. Each remote wireless channel and appliance is operated through a single receiver circuit on one frequency. Each remote station receives its power from any nearby electrical outlet and, therefore, may be located anywhere in the home.

5. *Battery Monitor for Powered Wheelchairs.* Lead-acid automotive batteries are normally used to power electrical wheelchairs. These batteries are capable of providing high surge currents for starting large engines. However, they are not designed to withstand frequent, heavy discharges. Although electrically powered wheelchairs do not demand high current discharge rates, the batteries are often almost completely discharged at the end of a day's use. Consequently, it is not uncommon

for powered wheelchair batteries to have very short lives. Furthermore, the charge capacity, as well as effective life, may deteriorate with little or no warning. It is not unusual for many relatively active powered wheelchair users to find themselves immobile towards the end of their day's activities. It is therefore important to prevent excessive battery discharge in order to maintain normal battery life.

The most suitable batteries for this application are the golf cart or electric vehicle type. This kind of battery does not deliver high discharge rates but is more effective for electric wheelchair applications than the automotive type. Unfortunately, electric vehicle batteries are not readily available and so the automotive variety is commonly used for powered wheelchairs.

We have developed two effective and inexpensive battery monitors to check battery charge. Included is a meter-type device (Fig. 18) that provides qualitative feedback on the battery charge level. The other (Fig. 19) makes use of flashing indicator lights that is activated when the battery energy falls below a predetermined level. Both indicating devices monitor the battery voltage level. When a freshly charged battery, in excellent condition, has expended a certain amount of energy during the day, either monitor will indicate a low voltage level, which means low battery energy. A battery, near the end of its useful life will be detected by either monitor if it has not retained sufficient charge for a normal day's operation after an overnight charge.

We believe that such a device will be useful to active wheelchair



FIGURE 18.—Close-up of battery monitor (meter-type).

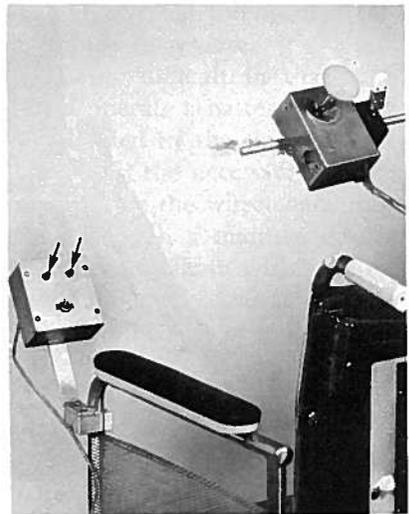


FIGURE 19.—Battery monitor with indicator lights.

users, especially those who are involved in vocational and educational activities.

6. *Foot Control for Electrically Powered Wheelchairs.* From time to time we receive requests for foot controlled electrically powered wheelchairs for patients who retain some foot motion but no arm or hand motion. One such case, an incomplete C-1 quadriplegic, requiring a respirator via tracheotomy for life support, exhibited good foot excursion. His arms and hands were, of course, paralyzed and a foot control for electrically powered wheelchairs was designed and fabricated for him.

The main power switch is operated pneumatically by generating positive pressure in a tube in the mouth. On/off commands are sequentially effected by breath (Fig. 20). The device employs a modified joy



FIGURE 20.—Foot control for electric wheelchairs has main power switch operated by means of breath control.

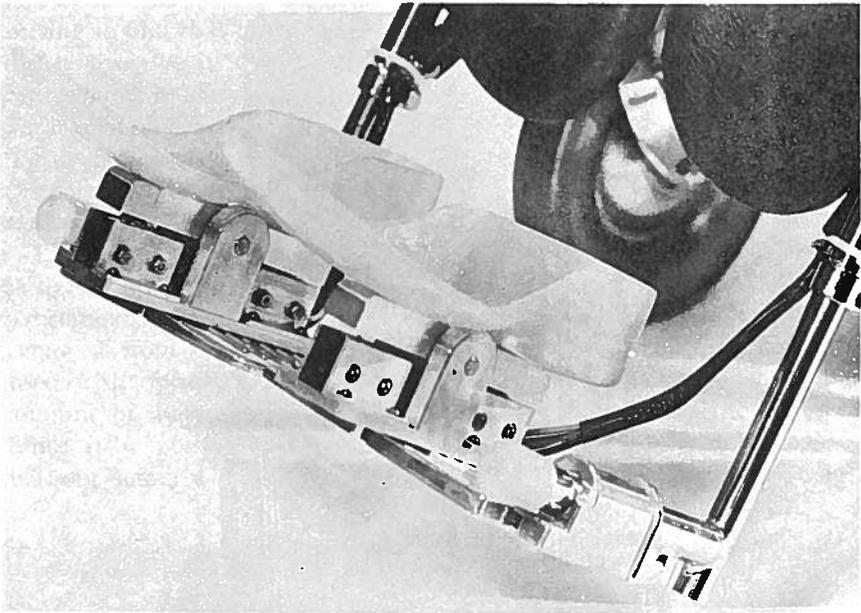


FIGURE 21.—Microswitches control an electric wheelchair via custom fabricated foot-plates.

stick control circuit in which each half of the control circuit is operated by one foot through a custom fitted foot plate (Fig. 21). Plantar-flexing the foot tilts the foot and drives the selected motor in a forward mode while dorsiflexion drives the motor in reverse.

