VETERANS ADMINISTRATION PROSTHETICS CENTER RESEARCH REPORT

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I. DEVELOPMENT AND EVALUATION

A. Prosthetics

1. *Lower Limb*

a. *PRS Load Cell.* The PRS Load Cell (Fig. 1), developed by James Moore, staff engineer at the Prosthetics Research Study in Seattle, Washington, provides an audible warning to the physical therapist when a patient with an immediate postoperative prosthesis (IPOP) exceeds a predetermined load on the limb. It is also useful in gait training and as a clinic-team aid for determining the adequacy of socket fit and alignment of newly fitted limbs.

The PRS Load Cell is currently being evaluated to determine its effectiveness in improving the training and prosthetic rehabilitation of below-knee amputees. PRS Load Cells were also sent to the Rancho Los Amigos Hospital, Los Angeles, California, and to the VAH, Atlanta, Georgia, and the VAH, St. Louis, Missouri, for continued evaluation.

b. *Prosthetic Skin.* "Prosthetic Skin" for lower-limb amputees uses cosmetic covers of soft polyurethane foam developed under a VA contract at George Washington University (BPR 10-26, page 217) to improve the cosmetic appearance of limbs. This technique is currently being evaluated by the American Academy of Orthotists and Prosthetists (AAOP).

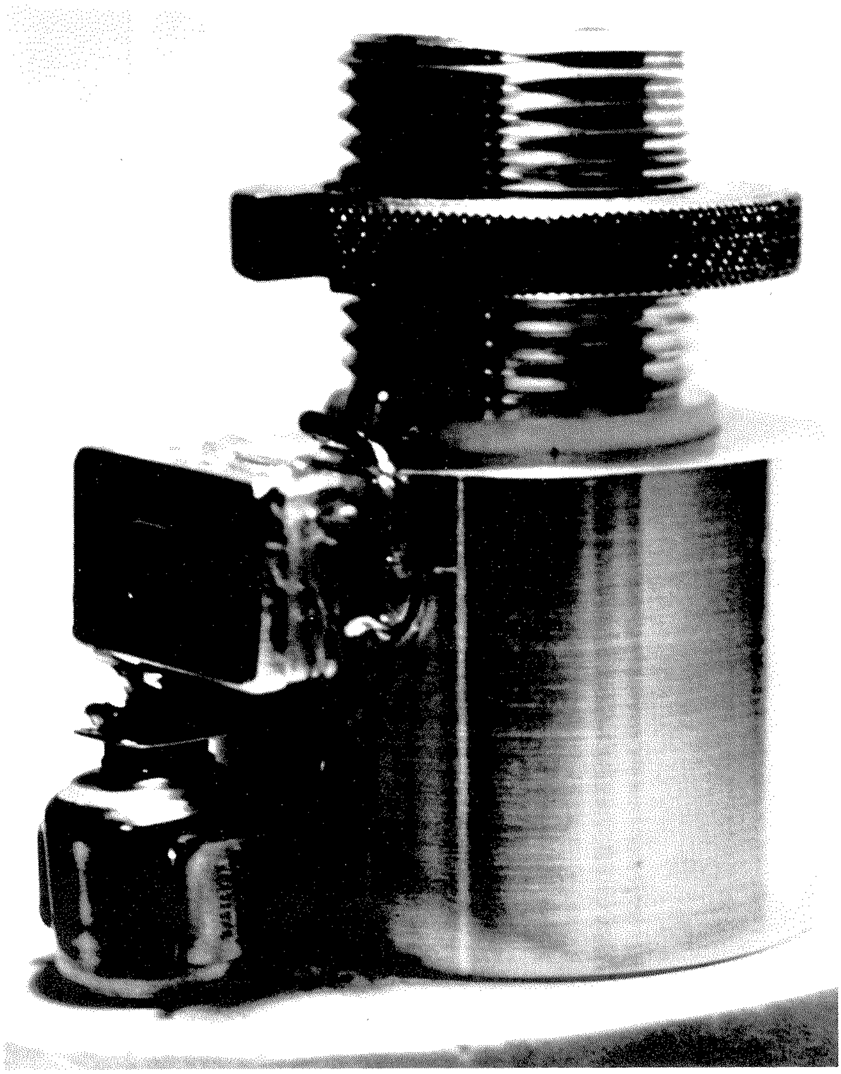


FIGURE 1.—PRS Load Cell.

B. Spinal-Cord-Injury Rehabilitation

1. *Environmental Control Systems*

a. *Remote Control AM-FM Radio.* The Remote Control AM-FM Radio (Fig. 2), commercially available from the Prentke Romich Co. of Shreve, Ohio, is a conventional solid-state AM-FM digital clock radio that has been adapted for the severely handicapped. Its operating functions are: OFF, ON, WAKE TO MUSIC, WAKE TO ALARM, TUNE, VOLUME DN (down), VOLUME UP, AM, and FM. The radio can be operated as part of an environmental control system if an interface cable is used to replace the single-action control switch.

The Remote Control AM-FM Radio has been laboratory tested and it is being clinically evaluated in the home of a disabled veteran.

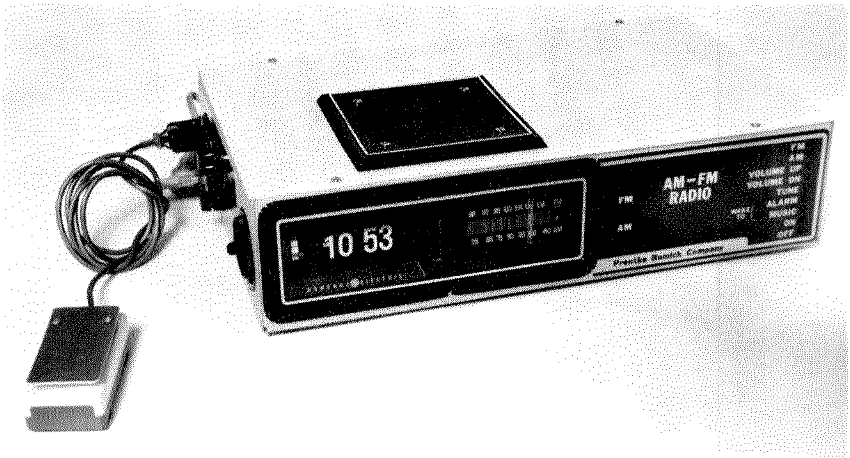


FIGURE 2.—Remote Control AM-FM Radio.

b. *Fidelity Comfort and Communication System (FCCS) Security Sentinel.* The FCCS Security Sentinel (Fig. 3) is a home security system that provides disabled persons with the means to respond to potentially dangerous home situations (BPR 10-26, pp. 222-223). Primarily, it consists of closed-circuit television, wired intercom, electric strike plate, fire detector, and automatic telephone dialer. The Security Sentinel was evaluated in the homes of 12 disabled veterans. Eleven of the 12 participants welcomed the entire package as installed, and felt that the added independent security had become a part of their lives. Suggestions to increase its utility and to encourage its widespread use among house-bound disabled veterans, were sent to the manufacturer.

The FCCS Security Sentinel performed satisfactorily and provided a measure of independent security for the participants. It has therefore been recommended, when it is medically prescribed and within VA policy, to supply veteran patients with this device.

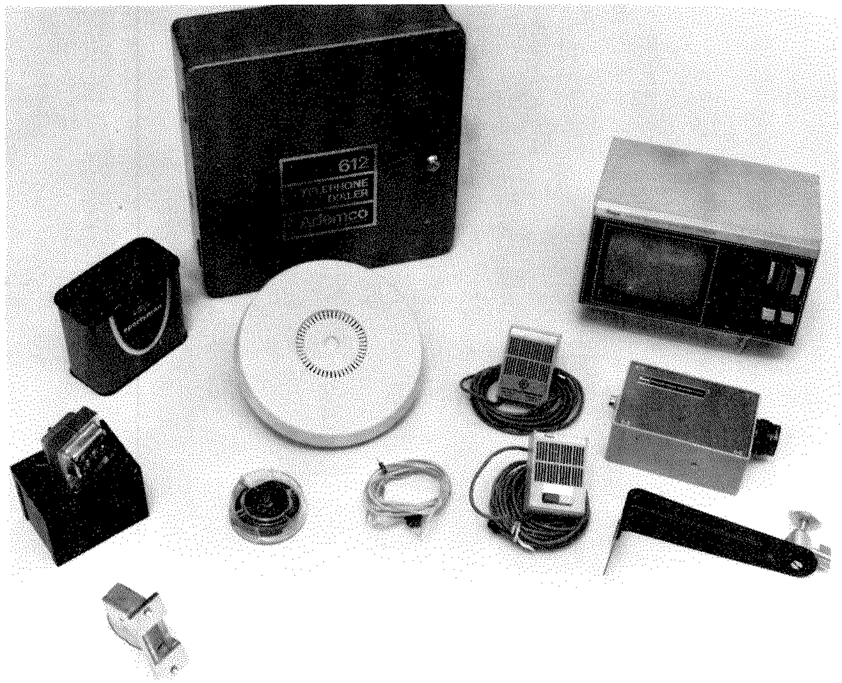


FIGURE 3.—Components of Fidelity Comfort and Communication System (FCCS) Security Sentinel.

2. *Communication Aids*

a. *Saltus Reading System.* This portable, automatic, scroll reading device for patients with upper-limb paralysis (previously identified as the Ealing Reader) is manufactured by the Ealing Corp., South Natick, Mass. It consists of a main frame to house the drive system, battery, control circuit boards, and cassette receptacle, plus a scroll cassette, a full tape on a spool, a takeup spool, and several control switches. It can be clamped on the over-the-bed table included in the package, or any other table. Operating power source is a built-in rechargeable battery or a standard 115-V a.c. source.

Prior to its being modified and renamed, the device was tested and clinically evaluated for safety, effectiveness, and usefulness (BPR 10-27, 102-104). It was concluded that the device provides a degree of reading independence for patients with upper-limb paralysis. Once set up, it operates more reliably than many other page-turning devices. In addition, it can be adapted easily for operation by an environmental control system. However, it requires considerable time for loading and all publications must be purchased in duplicate. In addition, a stable support stand to mount the device above the bed may be required for certain bedridden patients who are constantly positioned supine.

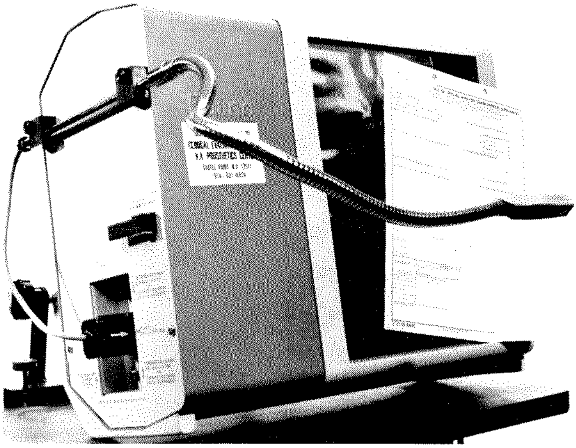


FIGURE 4.—The Saltus Reading System.

The Ealing Reader was modified (and renamed) after the evaluation was concluded (Fig. 4), as follows:

1. A lengthwise slit of 2.5 inches (6.35 cm) was cut in each scroll pocket for easy insertion of reading material, while the spool is moving, and without removing the cassette.
2. The battery can be recharged while the device is operating on standard 115 V a.c. house current.
3. The original hand control switch was replaced by sensitive mouth control switches (tongue, lips, or chin), a basic hand control switch, and forward and reverse double-throw adjustment switches to operate or rewind the spool a page at a time, or operate the spool continuously forward or in rewind while the switch is depressed.

The modification in design should reduce loading time considerably, and the optional mouth switches should be of practical use for high-level quadriplegics. The device is mechanically and electrically safe and allows a degree of independent reading for those with paralyzed upper limbs. Therefore, it has been recommended, when it is medically prescribed and within VA policy, that it be made available for veteran patients. Potential users should be made aware of the device's disadvantages as well as its advantages.

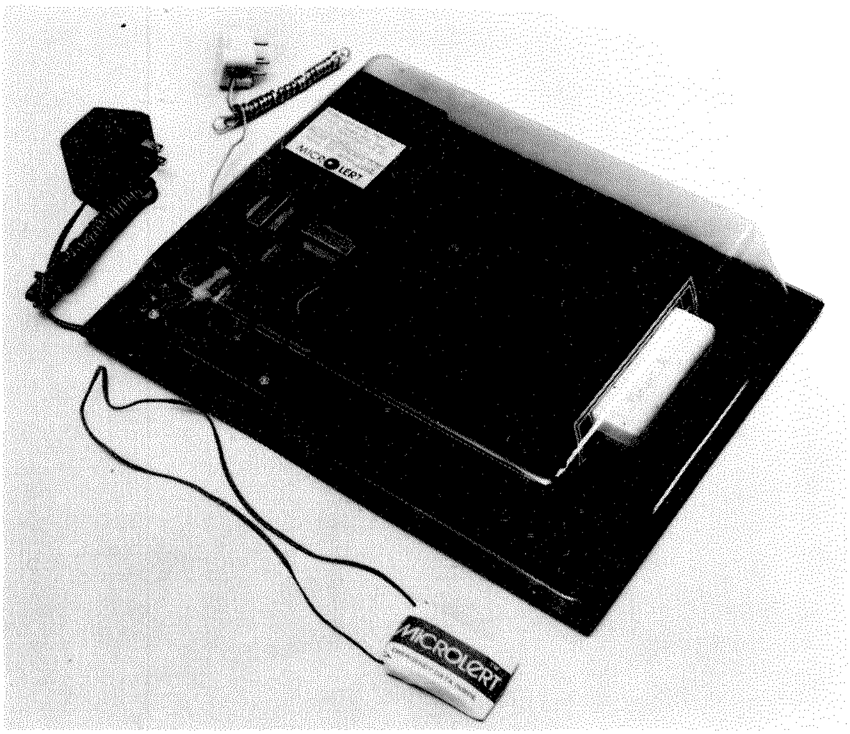


FIGURE 5.—The Microlert System.

b. *Microlert System.* The Microlert System (Fig. 5) is available from the Microlert Corp., North Hollywood, California (BPR 10-27, page 105). This electronic telephone alarm system automatically summons help in emergencies for disabled persons who live in their own homes. The system includes a base station connected to the community telephone line, preprogramed tape containing emergency telephone numbers and a message, and a lightweight transmitter so that the user can actuate the base station.

The Microlert System has been tested for safety and evaluated for effectiveness and utility. The system functioned satisfactorily: the dialing aspect operated successfully and the preprogramed message was transmitted satisfactorily. The transmitter is light in weight and convenient to wear. It has therefore been recommended, when medically prescribed and within established VA policy, that this device be made available to veterans who are responsible and will understand the use of the device.

