VETERANS ADMINISTRATION PROSTHETICS CENTER RESEARCH

INTRODUCTION

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The contributions of our VAPC staff have usually been contained in the VAPC Research Report. For the first time with this issue we are treating certain subjects representing products of the VAPC research and development effort as separate articles in the Bulletin.

Five such articles by VAPC staff members appear elsewhere in this issue. The range covered is significant: wheelchairs, an upper-extremity socket construction method, a procedure for installation of hydraulic mechanisms in prostheses for supracondylar and transcondylar amputations, and technical problems about facial and ear restorations. Some comments may be relevant.

Wheelchairs are like automobiles in that the personal taste of the user becomes highly significant. What may be considered by an observer as minor variations in design sometimes become very important to the person who must spend a major portion of his life in a wheelchair. We propose to have standards for quality, safety, and function for wheelchairs, but these will probably never be used alone as a basis for the choice of one chair over another. Although we need to ascertain that chairs being made available meet the basic requirements of our standards, the characteristics of the devices including the minor differences in design should be catalogued for the information of those who prescribe and those who are to use the chairs. We intend therefore to followup on the excellent paper presented by Dr. Peizer and Mr. Wright by developing catalog-type information on all chairs which have met the basic VA requirements. We hope that a future issue of this Bulletin will contain this information.

Powered chairs represent another problem. For many reasons, mostly therapeutic, typical paraplegic patients should be required to use an arm-driven chair. Yet there are some paraplegic cases and other disabled as described in the paper by Peizer and Wright who really need a power assist. A simple way of achieving such powering is by employing designs which can be placed on an existing wheelchair in a facile manner.

These designs should not restrict the desirable features of the conventional wheelchair such as foldability and minimal weight for transfer to and from automobiles. Thus, we are making a serious effort to find those cases in the VA system who might benefit from power assist while we evaluate designs which can readily be added to existing equipment.

The direct forming of sockets on upper-extremity amputation stumps is another step toward the elimination of plaster of paris and the consequent intermediate steps required for construction of prostheses. Our readers may know that a similar technique on below-knee sockets is being evaluated by the Committee on Prosthetics Research and Development. Hopefully, New York University's evaluation of the below-elbow application described by Pirrello and Labate will clarify this procedure sufficiently so that prosthetists and patients can soon benefit.

The long above-knee stump such as yielded with the supracondylar and transcondylar levels of amputation has presented some problems in prosthetic design. We are not completely clear on the relative advantages of supracondylar, transcondylar, and through-knee (disarticulation) amputation levels. If the supracondylar and transcondylar levels can allow some end bearing, then the technique for installation of a hydraulic control at the knee as described by Cortellino and Gardner will be extremely helpful to prosthetists. Permitted is the fitting of endbearing sockets while allowing the use of an adequate knee control; as we all recognize, the long above-knee stump with its greater capability for prosthesis control and powering requires an adequately high resistance knee system generally represented by the hydraulic units.

Our Restorations Service in the VA Prosthetics Center is a recent addition to our organization although the group of people practicing in that Service has been serving veterans for many years. They are extremely skilled; they are exceptionally artistic; they know their field.

When this group joined our Center, our first effort was to obtain clearly specified descriptions of their techniques not only for our own sake, but for others who might be practicing their art. The two articles presented in this issue of the Bulletin by Dr. Donald Gearhart and Mr. Joseph Coppolino present some thoughts on several aspects of facial and ear restorations. A very common restoration, that of the ear, must meet certain basic standards as Dr. Gearhart enumerates. Mr. Coppolino tells us that often facial restorations may sometimes be "functional" as well as cosmetic. He also pleads for the restorations technician to be concerned about the hygienic aspects of the appliance he is providing his patient.

In our progress report which follows one can easily recognize the emphases the VA Prosthetics Center has recently had to place on powered upper-extremity systems and on evaluations of miscellaneous aids for

the disabled. We have much that we want to do in the form of development work on devices and techniques covering a wider spectrum of patients, but for this report period much of our effort has resulted from reactions to requests. Our work with the Committee on Prosthetics Research and Development panels has produced the lengthy treatments on externally powered elbows and on the planned program for externally powered terminal devices. We have been motivated not only by our commitments to assist the Committee on Prosthetics Research and Development but also because many of these devices have been closeted in research laboratories for years. We thought it timely to start getting hardware available for organized evaluations. Those devices that have not been under wraps have been handled by the other extreme, in popular magazines, newspapers, and on television; we are compelled to have these evaluated to separate the fact from the fiction.

Thus, major efforts are being made to study available powered elbows and terminal devices to prepare for a program of evaluation. Included should be studies of the control problems which are probably more significant to our external power development programs than the analyses of industrial powered units.

We have also need to react to many private inventors and developers of miscellaneous aids for the disabled. The reader may note the variety of items that the VA Prosthetics Center is called on to evaluate. These range from bath lifts and wheelchair cushions to toilet aids. Nevertheless these orthopedic aids are significant items to many disabled people. We have no standard which covers the wide variability represented by these designs; thus, evaluation considers each and every one on its own merit supported by adequate clinical experience.

We are impressed with the relatively simple Aztec curb-climbing attachment for wheelchairs which may indeed be helpful to certain cases. So it is well that some organization such as ours, although required to conduct its own planned research and development program, still can review all such items.

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Gait Patterns of the Aged

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Functional Foot

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None

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REPORT

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I. LOWER-EXTREMITY PROSTHETICS

A. Basic Studies

1. Gait Patterns of the Aged. In the previous issue we described a study program aimed at determining whether older persons, commonly classed as "geriatrics," walk in a measurably different manner than younger people. A practical object of the program is to learn whether significant gait differences might indicate the need for specially designed prosthetic components.

To date seven normal men, averaging 75.3 years of age (range 68 to 80 years) participated in this study of kinematic and kinetic gait factors. To permit comparison with available reference data on normal human locomotion, each of these subjects walked across the force plates and through the cyclographic camera field in order to collect data on the following variables: vertical load, fore and aft shear, medial-lateral shears, and the angular positions of foot, shank, and thigh relative to the ground.

Analysis of the force plate curves for this group indicated a significantly different gait pattern than that displayed by younger groups. The vertical load pattern (Fig. 1) clearly shows that the aged people walk in a less than normally vigorous fashion. The less acute slope of the curve between heel-contact and foot-flat shows a gentler application of body weight. The lower-than-normal peaks reveal a less dynamic transfer of

body weight onto and off the stance leg. Perhaps the most striking aspect of the vertical load pattern is the fact that the peak loads normally recorded at foot-flat and at push-off barely exceed the body weight, e.g., the loading peak and push-off peak were respectively only 25 and 20 percent of the normal loads above the body weight. Correspondingly,

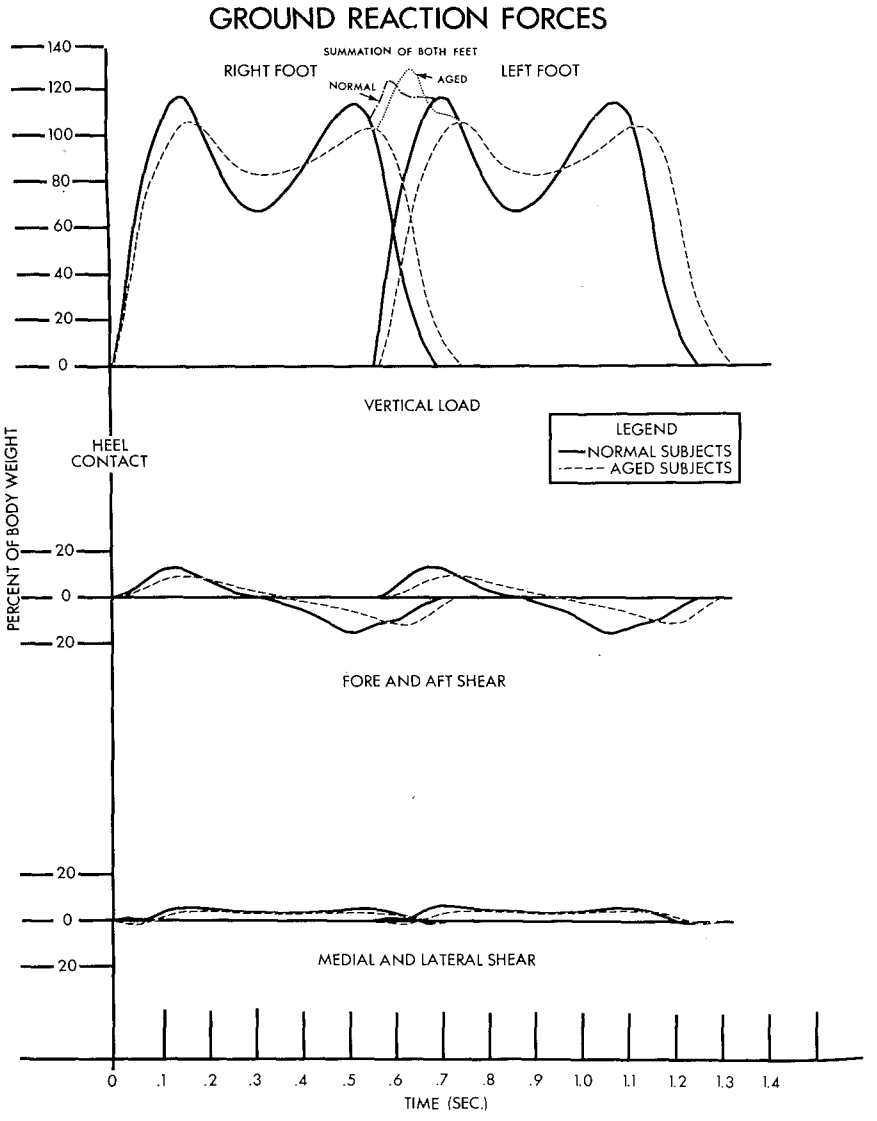

FIGURE 1.—Vertical load and shear forces of aged subjects walking on level ground and loads and forces of normal subjects.

inertial unloading (drop in vertical load below body weight) in mid-stance among the older people was only about one-half the normal value. On the face of it, the differences in peak loads seem anomalous—how can a person generate the kinetic energy to walk without generating higher inertial forces than those demonstrated to support himself and to transfer weight from one leg to another?

When the total load being applied during double support is considered rather than partial loads borne by each foot (dotted portions of the curve), one sees that the older people actually carried higher loads for shorter periods than the normal population. When an older subject walks he applies higher-than-normal vertical loads when both feet are on the ground and less-than-normal loads when he is on one foot. This may be the result of substantially reduced activity of the gastrocnemius, a possibility also shown by the significantly different aft shear pattern produced by the older people. Peak aft shears in the normal population coincide with the second peak of the vertical load and occur *before double support begins.* The older patients, on the other hand, generate maximum aft shears *after* double support has begun. This pattern may represent an adaptation in which older people use both legs (double support) to support maximum body weight rather than the one leg characteristic of the normal population.