The packaging requirements were unusually difficult in that sufficient space was needed to accommodate and operate a battery powered respirator. The problem was further compounded by the chair, a fully reclining model. The final assembly provided all the necessary features with one battery carried fore and the other aft on the wheelchair. The printed circuit (pancake) motors were mounted in a manner similar to the Motorette (Fig. 22). The completed wheelchair with motors, foot control assembly, portable respirator, and two batteries, in the fully reclined as well as upright position combined to make a highly effective system.

The patient learned to operate the wheelchair quickly and skillfully. A major problem noted during the first week of use was the difficulty of placing the patient in the chair the same way each time he used it. If his position shifted, he could not adjust it to properly operate the controls. In highly customized configurations used by patients with little or no independent movement, hospital staffs must be alert to these possibilities.

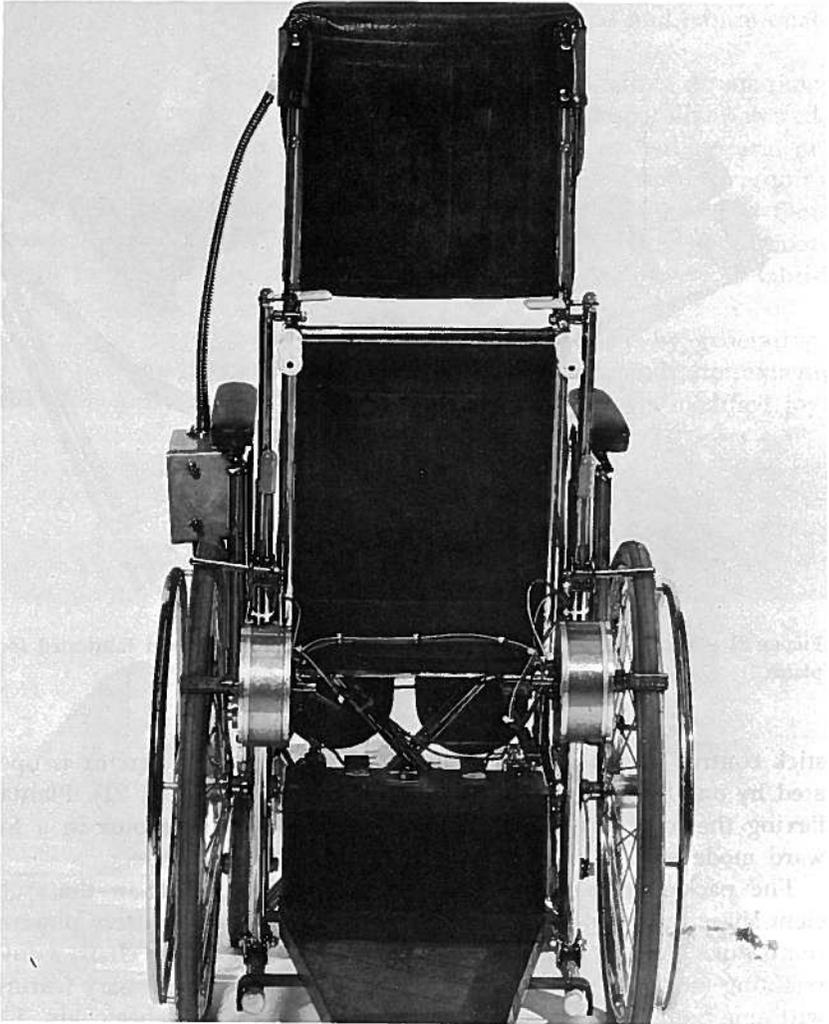


FIGURE 22.—Printed circuit (pancake) motors mounted on the rear of the chair for total packaging requirements.

7. *Motorized Litters.* Motorized litters are not frequently used. However, when a powered litter is required, wheelchair manufacturers usually assemble an underpowered electrical wheelchair motor package and controller to the litter. To improve the performance we have installed printed circuit (pancake) motors on the litter in Figure 23.

This power package is easily converted for use on litters. Care needs to be exercised in balancing the weight of the assembly. Since it is very awkward to steer the litter with the casters in the rear, the patient is

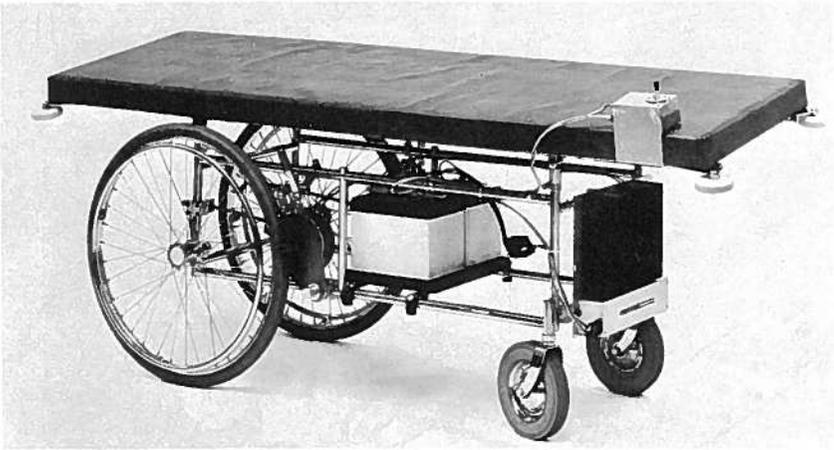


FIGURE 23.—Powered litter is maneuvered by proportional joy stick and printed circuit motor.

positioned with his weight forward towards the small casters to facilitate steering. The drive wheels are thereby unloaded and traction may be critically reduced between the drive wheels and the floor. This problem is alleviated by placing both 12-volt batteries in the rear just forward of the large drive wheels.