3. *Mobility Aids*

a. *LEM Power Chair.* The LEM Power Chair is manufactured in Vicenza, Italy. It is imported by the French-Italian Marketing Corp., Great Neck, New York, and distributed by medical equipment distributors throughout the United States (BPR 10-28, 114-115). The LEM is an electric wheelchair for paraplegics, lower-limb amputees, and other disabled persons who cannot ambulate but can use their arms and hands. The user is able to manually swivel the support base of this unique device completely around.

FIGURE 6.–LEM Fully Automatic Wheelchair, front oblique view.

FIGURE 7.—LEM Fully Automatic Wheelchair, rear oblique view.

The current model available, the LEM Fully Automatic Wheelchair (Fig. 6 and 7), is controlled by a joystick and includes two speed options. A later model can be swiveled 360 deg about its center by manipulating the joystick. Both models are undergoing tests and clinical evaluation.

b. *LEVO Stand-Up Wheelchair.* This item is manufactured by Valutec Ltd., Value Engineering, Zurich, Switzerland. The LEVO Stand-Up Wheelchair (Fig. 8 and 9) features both foldable and unfoldable models. It is conventional in appearance, and includes a "hammock" support for the occupant, adjustable footrests, small front casters and large rear drive wheels with pneumatic tires and

FIGURE 8.—LEVO Stand-Up Wheelchair in the sitting position.

chrome-plated hand-rims, padded armrests and push handles. Its stand-up feature includes special linkages, several motor drives, counter-balance tension springs, and batteries mounted in cylinders on the back posts.

Two models were laboratory tested, demonstrated for Spinal-Cord-Injury Service personnel at the VA Hospital, Castle Point, New York, and then clinically evaluated in the hospital's wards by subjects whose disabilities ranged from incomplete quadriplegia to paraplegia, and by a disabled outpatient in his home. Additional evaluations are being conducted in a home or in a job site setting.

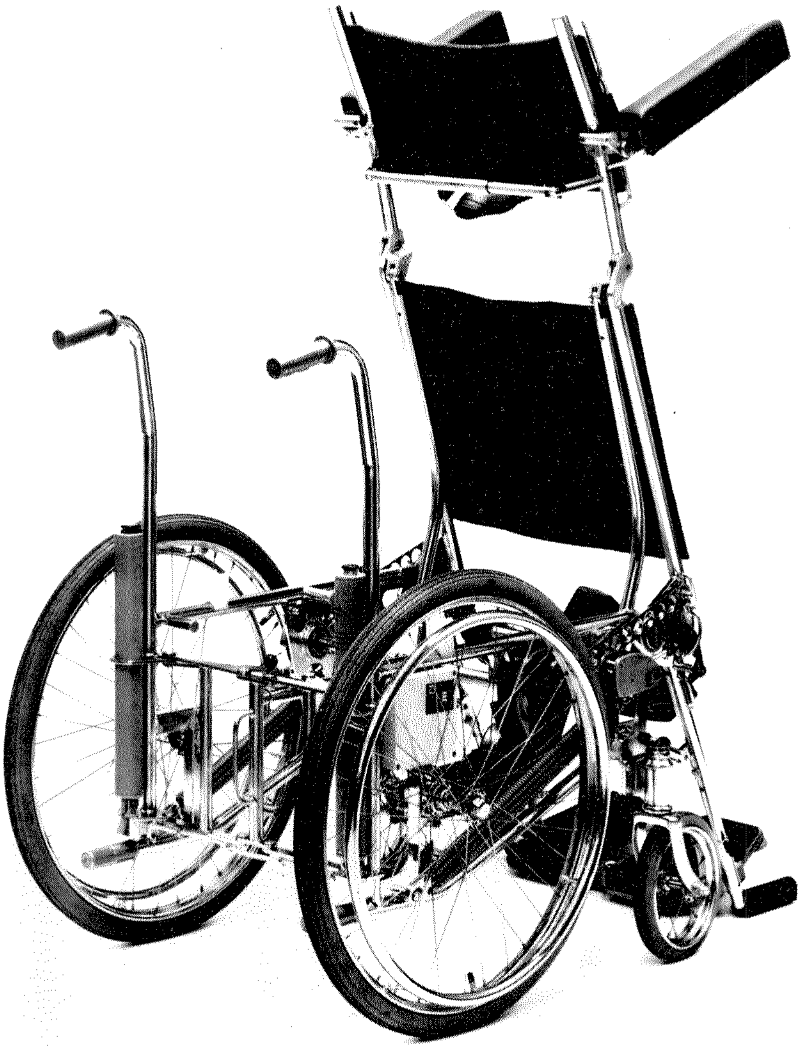


FIGURE 9.—LEVO Stand-Up Wheelchair in the standing position.

c. *Wheelchair Shock Absorber.* This device (Fig. 10), manufactured by National Handicrafters, Inc., Decatur, Georgia, is designed for installation between the rear-axle frame and wheel of most standard wheelchairs to provide a smoother ride over bumps. Two complete units, one for narrow axles, the other for wide axles, were evaluated for safety, effectiveness and utility. They are being evaluated for endurance.

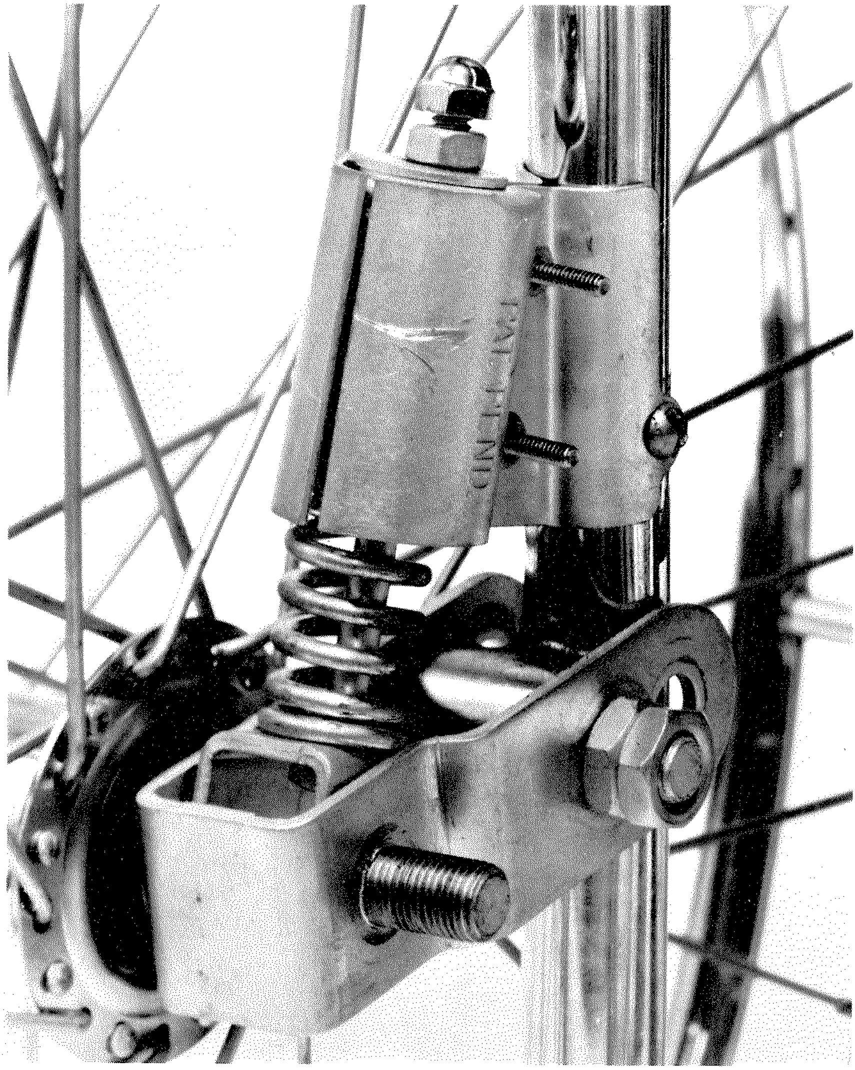


FIGURE 10.—The Wheelchair Shock Absorber installed between the rear-axle frame and wheel of a standard wheelchair.

d. *Independence Powered Recliner Kit.* The Recliner Kit, produced by Falcon Research And Development, Denver, Colorado, is used to motorize the reclining feature of an Everest and Jennings fully reclining wheelchair. Four different models are being clinically evaluated at the VA Hospital, Castle Point, New York: Model No. 8391, Model No. 8381A, Model No. 8381B, and Model No. 8389.

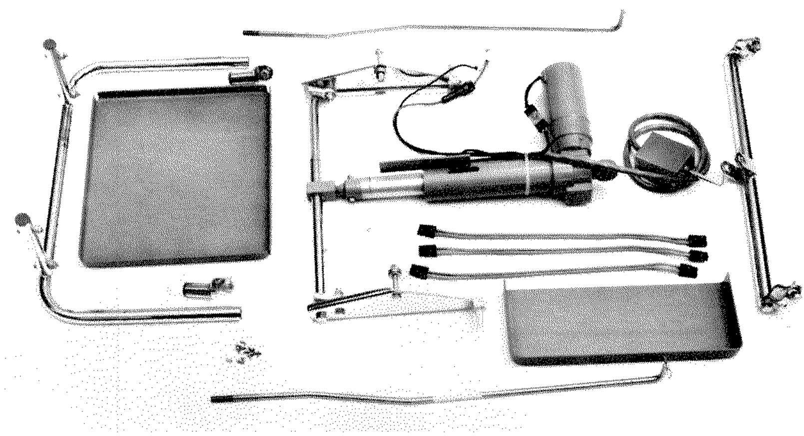


FIGURE 11.—Independence Powered Recliner Kit, Model No. 8391.

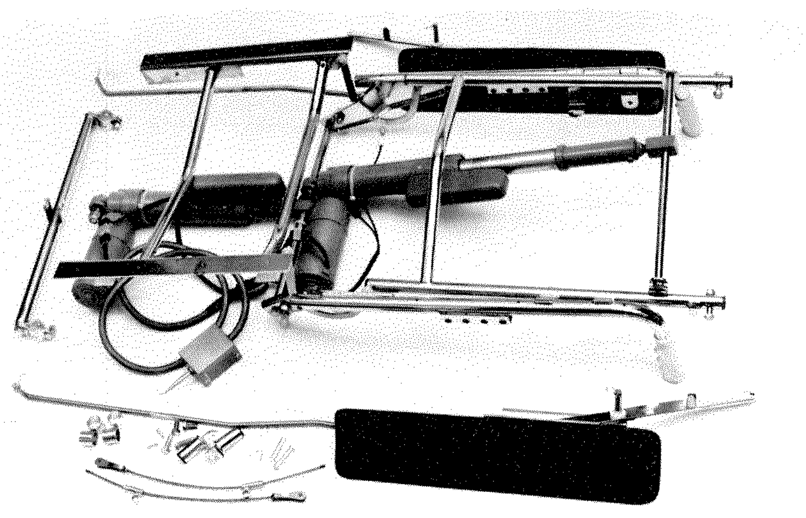


FIGURE 12.—Independence Powered Recliner Kit, Model No. 8381A.

Model No. 8391 (Fig. 11) features a linear actuator to simultaneously raise or lower the back of the wheelchair and the self-elevating leg rests. Model No. 8381A (Fig. 12) employs a high-torque linear actuator to adjust the backrest, leg rests and Rugg mechanism. (The Rugg mechanism maintains a proper relationship between the wheelchair seat and backrest as the attitude of the backrest is adjusted.) The company claims that weight-shifting of the body is not necessary with the 8381A system, but is required with the 8391 system when the recliner is used. In addition, Model No. 8381A, which is manufactured with a low back frame, incorporates a second actuator to raise or lower a self-elevating headrest extension, as well as self-elevating leg rests, arm troughs that recline as the backrest is reclined, and limit switches on the actuator for both extreme positions.

Model No. 8381B (Fig. 13) is similar to Model No. 8381A except that a high-back chair is used. And Model No. 8389 is similar to Model No. 8381B but features contoured calf-rests on the self-elevating leg rests, a sliding tray beneath the chair for a respirator, and an additional battery.

Each model can be controlled by the manufacturer's "zero-pressure" contact switches, "MED breath control" systems, or "DU-IT control" systems. Each model includes a toggle switch for operation by aides, attendants or patients with sufficient hand strength. Except for Model No. 8389, which uses a 12V battery exclusively,

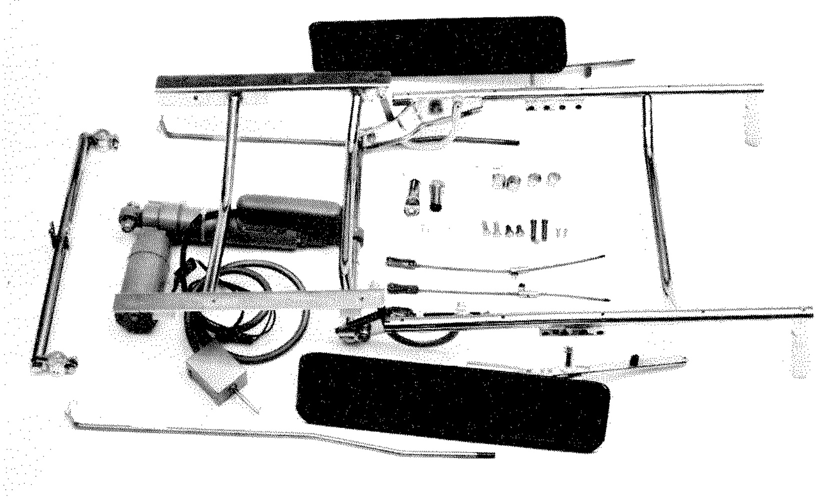


FIGURE 13.—Independence Powered Recliner Kit, Model No. 8381B.

each model can operate on either a 12V or 24V battery.

Laboratory tests and clinical trials of the Independence Powered Recliner Kit are in progress.

4. *Body Supports*

a. *Castor Portable Standing Frame.* The Castor Portable Standing Frame (Fig. 14) is manufactured by Arthur L. Castor, Inc., Compton, Calif. (BPR 10-27, page 111). Bilateral vertical axillary supports enable the quadriplegic or paraplegic to achieve and maintain an erect standing position. While the patient is in the erect position, systematic exercise can improve renal function and calcium retention, and strengthen functional musculature.

