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. LOWER-LIMB PROSTHETICS
  A. Basic Studies
    None
  B. Development (Techniques)
    1. Forming of Plastic Sockets
    2. Composite Endoskeletal Structures
    3. Aluminum Keel for SACH Feet
    4. Graphite Composite Keel for SACH Feet
  C. Evaluation
    1. VAPC Above-Knee Endoskeletal Structures
    2. Otto Bock Modular-Endoskeletal Hip-Disarticulation System
    3. Weber-Watkins Rotator for Lower-Limb Prostheses

II. UPPER-LIMB PROSTHETICS
  A. Basic Studies
    None
  B. Development (Components)
    Commercial Production of VA Externally Powered Hand and Elbow

III. LOWER-LIMB ORTHOTICS
  A. Basic Studies
    None
  B. Development
    Vacuum-Formed Orthoses
  C. Evaluation
    1. Ortazur Pneumatic Suit
    2. Exer-Shoe

I. LOWER-LIMB PROSTHETICS

A. Basic Studies

None

B. Development (Techniques)

1. *Forming of Plastic Sockets.* Prosthetic sockets for above-knee and below-knee are being vacuum formed of polyethylene and polypropylene sheets using a new portable system recently purchased from Orthomedics, Inc., of Downey, California (Fig. 1). The plastic sheet mounted in a metal frame is heated in a conventional oven. The heated sheet is placed, by hand, over the forming model. The advantages of this system over the commercial production vacuum systems to a facility our size and with our mission are: 1. the comparatively small size of the unit, 2. its portability and low initial cost, and 3. capability to manipulate by hand the heated plastic sheet to take advantage of the "drape" when indicated.

It has been found that an average molding time of approximately 10 minutes is required for forming a socket. It has also been noted that above-knee sockets are more easily drawn than below-knee sockets due to the pronounced conical shape of the thigh stump (Fig. 2). Difficulties previously encountered in maintaining critical anterior-posterior dimensions of the below-knee socket have been overcome by the use of a device which provides clamping pressures over the patellar-tendon and popliteal aspects of the socket.

Utilization of these sockets in prostheses has been limited because of a lack of suitable bonding between the plastic socket and the shank. New resins and mechanical attachments are currently being studied to overcome this problem.

2. *Composite Endoskeletal Structures.* The multiplex endoskeletal above-knee prosthesis, previously fabricated of aluminum, has been molded in a lightweight graphite-fiber-reinforced epoxy (Fig. 3) as described in BPR 10–19. The advantages are the 50–70 percent weight reduction offsetting, to some extent, the weight added when

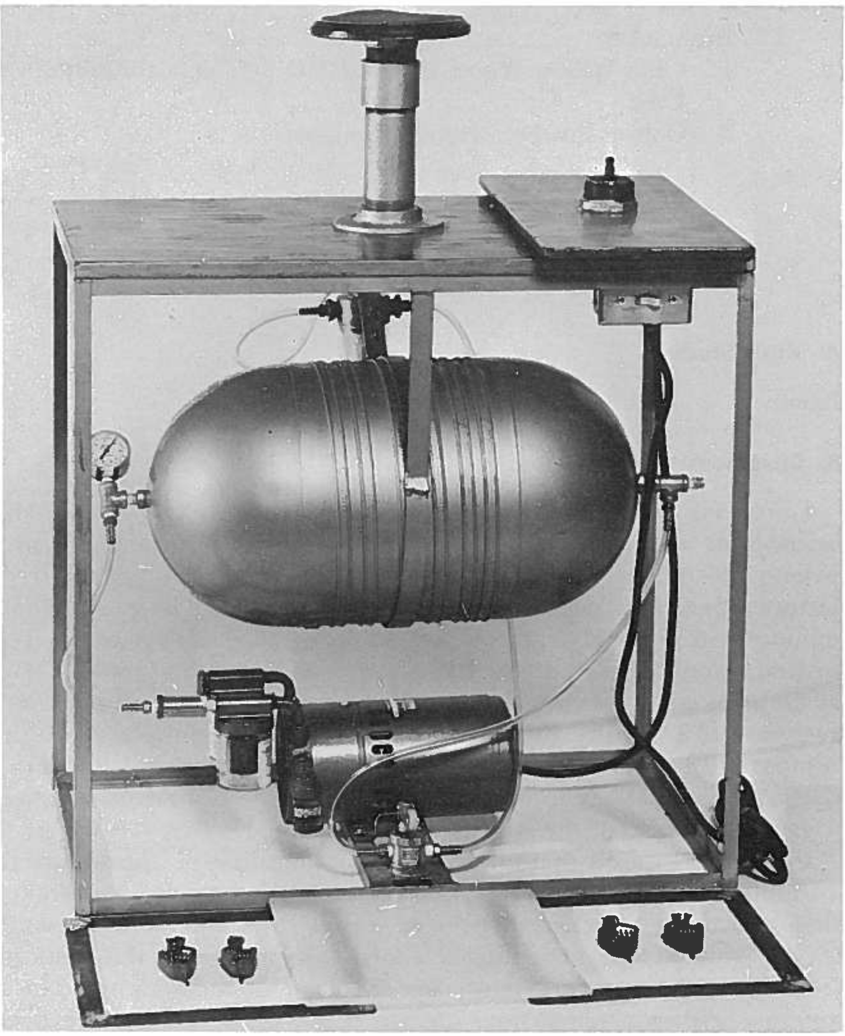

FIGURE 1.—Portable vacuum forming system.

fluid knee controls are used. Overall dimensions are being maintained, but the original structure has been modified to eliminate abrupt contour changes. Information from the VA Interstation Testing Program indicates that the single most troublesome problem is shaping the cosmetic foam cover over the prosthesis because of the aluminum structure's sharply angled external contours. The Northrop Corporation is considering ways of manufacturing those structures at a cost competitive with other systems now available.

3. *Aluminum Keel for SACH Feet.* Prototype castings of aluminum keels have been purchased. After machine finishing, they will be molded into SACH feet for testing and evaluation.

4. *Graphite Composite Keel for SACH Feet.* Models of a newly designed SACH foot keel are being fabricated of a lightweight graphite-epoxy composite. This material is potentially superior to wood. It is impervious to water, dimensionally more stable, and has greater resistance to breaking. It will improve attachment to the new endoskeletal prostheses. The keel is shaped better to distribute reaction forces generated in the compressible sections of the foot, an area of potential failure in conventional SACH feet. The new keel accommodates a split plug to facilitate attachment through the bottom of the foot, and to permit alignment changes to be made in

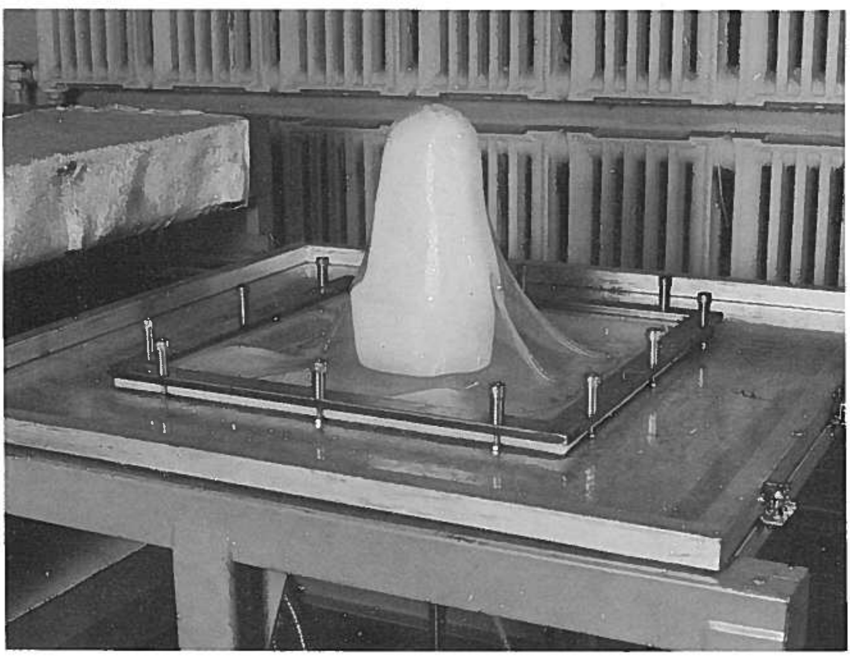

FIGURE 2.—Vacuum forming the conical shape of the thigh stump.

the foot attitude following completion of the appliance. Northrop Aricraft Corporation of California is developing the graphite-epoxy composite keels which will be molded into SACH feet for testing and evaluation.

C. Evaluation

1. *VAPC Above-Knee Endoskeletal Structures.* As previously reported, the evaluation of the "multiplex" by the VA Interstation Testing Program continued to point out the inadequacies of the cosmetic

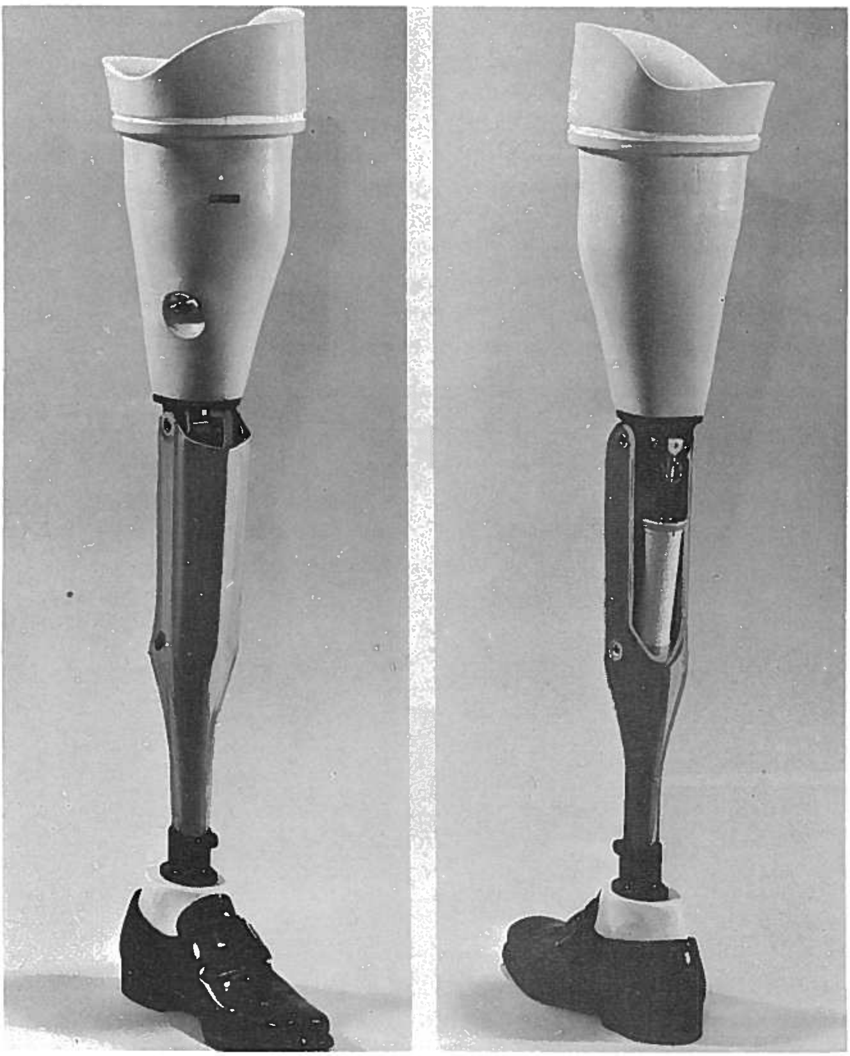

FIGURE 3.—Multiplex endoskeletal above-knee prosthesis.