8. *Microfiche Reader.* As discussed in the previous issue of the *Bulletin of Prosthetics Research* (BPR 10-20), we have been concerned with the development of a pneumatically controlled electromechanical microfiche reader for high lesion level quadriplegics. The Kodak Ektalite 120 Microfiche Reader in its normal configuration is manually operated and provides two knobs and a push-pull handle for operation. One knob adjusts focus and the other adjusts the horizontal travel of the microfiche card. The push-pull control adjusts the vertical travel of the microfiche card. To adapt these devices for use by quadriplegics, all three manual controls were replaced by electromechanical assemblies (Fig. 24).

The pneumatic control, similar in principle to that of the VAPC Environmental Control System, is operated by developing negative and positive pressures in the air tube. Sequential sucking on the air tube changes the three available modes: vertical travel, horizontal travel, and focus adjustment. Sequential blowing into the air tube activates the selected mode by causing motion in one direction, stopping motion, motion in the reverse direction, stopping, etc. The pneumatic control and the basic reading device are connected by means of plugs and sockets in a modular fashion. One unit, introduced into the Castle Point VA Hospital Library (Fig. 25) has been in service since



FIGURE 24.—Breath-controlled electromechanical microfiche reader.

December 1973. Preliminary reports from the librarian and several patients indicate that it is quite useful but that the viewing screen is too small. We are modifying several units for further evaluation.

9. *Breath-Controlled Microfilm Reader.* Microfiche readers are highly effective in reading up to 100 or more pages of text material on single 4 in. by 6 in. microfiche cards. However, for those severely physically disabled individuals who, for educational and occupational purposes, require access to relatively large amounts of reference material, the microfiche reader may not have sufficient capacity.

We are modifying a microfilm reader for breath control. The microfilm capacity exceeds that of microfiche cards by a factor of fifty or more. We are initiating this effort with the Kodak Recordak Motoromatic Reader. This device is already motorized and readily lends itself to conversion to breath control.

10. *Voice-Operated Environmental Controls.* As discussed in the previous issue of the Bulletin of Prosthetics Research (BPR 10-20), harnessing spoken speech, although technically difficult, may be a very natural and effective approach to the operation of environmental controls. To evaluate the utility of voice control we have obtained a voice recognition system from Scope Electronics Co., Reston, Virginia. The University of Santa Barbara has also developed a spoken speech recog-

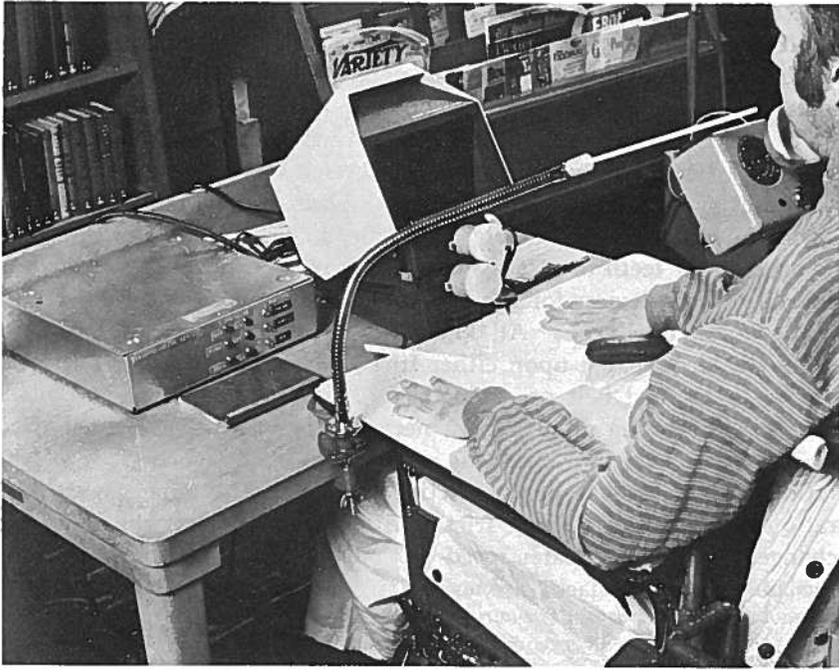


FIGURE 25.—Breath-controlled reader at VAH Castle Point, N.Y., library.

nition system. We are procuring several models of this system for evaluation in parallel with the Scope Electronics system. We plan to investigate the application of voice recognition techniques for the operation of electric typewriters as well as other appliances.

11. *Telescopic Mouth Instrument.* Since the first environmental control system ("POSSUM") came to our attention, the basic concept has generated considerable attention here and abroad. All the known devices exhibit common limitations in that the disabled user is physically confined to the system and/or the system is connected to the various appliances. Consequently, consideration has been given to advanced types of environmental controls such as voice recognition systems, and wireless, remote station subsystems, such as those described above. Remote manipulators, mounted on wheelchairs or any place convenient to the patient, may provide some substitution for upper-limb capability. Most of these devices, such as industrial teleoperators, are not readily available or directly applicable to the physically disabled.

In the meantime, a very basic but interesting device is the telescoping mouth stick (Fig. 26) developed by Arthur J. Cloran, D.D.S. His motorized telescoping device is operated by the patient's tongue.

The appliance is held in the patient's mouth by means of a custom-fitted mouthpiece (Fig. 27) to optimize pressure distribution. This device may be mounted on the user's wheelchair, enabling him to turn lights on and off, push elevator buttons, dial telephones, paint, etc. Two patients have been fitted with Dr. Cloran's device. They are presently being evaluated at the Cleveland VA Hospital. Initial responses by high level quadriplegics are positive. The battery-operated device is said to be relatively stable in the mouth and it does not damage either teeth or soft tissue. The device is a novel entry into the arsenal of new devices for the severely handicapped.