The device was clinically evaluated for safety, effectiveness and utility, and tested for conformance with *VA Specifications No. X-1460, for Walker, Invalid* (November 27, 1967).

b. *Stand-Aid.* The Stand-Aid (Fig. 15 and 16), manufactured by Main-Tainer Corp., Sheldon, Iowa, is a portable standing frame for the severely disabled. The basic metal frame unit comes in four sizes: Stand-Aid 900 (Adults), Stand-Aid 901 (Adults Jr.), Stand-Aid 902 (Mini Jr.), and Stand-Aid 903 (Little Tots). It features an adjustable, retractable grab-bar table for trunk stability, with the table being adjustable both horizontally and vertically; adjustable support pads and support belts; a foot platform with spaced foot locations with adjustable heel stabilizers; handgrips for attendant transporting assistance; casters for controlled mobility when moving the occupant; brakes for stability when standing; and contoured knee-support pads to secure the knees in a standing position. Optional equipment include a work table with a removable clear plastic insert, a buttocks pad, removable 2.5-inch (6.35-cm) blocks for additional height, and a pelvic support belt. The Stand-Aid can be folded for travel or storage.

The Stand-Aid is currently undergoing clinical evaluation for safety, effectiveness, and utility.

5. *Lifts and Transfer Aids*

a. *Duphar Lifelift.* The Duphar Lifelift (Fig. 17), functions as both a lift and a stretcher at the scene of an accident. It is available through Medical Methods, Bay St. Louis, Mississippi. By rotating a handle that moves a series of rollers located beneath the resting surface of the device, the operator can move a patient onto the stretcher with little or no movement of the patient's spine. Safety straps secure the patient to the stretcher.

The Lifelift has undergone limited clinical evaluation.

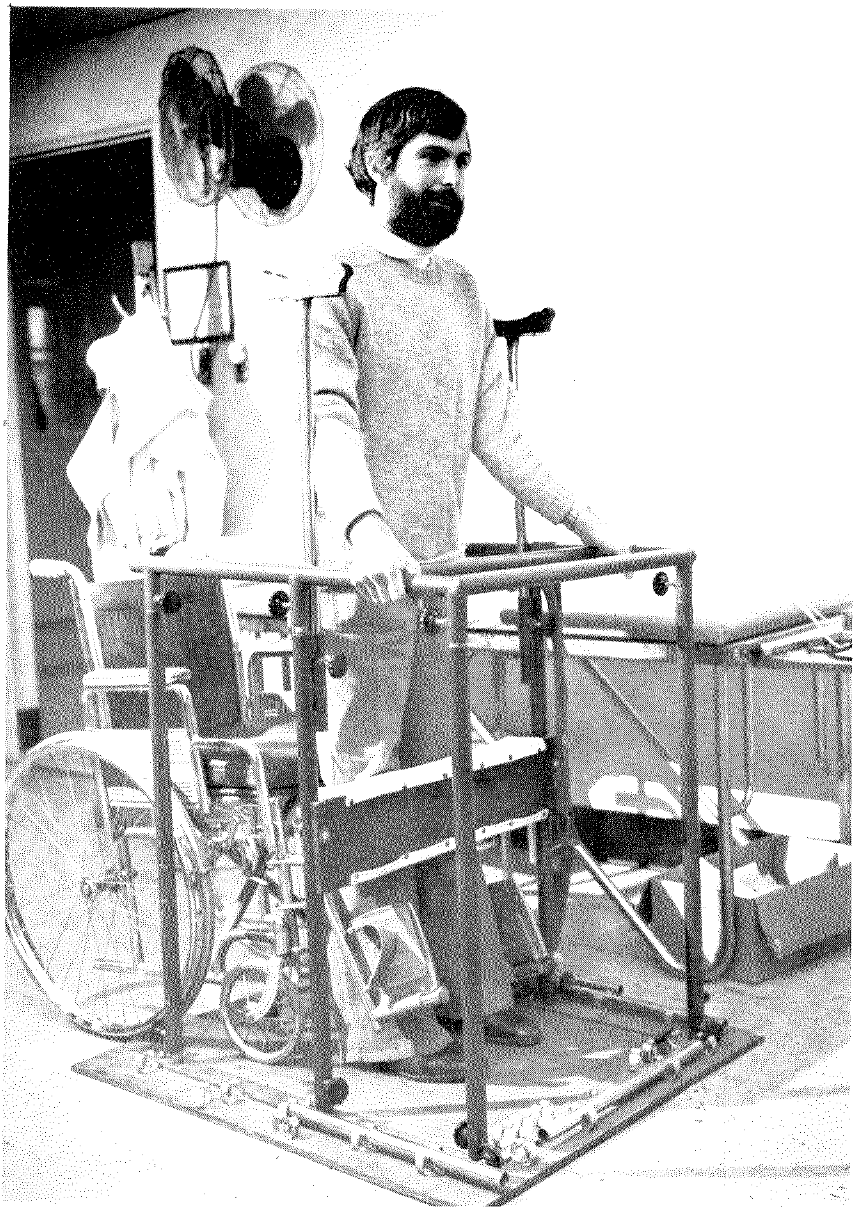


FIGURE 14.—Castor Portable Standing Frame.

FIGURE 15.—Stand-Aid portable standing frame.

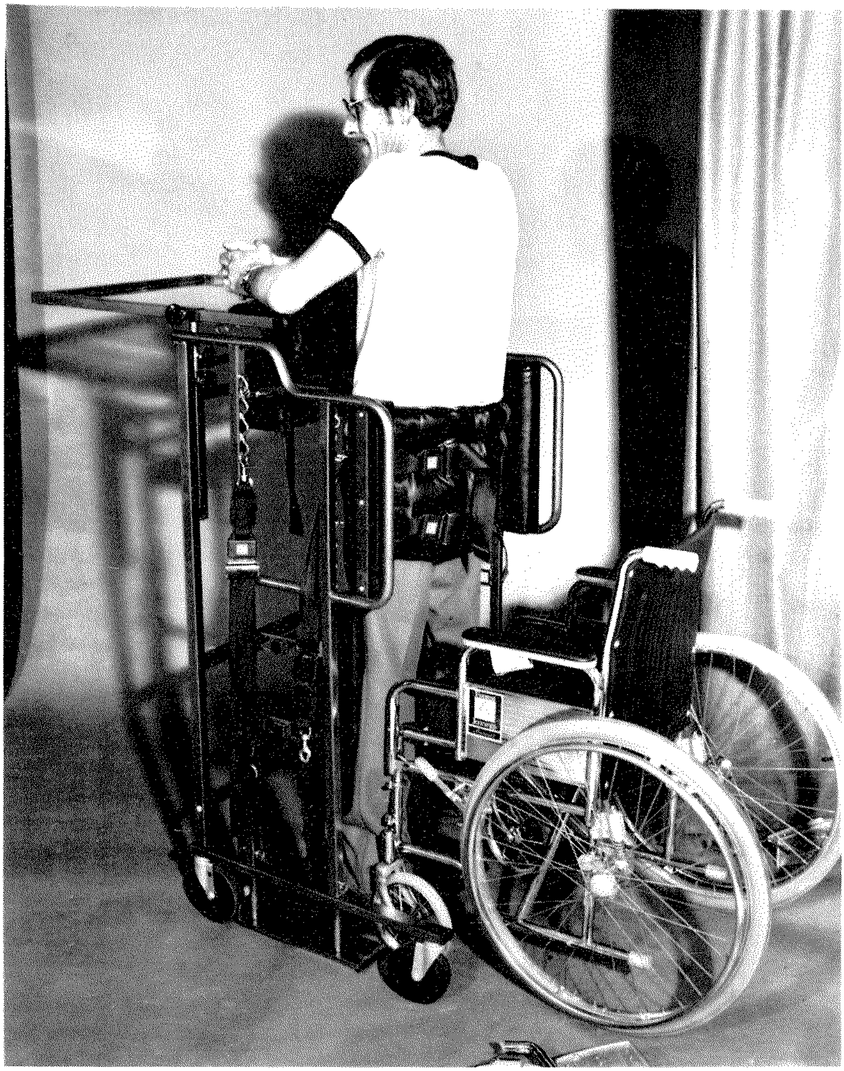


FIGURE 16.—Stand-Aid with occupant.

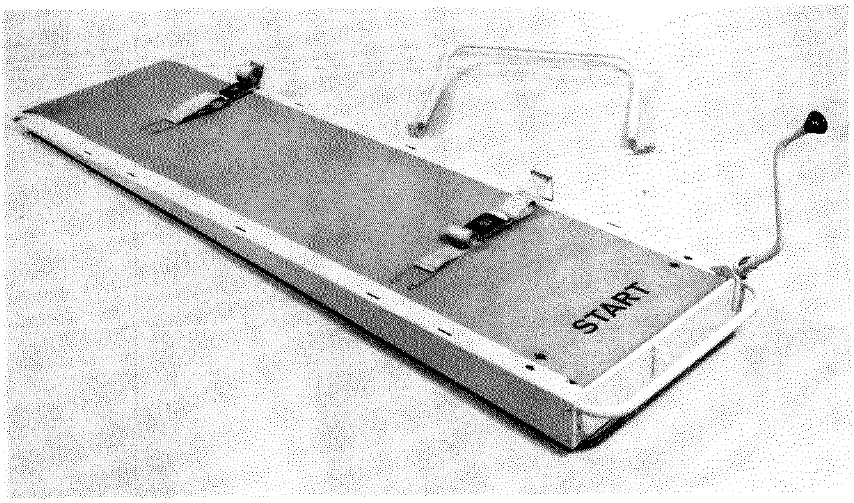


FIGURE 17.—Duphar Lifelift, patient lift and stretcher.

b. *Ambulift.* The Ambulift (Fig. 18), manufactured and marketed by Mecanaids, Inc., Gloucester, England, provides a rigid seat, sling, and stretcher for lifting nonambulatory patients. It also provides facilities for bathing, transporting, and toiletting these patients. The rigid seat can be attached to a four-wheeled frame and used as a shower chair and/or commode chair, with the commode attachment included. The armrests swing away to facilitate easy transfer, allowing a pivot or lateral transfer to or from the rigid seat. A mechanical winding mechanism raises the occupant, who may weigh up to 350 lbs.

The Ambulift was evaluated and found to be clinically acceptable. It has therefore been recommended, when it is medically prescribed and within VA policy, that the device be made available to veteran patients. (It is further recommended that, in the case of the spinal-cord-injury service of a hospital, the one-piece sling be used.)

c. *Autolift.* The Autolift (Fig. 19) is manufactured by Mecanaids, Inc. of Gloucester, England, and distributed by Gerapac Ltd. of East Aurora, New York. The device is operated manually to safely transfer a nonambulatory patient from his wheelchair to the bathtub, and back again, in his home. The device can be bolted to the bathroom floor (either concrete or wood) and can be operated either by the patient or by an attendant (BPR 10-26, 253-255).

The Autolift was evaluated for safety, utility, and effectiveness at the VA Hospital, Castle Point, New York. The patients who

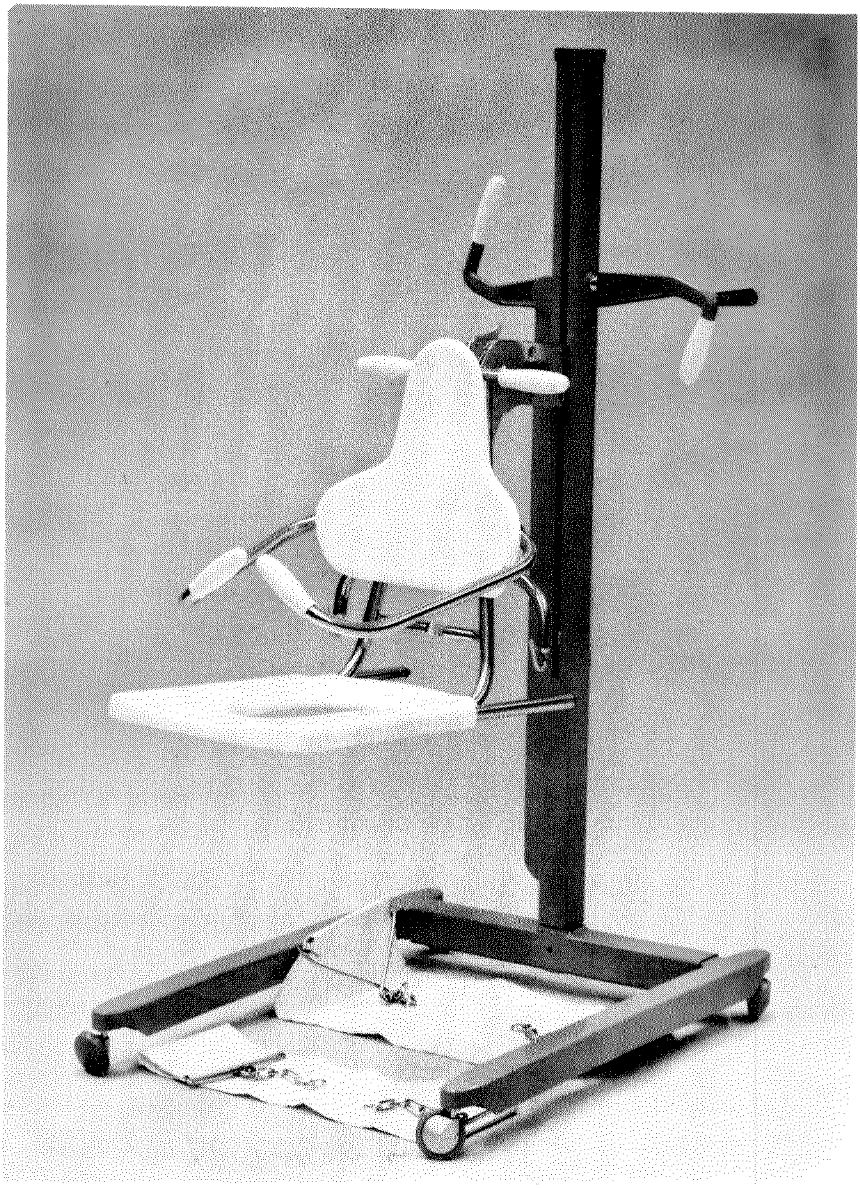


FIGURE 18.—Ambulift, for lifting nonambulatory patients.

