

FIVE YEARS OF WHEELCHAIR EVALUATION

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INTRODUCTION

The Veterans Administration has a keen interest in maintaining and improving the quality of wheelchairs and the accessory appurtenances designed to ameliorate the lot of its orthopedically disabled beneficiaries. During the past 5 years approximately 75 wheelchairs and accessories have been examined or evaluated at the Veterans Administration Prosthetics Center, and in many cases, the results have been published in the Bulletin. Among these devices were conventional wheelchairs, lightweight wheelchairs, various kinds of wheelchair accessories, power-driven chairs, multifunction wheelchairs, curb climbers, and stair-climbing wheelchairs. We know of no other agency which has evaluated a comparable quantity and variety of wheelchairs and related devices. A review of our work in this field during the past 5 years generated the following pertinent questions:

Are there significant differences among the commercially available conventional wheelchairs? Is it possible to "idealize" the design of a wheelchair by synthesizing the best features of all the known chairs? Are the "lightweight" wheelchairs of sufficient general utility? Should the advantages of lightweight wheelchairs be available to all patients? Are lighter materials the principal factor in the design of useful lightweight wheelchairs?

How extensive is the need for customized wheelchair accessories? Do designs for wheelchair accessories indicate faults in the basic design of conventional wheelchairs?

Are power driven wheelchairs indicated for any but completely immobile patients? Can the areas of need for power-driven wheelchairs among the less handicapped be identified? What are the relative merits

of powered vehicles, powered wheelchairs, and accessory power kits for wheelchairs?

Is there a sound rationale for multiple function devices? Can real economy be achieved by a single device designed to furnish the functions provided by several individual devices?

Are stair- or curb-climbing wheelchairs available today? Are they needed?

On the basis of our experience alone it was not possible to answer satisfactorily all of these questions. In retrospect, however, some light was shed on the current state of wheelchair technology and on design needs of the future, information which may be of value to developers, manufacturers, and purchasers.

CONVENTIONAL WHEELCHAIRS

The term "conventional wheelchair" refers to the general purpose, folding, common wheelchair of which the widely known Everest and Jennings Standard is the archetype (Fig. 1). The VA Prosthetics Center has evaluated 20 chairs of this type in the past 5 years including units manufactured by Everest and Jennings, Gendron, International Hospital Supply, Stainless Specialities, Sears Roebuck, American Wheelchair, Theradyne, Howmet, Colson, and Mobile Aid. Of this group, the International Hospital Supply and the Gendron are no longer being manufactured.

It is difficult to distinguish significant differences among those which meet the minimum standards of acceptability for the Veterans Administration. The real advantages of the special features which manufacturers emphasize in their advertising are often difficult to identify. Subjective opinions of patients and clinicians about the relative merits of these chairs are often colored by custom, salesmanship, advertising, marketing and servicing facilities, and reputation rather than by objectively determined factors.

No single wheelchair seems to meet all the needs of patients. Individual patients have very strong preferences for such special features as smaller (junior) models, individual heel straps, detachable and/or desk-type arms, swing away leg rests, toggle-type brakes, pneumatic tires, lighter weight, and other similar matters. Intrinsically, none of these features is more valuable than another; their value depends upon variable patient needs or subjective preferences. For example, while removable arms are invaluable for a patient who must transfer to a bed laterally, they may have little or no value for the patient who can stand and step out of the chair in a forward direction. *Yet, both may prefer them.*

For example, in 1968 the Research and Development Division of the

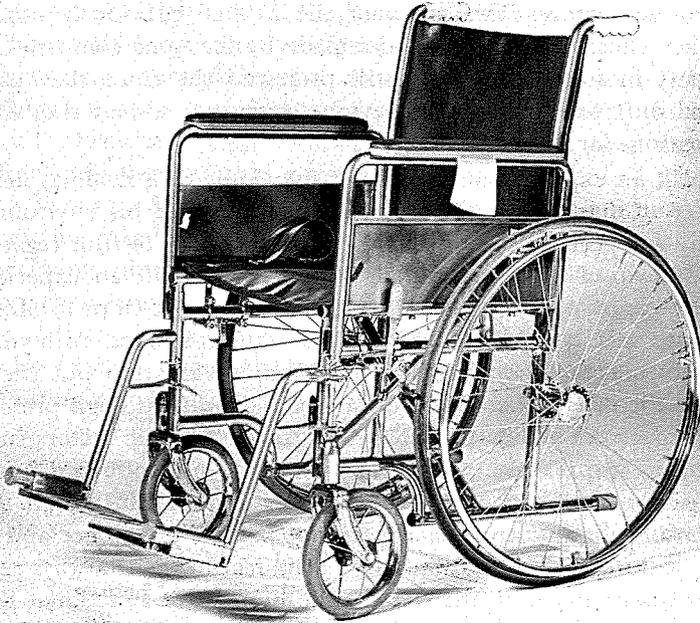


FIGURE 1.—Everest & Jennings Standard 8-in. caster folding wheelchair.

Prosthetic and Sensory Aids Service conducted an evaluation of eight different wheelchairs at seven VA stations in different regions of the United States. Each of 45 patients (29 of whom were inpatients and 16 outpatients) used each chair for a 1-week period. Each patient was interviewed three times: at the time he was selected to participate in the study; at the completion of each week's test use of a chair; and after having tested all of the chairs. In addition, the professional staff coordinating the study at each station was asked for their opinion regarding wheelchairs.

At the end of the study, three chairs (a standard weight, a light-weight manufactured by the same manufacturer, and a second light-weight) were preferred by the patients on the basis of a high incidence of favorable response and a low incidence of negative comments relative to each chair. Opinions of the professional staffs tended to agree with patient responses.

When the data were studied from a different perspective, a very interesting aspect of chair preference was revealed. At the conclusion of the study, each subject was asked to indicate his first and second preferences among the wheelchairs. The first choice of 31 of the 45 subjects were

different models made by a single company each of which included some unique feature. Twenty-six of the 31 had previously used the model they chose, or another model made by the same company. Only 17 patients indicated that they still preferred the chair they usually used, and only five cited their previous chair as a second choice. The precise reasons for shifting choice were not clear.