12. *Powered Wheels.* All known electrically powered wheelchairs use direct drive based upon either friction, or a more positive method such as a toothed belt or chain drive. Each has advantages or disadvantages depending upon patient needs. Friction drive is characterized by motor efficiency, an excellent mechanical advantage because of the ratio of the diameters of the friction drive and the large wheel. The ratio of the diameters of the friction drive and the large wheel is easily changed to achieve greater speed or ramp climbing capability. Among the potential drawbacks are excessive tire wear, the danger of tire



FIGURE 26.—Telescopic action is useful for a variety of applications.

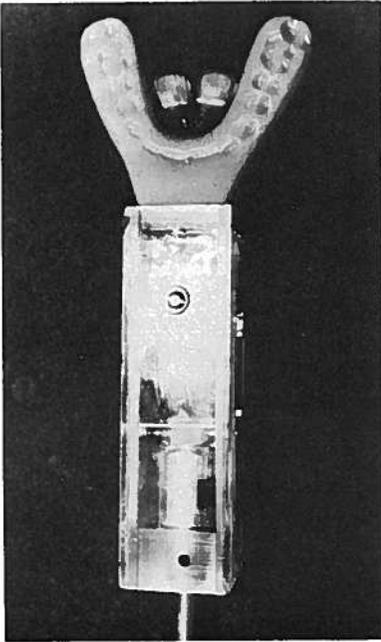


FIGURE 27.—The Telescopic Mouth Instrument incorporates a custom-fitted mouthpiece.

gouging, and the need for pneumatic drive wheels. Slippage on wet surfaces is also fairly common.

Belt or chain drive is desirable because wheel and tire wear are minimized due to relatively low friction. A solid tire may be used as well as a balloon tire.

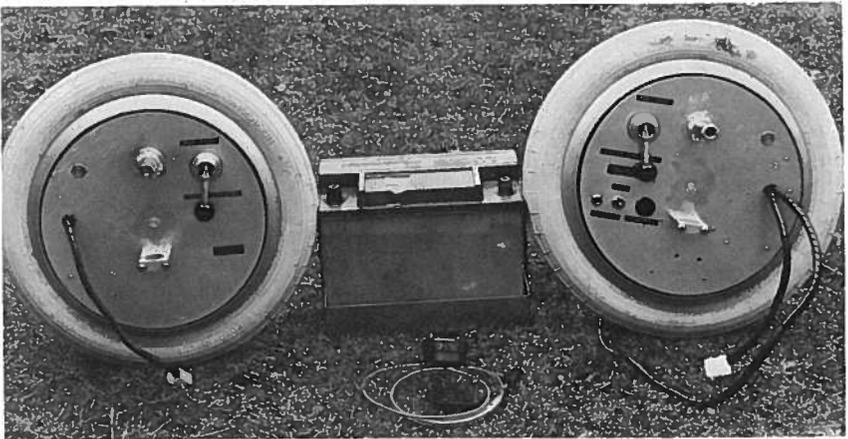


FIGURE 28.—Dudley Controls, Ltd., powered wheel kit.

With belt and chain drives it is usually very difficult to change or vary the mechanical advantage relationship between the motor output and the drive. Belt drives must be adjusted from time to time to preclude belt slippage. However, a novel "powered wheel," or drive wheel with integral motor may preclude some of the problems of both. However, it may present difficulty in varying gear ratios for attaining different speed and ramp climbing performances for a given wheelchair.



FIGURE 29.—Dudley Controls' powered wheel kit assembled to a wheelchair.

We have established contact with two manufacturers presently concerned with the development of motorized wheels. One device, a kit available from Dudley Controls, Ltd., of Aylesbury, Great Britain, uses a single motor in each powered wheel (Fig. 28). Another source, Gar Wood Enterprises of Miami, Florida, is developing a system with a multiple motor assembly.

We expect to receive the Dudley Controls powered wheel assemblies shortly (Fig. 29). If laboratory tests show them to be safe for general use, they will be deployed for clinical evaluation at a VA Hospital Spinal Cord Injury Service.

## B. Clinical Evaluation

1. *The Hayes Pneumatic Control for Wheelchairs.* In the previous issue of this Bulletin (BPR 10-20) we indicated that the manufacturer had converted the Sight Switch to a pneumatic control. This single tube pneumatic control has been mounted on an E&J belt driven powered wheelchair. Puffing pulses while the chair is in motion changes operating modes sequentially. Sequential puffs change operation from forward to off to reverse to off. Suction sequences the modes from left to off to right to off.

This system was evaluated by two patients, both of whom rejected it. Patients felt that even with the batteries fully charged the chair moved very slowly. The puffing and suction controls were too sensitive for efficient operation. These and several other deficiencies have been brought to the attention of the manufacturer.

2. *The Advanced Wheelchair.* Clinical evaluation of the Advanced Wheelchair (BPR 10-20) indicated that if it were modified as proposed by the Bioengineering Research Service, it would be acceptable to individuals who require such a vehicle (Fig. 30). Among the suggested modifications were incorporation of chain guards, anti-tipping casters to preclude the possibility of "wheelies," a more reliable electronic controller, and a single switch which actuates the electromechanical brake release while transmitting battery power for motor operation. Of secondary importance, but nevertheless necessary, is an automatically controlled battery charger. It had been common, during the course of clinical evaluation, for the batteries to be overcharged and acid electrolyte to evaporate at a rapid rate. Until these modifications have been inaugurated in production models, we cannot recommend general use.