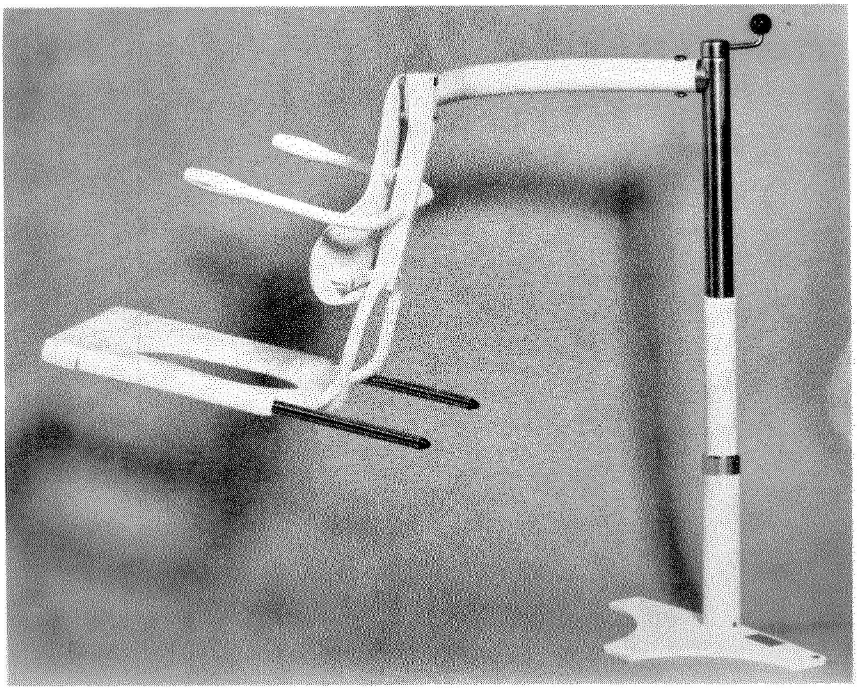


FIGURE 19.—Autolift, for transferring nonambulatory patients.

operated the lift found it to be physically exerting. In addition, the requirement to bolt the base of the device permanently to the floor was unacceptable since it was felt that this would impede maneuverability in the bathroom, and would require floor repairs when the lift was relocated.

d. *Mecalift.* The Mecalift (Fig. 20) is manufactured by Mecanaids, Inc. of Gloucester, England, and distributed by Gerapac Ltd., of East Aurora, New York (BPR 10-26, pages 256 and 257). This portable, compact, easily stored patient lift, designed for the nonambulatory patient in the home but also useful in the hospital, derives its lifting force through a mechanically driven worm screw. Patient transfer is accomplished with either a one-piece or two-piece sling.

The Mecalift has been evaluated for safety, effectiveness, and utility.

The Mecalift has been recommended, when it is medically prescribed and within VA policy, for use in VA medical centers and by veteran beneficiaries; this recommendation carries the following conditions: that (i) the device be equipped with caster locks which

FIGURE 20.—Mecalift, for transferring nonambulatory patients.

FIGURE 21.—Mecalift, conventional front-loading method.

can be ordered from the distributor, and (ii) that consideration be given as to whether the front- or side-loading procedure shall be used, and whether the one-piece or two-piece sling will best meet individual needs. If the conventional front-loading method is prescribed (Fig. 21), then the overall outside dimension of the patient's wheelchair must be indicated, to assure that the base width of the lift (the inside dimension) accommodates the chair (Fig. 22). The one-piece sling is recommended for general use or for use with flaccid patients, and the two-piece sling is recommended for spastic patients.

FIGURE 22.—Mecalift base width accommodates the wheelchair.

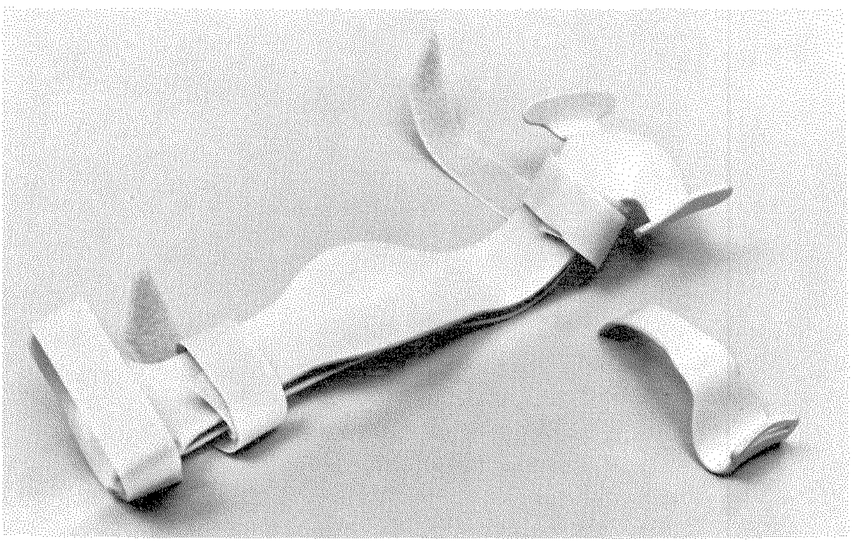


FIGURE 23.—L'Nard Sani-Comfo Arm Splint.

6. *Orthotics*

L'Nard Sani-Comfo Arm Splint. The Sani-Comfo Arm Splint (Fig. 23) is manufactured by L'Nard Associates, Inc., Providence, Rhode Island. It is designed to function as an alternative to the conventional I.V. board, and as a passive positioning hand splint for the wrist and fingers (BPR 10-27, page 115). This preshaped plastic device is available in small, medium and large sizes and employs adjustable Velcro attachment straps and a removable thumb post, so that it can be used for either hand.

The device was clinically evaluated at the VAH, Castle Point, N.Y., and Montrose, New York. It is recommended for use as an I.V. splint at the discretion of the hospital staff, but not as a passive orthosis.

7. *Driving Systems*

a. *Handicar TVE.* The Handicar TVE (Teillrot Voiture Electrique) (Fig. 24) is distributed by Gitane Corp., Hawthorne, Calif.

FIGURE 24.—Handicar TVE.

This battery-powered, glass-fiber-reinforced plastic bodied vehicle is designed for easy entry and exit by people in wheelchairs.

The Handicar TVE is currently undergoing clinical evaluation.

FIGURE 25.—Pak-A-Rak wheelchair carrier, shown mounted on rear bumper of automobile.

b. *Pak-A-Rak.* This rear-bumper-mounted wheelchair carrier (Fig. 25), according to its manufacturer, the Summit Corp. of Valparaiso, Florida, fits all American-made, and most foreign-made, automobiles. Constructed of acrylic-enamel-and-primer-coated tubular steel, the Pak-A-Rak is installed with open-end wrenches, screwdriver, hacksaw, and "superglue". The right bumper guard must be removed on automobiles with vertical bumper guards. The device can be folded up when not in use.

It folds down to receive wheelchairs with 22-inch (55.88-cm) or 24-inch (60.96-cm) wheels (Fig. 26). The chair is secured by wheel tracks and an adjustable spring lock. The car trunk remains accessible whether the Pak-A-Rak is carrying a wheelchair or folded up against the bumper when not in use. A clear vinyl "Pak-A-Jak" is

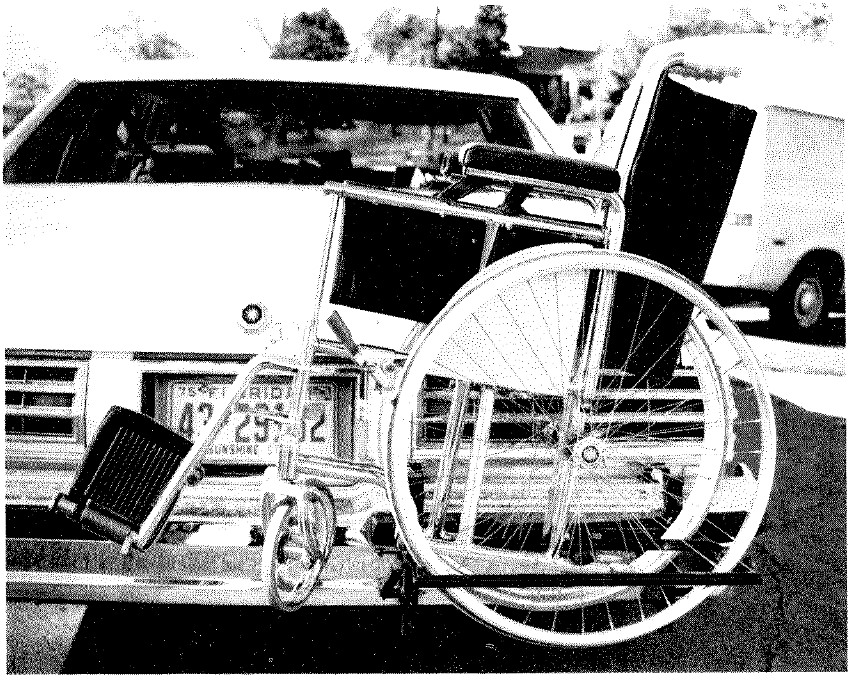


FIGURE 26.—Pak-A-Rak wheelchair carrier, shown carrying wheelchair.

available from the manufacturer to protect the wheelchair in inclement weather, and a "Tote-A-Coat" is also available for wheelchair protection in severe winter weather.

One Pak-A-Rak was evaluated for safety, effectiveness, and utility. Additional units are scheduled to undergo clinical evaluation.

8. *Activities of Daily Living*

a. *Porta-Care Sink.* The Porta-Care Sink (Fig. 27), manufactured by The Sinkette Corp., Gardenbill, Pennsylvania, is used to wash and shampoo the hair of bedridden or wheelchair-confined patients. This portable lightweight plastic device, molded in the form of a small sink, is adjustable in height, provides a plastic yoke that fits snugly about the neck to prevent the water from spilling on the patient, and has a reservoir with a disposable plastic bag for the soiled water, a shoulder-board for wheelchair patients, a spray-head hose, a water chamber, and a 12-V battery and power switch.

The Porta-Care Sink is being evaluated at the VAH, Castle Point, New York, and in the home of a disabled veteran.

FIGURE 27.—The Porta-Care Sink is used to wash and shampoo the hair of bedridden or wheelchair-confined patients.

b. *Portable Inflatable Bathtub.* The Portable Inflatable Bathtub (Fig. 28), distributed by Bathing Aids To The Handicapped, Greeley, Colorado, is designed for handicapped persons who cannot safely use standard bathtubs. The device is constructed of polyurethane-coated nylon covered in red fabric. Deflated, it weighs 6 pounds. Inflated, its outside dimensions are 60 inches (152.4 cm) long by 21 inches (53.34 cm) wide by 8.5 inches (21.59 cm) high. It employs a 50-ft. (1.59m) hose, a water pump, and a hand-held blower that uses standard 110-V a.c. power.

The patient is rolled on or off the tub's rims when the tub is deflated. The hand-held blower is used to inflate or deflate the tub, and the pump moves pre-heated water into the tub, or drains the tub, through the hose.

FIGURE 28.—Portable Inflatable Bathtub replaces the standard bathtub.

The Portable Inflatable Bathtub was evaluated in the Spinal Cord Injury Service at the VAH, Castle Point, New York.

c. *APOR Safety Shower and Tub Guard.* These devices (Fig. 29), produced by APOR Industries, Inc., Aurora, Ohio, replace standard shower heads and tub-filler spouts. Built-in temperature controls control the flow of water through the spout: when water temperature exceeds a predetermined limit of 110 deg F (43 deg C), water flow is automatically reduced ($<$ ½ gal/min or 1.89 l/min). Water temperature must then be reset. (For persons with reduced or non-existent sensation, that requirement may be critical.)

The APOR Safety Shower and Tub Guard are undergoing clinical evaluation at the VAH, Castle Point, New York.

d. *Handi-Cup.* This molded plastic beverage carrier for wheelchairs (Fig. 30) is manufactured by Clarke Carrier Corp., Fort Lauderdale, Florida. The device can be attached to either the left or right armrest of any tubular, desk-type wheelchair armrest, by simply "snapping" it in place.

The Handi-Cup was clinically evaluated by wheelchair patients at the VAH, Castle Point, New York.

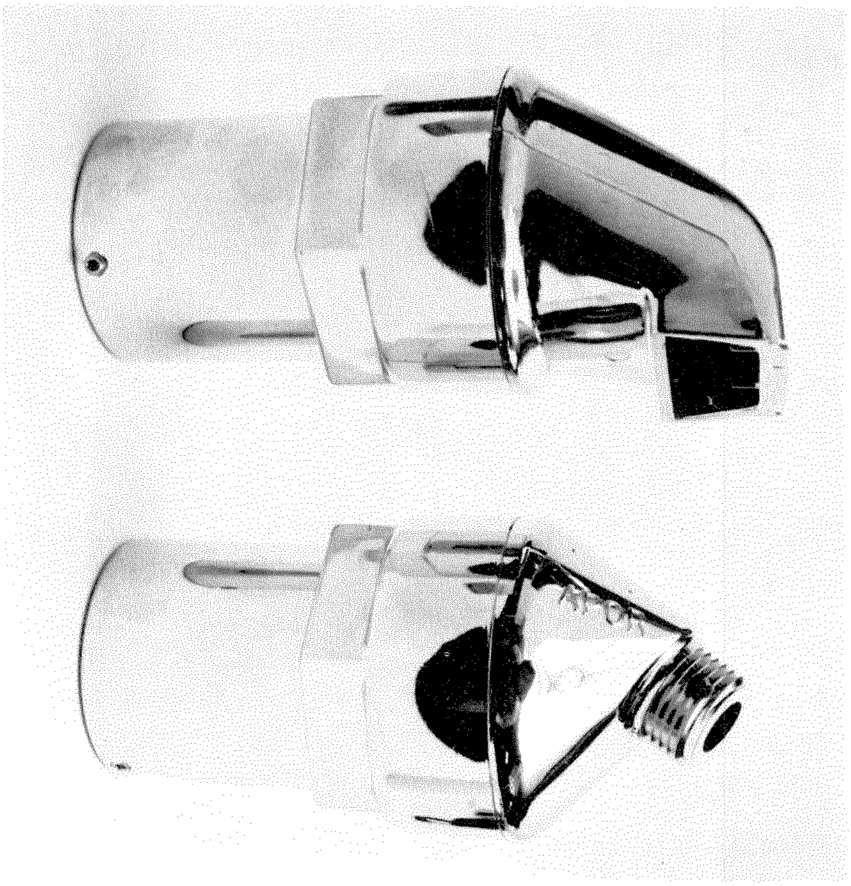


FIGURE 29.—APOR Safety Shower and Tub Guard.

II. COMPLIANCE TESTING

A. Standards Development

The *VA Standard Design and Test Criteria for Safety and Quality of Automatic Wheelchair Lift Systems for Passenger Motor Vehicles* appeared in the Federal Register, Vol. 43, No. 96, Wednesday, May 17, 1978, pages 21390-21402. The test program described in the Standard has been initiated. Commercially available wheelchair lifts have been procured for compliance testing. These standards provide detailed information on the Scope, Classification, Limitations, Design Requirements, Desirable Design Goals and Test Procedures of automatic wheelchair lift systems for passenger motor vehicles.

FIGURE 30.—The Handi-Cup, shown attached to wheelchair armrest.

Contents

VA Standard Design and Test Criteria for Safety and Quality of Automatic Wheelchair Lift Systems for Passenger Motor Vehicles

1.0. *Scope, Classification, Limitations, and Definitions.*

1.1. *Scope.* This standard relates to a special class of automotive assistive equipment used by wheelchair-bound persons to enter and exit commercially available motor vehicles. Maximum safety to handicapped drivers, passengers, and the general public is of primary concern.