The medial-lateral shear forces seem to exhibit a similar pattern, but since their magnitudes are far lower it is difficult to distinguish significant differences.

Further evidence that reduced gastrocnemius activity and dorsiflexion after mid-stance are distinguishing characteristics of an older person's gait is seen in Figure 2. Of particular interest is the angular position of the foot with respect to the ground during double support. Just prior to heel-contact of the swinging left foot, the heel of the normal walker has been lifted far higher than the older person's heel. This information is deduced from the foot to ground angle information and the fact that a part of the foot is in contact with the ground. During the entire double support period, the extent of heel rise of the older person is significantly less than that of the normal walker. When the foot angle with respect to the ground is subtracted from the angle of the shank with respect to the ground, we can calculate the position of the ankle joint. In double support the older person's ankle dorsiflexes far less than the normal.

The seven older patients studied to date have demonstrated such similar gait patterns that we feel they represent a typical sample. We are therefore planning to shift the focus of this study to include amputees in an even older age bracket. For this purpose we are obtaining the cooperation of people between 85 and 100 years of age.

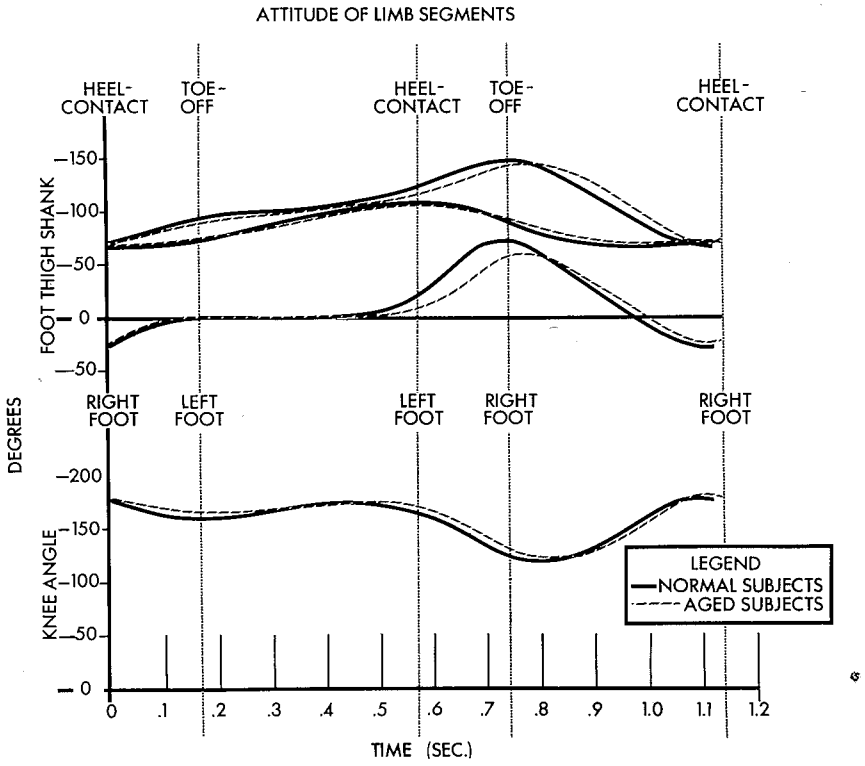

FIGURE 2.—Angular displacement patterns, with references to the ground, of the hip, knee, and ankle joints of aged and normal subjects walking on level ground.

B. Development (Components)

Functional Foot. Since the advent and standardization of the molded SACH foot there has been an apparent lag in efforts aimed at the development of prosthetic feet. A number of the problems associated with the use of single-axis wood feet were overcome by the development of the modern SACH foot, a mass-produced, standardized device which does not have to be significantly altered by the prosthetist before being used by patients. The availability of the single-axis wood and SACH feet has, in a sense, dulled the edge of the prosthetic foot problem; while these feet may still leave something to be desired, problems with prosthetic feet in general are not acute. The fact that both have persisted, that is, that one has not replaced the other completely, seems to indicate that each is a reasonably satisfactory answer to the problems of certain amputees.

The recent quiescence in this area is now being disturbed by rumblings from several quarters indicating that creative forces are again at

work. Mauch Laboratories is actively engaged in developing an ingenious hydraulic foot-ankle assembly. Professor Radcliffe at the University of California at Berkeley, Department of Mechanical Engineering, is working on an improved foot design as is the staff at New York University Prosthetic and Orthotic Devices Study. In our opinion this is the best time for research and development on foot-ankle assemblies. Because patients are reasonably well served, standards for new developments can be set higher and proceed in an orderly, thorough manner, uninfluenced by immediate patient needs.

In this connection we have also felt that there was room for improvement in the design of prosthetic foot-ankle assemblies, and accordingly we have undertaken a critical evaluation of the whole area with a view toward defining existing problems and studying the feasibility of a number of possible solutions.

Our views on the minimal requirements for prosthetic feet, including SACH feet, have previously been set forth in BPR 10-10. These standards and specifications were supported by several simple basic assumptions:

1. Prosthetic feet in general should resemble human feet.
2. The available motions in normal feet should also be available in prosthetic feet.
3. The ranges of motion and the resistances to rotation characteristic of normal feet should also be available in prosthetic feet to the extent necessary to permit amputees to walk in the most normal manner possible at the least expenditure of energy.
4. The locations of the axes of rotation in a prosthetic foot should approximate those of the normal human foot.
5. The newly developed prosthetic feet, regardless of the functional improvement that they purport to bring, should not weigh more than currently available prosthetic feet.

Ideally, a foot designed to overcome most of the current problems and represent a substantial improvement over current designs should be competitive in cost with conventional prosthetic feet. It should not require more advanced installation technology than currently used prosthetic feet, and it should meet the sometimes widely different needs of above-knee and below-knee amputees. Our conception of such a foot is of unusual design—a hollow, polyester laminate foot without a toe section and with a thin foam cushion over the fully formed plastic heel. This core unit is designed to receive an adjustable toe and a functional ankle assembly. The current plan is to design only three basic sizes of the foot shell corresponding to current SACH foot sizes, 7, 10, 13. The toe sections will all be of the same size; they can however be installed

into the foot shell to provide size 6, 7, or 8 in the smallest foot shell; 9, 10, or 11 in the middle-sized foot shell; and 12, 13, or 14 in the large foot shell. Toe units are conceived as not only adjustable in length, but also in resistance to toe extension, a motion which really serves the function normally obtained by dorsiflexion in the human foot. If normal dorsiflexion were to take place in a prosthetic foot at the same time and to the same extent as it does in a normal foot, the patient would run the risk of knee instability and/or drop-off at the end of the stance phase. Since amputees do not have active plantar flexion, the onset of dorsiflexion must be delayed in time until an extension moment is generated about the knee. In addition, this simulated dorsiflexion must be reduced in range to avoid drop-off.

At the present time we are considering the feasibility of several designs aimed at the development of a modular foot, i.e., one which permits the installation of selected components in a central core module. Three conceptions of a functional ankle assembly are under consideration. Each of them is designed to provide motion in three planes. The ranges of and resistances to these motions can be adjusted. Several models for a toe section are also being considered. Apart from length adjustment, we require that the toe section provide adjustable resistance to toe flexion. Such a versatile foot might very well represent an improvement over the existing devices.

C. Development (Techniques)
None

D. Evaluation (Components)
None

E. Evaluation (Techniques)
None

II. UPPER-EXTREMITY PROSTHETICS

A. Development

1. VA Electric Arm. We have undertaken the development of an electrical arm system designed for above-elbow and shoulder-disarticulation amputees. As presently conceived the system consists of the VAPC elbow and control system (BPR 10-10) and an electrically powered hand. The control system is designed to utilize the conventional control motions with sharply reduced excursions and forces. It is easily attached to the conventional above-elbow Figure "8" or similar harnesses. Flexion at the shoulder closes one switch producing extension at the elbow; continued flexion produces flexion at the elbow and the third increment of

shoulder flexion (total 9/16 in. [1.43 cm.]) actuates the electrically powered terminal device. In considering the design requirements for a terminal device we found that the Viennatone electric hand (described in BPR 10-8) with several simple modifications would meet most of the desired design requirements with respect to the physical properties and pinch forces. The terminal device for the VA Electric Arm System utilizes the Viennatone hand frame without the electronic system designed for EMG control. The original electric motor has been replaced by another with different characteristics. The present gear reduction system has been modified to permit operation of the new system at a maximum efficiency level which is significantly higher than the original unit. One patient has been equipped with this sytem to study fitting requirements and general utility.

2. *Physical and Functional Properties of Seven Externally Powered Elbows.* Despite a great deal of research and development effort in the area of externally powered upper-extremity prostheses, only one complete system including shoulder, elbow, wrist, and terminal device has been designed to date. Other systems remain incomplete although in several instances individual components have been developed. The increasing availability of externally powered hands, for example, is well known. Less well known is the fact that seven externally powered elbows have been developed in this country and Canada inviting questions as to where these units might be most useful to above-elbow and shoulder-disarticulation patients as components in otherwise conventional systems. Mr. A. Bennett Wilson, Jr., Executive Director of the Committee on Prosthetics Research and Development, authorized the Sixth Workshop Panel on the Design and Development of Upper-Extremity Components for the general purpose of examining this question (Fig. 3). The minutes of this meeting are available through his office. Presented below is an extract from those minutes describing the physical and functional features of each of the seven externally powered elbows examined during the meeting (Table 1).

a. AMBRL Electric Elbow

1. *Size.* This unit is slightly wider and substantially longer than the conventional Hosmer E-400 elbow. Although only 1/8 in. (.33 cm.) wider at its axis of rotation, due to the placement of the motor and drive system axially through the turntable, the overall length is approximately 6 3/4 in. (17.15 cm.) as against 3 5/16 in. (8.42 cm.) for the conventional Hosmer elbow. The motor and the drive system take up approximately 5 1/4 in. (13.86 cm.) above the axis of rotation thereby imposing a "limitation" on its application to above-elbow amputees with relatively long stumps. Dr. Fred Leonard and his group expressed

