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:

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I. DEVELOPMENT AND EVALUATION

A. Prosthetics

1. *Lower Limb*

Electromyographic Knee Control System. One of the many prosthetics problems in knee control is an unexpected situation such

as a slip or stumble. With the assistance of engineering students from the Polytechnic Institute of New York, an EMG-controlled knee lock, similar in certain important respects to the action of a normal knee, was built and tested. This work will continue in order to provide proportional control of knee resistance and perhaps, active knee action.

A number of methods are currently used to improve knee stability and "trip" response. Swing- and stance-phase knee control mechanisms (Wagner 320, 205, and 200; Teufel Secura; Boch 3P23, 3P28, and 3P25; Blatchford BSK and Kolman Safety Knee) all utilize body weight applied to the prosthesis to engage friction surfaces which provide a brake or "lock." This is effective in walking, but if an amputee slips or trips there is no body weight on the limb to lock the knee.

The Polycadence and Lawrence polycentric knees, and the Orthopedic Hospital, Copenhagen (OHC), Pneumatic Knee achieve additional control by changing the locus of the center of rotation for the knee. However, added stability only occurs in the last few degrees of extension and not necessarily when a person slips or trips.

The Regnell and Mauch S-N-S knee mechanisms apply hydraulic resistance to achieve stance-phase stability. The Regnall is activated by weight application and the Mauch by gravity sensing. The Mauch ankle also enhances stance-phase stability by gravity and load sensing to lock the entire system hydraulically when the shank is vertical.

Although all these devices aid ambulation, they do not respond to the kind of volitional or reflexive control usually required to avoid a fall. Amputees face a problem when the forces on the leg are not what they expect. Slipping is the loss of friction between the foot and ground; tripping is increased friction between the foot and ground causing the knee to flex. Walking downhill increases the forces tending to flex the knee. At the present time, EMG control of knee stability appears to be the most useful method to achieve this type of control.

EMG-controlled artificial hands are operated by the same signals that previously controlled the unamputated hand. This now fairly common application might also be applied to control the artificial knee by the signals that formerly controlled the normal knee. Fortunately, significant portions of the muscles that extend and stabilize the knee remain after amputation. The myoelectric output of the quadriceps, vastus medialis, vastus intermedialis, vastus lateralis, and the rectus femoris might be used for this purpose. Several students of the Polytechnic Institute of New York working under the direction of the Project Manager of the VAPC's Advanced Systems Program tested this possibility. They measured the myo-

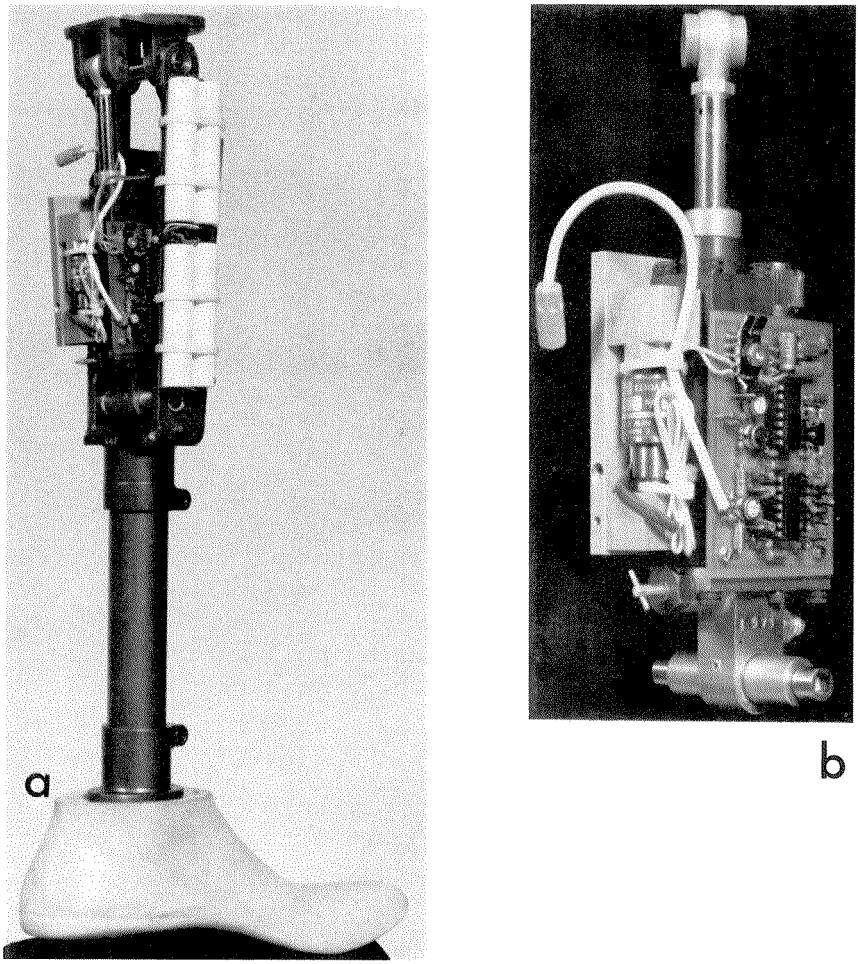

FIGURE 1.—a. Multiplex Endoskeletal above-knee prosthesis with an EMG logic-activated hydraulic valve and a check valve in series with internal resistive control, b. close-up view of the hydraulic knee unit with EMG controller.

graphic activities of these muscles in walking and in realistic trip and slip situations. From the results, they selected the best signals for controlling an artificial knee.

The system developed by VAPC (Fig. 1), which utilizes a Dyna-Plex hydraulic knee and a VAPC multiplex endoskeletal above-knee prosthesis with an EMG-logic-activated hydraulic valve. A check valve, in series with the internal resistance control, allows total locking against flexion and resistance to extension. The EMG amplifier utilizes classical instrumentation techniques for good signal detection and high common mode rejection. It selectively amplifies and

rejects the desired information, separating it from the unwanted noise. The system is capable of handling two signals simultaneously. Phase and amplitude logic are used to determine activation time. On a single patient who used the device to date, only the vastus medialis was available to control the amplitude logic and the time delay or release logic. When the system is energized, the knee is locked against flexion and increases its resistance to extension. This is intended to permit the amputee to recover from a stumble. The amputee walked intermittently for several hours during a day. He walked on level surfaces, up and down a ramp, and negotiated stairs. No attempts were made to induce stumbling or tripping; this type of testing will be deferred until more experience is gained. The system seemed to perform adequately to the laboratory observers and slow motion cameras. The amputee reacted very favorably to its use.

The system is self-contained and powered by rechargeable nicad batteries with sufficient energy to produce approximately 7,000 lock cycles of 500 ms duration. Laboratory tests have shown that the unit can be controlled by a patient. Rigorous reliability tests are now scheduled. Locking the knee at the wrong time can do as much damage as failure of the system to lock at the right time. In the event of electronic failure the system reverts to the original hydraulic function. A duplicate of the system is being built for the amputee to use regularly and to permit us to determine the reliability and general utility of the concept.

B. Orthotics

1. *Lower Limb*

VAPC Functional Equino-Varus Ankle-Foot Orthosis. For the past few years, the VAPC has used a drop-foot orthosis which actively corrects both drop-foot and varus deformity. This posterior leaf-spring AFO incorporates the upright and cuff of the VAPC shoe-clasp orthosis, a Pope double-action joint, and a flat caliper inserted into a box at the posterior portion of the heel (Fig. 2). The Pope joint is spring-loaded to correct a flaccid varus deformity and the Fiberglas-epoxy upright derived from the shoe-clasp orthosis provides toe pick-up. The axis of the mechanical joint is placed at the level of the subtalar joint and slightly lateral to the midline. It is not considered necessary to align the mechanical axis precisely with the anatomical subtalar axis since any additional motion that may occur is absorbed at the shoe-foot "joint." This motion is usually of minimal magnitude and patients are not conscious of it.

The first patient who used this device had Charcot-Marie-Tooth disease (peroneal muscular atrophy) and he had been wearing

FIGURE 2.—VAPC Functional equino-varus correction ankle-foot orthosis.

orthoses with spring-loaded Klenzak joints since the onset of his condition in 1951. These devices corrected the equinus deformity but the T-straps did not adequately prevent varus within the orthoses. This patient was originally evaluated by the Clinic Team on February 8, 1972, at which time a bilateral drop-foot deformity, associated with marked varus, was noted as he walked. The patient was provided with bilateral equino-varus correction orthoses as above described. The correction was satisfactory and his immediate response was favorable. At followup 2 weeks later, he indicated that he "walks better, tires less, and feels more stable with these devices than with his previously worn Klenzak orthoses." On March 29, 1972, to test the patient's response to elimination of active varus correction, the Pope joints were locked in the neutral position after removal of the springs. He indicated a preference for the spring-loading and the springs were replaced. The results obtained with the functional varus correction orthoses may be noted in Figure 3. The patient was last seen on June 11, 1973, at which time his response continued to be positive. The orthosis has since been successfully used for other neurologic conditions which develop an equino-varus deformity, such as polio, multiple sclerosis, and polyneuritis.

This orthosis has been found to be a useful device for neurologic conditions which have a common denominator of flaccid or mildly spastic equino-varus. It has been employed for such widely differing pathologic problems as multiple sclerosis, uremic peripheral neuritis,

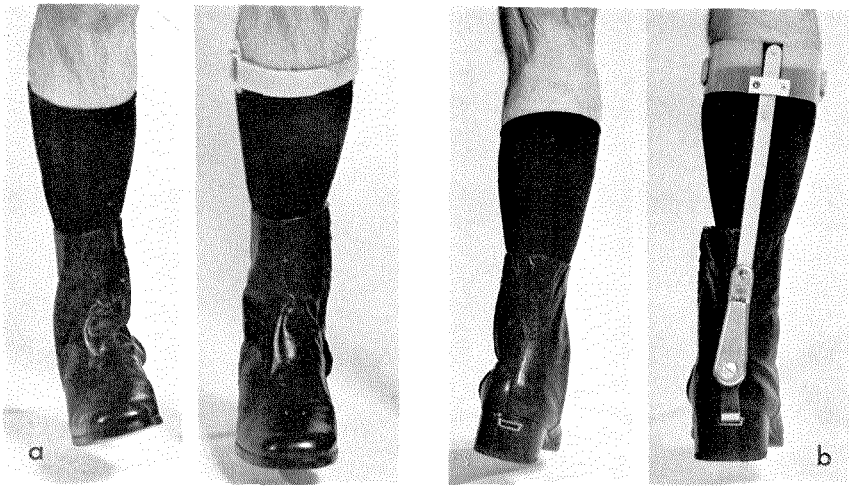

FIGURE 3.—a. VAPC functional equino-varus correction ankle-foot orthosis, anterior view and b. posterior view.

and isolated trauma to the peroneal muscles, as well as Charcot-Marie-Tooth disease.

2. *Upper Limb*

VAPC Powered Wrist-Hand Orthosis. As described in BPR 10-22 a Powered Wrist-Hand Orthosis has been designed and several models have been fabricated and tested. Models are presently being modified on the basis of early test results and are being fabricated for limited clinical evaluation. This modified unit is both functionally and cosmetically improved. The prehension force is now being more directly sensed: the load on the motor was initially being used to detect the finger prehension force, now, however, the mechanical output (tension force) is being directly monitored. The new high density armature and samarium cobalt magnet increases the output at a reduced speed. The nicad energy source is packaged within the same housing as the motor and gears, which are totally enclosed, making a cleaner, quieter assembly (Fig. 4).

C. Spinal-Cord-Injury Rehabilitation

1. *Environmental Control System*

a. *VAPC Remote Station Environmental Control.* All current environmental control designs are designed with a central power and control section, into which all peripheral appliances are connected.

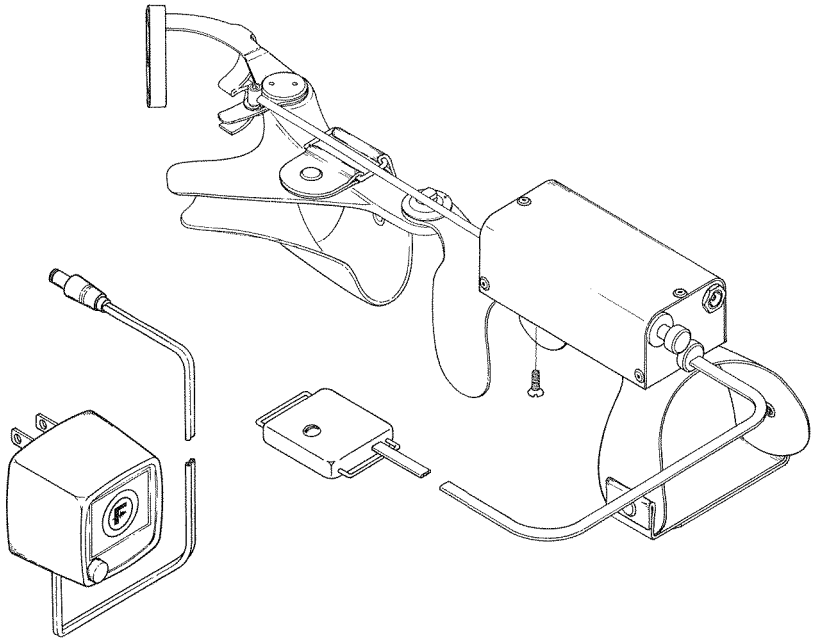

FIGURE 4.—VAPC Powered Wrist-Hand Orthosis.

This connection is even more imperative with the more advanced, wireless actuators. Potentially hazardous conditions may result from improper installation of such systems. Conventional, hard-wired environmental controls require the paralyzed user to remain immobile, while some recently developed wireless actuators permit limited wheelchair mobility. Since most of the important peripheral requirements such as T.V.'s are modified for operation by the environmental control system, use of these appliances is precluded by other individuals, especially family members at home. Dual actuators permit other individuals to have access to the user's system but most environmental controls do not offer dual actuators. It is desirable to maximize patient independence through environmental control capability without sacrificing mobility. This has been realized by designing a decentralized system consisting of a power unit, a control station, and 10 radio frequency receivers.