1.2. *Classification.* Automotive wheelchair lifts include a variety of electric powered mechanical and hydraulic systems used to raise or lower a person in a wheelchair from one level to another. They are classified by van door application (side or rear) and by power transfer method (e.g., hydraulic, electromechanical, or others).

1.3. *Limitations.* These standards are limited to powered lift systems manufactured for use by the handicapped and either retrofitted or furnished as original equipment in vehicles (e.g., vans).

1.4. *Definitions.*

1.4.1. *Controls.* A term denoting manually operated devices which in some way regulate the lift operation. Examples: switches, handles, thumbscrews.

1.4.2. *Electrical Components.* A term encompassing all electrical hardware used on a wheelchair lift. These components include, but are not limited to, batteries, fuses, circuit breakers, motors, switches, wiring, and terminals.

1.4.3. *Fasteners.* Devices used to secure by physical means other devices or parts in place. These include, but are not limited to, bolts, nuts, screws, washers, pins, rivets, and clamps.

1.4.4. *Floor.* The floor of the vehicle in which the wheelchair lift is installed.

1.4.5. *Ground.* The surface (nominally horizontal) on which the vehicle is parked.

1.4.6. *Lift Platform.* A term denoting that portion of a wheelchair lift device on which the wheelchair rests while being raised or lowered.

1.4.7. *May.* The term "may" where used shall be construed as permissive.

1.4.8. *Nip or Pinch Point.* A term for a hazardous location which exists when two closely spaced parallel shafts rotate in opposite directions, or at the point of contact between belt and pulley, chain and sprocket, or similar moving parts of machinery.

1.4.9. *Roll Stop.* A term for a device on a wheelchair lift to prevent a wheelchair from inadvertently rolling off the lift platform.

1.4.10. *Shall.* The term "shall" where used shall be construed as mandatory.

1.4.11. *Shear Point.* A term for a hazardous location where a moving (e.g., reciprocating or sliding) part approaches or crosses a fixed part.

1.4.12. *Should.* The term "should" where used shall be construed as advisory.

1.4.13. *Weatherproof.* The term applied to equipment so constructed or protected that exposure to the weather will not interfere with successful operation.

1.4.14. *Wheelchair Ground Plane.* An imaginary plane, nominally horizontal, upon which the wheelchair wheels rest.

1.4.15. *Wire Rope Components.* A term encompassing, but not limited to, wire rope, sheaves (pulleys), clips, thimbles, end fittings, and winch hardware.

2.0. *Applicable Documents.* Standards, Specifications, or Recommended Practices promulgated by the following agencies and specified herein are applicable to the design, manufacture, and/or use of wheelchair lifts.

2.1. American National Standards Institute, 1430 Broadway, New York, NY 10018

2.1.1. ANSI A17.1-1971, Elevators, Dumbwaiters, Escalators, and Moving Walks.

2.1.2. ANSI A117.1-1961 (R1971), Specifications of Making Buildings and Facilities Accessible to, and Usable by, the Physically Handicapped.

2.1.3. ANSI A120.1-1970, Safety Requirements for Powered Platforms for Exterior Building Maintenance.

2.1.4. ANSI B1.5-1973, Acme Screw Threads.

2.1.5. ANSI B1.8-1973, Stub Acme Threads.

2.1.6. ANSI B15.2-1972, Safety Standard for Mechanical Power Transmission Apparatus.

2.1.7. ANSI B29.1-1963 (R1972), Transmission Roller Chains and Sprocket Teeth.

2.1.8. ANSI B30.2-1967, Overhead and Gantry Cranes.

2.1.9. ANSI B30.9-1971, Safety Standards for Cranes, Derricks, Hoists, Hooks, Jacks, and Slings.

2.1.10. ANSI B153.1-1973, Safety Requirements for the Construction, Care, and Use of Automotive Lifts.

2.2. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

2.2.1. ASTM D 1005-51 (R1972), Measurement of Dry Film Thickness of Organic Coatings.

2.2.2. ASTM D 2200-67 (1972), Pictorial Surface Preparation Standards for Painting Steel Surfaces.

2.3. American Welding Society, 2501 N.W. 7th Street, Miami, FL 33125.

2.3.1. AWS D1.1-72, Structural Welding Code.

2.3.2. AWS D10.7-60, Recommended Practices for Gas Shielded Arc Welding of Aluminum and Aluminum Alloy Pipe.

2.4. National Highway Traffic Safety Administration, U.S. Department of Transportation, 400 7th Street, S.W., Washington, DC 20590.

2.4.1. Federal Motor Vehicle Safety Standard No. 302, Flammability of Interior Materials.

2.5. Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096.

2.5.1. SAE Handbook, 1976, Part 1.

2.5.2. SAE Handbook, 1976, Part 2.

3.0. *Standards and Tests.* Powered automotive wheelchair lifts shall be qualified by tests conducted by or for the VA. The standards and tests set forth in the following subsections shall be applied, and failure of a lift to meet specification shall disqualify the lift from purchase by the VA for veteran beneficiaries.

3.1. *Design Requirements.*

3.1.1. Safety to persons using wheelchair lifts shall be a prime design consideration. Any single point failure of the lift shall not compromise user safety.

Rationale. Paraplegic and quadriplegic persons do not have all normal capabilities of strength, reach, and grip necessary to operate mechanical equipment. Further, they may have visual, equilibrium, or tactile limitations which affect their ability to use lifts. Therefore, every effort should be made to ensure a lift system with minimum potential for injury.

3.1.2. Wheelchair lifts shall be capable of lifting at least 400 pounds (1780 N).*

Rationale. The Human Engineering Guide to Equipment Design gives the following data on weight, in pounds, of U.S. and Canadian civilian men and women (nude)[1]:

	50th percentile	95th percentile
Men	166	217
Women	137	199

It is recognized that some spinal cord injured and other physically handicapped persons lose some of the body weight attained prior to injury. Thus, the 95th percentile weight for men (217 lb., corrected for clothing to 225 lb.) would be a con-

*Discussion on Metrication is in Appendix 1.

servative estimate of the maximum body weight to be lifted. Standard electric wheelchairs (e.g., Everest and Jennings Model 34) weigh approximately 150 lb.[2] The sum of these two weights is 375 lb.

The smallest specified weight capacity of any lift tested was 400 lb. Therefore a figure of 400 lb. is well within the current planned capacity of lift manufacturers and is conservative when compared to expected loads.

3.1.3 The design factor based on ultimate strength shall be six (6).

Rationale. The factors of safety in equipment design commonly vary from 4 to 10 or higher. ANSI A17.1-1971, Elevators, Dumbwaiters, Escalators, and Moving Walks, specified varoius factors of safety for different components of a system. For example, factors from 7 to 12 are given for suspension ropes, depending on elevator speed. At 20 fpm, corresponding to the maximum allowable wheelchair lift speed, the value from ANSI A17.1 is 7.4. The factors for elevator driving machines and sheaves "shall be not less than:

a. Eight (8) for steel, bronze, or for other metals having an elongation of at least fourteen (14) percent in a length of two (2) inches.

b. Ten (10) for cast iron, or for other metals having an elongation of less than fourteen (14) percent in a length of two (2) inches."[3]

Also, factors of safety of 5 and 6 are given for hoisting equipment covered by other ANSI standards.[4, 5] Consequently, the structural design factor of 6 is chosen as a conservative value for equipment designed to lift persons for short distances at low speeds.

It should be noted that lifts are not required to move 2400 lb. (i.e., 400 × 6), but must be capable of suspending that weight.

3.1.4. Wheelchair lifts should be powered by a dual battery system with batteries characteristic of that supplied by the manufacturer of the vehicle on which the lift is used. The batteries shall be charged by the vehicle battery charging system and regulated by a commercially available dual battery charging device. If a bettery is placed inside the passenger compartment, the battery shall be located inside a restrained, protective, corrosion resistant enclosure.

Rationale. One of the dual batteries can be the vehicle battery. Battery compatibility allows charging by the existing vehicle system. A separate lift battery helps ensure that the wheelchair occupant will not be trapped inside the vehicle.

3.1.5. Battery powered wheelchair lifts shall operate at an electrical current of less than 100 amperes while lifting the rated load of 400 lb. at an ambient temperature between 50° F (10° C) and 90° F (32° C).

Rationale. The electrical current measured in most lifts was fairly low. The maximum measured current of 120 A and approximate lift time of 12 sec are well within the cold start test capacity of heavy duty batteries: approximately 400 A at 0°F for 30 sec.[6]

3.1.6. Installation of a wheelchair lift shall not require motor vehicle alterations that significantly diminish the structural integrity of the vehicle or in any way impair or reduce safety features provided by the motor vehicle manufacturer. The degree of alteration will be determined by analysis of the method of installation and of resulting structural changes.

Rationale. Self-evident.

3.1.7. The total weight of the lift should not exceed 275 pounds (1220 N).

Rationale. A minimum total weight of the lift, commensurate with adequate strength, should be a significant design goal. The weights of eight of the nine lifts evaluated were 146, 180, 188, 232, 255, 266, and 310 lb, respectively.[7] The ninth lift utilized the van doors as a platform and, therefore, was not of a similar design as the others. The average weight of these eight lifts was 225 lb with a standard deviation of 53 lb. The average plus one standard deviation is 225 + 53 = 275 lb.

3.1.8. Hand holds, if used, should be of round cross-section and approximately 1½ inches (3.81 cm) outside diameter.

Rationale. The Human Engineering Guide to Equipment Design gives maximum grip diameter and showed that a 2½ in. diameter was optimal for male pilots used in the experiment.[8] The Occupational Safety and Health Standards gives the diameter of similar railings as 1½ in. nominal diameter.[9] In consideration of the smaller female hand,[10] the 1½ in. diameter was chosen. Several lifts have a platform framework of rectangular and square cross-section (1½ in. side) and another lift has a similar 2 in diameter tube, all of which serve as lateral hand hold bars. There were favorable comments from disabled users about being able to hold on, but the square tube was less comfortable to grip.

3.1.9. The lift shall have no dirty or greasy surfaces which will contact the wheelchair occupant during normal lift operation as specified by the manufacturer.

Rationale. This item relates to the aesthetic characteristics of a lift and convenience to the user. Some of the lifts evaluated had dirty or greasy parts within reach envelope of the user. The possible soiling of clothes, hands, arms, and legs is apparent.

3.1.10. Lift framework dimensional requirements to ensure accommodation of wheelchair occupant in the following four subparagraphs and as shown in Figures 1 and 2.

3.1.10.1. The width provided for the wheelchair ground plane, measured laterally, shall be at least 29 inches (73.7 cm).

Rationale. The nominal wheelchair width of 25 in. is given in ANSI A117.1-1961 (R1971), Specifications for Making Building and Facilities Accessible to, and Usable by, the Physically Handicapped.[3] A platform width of 29 in. will allow 2 in. on each side as maneuvering space. Further, the evaluated lifts had a range of platform widths from 28 3/8 in. to 48 in. with the mean being 31 3/8 in.

3.1.10.2. The width between any vertical members twelve (12) inches (30.48 cm) or more above the wheelchair ground plane, measured laterally, shall be at least 29 inches (73.7 cm).

Rationale. The basic consideration here is hand clearance for the occupant in a manual wheelchair during manipulation of the chair onto and off of the platform. Observation shows that the hand, while gripping the hand rim, extends outside the rim some 1½ in. to 2 in. Therefore any vertical framework through which the wheelchair must pass should be as wide as the wheelchair hand rims plus at least 4 in. Using the ANSI A117.1-1961 (R1971) dimension this value becomes 25 + 4 = 29 in.

The range of frame width dimensions of the evaluated lifts was 26 in. to 40 in. with the mean at 32 in.

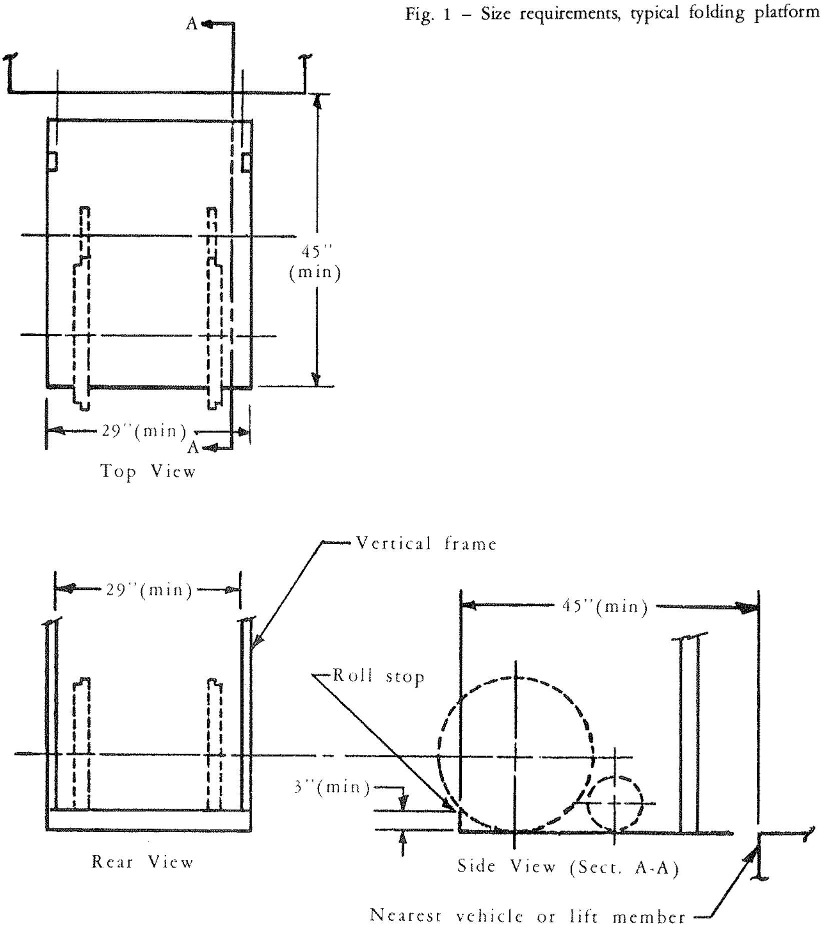
3.1.10.3. For those lifts in which the occupant faces the van side (or rear in the case of rear door installation), the distance, measured horizontally along the wheelchair ground plane from the occupant's rear to front between the inside edge of the roll stop in its active position and the nearest point on the vehicle or a lift member at all "occupant carrying" positions shall be at least 45 inches (1.143 m).