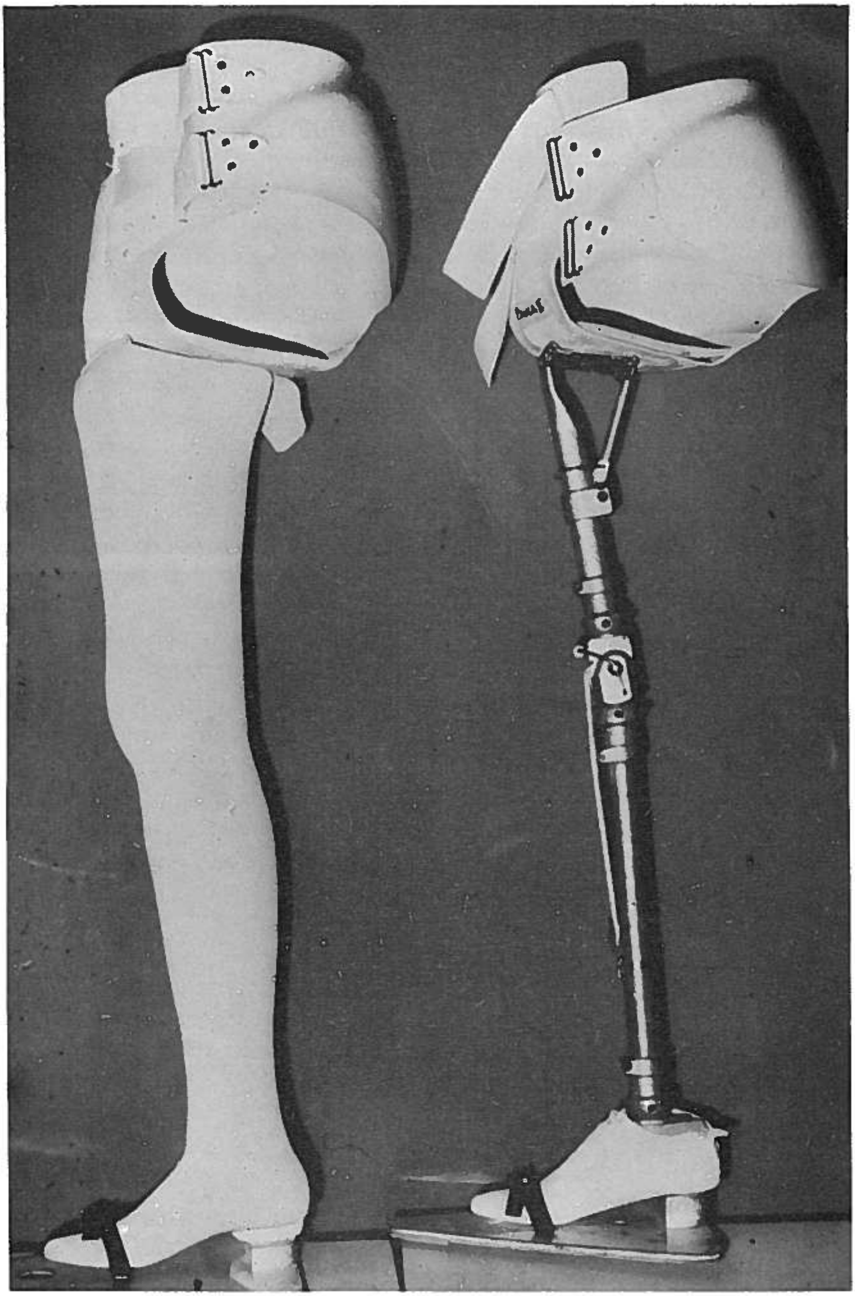

FIGURE 4.—Otto Bock hip-disarticulation endoskeletal system.

treatment of the above-knee endoskeletal prostheses. Since the results of these studies indicate that the system is mechanically sound, the replacement of the unitized (one piece) cosmetic cover with the Hydra-Cadence knee cap and socket attachment plate has been proposed. While this change constitutes a temporary return to the conventional "two piece" cosmetic treatment, the Hydra-Cadence shank cover and conventional lamination over the socket, it will permit earlier clinical use of the multiplex design: evaluation of the functional adequacy of this unique endoskeletal structure will therefore not be delayed because of the persisting cosmetic problem.

2. *Otto Bock Modular-Endoskeletal Hip-Disarticulation System.* Six Otto Bock hip-disarticulation endoskeletal systems (Fig. 4) were fitted in the VAPC Patient Care Service to evaluate the durability of the cosmetic cover and the mechanical structure. Difficulties were noted in shaping the foam cover. However, these problems were not as severe as those encountered when shaping above-knee prostheses. To date, maintaining adjustment of alignment and knee-friction control continues to be a problem. The difficulty is compounded by the concealment of the components beneath a formed cover which does not tolerate much handling.

3. *Weber-Watkins Rotator for Lower-Limb Prostheses.* Several models of this device have been fitted to patients. Initial reactions of both the above-knee and below-knee patients were very positive. Most reported that they experienced more "freedom," i.e., the ability to move with less restriction. Although, frequent adjustment, noise, and slightly substandard cosmesis remain problems, results of continuing evaluation indicate that durability and maintenance aspects of these units are generally acceptable. Preparations are being made to include this item in the artificial limb contract.

II. UPPER-LIMB PROSTHETICS

A. Basic Studies

None

B. Development

Commercial Production of VA Externally Powered Hand and Elbow. The VA-Northwestern University self-contained, electrically powered, myoelectrically controlled hand has been produced in limited quantity by commercial sources. By the time this issue of the Bulletin is distributed, it is expected to be available on prescription from the VAPC for veteran beneficiaries and from Fidelity Electronics, Inc., of Chicago, Illinois, for non-veterans. The VA hand is also available in a switch-controlled model.

The VA electric elbow has also been produced commercially. It is expected to be available, by the time this issue of the Bulletin is distributed, to veteran beneficiaries on prescription from VAPC, N.Y., and to non-veterans from the Hosmer Corporation of Campbell, California.

C. Evaluation

None

III. LOWER-LIMB ORTHOTICS

A. Basic Studies

None

B. Development

Vacuum-Formed Orthoses. The same vacuum forming techniques previously described for making prosthetic sockets have also been applied to the fabrication of orthotic devices (Fig. 5). Approximately 60 orthotic appliances of various types have been fabricated of polypropylene sheets ranging from 1/8 in. to 1/4 in. in thickness.

The quality of the orthoses has been quite satisfactory. Ankle-foot orthoses (AFO's) are routinely molded in an average time of 10 minutes but knee-ankle-foot (KAF) orthoses require substantially longer periods. In the present procedure for molding KAF orthoses, knee joints are added after separately molding upper and lower portions over a cast. The length of the KAF orthoses is sometimes a problem. Trials are in process to develop a method for vacuum forming a knee orthosis (KO).

C. Evaluation

1. *Ortazur Pneumatic Suit.* The French adaptation of a pilot's anti-blackout "G" suit (BPR 10–19) has been redesigned and is available from the International Latex Corporation (ILC), Dover, Delaware, through Mr. Frederick Seufert. ILC-Dover has modified the design of the original inflating mechanism. The company provides the suit with an a.c. or d.c. compressor as well as small throw-away-type compressed gas bottles. Four suits previously furnished to VA beneficiaries have been sent to ILC for updating.

The initial evaluation of this suit on four patients focused on its utility as an ambulation aid. Experience with 11 other patients at the

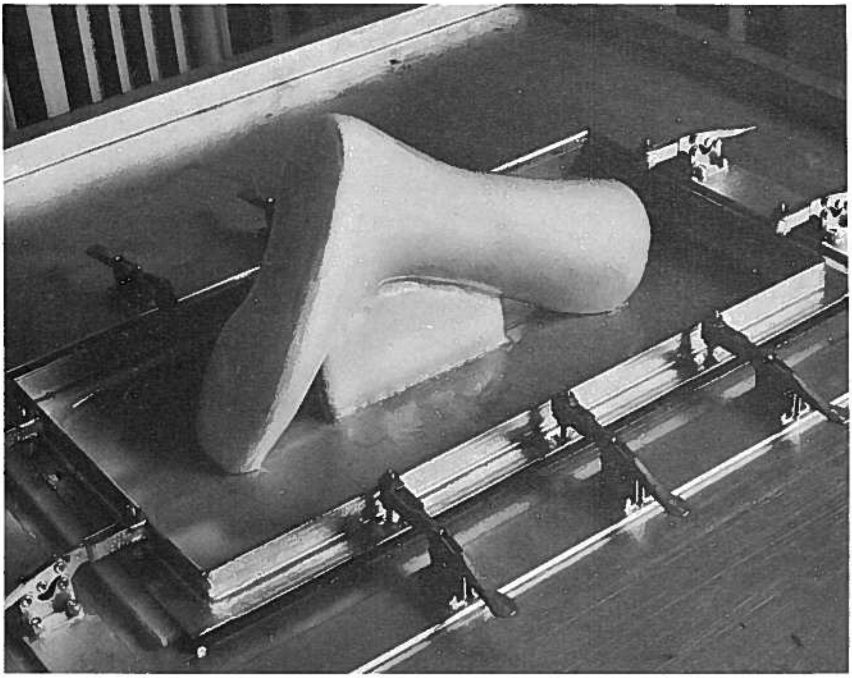

FIGURE 5.—Vacuum forming ankle-foot orthosis (AFO).

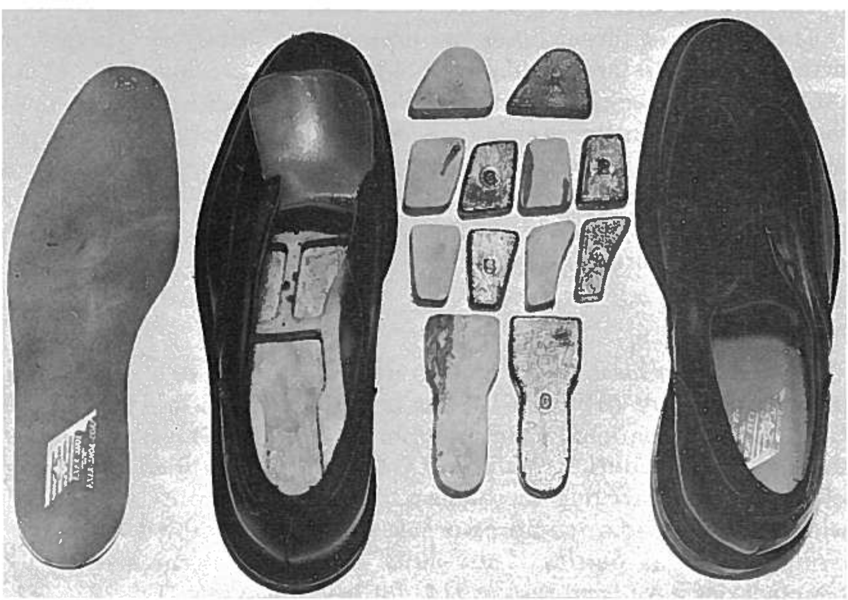

FIGURE 6.—The Exer-Shoe.

Bird S. Coler Hospital, Roosevelt Island, New York, fitted under the direction of Dr. Maurycy Silber, identified several positive physiological outcomes. Among them is the anti-blackout effect when recently injured spinal cord patients first try to sit up or stand up. Dr. Silber also noted better calcium retention and improved vital capacity. We intend to refit our upgraded suits and to extend the program to additional patients in order to investigate the utilization of this device, not only as a standing and walking aid, but also as a medical treatment appliance.

2. *Exer-Shoe.* The Exer-Shoe Corporation of Washington, D.C., has submitted for evaluation a pair of specially constructed dress shoes featuring inner soles with compartments used for adding weights (Fig. 6). The weight of each shoe can be adjusted from 3 to 8 lb.

The developer states that by gradually adding individual weights, the Exer-Shoe can strengthen 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 in New York and Castle Point.