The initial laboratory model of the VAPC Remote Station Environmental Control consists of 13 separate sections. Three sections are mounted on a wheelchair and include a main logic controller, a monitor, and an actuator (Fig. 5). The main controller incorporates the logic circuits used for automatic sequential selection of 10

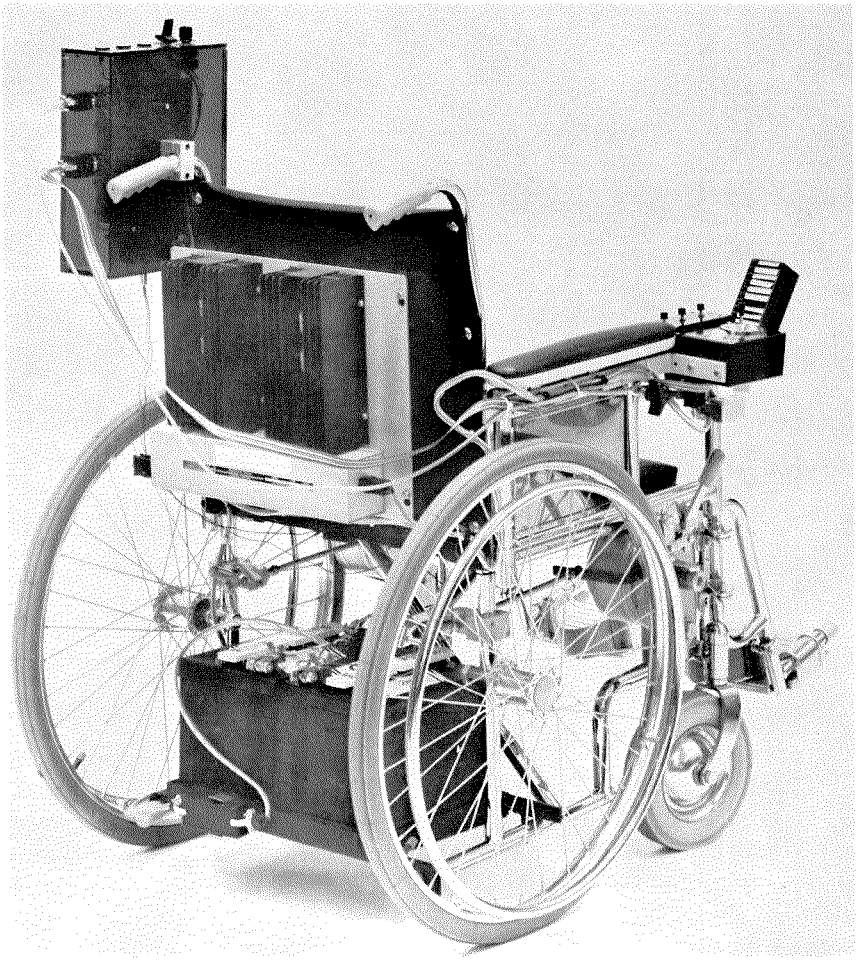

FIGURE 5.—VAPC Remote Station Environmental Control mounted on a power wheelchair.

environmental control channels. Simultaneously, the system is prepared for transmission of 10 different frequency-modulated radio signals. This section also incorporates a control governing the rate of channel sequencing.

The monitor (Fig. 6) has 10 light emitting diodes which indicate the channel-select status to the patient. The actuator is used with pushbutton switches for test purposes; a modular pneumatic and a magnetic actuator will be designed for the system.

The remaining 10 sections, the remote radio receivers (Fig. 7), have been designed to provide three types of electrical outputs similar

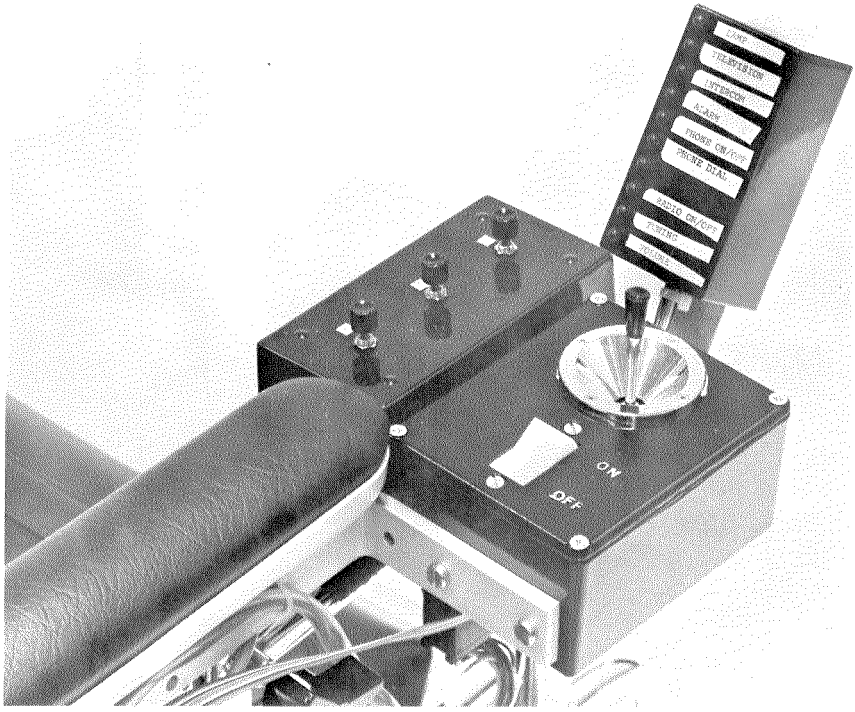

FIGURE 6.—VAPC Remote Station Environmental Control actuator and monitor.

to the present VAPC system. These outputs are 115-volt a.c., momentary switching, and latching closure. The stations may also be modified for momentary low voltage signal outputs. The stations (consisting of the radio receiver and an output section) are connected to common or adapted appliances normally located adjacent to ordinary household power wall receptacles. They may be operated by the user via the wireless actuator or directly by any other person by push button switches on each station.

Three operational modes are provided: automatic sequential channel select, appliance activate, and clear/reset. The first two modes are representative of most other environmental controls but the third is a characteristic of the VAPC system circuitry. This third mode also permits the user to evoke a standby state, in which all monitor lamps are turned off until operation of peripheral appliances is again desired.

The VAPC Remote Station Environmental Control was introduced for a limited period into a nearby VA Spinal-Cord-Injury Service. It was assembled to operate a patient alarm, remote-operated T.V., intercom, lamp, telephone, and radio with tuning and volume con-

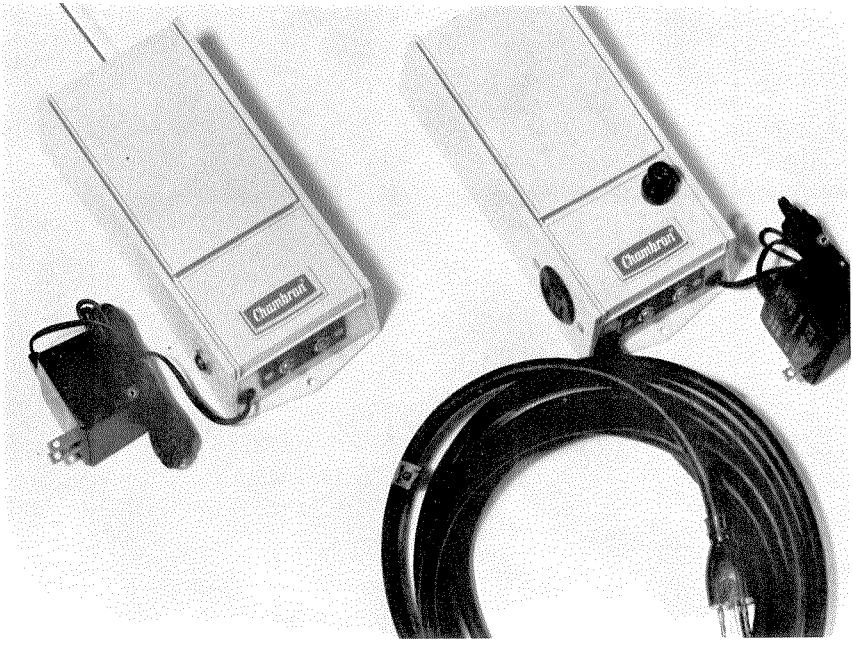

FIGURE 7.—VAPC Remote Station Environmental Control receivers.

trols. Initial problems were experienced with inadvertent activation or failure of the receiver to activate. A "debugged" system will be installed in a patient's home.

b. *GENIE Environmental Control.* The GENIE Environmental Control is available from Western Technical Products in Seattle, Washington. The model evaluated has 12 channels of which five provided other than the 115-volt a.c. power required for standard peripheral appliances. It is comprised of four sections including a master electronic control unit, a slave control unit, an input control actuator, consisting of either a pneumatic or pushbutton switch, and a light indicator unit, which monitors the status of the system (Fig. 8). The master electronic control unit contains the control circuitry as well as power distribution and switching for 8 channels (Fig. 9). The slave section, connected to the master control, receives all control signals from the master unit. It contains the power distribution and switching for four 115-volt a.c. outlets. The input control actuator has two breath-operated switches.

When the GENIE is turned on, the six lamplight indicator unit automatically turns each lamp on at an adjustable rate. Each lamp represents two channels, either of which may be activated by either blowing into or sucking on the air tube. Positive pressure activates

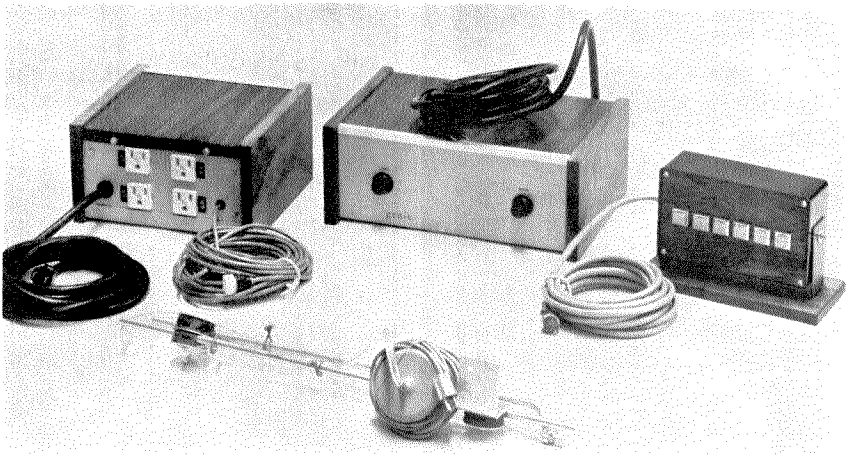

FIGURE 8.—GENIE Environmental Control with pneumatic actuator mounted on bracket.

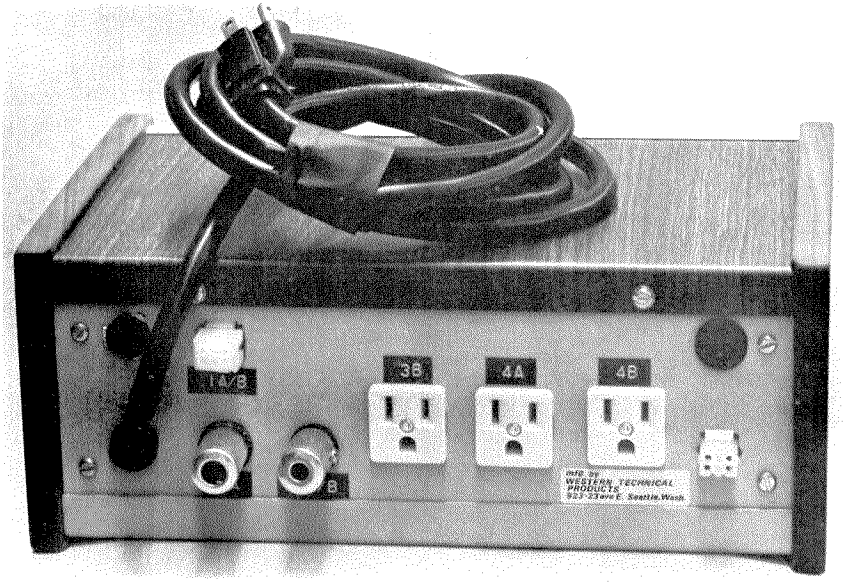

FIGURE 9.—Rear view of the GENIE electronic control unit.

one channel, and negative pressure the other. A blow or suck on the air tube changes the mode of the selected channel associated with the given lamp. To change the mode again, it is necessary to sequence the lamps to the selected channel another time.

Although two channels are designed to operate a special telephone, the telephone was not available. Two other channels are set aside for

raising and lowering the head section of an electric bed or to operate another electrical appliance. The fifth channel may be used for calling the nurse's station via the hospital nurse call system. The remaining channels incorporate standard 115-volt a.c. grounded outlets.

The automatic channel sequencing feature of the system demonstrates a similarity to the POSSUM and Sonotrol environmental controls. Our analysis shows the GENIE to be electrically safe for general use. The single pneumatic input (actuator), without provision for manual actuation, may present some inconvenience to the staff in a typical hospital setting, since hospital personnel are precluded from operating this unit.

c. *Nu-Life Environmental Control System.* Nu-Life is a solid-state environmental control system manufactured by Scientific Systems International, Huntsville, Alabama. Unlike other environmental controls, each model is custom fabricated to meet individual patient needs in the hospital and home. Several types of actuators are offered by the manufacturer on request.

The Nu-Life is available with a wider variety of adapted appliances (Fig. 10) than other systems. For example, an automatic T.V. channel changing mechanism, bed vibrator, telephone, intercom,

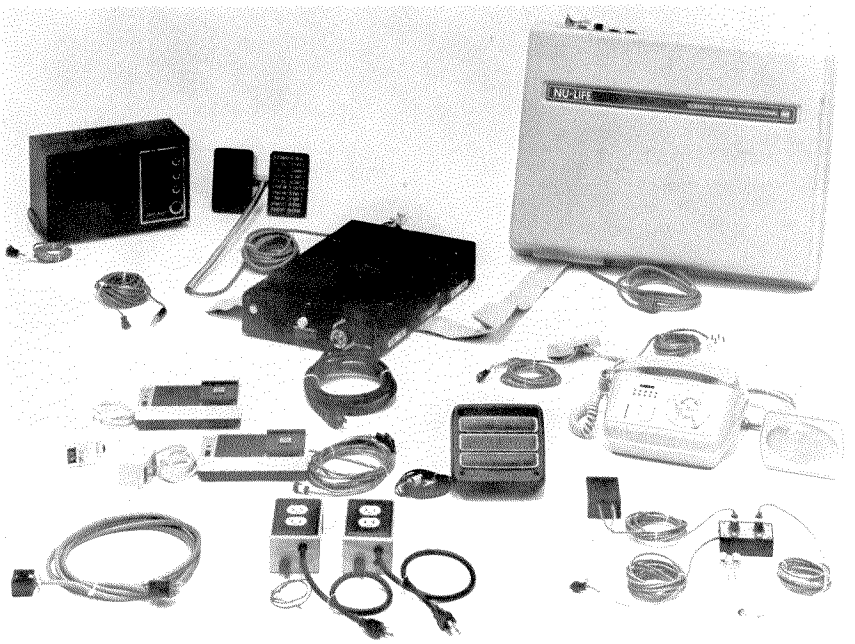

FIGURE 10.—Nu-Life Environmental Control System with special adapted appliances including telephone, intercom, and radio.

cassette tape recorder, curtain traverse rod, door lock system, and page turner may be operated and controlled by the Nu-Life. Scientific Systems International installs their systems at additional cost.

The basic controller is large and non-portable. Although this may present an installation problem in some hospital settings, in most homes the wall mounting may be desirable (Fig. 11).