Rationale. This section applies only to the folding platform lifts. A significant problem in the design of such lifts is adequate foot clearance. For example, one lift evaluated had a platform length dimension of 43 in. A tall person (6 ft 1 in.) with an electric wheelchair (20 in. wheels) can, when facing the van, move onto the platform, rest the rear wheels against the roll stop and have no foot interference. This same person could not use a lift with a 39 in. long platform in a similar manner because of foot interference, but he can face away from the van and successfully use the lift.

The 45 in. dimension has no real significance for lifts which have a swing-in platform, since there is no foot interference problem in those cases.

3.1.10.4. The interior height from the wheelchair ground plane, measured vertically, to any lateral lift member shall be at least 32 inches (81.3 cm).

Fig. 1 – Size requirements, typical folding platform lift.



Rationale. The arm-rest height of wheelchairs as given in ANSI A117.1-1961 is 29 in.[3] Measurements on a number of wheelchairs confirmed this, but the electric wheelchair joysticks protrude such that their tops are about 32 in. above floor level, depending, of course, on the user's choice of joysticks.

The 32 in. dimension was chosen based on observation of a number of wheelchair joysticks and upon the three lifts evaluated which have lateral frame member heights of 31 in., 32 in., and 32¼ in., respectively.

3.1.11. The use of the lift shall not require an on-platform turning movement for proper alignment and location of the wheelchair.

Rationale. A turning maneuver of a wheelchair on a lift platform is difficult unless the wheelchair occupant can look down to see the wheel location. And, if not made properly, the maneuver may leave one or more wheels improperly located or interfer-

Fig. 2 – Size requirements, typical swing-in platform lift.

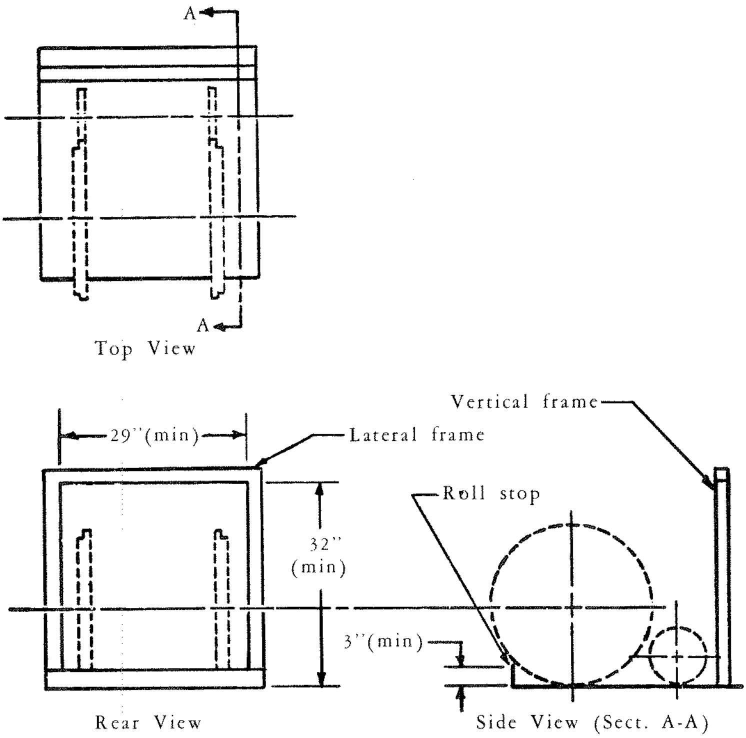


Fig. 2

ing with the roll-stop. One lift of those evaluated does require a left turn of approximately 30°, then a return to the straight-ahead direction in order to align the wheelchair properly.

3.1.12. *Tests.*

3.1.12.1. *Receiving Inspection Test.* A receiving inspection shall be conducted and shall include:

a. Weighing the wheelchair lift

b. Assessment of installation method and required vehicle alterations.

c. Assessment of battery power supply, connections, and charging method.

3.1.12.2. *Dimensional Test.* Upon installation of the lift on a test fixture according to manufacturer's instructions, measurements will be taken to determine compliance with dimensional requirements of Section 3.1.10.

3.2. *Desirable Design Goals.*

3.2.1. Ease of operation by a broad range of handicapped persons should be a prime consideration of the designer/manufacturer.

Rationale. Experience in using handicapped persons to assist in evaluations and discussions with users indicate a wide variety of capabilities among quadriplegics and paraplegics. Also, it is known from personal contact with one manufacturer [11] that he, and perhaps other manufacturers, make modifications of their standard lifts for purchasers who cannot use the standard model. It is to the manufacturers' advantage to produce lifts that are satisfactory to most users and, therefore, to avoid the necessity of customizing.

3.2.2. The lift should be designed with an integral system allowing manual operation in the event of failure of the primary operation method. An alternative to such a manual system should be written instructions for actions to be taken in event of such failure.

Rationale. Failure of the primary operation method (e.g., dead battery, burned-out motor, etc.) can result in great inconvenience to a lift user. A back-up mode of lift operation is highly desirable.

3.2.3. Required user actions such as pulling, pushing, holding, and similar physical actions should be kept to a minimum.

Rationale. The lift operation should be as free of required user action as possible. This minimizes the possiblity of human error. For example, limit switches can be used to turn off the lift drive motor, but depending on the user to release a manual switch at the proper time may result in injury to the user or damage to the equipment.

3.2.4. A wheelchair lift should be designed for minimum interference to normal vehicle usage.

Rationale. The convenience of able-bodied family members and guests to use the lift-equipped van is important and should be considered by the designer.

3.2.5. Commercially available components should be used in the design wherever possible.

Rationale. Commercially available components have advantages of cost, availability, and standardization.

3.3. *Materials and Components.*

3.3.1. *General Performance.*

3.3.1.1. *Standard.* Wheelchair lifts shall be constructed to prevent permanent deformation under the stress of normal usage as specified by the manufacturer and to operate reliably over an extended period of time.

3.3.1.2 *Specification.* A fully assembled and installed wheelchair lift shall withstand without fracture the stresses resulting from a static load of 2400 pounds (10676 N) to ensure a minimum factor of safety of six (6) for the rated load of 400 pounds (1780 N).

Rationale. The rational statements given for Sections 3.1.2. and 3.1.3. apply here. In summary, the rated load specification of 400 lb. was chosen by combining anthropometric data and wheelchair weights, and the safety factor was based on ANSI standards for similar-use equipment.

The lifts are not required to lift 2400 lb. but must be able to suspend that load.

In addition to a static load test of 2400 lb. an accelerated life cycle test of 400 cycles will be conducted. The value of 400 cycles (approximately two year's use) was developed from a telephone survey of individuals who have lifts installed in their personal-use vans.

3.3.1.3. *Tests.*

3.3.1.3.1. *Accelerated Life Cycle Test.* An accelerated life cycle test will be performed by repeating the wheelchair lift use cycle 4400 times. The time between each cycle shall be not less than six minutes. Ambient temperature shall be between 50° F and 90° F (10° C and 32° C). Alternating cycles of loaded and unloaded platform configuration will be simulated by applying a 400 pound (1780N) load for 100 cycles, then removing the load for 100 cycles. Periodic visual inspection without disassembly of the lift will be made in intervals of 500 cycles and changes in alignment, component wear, loosening of fasteners, and the like will be recorded. Failure mode analyses will be performed and a decision will be made based on those analyses. Preventive maintenance will be performed in accordance with the manufacturer's instructions.

3.3.1.3.2. *Static Load Test.* A static load of 2400 pounds (10676 N) shall be applied through the centroid of a test pallet placed at the centroid of the platform when the platform is positioned at van floor level. The length and width dimensions of the test pallet shall be 23" length × 23" width to correspond to the approximate outer dimensions of a wheelchair "footprint". The load shall remain on the platform not less than two (2) minutes. After the load is removed an inspection shall be made to determine if fractures have occurred. An equivalent test shall be performed on lifts which do not have a platform. The Static Load Test shall be performed after the Accelerated Life Cycle Test.

3.3.2. *Electrical Components and Wiring*

3.3.2.1. *Standard.* Electrical components and wiring shall conform to the Society of Automotive Engineers Standards or Recommended Practices as applicable.[6] Those listed below are applicable to all lifts.

SAE J258, SAE J553c: Circuit Breakers
SAE J537h: Storage Batteries
SAE J538a: Grounding of Storage Batteries
SAE J554a: Electric Fuses
SAE J556: Automobile Wiring
SAE J561b, SAE J858a, SAE J928a: Electrical Terminals

Rationale. Electrical components of wheelchair lifts should be of the same quality as those of the vehicle on which the lift is installed. SAE standards are developed, accepted, and utilized in the automotive industry.

3.3.2.2. *Standard.* All electrical systems shall be designed and packaged to protect the driver or passengers against injury resulting from short circuits, electrical fires, and similar incidents.

Rationale. The protection of the lift user and passengers from injury and protection of the vehicle from damage is of obvious concern.

3.3.2.3. *Standard.* Electrical components which are exposed to the environment outside the vehicle shall be protected by a suitable weatherproof enclosure.

Rationale. By their very nature electrical components must be protected from moisture to eliminate one cause of short circuits and corrosion. Such protection increases the overall system reliability. An example of non-protection of components was seen on one lift which had parts of the mechanism and electrical components under the vehicle. While this concept is acceptable, the components must be protected from such under-vehicle hazards as dirt, rock impacts, salt, and water.

3.3.2.4. *Standard.* Externally mounted wheelchair lift controls shall be installed so that they are weatherproofed by the use of inset compartments or protective coatings. Controls will be protected from misuse or vandalism by the use of key locks or key switches. Controls shall be located so that the operator of the controls will be well clear of the moving doors and lift mechanisms and in a position which will allow observation of lift movement.

Rationale. Since a function of a lift is entry into a van from the outside, there must be a means of actuating the lift from the van exterior to enable independent usage by a disabled person. This is typically done by installing toggle switches through the van side panel near the right front or right rear wheels and clear of the descending lift. Weatherproofing can be done by rubber or plastic-coated toggles or by insetting the switches in a commercially available recessed compartment. Weatherproofing will contribute to reliability, and the use of an electrical lock, key lock, or locked compartment door will help prevent unauthorized entry into the van. Installing the switches near the front or the rear of the van (for side door lift) will keep the wheelchair occupant clear of the moving doors and lift.

3.3.2.5. *Standard.* A solenoid or other device shall be designed into the power circuit to ensure that no electrical component on the lift has voltage applied to it until a lift operating control is actuated.

Rationale. Inadvertent operation of the lift must be avoided, thereby giving a measure of accident/injury protection. In the electrical system of some lifts, there is such a solenoid, and it operates very effectively to prevent lift operation except by conscious intent. With this solenoid loose wiring or accidental shorting across electrical contacts during maintenance cannot, for example, cause inadvertent lift operation.

3.3.2.6. *Electrical Tests.*

3.3.2.6.1. *General.* Electrical components and wiring shall be considered integral parts of the lift system and shall be tested for failures during the performance of Accelerated Life Cycle Testing, Section 3.3.1.3. Any failure or any hazardous condition caused by an electrical component during testing shall disqualify the entire system from acceptance.

3.3.2.6.2. *Water Spray Test.* The exposed portions of electrical components intended for installation external to the vehicle will be subjected to a five minute, fine droplet water spary test in which the droplets contact the components both vertically and horizontally. The wetted components will be allowed to air dry for approximately three (3) minutes and then the circuits will be electrically checked for successful operation.

3.3.2.6.3. *Electrical Current Test.* Electrical current flow will be measured for each lift movement. The ammeter used will be of laboratory quality with appropriate shunts. Only steady-state current, ignoring momentary surges, will be recorded.

3.3.3. *Chain Drive Components.*

3.3.3.1. *Standard.* Chain drive components shall conform to either: ANSI B29.1-1963 (R1973), Transmission Roller Chains and Sprocket Teeth [3] (for standard base series chain), or other ANSI standards applicable to specialized use chains.

Rationale. Conformance to applicable industry standards is required.

3.3.3.2. *Chain Drive Test.* Chain drive components shall be considered integral parts of the lift, and shall be tested for failures during the performance of the Accelerated Life Cycle Test, Section 3.3.1.3., and inspected for conformance to the above standards. Discrepancies in conformance or failures during the test shall disqualify the lift from acceptance.

3.3.4. *Hydraulic Components.*

3.3.4.1. *Standard.* Hydraulic components shall conform to the following Society of Automotive Engineers Standards or Recommended Practices as applicable. [6]

SAE J514h: Hydraulic Tube Fittings

SAE J516a: Hydraulic Hose Fittings

SAE J517c: Hydraulic Flanged Tube, Pipe and Hose Connections, 4-Bolt Split Flange Type.

Rationale. Conformance to applicable industry standards is required.

3.3.4.2. *Standard.* Hydraulic hoses shall be protected from bearing or rubbing on structural components.

Rationale. This self-evident requirement is inserted primarily as a reminder to manufacturers. While the high pressure hoses used on lifts have thick walls and wear-through is unlikely, the potential exists if the hose bears or rubs on a sharp edge, and therefore must be avoided.

3.3.4.3 *Hydraulic Components Test.* Hydraulic components shall be considered integral parts of the wheelchair lift and shall be tested for failures during the performance of the Accelerated Life Cycle Test, Section 3.3.1.3. Any failures, including significant leaks, shall disqualify the lift from acceptance. A significant leak is defined as seepage or leakage which produces one or more droplets (e.g., a teardrop, approximately 0.1 cc) in ten (10) complete cycles of the wheelchair lift.

3.3.5. *Wire Rope Components.*

Comment. The rationale statements for the various subsections are combined and placed at the end of the section.

3.3.5.1. *Standard.* Wire rope systems shall be designed and fabricated using rope and support components of proper dimensions and arrangement.

3.3.5.2. *Specifications.* Industry standards and specifications relating to wire rope components are generally for larger, higher capacity systems other than wheelchair lifts. However, the design principles of wire rope systems in general are applicable to wheelchair lits; therefore, the principles given in the following documents should be employed in lift design and so certified in writing by the manufacturer upon submission of the lift for testing:

3.3.5.2.1. ANSI A120.1-1970 - Safety Requirements for Powered Platforms for Exterior Building Maintenance, Section 14.8, "Drums and Sheaves," and Section 15, "Hoisting Ropes and Rope Connections". [3]

3.3.5.2.2. ANSI B30.2.0-1967 - Overhead and Gantry Cranes, Section 2-1.10, "Hoisting Equipment." [3]

3.3.5.2.3. McElroy, Frank E. (ed): *Accident Prevention Manual for Industrial Operations.* 6th Edition, National Safety Council, Chicago, IL, 1969, pp 641-657. [12]

3.3.5.2.4. Rossnagel, W. E.: *Handbook of Rigging,* 3rd Edition, McGraw-Hill Book Company, New York, NY, 1964, pp 41-83. [13]

3.3.5.3.5. Wire rope manufactuere's recommendations.

3.3.5.3. *Specifications.* If the manufacturer/designer chooses not to use the documents specified in Section 3.3.5.2. for design guidance, then these specifications shall be used:

Material. Wire rope material shall be galvanized carbon steel (aircraft cable quality), Type 302 stainless steel, or equivalent in strength and corrosion resistance and so certified.