IV. UPPER-LIMB ORTHOTICS

A. Basic Studies

None

B. Development

None

C. Evaluation

1. *Orthomot Myoelectric Orthosis.* Several Orthomot units, OM–1 (Fig. 7), have been evaluated at the VA Hospitals, Bronx and Castle Point, New York. The Orthomot is an electrically powered forearm orthosis with a bioelectric control amplifier. The contralateral biceps has been selected as a control site, and training in its use has begun, using a page turner. Two additional units have been fabricated and are scheduled to be delivered. The cable and housing have had to be lengthened as they were originally received too short.

At present there has been some difficulty in obtaining an efficient amount of electrical signal to operate the units. In some cases, due to an excess of fatty tissue, the signal is too weak to control the unit.

2. *Hosmer Electrically Powered Orthoses (Fig. 8).* This mechanically powered forearm orthosis is being currently tested at the VA

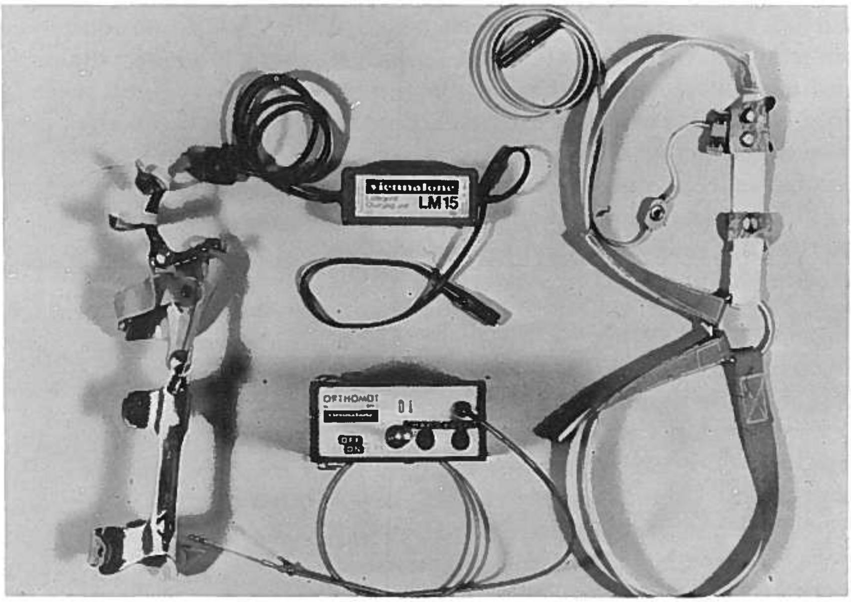

FIGURE 7.—Orthomot myoelectric orthosis.

Hospitals, Bronx and Castle Point, New York. The unit is operated by a manual switch with a "light" and "heavy" touch to open and close it. This mechanism is patterned after the Rancho Los Amigos Tongue Switch.

V. AIDS FOR SPINAL-CORD-INJURED PATIENTS

A. Basic Studies

None

B. Development

1. *VAPC Home-Type Environmental Controller.* The original controller described in the previous issue of this Bulletin (BPR 10–19) provided spinal cord patients living at home with many useful self-help capabilities. However, evaluation showed that patients wanted to control more appliances in the home environment. Consequently, an improved model has been developed; it includes an automatic mode sequencing circuit and display, and it has increased capacity (20 now versus 12 channels formerly) for handling additional appliances (Fig. 9). Several units were installed in patients' homes. The new unit permits operation of an intercom system and a special

radio (Fig. 10), and accepts additional special appliances such as a television surveillance and communication system for the entrance to a home or apartment. The new 20-channel model has been performing reliably. Additional units will be evaluated in the New York City area.

2. *Equipment Systems for SCI Patients Attending Schools.* To meet the needs of quadriplegics who wish to attend classes at a school, we are developing special equipment. Reasonable mobility is afforded by any of several new electric wheelchairs and control systems. However, attending classes requires the taking of notes and reviewing textbook material. A recently developed recorder, Sharp Tape Recorder Model RD–428U, actuated by head motion, permits patients to take class notes. A VAPC Water Dispenser mounted on a chin-controlled Motorette and a tape recorder provide the minimum

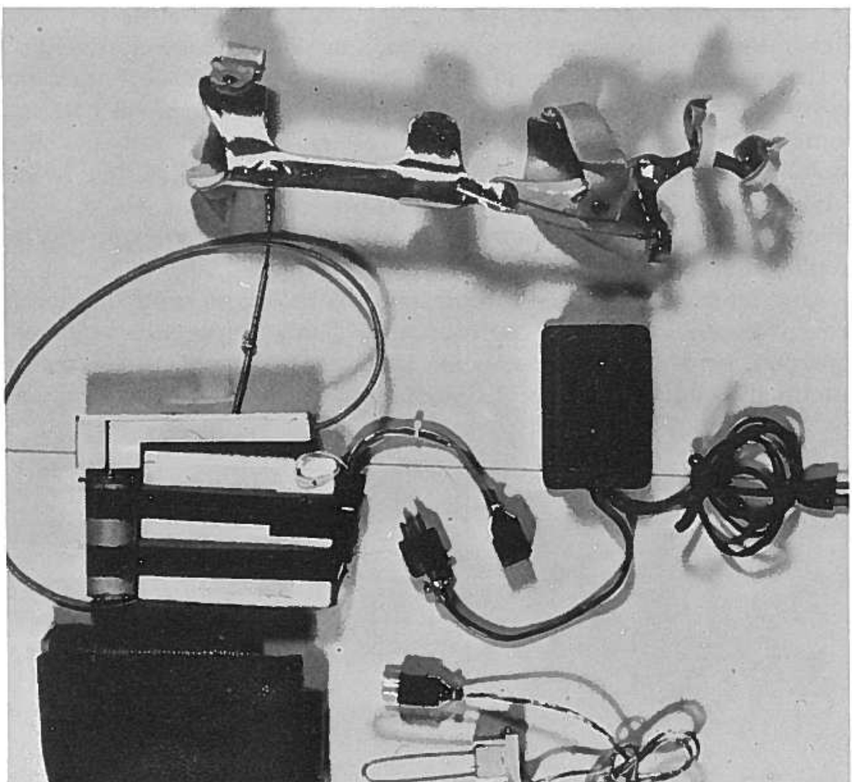

FIGURE 8.—Hosmer electrically powered switch-controlled orthosis.

equipment (Fig. 11). Obviously, the student should be able to read printed material, a great problem for quadriplegics who cannot handle the material even though their eyes are unimpaired. The use of special motorized microfiche and microfilm readers operated by the VAPC controller will be of significant value for these individuals. Additional demands will become apparent as we continue this program. To date, one patient at VAH Bedford, Mass., has been furnished a wheelchair equipped with the minimum "package."

3. *New Concepts for Environmental Controls.* The utility of environmental control systems for the hospital as well as the home has become increasingly apparent. However, all of the known devices restrict mobility during operation. Some require the patient to be in bed; all are artificial in that physical body motion or generation of positive and/or negative pneumatic pressures are necessary for employing controls normally operated by the hand and fingers.

The Bioengineering Research Service has mounted a two-pronged attack on these problems. One approach involves the development of a wireless environmental control system which will permit the patient to operate appliances while in bed, in his powered wheelchair, or some distance away from the controller. This will improve the mobility of the patient. It will be even more useful in the home environment than in the typical spinal-cord-injury ward. One laboratory model using telemetry is under development and will be deployed at a local hospital.

Another concept under consideration is the harnessing of speech to activate environmental controls or appliances. Speech is a normal function, and a machine capable of "taking orders" orally seems potentially valuable. Although initial costs are high, we are evaluat-

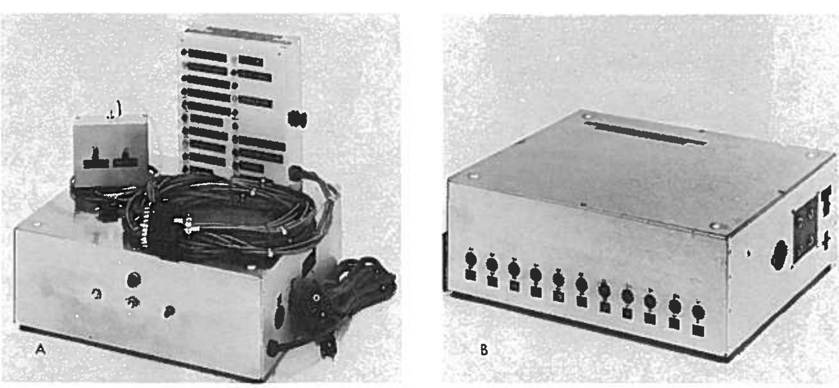

FIGURE 9.—a. VAPC Home Environmental Control, b. rear view.

ing this method of control. We expect to deploy at least one operational unit shortly.

4. *VAPC Communicator.* This device is a simplified version of the ViewCom which was evaluated approximately a year and a half ago (BPR 10–18). Designed to overcome some of the problems identified with the ViewCom, it is intended for those patients who are paralyzed from the neck down and cannot speak.

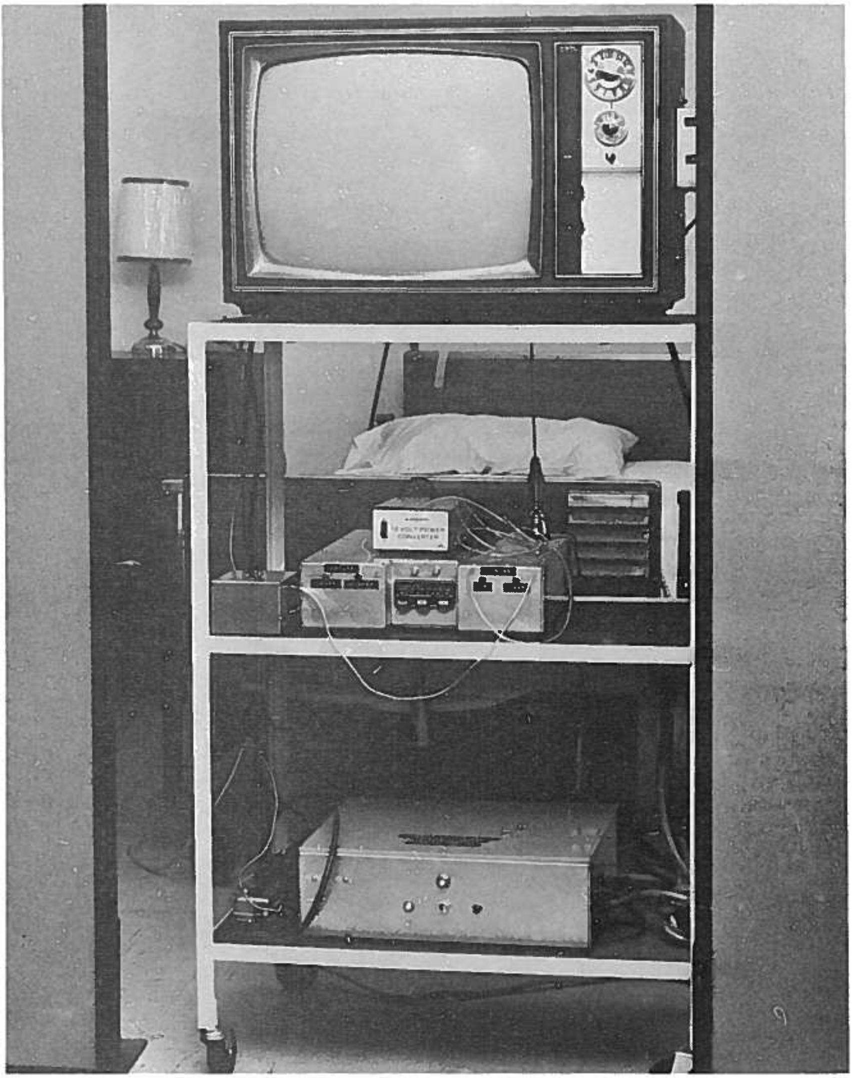

FIGURE 10.—VAPC Home Environmenal Control handles TV and radio with channel or station selection function and volume control.