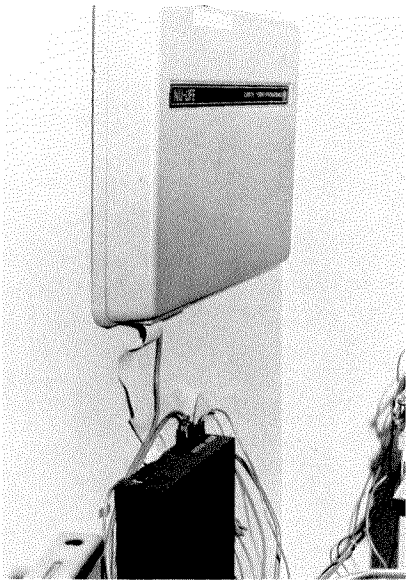

FIGURE 11.—Nu-Life Controller mounted on the wall.

The Nu-Life System is available in four basic configurations including 9, 19, 29, and 39 environmental control channels. Each of the channels may be used for standard 115-volt a.c. or custom modified appliances. The Nu-Life consists of the logic center containing the logic and scanning circuitry, a junction box providing connectors for custom appliances and standard 115-volt a.c. power, and the display (Fig. 12) which provides a two-digit readout indicating the channel function selected and numerical digits for telephone dialing. Actuation of the selection switch (a puff into an air tube for pneumatic control) starts a channel scanning sequence. The desired channel is selected by actuating this switch a second time. The on/off switch turns the selected appliances on-or-off by momentary actuation (drawing negative pressure on the air tube for pneumatic controls). The sequence rate of channel scanning may be varied, but not during the course of operation.

Approximately 15 Nu-Life Systems are undergoing evaluation in various VA Spinal-Cord-Injury Services in the 9 channel configura-

FIGURE 12.—Nu-Life readout display.

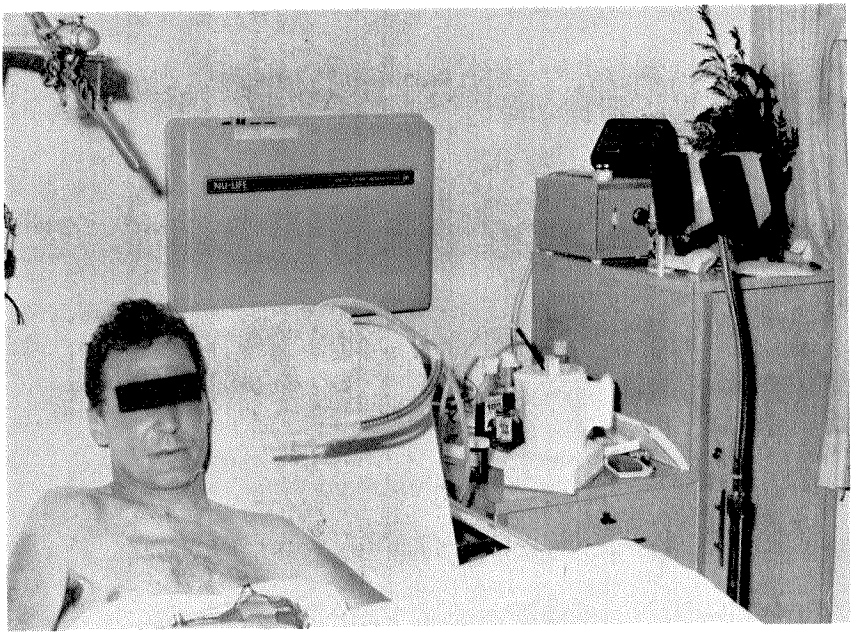

FIGURE 13.—Nu-Life installed in a VA Spinal-Cord-Injury Service.

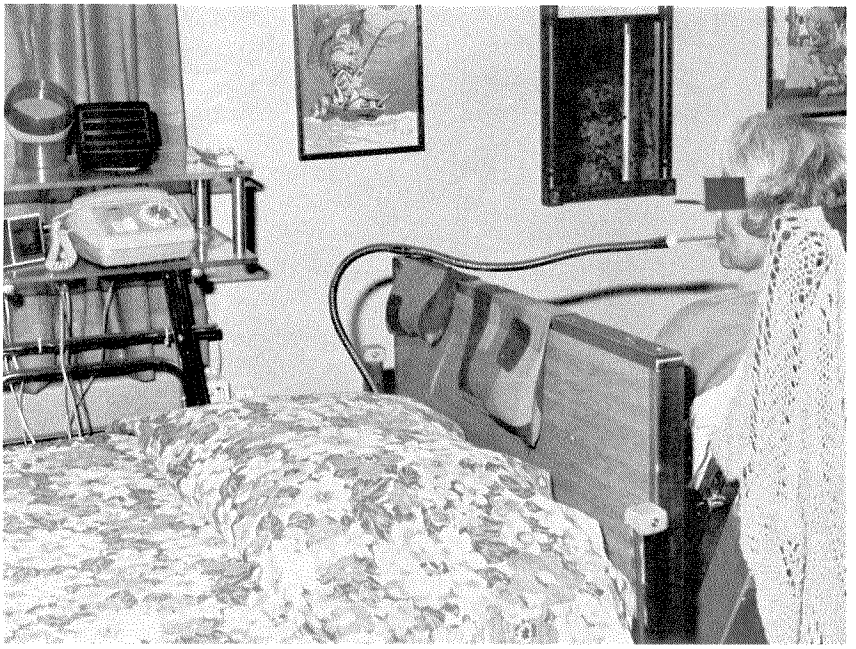

FIGURE 14.—Nu-Life installed in a VA beneficiary's home.

tion (Fig. 13). A 19 channel unit is under evaluation in a VA beneficiary's home (Fig. 14).

d. *POSSUM Environmental Control.* The name POSSUM was derived as an acronym for Patient Operated Selector Mechanism and then modified for pronunciation reasons. It is believed that the POSSUM, conceived by Mr. Reginald Maling of the POSSUM Research Project in Buckinghamshire, England, is the precursor of all environmental controls.

The present system is operated by microswitch or pneumatic switch. Continuous depression of the microswitch button or continuous suction on the pneumatic switch assembly tube is the only action required for operation of the power and control section and the monitor. The single switch operation is especially suitable for the most severely paralyzed individuals since automatic environmental control channel sequence and appliance operation are both controlled from the single switch.

Depression of the microswitch or suction on the pneumatic switch assembly initiates the automatic sequential selection of environmental control channels while cessation of the switch activation halts the channel sequencing action and turns the selected appliance, associated with the chosen channel, on-or-off, depending upon its

previous state. This procedure is repeated to operate other appliances or to change the on/off state of the previously operated appliance. Among the peripheral appliances which the POSSUM organization normally provides to patients in the United Kingdom are telephones, intercoms, doorlock devices, and remote control tuners for televisions. VAPC acquired two systems, one suitable for the home (Fig. 15) and the other for the hospital. The home model system provides 11 channels including eight 115-volt a.c. grounded outlets and three signal receptacles for remote switching functions (Fig. 16). It also has an intercom and telephone unit. This system has undergone limited evaluation in a home setting. It was assembled for operation of common appliances such as television, lamp, and record player, as well as the specially adapted intercom and telephone.

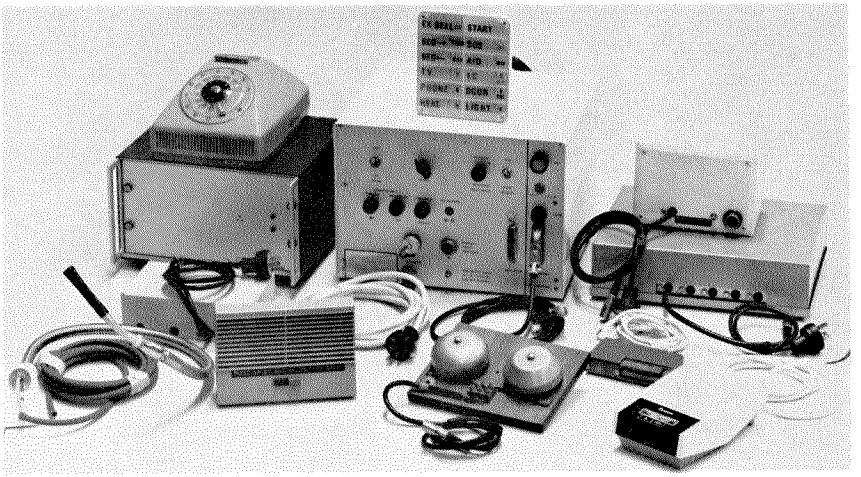

FIGURE 15.—POSSUM Environmental Control System with telephone dialer, intercom, and buzzer.

Evaluation in the home continues and the hospital model will be prepared for clinical installation.

e. *Voice Recognition System—University of California in Santa Barbara.* Professor Robert Roemer, associated with the Department of Mechanical and Environmental Engineering at the University of California in Santa Barbara, has designed and developed a voice recognition system for operation of a powered wheelchair (Fig. 17). This effort is sponsored by the Easter Seal Foundation. The VA Prosthetics Center, which envisions little practicality in a voice-operated mobility system, sponsors Professor Roemer's work in the development of a voice-operated environmental control.

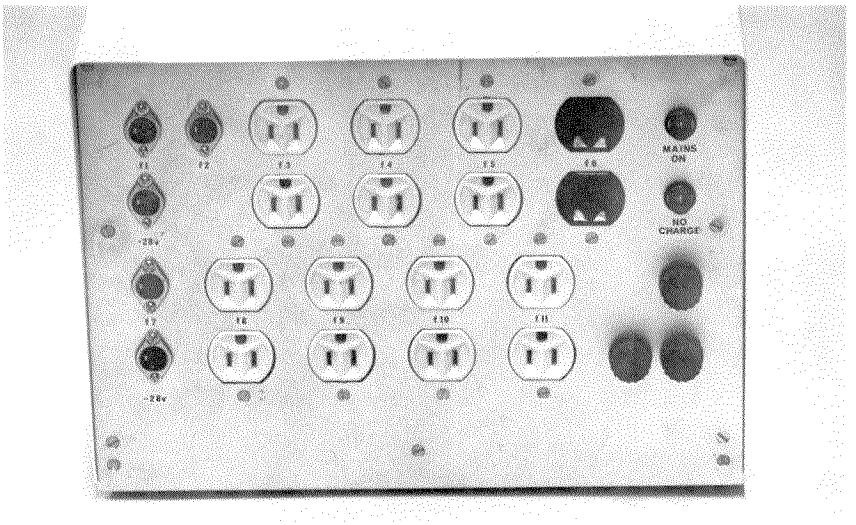

FIGURE 16.—Rear view of POSSUM controller illustrating power outlets and special signal receptacles.

Six units are being prepared for clinical evaluation at VA Spinal-Cord-Injury Centers throughout the United States. These systems provide eight channel capability for operation of a nurse call, lamp, remote control television, and the three operational modes of an electric bed.

f. *Heimco Nurse Call.* This device was developed by Heimco Incorporated of Lakeland, Florida. It is intended for bed-patients with severe paralysis, particularly those who are unable to use conventional, pushbutton-type nurse call switches.

The Heimco Nurse Call (Fig. 18) is an "L" shaped metal bracket, which incorporates a momentary and a latching switch. The switch is operated by application of a slight force against a flat metal plate mechanically linked to the switch's-actuating button.

Incorporation of a momentary switch permits electrical operation of most nurse call systems. However, the latching switch, while suitable for operation of common 115-volt a.c. appliances, may bring potentially dangerous current in close proximity to the patient.

Although the Heimco Nurse Call is conceptually sound, certain undesirable features have been noted.

g. *Bunting Remote Operated Television.* Bunting Sterisystems of Bridgeport, Connecticut, has developed a remote operated television set suitable for use by quadriplegics and similarly disabled individuals.

The basic television, manufactured by Sony, is mounted on a "gravity-free" support arm (Fig. 19) which may be used in the

FIGURE 17.—Voice Recognition System for power wheelchairs designed at the University of California in Santa Barbara.

hospital or home. Its minimal space requirement is a major convenience. The support arm permits the television set to be oriented in space for maximum accessibility to the patient, even while flat on his back. The set may be operated manually through a remotely located pneumatic switch or via any environmental control with suitable switch closure capability.

This unit has been evaluated extensively in many VA Spinal-Cord-Injury Services and has generally been found suitable for patient use.

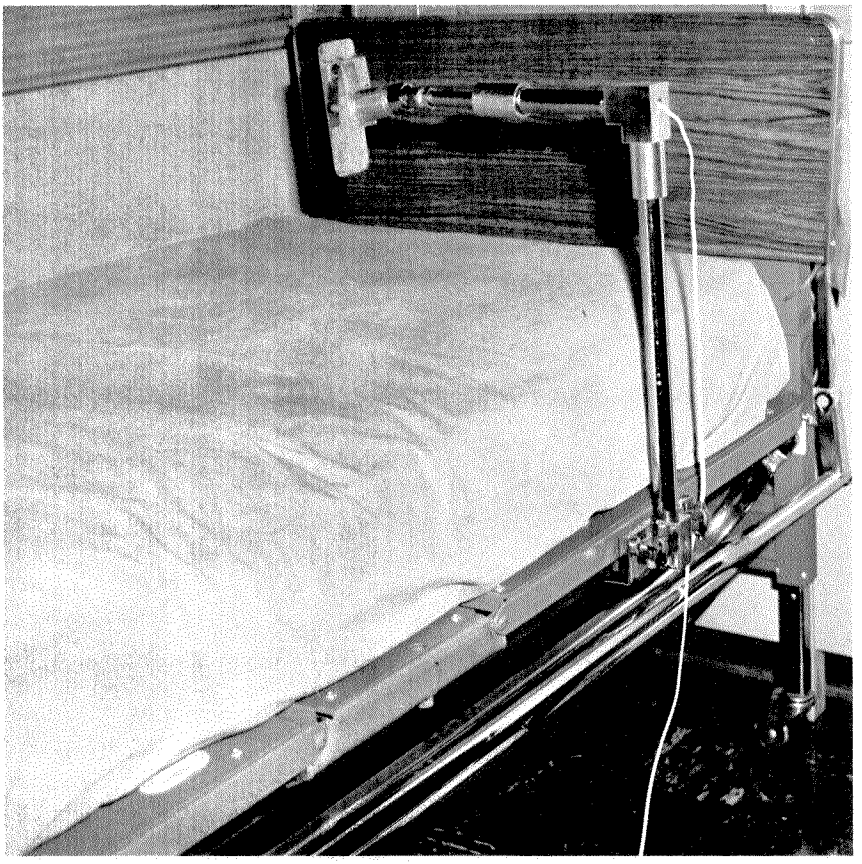

FIGURE 18.—Heimco Nurse Call attached to a hospital bed.

h. *VAPC Projection Screen Reading Machine.* In BPR 10-21 the development of microfiche and microfilm readers was discussed. Introduced into VA Spinal-Cord-Injury Services and several VA Hospital libraries, the viewing screen of the microfiche reader was found to be too small. A microfiche reader with a larger screen is under development and Kodak has promised a model later this year. The microfilm reader is still under development and a prototype is expected to be available for evaluation at the end of this year.