Construction. Wire rope shall be of 7 × 19 construction.

Sheaves. Sheaves shall be grooved with a minimum groove diameter of 25 times the nominal wire rope diameter. Grooves shall be shaped so as to saddle the rope with a 150 degree arc of support. The radius of curvature of the groove shall be one-half the nominal rope diameter plus 1/32 inch (0.8 mm). The sides of the groove shall be tangent to the groove arc. The total depth of the groove shall be between 1.5 and 2.0 times the nominal rope diameter. Material shall be aluminum alloy 2024-T6, or equivalent.

Attachments. When a wire rope is formed into an eye as a removable method of attaching the rope to equipment, a thimble shall be used inside the eye, and at least two U-bolt clips shall be attached to the doubled rope. The U-bolt portion of the clips shall bear upon the dead end of the rope, with clips spaced not less than six (6) rope diameters apart. One clip shall be as near to the thimble as possible.

Fittings. The lift manufacturer shall provide, upon request, a rope manufacturer's certification that permanent rope fittings have not less than 90% of the rope manufacturer's stated rope strength.

Drums. Drum diameter shall not be less than 25 times the nominal rope diameter. It is desirable that there be only one layer of rope on the drum, but the maximum number of layers shall be three. Helically grooved drums should be used to minimize crushing and excessive wear of the rope. The dimensions of such grooving shall be that of the sheave grooving, with the exception that the total depth should be approximately 0.2 times the nominal rope diameter. There shall be at least one turn of rope on the drum when the wheelchair ground plane is at ground level.

Alignment. The drum and lead sheave shall be aligned to control lateral movement of a wire rope when winding on a drum. The fleet angle shall not excees 1½ degrees. The same maximum angular relationship shall exist between centerlines of adjacent sheaves.

Orientation. The design of the wire rope system should avoid reverse bending of th rope. The wire rope shall not bear on any portion of the lift framework.

Rationale. As noted in the opening specification statement (Section 3.3.5.2.), related industry standards are primarily for larger systems. The wire rope components used on lifts are comparable in size to those of aircraft systems. This leads to the application of military standards and manufacturer's recommendations. Consequently, in keeping with the general theme of the standard, the designer/manufacturer is given an option of adhering to the principles of industry standards as given in Section 3.3.5.2. or to those detailed specifications in Section 3.3.5.3. The detailed specifications were written from information taken from two wire rope manufacturers' recommendations (American Chain and Cable Company [14] and Carolina Steel and Wire Corporation [15]), from Military Standards (MS 20220: Pulley, Groove, Flight Control, Aircraft [16] and other similar standards for pulleys), and from the references in Section 3.3.5.2.

3.3.5.4. *Wire Rope System Test.* An inspection of the wire rope system shall be made and shall include measurement of the nominal diameters of rope, sheaves, and drum. The fleet angle between the lead sheave and drum and between sheaves at all platform positions shall be measured. Attachments and fittings shall be inspected for conformance to Section 3.3.5.3. The travel of the rope during all lift movements shall be followed to observe possible rope contact with structural members.

3.3.6. *Power Screw Components.*

3.3.6.1. *Standard.* The power screw system even when disconnected from the driving source should not allow the platform to exceed the acceleration specification by more than 50%.

Rationale. The self-locking feature of a vertical power screw requires that torque be applied (to the nut or the screw, depending on the design) to raise and to lower the load and is dependent only upon the screw lead angle and the coefficient of friction. The drive motor and connecting components (gears, belts) may contribute toward a condition which would prevent the platform from a high rate of overhauling, but from the safe operation standpoint, the design of the power screw system should positively control such inadvertent action.

3.3.6.2 *Standard.* The power screw system shall transmit power in both directions.

3.3.6.3. *Specification.* Power screws shall be of the Acme screw thread type in conformance with ANSI B1.5-1973, Acme Screw Threads [3], ANSI B1.8-1973, Stub Acme Threads [3] or equivalent. The 60-degree (V-type) thread shall not be used as a power screw.

Rationale. The Acme thread has been standardized and is in wide use for power screw applications. It is less expensive to manufacture than the square thread [6, 17, 18]. The 60° (V-type) thread normally used in fastener applications is not to be used.

3.3.6.4 *Standard.* The lift designer should ensure that the power screw is checked for long-column conditions and that an appropriate column design formula is used.

Rationale. The variety of design approaches precludes specification of a particular long or short column condition and the appropriate design formulas. Further, the slenderness ratio used in such formulas may actually be different from that directly calculated from the column length and radius of gyration because of the overall design approach used.

3.3.6.5. *Power Screw Tests.* The threads on the power screw shall be inspected to ensure that Acme screw threads (or equivalent) are used and that the system transmits power in both directions.

3.4. *Fabriaction.*

3.4.1 *Weldments.* The design and fabrication of any weldments used in a wheelchair lift shall conform to Sections 1, 2, 3, and 4 of the American Welding Society Structural Welding Code, D1.1 -72 [19] (for steel construction) or to the AWS Recommended Practices for Gas Shielded Arc Welding of Aluminum and Aluminum Alloy Pipe, D10.7 - 60 [19], as applicable.

Rationale. It should be noted that the AWS code D1.1 - 72 is for steel construction and D10.7 - 60 is for aluminum alloy *pipe.* It is expected that aluminum lifts will have portions of the weldment which are not pipe; however, code D10.7 - 60 is general enough relative to welding techniques, bead dimensions, filler materials, and other factors to be applicable here.

3.4.1.1. *Weldment Test.* A close visual inspection shall be made of all welds to detect (1) structural flaws such as undercutting, cracking, poor penetration, and surface defects, and (2) dimensional flaws such as warpage, incorrect weld size or profile, and incorrect joint separation. Other nondestructive testing using radiographic, ultrasonic, dye penetrant, or other methods may be conducted if deemed necessary by the testing agency. Significant defects shall disqualify the lift from acceptance.

3.4.2. *Fasteners.*

3.4.2.1. *Standard.* All fasteners used shall conform to the Society of Automotive Engineers Standards or Recommended Practices as applicable. [6]

Rationale. Conformance to applicable industry standards is required.

3.4.2.2. *Standard.* All fasteners used shall be designed or treated for resistance to vibration.

Rationale. It was noted during the accelerated life cycle testing that one non-locking cap screw in a critical location frequently became loosened, as did two other less critical bolts. Although the in-van lift installation is such that it is not in a high vibration environment, the repetitive operation could cause non-locking fasteners to fail and possibly result in injury or damage.

3.4.2.3. *Fastener Tests and Inspection.* Fasteners shall be considered as integral parts of the lift system and shall be tested for wear, integrity, and resistance to loosening or loss through vibration or use conditions. Such testing and inspection will be done during the Accelerated Life Cycle Test, Section 3.3.1.3.1.

3.4.3. *Level of Lift Platform.*

3.4.3.1. *Standard.* With the lift installed on a rigid structure the platform at floor level shall not slope more than 0.75 inches (1.9 cm) rise to twelve (12) inches (30.48 cm) of run (3.6 degrees) in any direction, both with no load on the platform and with the rated load of 400 pounds (1780 N) applied in the same manner as in the Static Load Test, Section 3.3.1.3.2.

Rationale. The slope requirement is primarily to avoid the steep-ramp effect of folding platform lifts. Evaluations on these lifts showed a variation at van floor level ranging from a positive to a negative slope into the van. Such a slope is, in effect, a ramp which the wheelchair occupant must negotiate, and excessive slope could be difficult or dangerous. The platform slope of a lift installed in a van will change from the static value depending on van suspension characteristics and the total wheelchair and occupant weight, the worst case being if the static platform slope is an up-slope into the van. The slope given in this section is approximately 1° less than the maximum ramp angle given in ANSI A117.1-1961 (R1971), Specifications for Making Buildings and Facilities Accessible to, and Usable by, the Physically Handicapped. [3]

3.4.3.2. *Platform Angle Test.* The lift shall be installed on a rigid structure. Measurements shall be taken to determine the lift platform angle at the van floor position.

3.4.4. *Coating and Finishing.*

3.4.4.1. *Standard.* Corrosion of ferrous metal wheelchair lift components can be expected as a result of contact with atmospheric moisture, road deicing salt solutions, mud, and possibly other corrosive agents. Ferrous metals shall be protected from such corrosion by the application of protective coatings.

3.4.4.2. *Specifications.*

3.4.4.2.1. Ferrous metal surfaces shall be prepared for the chosen coatings and the coatings applied in accordance with the following minimum requirements:

Surface preparation. Residues such as oil, grease, dirt, weld slag, mill scale, and rust shall be removed from the surface. Solvent or solvent vapor cleaning shall be used to remove residues prior to removal of rust and scale. The degree of rust and scale shall be determined by the methods of ASTM D2200 - 67 (1972), Pictorial Surface Preparation Standards for Painting Steel Surfaces [20]. The surface shall be cleaned to condition "St 2" (Scraping and wire brushing, thorough) or "Sa 2" (Blast cleaning, thorough) as given in ASTM D2200 - 67 (1972). Surfaces thus cleaned shall be prime coated not more than twenty-four (24) hours later [20].

Primer coat. At least one primer coat containing rust inhibitive pigments shall be applied to the cleaned surface. A coating thickness of 1 mil (0.03 mm) to 1½ mils (0.04 mm) is adequate [21].

Color coat. Two or more coats of corrosion and abrasive resistant flat finish shall be applied [22].

Rationale. A high quality surface coating is necessary for long-term durability and pleasing appearance. While lift manufacturers have a wide choice of coatings for ferrous metals, the minimum requirements are specified to ensure proper preparation and choice of coatings. The lifts evaluated showed much variation in coatings, especially in the surface preparation. For example, paint sprayed over greasy areas and weld slag areas chipped off very rapidly after the lift was put into use.

3.4.4.2.2. Specular glare from the lift framework surfaces shall be minimized by using a flat or matte surface finish.

3.4.4.2.3. Finish coating colors which have a coefficient of absorption equal to or less than 0.55 should be chosen to minimize solar radiation absorptivity of the lift framework: e.g. white (0.25), light cream (0.35), light yellow (0.45), light gray (est. 0.4), light green (0.50), aluminum (0.55).

Rationale. The objective of these two sections is to minimize specular glare into the driver's eyes and to minimize solar absorptive heating of the lift framework which might burn the skin of the lift user. The driver could be subject to reflectance through the rear view mirror or while looking to the right rear. Recommendations were taken from the *Human Engineering Guide to Equipment Design* [23] and from the *Handbook of Chemistry and Physics* [24].

3.4.4.3. *Finish Coating Test.* An inspection of the coating shall be made to include, but not be limited to, overall appearance and existence of a dull, matte surface finish. Measurements of film thickness shall be made in at least three locations using a dial comparator or dial indicator as described in ASTM D 1005-51 (R1972), Measurement of Dry Film Thickness of Organic Coatings. [20] A subjective evaluation of coating adherence will be obtained in at least three locations as follows: use a machinist's scribe to scribe a single line approximately one inch long with suffucient force to penetrate to the base metal. Lay on a strip of transparent mending tape and burnish the scribed area for approximately 15 seconds with a smooth-ended metal tool. Pull the tape off with a quick, perpendicular motion. A very thin line of coating particles is indication of good adhesion. Upon completion of the Accelerated Life Cycle Test, Section 3.3.1.3.1. and the Operational Safety Test, Section 3.6.9.4., another inspection will be made to determine long-term wear and use characteristics of the coating.

3.5 *Operation.*

3.5.1. *Human Factors Standards and Specifications.*

3.5.1.1. *Controls Standard.* Control selection and application shall be done in accordance with good human factors practice of location, direction of control movement, force, range, and identification.

3.5.1.2. *Controls Specification.* Selections and application shall be made in accordance with the principles and recommendations presented in Chapter 8, Design of Controls, *Human Engineering Guide to Equipment Design,* Harold P. Van Cott, Editor (U.S. Government Printing Office) [25], or an equivalent publication as applicable. See Appendix 2.

Rationale. There is a wealth of data available concerning selection and application of human-actuated controls. The lifts evaluated showed a wide variety of application and misapplication of such human factors principles. Examples include the use (wisely) of 2 in. long toggle switches which the disabled users found very convenient, the orientation of toggle switch motion exactly backward from the corresponding equipment motion, and good to bad selections of switch locations.

3.5.1.3. *Acceleration Standard.* The motion of the platform shall not subject the wheelchair occupant to lateral or vertical accelerations which are frightening, uncomfortable, or potentially dangerous.

3.5.1.4. *Acceleration Specification.* Lateral and vertical accelerations shall not exceed 0.3 g during any operational motion of the lift in which a weight of 400 pounds (1780 N) is being raised, lowered, or moved horizontally.

Rationale. Accelerations imposed on the wheelchair occupant by the lifts evaluated were at a low level comparable to those experienced by high performance aircraft pilots or even automobile passengers involved in a minor collision. All lifts had vertical lift accelerations below 0.5 g, and most were in the 0.1 g to 0.3 g range. The vertical lift acceleration problem is primarily one of comfort rather than danger, but a horizontal acceleration can possibly throw the wheelchair and occupant off the platform. It was seen in the evaluation of an early model of a lift that horizontal accelerations of the order of 0.5 g to 0.6 g were "very rough. . ." and that 1.0 g was sufficient to cause the wheelchair, with an instrumented, 179 lb anthropometric dummy, to be thrown off the platform. The specification value of 0.3 g was chosen as an upper limit of the comfort range for vertical accelerations and as a conservative upper limit for the protection of the wheelchair occupant.

3.5.1.5. *Platform Access Standard.* Ramps or steps over which the wheelchair must roll onto the platform shall not preclude ease of access.

Rationale. This specification is based on the ramp angle of 1 in 12 as specified in ANSI A117.1-1961 (R1971), Specification for Making Buildings and Facilities Accessible to, and Usable by, the Physically Handicapped. [3] It was noted during the evaluations that the platforms on three of the lifts did have ramps and that two of these were of a greater angle than that specified. Also, the ramps were short, on the order of 3 in., which made the ramp more of a step to be rolled over. The ramps were not difficult to climb in an electric wheelchair, but did give the occupant a jolt when the wheels contacted the ramp. Access was much more difficult for those persons using manual wheelchairs.

The maximum step height of 5/8 in. was not found documented in the literature but was determined by a series of subjective tests of attempting to roll a manual wheelchair, with 8 in. hard rubber front wheels, over steps of 3/8 in., 1/2 in., 5/8 in., and 3/4 in. height.