The Communicator (Fig. 12) provides a total of 10 channels of information. Each channel alternates between a "yes" and "no" reply. Each channel also provides space for a message required by a particular patient. By sucking on the tube, each channel or message is sequentially identified. Two sucks provide two sequences. Each time the patient blows into the air tube the unit automatically returns to the first channel or message display.

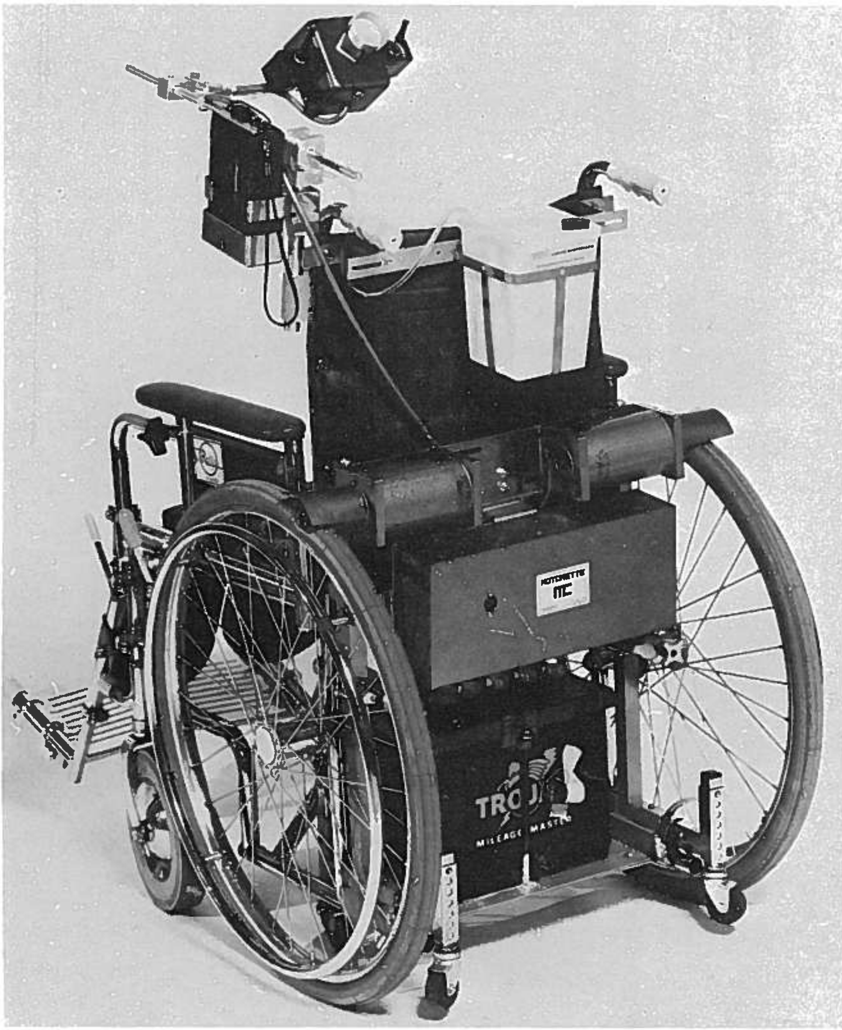

FIGURE 11.—A chin-controlled powered wheelchair with adaptations to permit quadriplegics to attend classes, take notes, and drink water.

C. Evaluation

Hayes Environmental Control. This unit, acquired from the Hayes International Corporation, is based on the original Hayes Sight Switch employed for control of electric wheelchairs. The environmental control incorporates a logic and a power section, and a remote wireless monitoring section (Fig. 13). Ten channels are available. Each offers an option of 110-volt a.c. grounded outlets or low-voltage sockets (jacks) for remote relay operation. The units will soon be placed in hospitals.

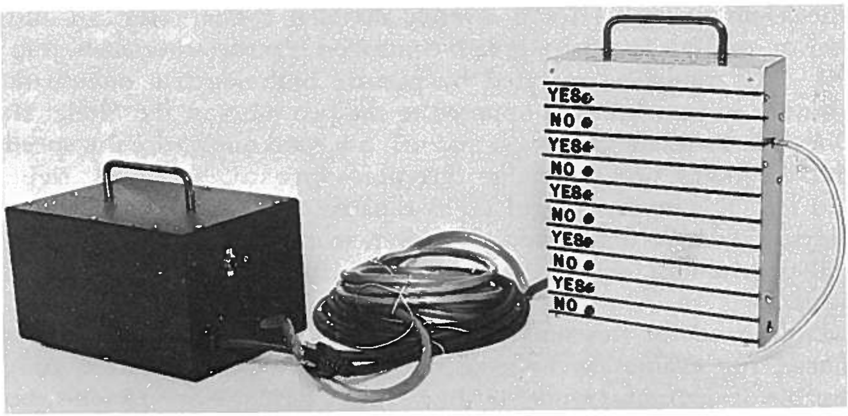

FIGURE 12.—VAPC Communicator.

FIGURE 13.—Hayes environmenal control operated by Sight Switch or pneumatic control.

VI. MISCELLANEOUS AIDS

A. Basic Studies

None

B. Development

1. *VAPC Pneumatic Control for Powered Wheelchairs, Model III.* As discussed in the BPR 10–19 Spring 1973 issue of the Bulletin, the Model III Pneumatic Control provides improved control over wheelchair operation for a severely disabled patient who can only use, or prefers to use, a breath-controlled electric wheelchair (Fig. 14). This model is operated by positive and negative pneumatic pressure in four tubes as opposed to the two tubes of the Model II. One tube turns the power on and off, a second one varies the speed and the other two determine direction—forward, backward, right, and left. Pneumatic control III is capable of veering or correcting course similar to other units. However, it is also capable of turning 180 deg. almost within its own length, thereby permitting sharp turns.

Little need for this unit was found in one hospital where it was placed for evaluation because the quadriplegics there are fully capable of operating Model II. In a second hospital, one patient who has been using a Model II breath control unit attempted to use a Pneumatic III control and found it difficult to operate. Apparently, Model III demands mechanical understanding and "driver aptitude." This was corroborated by a third patient who had been exposed to other types of pneumatic controls. This patient found Model III to be very useful because of the apparent ease of operation and its capability in varying speeds. Possessing excellent coordination, he finds the Model III advantageous in reducing speed inside hospital corridors and in other areas where maneuverability is difficult. It was also found very useful where higher speeds are acceptable. Negotiating ramps is also easier, since the patient can regulate power to the motors from minimum to maximum.

It seems, then, that while the Model III Wheelchair Control provides a very high level of independence to electric wheelchair users, it also requires special aptitude. Evaluation will be expanded as additional units are introduced into spinal-cord-injury services.

2. *Radio for VAPC Environmental Control System.* The VAPC Environmental Control, with remotely operated television and ordinary radio, has provided the principal source of entertainment for the high level lesion quadriplegic patient in spinal-cord-injury services. The system permits disabled patients to turn sets on and off

and to change channels. However, the patient has no control over station selection or volume control of a radio. Although the remotely operated television sets provide maximum reception on all TV channels, patients have complained that the TV programs during the morning and early afternoon are generally not interesting and they have expressed a desire for radios which permit station selection and volume control.

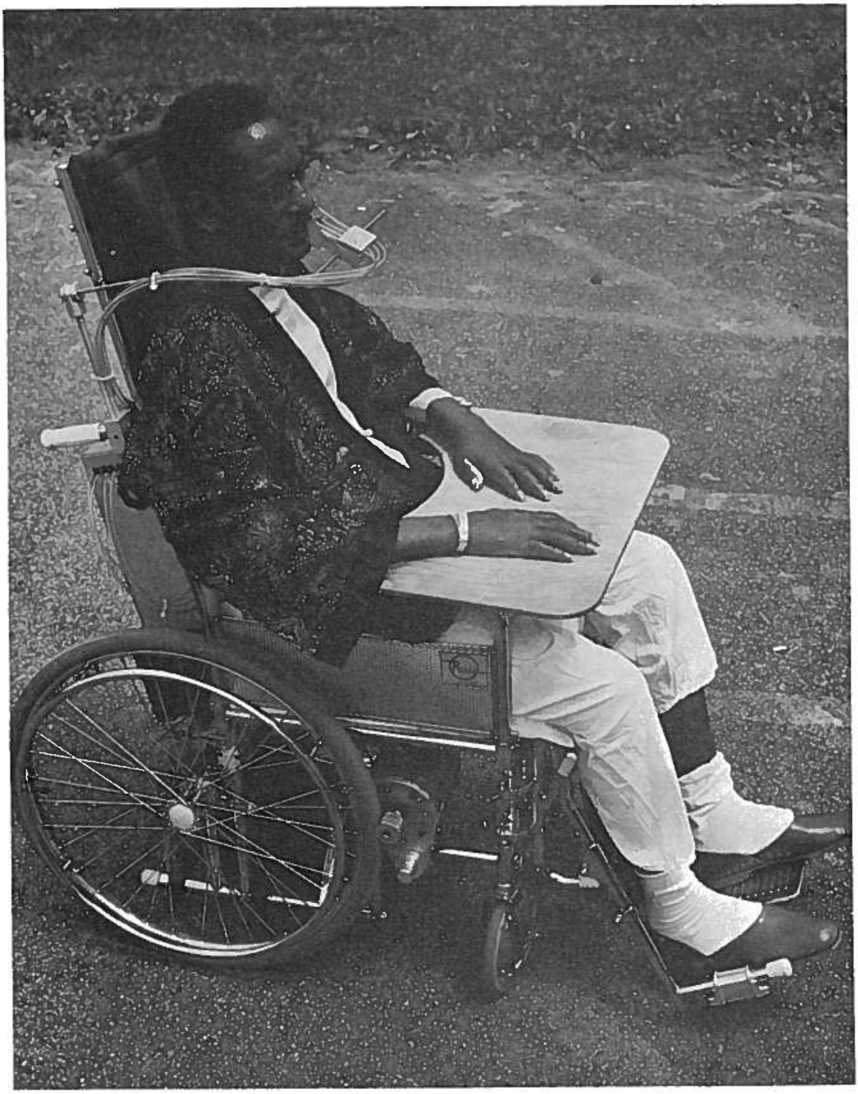

FIGURE 14.—VAPC pneumatic wheelchair control, Model III.

In response, we have developed a radio (Fig. 15 and 16) which permits tuning, volume control, and control of an on/off switch. Three channels of the environmental control are used for the radio. When the first channel (tuning) is activated once, the tuning mechanism responds up scale; the second stops the tuning process; the third causes the tuning mechanism to move down scale; the fourth stops the tuning process. Another channel, a low voltage outlet similar to that used for tuning selection, operates volume

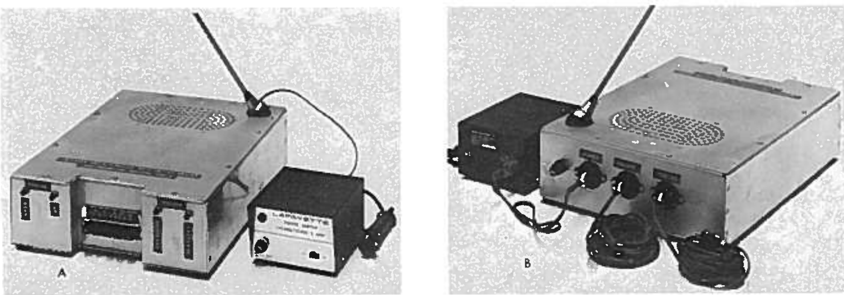

FIGURE 15.—a. VAPC environmental control radio, b. rear view.