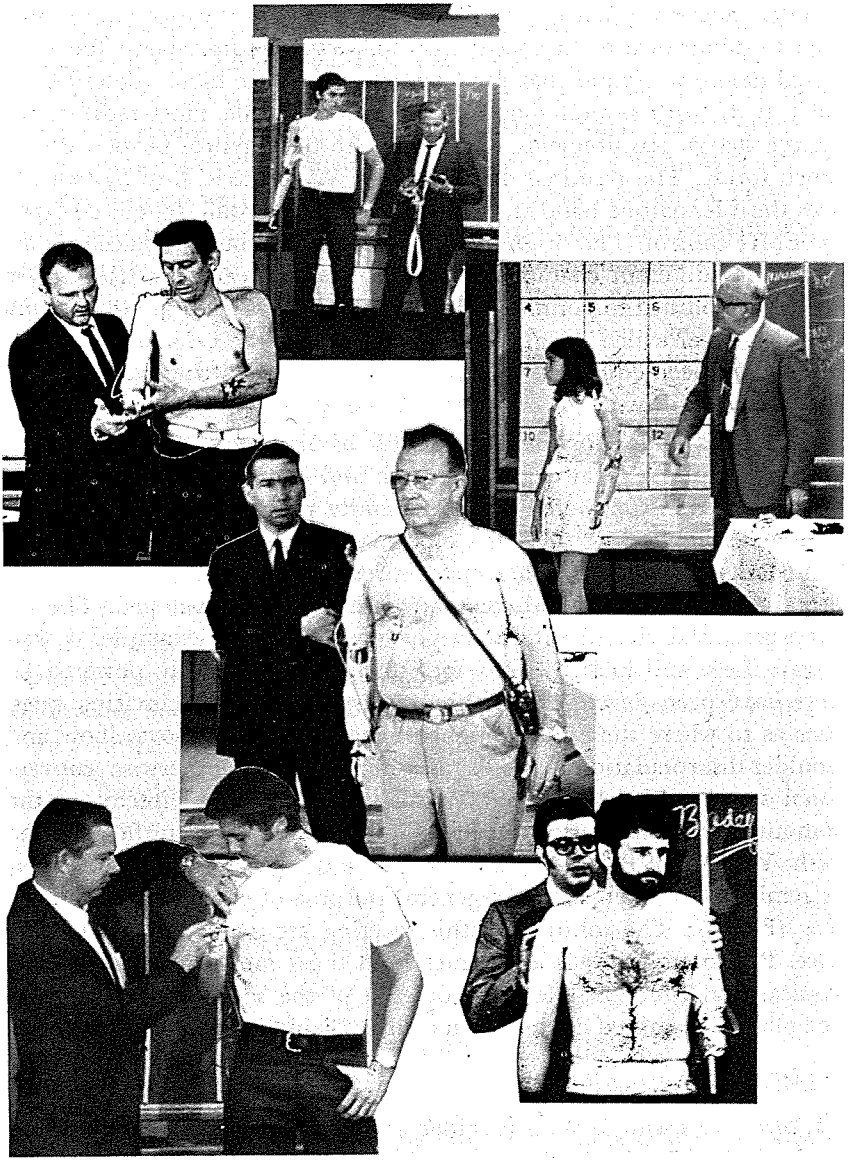

FIGURE 3.—Six different externally powered elbow systems were reviewed during the CPRD meeting of the Sixth Workshop Panel on Upper-Extremity Prosthetic Components.

the view that the need for powered elbows only becomes significant at higher levels of above-elbow amputation and that therefore the length of the AMBRL elbow did not represent a realistic limitation.

TABLE 1.—*Some Characteristics of Seven Externally Powered Elbow Units*

	Standard[a]	AMBRL	VAPC	Boston	OCCC[c]	Gilmatic	Rancho[d]	AIPR Pneumatic[f]
A. Dimensions								
1. Width at axis (inside saddle).	2¼ in.[a]	2⅝	2¼	2⅝	2 5/32	2¼	2 5/16	3
2. Minimum distance—axis to stump end.	2 in.[a]	5½	2	1⅞	2½	2⅜	2⅛	2¼
3. Total length in full extension.	3 3/16 in.[a]	6 13/16	3⅛	3 9/16	----------	3 5/16	3⅜	----------
4. Can regular turntable be used?	----------	No	Yes	No	Yes	Yes	Yes	No
5. Can regular forearm be used?	----------	No	Yes	No	Yes	Yes	No	No
B. Weight								
1. Elbow unit only.	12 oz.[a]	15.6	8.2	[b]33.7	10.5	[e]13	18.5	12.5
2. All additional equipment amputee must carry.	40 oz.	12.3	13.2	60	12.2	12	27	28
C. Range of motion (flexion-extension).	10-135 deg.[a]	0–125	12–138	17–135	0–135	10–135	0–135	8–134
D. Speed (flexion)								
1. No load.	2 sec.	2.0	1.8	1.0	2.1	3.0	2.5	2.0
2. With 1 lb. at 12 in.	2 sec.	2.6	1.9	1.0	4.3	3.0	3.5	2.3
E. Maximum lift.	100 in. lb.	72	25	84	18	30	36	48
F. Resistance to extension load.	600 in. lb.	192	360	----------	----------	50	----------	----------
G. Noise level.	68 dB	64	73	65	62	79	60	63
H. Estimated cost.	$60[a]	$250	$150	$1000	$200–250	$150	[d]$300	[g]$335

[a]Data taken from Hosmer E-400 elbow.
[b]Includes forearm.
[c]Child size.
[d]Commercially available in 3 sizes.
[e]Includes built-in charger.
[f]All units except AIPR are powered electrically.
[g]Includes all auxiliary equipment.

2. *Weight.* The elbow unit together with its motor and gear box weighs 443 grams or approximately 15.5 oz., a figure in excess of the weight of the standard Hosmer elbow at 10.4 oz. (294.84 gm.). The switch and battery pack weigh an additional 350 grams or approximately 12.3 oz. which is significantly below the operating standard of 40 oz. (1.13 kg.) for all accessory hardware.

3. *Range.* Although the unit is rated as providing a range of 0 to 125 deg. of flexion (operating standard 10 deg. to 135 deg. or a total range of 125 deg.), the model demonstrated provided a range of 115 deg.

4. *Speed versus Load.* The AMBRL unit is capable of rotating through its entire range of flexion from a position of full extension to full flexion within 2 seconds and in this respect it complies with the operating standard (2 seconds). Under a standard load of 1 lb. (.45 kg.) it required 2.6 seconds to rotate from full extension to full flexion. It was capable of lifting a maximum of 6 lb. (2.7 kg.) at 12 in. (30.48 cm.) from the center of rotation or approximately 72 in.-lb. (82.8 kg.-cm.), a figure somewhat below the operating standard of 100 in.-lb. (115 kg.-cm.). According to the devloper, positioned at 90 deg., the elbow will resist a static load of approximately 200 in.-lb. (230 kg.-cm.) (operating standard 600 in.-lb. [690 kg.-cm.]).

5. *Life.* Although no standards have been established for the minimum number of cycles required per day, nor for the total life span of electrical elbows, this unit was considered by the panel to be adequate in both respects. This judgment is based on opinions of the design and its components.

6. *Noise.* The unit was tested and rated at 64 dB.

7. *Applicability.* Installation of the AMBRL elbow does not interfere with control of the terminal device regardless of type or power source. It requires no significant changes in the design of a prosthesis and its use does not interfere with or cause the loss of other functions. It does, however, require a new socket and is not designed for replacement of conventional elbows without replacement of socket. Backup equipment is minimal in that only a conventional battery charger is required. Patient training and retraining requirements are minimal since the unit can be operated by any of several pull switches.

8. *Special Features.* This unit features a convenient disconnect to facilitate removal for repair or adjustment, an external adjustment of the turntable friction, and a "free swing" which allows the forearm to flex and extend during walking.

9. *Cosmesis.* Although a highly subjective matter, this unit seems entirely acceptable as regards appearance in relation to the conventional Hosmer E-400.

10. *Cost.* Dr. Leonard estimated that these units would cost approximately $250 in lots of 50. In comparison, Hosmer elbows cost approximately $60 each.

b. VAPC Electric Elbow

1. *Size.* The VAPC elbow is essentially the same size as the conventional Hosmer E-400.

2. *Weight.* The elbow unit weighs 237.7 grams or approximately 8 oz., 2 oz. (56.7 gm.) less than the Hosmer E-400 elbow. The battery, belt, and the operating switch weight 13.2 oz. (374.2 gm.), a figure significantly below the operating standard of 40 oz. (1.13 kg.).

3. *Range.* The unit produces a flexion range from 10 deg. to 135 deg. meeting the operating standard. It is electrically blocked from exceeding these limits and does not waste power if activated in the end positions.

4. *Speed versus Load.* Unloaded, the VAPC elbow rotates through its entire flexion/extension range in 1.8 seconds. With the standard load of 1 lb. (.45 kg.) in the terminal device, it traversed the complete range in 1.9 seconds, well within the operating standard of 2.0 seconds. The unit lifted a maximum load of 2.1 lb. (.95 kg.) placed 12 in. (30.48 cm.) from the elbow center. This function is well below the operating standard of 8.3 lb. (3.8 kg.) at 12 in. (30.48 cm.) from the center of rotation. The unit resists external loads of approximately 30 lb. (13.6 kg) before yielding

5. *Life.* The unit has been cycled for 25,000 cycles with no discernible wear. Although no standard has been established 25,000 cycles is estimated as roughly 4-6 months use. The unit provides over 250 cycles per battery charge.

6. *Noise.* The unit was tested and rated at 73 dB.

7. *Applicability.* It requires no changes in the present prosthesis and minimal retraining of patients. Required backup equipment is a small conventional battery charger.

8. *Special Features.* The control switch is designed to employ a very small range of the same control motion, shoulder flexion, as the conventional system.

9. *Cosmesis.* This unit does not have a cosmetic cover at present.

10. *Cost.* The estimated cost of the unit in lots of 50 is $150.

c. Boston Electric Elbow

1. *Size.* The Boston elbow is somewhat narrower ($2\frac{5}{8}$ in. [6.67 cm.] at the elbow axis) than the conventional Hosmer ($2\frac{15}{16}$ in. [5.88 cm.]).

More space than in the Hosmer is available ($1\frac{7}{8}$ in. [4.95 cm.]) between the axis of rotation and the point which a stump might reach. In theory, at least, stumps of even greater length could be accommodated. Its overall length at $3\frac{9}{16}$ in. (9.05 cm.) is slightly longer than the Hosmer at $3\frac{5}{16}$ in. (8.42 cm.).

2. *Weight.* At 924.5 grams or 33.7 oz. the unit is heavier than the Hosmer at 15.5 oz. (439.4 gm.). The battery pack and electrode section weigh a total of 1,710 grams or approximately 60 oz. compared to the operating standard of 40 oz. (1.13 kg.).

3. *Range.* Although the rated range of flexion/extension was from 0 to 135 deg., the range of the model demonstrated was 118 deg. (from 17 deg. to 135 deg.).

4. *Speed versus Load.* The Boston Arm was capable of rotating through the full range of flexion/extension in 1 second, well under the operating standard of 2 seconds. Moreover, it rotated through the same range under a standard load of 1 lb. (.45 kg.) in exactly the same time, a demonstration of the torque and velocity feedback features inherent in this unit. By means of semiconductor strain gages, force along the lead screw axis generates feedback signals. Differentiation of the potentiometric output measuring elbow angle provides velocity feedback. The net effect is that of a constant speed of elbow flexion regardless of load within the limits of the load lifting capacity. This unit produced a maximum lift of 7 lb. (3.2 kg.) at 12 in. (30.48 cm.) from the center of rotation or approximately 84 in.-lb. (96.6 kg.-cm.). Although somewhat below the operating standard of 100 in.-lb. (115 kg.-cm.), this elbow was capable of generating higher torques than any of the others demonstrated. This unit was also capable of resisting static loads up to 50 lb. (22.7 kg.), 12 in. (30.48 cm.) from the center of rotation with the elbow positioned at 90 deg. This is well below the operating standard of 1,440 in.-lb. (1,656 kg.-cm.), but it is equal to the requirement for non-yielding elbows such as a locked Hosmer (600 in.-lb. [690 kg.-cm.]).