Another type of reader has been developed, suitable for use by severely paralyzed individuals. This reader incorporates a standard slide projector carousel (Fig. 20) within a projection-type theater sometimes referred to as Theaterama (Fig. 21). With the use of a flat-field lens, any photographic studio will be able to photograph desirable reading material in 35 mm slide format. This technique

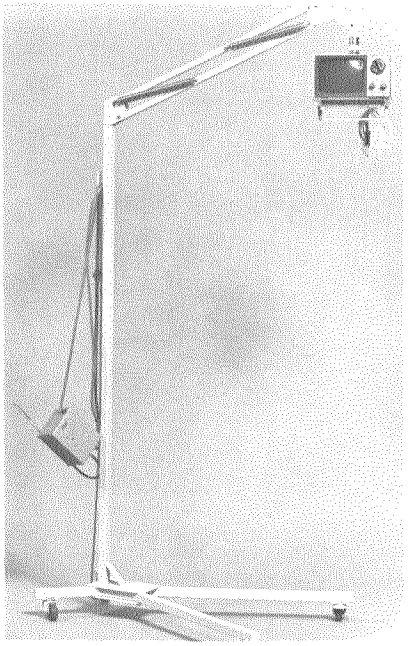

FIGURE 19.—Bunting Remote Operated Television for quadriplegic patients.

will permit hospitals to record weekly issues of popular magazines and students to read textbooks while attending classes. Other conveniences are apparent such as relatively low cost, independence in reading selection, and availability of recent publications.

The carousel, mounted on top of a standard carousel projector, is introduced into the rear section of the projection theater. The system is operated by the standard projector switches which have been replaced by suitable pneumatic and magnetic switches.

Clinical evaluation of this device is in progress.

2. *Wheelchairs and Accessories*

a. *VAPC Indoor-Outdoor Wheelchair.* In BPR 10-23 the VAPC development of an outdoor wheelchair which retains the necessary characteristics for indoor use was discussed. In a parallel effort, a similar unit with an elevating seat is being designed.

Seat height and coordinated footrest extension are adjusted by manipulating a toggle switch located posterior to the joystick assembly. While the vehicle demonstrates exceptional stability in the elevated seat configuration, the lowest position is especially desirable at maximum speed, 6.8 mi/h (10.9 km/h) (Fig. 22). The wheelchair readily negotiates a 12 deg ramp with a 175 lb (79 kg) subject aboard.

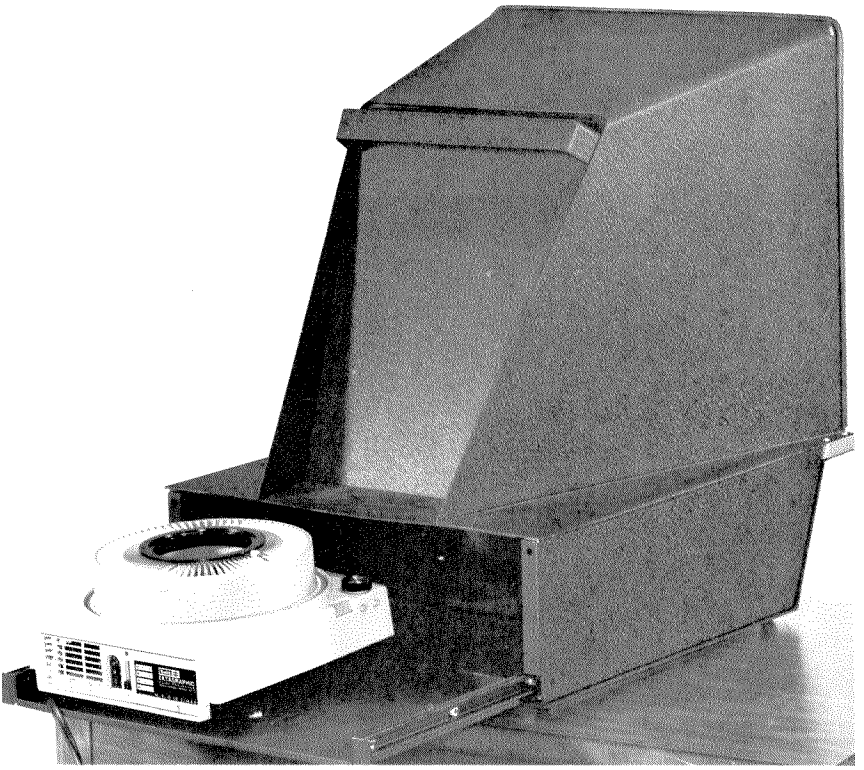

FIGURE 20.—A standard slide projector with carousel is inserted into the rear of the projection screen theater.

This vehicle, the first of its type, still exhibits certain deficiencies similar to the stationary seat model. The non-adjustable footrests, undersized batteries, and another low capacity, non-automatic battery charger, are remediable deficiencies. However, it also has highly advantageous features; such as quick motor disengagement, small size, and an automobile-type bucket seat which provides excellent patient support and comfort, especially on rough terrain. A proportional control joystick is used to operate the vehicle.

This wheelchair is under clinical evaluation at a nearby VA Spinal-Cord-Injury Service.

b. *Everest & Jennings "32" Power Drive.* An experimental 24 Volt E&J Electric Wheelchair was discussed in BPR 10-20. Two proportional control joystick models, one manual and the other chin-operated, were evaluated at a VA Hospital, Spinal-Cord-Injury Service with excellent results. Smooth operation in combination with higher speed (over 5 mi/h or 8 km/h) and excellent ramp climbing capability were the positive features.

FIGURE 21.—VAPC Projection Screen Reading Machine.

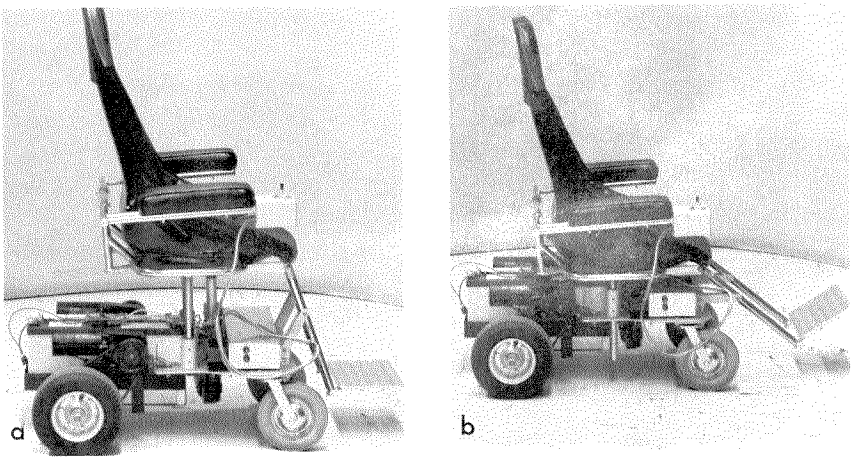

FIGURE 22.—a. VAPC Indoor-Outdoor Wheelchair with elevating seat at maximum height and b. minimum height.

As a result of this initial clinical feedback, E&J proceeded to develop a production model of this 24-volt unit. Designated "32" Power Drive (Fig. 23), the new model is a 24-volt analog of the "33" Power Drive. A toggle switch, positioned underneath the joystick assembly, permits the user to select one of two modes of power. One toggle switch position permits the chair to perform in a fashion similar to the "33" unit while the other transmits full voltage to the motors as dictated by excursion of the proportional joystick control.

The new "32" model is built on a standard, heavy-duty tubular frame, similar to the "33" model. Two 12-volt batteries are supported in a single tray on top of which is located an electronic control module. The entire assembly is mounted on a gimbal, sus-

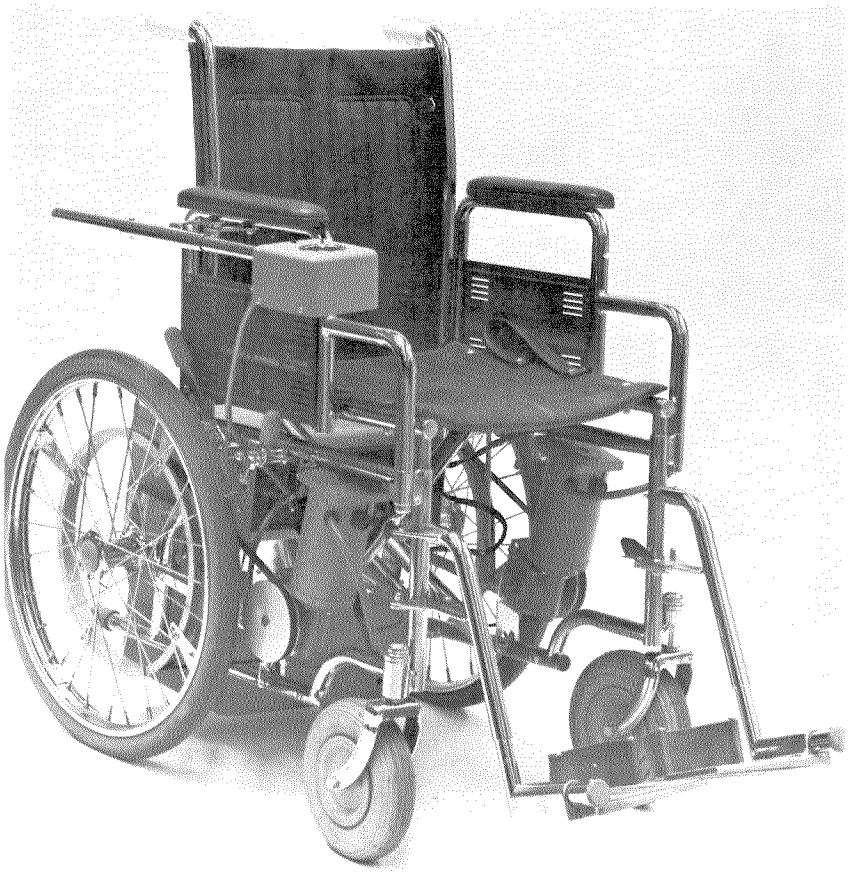

FIGURE 23.—Everest & Jennings "32" Power Drive.

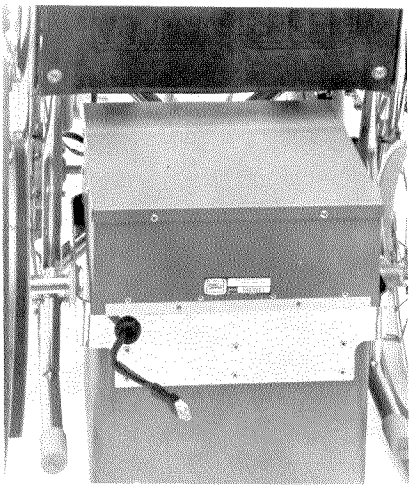

FIGURE 24.—Dual battery and electronic module assembly supported from new "32" power drive via gimbal support.

pended from the rear main drive wheelaxles (Fig. 24). The gimbal structure permits the entire battery-control module assembly to pivot in response to changes in the slope of the terrain and to maintain a horizontal orientation preventing battery-acid spillage.

A 175 lb subject may readily climb a 10 deg incline from a dead stop. With the low speed option, maximum speed on level ground is approximately 2¾ mi/h (4.4 km/h). The high speed option permits a maximum speed of approximately 4¾ mi/h (7.6 km/h). Battery current drain, on level ground, is approximately 25 amp, a reasonable drain.

The new Power Drive incorporates short throw front casters fitted with pneumatic tires and innertubes to provide a smoother ride, improved capability, and the ability to traverse small obstacles.

This wheelchair is under evaluation at a nearby VA Spinal-Cord-Injury Service.

c. *A-BEC Electric Wheelchair.* Abbey Rents of Los Angeles, California, markets a small, lightweight, portable electric wheelchair, through various distributors in the United States, for the British Electric Company, in the United Kingdom.

Three models, including the BEC-3, BEC-12, and BEC-14 are commercially available in this country. The three models are essentially similar with the following variations: the BEC-3 provides low speed, the BEC-12 provides high-speed, and the BEC-14 provides high speed with a proportional control joystick (Fig. 25). The chairs are very light, weighing approximately 30 lb without the battery and approximately 60 lb with it. They are foldable and portable with the battery removed. Maximum speed of the proportional

FIGURE 25.—A-BEC Electric Wheelchair.

control BEC-14 is almost 2½ mi/h (4.0 km/h). It demonstrates a capability to negotiate a 12 deg ramp with a 190 lb test subject, an accomplishment not matched by many power wheelchairs. It also performed well on grass. A novel innovation is a motor disengagement mechanism, which is operated by turning the cap screw nut on the motor drive wheels. This mechanism sometimes results in inadvertent re-engagement because of frictional effects. Because of its small size, the chair is excellent for indoor use where it can accommodate the physical size of a large patient and provide sufficient body support.

An automatic battery charger is used to recharge the 24-volt battery package used with the BEC-12 and BEC-14 models. Small

"charge beads" within the battery and viewed through a transparent window provide some reading on the charge retention of the battery.

The A-BEC is a portable, lightweight vehicle undergoing evaluation at a nearby VA Spinal-Cord-Injury Service and in several patients' homes.

d. *Montreal Head Control.* Chin and other controls utilizing head motions for severely paralyzed individuals are mounted in front of the user's mouth or face. This obscures a full view of the user and may reduce his field of vision. Other control methods, such as those which depend upon eyeball motion, require components to be

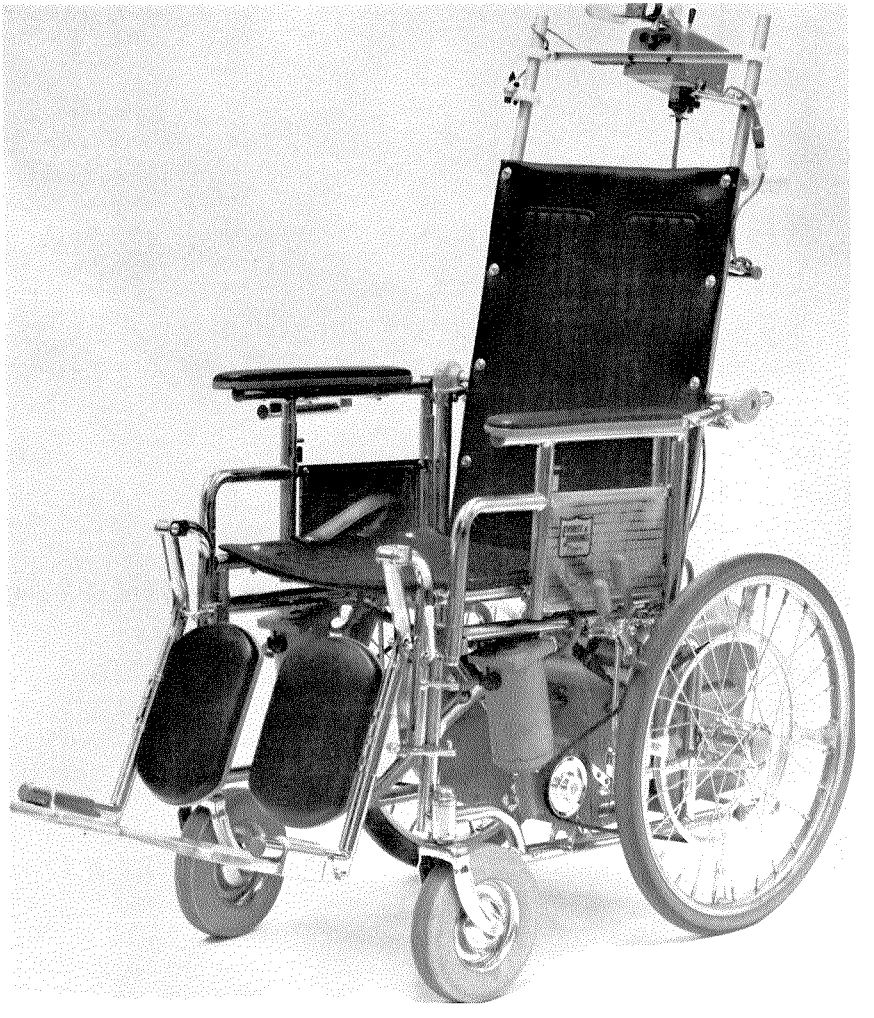

FIGURE 26.—Rehabilitation Institute of Montreal Head Control.

mounted on the user's head, coupling him to a wheelchair. Consequently, the development of a novel head control, by the Rehabilitation Institute of Montreal, may be a valuable addition to the family of rehabilitation aids.