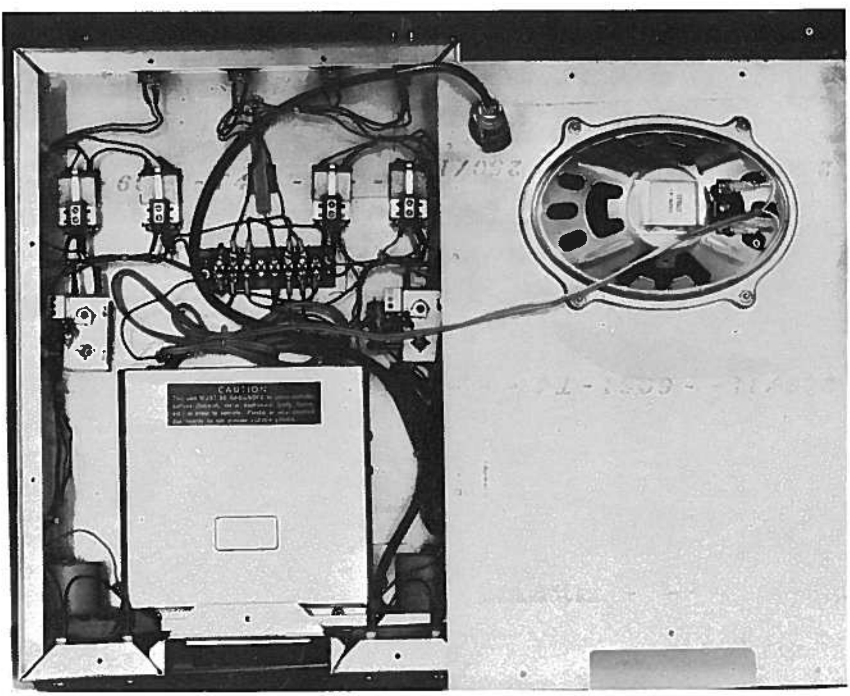

FIGURE 16.—Inside view of VAPC environmental control radio showing radio and electromechanical components.

control on the radio. It also operates sequentially: first activation of the low voltage outlet increases volume, the second stops it, the third decreases volume and the last activation stops it again. The third channel turns the power on or off.

A number of units now being fabricated will be introduced into both patients' homes and in hospitals.

3. *VAPC Water Dispenser.* Many quadriplegic patients ordinarily must consume 6 to 8 qt. of water each day to maintain normal kidney function. An active wheelchair user often forgets to consume sufficient water. We have developed a water dispenser which readily adapts to chin-controlled powered wheelchairs (Fig. 17). A simple microswitch adjacent to the wheelchair joy stick control (Fig. 18),

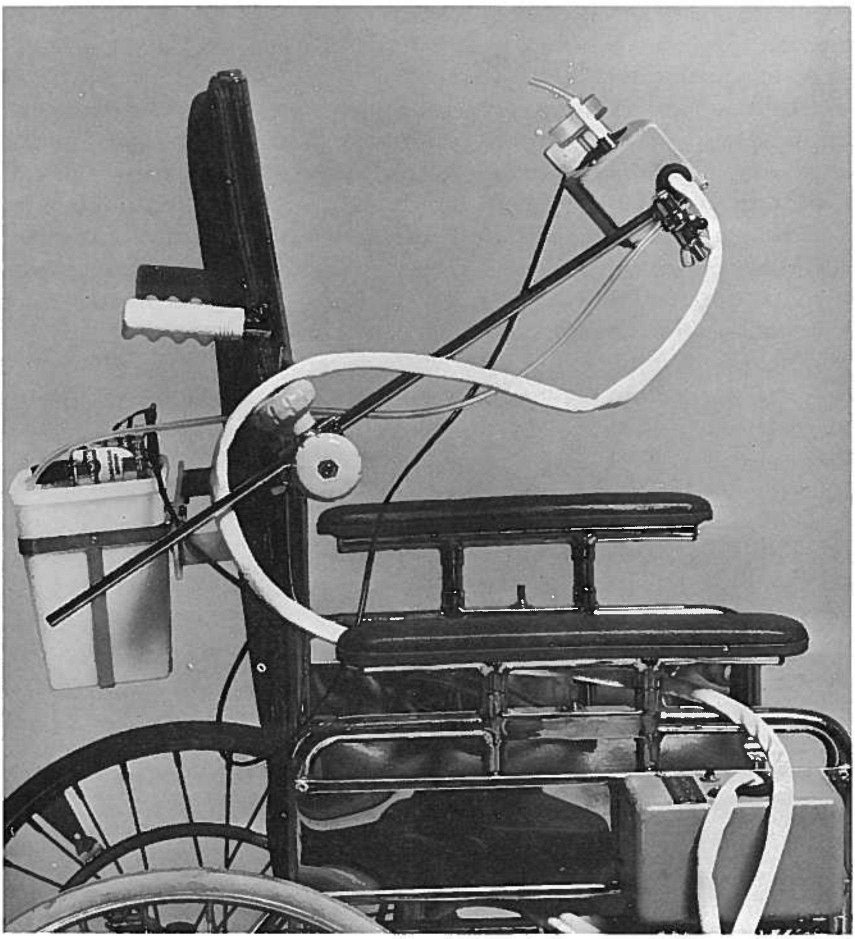

FIGURE 17.—VAPC water dispenser for electric wheelchairs.

actuated by the patient's chin, turns on a miniature water pump within the water container (Fig. 19). The water dispenser, of plastic and stainless steel, can be easily sterilized. Patients in bed need a flexible bracket because the bed patient must alter his position periodically to maintain adequate circulation and prevent bed sores. We are therefore designing a water dispenser control which will be applicable for both bed and wheelchair use.

4. *Reading Machines.* Quadriplegic and similarly disabled patients are unable to manipulate reading material and, although their eyes are functional, they cannot read independently. With help in placing the reading material properly, patients can turn pages with a mouthstick. Other more sophisticated and hopefully more efficient methods are being explored. Attempts are under way at other organizations to develop practical reading devices. We are approaching this problem by converting all reading material (e.g., newspapers, magazines, texts) into a standard format such as microfiche or microfilm. The advantages of microfiche include relative ease in duplication, low cost, capability of reproducing photographs and illustrations in color, as well as black and white, and the capability of providing up to 100 or more pages of text material on a single 4 in. x 6 in. microfiche card. Microfilm offers a different set of advantages such as the capacity of displaying several texts on one strip of film, including color as well as black and white photographs, schematics, and diagrams. This is particularly beneficial to severely handicapped individuals who wish to attend school. Microfilm readers are relatively expensive, but they handle a wealth of information.

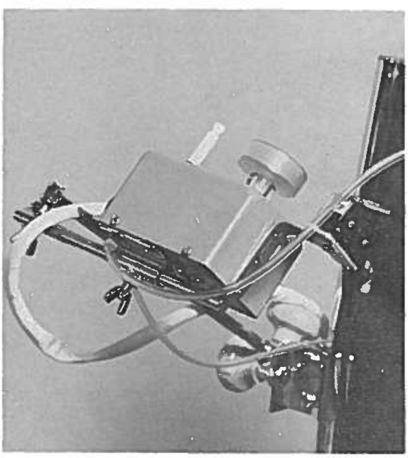

FIGURE 18.—Chin control assembly for VAPC water dispenser.

FIGURE 19.—VAPC water dispenser components.

We are presently developing several microfiche readers (Fig. 20) that are operated by pneumatic controls similar to those used in VAPC Environmental Controllers and Pneumatic Wheelchair Controls. Several of these units will be introduced into local VA Hospital libraries in the near future. We also plan to modify a microfilm reader and introduce it into a VA Hospital Spinal Cord Injury Service.

We are maintaining close liaison with Eastman Kodak and other interested organizations to facilitate the development of these readers.

C. Evaluation

1. *Optimizing Powered Wheelchair Performance.* As discussed in the BPR 10–19 Spring 1973 and earlier publications of the Bulletin, we have developed an electric wheelchair capable of providing improved function. The chair is a proportionally controlled printed circuit motor wheelchair power package. The latest versions of this device are a direct drive (Fig. 21) and a belt drive (Fig. 22) model. Efforts are being devoted to the incorporation of a chin control for quadriplegics and similarly disabled individuals.

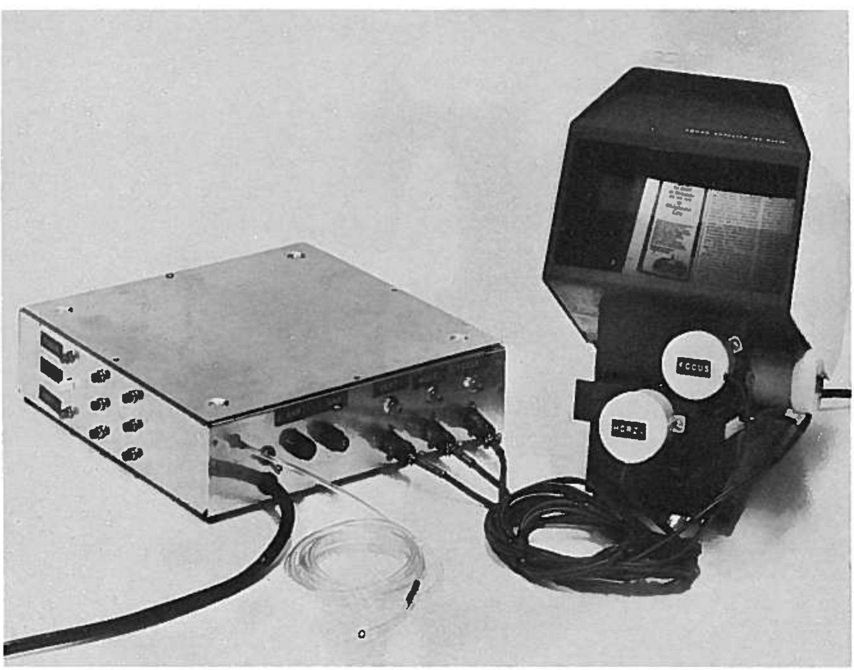

FIGURE 20.—Microfiche reader operated by pneumatic control.

These chairs continue to receive the most favorable patient responses. We are therefore taking steps to make this chair available for distribution through commercial sources within a few months. The assembly costs approximately $100.00 more than other commercially available models. However, for those patients who require or prefer a higher performance wheelchair, the additional cost may be worthwhile.