5. *Life.* The unit is designed to operate over 500 cycles per battery charge, a figure deemed more than adequate for a single day's use. No figures were available as to its total life.

6. *Noise.* Audio energy radiating from the unit was measured at 65 dB under the test conditions.

7. *Applicability.* Application of this unit does not interfere with the control or operation of the terminal device. As an EMG-controlled electric elbow system, the unit requires as backup equipment only a battery charger. However, an instrument to sample EMG outputs in order to determine optimum sites for electrode placement was deemed useful although perhaps not absolutely necessary.

Installation of this unit requires a new forearm and a new socket. The unit does not require major changes in conventional prosthesis design. The training of patients to actuate the system by means of EMG signals is not significantly different from conventional requirements. The utilization of electrodes does not entail the loss or diminution of other functions. However, certain motions of the stump, as for example shoulder abduction, may be restricted since they may cause inadvertent operation.

8. *Special Features.* This unit provides proportional control of torque by means of internal velocity and force feedback loops. The functional outcome is that the speed of elbow flexion remains relatively constant and proportional to the input EMG signal, regardless of the load being lifted, up to 7 lb. (3.2 kg.) at the terminal device. In the configuration demonstrated, the battery pack makes sitting awkward by reason of its bulk and location.

9. *Cosmesis.* Installed in a forearm and covered with an appropriate cosmetic cover, the unit is reasonably acceptable in appearance.

10. *Cost.* A crude estimate of the cost of this unit was given as approximately $1,000 each in lots of 50.

d. AIPR Pneumatic Elbow

1. *Size.* Designed originally as one component of a completely powered system, the AIRP elbow is slightly wider and longer than the Hosmer E-400 elbow. It is $\frac{1}{16}$ in. (.16 cm.) wider at the axis, and its overall length at $3\frac{11}{16}$ in. (9.37 cm.) is approximately 15/16 in. (2.38 cm.) longer. These dimensional differences are not functionally significant but indicate non-interchangeability with conventional components.

2. *Weight.* At 356.4 grams or 12.5 oz. this elbow is 2 oz. (56.7 gm.) heavier than the Hosmer. The twin canister power pack and valve weigh approximately 800 grams or 28 oz., a figure well within the 40 oz. (1.13 kg.) specified for auxiliary equipment.

3. *Range.* The demonstrated unit provided a range of flexion/extension of 130 deg., adequately meeting the standard.

4. *Speed versus Load.* Unloaded, the AIRP elbow flexes through its complete range in 2 seconds. Under a standard load of 1 lb. (.45 kg.) it required 2.3 seconds to traverse the full flexion range. It was capable of lifting a maximum of 4 lb. (1.8 kg.) at 12 in. (30.48 cm.) from the center of rotation or approximately 48 in.-lb. (55.2 kg.-cm.) compared with the operating standard of 100 in.-lb. (115 kg.-cm.). The unit was capable of resisting approximately 25 lb. (11.3 kg.) placed 12 in. (30.48 cm.) from the center of rotation with the elbow positioned at 90 deg. This is approximately half the specified static resistance to load.

5. *Life.* The unit is adequate with respect to number of cycles per day and total life. This judgment was based on the previous experience with the unit of several panel members.

6. *Noise.* The AIRP unit produces a "hissing" sound measured at approximately 63 dB.

7. *Applicability.* Installation of this elbow requires a new socket and new forearm but does not require any changes in the basic prosthesis design. Operation of the unit by patients does not entail training requirements beyond those of a conventional elbow. However, the canisters in the power pack are charged by means of a special filling device. This operation requires some training and attention to detail. Utilization of this unit by patients does not affect other functions. The backup equipment required for this system includes a special filling device, bottled compressed CO_2, and a weight scale.

8. *Special Features.* Precise application of force to the components which directs CO_2 into the actuators will permit a trained amputee to adjust the rate of gas flow and hence the speed of flexion/extension.

9. *Cosmesis.* The elbow itself is adequately cosmetic in appearance.

10. *Cost.* The current cost of these units is given as $150 for the elbow in lots of 50, $55 for the valves, and $90 for a dual storage tank. The cost of the filling device is estimated at $40. The total cost, therefore, is approximately $335 exclusive of the cost of the bottled gas.

e. Ontario Crippled Children's Centre Elbow

1. *Size.* The Ontario Crippled Children's Centre (OCCC) elbow is slightly larger than the Hosmer child's size elbow. It is interchangeable with the Hosmer elbow and forearm. No limitations are placed on stump length which may be fitted with the unit.

2. *Weight.* The unit weights 10.5 oz. (297.7 gm.) approximately the same as the adult standard Hosmer E-400. The Nicad power package weights 12.2 oz. (345.87 gm.) well below the operating standard for auxiliary equipment of 40 oz. (1.13 kg.).

3. *Range.* The OCCC elbow unit provides 125 deg. of flexion/extension ranging from 10 deg. to 135 deg.

4. *Speed versus Load.* Without load, the elbow rotates through the full range of flexion in 2.1 seconds. When the standard operating load was applied, flexion required 4.3 seconds or more than twice as long as the operating standard, 2.0 seconds. The maximum lift to stall was 1.5 lb. (.68 kg.). Though well below the operating standard for adults, as a child's elbow it may be adequate in this respect.

5. *Life.* Models of this elbow have been used by children at OCCC.

Although exact figures on the number of cycles per day or on total life are not available, these factors have not been a problem according to the developer.

6. *Noise.* The OCCC elbow is relatively quiet, being rated at 62 dB. The use of a special low speed, high torque motor has helped reduce the noise level.

7. *Applicability.* No changes in conventional fabrication methods are required to install the elbow. The unit is interchangeable with the Hosmer standard child's elbow. A small Nicad battery charger is required. The unit does not affect terminal device control and only minimal retraining is necessary.

8. *Special Features.* An overload clutch is featured which yields under load to prevent breakage.

9. *Cosmesis.* The unit is adequately covered with a cosmetic cover and appears similar to the standard Hosmer unit.

10. *Cost.* The estimated cost of the elbow in lots of 50 is between $200 and $250, the most expensive item being the special motor.

f. Gilmatic Electric Elbow

1. *Size.* The Gilmatic elbow is the same size as the Hosmer E-400 unit.

2. *Weight.* The elbow with its internal charger weighs 13 oz. (368.5 gm.), only 1 oz. (28.35 gm.) over the 12 oz. (340.2 gm.) operating standard. The battery pack weighs 8 oz. (226.8 gm.), far below the operating standard of 40 oz. (1.13 kg.).

3. *Range.* The unit rotates through a range of 125 deg., from 10 deg. to 135 deg.

4. *Speed versus Load.* The Gilmatic elbow required 3.0 seconds to position or lift a standard test load. This is significantly slower than the operating standard of 2.0 seconds. The maximum load lifted was 2.5 lb. (1.1 kg.), well below the operating standard (8.3 lb. [3.8 kg.]) but not significantly different from the other devices being tested. It can sustain a static load of 50 lb. (22.7 kg.) at 12 in. (30.48 cm.) from the center of rotation conforming to the requirement of 600 in.-lb. (690 kg.-cm.).

5. *Life.* The number of cycles per day provided was generally assumed to be adequate on the basis of the components used.

6. *Noise.* Tested by the standard procedure, the unit was rated at 79 dB.

7. *Applicability.* Application of the Gilmatic electric elbow to a prosthesis does not interfere with the operation or control of the terminal device. It requires minimal retraining and no changes in the prosthesis

design. No backup equipment is needed; the battery charger is incorporated in the unit.

8. *Special Features.* Although not fully operable at the time of the demonstration, the unit was designed for control by means of a switch actuated by a muscle bulge.

9. *Cosmesis.* This unit does not have a cosmetic cover.

10. *Cost.* The cost estimate in lots of 50 is $150 per unit.

g. Rancho Los Amigos Elbow

1. *Size.* The Rancho elbow is built on a standard Hosmer frame and is the same dimensionally except for the motor extension into the forearm. It is available in the three sizes.

2. *Weight.* The elbow in the adult size weighs 18.5 oz. (524.5 gm.) with a large part of the weight distal to the elbow. The operating standard is 12 oz. (340.2 gm.). The battery package weighs 27 oz. (765.4 gm.), a figure within the standard of 40 oz. (1.13 kg.).

3. *Range.* The range of elbow rotation is 0 to 135 deg.

4. *Speed versus Load.* The Rancho elbow rotates through its entire range in 2.5 seconds (.5 second slower than the standard). It lifts the standard lift load in 3.5 seconds (1.5 seconds slower than the standard). The maximum resistance to load has not been tested.

5. *Life.* The unit is commercially available and has apparently provided adequate daily and total life service.

6. *Noise.* The Rancho elbow was rated at 60 dB.

7. *Applicability.* Application of the Rancho elbow requires no significant alterations of either prosthesis design or fabrication methods. A number of special controls including EMG are available from the manufacturer. A battery charger is the only backup equipment necessary. It does not interfere with the terminal device control.

8. *Special Features.*The unit is commercially available in three sizes.

9. *Cosmesis.*This unit has a partial cosmetic cover which leaves some working parts exposed.

10. *Cost.* In lots of 20 or more the elbow costs $300, the battery pack $40, the charger $12.50, and the battery case $7.50. It is available from Electric-Limb Corp., Hollywood, Calif.

3. Proposed Standards for Externally Powered Elbows

The Sixth Workshop Panel on the Design and Development of Upper-Extremity Components besides determining the present state of development of seven externally powered elbows and assorted control systems also brought out the need for extensive consideration of stan-

dards and specifications for powered elbows as well as for other powered components. Time did not permit adequate examination of currently available criteria and those "operating standards" established principally for purposes of this meeting to provide a common frame-of-reference for comparison. The operating standards include items relating both to the physical and functional characteristics of the elbows and to the compatibility of an elbow with conventional prosthetic technology and with the prosthetic skills of patients. Several previously established standards relating principally to the size, weight, shape, and cost of the conventional Hosmer E-400 elbow were employed. Also included were arbitrarily determined standards relating to the power feature of these elbows—speed/load relationships, maximum torque output, and control methods.