The RIM control consists of a standard E&J proportional joystick control mounted on the wheelchair, posterior to the user's head (Fig. 26). The joystick handle is mechanically linked to a dual lever assembly (Fig. 27). If the patient applies pressure directly to the rear, a linear slide bar pushes the joystick backward. This electrically commands the chair to move forward. If the user leans his head to the right or left, the joystick handle is pushed in the opposite direction, which electrically commands the chair to move to the left or right. With the "33" Power Drive controller, proportional control is available.

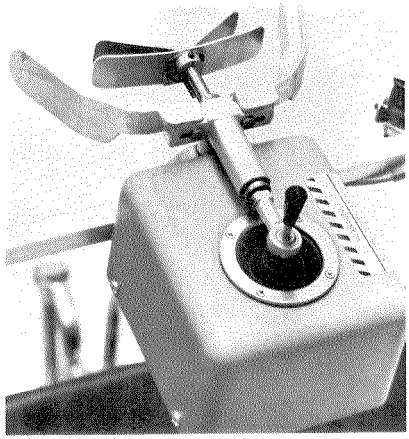

FIGURE 27.—Close-up view of RIM head control unit.

An inner "C" shaped member, which responds to forward or reverse commands, is placed within an outer "C" shaped member, which manipulates the joystick to the left or right. On/off and reverse direction commands are achieved by operating push button switches, above both shoulders. The right hand switch turns the main power on and off sequentially. The left hand switch changes the direction sequentially to forward and reverse. This control technique is advantageous since it connects directly with an acceptable wheelchair control device. However, the head control will be confined only to those individuals who retain sufficient shoulder elevation on both sides. Consequently, the control device may have limited application.

The system is under clinical evaluation at a nearby VA Spinal-Cord-Injury Service.

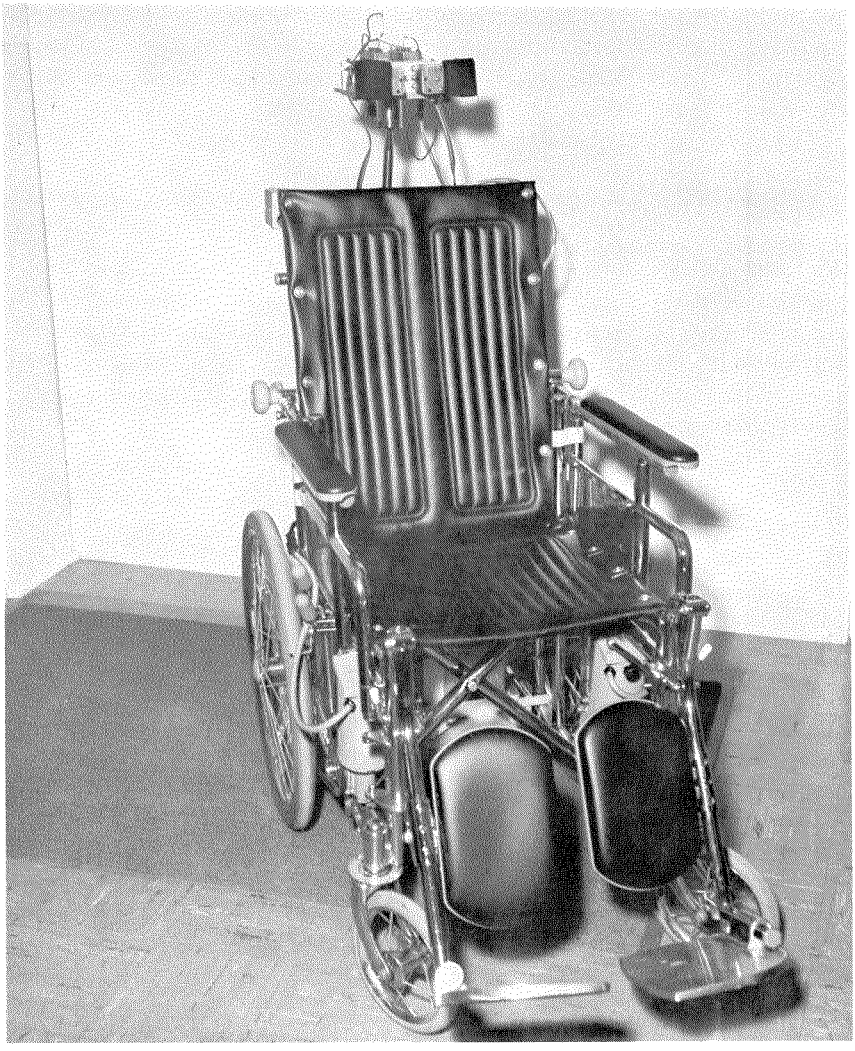

FIGURE 28.—N.E.L.C. Head Control for powered wheelchairs - laboratory model.

e. *Naval Electronics Laboratory Center Head Control.* The Naval Electronics Laboratory Center (N.E.L.C.) in San Diego, California, has also developed a novel head control (Fig. 28) for powered wheelchairs. It is somewhat different from the Montreal design with respect to both human factors and electronics.

The control is similar to the RIM design, since it is also mounted just behind the user's head. However, no shoulder elevation is required and all required functions are obtained by movement of the head only. The electronic system is different from the Everest &

Jennings "33" unit although certain components may be common to both. It also provides proportional control with respect to speed and direction.

Each time the user presses gently against the lever assembly with his head, the operating mode changes from forward to reverse and back to forward. This is accomplished whether the head is moved straight back or slightly to the side. However, distinct motions to the left turn the chair left and head movements to the right turn it to the right. While this action may possibly result in awkward responses during early training stages, the control lends itself to higher level paralytic impairments than the Montreal system. The N.E.L.C. unit requires less head excursion and force to push the levers than the Montreal unit. Although the Montreal design is well advanced and has been introduced into Canadian clinics, the N.E.L.C. design is still in a development stage. It is planned to acquire two more units for evaluation.

f. *Naval Electronics Laboratory Center Stand-Up Wheelchair.* In an effort to improve the mobility of high-level paraplegic patients, a three-phase program has been organized utilizing, on contract, the facilities of the Naval Electronic Laboratory Center and other agencies. The three development phases include: 1. the design and fabrication of a limited range and limited environment highly maneuverable standing platform, 2. a high performance wheelchair-like device into which the independently powered "ambulator" rests and from which it detaches, and 3. a licensed electro-vehicle designed or used by both with special paraplegic and quadriplegic control and access features.

As a first step, the Naval Electronic Laboratory Center, San Diego, California, under VAPC contract, has developed an interim version of the detachable chair/rover combination. It is a Stand-Up Wheelchair which is a half step towards the independently mobile chair and rover. It is a type of powered wheelchair with facilities to raise a user to a standing position (Fig. 29). Considered a "spin-off" of the main program, it will provide a means for testing the value of patients to be able to move about and work in the erect position. It also serves as a test prototype for determining the best approach to get from the sitting to the erect position.

One unit now under clinical evaluation by the Clinical Evaluation Service of VAPC, at VAH Castle Point, N.Y., if results warrant, will be modified as necessary for further testing.

3. *Beds, Lifts, and Other Aids*

a. *Jouk Power-Aid Ambulator.* This battery-powered ambulator is designed to allow paraplegic subjects wearing pneumatic or HKA

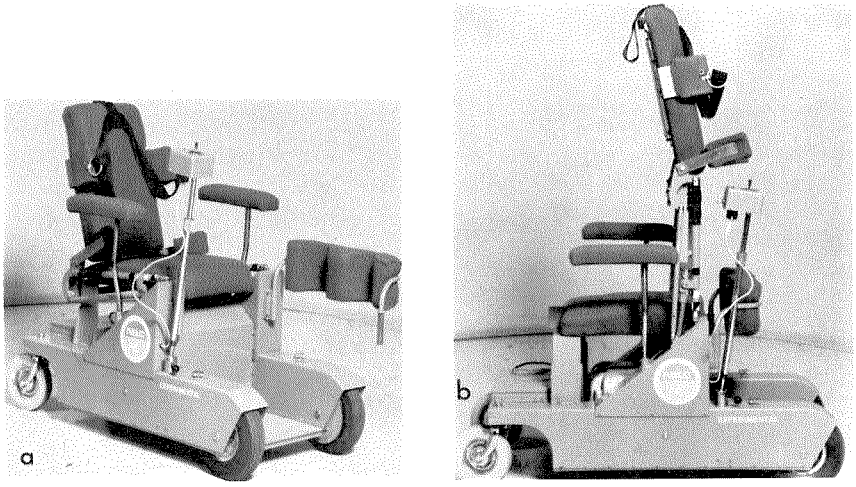

FIGURE 29.—N.E.L.C. Stand-up Wheelchair, a. lowered position and b. standing position.

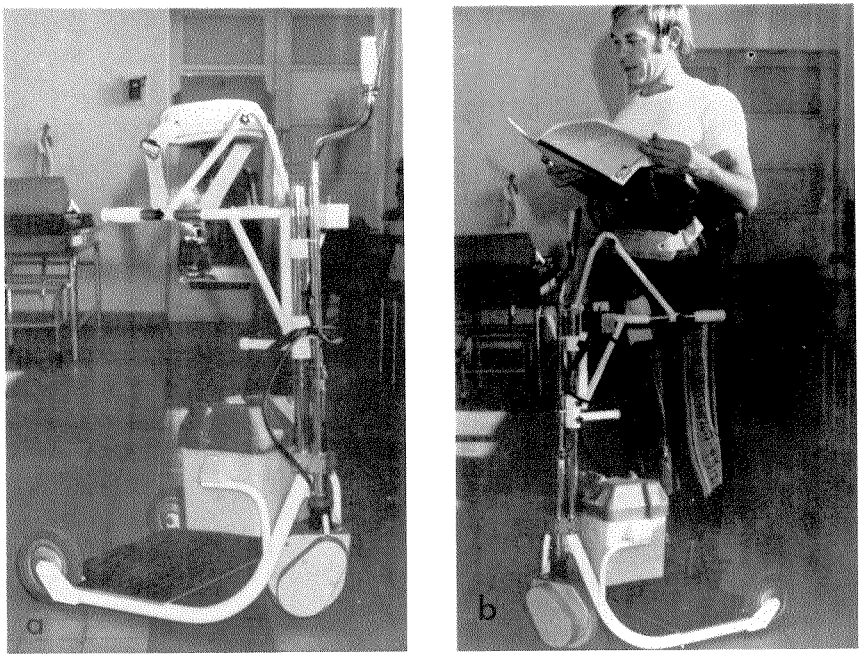

FIGURE 30.—a. Jouk Power-Aid Ambulator and b. paraplegic subject standing in a vertical position.

orthoses to stand in a vertical position and propel themselves about the home (Fig. 30). It is not intended for use on rough or uneven ground. The Jouk Ambulator consists of a three-wheeled platform,

the front wheel being a modified Power-Aid, a device that in the past has been used to power a conventional wheelchair by substituting it for the front caster wheel (see BPR 10-8 pp. 274-277). Steering and speed control are accomplished by means of a tiller bar and hand grip arrangement. Power is supplied by a 12-volt, rechargeable, heavy-duty automobile battery, mounted in a plastic case just forward of the user's legs. Although the evaluation is not complete, preliminary findings reveal several possible shortcomings. The tiller bar does not permit the device to closely approach certain work areas, and the location of the battery in front of the shins is uncomfortable for some users and could be a source of pressure sores.

b. *Godfrey Standing Aid.* This device is manufactured by Godfrey Engineering, Ltd., Hanworth, England (Fig. 31). The fully adjustable Godfrey Standing Aid is fitted with casters and locking devices and may be easily folded from side to side for transport or storage. The standing aid is essentially a body caliper and the patient needs no other aid to use it. Transfer from a wheelchair is achieved by approaching from the rear and lifting the legs over its seat. The patient then slides forward onto the seat of the aid and a lap strap is clipped into place.

A person with normal upper limbs may raise himself unaided to the standing position by pulling himself up on the two vertical hand grips. If he lacks the necessary strength, he may be raised to the standing position by an attendant. The lap strap causes the seat to rise with the patient. A ratchet mechanism will not allow the seat to return so that the patient is fully supported during the lift. In the standing position, the user is supported at the heels, knees, and buttocks. A padded chest constraint may be provided, if necessary, in place of the hand bar. In order to lower himself, a person must put his weight on the handles before depressing a release button. If the release button is not held down the seat immediately locks in whatever position it has reached.

Use of this aid enables new patients to achieve the upright position as early as possible in their treatment and to remain standing for long periods without constant attention. With the arms and legs free, physical and occupational therapy may be performed. Other major potential benefits of the aid is prevention of contractures and pressure sores. Improvements in circulation, urinary drainage, respiration, and other vital functions are also possible outcomes. In addition, calcium loss may be prevented by normal weight-bearing on the long bones which the aid provides.

The Godfrey Standing Aid is intended for use in the management of paraplegics and quadriplegics with complete lesions and of other neuromuscular disabilities which impair support and balance.