After all, an experienced wheelchair user *knows* his chair as he does his overcoat; it is one of the more intimate parts of his environment, and minute aspects of its topography are significant to him regardless, in many cases, of their functional value. No one but an experienced user sees a chair in this light and it may be idle to attempt to objectify or evaluate validly certain factors of patient preference. Idiosyncratic preferences may not be amenable to objective valuation but they are nonetheless real, and there must always be a definite, though preferably limited, variety of chairs available to patients. Esthetic factors such as color, shape, and texture of materials which do not influence function are difficult to prescribe or specify. Perhaps they should be left to the discretion of manufacturers as a matter of patient preference and business competition. While certain wheelchair features will always remain matters of patient choice there is a large number of functional factors commonly desired and required by all wheelchair users. These features relate to comfort, safety, durability, and function and do lend themselves in various degrees, to objective description and measurement. Certainly minimum standards of safety, comfort, maneuverability, and effort to propel wheelchairs can be established.

The matter of minimum standards of wheelchair weight, for example, has received some attention. At the present time, commercially available wheelchairs weigh between 30 and 56 lb., a rather wide range. The significance of wheelchair weight lies not so much in requiring excessive forces to propel as it does in making it difficult to fold, store, and to load and unload from an automobile. During the past several years, "lightweight" chairs have come on the scene. Classified by their manufacturers as lightweight chairs are the Howmet, Everest and Jennings Lightweight, and the Stainless Specialties chair. These range in weight from 30 to 42 lb., the upper limit of which is not significantly different from the lower limit of the weight range of conventional chairs. The concept of a "lightweight" chair may be faulty if it implies less durability than that afforded by conventional chairs. The ideal design is the lightest possible chair which meets all the minimum standards for durability. In this sense then there is really no lightweight chair. Of the two lightest "lightweight" chairs, one does not meet generally accepted minimum standards and the other is generally considered to be restricted for use by patients under 175 lb. As the quality of "lightweight" designs im-

proves to the point where they meet all minimum requirements, their weights increase slightly until they may not differ significantly in this respect from well designed conventional chairs.

Reviewing and evaluating the problems encountered with lightweight wheelchairs enable us to identify a number of standards which we believe all wheelchairs should meet. We also believe that the current standards and specifications governing the procurement of wheelchairs by the Veterans Administration need revision. They are based on the concept that standards of safety, comfort, and function can be achieved by specifying minutely the materials and types of fastenings to be used in wheelchair construction. This stifles creativity in development and severely restricts the use of new materials and construction methods. It may also fix costs at higher than necessary levels. More to the point is a specification of minimally acceptable *functions* regardless of type of material or construction employed to achieve these functional standards. To this end we have proposed a set of standards and specifications which are presented below. For brevity and organizational purposes they are outlined in a form similar to official standards and specifications. A statement of the rationale underlying the less conventional proposals is included. At the risk of some repetition we have appended descriptions (Appendix A, following The Proposed Standards for Wheelchairs, Self-Propelled, Folding, Multipurpose) of proposed test procedures devised to determine compliance with the standards and specifications.

Proposed Standards for Wheelchairs, Self-Propelled, Folding, Multipurpose

1. Scope, Classification, and Limitations

1.1 Scope. These standards relate to mechanical devices which are capable of supporting patients in a seated position with no part of their anatomy in contact with the floor, and which can be propelled by the occupant, with or without the aid of other sources of power.

1.2 Classification. These wheelchairs shall be of one grade and one type. They shall be appropriate for use indoors and outdoors, on level ground and slopes, and for all types of patients who are deemed, by competent medical authority, unable to ambulate more efficiently by means of other orthopedic aids.

1.3 Limitations. These standards establish acceptable levels of safety, comfort, function, and durability for multipurpose wheelchairs. The specifications set forth the *minimum requirements* to meet these standards with respect to design, construction, dimensions, resistance to wear and deformation, adjustability, operating characteristics, and ease

of operation. These standards do not limit the prescription of wheelchairs featuring variations of the basic type described herein provided that the minimal functional requirements specified are met. These standards place no restrictions on the design of wheelchairs with respect to materials or construction provided the minimum functional specifications are met.

2. *Applicable References and Specifications*

The following specifications and standards of the issue in effect on date of invitation for bids, form a part of this specification.

Federal

- | | | |
|-----|-------------------------------------------------------------------------------|--------------------------------------------------------------------------|
| 2.1 | QQ-C-320 | Chromium Plating (Electrodeposited) |
| 2.2 | QQ-N-290 | Nickel Plating (Electrodeposited) |
| 2.3 | QQ-S-766 | Steel Corrosion-Resisting, Plates, Sheets, Stripes and Structural Shapes |
| 2.4 | CC-A-700 | Artificial Leather Upholstery (Synthetic Resin Coated Cloth) |
| 2.5 | CCC-C-419 | Cloth, Cotton, Duck, Unbleached, Plied-Yarns
(Army and Numbered) |
| 2.6 | Federal Standard Number 123—Marking for Domestic Shipping (Civilian Agencies) | |

3. *Requirements*

3.1 General. The wheelchairs covered by these specifications shall be capable of folding as a complete unit without requiring the removal of any integral component.

3.2 Components. A wheelchair shall include: (a) a supporting structure consisting of a backrest, a seat, armrests, and footplates; (b) a propulsion system consisting of wheels (or other devices providing a similar function), drive mechanism, brakes, and locks; and (c) a folding mechanism.

3.2.1 Materials.

a. Standard

The supporting structure, propulsion system, and the folding mechanism shall be of materials and construction which do not deform permanently under the stress of normal usage.

b. Specification

These structures shall withstand loads with energies of 125 ft.-lb. applied 100 times without permanent deformation. This is based on the idea that a "worst condition" of normal use is found in curb descent. A

200-lb. man descending a 6-in.-high curb subjects a 50-lb. chair to high impact loads with energies of approximately 125 ft.-lb.

3.2.2 Supporting Structure.

a. Standard

1. The supporting structure shall conform to mechanical standards of stability based on positions and displacements of the center of gravity (c.g.) in the loaded and unloaded condition.

2. Certain components of the supporting structure shall be available in a range of dimensions conforming to anthropometric standards for the human body; dimensional variation may be provided by adjustability of components or by prescription order.

b. Specification

1. Stability

The wheelchair shall remain stable with an occupant seated during movement on level ground and on slopes of 10 percent (6 deg.). The notion underlying this specification is that with each stroke, the wheelchair occupant applies a reaction force against the chair's backrest. This provides a clockwise moment around the drive axles which is resisted by a counterclockwise moment produced by the weight of the system at a certain distance from the drive axles. All other things equal, the shorter the horizontal displacement, and the higher the c.g. location relative to the drive axles (resistance moment arm), the smaller the clockwise toppling moment that can be resisted.

2. Dimensions

The minimum dimensions of the seat shall accommodate the appropriate anthropometric dimensions of legs, seats, and backs of 95 percent of the normal adult male population.