In establishing tentative standards for powered elbows, consideration must be given to the need for at least two sets of requirements. One set relates to a type of powered elbow which is essentially a powered analog of the conventional Hosmer elbow, offering only the same functions performed perhaps differently and better. The second set of standards should incorporate the first and also include other items relating to the design and function of elbow mechanisms which furnish functions beyond those of the conventional elbow, i.e., rotation in the transverse plane or perhaps more sophisticated control elements. On the basis of general experiences with conventional elbows and the panel discussions, the following are recommended as tentative standards for the design and the evaluation of powered systems of the first order discussed above:

1. *Size.* It is unnecessary to specify dimensionally the standard for size because the dimensional aspects of the elbow are only significant in relation to cosmesis, length of stump which can be accommodated, and compatibility with other conventional components of prostheses. The cosmetic acceptability of an elbow is more readily controlled by criteria for compatibility with components proximal and distal to it. At the present time the potential value of externally powered elbows over conventional elbows is not conditioned on the level of above-elbow amputation. Therefore, any powered elbow which is potentially superior to a conventional elbow is applicable to any above-elbow amputee. Since the type of elbow referred to in these standards is designed principally to reduce excursion requirements for operating the elbow and to eliminate individual locking/unlocking functions, the third factor, compatibility with other components, is the principal size criterion. The tentative standard governing size therefore can be stated as follows: the size of the elbow should not limit its application to any particular level of above-elbow amputee and its dimensions should be such that it readily

accepts and it is readily accepted by conventional above-elbow forearm/saddle assemblies and conventional elbow turntables.

2. *Weight.*There seems to be no essential reason why elbows of the type being considered should exceed 12 oz. (340.2 gm.) including all components contained within the elbow unit and its cosmetic cover. This is approximately the weight of the Hosmer E-400 elbow. The weight of all other components of the powered elbow system should not exceed 24 oz. (680.4 gm.) including power pack and controls.

3. *Range of Rotation.* The position of maximum flexion should not be less than 135 deg. The total rotation range should not be less than 125 deg. nor should the elbow hyperextend beyond 0 deg. of flexion.

4. *Speed versus Load.* Standards for speed of elbow rotation cannot be sensibly considered without also considering load factors. Experience to date and current opinion seem to indicate that optimum control by a patient requires that speed of elbow rotation fall between 1 and 2 seconds. At speeds above 135 deg. per second it is difficult to control elbow position. At speeds lower than 2 seconds per 135 deg. patients have to "wait" for the forearm to come up.

Current experience and opinion also indicate that "live-lifting" more than 1 (.45 kg.) to 1½ lb. (.68 kg.) by above-elbow and shoulder-disarticulation patients is extremely rare. Prosthetic elbows are used principally as positioning devices and for live-lifting only relatively light loads. The Panel was hard put to identify common objects weighing in excess of 1½ lb. (.68 kg.) which amputees might normally "live-lift." We may, therefore, express a useful standard as—powered elbows should be capable of rotating through 135 deg. with a load of 1.0 lb. (.45 kg.), 12 in. (30.48 cm.) from the center of rotation within 2 seconds. In the unloaded condition the speed of rotation should not exceed 135 deg. per second. Minimum torque output (live-lift) should be 1.5 ft.-lb. (.21 met.-kg.). No purpose is served by specifying "maximum" torque output.

5. *Resistance to External Load.* Powered elbows should maintain a position of flexion under static loads of 25 ft.-lb. (3.45 met.-kg.) without damage.

6. *Noise.* On the basis of the noise levels measured on the seven powered elbow systems, subjective reactions indicate that noise levels not exceeding 68 dB are minimally tolerable. Noise level should be determined by the following technique, developed by Laura Wilber, Ph. D., Director of Otology, University of California at Los Angeles Rehabilitation Center:

1. Quick look procedure: Using a sound level meter (calibrated with A, B, and C scales) the prosthetic device will be placed 1 meter from

the face of the microphone. Using a slow scale (slow meter deflection, rms-type averaging) output measurements will be obtained on the "A," "B," and "C" scales. These measurements are in dB SPL (Sound Pressure Level).

2. Detailed procedure: Using a level recorder, sound level meter (or spectrometer) with condenser microphone, measurements over time (a time of 1 minute should be sufficient) will be obtained for each device for the "A," "B," and "C" scales and at one other octave band (such as 2,000 Hz at which man's hearing is quite sensitive). The purpose of making measurements over time is that it is apparent that various devices vary in intensity depending on whether the task is to raise or lower or keep stable the prosthetic device. By using a time intensity scale differences over time will be obtained. Again, measurements should be obtained in rms, but in this instance either the fast or slow scales may be used. Probably, it would also be wise to use overall intensity, but, one of the above "A," "B," or "C" scales will be close (because of its built-in weighting network) to a "noisiness" classification. If possible, a separate reading should be obtained using a frequency analyzer and level recorder to record differences in frequency bands over time to demonstrate at which frequency the maximum intensity appears. (If, for example, one instrument has its greatest output at 10,000 Hz where man's hearing is not so sensitive, it would probably appear to be less noisy than one at which the maximum intensity reading was obtained at 1,000 Hz.)

7. *Cycles per Charge.* The only available data bearing on the number of elbow flexions normally performed by an above-elbow amputee are those recently collected on a single highly active patient using a conventional elbow. The data indicate that approximately 250 cycles is the average daily use over a period of a week ranging from a maximum of 338 per day to 97 per day. In view of the relationship between cycles per charge and power source, size, and weight, an adequate minimum standard would be 500 cycles per charge.

Powered elbows should be designed to give a minimum of 2½ years of service during which a total of 250,000 cycles are completed without requiring the repair or replacement of major components.

8. *Cosmesis.* The elbow should present a clean, smooth exterior surface without protrusions or exposed moving parts. Its general shape and dimensions should permit it to be faired smoothly into the socket.

9. *Applicability.* Since these tentative standards relate to a powered elbow intended for use in systems in which the other components may be either conventional or externally powered, the compatibility of a powered elbow with other conventional prosthetic components is signif-

icant. Although it is not possible to specify all the elements of compatibility, this standard should indicate the desirability of matching the powered elbow to the other components of a conventional prosthesis with respect to color, fittings, and the like.

B. Evaluation (Components)

Externally Powered Terminal Devices. Recent developments in the field of externally powered prosthetic components had generated a great deal of interest, particularly in the area of externally powered terminal devices for upper-extremity amputees. We had surveyed the available externally powered terminal devices for the purpose of analyzing their design concepts and evaluating their potential utility for patients (BPR 10–8). Despite the number of different terminal devices, extremely small numbers of patients have been fitted with them to date. As a result the increasing general desire for more information in this field cannot be readily satisfied at the present time. The Committee on Prosthetics Research and Development, recognizing the immediate need for more information, authorized the chairman of its Panel on the Design and Development of Upper-Extremity Prosthetic Components to convene a special meeting to examine the status of these developments with respect to design requirements and practical utility. A two-part program was organized for this purpose. The first part was a week-long meeting held at the Prosthetics and Orthotics Education Program of the University of California at Los Angeles in which the developers of six different externally powered terminal devices fitted patients with their hands. The second part of this program will be a meeting of the entire panel to examine and evaluate the results of having fitted six different patients with externally powered terminal devices.

The specific purposes of this program are to:

Define for CPRD the similarities and differences in the design concept and construction of all available externally powered terminal devices.

Clarify the applications and prescription indications for each of the externally powered terminal devices.

Provide data for standards and specifications for externally powered terminal devices.

Identify areas of inadequate knowledge for future laboratory and field studies.

Selected above-elbow and below-elbow amputee wearers of conventional terminal devices have been fitted with one of the six different externally powered devices currently available. Included are two exter-

nally powered hooks and four externally powered hands. The following facilities will be represented: Northern Electric of Canada, Rehabilitation Institute of Montreal, AIPR, Ontario Crippled Children's Centre, AMBRL, and Viennatone. Prior to being fitted each subject's performance was tested with his own conventional terminal devices. The information will be used solely as a basis of interpreting his performance with one of the experimental devices. Following a controlled training program the subject was given an initial performance test and told to use the experimental terminal device on a routine basis. After a wear period of approximately 8 weeks duration, each subject's performance will be evaluated for comparison with his previous initial performance and his conventional performance. In addition, the subjective reactions of each subject to the externally powered device will be recorded. The results of these objective and subjective experiences will be considered at a second meeting of the CPRD Workshop Panel on Design and Development on this subject.

C. Evaluation (Techniques)

None.

III. LOWER-EXTREMITY ORTHOTICS

A. Development

None.

B. Evaluation (Components)

Arch Supports. The purpose of this program is to evaluate the effectiveness of several types of arch supports for redistributing weight on the plantar surface of the foot and in controlling foot balance with respect to the angular position of the subtalar joints. For this purpose, each of a series of patients was fitted sequentially with leather Schaeffer plates, Fiberglas heels, stabilizers, and two types of plantar molds (the AMBRL and the VAPC). Each device was worn for a period of 1 month. Tests were performed prior to fitting and again at the end of the 1-month period. The patients' reactions were also elicited to provide a basis for evaluation. To date, one patient has completed the cycle of fitting. A 30-year-old male had, according to his physician's finding, bilateral pes planus with a prominent tibial malleolus on the right side. There is a tenderness on the plantar aspect of both feet just at the head of the osalsis and the plantar fascia. There is also valgus of the heel which is more marked on the left. The radiographic report indicated marked bilateral flattening of the plantar arches classified as third-degree pes planus deformities. Accessory scaphoids are noted and accessory

ossicles are noted in the region of the cuboids. No intrinsic bone pathology is visualized. The results indicated that the heel stabilizers were preferred over the other supports tested. The patient stated that the heel stabilizers were more comfortable and fit better. This program is continuing and we are collecting data on other patients.

C. Evaluation (Techniques)

None.

IV. MISCELLANEOUS AIDS FOR THE DISABLED

A. Development

None.

B. Evaluation (Components)

1. Eaton E-Z Bath. The E-Z Bath, manufactured by Eaton Co., Garden City, Kan. 67846, has been evaluated. The transfer of patients from wheelchairs to bathtubs, particularly heavy patients, has always been burdensome for attendants and there is, therefore, a need for such a product.

Designed to lift a disabled person in and out of a bathtub (Fig. 4), the frame, seat, and support arm of the unit are of welded aluminum construction coated with a white enamel finish. Four suction cups, one at each corner, are mounted on the base. The E-Z Bath is placed by an attendant in the end of the tub, opposite from but facing faucets and drain. The support arm extends over the tub lip and is secured to it by two adjustable suction cup brackets that are mounted on its underside. With the aid of an attendant, the patient transfers from wheelchair to the support arm and then onto the seat of the device. All components are of similar height to facilitate this process.

The seat is 17 in. (43.18 cm.) wide by 18 in. (45.72 cm.) long including a detachable tubular backrest support with chest straps. A handcrank mechanism (incorporating worm screw, worm gear, shaft, pulleys, guide rollers, and cables) is mounted at the rear of the unit. It is operated by an attendant who lowers, as well as raises, the seated patient. Several deficiencies in the E-Z Bath noted during our evaluation have been referred to the manufacturer.