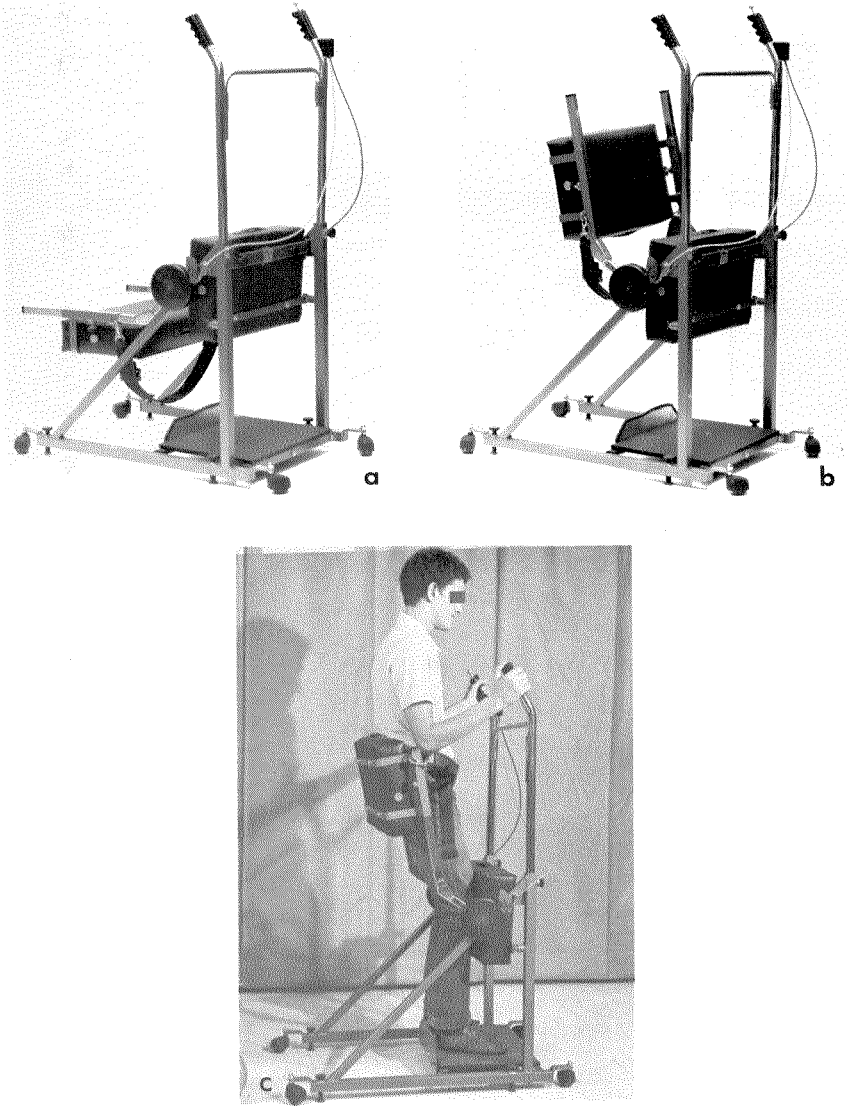

FIGURE 31.—a. Godfrey Standing Aid with seat in position for sitting, b. with seat in back-support position for standing, and c. with a patient standing in the device.

This device is being evaluated by the Clinical Evaluation Service of VAPC at VAH Castle Point, N.Y.

c. *Crozier Transfer System.* This transfer chair (Fig. 32) was developed by Crozier Chair, Pty. Ltd., of Victoria, Australia. It permits severely physically handicapped persons to be transferred into and out of an automobile without an attendant having to lift

FIGURE 32.—Crozier Transfer System.

him. The system must be used in conjunction with a modified two-door sedan with the seat on the passenger side removed. The unit basically consists of two units: a wheel base and a detachable seat unit. The seat unit may be unlocked and slid forward off the base. Transfer is achieved by progressively sliding the patient in the seat unit off of the wheelchair base to a track mounted on the car door and onto a baseplate mounted in the position normally occupied by the passenger seat. Once the patient and seat unit clear the wheeled base, it can be moved aside and the car door closed to bring the patient into a forward facing position within the car. The wheeled base is then stored in the trunk or rear compartment of the vehicle. The Crozier Chair was installed in a Pontiac Catalina two-door sedan owned by a paraplegic person (Fig. 33). No difficulty was encountered in installation. During preliminary testing, it was evident

FIGURE 33.—The Crozier Chair installed in a two-door sedan.

that the ground had to be level to allow the chair frame to be aligned with the track on the door. Otherwise, it was impossible to unload the subject onto the sidewalk because of the disparity in height. Several additional problems are being brought to the attention of the manufacturer.

d. *Blair Bed.* This device was developed by Reed F. Blair, Inc., of Pittsburgh, Pennsylvania (Fig. 34). The Blair Bed consists of two Blair Bed bars and a netting. The Blair Bed bars attach to the hospital bed's side rails. The netting is draped over the Blair Bed bars and attached to the bars. The patient lies on top of the netting. The patient may be raised by turning the right Blair Bed bar using a ratchet handle (Fig. 35). This procedure is intended to permit a flow of air over a bedridden patient's back to prevent or treat decubitus ulcers.

One quadriplegic patient who had severe decubiti over several areas of his back and hips used the Blair Bed. The patient reported discomfort in the Blair Bed and clinical observation indicated that the effect of the hammock pressure might be disadvantageous to the healing of his ulcers.

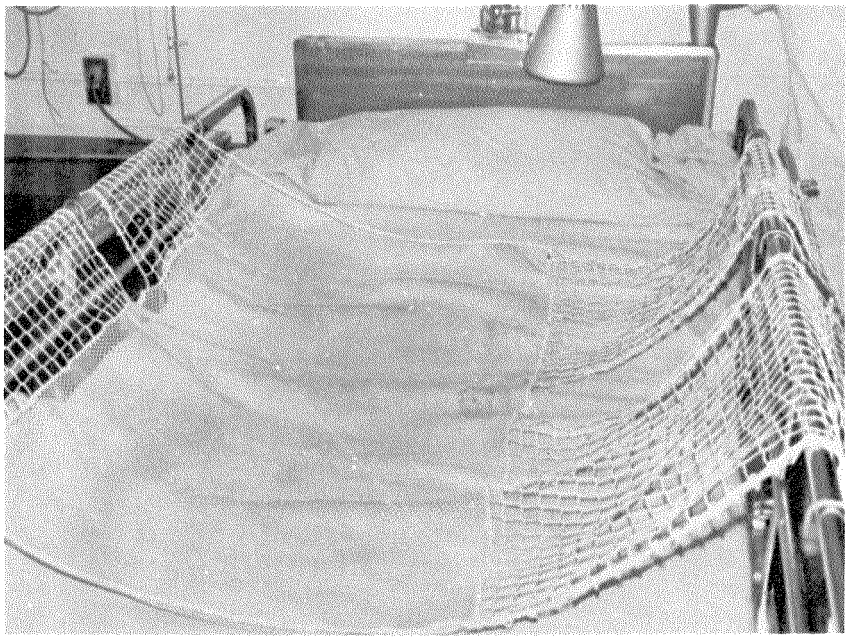

FIGURE 34.—Blair Bed.

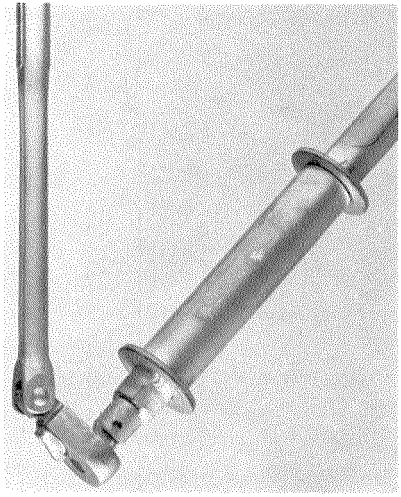

FIGURE 35.—Ratchet handle for a Blair Bed.

e. *The IMSECO Orthopedic Seat.* The International Medical Seating and Equipment Corporation (IMSECO) of Omaha, Nebraska, submitted several models of their Orthopedic Seating System (Fig. 36) for evaluation. The chairs naugahyde-covered seating

FIGURE 36.—IMSECO Orthopedic Seat.

surface has been designed to maintain the postsurgical rehabilitation patient in the "correct" sitting posture. The manufacturer states that the seat is intended for use in hospitals, extended care centers, and nursing homes. The legs extend out to the rear providing a very wide base of support for getting in and out of the chair and permitting the chair to be placed close to low objects.

The IMSECO Orthopedic Seat System was clinically evaluated by the nursing staff, nursing-home-care service, and orthopedic service VAH Castle Point, N.Y. In general the chair is well constructed and easily maintained. It was found to be comfortable by the patients. Its shape tends to support the thoracic vertebrae. It is recommended that the IMSECO Orthopedic Seating System be made available to VA hospitals.

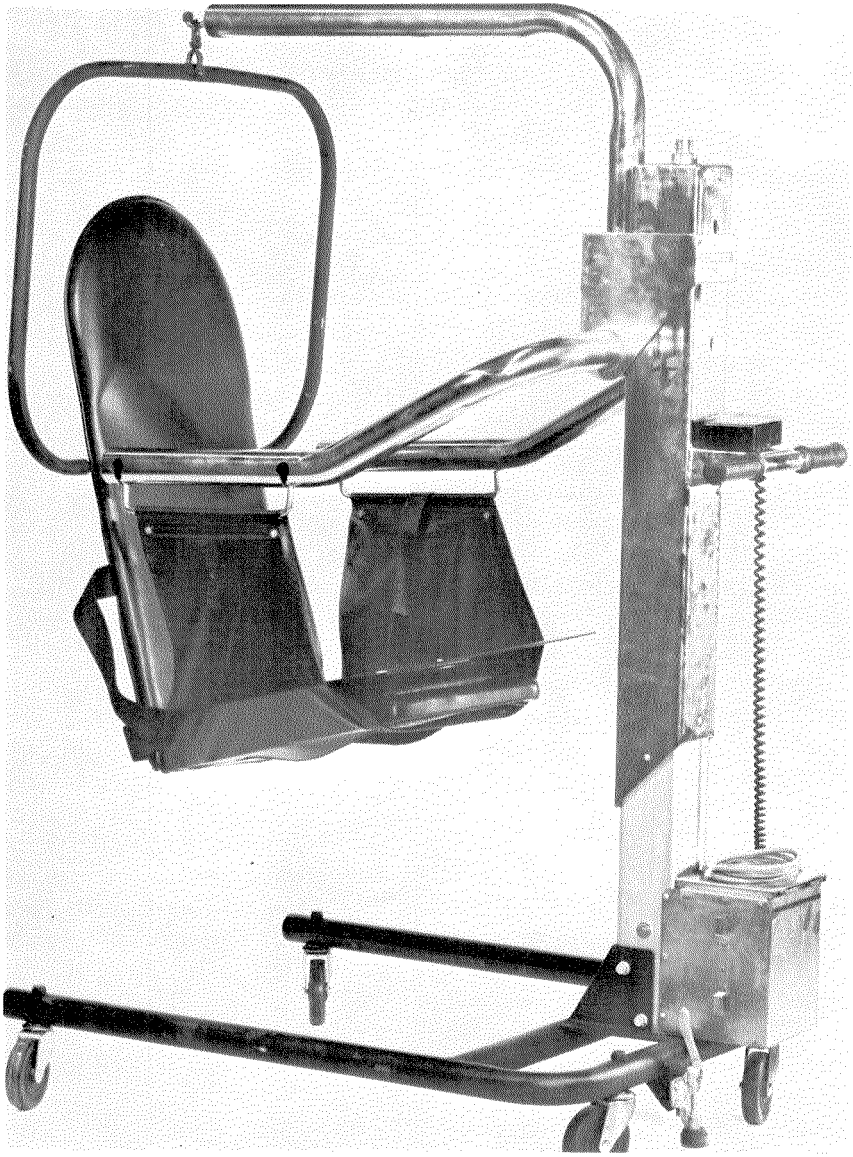

FIGURE 37.—IMSECO Patient Transfer System.

f. *The IMSECO Patient Transfer System.* IMSECO of Omaha, Nebraska, manufactures a battery-operated patient transfer system (Fig. 37) which is intended for use in hospitals to lift and transport severely disabled patients. The lift features a high-back seat of sturdy construction which, by removal of a center section, becomes a commode seat. A compact, fully rechargeable battery power unit is fur-

nished, as well as a manual backup system for use in a power failure. It also features a unique seat swivel which is used for turning patients while in the sitting position thereby eliminating the need to pull or push in positioning the patient for the lifting procedure. The manufacturer states that the IMSECO Patient Transfer System is designed to enable one nurse or attendant to safely lift and move any patient to bed, commode, or chair.

The IMSECO lift was checked against VA Standards for Patient Lifts and was clinically evaluated by the nursing staff at the VA Hospitals, Castle Point and Montrose, New York.

In general, the IMSECO Patient Transfer System complied with the functional requirements for VA patient lifts. It is well constructed and requires minimal maintenance. The nursing staff at the VA hospitals were generally enthusiastic about the concept of a self-contained battery-operated patient lift. However, several other problems were encountered and brought to the attention of the manufacturer who is taking steps to remedy them.

g. *AMBRDL Microsphere Mattress.* The U. S. Army Medical Bioengineering Research and Development Laboratory, Department of the Army developed a foam microsphere mattress for patients susceptible to pressure sores.

The prevention and care of pressure sores involves careful medical and nursing procedures by both hospital personnel and patients. The development of pressure sores is directly related to the distribution of the body's weight (local pressures) while lying or sitting, a matter affected by the type of bed, mattress, or wheelchair cushion used. The AMBRDL Foam Microsphere Mattress is designed to distribute the body's weight uniformly. Normally high pressures on such areas as the trochanters, sacral or ischial tuberosities will be reduced, and it is expected, will prevent or aid the healing of pressure sores.

In late 1973 the first mattress was evaluated in the Spinal-Cord-Injury Service at VAH Castle Point, N.Y., by patients who were undergoing care for existing pressure sores. Based on experiences with this mattress, a modified version was put into service in late 1974. A third, the present version of the Foam Microsphere Mattress has been in use since January 7, 1975 (Fig. 38).

The mattress measures approximately 36 in. × 78 in. × 7½ in. which fits a typical hospital bed used at VAH Castle Point, N.Y. The mattress consists of four major sections: a urethane base shell, a cover assembly, a cushion assembly, and a "fluidized" cushion assembly.