A safe vehicle of this type would be a most welcome addition to the family of mobility devices for the physically handicapped. Individuals who attend colleges or universities, or those who must negotiate difficult terrain and steep inclines at reasonable speeds, will find it useful. The vehicle ideally should be small enough to permit use indoors.



FIGURE 30.—Advanced Wheelchair.

We are proceeding with the development of an intermediate-type wheelchair that would meet the needs of this portion of our patient population.

3. *Twenty-Four Volt Everest & Jennings Electric Wheelchair.* As discussed in BPR 10-20, the E&J Company, Los Angeles, California, submitted for evaluation two models (hand controlled, Fig. 31, and chin controlled, Fig. 32) of a high performance powered wheelchair. Both E&J wheelchairs are belt driven with large motors mounted in front of the large drive wheels. The unit with the hand-operated joystick is being used routinely by a quadriplegic patient. The use of an overhead arm sling provides him with enough arm motion to operate it. He previously used an E&J hand-operated, constant speed powered wheelchair which he felt had a jerky motion. He is pleased with the

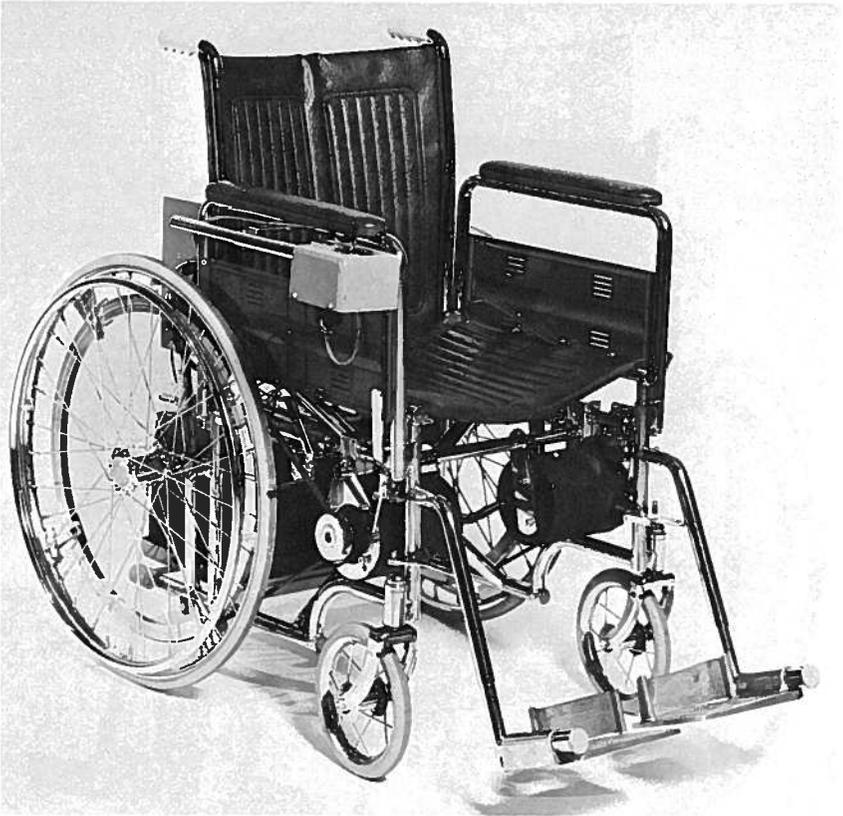


FIGURE 31.—Everest & Jennings 24-volt wheelchair with hand control.

new model, particularly the proportional control, because it operates smoothly.

The second unit was operated by a chin control mounted on the VAPC bracket. The drive belts tend to come off periodically probably because there is no provision for adjusting the tension on these belts. These findings have been brought to the attention of the manufacturer.

4. *Motorette 24 Volt Power Package for Wheelchairs.* Described in BPR 10-20 this new system operates on two 12-volt batteries (Fig. 33). A triplegic patient with a functional left arm and hand used the chair 9 hours a day. The Motorette received heavy use since the patient climbs high ramps to get into his home and van. He expressed satisfaction with the unit.

After 6 weeks use, the unit malfunctioned and had to be replaced. The only complaint received to date is that the 24-volt system is too fast for hospital corridors.



FIGURE 32.—Everest & Jennings 24-volt chin-controlled wheelchair.

5. *Mobilizer*. The Mobilizer (Fig. 34) is a powered patient transfer device manufactured by Diamondhead Corporation, Mountainside, New Jersey. This unique device features a supporting surface and a transfer surface, which extends out laterally from the device itself and slips under the patient, transporting him from one surface to another. With this device, one attendant can transfer patients gently, safely, and economically without lifting or touching the patient in any manner. This unit features a hand-held remote control box that allows one attendant to transfer a supine lying patient onto and off a bed or treatment table, and to raise or lower the transfer surface of the device 16 in. approximating the surface of beds or tables. It is powered by a 24-volt d.c. storage battery with a built-in charger. The unit is also