Seat Width—Chairs designed for general use shall include seats not less than 16.0 in. wide in a frame not less than 17.0 in. wide. Chairs with narrower seats are considered "junior" or undersized models; extra wide chairs shall be available.

Seat Length—The depth of the seat shall be not less than 16.0 in.

Seat Height—The height of the forward edge of the wheelchair seat from the floor shall not be greater than 20.0 in.

Seat Incline—The seat shall incline downwards to the rear not less than 4 deg. nor more than 8 deg. with respect to a horizontal reference.

Backrest Width—The back of the chair and the seat shall be of the same width.

Backrest Height—The upper edge of the backrest shall not be less than 16.0 in. above the center of the seat nor more than 20.0 in.

Backrest Incline—The backrest shall incline not less than 10 deg. to the rear from the vertical reference.

Leg Rest Length—Leg rests shall be adjustable through a range of 14.0 in. to 18.0 in. measured from the footplate to the surface of the forward edge of the seat. In providing this range the lowest point of the footplates shall always be maintained at least 2.5 in. above the floor surface.

Footplate Depth—At least two sizes of footplates, 6 and 8 in. in depth, shall be available for each chair. Footplates may be of two specific sizes, i.e., 6 in. and 8 in., or they may be adjustable to provide these dimensions.

Footplate Width—Footplates shall provide a bearing surface for the shoe of not less than 6 in. in width.

Footplate Inclination—Footplates shall incline downward toward the rear of the chair not less than 5 deg. with respect to a horizontal reference line without preventing an occupant from maintaining a 90 deg. angle between shank and foot (0 deg. plantar flexion or dorsiflexion).

3.2.2.1 **Upholstery.** Upholstery shall be flexible, non-absorbent, stain resistant, and flame resistant. It shall be easily cleaned when attached, or capable of being removed easily for laundering. It shall resist scuffing, abrasion, splitting, and tearing. It shall be colorfast and non-irritating.

3.2.3 **Propulsion System**—The propulsion system of these chairs shall include: a. driving rims, bars, or other devices for transmitting propulsion force from the patient to the drive mechanism; b. drive wheels or other devices for converting force applied by the patient to motion of the wheelchair; c. casters or other devices to provide stability, maneuverability and ease of operation; and d. brakes and locks to control chair motion.

3.2.3.1 **Drive Mechanism**—Rims, bars, or other devices driven by the patient shall be of uniformly finished material with non-slip, non-splintering grasping surfaces. They shall be firmly linked to the drive wheels with no relative motion between them. They shall be replaceable independently of the drive wheels. They shall be positioned so that no part of the patient's hand touches any other component when propelling the chair.

3.2.3.2 **Wheels**

Drive Wheels: The diameter of the drive wheels shall be not less than 22.0 in. for wheelchairs weighing 30.0 lb. and not less than 24.0 in. for wheelchairs weighing more than 30.0 lb.

The wheels shall not rotate in more than one plane (flutter, wobble) when the chair, loaded with 200 lb., is propelled.

The replacement of unsealed wheel bearings shall not require the replacement of any other major component.

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Sealed wheel bearings whose replacement also requires the replacement of wheels or other major components shall be guaranteed for a minimum life of 10,000,000 cycles under 100 lb. of load.

Axles shall not extend beyond wheel hubs and shall be covered by dust cups.

Casters: Casters shall swivel 360 deg. in both directions. The diameter of caster wheels shall be not less than 8.0 in. The casters shall be firmly seated in the wheelchair frame and positively attached or locked.

Tires: Tires shall be of a nonmarking resilient material, either solid with smooth treads or pneumatic.

Solid tires shall not gap more than 0.0625 in. at the joint under dynamic loading conditions.

Tires shall not roll up on the wheel rim under normal loads applied perpendicularly to the normal line of wheel progression.

The compressibility of the drive wheel tires shall be such that adequate tire surface area remains in contact with the ground to insure proper traction and braking. When the chair is loaded with 200 lb., the contact surface between each tire and the ground shall not be less than 1.0 sq. in.; the contact surface between the caster wheel tires and the ground shall not be less than 0.5 sq. in. per tire.

3.2.3.3 Brakes and Locks—Each drive wheel shall be equipped with a device to prevent wheel rotation. When set to prevent wheel rotation, these devices shall not permit the chair, loaded with 200 lb. to move on a slope of 10 percent (6 deg.). These devices shall be hand operated from both sides of the chair. Brakes may be independently applied to each wheel or they may be designed to brake both wheels by operation of either or both of the handles. The handles shall extend upward at least to seat level and be located in a convenient position.

Each wheelchair shall provide a braking feature by adjustment of the wheel lock or by any other device which retards the velocity of wheel rotation. Operation and installation shall meet the requirements for wheel locks above.

3.2.4 Folding Mechanism—The chair shall be capable of being folded or opened easily with one operation and without removing any parts integral to the chair.

The chair shall be capable of being pushed or pulled when folded. The folded chair shall not be more than 12.0 in. wide.

3.2.5 Function—These devices shall conform to standards of safety, comfort, maneuverability, and ease of operation as specified below:

3.2.5.1 Safety

Handles—Coverings for handles or other devices for pushing or tilting wheelchairs shall be permanently attached and not readily remova-

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Caster wheels shall not come in contact with the occupant's heels when the chair is operated.

The backrest uprights shall not interfere with movements to propel the wheelchair. The occupant's thighs shall be adequately supported, that is, the entire posterior surface of the thighs shall remain in contact with the seat when his feet are placed on the footplates. The chair shall provide means to prevent the occupant's feet from sliding backwards off the footplates when the chair is tilted backwards as when ascending or descending curbs.

3.2.5.3 Maneuverability—The wheelchair shall be capable of being propelled by the occupant through a doorway 30.0 in. wide.

The chair shall be capable of being turned 180 deg. in a corridor 50.0 in. wide.

The chair shall be capable of climbing and descending door saddles, curbs, and stairs when operated by the occupant or with the aid of an attendant.

The chair shall be capable of being positioned to effect easy transfer from chair to bed, car, commode, etc.

The chair shall permit the occupant to reach the floor with his hand and to reach the average work height areas.

When folded, the overall height of the chair shall not preclude the storage of the chair in the trunk compartment of an automobile (40.0 in.).

3.2.5.4 Ease of Operation—No accessories or other encumbrances shall be mounted on the sides or the front of the wheelchair in a manner to interfere with or prevent transfer activities.