The urethane base shell is medium density foam, 1.25 lb/ft^3, with side rail assemblies, 78 in. × 6 in. × 4 in., made of the same foam. The top and bottom of the shell are sealed with nylon webbing. The

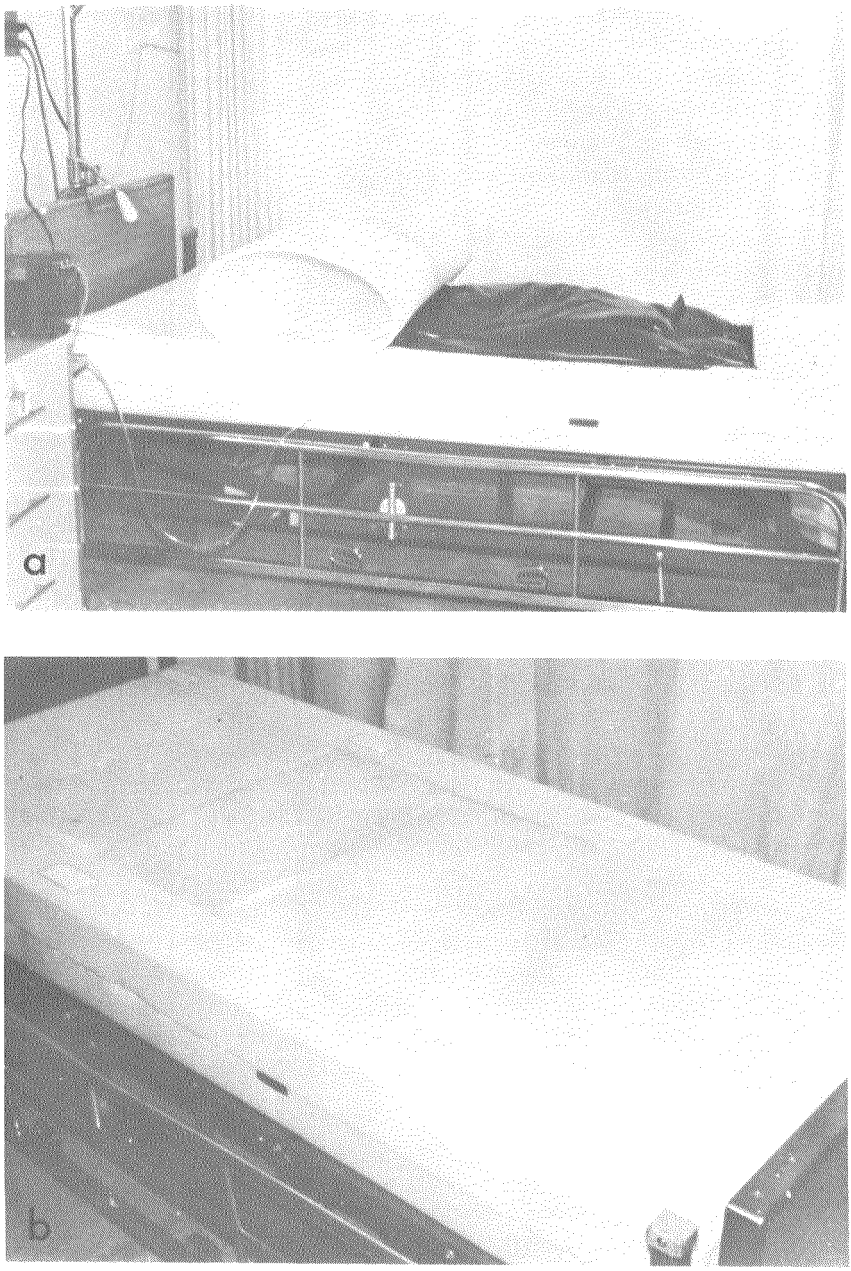

FIGURE 38.—a. AMBRDL Microsphere Mattress and b. the present version.

top surfaces of the base and side railings have Velcro pile for securing cushion assemblies and the cover assembly.

The cover assembly is a medium (1.25 lb/ft^3) or a soft (1.1 lb/ft^3) density urethane foam. It also has sections of Velcro hook for securing to the base side rails.

The cushion assemblies are made of medium or soft density urethane foam.

The "fluidized" cushion assembly consists of a "fluidized" fill contained in a polyurethane Tuftane film, 2 mil thick. The fill is made by mixing Dylite steam expanded polystyrene beads, 1/16 in. dia, 3 lb/ft^3 density with silicone fluid, 12,500 cSt. viscosity type DC-200, in the proportion of 4:1. The "fluidized" cushion assembly with a density of approximately .75 lb/ft^3 is made in two sizes: 21 in. x 32 in. and 34 in. x 32 in. The "fluidized" cushion assembly has Tygon tubing which passes between the side railing and the cover assembly and is connected to a pneumatic pump which delivers a minimum of 500 in.^{3}/min. One model does not have a removable cover assembly or removable cushion assemblies; the other has two voids to accent the "fluidized" cushion assembly. One is around the general buttock region and the other around the general foot region. Use of a sheet with a loose elastic/knit is recommended to allow circulation and avoid moisture buildup around the patient-mattress interface.

The AMBRDL mattress has been used by seven patients to date. A typical patient was paraplegic with severe pressure sores bilaterally on the ischial tuberosities and the heels of the feet. The physicians and nurses observed improvement in coloration and apparent healing of the ulcers.

In general our experience indicates that the AMBRDL mattress is potentially very useful in the treatment of decubitus ulcers. However, due to its relatively complex construction and its flammable material, several difficulties arise in producing it for general use. Steps are now in progress to redesign the mattress to overcome the shortcomings noted and to produce it in relatively small quantities.

4. *Automotive and Driving Aids*

a. *VAPC Electro-Hydraulic Servo Control for Handicapped Drivers.* The development of the VAPC Electro-Hydraulic Service System was described in BPR 10-23, p. 253. The handicapped driver operates a pair of coaxial wheels (the standard steering wheel and the inner brake-accelerator control wheel) of this first functional model of this automotive control. The "double-wheel" control concept appears to be useful to a wide variety of handicapped drivers with nearly normal strength and mobility of at least one upper limb

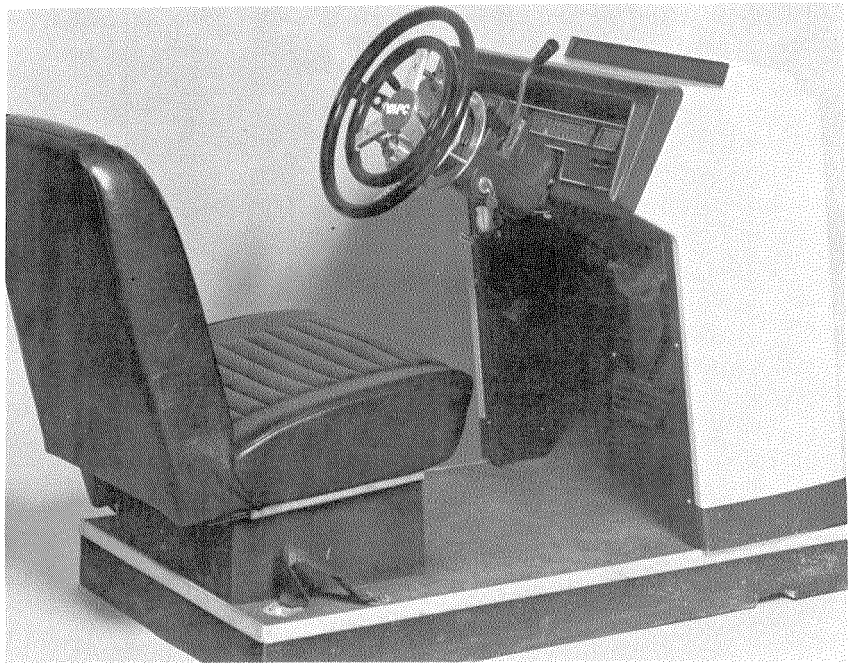

FIGURE 39.—AETNA DRIVOTRAINER-71.

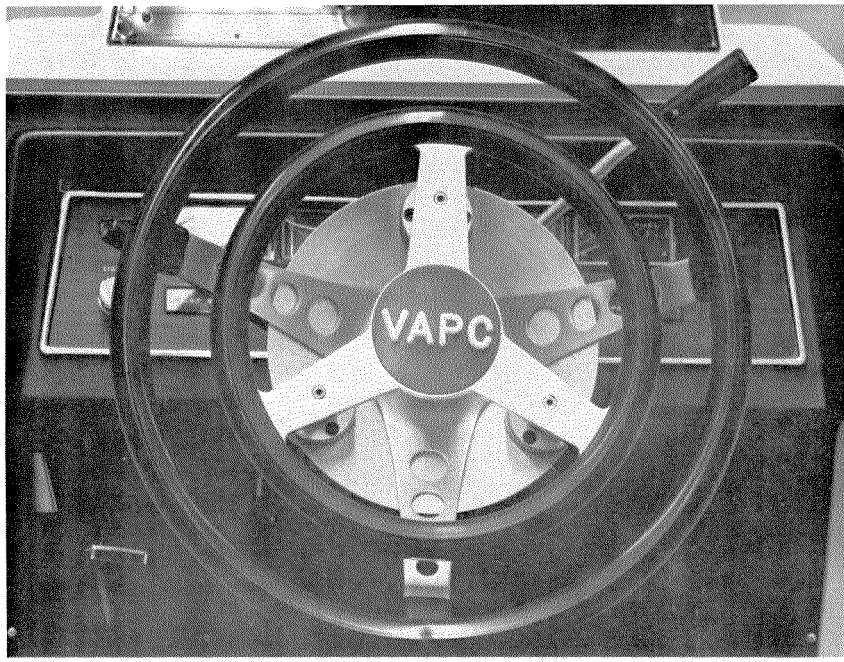

FIGURE 40.—VAPC Electro-Hydraulic Servo Control coaxial wheel mounted for use.

to control a motor vehicle adequately. Figure 39 shows an AETNA DRIVOTRAINER-71 with the VAPC Electro-Hydraulic Servo co-axial wheel (Fig. 40) mounted for use.

The laboratory simulator is a tool that provides dual functions: instruction and electronic monitoring. It represents an important link between laboratory testing and actual driving conditions. A computer monitors a driver's performance by identifying specific errors.

We plan to conduct extensive experiments with the VAPC Servo Control not only to examine the validity of the "double-wheel" interface with a variety of handicapped drivers, but to accumulate performance data on the reliability of individual components of experimental automotive control systems. Safety is the primary concern in the development of a new generation of automotive control systems for handicapped drivers.

b. *Design Changes in Mechanical Adaptive Automotive Hand Control Systems.* Compliance testing of commercially available adaptive automotive hand control systems, in accordance with VA Standard Design and Test Criteria for Safety and Quality of Federal Register, Vol. 40, No. 65, April 3, 1975, has revealed a number of substandard items. VAPC offered technical help to manufacturers of adaptive devices in modifying their systems, to comply with current VA standards. This offer of aid remains open in an effort to enable all available adaptive automotive equipment to meet the standards. Installation techniques with special emphasis on safety and reliability are also part of the requirements since even the best of auto driving controls may be rendered ineffective or dangerous by poor installation. Our close liaison with the adaptive automotive control industry has already produced many positive results, and it is expected that all design changes and modifications of adaptive equipment will be completed in the very near future. Handicapped drivers will have a choice of a wide variety of mechanical "add-on" equipment, but all should be in compliance with VA requirements on January 1, 1976. It is believed that this program is a fine example of government and industry cooperation for the benefit of the handicapped consumer.

II. TESTING

A. Testing

1. *Lower-Limb Torque Absorbers.* Several devices have been designed to allow controlled differential axial rotation between an amputee's socket and a prosthetic foot. The use of such a torque

absorber should modify the shear stress pattern which develops in the stump tissue adjacent to the socket during stance phase. Four torque absorbers are now being tested to determine their static and dynamic characteristics. These data, along with the results of a clinical pilot wearer study now in progress will be used to develop VA standards and specifications.

Four units are now being tested to determine torque vs. angular deflection, with and without an axial load. These are the Weber-Watkins, UC-BL, Hosmer, and the U.S. Mfg. Star rotators. The series of tests to be performed using the Instron tester also will include performance under loads related to walking activities. Loads will be applied at a rate equivalent to the number of steps taken in one week. The "cadence" will be 0.75 Hz, equivalent to 90 steps/minute, since all the units employ elastomer springs which require "real time" testing. Various combined loads, based on available locomotor data, will be applied. Finally, the units will be fatigue tested in an attempt to predict their useful life. These tests will be conducted on the SACH Foot Cycler which will be modified for this task.

2. *Mauch Knee Bolt.* A Mauch three-piece knee bolt assembly, designed to eliminate play in side straps of wood setups, was subjected to 500,000 cycles of flexion and extension at a frequency of 0.72 Hz. The two assembly screws, torqued to 120 in.-lb (13.5 Nm) did not loosen during the test.

3. *ISPO Collaborative Program.* The VA Prosthetics Center has begun a new test series in a collaborative effort with several other laboratories in foreign countries. At the request of the International Society for Prosthetics and Orthotics, VAPC is cooperating with the West Berlin Technical University and the Biomechanical Research and Development Unit, Roehampton, London. In this program collaboration helps to:

a. develop international standards for lower-limb prostheses,

b. assess the proposed physical tests which will be a part of these standards, and

c. provide a direct comparison of the test procedures employed by the participants.

Each participant will provide at least two samples each of above-knee and below-knee prostheses to each of the other laboratories. VAPC will provide samples of the above-knee Multiplex System and the below-knee Endoskeletal System, and will itself test these units extensively. The program, as presently planned, will include in each laboratory:

a. Cyclic testing to 3 million cycles at frequencies of 1, 5, and 10 Hz to determine whether test results are frequency dependent.

b. Testing the above-knee Multiplex as a structural system. Later

tests in this series will include the simultaneous application of an axial load, A-P and M-L bending moments, and an axial torque.

The VA Prosthetics Center proposed and BRADU has already agreed that - S/N/ - Fatigue Life Gages would be mounted on the modular prostheses to be tested during the joint effort. At a later date they would also be mounted on identical units issued to selected amputees. The gage is small, requires no power and can be located on a part of the prosthesis which is normally covered. As the prosthesis is subjected to normal use, a permanent change in the electrical resistance of the gage occurs. This change is proportional to the number of loading cycles and their magnitudes.

The selection of the amputees will be based, in part, on weight, activity level, occupation, and periodic availability. It is expected that these data will confirm or indicate the shortcomings of the proposed ISPO standards for cyclic testing and indicate the validity of current design specifications.

4. *Contracted Services.* VAPC will sometimes employ the testing services of other public or private laboratories in areas which it is not adequately experienced or equipped. Specific tests requiring the use of expensive, difficult to maintain equipment, are sometimes performed by other agencies on contract to VAPC. In most instances it is a combination of both needs—expert personnel and special facilities.

5. *Test Standards for Wheelchair Cushions.* This program will be carried out by the Biomechanics Research Unit, Helen Hayes Hospital, West Haverstraw, New York, under the direction of George Van B. Cochran, M.D., Med. Sc. D. on contract with VAPC.

Patients at VAH Castle Point, N.Y., will be test subjects during the clinical evaluation phase of the program. The group at West Haverstraw under Dr. Cochran, has a wealth of experience in evaluation and design of cushions and mattress materials for the spinal-cord-injured and similar-type patients. The Center will use the test standards to be developed to evaluate the performance of all upholstered cushions and cushion materials.

6. *Flammability and Toxic Fume Tests.* We are negotiating for the services of Fire Research Section, Structural Research and Ocean Engineering Division of Southwest Research Institute, for a series of tests to be conducted in its Burn Room Facility. The Facility is well equipped to analyze the gaseous products of combustion and smoke level and to document test results photographically and by closed-circuit T.V. The items and materials to be tested will be those found in VA Hospitals on and around patients. The items to be tested include bed linens, blankets, and mattresses. Standards will be developed as test results provide an adequate data base.

B. Compliance Testing

1. *Upper-Limb Components*

a. A.J. Hosmer, Inc., submitted two upper-limb components for compliance testing, the Hosmer External Elbow (Outside Locking Hinge), Model E-500 and the Sierra Voluntary Closing Hand, Model 44-00. Both met the specification requirement.

b. The Internal Elbow, Model PEI-6C, submitted by the Pope Brace Company also met the specification requirement.