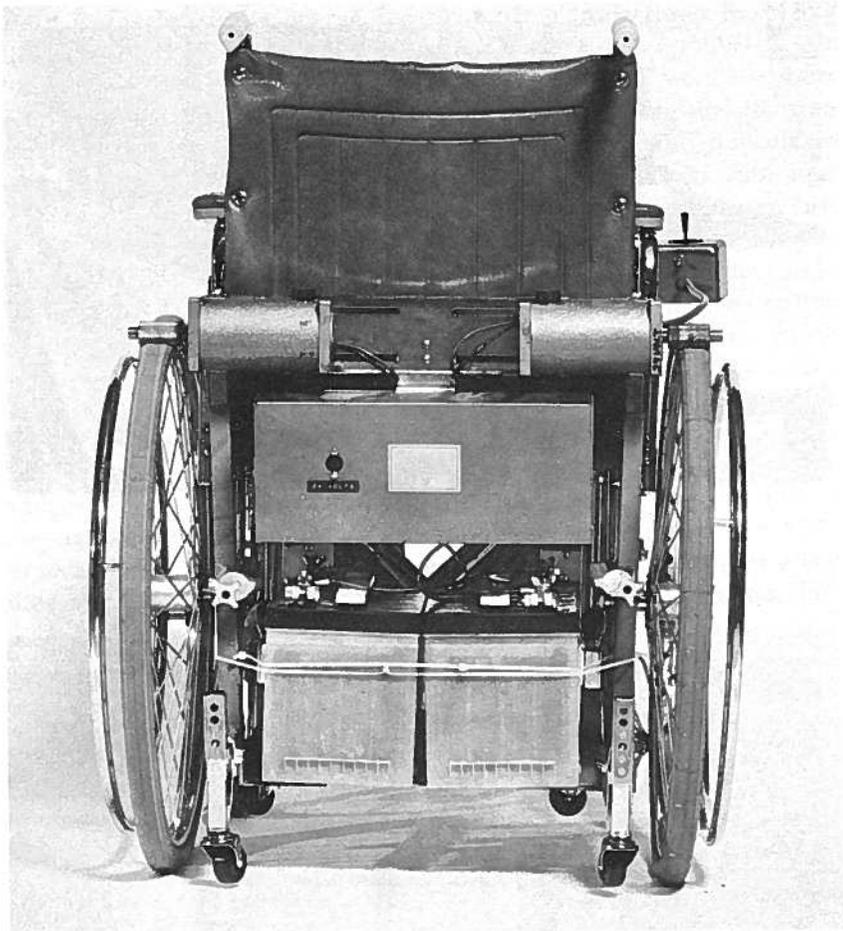


FIGURE 33.—Motorette 24-volt unit.

provided with removable side rails, and it is mounted on four 10 in. casters for easily transporting patients to other areas by pushing or pulling (not powered).

During clinical evaluation at two VA Spinal Cord Injury Centers, those working with the unit have unanimously agreed on the Mobilizer's easy mobility, ease of operation, overall utility, safety, and comfort. One nurse reported that one of the worst fears of a quadriplegic patient was that of being dropped. They emphatically stated that the Mobilizer had successfully erased that fear. More units are being obtained for replication of this evaluation at other VA Spinal Cord Injury Centers.

6. *Mercy Lift*. This device (Fig. 35) previously described in BPR



FIGURE 34.—The mobilizer powered patient transfer device.



FIGURE 35.—Mercy Lift.

10-18 is an electrically operated patient lift manufactured by Mercy Lift, Inc., of Lake Wales, Florida. Clinical evaluation at VAH Castle Point, New York, indicated that the building elevators were too short to accommodate the lift so that transporting a patient on the lift from one floor to another was extremely difficult. It was also difficult to maneuver the device on the floor. In small wards or rooms with four beds, there is insufficient space to maneuver the Mercy Lift from bed to bed. In one case, where it remained over the patient's bed full time, it proved useful in permitting the patient to be tilted without interfering with I.V. feeding tubes. These findings have been given to the manufacturer who advises that a shorter and more compact unit which would fit standard elevators is being made to replace the current model.

7. *Gaymar High Density Fluid (HDF) Support System.* This high density fluid support system (Fig. 36) is manufactured by Gaymar Industries, Inc., Buffalo, New York. It was developed at Rancho Los Amigos Hospital, Downey, California, for use in hospitals or homes of long-term, bedridden patients susceptible to pressure sores. The HDF Support System is based on the concept of floating the patient on a bed of heavy thixotropic fluid having twice the specific gravity of water. The

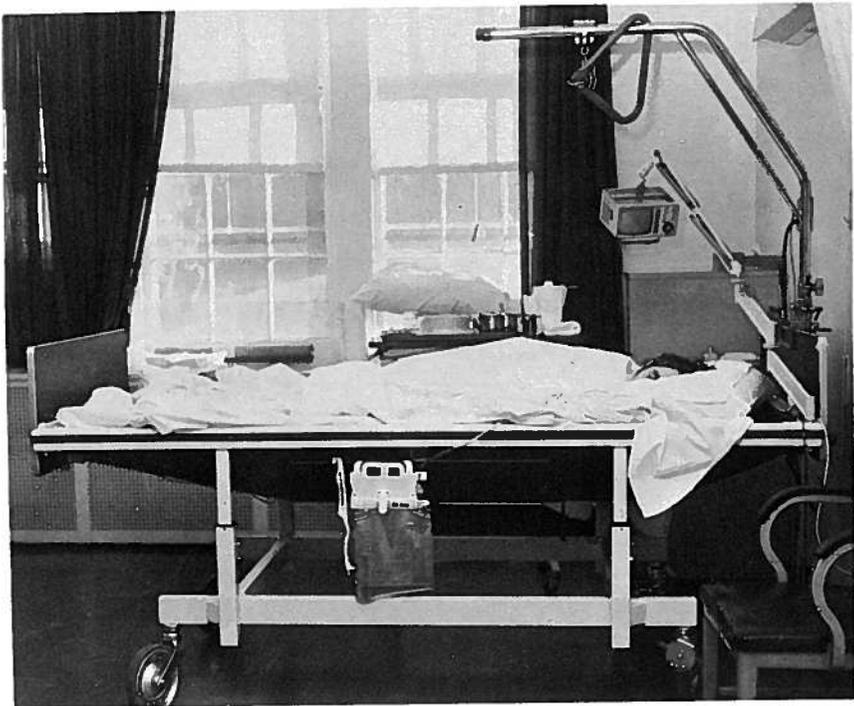


FIGURE 36.—Gaymar High Density Fluid Bed.