2. *The Hayes Pneumatic Control for Wheelchairs.* The Hayes Sight Switch control for powered wheelchairs was originally discussed in BPR 10–14 (p. 127) and again in BPR 10–17 (p. 222). The Hayes

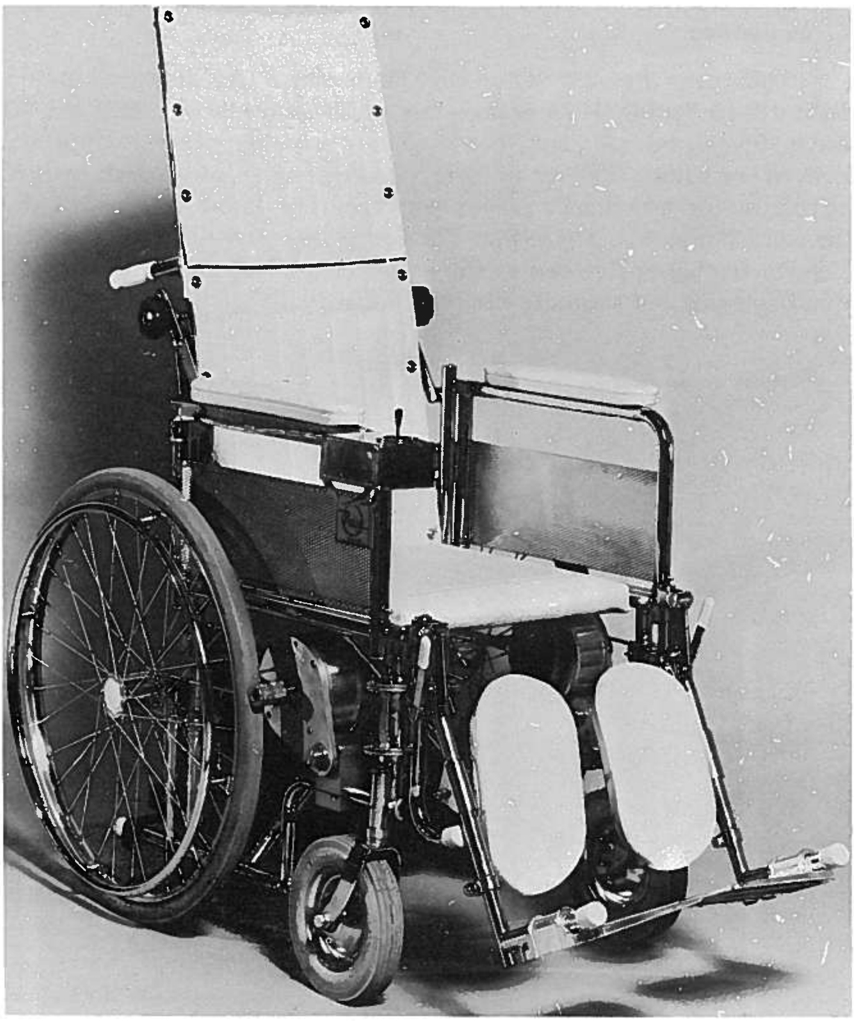

FIGURE 21.—Direct-drive printed motor package for electric wheelchair.

Corporation attempted to improve their Sight Switch device by converting it to a pneumatic control.

The logic for the pneumatic system is identical to the optical approach except that positive pressures (puffs of air), momentarily injected into the air tube, are analogous to using the right eye control on the Sight Switch. Generating continuous negative pressures in the air tube (sucking) is analogous to using the left eye control on the Sight Switch.

The original E&J "34" Power Drive electric wheelchair, with Sight Switch Control, was converted to the Hayes Pneumatic Control (Fig. 23). It has recently been sent to a VA Hospital Spinal Cord Injury Service where it is undergoing clinical evaluation.

3. *"Wheelchair-Type" Vehicles.* In referring to electrically powered wheelchairs one generally visualizes an otherwise conventional, heavy duty wheelchair frame to which have been added motors, batteries, and other appurtenances for control, stability, etc. Commercially available electrically powered wheelchairs are generally designed along these lines. Perhaps as a result of the increased use of electric wheelchairs and the subsequent demand noted for higher speed and improved performance characteristics, we are seeing larger numbers of vehicles intended for use by wheelchair patients but which represent different design concepts. These are not the conventional wheelchair frame with power features added; they are more in the nature of modified "golf carts" with some reconfiguration to accommodate particular needs of the disabled. In the past we have evaluated several such devices and reported the results in this

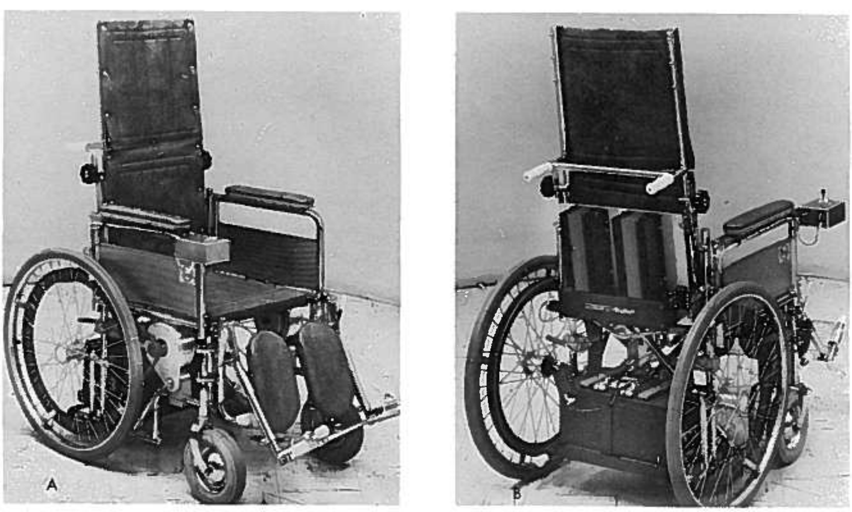

FIGURE 22.—a. Belt-drive printed motor package, b. rear view.

publication (Permobil Superior, BPR 10–16, among several others). Detailed below are reports on our evaluation of four additional devices which fall into a class midway between the conventional powered wheelchair and a licensed vehicle.

a. *Everest and Jennings Mark 20 Power Cart.* The Mark 20 Power Cart (Fig. 24) originally described in BPR 10–17, was received by the Bioengineering Research Service during the spring of 1972 and was submitted for evaluation to a local VA Hospital Spinal Cord Injury Service shortly thereafter.

The Power Cart is not a wheelchair in the traditional sense. It does not permit adjustments for different leg lengths, but the removable armrests provide the opportunity for lateral transfer. The Power Cart is a fine looking vehicle and frequently creates the

FIGURE 23.—Hayes pneumatic control for electric wheelchairs.

illusion of being easy to handle by individuals who suffer disabilities in the upper limbs. It is necessary for the Power Cart's occupant to have good finger, hand, arm, and shoulder excursion and strength in order to operate this vehicle satisfactorily. The tiller provides directional control of the front wheels and incorporates a lever which permits proportional speed and direction control. Good finger and thumb motion is required for operation of the speed control, and the tiller demands excellent hand, arm, and shoulder function. A mechanical hand brake may be used to slow down the vehicle and for parking. Good upper-limb function and trunk stability are required.

The Power Cart uses a separate automatic battery charger, a desirable feature which prevents overcharging. The Mark 20 Power Cart has been well received by only a limited number of patients, apparently due to its entertainment value and/or unusual mobility problems encountered by them (Fig. 25). Most patients preferred to use a conventional electric wheelchair in which they felt more comfortable and which satisfied most of their mobility requirements, at least indoors.

The Power Cart had a minimum number of malfunctions during the evaluation period. When compared with other similar devices,

FIGURE 24.—E & J Mark 20 Power Cart.

this is a vehicle of limited practicality for most spinal-cord-injured patients. There may, however, be a still undefined portion of the disabled population who may find it useful for special purposes.

b. *The Advanced Wheel Chair.* A number of electric wheelchair users have expressed interest in acquiring a vehicle which performed equally well indoors and outdoors. While Everest & Jennings and Motorette, as well as the Veterans Administration Prosthetics Center, are currently developing high performance wheelchairs, to the best of our knowledge nothing is presently available which may be

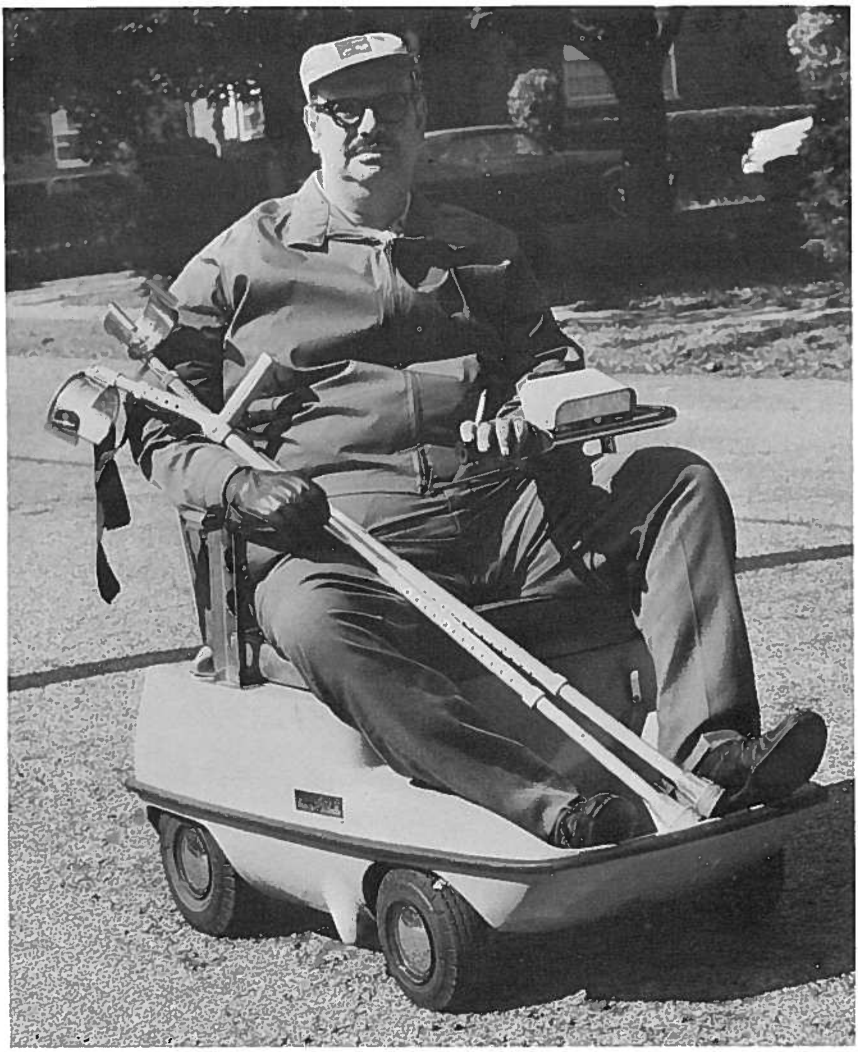

FIGURE 25.—The Mark 20 Power Cart handles difficult transportation problems.

reliably used both indoors and outdoors under a variety of weather and environmental conditions.

The Advanced Wheel Chair (Fig. 26) incorporates a 24-volt system with proportional control. It is a high performance vehicle for an active individual but with wheelchair characteristics for a severely disabled electric wheelchair user. The chair is small enough to be used indoors and features a reclining back, adjustable footrests and adjustable, removable armrests, permitting lateral transfer. The present motors are noisy, especially for indoor use; noise is rarely a problem outside the home or hospital. The outdoor environment is easily handled by this vehicle because of the deep-treaded tires fitted on the rear wheels.

The wheelchair uses a separate 24-volt battery charger. It is non-automatic and, therefore, care must be exercised to avoid overcharging the batteries too frequently to prevent permanent damage.

FIGURE 26.—The Advanced Wheel Chair modified for clinical evaluation.

FIGURE 27.—Zip Car.

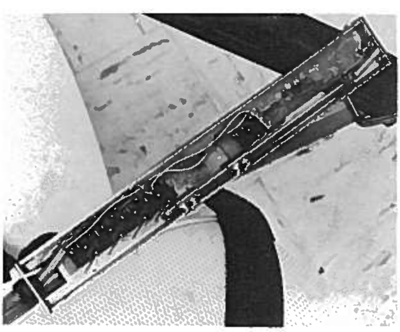

FIGURE 28.—Zip Car's speed/directional control assembly.