2. *Lumbosacral Corset Material.* Three manufacturers submitted nine samples for annual specification compliance testing. Tests were conducted in accordance with federal specification CCC-T-121b, Part 5550.2 (D.O.D.), September 1963. All samples submitted by the following companies conformed with the requirements: Camp International, Inc., Kellogg Industries, Inc., and Warrior Surgical Supply Co.

3. *Adaptive Automotive Hand Controls.* The aim of this program is to assure that handicapped drivers are able to acquire hand-operated brake and accelerator controls and steering assists (adaptive equipment), for passenger vehicles, that meet the minimum VA safety and quality standards required by *PL* 91-666.

A secondary aim is the refinement of VA Standard Design and Test Criteria for Safety and Quality, as set forth in the Federal Register, Vol. 40, No. 65, April 3, 1975. This refinement is based on experience gained during the course of the program. An additional secondary aim is the test program itself.

Compliance testing was conducted on hand controls and steering assists submitted by all cooperating adaptive automotive equipment manufacturers. Equipment that initially did not meet minimum standards was modified by the manufacturer with the cooperation and aid of VAPC engineers.

Any equipment that initially failed to meet minimum standards was modified by the manufacturer, with the cooperation and aid of the VAPC engineering staff, so that compliance with the standard could be attained. Following is a list (effective February 25, 1976) of those manufacturers whose products have been approved for issuance.

Blatnik Precision Controls, Inc.
1523 Cota Avenue
Long Beach, California 90813
(213) 436-3275

Mross Inc.
Star Route Box 42
Elizabeth, Colorado 80107
(303) 646-4096

Drive-Master Corp.[a]
61 North Mountain Avenue
Montclair, New Jersey
(201) 744-1998

Ferguson Auto Service[a]
1112 North Sheppard Street
Richmond, Virginia 23230
(804) 358-0800

Gresham Driving Aids[b]
P.O. Box 405
Wixom, Michigan 48096
(313) 624-1533

Handicaps, Inc.[a]
4345 South Santa Fe Drive
Englewood, Colorado 80110
(303) 781-2062

Hughes Hand Driving Controls, Inc.
Box 275
Lexington, Missouri 64067
(816) 259-3681

Kroepke Kontrols, Inc.
104 Hawkins Street
Bronx, New York 10464
(212) 885-1547

Manufacturing & Production Services
4666 Mercury Street
San Diego, California 92111
(714) 292-1423

Nelson Products
5690-A Sarah Avenue
Sarasota, Florida 33577
(813) 924-2058

Smith's Hand Control
1472 Brookhaven Drive
Southaven, Mississippi 38671
(901) 743-5959

Thompson Hand Control[a]
4333 N.W. 30th Street
Oklahoma City, Oklahoma 73112
(405) 946-9517

Trujillo Industries
(Steering Assists Only)
5726 W. Washington Blvd.
Los Angeles, California 90016
(213) 933-7469

Wells-Engberg Co.[c]
P.O. Box 6388
Rockford, Illinois 61125
(815) 874-6400

Wright-Way Inc.
P.O. Box 907
Garland, Texas 75040
(214) 278-2676

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[a]Modified after September 1, 1975.

[b]Modified after June 1, 1975.

[c]Modified after March 1, 1976.

III. TECHNOLOGICAL UTILIZATION PROGRAM

Evaluation of Aids for the Elderly

The VAPC has been asked to support the newly evolving program of Veterans Administration Geriatric Research and Clinical Centers. The Center has begun to collect what is becoming a substantial body of literature on the needs and care of the aged and has attended several conferences on VA needs in caring for aged veterans. From these experiences specific areas have been identified in which bio-engineering support can be of substantial help in meeting VA objectives in caring for elderly veterans. There is a powerful thrust toward making these efforts fruitful, productive, and developmental for VA beneficiaries.

The population to be served by this proposed program is delimited by the degree of medical care required. At one end of the spectrum are those veterans residing in domiciliaries. These persons normally require no medical supervision, and very little, if any, nursing supervision. When ill, they are transferred to a hospital and treated like other in-patients.

Another is the group in the Geriatric Research and Clinical Centers (GRCC's). These beneficiaries are the principal focus of the proposed VAPC support program. With a certain amount of overlapping, GRCC's serve four classes of people ranging from Class 4, who are fully ambulatory and need only minimal nursing care, to Class 1, who are non-ambulatory and need extensive nursing care but only intermittent medical care. They may have chronic diseases requiring periodic medical treatment but are not suffering from acute conditions. When they become ill they too are treated in hospitals.

There is a third group of beneficiaries in Intermediate Care Units who may fall within the scope of this program. This group of people are on the average more than 65 years of age; people whose physical, sensory, or mental capacities may be diminished in various degrees due to aging. Their patterns of daily living may be facilitated or enriched with the help of specially adapted utensils, facilities, clothing, and newly designed mobility devices. They may be able to participate in recreational activities, paid or volunteer work, in or outside the hospital, and educational activities.

A continued and accelerated survey of the field has been recommended including an expanded literature search. Visits to existing GRCC'S within the VA system and in the non-VA sector have also been recommended. The following GRCC's have been visited: VAH, Bedford, Mass., VAH, Palo Alto, Calif., VAH, Bay Pines, Fla., VAH Sepulveda, Calif., VAH Wadsworth, Calif. These stations represent a wide range of case loads (40 to 162) and their programs address

themselves to the elimination of self-destructive and depersonalizing effects of hospital environments. Also to be visited in a second round of visits are VAH St. Albans, N.Y., VAH Castle Point, N.Y., VAH Bath, N.Y., VAH Little Rock, Ark., and VAH American Lake, Wash.

The purpose of this survey is to identify needs for adaptation of existing devices, design and development of new devices, and procurement and deployment of commercially available devices presently used in other applications. These needs will be considered within the framework of beneficiary requirements for shelter, feeding, hygiene, mobility, manipulation of objects, vocational/avocational activities, communication, and physical/medical treatment.

A great deal of useful information has been obtained from visits to programs abroad, Sweden, the United Kingdom, and the Netherlands, where similar social objectives have been pursued.

Simultaneous with the initiation of the survey is a proposal to establish a VAPC Clinical Engineering Unit at VAH, St. Albans, N.Y. This unit will consist of an engineer and a technician working closely with the beneficiaries. The primary mission of this unit will be to evaluate currently used adaptive aids of all types. Every effort will be made to encourage clients to contribute and participate in the development and modification of their own environment and objects within it. As experience is gained and specific needs are identified, the focus of the Clinical Engineering Unit's mission will shift to the development and evaluation of new devices. It would also undertake an equipment deployment program for evaluation purposes in all appropriate Centers of the Extended Care program.

Another aspect of VAPC's support program is aimed at prolonging life and preventing the onset of sudden debilitating or catastrophic physiological changes (trauma, stroke, cardiopulmonary changes, etc.). Several devices have been designed to continuously monitor key physiological parameters. Proceeding in stages, the first step is aimed at producing a relatively simple monitor with limited capability, perhaps no more than two directly monitored and two derived cardiorespiratory variables. It will be worn by a patient but will not require his intervention to actuate. It will signal a nurses' station when an incipiently dangerous or acutely dangerous condition exists. Deployment of a reasonable number of these relatively simple devices will provide information on utility, design improvement, and provide a longer time frame in which to design more sophisticated monitors capable of handling greater numbers and perhaps more significant variables.

IV. VAPC SPECIAL CLINIC TEAM

A. Service

VAPC Special Clinic Team exists to provide the veteran patient with an efficient, broad-based, and knowledgeable evaluation of his prosthetic or orthotic needs, without overlooking the fact that there is a human being at the other end of the prosthesis.

For that reason the Team has been organized to include personnel with many years of experience in prosthetics, orthotics, physical therapy, and orthopedics. In addition, because of the proximity to an outpatient clinic and hospitals, consultation with other specialists can be readily arranged. Dermatologists, neurologists, psychologists, psychiatrists, and social workers are amongst those available on short notice.

Originally, appointments were made for patients to be seen two afternoons per week. This was very convenient for the staff but was a hardship for the patients. It was decided to change the schedule to a daily one, and patients are now seen every afternoon at 1:00 PM, a significant improvement.

Sometimes amputees who develop problems will come in as soon as possible, frequently in the morning. They will take time off from work and be required to wait until afternoon to be seen on days when many other scheduled patients were being seen. This was not an ideal situation. Clinic Team meetings are now held daily at 10:00 AM and 1:00 PM. At the same time the orthopedic surgeon member of the team is available to see a patient at all times when requested by a prosthetist or orthotist. It is felt that this schedule accomplishes the primary mission of service.

B. Teaching

Throughout the year many visitors interested in the clinical application programs at the VAPC sit in on the clinics. They come from South America, Europe, and Asia as well as from the United States. Most of them spend between an hour or two or a day or two although occasional visits are much longer. A most recent visitor, a physiatrist from Yugoslavia, spent several months in the clinic on an almost daily basis.

Maintaining an affiliation with Maimonides Hospital, Brooklyn, N.Y., also provides new orthopedic residents for brief periods of indoctrination.

Perhaps the most valuable aspect of the educational program is the exchange of information amongst the members of the team. Each learns from the other. The team meetings are leisurely and are

not pressed for time since the meetings are held frequently. This permits extensive discussion and unhurried evaluation of the patient problem.

To maintain a current knowledge of new devices, a monthly Interdepartmental Information Exchange meeting is held. Personnel from all of the key departments of the VAPC attend the meeting, and the Clinic Team is kept informed of the status of the newer experimental units, while at the same time sharing their experience with experimental units which had previously been issued to patients for a clinical trial.

C. Development

By virtue of its unique position as the patient-VAPC interface, the Team has the engineering and administrative backup to develop, refine, fabricate, and issue originally designed prostheses or orthoses. Such developments are a direct result of an attempt to solve a specific problem in the milieu of the clinic team when it has become obvious to the Clinic Team members that the problem cannot be satisfactorily solved by available devices. As a result, the Clinic Team has initiated the development of such useful items as the PTB orthosis, the VAPC lumbosacral orthosis, the open-mesh distal end PTB soft socket insert, the cosmetic glove cover for a hook, the partial foot prosthesis, the all-polypropylene KAFO, the slip-cuff for the polypropylene AFO, a wrist-driven hand prosthesis, and many others.

D. Evaluation

Untried and unproven prosthetic and orthotic devices developed outside the VAPC as well as within the VAPC are introduced to co-operative and interested patients via the Clinic Team. This provides the Clinic Team with a broad knowledge of current developments and the opportunity to feed information back to the engineering component of the Center on such aspects as patient and clinic team response, durability, and function when the new item finally reaches its ultimate destination—the patient. For example, the team has most recently been involved with evaluation of various rotators, the UC-BL Four-Bar Linkage knee, the Multiplex knee, the Polypropylene Knee Orthosis with PTB Suspension Strap, and the Johns Hopkins Externally Powered Prosthetic System.

V. VAPC CONTRACTUAL DEVELOPMENT PROGRAM

It is abundantly evident that VAPC's responsibilities have been growing at a rapid rate. Not so apparent is the fact that the increase

in operations has outstripped the increase in facilities and personnel available within VAPC to mount the full range of new development and evaluation missions. Were the new tasks assigned to VAPC simply extensions of operations already in progress, they could easily be accommodated by the addition of personnel and equipment. But this is not the case; in fact all the new missions assigned to VAPC during the past 5 years have required ground-breaking, pioneering efforts in new fields. Some 5 years ago, for example, VAPC was assigned the task of providing bioengineering support for VA's Spinal-Cord-Injury Programs, a field new to us and generally untilled by the tools of bioengineering development and evaluation. That bioengineers are increasingly applying their efforts to this field today and have produced (we among them) an unprecedented harvest of new devices to improve the mobility and daily life patterns of spinal-cord-injury patients is ample testimony to the success of that program. Other programs of equal significance, if not magnitude, to which we have recently bent our efforts, include bioengineering support of the Extended Care Programs, a 2-year crash program to achieve full compliance with Public Law 91-666, a program to improve the delivery of prosthetic and orthotic devices via new VA-industry contractual relationships and several others. An essential ingredient in our management procedures enables us to accept and accomplish increasing numbers of tasks successfully without extensive expansions in personnel and facilities. Through out Contractual Development and Evaluation Program we obtain the temporary use of highly specialized facilities which we cannot duplicate readily and the services of highly specialized professional personnel whose skills are not available.

At the present time VAPC has either awarded contracts or has issued purchase orders for contracts to 17 agencies of various types including federal and state agencies, universities, and private facilities. Contracts have been awarded or purchase orders for contracts have been issued to the following:

1. Center for Concerned Engineering, Washington, D.C., to develop combination wheelchair and a mechanical device to enable a patient to stand up.

2. Falcon Research and Development, Colorado, to fabricate seven models of the PRAHN, an extremely versatile multifunction wheelchair.

3. George Washington University, Washington, D.C., to develop a sprayable latex coating to improve the cosmesis and stain resistance of artificial limbs.

4. Health Research Inc., New York, to develop test standards governing the quality of wheelchair cushions.

5. NASA, through its contractor, Jet Propulsion Laboratory, California, to develop a wheelchair-mounted voice control system for a VAPC designed manipulator.

6. Naval Electronics Laboratory Center, California, to develop an electric wheelchair which also elevates a partial quadriplegic patient to an upright position.

7. Northrop Corporation, California, to develop a graphite composite knee mechanism to be compatible with the endoskeletal system mentioned in 8.

8. Northrop Corporation, California, to fabricate graphite-epoxy endoskeletal prostheses for improved strength and reduced weight.

9. Rancho Los Amigos, California, to evaluate a functional electrical device to extend the wrist and fingers of hemiplegics.

10. Rancho Los Amigos Hospital, California, to furnish two veteran beneficiaries with upper-limb prosthetic systems providing sensory feedback by means of surgically implanted electrodes.

11. Scientific Systems International, Alabama, to develop a five-station food server for quadriplegic veterans.

12. Scope Electronics, Inc., Virginia, to fabricate a mechanically operated voice synthesizer for dysarthria.

13. Southwest Research Institute, Texas, to adapt the NASA-developed lunar vehicle control stick for terrestrial vehicles.

14. Southwest Research Institute, Texas, to develop an electro-mechanical physiological monitor for geriatric beneficiaries.

15. United States Manufacturing Co., California, to redesign the common SACH foot for special applications in below-knee and above-knee amputation.

16. University of Southern California, California, to develop an electronic physiological monitor for geriatric beneficiaries.

17. Whittaker Corporation, Connecticut, to develop a sonic physiological monitor for geriatric beneficiaries.

Several other contracts not mentioned above are in the process of being negotiated for other work. The VAPC Contractual Development and Evaluation Program provides a flexibility and scope of operations unmatched by any other government or private agency in this country or abroad. This system enables VAPC to respond to any tasks that may be laid upon it in the service of the American veteran.