patient, therefore, becomes highly buoyant. With only half of his body below the bed surface, routine nursing care of the patient, including turning when necessary, is facilitated. The high density fluid covered with a polyurethane sheet, is electrically heated to a temperature of about 85 deg. F. to afford comfort and regulate sweating.

Three units have been procured and are being clinically evaluated by the SCI Services at the VA Hospitals, Castle Point, New York, West Roxbury, Massachusetts, and Long Beach, California. To date several problems have been reported. The polyurethane cover developed holes or slits. This allowed water to evaporate from the fluid and made the fluid denser. Getting patients in and out of the bed is a problem unless some kind of temporary floor stand arrangement is used. Some nurses felt that the bed was too low and quite uncomfortable for caring for the patient. Siderails were also recommended. In general, however, the Gaymar HDF Support System has been found satisfactory in the treatment of patients with skin problems.

8. *Royalaire Air-Fluidized Bed.* The Royalaire Bed (Fig. 37) is manufactured by the Milton Roy Co., St. Petersburg, Florida. As

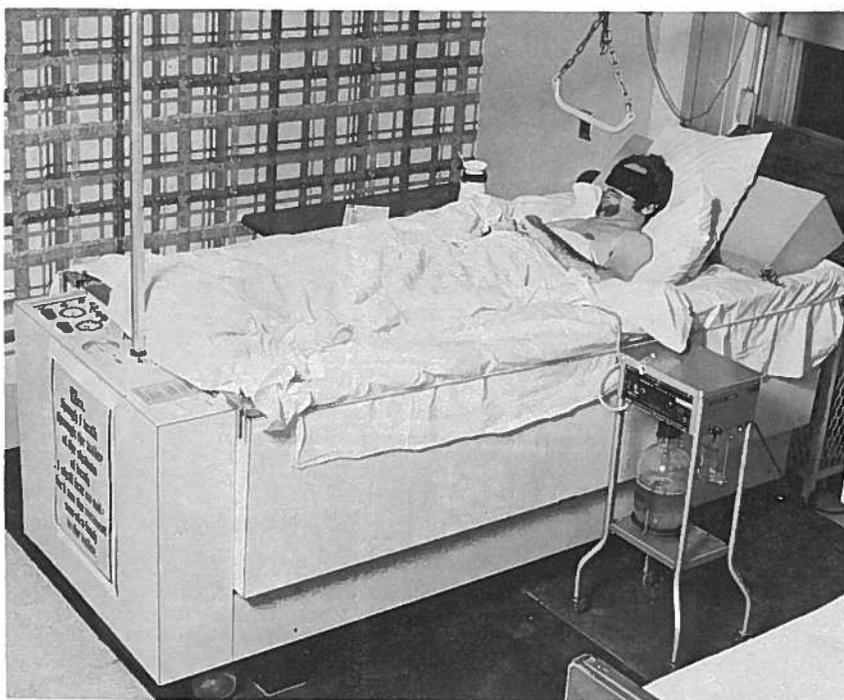


FIGURE 37.—Royalaire air-fluidized bed.

described in BPR 10-15, the patient is supported (floats) on a medium of silicone ceramic beads through which warmed air is pumped. The whole system is covered by a loose polyester-filled sheet which prevents the beads from escaping. In general, clinical evaluations at the VA Hospitals, Bronx, New York; Castle Point, New York; and Richmond, Virginia, indicated that the Royale Bed was quite beneficial for patients, even promoting healing of ulcers. There were, however, some technical problems that had to be corrected such as inadequate drainage, noise, and escaping dust.