Since this high-powered vehicle accelerates rapidly, one must exercise care in its operation. For example, if a wheelchair occupant throws the control into full-speed reverse followed by full-speed forward, the chair rears up. Prior to submitting this chair for clinical evaluation, we attached anti-tipping casters to the rear of the chair. For additional protection, chain guards were added. Another interesting feature of this vehicle is the incorporation of electromechanical brakes on the motor shaft. When starting the chair, the brakes need to be electrically disengaged by a toggle switch. Since there is no mechanical or electrical interlock, it is possible in the evaluation models to leave the brakes engaged when starting the chair. Consequently, it is possible to wear the brakes and overload the motors. The concept of an electromechanical brake system is

FIGURE 29.—Steven Motor Chair.

very interesting especially for those patients who must use a chin or breath control system. The device is undergoing clinical evaluation in the hospital as well as in patients' homes.

c. *Zip Car.* This vehicle (Fig. 27) was obtained from Royce International of Englewood, Colorado, and is similar to the vehicle employed by Governor George C. Wallace. Zip Car requires good trunk stability as well as excellent control of the upper limbs. The right hand operates a tiller for steering both front wheels. The left hand operates a combination speed and forward-reverse control lever. The tiller demands good trunk, shoulder, arm, and hand capability while the speed and directional control lever demand good finger and arm motion. Pulling back on the lever engages a series of switches (Fig. 28) which provide more power to the motors. Reversing direction is accomplished by swiveling the lever laterally and then pulling back for speed control. The operation is awkward, even for a normal person, and the availability of full speed (approximately 10 miles per hour) in the reverse mode is dangerous. A mechanical brake is available but this requires good shoulder and arm excursion as well as trunk stability. The Zip Car has been rejected by all of our spinal-cord-injury patients who tried it because of the difficult handling characteristics.

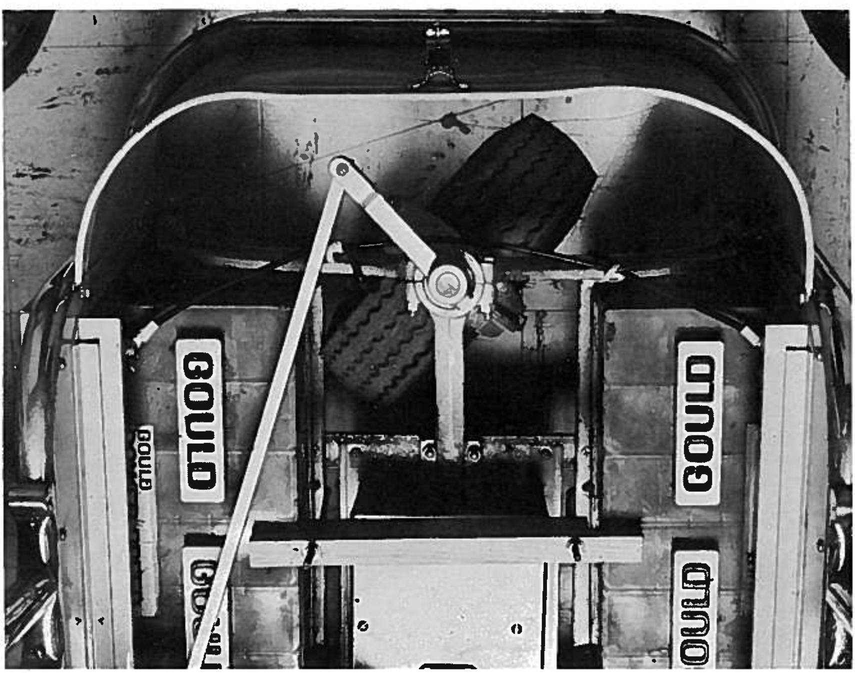

FIGURE 30.—Inside view of Steven Motor Chair showing single rear steering wheel.

d. *Steven Motor Chair.* The Bioengineering Research Service received for evaluation two units of this device (Fig. 29) from the Steven Motor Chair Company of Kansas City, Kansas. This chair is designed to meet the requirements of those physically handicapped individuals who wish to travel longer distances than conventional electric wheelchairs permit them.

The Steven Motor Chair incorporates two large motors which are powered by a 24-volt supply (two automobile-type batteries). Acceleration, speed, and ramp climbing capability are relatively high. Speed control is obtained via a coarse and fine switching mode; within each mode four speeds are available by use of a throttle handle. The speed control is located on one of the armrests. Steering is achieved by pivoting this armrest medially or laterally; an action which orients the single rear wheel in the desired direction. This steering action, in conjunction with speed selection, requires good finger, hand, arm, and shoulder excursion as well as strength. Therefore, it is rather difficult and awkward for many physically handicapped individuals to use this vehicle. The pivot of the control arm is located adjacent to the elbow. At high speed, the steering is too responsive, causing weaving. Sudden stopping or starting generates a jerky motion.

As we have indicated, the Steven Motor Chair is not a wheelchair; it lacks an adjustable footrest, and the non-removable armrest precludes lateral transfer. The back, however, is adjustable for different angles. A seatbelt provides some measure of patient trunk stability.

The vehicle is inherently unstable because of its three-point support. The single rear steering wheel hits and rubs against the chassis during tight turns (Fig. 30). A self-contained battery charger is packaged within the chair's chassis. It is activated by connecting an extension cord from a 110-volt a.c. household outlet directly into an ungrounded receptacle located on the side of the vehicle. This is a potential shock hazard.

Some patients in Spinal Cord Injury Services noted difficulty in operating the steering and speed control assembly. The vehicle was apparently well received at the VA Hospital in Richmond, Virginia, which offers a rather unique environment including 7 miles of hospital corridors. The wide corridors and extended distances are ideal for a high performance vehicle such as the Steven Motor Chair, and patients who are able to use this unit find it advantageous there. However, it should be pointed out that because of its low carriage, the user has difficulty over uneven and rough terrain, limiting its use outdoors.

4. *Twenty-Four Volt Everest and Jennings Electric Wheelchair.* The Everest and Jennings Company has developed a high performance

powered wheelchair and has submitted for evaluation one hand-controlled (Fig. 31) and one chin-controlled (Fig. 32) experimental unit.

Speed on each model is proportionally controlled and each employs a modular electronics package that is easily attached to the rear of the wheelchair. While neither unit is in production, their appearance and performance are excellent. They have been delivered for clinical trials at a local VA Hospital Spinal Cord Injury Service.

Patient response to both units has been excellent. They have enjoyed the higher speeds (over 5 m.p.h.) and improved ramp-climbing capability, especially outdoors. We plan to continue this clinical evaluation to assist the company in their future design and development efforts.

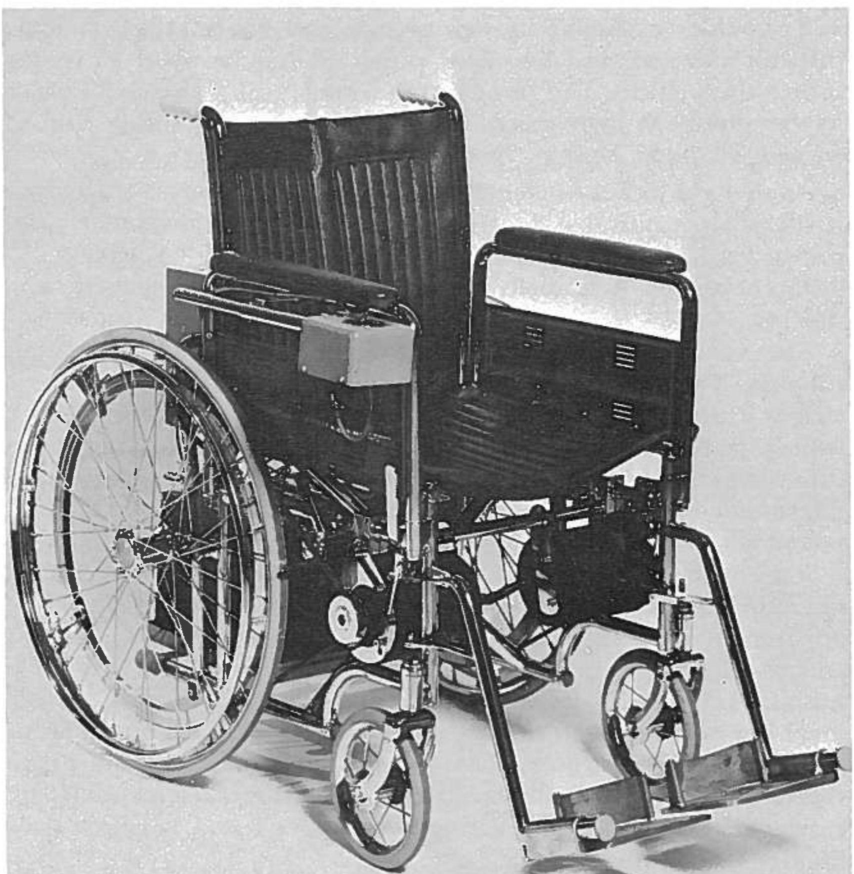

FIGURE 31.—Twenty-four volts E & J hand-controlled electric wheelchair.

5. *Motorette 24 Volt Power Package for Wheelchairs.* The VA Prosthetics Center has acquired two models of the 24-volt Motorette system for evaluation. This unit is virtually identical to the conventional 12-volt package which has received VA approval. The increased power of the new Motorette is intended for those powered wheelchair users who require higher speed and ramp-climbing capabilities. This evaluation is aimed at determining the general

FIGURE 32.—Twenty-four volts E & J mouth-controlled electric wheelchair, modified in clinic for chin control.

utility of the new power package and to confirm the utility of the considerably greater performance characteristics.

6. *Automatic Telephone Dialers.* In the Spring 1973 issue of the Bulletin of Prosthetics Research we described an automatic telephone dialer available from the Prentke-Romich Company of Wooster, Ohio. Since then a second dialer has been acquired from another company, Technical Aids to Independence of Bloomfield, New Jersey, and several other telephone communicator systems are being evaluated.

a. *Puff and Sip Auto-Dialer.* This unit is operated in a manner similar to the Prentke Romich unit. However, it functions in a breath control mode, that is, numbers to be dialed are sequenced by puffing and sucking. The "Puff and Sip" telephone device, presently being evaluated in the pneumatic mode, is compatible, according to the company, with the VAPC Environmental Control System.

Installation of the "Puff and Sip" telephone dialer requires a special coupling device installed by the Bell Telephone System. The Prentke-Romich unit is an independent system which includes the telephone instrument that can be connected directly into the telephone company's coupler. The Auto-Dialer consists of a control system which is attached to a *conventional telephone* via the coupler.

The operation of both units is essentially the same. Although the Auto-Dialer (Fig. 33) is available with a manual control, we are evaluating it in a breath control version. A light puff is analagous to lifting the receiver. A second light puff hangs up the telephone receiver. Dialing is achieved by sipping or sucking on the air tube and holding the sip until a light appears above the digit (displayed on a monitor) one wishes to dial. A rotary pattern of ten lights (digits) is available. When the digit is located, negative pressure is released and the selected digit is dialed. As with the Prentke Romich Unit, the speed of number sequencing is variable.

b. *Voicephone.* Telmec Systems, Incorporated, of Old Hickory, Tennessee, have sent their version of a special telephone for evaluation. Their device, the Voicephone, provides contact with the telephone operator who places the call. The unit incorporates a loud speaker for listening to conversation. An appropriate noise, such as a whistle, a loud voice, or a hard breath of air blown into a microphone activates the unit in a manner analagous to manually lifting the telephone receiver and calling the operator. If a call is coming in, then this operation permits the user to speak to the caller. If a call is to be initiated, then this action automatically dials the operator. The operation of the Voicephone is less complicated than the telephone dialers described above; however, reliance on the telephone operator is a necessity.