Each wheelchair shall be provided with a means for propelling and maneuvering the chair by a person other than the occupant. This device shall be attached to the frame at a height that allows the person propelling the chair to walk comfortably in an erect manner: handles shall be located not less than 35.0 in. nor more than 40.0 in. above the floor. Human efficiency in pushing forward with the arms is greatest when the pushing force is coplanar with the body center of gravity. The c.g. in humans is found at approximately 54 percent of the vertical height of women and 56 percent of the vertical height of men; average heights are respectively 64 in. and 69 in. The average woman's c.g. is therefore approximately 35 in. high and the average man's approximately 39 in. high.

The wheelchair shall have a maximum weight of 48.0 lb. for ease of portability and loading into a car by the occupant or an aide. This standard applies to items on contract. New designs submitted for evaluation to determine eligibility for contract shall not exceed 35.0 lb. exclusive of special features.

ble without the aid of tools. This does not apply to levers or other tilting aids designed to be stepped on; covers for these components shall be of a material with a high friction coefficient (non-skid).

Footplate Surfaces—Footplates shall be corrugated or otherwise treated to increase friction between the shoe surface and the plate. They shall not have raised edges.

Movable Footplates—Footplates shall be capable of being moved simply and quickly by the chair occupant or an attendant to permit direct wheelchair entry.

Functional Control of Footplate Position—Footplates shall remain in the position in which they are placed until moved by the chair occupant or an attendant.

Skirtguards—Two skirtguards shall be provided to prevent contact between hands or clothing and wheel spokes, and to prevent dirt and other objects from being deposited on the occupant. Clearance between the skirtguards and the drive wheels shall be at least 1.0 in.

Projections—All vertical projections, and all other projections beyond the footplates to the front, beyond the armrests to the sides, and beyond the seat and back to the rear shall be covered with a resilient material.

Component Locks—All removable components, including armrests, leg rests, footplates, shall be equipped with positive locking devices.

Stability—The wheelchair shall remain stable when the occupant moves around in it as well as during transfer activities.

3.2.5.2 Comfort—The space between the seat and backrest shall not exceed 2.0 in. with an occupant (gapping).

The patient shall be maintained in a comfortable upright sitting position.

Armrests—Each chair arm shall be equipped with two armrests. They should not interfere with the operator's arm motion during propulsion. Their length should not interfere with, or preclude, a close approach to tables or desks.

Arms shall be provided with removable padded armrests. The combined height of the arm and armrest from the seat shall be such that the occupant's elbow can rest comfortably without having to drop or elevate the shoulder. Width of armrests shall not interfere with transfer activities, nor hinder propulsion of the chair by the occupant.

Shock Absorption—Each chair shall be designed to absorb the impacts of curb descent and obstacle clearance, and the effects of uneven surfaces by means of shock absorbers, frame design and construction, balloon tires, or any other effective means.

The backrest shall be flexible and conform to body contours.

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The force to initiate motion shall not exceed 5.0 lb. with a 200-lb. load.

The wheelchair shall be capable of being folded with one hand. The force to fold the wheelchair shall not exceed 15.0 lb.

4. *Instructions*

Each chair shall be provided with an illustrated description of the assembly, operation, and care of the device together with a list of component parts.

5. *Quality Control*

Each contract unit shall be subjected to appropriate quality control measures by the manufacturer or distributor prior to delivery to insure compliance with these specifications. Each unit will also be inspected at the Supply Depot or receiving station.

5.1 Sampling, Inspection, and Test Procedures.

5.1.1 Inspection. Every device (100 percent of sample) will be visually inspected for complete assembly, finish, workmanship, and condition and checked for operability.

5.1.2 Testing. One unit each year will be subjected to appropriate testing by the Bioengineering Research Service, VA Prosthetics Center, New York.

APPENDIX A

Test Procedures

3.2.1 Durability and Resistance to Deformation (Destructive)

a. The chair and its supporting components shall not deform permanently under tests simulating normal loads. The wheelchair loaded with a 200-lb. test load is rolled off a square-edged 6-in. wooden platform 100 times. Each cycle starts with the weighted chair resting on the platform; the chair is propelled backward at a slow, uniform rate until both drive wheels are resting on the floor.

After 100 cycles the wheelchair is unweighted and the supporting structure, propulsion system, folding mechanism, upholstery, and fastenings are inspected and measured for evidence of permanent deformation. Changes in the dimensions, shape, or operation of the component parts of the wheelchair are considered failures.

The standard 200-lb. test load shall consist of a rigid 14-in. cube with its center of gravity at the intersection of the anterior-posterior and medial-lateral planes at a height 4 in. above the bottom surface. It shall be covered with a 0.5-in. thick layer of 12 lb./ft.³ density, 30 durometer,

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foam rubber. An equivalent load of different structure may be substituted.

3.2.2 Stability

a. The wheelchair must resist toppling. All wheels must remain in contact with the surface of a 9-deg. slope when the wheelchair is loaded with a 200-lb. test load and positioned on the 9-deg. slope with the front of the chair pointed up-slope and the locks on the drive wheels engaged.

Weight and Dimensions

b. Nondestructive Mechanical Test

The gross weight of the chair including all basic accessories, such as footplates and armrests, shall not exceed 35 lb. The seat cushion as measured from the edges of the upholstery shall not be less than 16 in. at its narrowest point. The area above the seat shall not be less than 17 in. wide as measured between the inside walls of the skirtguard of the armrests at mid-depth of the seat. The seat shall be not less than 16 in. deep as measured between the front and rear edges of the upholstery at mid-width in the chair. The seat shall incline rearward between 4 deg. and 8 deg. as measured by a liquid level placed on a 16-in. flat square of wood lying on the seat.

The backrest shall be at least as wide as the seat as measured on the forward surfaces. The top edge of the backrest shall be at least 16 in. and not more than 20 in. above the maximum height of the seat at the rear edge. The backrest shall slope backward from the seat not less than 10 deg. as measured with a liquid level and a 16-in. flat square held against the backrest.

The leg rests shall be adjustable from a minimum length of 14 in. to not less than 18 in. measured perpendicularly from the upper surface of the footplate at a point 3 in. forward of its rear edge to a flat 16 in. square resting on and extending to the edge of the seat. Footplates shall have minimum 5 deg. rearward slope as measured with a liquid level. The lowest point of the foot support ensemble shall be at least 2½ in. above the floor surface.

3.2.2.1 Upholstery: A 1-sq.-ft. sample of upholstery material provided by the wheelchair manufacturer will be subjected to laboratory testing to determine its resistance to flame, to food and grease stains, and its laundering and/or cleansing characteristics.