2. Touch-Turner. The Touch-Turner, Model M-202, manufactured by the Touch Turner Co., 1134 Broadway East, Seattle, Wash. 98102, is a switch-operated, electrically powered page turner for use by subjects who are, for any reason, unable, to turn pages when reading magazines, paperbacks, or hard cover books. Experience with the subject device at the VA Hospital, Madison, Wis.; the VA Hospital, Batavia, N.Y.; and

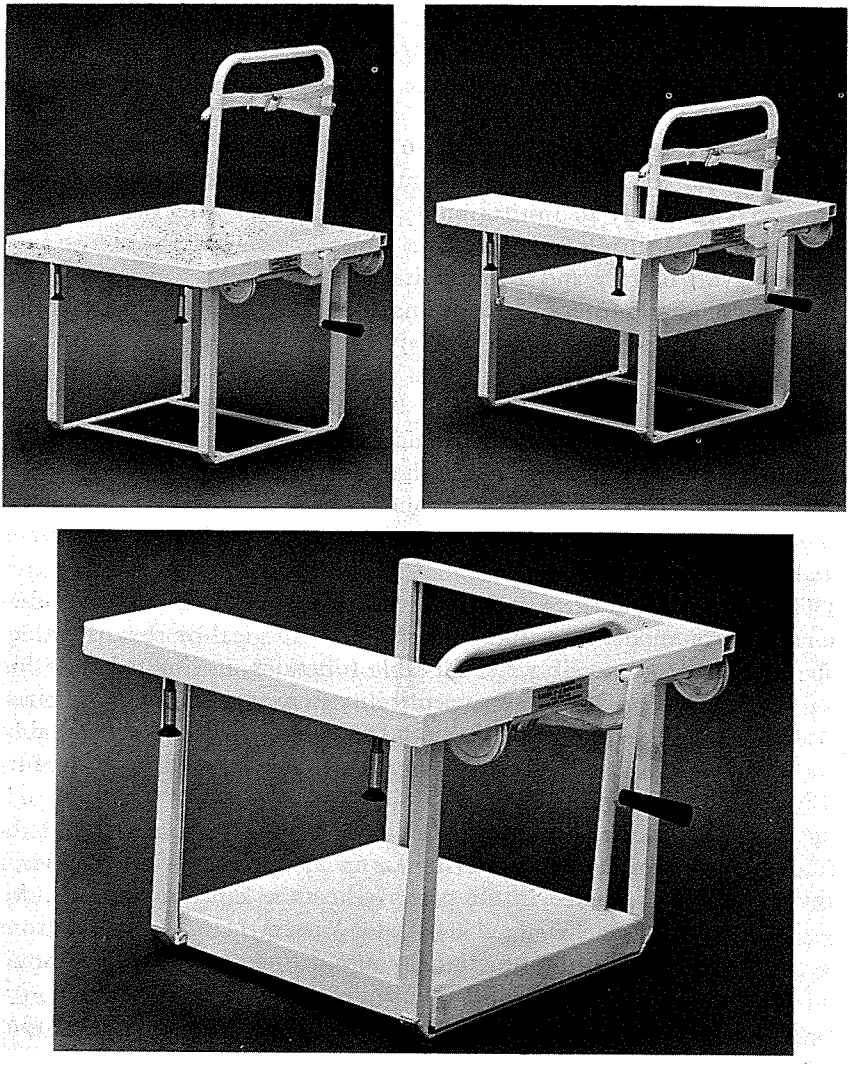

FIGURE 4.—The Eaton E-Z Bath is a manually operated patient lift which is placed in the bathtub as an aid in getting disabled persons in and out of the tub.

the VA Center at Prescott, Ariz., reveals that in general, the Touch-Turner meets the needs of patient—once the reading material has been properly aligned by an attendant. It is small, compact, lightweight, simple, and easy to operate. It is cheaper than other devices of its kind and at least as functional. Although the mechanism is delicate and requires the service of a technician to repair it, the Touch-Turner, Model M-202, appears to meet the requirements of certain patients.

3. Rehab-Chair. Specifications, drawings, design information, and brochures relating to the ASK Rehab-Chair were submitted for evaluation by Applied Scientific Knowledge, Inc. (ASK), 800 South 13th St., Lincoln, Nebr. 68508.

As a mechanical device, the Rehab-Chair seems to be well designed and at 210 lb. (95.26 kg.) it is obviously neither foldable nor portable, limiting it generally to institutional use. It is essentially a wheelchair with a powered tilting function. The power system consists of two motors, a 12-volt battery and a four-switch electrical control system, all of which serve the purpose of adjusting the chair from a conventional seat to a horizontal cart surface or to an upright tilt table.

The concept of powering the tilt of the device seems dubious. If a patient capable of propelling the chair by himself is involved, a mechanical system might be cheaper, safer, and lighter. In any event, during the use of the device as a wheelchair, the patient is required to carry the power system at all times. The number of times per day that a wheelchair patient will utilize modes other than a wheelchair seems rather small.

The Rehab-Chair seems to be designed as a wheelchair and also functions as a commode, a recliner, a cart, and a surgical or therapy table. The reclining and possibly the tilt-table functions may be valuable for persons who have a history of susceptibility to pressure sores and a clear need for mobility. However, the number of such patients is probably very small and there already exist several commercial devices which furnish this feature.

A study of the literature and a analysis of drawings of the Rehab-Chair indicated that it is quite similar to at least three other devices which we have evaluated in the past 4 years: the Lincoln Carriage, the Independence Wheelchair, and the Gates Patient Handler. Apart from mechanical adequacy, the functional concept underlying this and similar devices, and the nature and number of patients for whom it is intended, remain in doubt. All of these multifunction devices suffer from the same malady—while they may be designed to do as many as seven jobs, they rarely if ever do any one of them as well as the single device they purport to replace. Moreover, a single patient rarely needs the seven devices which this unit might replace. Most patients do not require more than two devices whose net cost may be lower than these multifunction devices and whose performance may be better.

4. Krohn Crutch Handles. Mr. Robert D. Krohn of Los Alamos, N. Mex. 87544, submitted for evaluation prototype models of a pair of "offset" crutch handles (Fig. 5) which he has designed to replace the typical handles on standard axillary crutches. The inventor stated that the offset handles provide better control by maintaining the wrist

FIGURE 5.—Krohn Crutch Handle features an "offset" design which reduces the uncomfortable lateral forces against the rib cage of crutch users. Handle fits conventional aluminum adjustable crutch.

straight. Moreover, offsetting the handles improves the comfort by reducing the lateral pressures against the ribcage during ambulation. The hand grip piece is covered by gum rubber.

Our evaluation indicated that the Krohn crutch offers some improvement over the conventional crutch handles. A comparative analysis of the forces involved in using the offset handles and conventional crutches reveals that offset handles can significantly reduce the horizontal axillary loads in walking. If the crutch tips are placed within 5 in. (12.7 cm.) of the axillar piece projection, as is normally done, the horizontal load can be reduced as much as 75 percent. Moreover, it is easier to position the crutches in the above attitude.

5. Power Aid. As previously noted a number of units have been distributed for limited field testing. Prior to their distribution to local stations, it was found necessary to make several improvements due to recurring problems. In addition, the taper battery charger that comes with the unit was found inadequate for daily routine use. It did not taper sufficiently to prevent overcharging and subsequent loss of electrolyte. New solid state electronic cut-off chargers have been purchased and are being redistributed.

As a result of earlier evaluation (BPR 10-9) several modifications of the Power Aid were proposed. A number of units have been updated and are being used in the field on a routine basis. The result to date indicates that most of the patients are finding the device quite useful and are encountering no significant problems. The few problems noted to date relate to lack of battery maintenance and the loss of control settings due to vibration during use. In addition, attempts to make unau-

thorized adjustments by well meaning, but untrained personnel in the field have invariably compounded the problems and resulted in damage to units.

The types of disabled patients who have participated in this study include: a paraplegic with below-elbow amputation; a paraplegic with an ileocolostomy (necessary to minimize muscular activity); a triple amputee; an emphysema patient; a muscular dystrophy patient; and four geriatric subjects (two above-knee amputees and two arthritics).

In general the Power Aid and Howmet wheelchair unit (as presently modified) appears to be mechanically adequate in that earlier noted problems have been overcome. In addition, certain tentative prescription indications previously proposed have been corroborated in view of the variety of patients in this study to date.

6. *Motorette.* Two models of the Motorette (Fig. 6), an electronically controlled wheelchair motor attachment, were submitted for evaluation by the Motorette Corp. of Reseda, Calif. 91335. The device is designed to convert a conventional wheelchair into an easily controlled powered chair, simply, quickly, and efficiently.

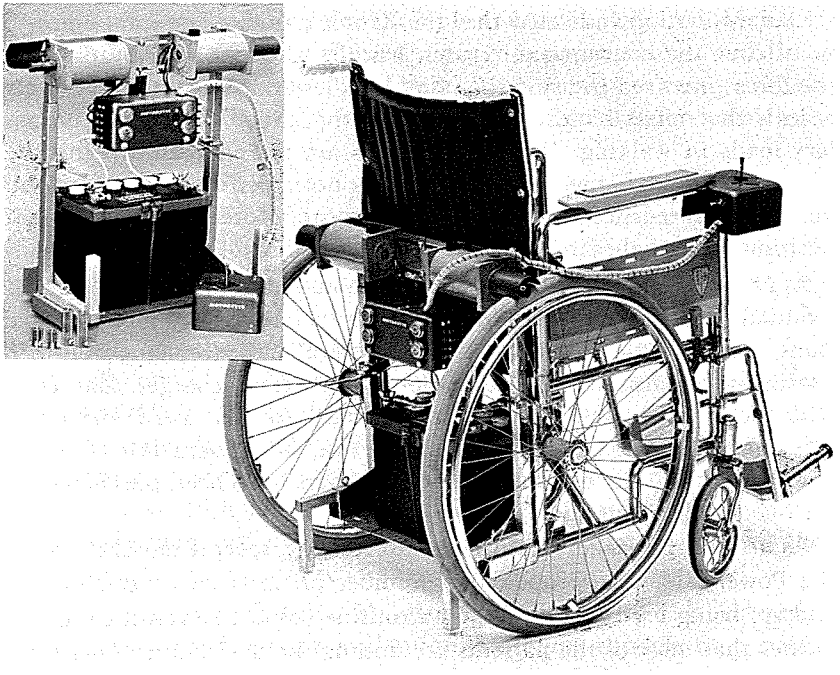

FIGURE 6.—The Motorette is a portable, self-contained, battery-powered unit which can be easily attached to a conventional wheelchair to provide an externally powered device.

Once adjusted to the size of the chair, the unit can be attached or removed in less than a minute by means of two self-locking latches on the unit frame and two spring clips on the control box. Two specially designed ¼ horsepower motors driving individual rollers which bear on the wheelchair tires, propel the chair at speeds up to 5 m.p.h. An electrical storage battery provides energy for the unit and a pulse-width-modulated, transistorized power system drives the motors. A "joy stick" control steers the chair; the unit goes in the direction in which the stick is moved at a velocity related to the force and displacement of the control stick.