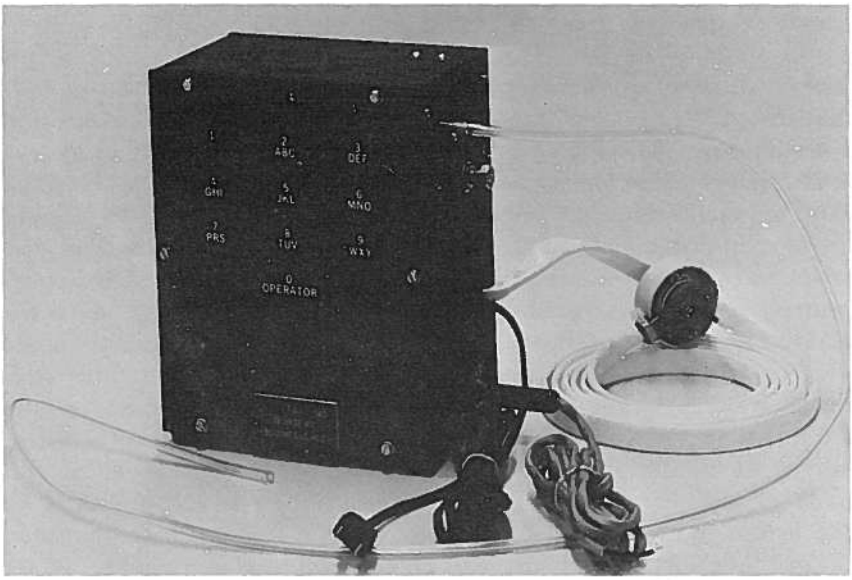

FIGURE 33.—Technical Aids to Independence (TAI) Auto Dialer is operated by breath control.

c. *Bell Laboratories Telephone Dialer.* Bell Laboratories has developed a sound (noise) operated telephone system (Fig. 34) which responds in a manner similar to the Voicephone. It is capable of dialing a complete number without the intervention of the telephone operator. An automatic sequencing circuit illuminates the complete rotary dial sequentially; the introduction of a noise into the telephone mouthpiece at appropriate times, dials the selected digits. A coded sequence is set for electronically lifting the receiver, and another

FIGURE 34.—a. Bell Laboratories Telephone Dialer is operated by sound, b. close-up view.

coded sequence is used to "hang up" the receiver. In its present configuration, the Bell Laboratories dialer is sensitive to ambient sounds during regular telephone conversations, a factor which may inadvertently "hang up" the receiver. Bell Laboratories indicates that a working system will be available for evaluation in about 1 year.

7. *Egerton Stoke Mandeville Electric Hospital Bed.* Egerton Hospital Equipment, Limited, of London, England, has submitted for testing and evaluation an electrically operated turning-tilting bed (Fig. 35). It includes a head-traction unit which is used for acute spinal-cord-injured patients, particularly where turning the patient onto his abdomen is contraindicated. It is designed to prevent pressure sores in such cases and to facilitate proper turning of acute cases with fewer ward personnel. Use of the bed makes it possible for one attendant to turn a patient onto either side to an angle of 70 deg. and/or to tilt the patient's head or feet down by 15 deg. independently or simultaneously. Turning and/or tilting is accomplished by the action of two small single-phase electric motors, each mounted on one side of the bed. The bed comes with a tri-sectional polyester

FIGURE 35.—Egerton Stoke Mandeville Tilting-Turning Bed.

mattress. The Guttman head-traction unit allows turning patients from side to side without losing cervical traction forces. It may be used in the treatment of any condition where routine turning is necessary or desirable, and especially in the avoidance of pressure sores. It is designed to combat staff shortages and their attendant expenses, and considerably facilitates the treatment of all heavy patients.

The Egerton Stoke Mandeville Tilting and Turning Bed was clinically evaluated by the nursing staffs at the Spinal Cord Injury Centers at VA Hospitals, Bronx and Castle Point, New York. Evaluation was limited to use of the electric bed and did *not* include use of the Guttman Head Traction Unit, as no suitable candidate requiring cervical traction could be located during the evaluation period. Patients using the Egerton Electric Bed were in the rehabilitation stage of their illness. Accordingly, use of the bed reflects a comparison with conventional hospital beds, powered and manually operated. In general the Egerton Stokes Mandeville Tilting and Turning Bed is a well constructed, maintenance-free device. It was found to be effective in turning patients when positioning the patient was otherwise difficult or impossible. It proved effective in removing pressure from specific areas on the patient at a minimal amount of physical strain to the staff. The tilting feature was useful for both postural and urinary drainage.

Since the Guttmann Head Traction unit had not been evaluated as part of this study, clinical experience at other hospitals using the *entire* system routinely were obtained. The consensus was that the entire system (bed and traction unit) is the best device for the treatment of acute patients with cervical spine injuries or dorsal spine injuries associated with chest and/or abdominal wounds, rib fractures, pulmonary complications, or injury. However, effective use of the device depends on thorough in-staff training and proper patient selection.

As the result of our evaluation supplemented with the clinical experiences of other institutions, we have recommended that the Egerton Stoke Mandeville Tilting and Turning Bed with Guttmann Head Traction Unit be made available to VA Hospitals, particularly those with active trauma departments.

VII. TESTING

A. Standards Development

Myoelectric Systems. Among the important developments in recent years has been myoelectric control of externally powered prosthetic and orthotic components for upper-limb disabilities. These systems offer more physiological control of the device, while minimizing the force and excursion usually required to control conventional devices.

To assure the quality and performance of myoelectric systems, test procedures were developed to determine their functional characteristics. It was also necessary to design special test apparatus with the capacity for testing all types of myoelectric controls.

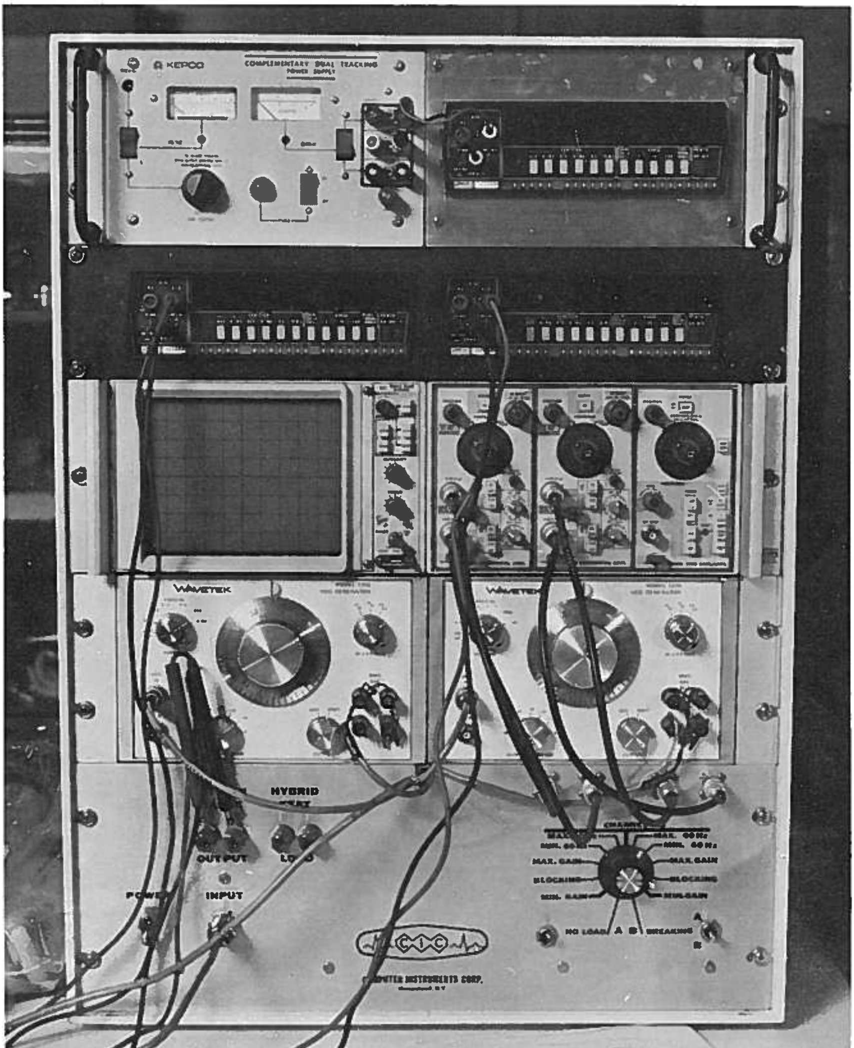

FIGURE 36.—VAPC/CIC myoelectric tester.

The test apparatus, developed by VAPC and the Computer Instruments Corp. (CIC) (Fig. 36) is modular in design, and controlled by a complementary dual tracking power supply which distributes power evenly to the modules. The power supply replaces the battery and eliminates electrical noise and ripple.

The inputs and functional outputs are regulated and monitored on the digital multimeters which provide an accurate numerical read-out of prehension force, voltage, current, and resistance. An oscilloscope module permits visual monitoring and measuring of artificially generated EMG input signals and time-related phenomena. The storage mode measures time delay in the dynamic braking circuits and the delay between signal inputs and functional outputs. It also has the capacity of viewing signals at a low range (10 microvolts per centimeter).

The impedance of two Wavetex generators is matched to simulate physiological EMG impedance. The device also programs voltage and frequency of any two signals simultaneously or sequentially.

In testing myoelectric hands, specific operational and performance characteristics are categorized by tests of functional gain, 60 Hz noise rejection, dynamic braking, and power consumption. A full bridge (semi-conductor) and a C-shaped Prehension Gage measure the force between the fingers. The test apparatus is also equipped with a control console, which can preset all electronic signals, simplifying large scale testing.

Test procedures are currently being performed on several hundred commercially produced VA myoelectric devices to determine functional adequacy and to refine specifications.

B. Compliance Testing

1. *Stump Socks.* Samples of wool stump socks for lower and upper limbs were submitted by four manufacturers for annual compliance tests. All samples submitted by the following companies conformed to the requirements: Bennington Stump Sock Co., Knit-Rite Co., Ohio Willow Wood Co., and Accurate Knitting Mills, Inc.

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 to the requirements: Atco Co., Kellogg Co., and Warrior Surgical Supply Co.

3. *Upper-Limb Components.* A.J. Hosmer, Inc., submitted three upper-limb components for compliance testing: The Hosmer Internal Elbow, Model E–400; Sierra Voluntary Opening Hand, Model E–223–00; and the A.P.R.L. Voluntary Closing Hook, Model Bearing

Serial Number 7163. All three components met the specification requirements.

4. *SACH Feet.* Five manufacturers submitted samples for annual compliance testing. Tests were conducted in accordance with Standards and Specifications for Prosthetic Foot/Ankle Assemblies, VAPC–L–7007–2, June 1, 1973. All samples submitted by the following companies conformed to the requirements: Wagner Orthopedic Supply Co., Kingsley Manufacturing Co., Laurence Orthopedic Co., Otto Bock Orthopedic Industry, and U.S. Manufacturing Co.

C. Evaluation

1. *Ohio Willow Wood Model #25D Mechanical Friction Unit.* Tests have been completed on the Ohio Willow Wood Mechanical Friction Unit, submitted by the Ohio Willow Wood Co., Mount Sterling, Ohio. The device provides relatively high resistance to knee rotation for a mechanical friction device. It can be installed in endoskeletal systems. We have recommended that this unit be made available to veteran beneficiaries on prescription.

2. *Colson Featherweight Wheelchair.* One Colson pneumatic-tired wheelchair; Model Number F WA–2211 H5, was submitted for evaluation by the Colson Corp., 3700 Airport Road, Jonesboro, Arkansas 76461. The Colson wheelchair (Fig. 37) passed destructive testing requirements and complied with all but three of the tentative VA Standards for Wheelchairs, Self-Propelled, Folding, Multi-Purpose. The deficiencies were poor leg-rest adjustability, insufficient skirtguard clearance, and excessive seat gapping. Several good features incorporated in this wheelchair are adjustable cup and cone bearings in the wheels, axle housings welded to the rear of the main structural members, and toggle brakes. It is a standard size chair, weighing 43 lb. The manufacturer has been informed of the relatively minor deficiencies.

FIGURE 37.—Colson Featherweight pneumatic-tired wheelchair.