3.2.3.2 Wheels

Drive Wheels: Drive wheels and tires of chairs weighing more than 30 lb. shall have an outside diameter of not less than 24 in. Chairs weigh-

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chair elevators. Listed below is a fair sample of wheelchair accessories examined during the past 5 years:

American Wheelchair Padded Upholstery	Bye Bye Decubiti Pads
General Motors Research Wheelchair Loader	Swingaway Wheelchair Lap Tray
E&J Elevating Wheelchair Seat	E&J Elevating Leg Rest
Camp Wheelchair Assist	Edward Wheelchair Frame
Wheelchair Propulsion Bars	Portable Elevator
Wheelchair Safety Adaptor	Stairway Lift
Wheelchair Backpiece Strap	Wheelchair Posture Adjusting Device
Trenchard Wheelchair Pad	Wheelchair Gear System
Jaeco Hill Holder	Wheelchair Narrower
Prototype Walker	Quiver Wheelchair Pad
	Airfoil Wheelchair Pad
	Stryker Wheelchair Pad

Most of these devices are designed or developed by individuals who are attempting to meet highly specific personal needs within a particular rehabilitation setting. Most are highly individualized items for which no generally accepted standard exists, a situation making it difficult to evaluate them. In some cases the designers of these devices present them to the Veterans Administration to obtain help in developing them. Others submit them to the Veterans Administration for possible purchase.

We have the general impression that the design and development of many wheelchair accessories are the product of interested individuals who design hardware to meet highly specialized needs in particular hospital settings. A device may appear to have merit in a particular setting; considered for general use, its luster often dims. It is even questionable whether there is a need for "wheelchair accessories" if one considers the presence of wheelchair accessories as indicative of deficiencies in current wheelchair design. This is not to say that many wheelchair accessories are not useful, but rather that the needs in this field have not adequately been determined. Here, as perhaps nowhere else in the field, valuable guidance may result from a meeting of interested minds, perhaps in a symposium organized to consider the whole area of wheelchair accessories and to identify real needs and design requirements.

MULTIPURPOSE CHAIRS

Included in this category are some six devices designed principally as wheelchairs but with several auxiliary functions. Those we have seen range from rough prototypes to highly stylized vehicles (Fig. 2). These devices are intended to fulfill a number of functions which certain patients require in addition to wheelchair use: transfer between wheelchair and bed, commode, or treatment table. They are presented as multipurpose devices whose proper use can perhaps be justified on

ing less than 30 lb. shall have an outside wheel diameter not less than 22 in. measured the same way.

Casters: Casters shall swivel 360 deg. Casters and tires shall have an outside diameter of not less than 8 in.

Tires: Tire joints shall not gap more than 0.0625 in. With the wheelchair loaded with a 200-lb. test load, a 50-lb. force is applied to the tire at a point not more than 1 in. from the joint, tangent to the tire surface in a direction away from the tire joint. Gapping at the joint under these conditions of more than 0.0625 in. shall be a failure.

Tires shall not peel off rims under appropriate lateral forces. When the wheelchair is loaded with the 200-lb. test load and on a sloping plane of 10 deg. (a medial-lateral height difference of 6 in.), the tire shall not roll off the rim.

Tire Compression: With the chair loaded, not less than 1.0 sq. in. of drive wheel tire surface on each drive wheel shall be in contact with the floor. Not less than 0.5 sq. in. of caster tire surface shall be in contact with the floor under similar conditions. Tires are marked with a soft crayon and the wheelchair loaded with a 200-lb. test load is placed on a sheet of paper. Upon removal of the chair, the area of the tire imprint on the paper is measured. A drive wheel tire mark shall not be less than 1.0 sq. in.; a caster wheel tire mark shall not be less than 0.5 sq. in.

3.2.3.3 Brakes and Locks: Locks shall prevent wheel rotation when the wheelchair loaded with a 200-lb. test load is positioned on a 6-deg. slope with the front of the chair pointed down-slope. Any movement with the locking device engaged shall be considered a failure.

3.2.4 Folding Mechanism: The overall width of the wheelchair when folded as measured at its greatest width shall not be more than 12 in. wide.

3.2.5.4 Ease of Operation: The force to initiate motion shall not exceed 5.0 lb. The wheelchair is loaded with the 200-lb. test load. One end of a light cable which passes over a pulley is attached to the wheelchair at its c.g. and the other end is connected to a weight. The weight (in ounces) producing a continuous movement of 12 in. is recorded. The average of five such tests shall not exceed 5.0 lb.

Force to Fold Chair: The force to fold the chair shall not exceed 15.0 lb. By means of a light cable attached to the seat, the force to fold the wheelchair is measured. The average force of five such tests shall not exceed 15.0 lb.

WHEELCHAIR ACCESSORIES

In this category is included a variety of devices ranging from conventional wheelchair components constructed with new materials to wheel-



FIGURE 2.—Prototype of Lincoln Carriage Patient Handling Aid, Model C—combines the functions of patient lift, wheelchair, and commode seat in a single folding apparatus.

grounds of economy in making it unnecessary to have in addition to a wheelchair, several other devices such as lift-aids, gurneys, and commode chairs. It is quite possible that such devices may reduce the burden of caring for patients with multiple needs; they do not however, increase patient independence.

As a class, all these devices suffer from the same malady. In our experience none of the multiple functions they furnish is performed as efficiently as the individual devices they are intended to replace. In certain cases, we have found that third and fourth order functions designed into these chairs, actually interfere with the primary function of

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locomotion. The overall design modifications required to provide second and third order functions rarely permit the primary function, that of wheelchair, to meet minimum standards for wheelchairs.

For example, one device is designed to perform no less than seven different functions. It is highly unlikely that any one patient would require more than two of these specific functions in addition to that of wheelchair. Therefore, for an individual to propel a cumbersome non-folding 210-lb. wheelchair all day in order that he might conceivably use one of the secondary functions once or twice daily seems uneconomical.

Other devices of this type present similar problems. Perhaps designers would be well advised to consider only the principal functions of each device with a view toward substantial improvement.

POWERED WHEELCHAIRS

During the past 5 years a dozen devices described by their developers as powered wheelchairs have been examined. At least four of them were more sensibly classified as either powered carts or simply vehicles for the transportation of wheelchairs, and not as replacements for conventional chairs.

Powered wheelchair transporters are evidently aimed at a rather narrow band of patients who also require the use of a powered wheelchair to get in and out of the transporter. Most paraplegics or other patients who are capable of handling conventional wheelchairs are also capable of transferring in and out of a conventional, appropriately modified, automobile. Moreover, these devices are severely limited by local safety requirements, licensing, and registration problems and, in some cases, protection from the elements.