An improved "low contour" model has become available that has

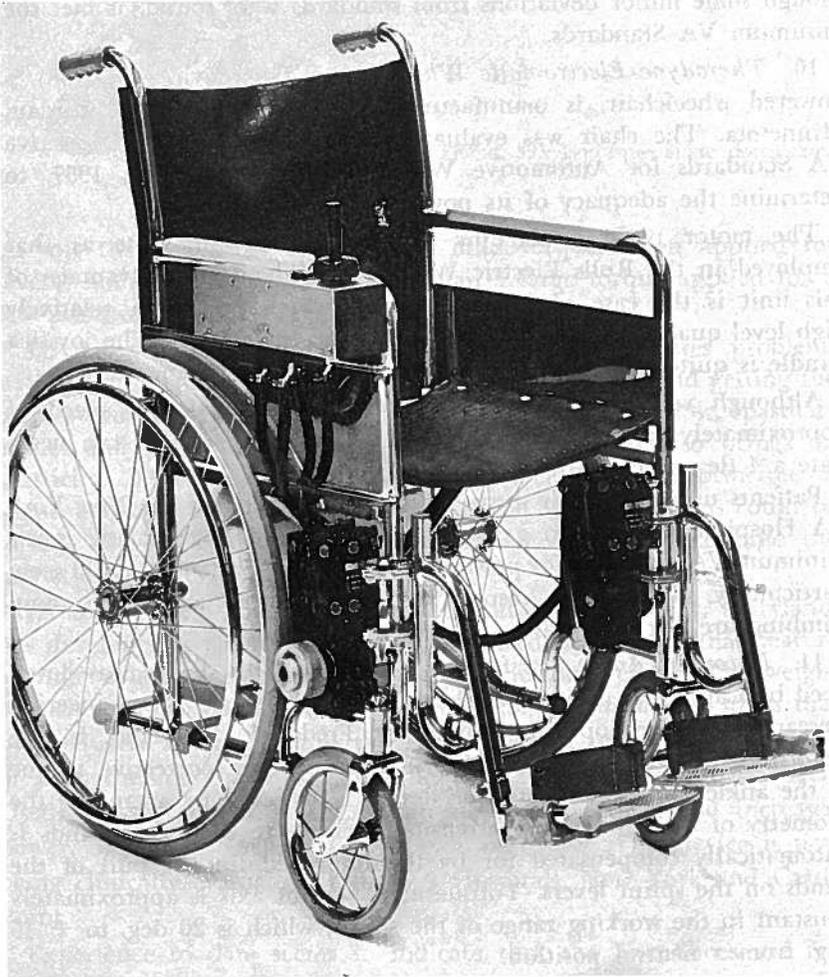


FIGURE 38.—Theradyne electric wheelchair.

resolved some of the above problems. Several of these new models are being obtained for further clinical evaluation at selected VA Hospitals.

9. *Theradyne Marquis Wheelchair.* One conventional wheelchair, Model 920 Marquis, was submitted for evaluation by the Theradyne Corporation, Jordan, Minnesota. The chair features swing-away, removable footrests, full length removable arms, offset wheel housing, and pneumatic tires. This chair was evaluated in accordance with tentative VA Standards for Wheelchairs, Self-Propelled, Folding, Multipurpose, dated May 1966.

In general, the Theradyne Model 920 Marquis Wheelchair, was found to be of satisfactory construction and workmanship. Even though some minor deviations from standards were found, it met the minimum VA Standards.

10. *Theradyne Electromatic Wheelchair.* This device (Fig. 38), a powered wheelchair, is manufactured by Theradyne Corp., Jordan, Minnesota. The chair was evaluated for compliance with Tentative VA Standards for Automotive Wheelchairs, dated July 1, 1957, to determine the adequacy of its power and control systems.

The motor package and joy stick control is the same as that employed in the Rolls Electric Wheelchair. The major advantage of this unit is the ease of joystick control which permits a relatively high level quadriplegic patient to handle the chair easily. The joystick handle is quite large and requires very little force to operate.

Although very reliable, the Electromatic has maximum speed of approximately 3 miles per hour which is relatively low. It can negotiate a 4 deg. ramp with a 170 lb. occupant.

Patients using the chair during clinical evaluation at the New York VA Hospital liked it. In general the Theradyne Electromatic meets minimum VA standards for powered wheelchairs. The chair would seem particularly suitable for hospital use where speed and steep ramp climbing are not important.

11. *Isotorque Ankle Dorsiflexor.* (Fig. 39) This device was developed by Capt. S. L. Bajema of the U.S. Army Medical Bioengineering Research and Development Laboratory, Frederick, Maryland. In the isotorque splints, rubberbands are used to apply a corrective torque at the ankle joint. The isotorque design is achieved by arranging the geometry of the splint so that tension decrease in the rubberbands is automatically compensated for by the improved line of pull of the bands on the splint levers. Torque at the splint axis is approximately constant in the working range of the splint, which is 20 deg. to + 15 deg. from a neutral position.

Isotorque corrective splints provide a self-adjusting, non-diminishing corrective torque which is compatible with the time-dependent yield



FIGURE 39.—Isotorque ankle dorsiflexor.

on soft tissue. Results show that a mild torque, when applied for several hours can be more effective than a large torque applied for a few minutes.

To date, clinical experience with this device indicates problems with the rubberbands. They tend to dry out and break and getting the correct amount of tension is difficult. If resistance is too low, spasticity ensues and overcomes the resistance; if too high, it also brings on spasticity. Nevertheless, some physicians feel that the principle is sound and the device would be useful if the above problems could be solved. Clinical evaluation continues in an effort to determine the merits of this device.

12. *Exer-Shoe*. The Exer-Shoe Corporation of Potomac, Maryland, has developed a pair of specially constructed dress shoes that feature an inner-sole with compartments used for adding weights. The weight of each shoe can be adjusted from 3 to 8 lb. The *developer states* that by gradually adding weight, the Exer-Shoe can provide an easy way of strengthening the muscles of the legs, abdomen, and lower back. Used as a therapeutic device, it can aid in the return, and increased power, of muscles weakened by disease or disuse. This device is now being clinically evaluated at the VA Hospitals, New York and Castle Point.

Experience to date seems to indicate that the Exer-Shoes are too heavy for use with many disabled persons. They could provide good muscle training for healthy young men.

IV. TESTING

A. Standards Development

*Hand Controls*

B. Compliance

*Compliance Tests Were conducted on the following upper limb devices:*

a. One Sierra/APRL #44 Voluntary Closing Hand (Tentative Specifications for Hand, Adult Size, Mechanical, Voluntary Closing, for Upper Extremity Amputees).

b. One Sierra/APRL Voluntary Closing Hook (Tentative Standards for Hook, Mechanical, Voluntary Closing for Upper Extremity Amputees).