The unit is light at 28¾ lb. without the battery which adds 43¼ lb. Its center of gravity is located almost directly under the rear axle when mounted on a chair and therefore has little effect on the stability of the entire man-wheelchair-Motorette complex. The system is inherently stable although initially it may seem unstable due to the relatively high starting torques available. The unit is very sensitive and fast when used with the standard control card, a mode which is better for use in large areas and on ramps such as in a hospital. With a dampened response card, the unit is "electronically sluggish," a mode which is good for patients with tremor or spasticity as well as for operating in more confined areas such as in a home. In this configuration the unit has very little tendency to tip the driver backwards even when starting at maximum acceleration.

Tested, the Motorette meets all the currently applied criteria for powered wheelchairs quite satisfactorily (see "Five Years of Wheelchair Evaluation" by Peizer and Wright, elsewhere in this issue).

The Motorette is an acceptable device for both hospital and home use. It should only be made available on a prescription basis which specifies dampened (slow) or undampened (standard) control card. If unspecified, the unit should be provided with the dampened card.

7. *Lord Calvert Buoyant Air Cushion D-4-75.* The Buoyant Air Cushion (Fig. 7), manufactured by Air Foil Seating Manufacturing Co., of Beltsville, Md. 20705, is a pad for use by persons who are confined to wheelchairs for long periods of time, and who because of inactivity or sensory loss, are in danger of developing pressure sores. It is designed to be used with a "U" shaped plywood seat board. The cushion itself consists of 5 in. (12.7 cm.) thick foam rubber constructed in sections with different densities and cemented together in order to provide variable resistances to the differential pressures applied by a seated patient. The cushion was covered with a zippered waterproof nylon plastic covering. The manufacturer provides pads made to a physician's prescription for a patient at any given weight. The proper combination of foam rubber blocks designed to achieve a specific load-carrying pattern is produced.

FIGURE 7.—The Lord Calvert Buoyant Air Cushion together with a cut out seat board is a wheelchair cushion system which, by conforming faithfully to the weight-bearing areas of the buttocks, aids in preventing pressure sores.

Resiliency tests (10-second readout with a sponge rubber gage, PANDUX, Model-302S) indicated relatively minor differences in the compression resistance of the cushion surface in the model evaluated. The significance of the differences could not be determined. In general, the center area, front to back, offered the least amount of resistance. Nevertheless, the Lord Calvert Buoyant Air Cushion for wheelchairs ap-

pears to be a useful miscellaneous aid for the disabled. Because the cushion is designed for use with a board, active patients who get in and out of automobiles regularly might find it inconvenient to remove two articles (the board and the cushion) at each transfer.

8. Aztec Curb-Climbing Attachment for Wheelchairs. This attachment, manufactured by the Aztec Manufacturing Co., Tijeras, N. Mex. 87059, enables the occupant of a wheelchair to climb curbs up to 9 in. (22.86 cm.) in height without aid. (See Fig. 11 in "Five Years of Wheelchair Evaluation," appearing elsewhere in this issue.) It consists of two devices, a drop-back dolly and a curb-climbing segment. Both devices are readily installed on almost any conventional wheelchair. The drop-back dolly unit is a stock item which is used alone as an anti-tipping device on ramps and uneven ground, or for tilting a chair backwards to relax and partially unweight the buttocks. The curb-climbing attachments submitted for testing were prototype models. Based on a mechanical analysis of the design and the experiences of a highly motivated paraplegic patient who used the system under supervision, the device is the first practical curb-climber we have seen.

The following procedure is used in climbing curbs: First the dolly is extended and the chair tilted to the rear. The forward section of the chair is then positioned at a point where both drive wheels are approximately 2 ft. (.61 met.) from the curb. The occupant then places the curved curb-climbing segments in close contact with the front region of the drive wheels, at surface level. The drive wheels are then forwardly propelled by the occupant until they are driven completely upon the segments. A subsequent forward thrust will enable the chair to clear the lip of the segments and alight onto the curb.

Constructed of aluminum with rubber surface treads, the curb-climbing attachment consists of both right- and left-side attachment units whose total weight is 4.5 lb. (2.0 kg.). The channeled shaft sections are mounted on special axle fittings supplied with the device. Retaining brackets, also supplied, are attached to the front vertical members of the armrests. They in turn support the curved climbing segments, when not utilized.

The force required to propel the drive wheels onto the climbing segments might be excessive for some occupants. Assuming there are no inertial forces, the average 200-lb (90.7 kg.) man would require a force two thirds of his body weight (136 lb. [61.7 kg.]).

The force required to extend the drop-back dolly attachment is approximately 6.6 lb. (2.99 kg.). To retract it requires approximately 2 lb. (.90 kg.). These forces cannot be considered excessive. Both right and left side of the dolly together weigh 10.3 lb. (4.67 kg.).

Several minor problems regarding this prototype model have been

brought to the attention of the manufacturer. Nevertheless, the curb-climbing segment and drop-back dolly are extremely effective devices for attaching to standard wheelchairs in order to make them capable of climbing curbs.

9. Toilet Seat with Handles (T1) and Raiser (TR-4). Manufactured by the Safety Brothers, 254 South Berkeley Ave., South Pasadena, Calif. 91107, and distributed by Everest and Jennings, Inc., the handles provide assistance for arthritics and other handicapped persons in getting on and off the commode. The Toilet Seat Raiser raises the toilet seat height 4 in. (10.16 cm.) to approximate the height of a wheelchair seat, allowing easier and safer transfer to and from the commode.

The concept of raised toilet seats is not a new one. Toilet facilities in most VA hospitals feature some form of permanently elevated commode seat to make wheelchair transfer quicker, easier, and safer. Moreover, the devices are customarily open in the front, and/or back, to permit access for enemas and for self-cleansing purposes (Fig. 8).

The toilet seat with handles and raiser makes it unnecessary to separately buy grab bars or hand holds, the conventionally used aid in homes of disabled persons.

For safety reasons grab bars need to be secured to stud beams with anchor plates. Installation in a finished wall by drilling into plaster on cinder block requires special precautions. In apartments and rented homes such expensive installations may not be possible.

The Toilet Seat with Handles and the Seat Raiser in combination, or separately, can be quickly, easily, and inexpensively installed in almost any toilet facility. Moreover, its use does not hinder other members of the family who must also use the facilities.

Both the Toilet Seat Raiser and the Toilet Seat with Handles are well designed and of adequate strength. Both have smooth, noncorrosive finishes which can be easily cleaned with a mild, nontoxic cleansing solution. A multiple sclerosis patient has used the subject device for approximately 1 year. Installation on his home-type commode was easily accomplished. The device has made him independent in managing his toilet needs. There has been no evidence of excessive wear.

The Safety Brothers Toilet Seat with Handles, and the Seat Raiser, seem to meet the needs of those handicapped individuals who need assistance in meeting their toilet needs independently. It is particularly useful in rented homes or apartments.

10. American Bidet. A highly significant but frequently overlooked problem of high-level bilateral upper-extremity arm amputees is that of toilet care. Commonly, the congenital child amputee of this type learns to manage his toilet needs with the use of his feet. Adults with traumatic amputations are required to seek help from attendants or mem-

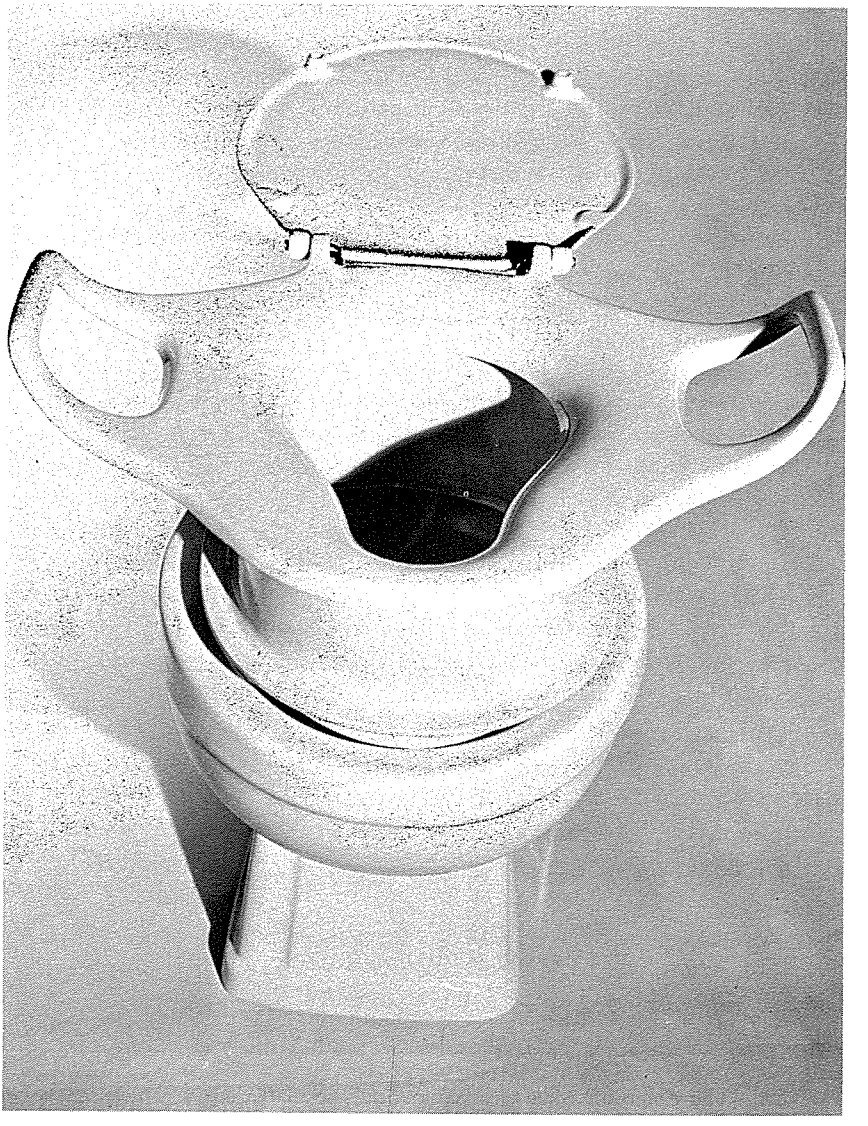

FIGURE 8.—The E & J Toilet Seat with Handles and Seat Raiser offers a safe and easy way for wheelchair patients to get on and off the commode.

bers of their families, or to use any of a number of improvisations, solutions which are inadequate from both psychological and hygienic points of view. Another solution to this problem is afforded by the American Bidet (Fig. 9), a self-contained appliance which replaces the conventional toilet seat. The unit is available from World Industries, Inc., 2