Even the older, commercially available, fully powered "wheelchairs" are not really wheelchairs in the conventional sense. They are designed for the partially or completely quadriplegic patient who lacks the muscle power to operate anything but an electrical switch, sometimes by means of his tongue or chin. Included in this class are the well-known Everest and Jennings Power Glide (Fig. 3) and the Independence Wheelchair (Fig. 4) designed by Mr. Donald E. Rugg of Denver, Colorado. These devices are not portable, collapsible, nor adequately maneuverable.

Devices of this type are frowned upon in most hospital settings, except in centers for paralytics. They are too heavy and bulky for convenient use in most private homes or apartments and they are not designed for any but stringently restricted outdoor use. They are highly customized and, in our opinion, the total number of patients they serve is small. Medical opinion discourages the use of powered chairs in cases

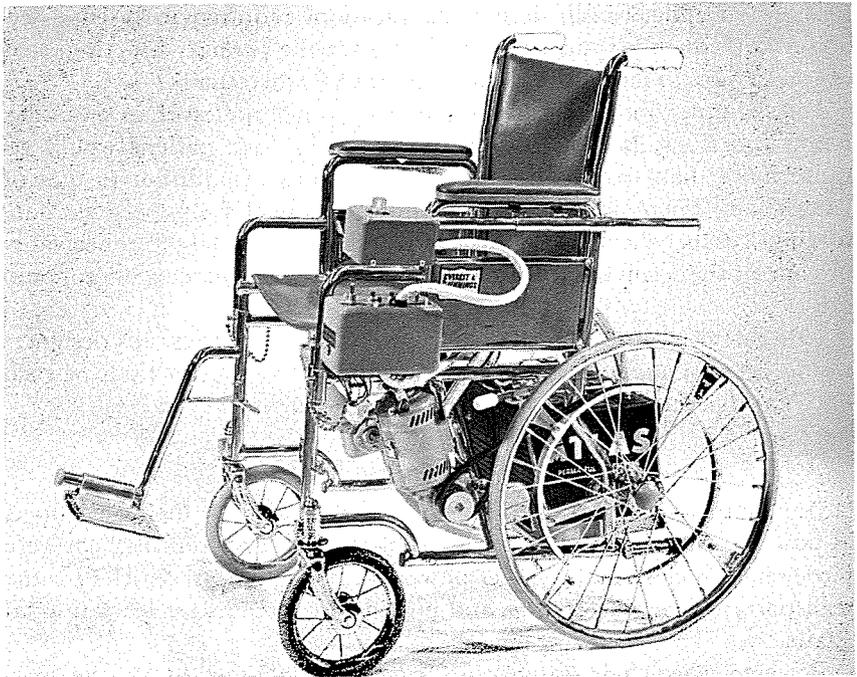


FIGURE 3.—Everest & Jennings Power Glide Chair—the push button-controlled folding wheelchair.

where even limited muscular power is available. Since the number of patients who use these devices is comparatively low, and since their appropriate prescription almost inevitably requires extensive customization, there seems to be little need at the present time for developing new standards and specifications. Existing standards relating to safety, function, and reliability of electrical systems and the safety and comfort of any vehicle designed for sitting may suffice.

A rather different family of powered wheelchairs includes at least three devices which are designed for attachment to a conventional wheelchair thereby converting it to a power-driven chair. Available for this purpose are the Everest and Jennings Mono Drive (Fig. 5), the California Medical Aids Power Aid, and the Motorette (Fig. 6). Although not in wide use, the number of users is increasing. At the present time, there is still a significant degree of doubt as to their proper utilization and prescription.

As a class these units offer a number of advantages including easy attachment and removal from a conventional chair which remains foldable and transportable. They may be particularly useful in cases where



FIGURE 4.—The Independence Wheelchair.

there is an intermittent or periodic need for auxiliary power as for example, among cardiacs, geriatrics, or other debilitated persons. They may also be advantageous for multiple sclerosis patients who are physically incapable of propelling conventional wheelchairs but who are, nevertheless, mentally alert, energetic, and need more mobility than can be obtained with the more cumbersome conventional powered chairs.

Among their disadvantages is the fact that these power units require storage batteries weighing from 40 to 50 lb. which must be removed before the chair can be folded, lifted, or stored. Their power requirements are high enough to deplete the energy source in one day's use and they must be recharged nightly, a procedure which requires a certain amount of battery maintenance, particularly the careful monitoring of water level. Thirdly, all of these systems add approximately 70 to 80 lb. of weight including battery, to the total load carried by the chair. This



FIGURE 5.—The Everest & Jennings Mono Drive.

may accelerate the wear on components and substantially increase maintenance requirements.

Devices of this type certainly need to meet two sets of standards and requirements. As wheelchairs, they should conform to all requirements for conventional wheelchairs as indicated earlier. As electrically powered systems, they should meet all requirements for automotive wheelchairs listed below.

Criteria for Powered Wheelchairs

The doorways and halls in VA approved specially adapted housing must meet minimum specifications as outlined in *Emergency Interim Issue*, EM 44-126. In new construction, halls must be 48 in. wide and doorways must have a 36-in. opening. In existing construction (remodeling) halls may be 42 in. wide and doorways have a 32-in. opening. En-



FIGURE 6.—The Motorette Power Unit conveniently converts any standard folding wheelchair into a power chair.

trance ramps cannot exceed a 10 percent grade (1 ft. rise in a 10 ft. length).

Based on the above, it is possible to arrive at criteria against which the units could be evaluated objectively. These criteria are listed in the following table:

<i>Item</i>	<i>Criteria</i>
Dimensions	Wheelchair dimensions to conform to those in Sec. 3.4 of VA specification No. 7043400-1A for CHAIR, INVALID, WHEEL, FOLDING. The automotive unit should not add to the overall dimensions if the unit is to be used in the home.

<i>Item</i>	<i>Criteria</i>
Speed	Adjustable to a low of 1 m.p.h.
Curb Climb	Should be able to ride over a 1 in. curb.
Ramp Climb	Must be able to go up a 10 percent ramp and also come down the same at a safe speed.
Turning Radius	30 in. maximum.
Maneuverability	In itself cannot be measured objectively, but is a combination of factors such as speed, turning radius, and control sensitivity.
Design	Motor unit (s), battery carrier, and the like should not be permanently installed in the wheelchair, that is, riveted or welded to the chair frame.
Power Supply	Power supply should be such that the unit may be operated under normal conditions for a full day without recharging the battery (ies) and can be fully charged overnight.

It is simple to determine what class of patient requires a fully powered vehicle such as the Independence or the Everest and Jennings Power Glide. It is not nearly as simple to determine which patients really require and can benefit significantly from the power assemblies which convert conventional to powered wheelchairs. These matters are under the active consideration at several Centers including our own, where a field study is in progress to determine the applicability of several devices of this kind.

STAIR CLIMBERS

Several years ago, a great deal of interest was generated in the design and development of stair-climbing wheelchairs. Although many design concepts were advanced, only a few models were fabricated. A fundamental problem persists in attempting to integrate two primary functions in one vehicle. The design requirements for conventional wheelchairs are often incompatible with the irreducible minimum in hardware and weight for stair climbing. In the past 5 years we have evaluated perhaps a dozen such devices and the results indicate that this is a very complex problem which remains unsolved today.

Stair-climbing wheelchairs, generally speaking, tend to evolve into stair-climbing vehicles losing in the process most of the features re-

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quired for a wheelchair. For example, the device shown in Figure 7 is a prototype stair-climbing wheelchair. It consisted essentially of two main sections: (a) a conventional heavy-duty Hollywood wheelchair, with (b) a stair-climbing assembly consisting of two cleated rubber tracks mounted on idler and drive wheels.

In this configuration it was designed to operate on level ground as a conventional wheelchair carrying the stair-climbing assembly beneath the frame. For stair ascent and descent, the climbing tracks are lowered to the ground and the conventional driving wheels, linked by a system of levers and cams, are raised off the ground; at the same time the seat reclines. Once in position, the tracks are operated by means of the conventional drive wheels through the linkages.

To climb stairs, the patient backs the chair against the first step until a rubber cleat catches the top of the step. He rotates the drive wheel which causes the track to climb the step, slipping to readjust itself every

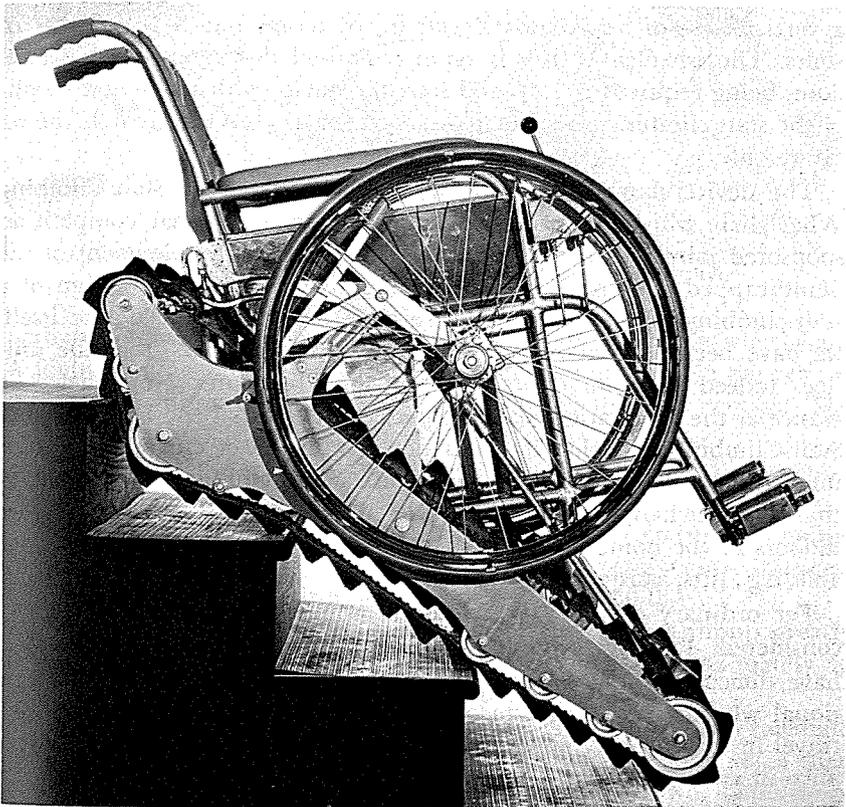


FIGURE 7.—The Project Progress (Virginia, Minn.) Stair-Climbing Wheelchair.

time the one cleat that is supporting the load reaches the end of its travel and another load-bearing cleat becomes engaged. At the top of the flight of stairs, the chair tilts backward and the track slips until a second cleat engages the top step. The chair pivots about the top step until the track is flat on the landing. The patient drives the chair clear of the stairs and retracts the climbing gear and repositions the seat to a level attitude.

The precise patient need underlying this design is not clear. The muscular power required for conventional wheelchair use on level ground is of a significantly different order than that required for a body-powered stair-climbing device. The power required to raise a 100-lb. chair up a flight of stairs in a reasonable time, with a 150-lb. man aboard is very high. For example, if the vertical height of the stairway is 10 ft., the required work is approximately 2,500 ft.-lb. at 100 percent efficiency, or as is more likely, at approximately 15 percent efficiency, 17,000 ft.-lb. This amount of work is equivalent to the work done by a normal person (30 percent efficiency) walking up a flight of stairs with a vertical rise of approximately 40 ft., or more than 4 full flights of stairs. The wheelchair user is again penalized in operation on a level floor, being required to stop and start the device with the added weight of the stair-climbing gear which accounts for approximately half the total weight.

The device shown in Figure 8 is the Hale-Gardner Stair-Climbing Wheelchair which was awarded first prize in a national competition sponsored jointly by the President's Committee for Employment of the Handicapped and the National Inventors Council for the design of a stair-climbing wheelchair. While we have never seen the device itself, we have been assured by others including its designers, that the unit does indeed carry an occupant up a flight of stairs. Nevertheless, a glance at the illustration makes it perfectly clear that the Hale-Gardner Stair-Climbing Wheelchair could not possibly meet current standards for wheelchairs and therefore represents a stair-climbing vehicle rather than a wheelchair. Also to be considered, is the utility of such a device indoors in the home where other means of negotiating stairs are available, e.g., lifts, assistance by others, ramps.

For ordinary outdoor use, climbing both curbs and stairs must be considered. Paraplegics with no involvement of the upper extremity have difficulty but, nevertheless, manage to climb curbs with conventional wheelchairs. Complete quadriplegics should not be required to travel in streets unaccompanied by another person who can offer assistance in curb climbing as well as in level movement. The most significant area of need seems to be for the otherwise capable patient, i.e., paraplegics who may have occasion to travel outdoors in a wheelchair and



FIGURE 8.—Prototype Hale-Gardner Stair-Climbing Wheelchair.

perhaps to enter public or other unmodified buildings in a wheelchair. A flight of stairs, at the present time, is an insurmountable barrier for the patient without assistance which he normally does not require. The requirements for such a device should include:

1. Operation on level ground in much the same fashion as current conventional wheelchairs.

2. Easy collapsibility for loading and unloading from an automobile by the patient himself implying a total weight not significantly in excess of conventional wheelchair weights (approximately 50 lb.).