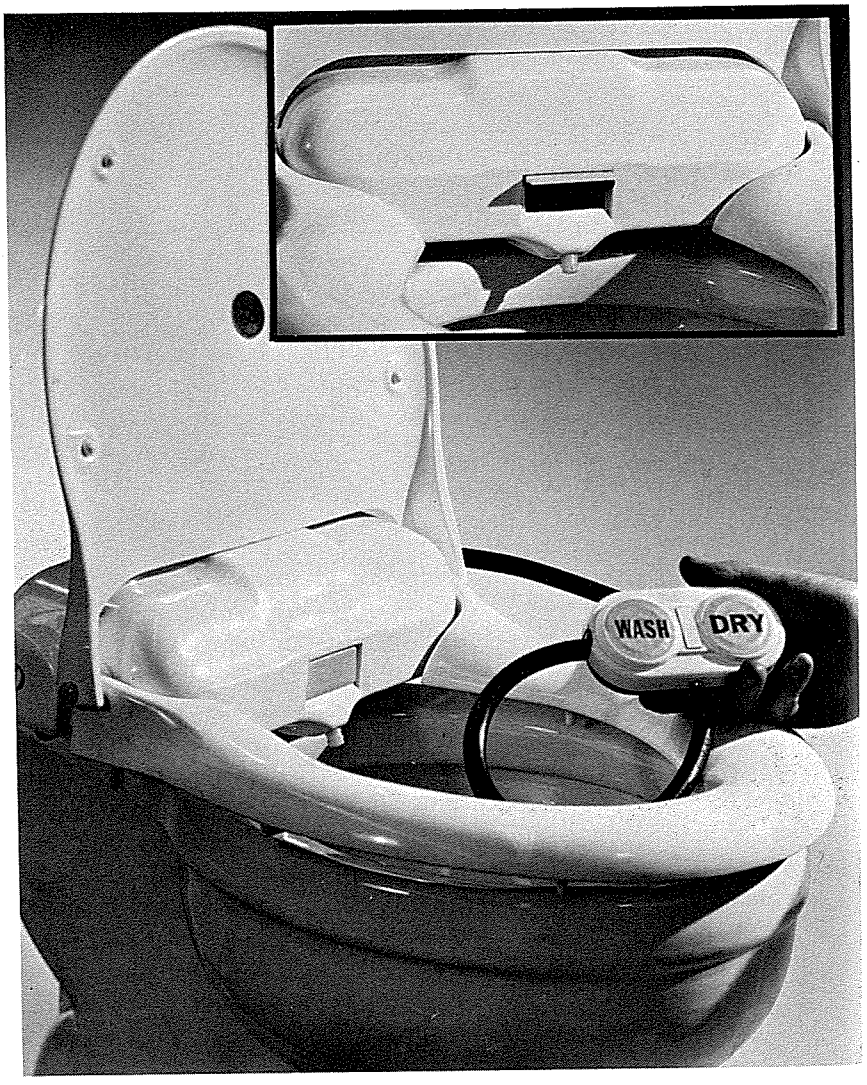

FIGURE 9.—The American Bidet is a commerically available device which can be attached easily to any toilet in the home for patients who have been unable to meet their toilet needs by themselves.

Division Street, Somerville, N.J. 08876. It constists of a lid, seat ring, and a housing containing controls for heating and regulating the pressure of a stream of water and stream of air. By moving one lever located at approximately hand position, when the patient is seated, a stream of warm water is available for washing as well as a stream of hot air for drying.

This device has been found highly useful by a bilateral shoulder-disarticuation amputee who used it for 4 months. His highly positive reactions indicated adequate reliability, efficiency, and ease of operation. He was particularly pleased that it eliminated the need for the assistance of family members for toilet care.

This device seems entirely adequate for toilet care in the home.

V. TESTING

A. Standards Development Program

Stump Socks. As reported in BPR 10–10, a limited field study has been initiated in order to relate certain subjective functional stump sock qualities to specific objective physical qualities. Two highly sophisticated bilateral below-knee subjects have been wearing, on a routine basis, a selection of stump socks currently on VA contract. Socks were prewashed and coded prior to the wear period. Their experiences and reactions have been recorded daily.

One subject who has been participating in this study for 3 months initially discarded one sock of one manufacturer as having shrunk (after 5 wash-dry cycles) to the point where he was unable to don it. He wore the remainder of the sample on a routine basis and observed no differences between them. However, after approximately 10–12 wearings he experienced extreme stump discomfort with one stump sock. He attributed this pain to a general thinning of the sock which allowed him to "sink" down into his socket.

The original samples for the second pilot wearer were all initially rejected as having shrunk too much, following the usual 5 wash-dry cycles, to be put on.

A second sample of socks was obtained, coded, and after *one* wash-dry cycle given to the subject to use. In this 2-week-wear period the subject reported several instances of discomfort and sock shrinkage.

This study will be continued and the sample expanded to less sophisticated pilot wearers.

B. Compliance Testing

1. Stump Socks. During this period stump socks manufactured by two different companies were tested for compliance with specifications. One manufacturer, Breeze and Belgard, Ltd., of Leicester, London, England, was found to comply with current requirements. The other, manufactured by Bennington Stump Sock, Corp., was also found to be in compliance with specifications.

2. Upper-Extremity Components. One model of the Sierra V.O. Hand was checked for compliance with currently applied specifications. Al-

though the results were satisfactory, the unit required frequent lubrication, a matter brought to the attention of its distributor, the A. J. Hosmer Corp.

3. SACH Feet. During this period, three manufacturers submitted samples of SACH feet for annual compliance testing. The results of the tests indicated that all three manufacturers' products were in substantial compliance with the requirements.

VI. OPERATIONS REPORT FOR FIRST HALF, FISCAL YEAR 1969

The VA Prosthetics Center rendered 46,992 services during the first half of fiscal year 1969 as compared with 95,645 services rendered for the entire fiscal year 1968. Of this amount, 7,620 were services received directly by veterans reporting at our Center. A total of 22,420 disabilities were treated, averaging slightly over two services per disability.

Issues of custom orthopedic shoes and shoe repairs remained relatively constant, as did issues of surgical supports and elastic hose. Distribution of prosthetic components dropped somewhat.

A. The Orthopedic Shoe Service

Table 2 reflects full fiscal year distributions from 1965 through 1968 for comparison with the present fiscal year. Ortho-inlay shoes, not reflected in the table, were provided to 181 veterans. A savings of $7,664 was realized since ordinarily they would have been issued custom orthopedic shoes at a far higher cost. We also issued 70 pairs of overshoes and rubbers.

B. The Prosthetics-Orthotics Service

Table 3 reflects the activity in the Orthotic Components Unit of the Prefabricated Appliances Section relating to the distribution of surgical

TABLE 2.—*VAPC National Orthopedic Shoe Program*

	1965	1966	1967	1968	1st half, F.Y. 1969
Beneficiaries on rolls	10,322	10,587	10,861	11,127	----------
New shoes, pairs	7,336	7,688	7,181	8,274	3,907
Pairs of new shoes issued per beneficiary on rolls per year	0.71	0.73	0.66	0.74	0.68[a]
Repaired shoes, pairs	9,422	10,432	8,932	9,938	5,212
Pairs of shoes repaired per beneficiary on rolls per year	0.91	0.99	0.82	0.89	0.92[a]

[a]Projected for full fiscal year.

TABLE 3.—*VAPC Surgical Support and Elastic Hoisery Program*

Issuance channel	Fiscal year 1965		Fiscal year 1966		Fiscal year 1967		Fiscal year 1968		1st half, fiscal year 1969	
	Surg. supp., ea.	Elas. hos., ea.	Surg. supp., ea.	Elas. hos., ea.	Surg. supp., ea.	Elas. hos., ea.	Surg. supp., ea.	Elas. hos., ea.	Surg. supp., ea.	Elas. hos., ea.
Directly to veterans	2,482	9,554	2,634	9,801	2,697	10,866	2,712	11,201	1,536	5,638
Orthopedic shops.	3,722	11,049	5,885	14,517	5,056	15,924	4,630	16,333	1,868	8,602
Total	6,204	20,603	8,519	24,318	7,753	26,790	7,342	27,534	3,404	14,240

supports and elastic hosiery. Table 4 reflects the distribution of prosthetic components.

Table 5, 6, and 7, reflect the fabrication and delivery of lower-extremity prostheses and braces. Also fitted were 21 artificial arms and 730 arch supports.

TABLE 4.—*Distribution of Prosthetic Components by VAPC, F.Y. 1969*

Issuance Channel	Temporary prostheses[a]		SACH feet	Hydraulic systems[b]		
	AK	BK		Initial issue	Replacement issue	Active wearers
For specific beneficiaries	37	62	37	205	693	
VA orthopedic shops	36	53	65	—	—	
Total	73	115	102	205	693	2,672

[a]In F.Y. 1968, 82 above-knee temporary prostheses and 251 below-knee prostheses respectively were distributed.

[b]In F.Y. 1968, 2,467 were active wearers.

TABLE 5.—*Complete Below-Knee Artificial Limbs Fitted by VAPC, First Half F.Y. 1969*

Type	Permanent	Temporary	Totals
PTB			
Cuff	12	4	16
Lacer	9	4	13
Carved wood	14	—	14
Molded socket non-PTB	19	13	32
Syme	10	—	10
Chopart	1	—	1
Total	65	21	86[a]

[a]In F.Y. 1968, 175 below-knee artificial limbs were fitted.

TABLE 6.—*Complete Above-Knee Artificial Limbs Fitted by VAPC, First Half F.Y. 1969*

Type	Permanent	Temporary	Totals
Molded socket, non-total contact	24	8	32
Molded socket total contact	18	8	26
Carved wood socket	5	—	5
Hip disarticulation	2	—	2
Knee bearing	2	—	2
Totals	51	16	67[a]

[a]In F.Y. 1968, 188 above-knee artificial limbs were fitted.

TABLE 7.—*Braces Fitted by VAPC, First Half F.Y. 1969*

Item	Number
Below knee	74
Above knee	92
Arm	22
Spinal, custom	3
Spinal, prefabricated but custom fitted	43
Cervical collars, prefabricated but custom fitted	9
Total	243[a]

[a]In F.Y. 1968, 463 braces were fitted.

C. The Restorations Service

Table 8 lists the major items fabricated and fitted by the Restorations Service.

TABLE 8.—*VAPC Production of Restorations Items, First Half F.Y. 1969*

Item	Number
Artificial eye	197
Body restorations	—
Cosmetic gloves	57
Facial restorations, ear	13
Facial restorations, nose	—
Facial restorations, orbital	1
Ocular Conformers	94
Plastic hands	36
Repairs to appliances (all)	22
Other items or services	279

D. Special Clinic Team

The function of the Special Clinic Team is to evaluate, prescribe, and checkout prostheses for problem cases referred to it by other stations. The Clinic Team met 40 times during this period. A total of 156 veterans were referred by 20 field stations. Almost twice as many veterans were seen and served as compared with the previous 6-month period.