3. The stair-climbing mode should not require energy inputs greatly in excess of level ground operational requirements (approximately 50 ft.-lb. per stroke) indicating a need for external power.

As a result of this impasse, designers have sought an intermediate goal; the design of a vehicle to ascend and descend one step, i.e., a curb climber. At first blush this seemed like a sensible endeavor. The problem to be considered, the climbing of one step versus a flight of stairs, is simpler; the frequency of having to climb one step is probably greater

than for a flight of steps; power requirements will be lower, and probably the climbing gear would be lighter.

On reflection, however, we remain unconvinced that a curb-climbing wheelchair does indeed represent an important step forward for large numbers of wheelchair users. We are not at all certain that the climbing of curbs in city streets is a sufficiently significant problem to warrant inevitable compromises in the design of conventional wheelchairs. To refine the problem, several years ago we proposed the following set of requirements for such a device (letter to Director, Prosthetic and Sensory Aids Service, January 23, 1968).

1. Ideally, the curb climber should be designed as a supplemental device, to be added to existing VA-approved folding wheelchairs: folding capability should not be restricted by the additional apparatus; the supplement should be easily removable to permit facile folding.

2. Added weight should not be more than 10 lb. If an external power system (based on a 12 volt d.c. battery) were used for the curb-climbing feature alone, the battery weight could be in excess of the 10 lb. provided the battery could be easily removed for wheelchair folding.

3. The device should provide capability for ascent and decent of

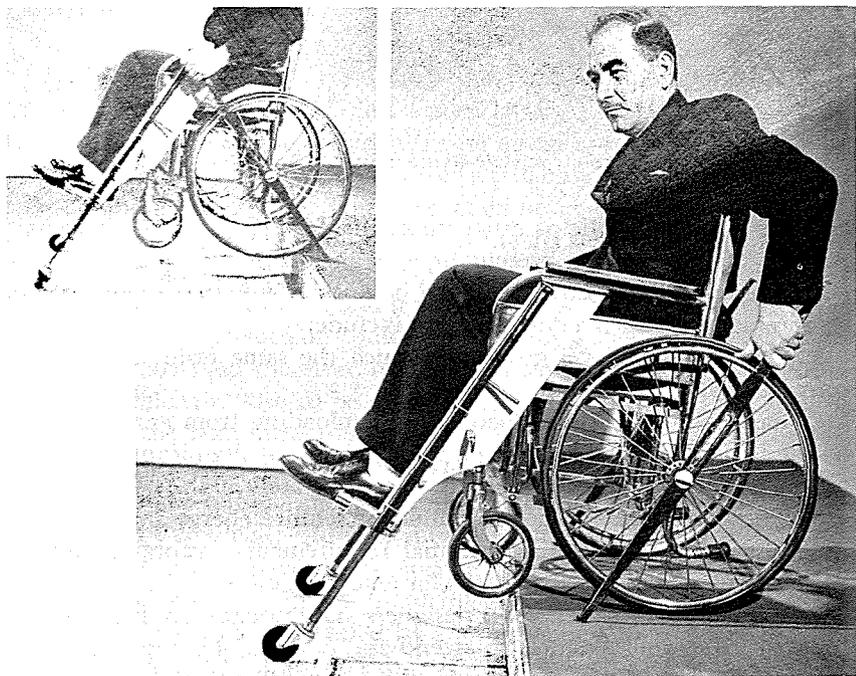


FIGURE 9.—Patient ascending curb using a prototype Proreco Curb Climber. Once in position, patient raises himself to level of curb by pulling the lifting levers.



FIGURE 10.—Hand-driven curb-climbing lift device developed by New York University. It is operated by a rotary arm motion.

curbs up to 8 in. high under control of the wheelchair occupant and without affecting the stability of the chair or the safety of the occupant. The device should not require extraordinary effort on the part of the wheelchair user nor should operation demand extreme motions of the arms or the torso of the occupant. A minimum of maneuvering to orient the chair with respect to the curb is desired.

4. Under certain circumstances, a non-folding design might however be acceptable, as for example, in chairs which are powered for general use and for which foldability has been excluded as a criterion. In this case weight standards would not be critical, approximating that for a powered chair, 160 lb. During the past several years we have had the opportunity to evaluate several devices designed as curb-climbing wheelchairs or as wheelchair attachments for climbing curbs. Of all those seen to date (Fig. 9 and 10), only the one shown in Figure 11, the Aztec

Curb Climbing Attachment for wheelchairs, seems to perform this task adequately.^a

The Aztec Curb Climbing system represents the first known device which enables a wheelchair user to ascend and descend curb-high obstacles with reasonable facility. It very closely fulfills the theoretical requirements laid out by this Service several years ago for such a device. With training, paraplegics and similar patients have no difficulty in negotiating curbs. Once attached, the device adds 15 lb. to the overall weight of a chair. If curb-climbing represents an essential requirement for a patient and he is physically capable of generating the force needed to operate the unit, this device will be useful to him. Its drop-back dolly alone facilitates the ascent of obstacles up to 4 in. high and in addition, permits the patient to readjust his position by tilting backwards. With the curb-climbing attachment almost any known curb can be negotiated.

Nevertheless, its prescription should be carefully considered. No patient should be issued this unit without complete instructions and formal training in its use. Prior to issue, it should be determined that a



FIGURE 11.—Aztec Curb Climbing Attachment for wheelchairs.

^a See Section IV.B.8. of the Veterans Administration Prosthetics Center Research Report in this issue of the Bulletin.

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patient can generate sufficient force to operate the device. Time and the demands for such a unit will tell us the story of its efficiency.

SUMMARY

In summary, during the last 5 years the Bioengineering Research Service of the VA Prosthetics Center has officially tested and evaluated a great number of wheelchairs and wheelchair accessories, perhaps more than any other known agency public or private. Out of this experience there has evolved a new set of tentative VA standards and specifications for wheelchairs which spell out in functional terms the absolute *minimum* requirement that all wheelchairs should possess regardless of the manufacturer, the patient, or the disability.

In addition, our findings have clarified the requirements for powered wheelchairs and for stair-climbing wheelchairs. With respect to multi-purpose chairs, our position is that second order functions should not compromise the minimum standards for wheelchairs. There remains a number of cogent questions in this field which further study may serve to clarify.