3.5.1.6. *Platform Access Specification.* A ramp, if used, shall have a slope of not more than one (1) inch (2.54 cm) rise to six (6) inches (15.24 cm) of run and provided that the slope between front and rear wheels shall not exceed 1 inch in 12 inches. A step over which a wheelchair must roll to enter the platform shall have a vertical dimension of not more than 5/8 inch (15.9 mm) above the surface on which the platform rests.

3.5.1.7. *Tests.*

3.5.1.7.1. *Control Inspection Test.* Inspection of controls in accordance with the principles and recommendations in the referenced volume (Section 3.5.1.2.).

3.5.1.7.2. *Acceleration Test.* Accelerations will be measured by means of accelerometers in the head or chest cavity of an anthropometric dummy which is seated in a wheelchair on the platform. The wheelchair and dummy weight will be supplemented to a total weight of 400 pounds (1780 N). Accelerometer readings will be taken for all lift motions on which an occupant is carried.

3.5.1.7.3. *Slope Diemnsion Test.* The empty platform will be lowered to the ground position with the ramp, if any, at its entry/exit position. Linear measurements of rise and run will be made. Likewise, any step over which the wheelchair must roll will be measured.

3.5.2. *Constraints.*

3.5.2.1. The manufacturer shall specify in writing to prospective purchaser prior to purchase any type of wheelchair or specific physical handicap which hinders effective use of his lift.

3.5.2.2. The manufacturer shall specify in writing to prospective purchaser prior to purchase any factors such as ambient air temperature, rain, low battery voltage, and street slope which would hinder the designed operation of the lift.

Rationale. As might be expected, very little of current advertising of lifts relates to the constraints in using the lift. The positive rather than the negative aspects are usually emphasized. The intent of this section of the standard is to encourage the manufacturer to fully inform potential purchasers concerning lift operation so a more intelligent purchasing deicsion can be made.

3.5.3 *Operating Instruction Manual.* The manufacturer shall provide to the purchaser a manual of instructions concerning the proper use and operation of the lift. The instructions shall address at least the following areas: general operation, preferred entry/exit technique, operation of all controls and resulting platform movements, required user actions, actions (if any) which the user should not/must not take, warning of unusual noise, movements, or other fright-producing factors, and potential hazards. The instructions should be supplemented by photos and illustrations as necessary.

Rationale. The need for operating instructions is almost self-evident, even recognizing that many people do not read operating instructions provided with any piece of equipment. This section will prompt the manufacturer to give proper consideration to informing and warning the user about the operation of the lift.

3.5.3.1. *Visual Inspection.* A visual inspection shall be made as to the inclusion of the required Operating Instructions and the suitability of the contents.

3.6. *Standards for Product Safety.*

3.6.1. The requirements of ANSI B15.1-1972, Safety Standard for Mechanical Power Transmission Apparatus, [3] with respect to the safeguarding of (1) sources of mechanical power, (2) the associated and intermediate equipment, and (3) the driven components shall be applied in the design and manufacture of wheelchair lifts.

Rationale. Protection of wheelchair lift users and van occupants from the hazards of moving machinery is extremely important. The lifts evaluated had a variety of hazards (exposures); some were safeguarded and others were not. Some lifts may have to be redesigned in order to remove or to protect against mechanical hazards.

3.6.2. The wheelchair lift operation shall be such that no movement of the wheelchair is required during the raising or lowering of the platform.

Rationale. One lift evaluated and another one known to be on the market are designed such that the wheelchair must roll during the raising or lowering of the platform. This motion requires a degree of attention, manual dexterity, and equilibrium that may not exist in paraplegics, and rarely exists in quadriplegics. The maximum physical action that should be expected of a lift user is the actuation of the lift control – typically a toggle switch.

3.6.3. The lift shall have an automatically operating device at the ground-to-platform entry/exit area, the purpose of which is to prevent the wheelchair and occupant from falling off the lift. The device shall conform to the following:

It shall be electrically or mechanically interlocked with the lift such that any time the platform is nominally horizontal and more than two (2) inches (5.08 cm) above the ground, the device will be effective.

It shall have the same effect on a rearward moving wheelchair as a lateral, fixed step which is three (3) inches (7.62 cm) high and perpendicular to the wheelchair ground plane and which can resist a distributed force of 1600 lb (7100 N) applied parallel to and three (3) inches (7.62 cm) above the wheelchair ground plane.

Rationale. Experience in industry and in consumer product usage has shown that safety devices must be designed into the equipment to ensure that they will be used. It is poor practice to expect the operator to use optional safety devices with regularity. An automatically operating roll preventing device is in this category; the lift user should not be given the option of using or not using it. As with safety devices on other equipment, the roll preventing device can be designed so that it does not interfere with normal use of the lift. In those lifts evaluated, there were five that had such devices and which functioned reasonably well. Two lifts had no roll preventing mechanism whatsoever, and two had manually operated devices.

The step height value of 3 in. was determined from a series of experiments in which an electric wheelchair (20 in. balloon tires) with a 170 lb occupant was operated rearward down a 5° ramp into a firmly attached vertical wood barrier of various heights. The wheelchair travelled 1 ft prior to striking the stop, at the velocity of approximately 3 fps as determined by other distance-time measurements. The chair rolled over 1½ in. and 2 in. stops but would not roll over a 3 in. or higher stop. The force value of 1600 lb was determined by analytical methods: writing and solving the equations of motion for the wheelchair and occupant moving down a 5° ramp and striking the stop at a velocity of 3.6 fps. The impulse ($F\Delta t$) of the wheelchair wheels on the stop of 3 in. height was calculated to be 13.55 lb-sec. Assuming a contact velocity of 3.6 fps and a zero velocity at a combined tire and stop deflection of 1 in., we get the average impact time as:

$$\Delta t = \frac{1/12 \text{ ft}}{\frac{5.6 - 0 \text{ ft/sec}}{2}} = 0.046 \text{ sec, say } 0.05 \text{ sec.}$$

The impulse $F\Delta t = 13.35$ lb-sec can be solved to yeild

$$F = \frac{13.35 \text{ lb-sec}}{0.05 \text{ sec}} = 267 \text{ lb.}$$

Applying the factor of safety of 6 gives F = 1602, which is rounded to 1600 lb.

3.6. Limit devices or methods shall be employed to ensure that the platform ceases movement at the desired position as required by the design. As a minimum, the floor level position of the platform shall be positively controlled such that the wheelchair does not have to roll over a step greater than 5/8 inch (15.9 cm) in height. Ground and stowage positions of the platform should be controlled as necessary to prevent equipment damage.

Rationale. The need for limit devices is closely related to the need for a roll-preventer, previously discussed. On the folding-platform lifts, it is very important from the safety standpoint to ensure that the platform, when being rasied from ground level, automatically stops at the floor level, thereby allowing the wheelchair to be rolled into the van. If the platform does not stop, it may begin its folding action, which could cuase the wheelchair occupant to fall forward into the van. Other limit devices are highly desirable, but their employment depends upon the lift design. For example, there is no need for a limit switch to open the DOWN circuit of a gravity-type hydraulic lift.

3.6.5. During those portions of the rasie/lower cycle in which the platform is nominally horizontal, any openings in the platform shall reject a 3/4 inch (19.1 mm) diameter metal ball.

Rationale. The hard rubber caster wheels of wheelchairs vary in tread width from 7/8 in. to approximately 1½ in. In the evaluations it was noted that some lift platforms had openings of such dimensions that the smaller tread tires could fall through, or at least become wedged. The Speedy Wagon and Para lifts have a slot of approximately 1 in. wide running the full width of the platform and located at the roll-stop area. The Ricon platform has a very coarse expanded metal grating which prevents proper wheel castering action. The implications of a wheel falling through a slot is obvious, and the inconvenience of difficult wheelchair movements makes Section 3.6.5. a firm requirement.

3.6.6. The wheelchair lift system shall be free of sharp edged and jagged projections, thereby minimizing minor injuries and damage to clothing of lift users and vehicle passengers.

Rationale. This requirement is necessary to ensure that manufacturers remove sharp edges and projections. There were some very obvious examples of inattention to this type exposure on some lifts.

3.6.7. The wheelchair lift platform surface shall be of a slip resistant type material to provide adequate tire-platform traction.

Rationale. Slip resistant surfaces are considered mandatory because of the slight ramp angle allowed by Section 3.4.3. It is reasonable to expect that lifts will be used in wet weather which could cause the platform to become slippery. A slip resistant surface will negate problems resulting from such conditions.

3.6.8. Federal Motor Vehicle Safety Standard No. 302, Flammability of Interior Materials, [27] shall apply to non-metallic components such as protective coverings, housings, and paddings.

Rationale. This requirement refers to those non-metallic materials used on some lifts which were evaluated. There were very few such materials, but with the requirement for safeguards, for electrical component packaging, and suggestions concerning dirty surfaces, this requirement will become more significant.

3.6.9. *Tests.*

3.6.9.1. *Occupant Hazards Test.* The fully assembled and installed wheelchair lift shall be carefully inspected with regard to safeguards, sharp edges, projections, and dirty or greasy surfaces with which the occupant might come in contact during normal operation of the lift.

3.6.9.2. *Slip Resistance Test.* The wheelchair platform shall be inspected for utilization of slip-resistant surfaces on which the wheelchair rolls. Slip-resistant characteristics will be observed in these cases when the platform is at ground and at floor level: occupant in manual wheelchair onto/off of dry and wet platform; occupant in electric wheelchair onto/off of dry and wet platform.

3.6.9.3. *Platform Opening Test.* The platform will be positioned at ground level and at van floor level, and all openings therein will be tested with a metal ball of 3/4 inch (19.1 mm) diameter for oversize dimensions.

3.6.9.4. *Operational Safety Test.* The fully assembled and installed wheelchair lift shall be oeprated by both able-bodied and disabled persons, in the manner specified in the Operating Instructions, and observations made as to whether the lift can be operated safely, with minimum potential to injury. Observation shall be made as to a requirement for an on-platform turning movement of the wheelchair. Observations shall be made of the floor level stop position as to safe entry/exit of the wheelchair into/out of the van.

3.6.9.5. *Wheelchair Retaining Test.* Test equipment will be constructed to fit each wheelchair retaining device. The equipment will apply a static load of 1600 pounds at a height of three (3) inches above and parallel to the wheelchair ground plane, evenly distributed over the full width of the roll stop device. The load will be applied for at least five (5) seconds with the lift platform at the van floor level and also will be applied as the wheelchair ground plane moves down (or up). A load of 400 pounds will be on the lift during the test if the wheelchair retaining operation is dependent on such a load for its proper operation.

4.0. *Installation and Maintenance of Wheelchair Lift Systems.*

4.1. *Installation.*

4.1.1. *Installing Agency.* The manufacturer shall specify, when advertising or otherwise promoting his wheelchair lift, whether the lift must be factory or distributor installed or whether it can be installed by an individual or agency of the purchaser's choice.

> *Rationale.* It is known from the experience gained in purchasing and receiving the lifts for evaluation that some manufacturers sell and install lifts only through distributors, others install at the factory, and yet others may have no preference who or what agency installs their lift. The manufacturer, for his own protection, should be allowed to specify the conditions under which he will sell and install the lift. In either case, the consumer should be informed, and this section is included for that reason.

4.1.2. *Method of Installation.*

4.1.2.1. *Standard.* Manufacturers shall specify the appropriate method of installation for the complete wheelchair lift system.

4.1.2.2. *Installation Manual Specification.* Wheelchair lifts which are identified as suitable for installation by an individual or agency of the purchaser's choice shall be accompanied by an Installation Manual which shall contain written and graphic instructions for installing the lift and shall contain specific installation information relative to the make, year, and type of van for which the lift is suited. The manual should be written at a technical level comparable to an automotive service manual.

4.1.2.3. *Installation Hardware Specification.* Wheelchair lifts distributed for installation shall be accompanied by all necessary installation hardware for the vehicle on which the lift is to be installed.

> *Rationale.* Regardless of the agency selected for installation of lifts, the manufacturer must provide the instructions and hardware to ensure that the task can be performed properly. This effort protects the manufacturer from potential product failures, adverse reputation, and perhaps litigation. It also provides the purchaser with sufficient information to determine if a quality installation has been performed.

4.1.2.4. *Visual Inspection.* A visual inspection will be made as to the inclusion of required Installation Manual and the suitability of its contents and of the existence of the necessary installation hardware.

4.1.3. *Certified Installation.* The VA strongly urges that installation be accomplished by experienced technicians who have familiarized themselves with lift systems. The individual or agency who does the installation should certify in writing to the user/owner that the lift installation is complete and done according to the manufacturer's instructions.

4.2. *Maintenance.*

4.2.1. *Standard.* The manufacturer shall specify user/owner maintenance to be performed and make adequate provision in the design for the performing of such maintenance.

4.2.2. *Repair Parts.* The manufacturer shall develop and maintain an appropriate stock level of repair or replacement parts. Appropriate records related to purchased parts shall be maintained. Repair parts shall be available for purchase.

4.2.3. *Maintenance Manual Specification.* The manufacturer shall provide to the purchaser a manual of instructions concerning required maintenance to be performed by the user/owner. The maintenance instructions shall address at least the following areas: theory of operation, lubrication (types, location, and frequency), fluids (types, levels, and frequency of checking), adjustments (function, location, and method), calibration and alignment procedures, trouble-shooting (possible failures and required corrective action), parts lists, components requiring special attention, definitions and measurements to determine excessive wear, and name, address, and telephone number of the manufacturer or his representative.

> *Rationale.* Owner/operator performed maintenance is likely to be the only maintenance that many lifts will receive until the manufacturers further develop their distributor-owner relationships. In order for this maintenance to be accomplished,

the manufacturer must prescribe it in terms of those items listed. In the lift evaluations, as in other aspects, there was a wide variety of maintenance instructions ranging from none to adequate.

4.2.4. *Documentation Specification.* The manufacturer shall provide to the purchaser all electrical and hydraulic schematic diagrams necessary to properly maintain and repair the lift. These diagrams shall include wiring diagrams, component layout, parts lists, and applicable test and calibration points. A list of authorized distributors or service agencies shall be provided.

4.2.5. *Tool Specification.* The manufacturer shall design and fabricate a lift such that the tools needed for the required user/owner maintenance are of the standard, readily available type, e.g., adjustable, end, or socket wrenches for bolt heads equal to or less than 3/4 inch (20 mm, nominal), slot-type screwdriver, phillips-type screwdriver.

Rationale. During the performance of maintenance on the lifts undergoing accelerated life cycle tests, it was very evident that some manufacturers were not concerned about the availability of proper maintenance tools. If tools other than standard, readily avilable types are required, it can be expected that maintenance will not be done – to the detriment of the equipment, and perhaps to the bodily harm of the lift user.

4.2.6. *Accessibility Specification.* The manufacturer shall design and fabricate his lift such that parts requiring owner/operator maintenance are readily accessible without major disassembly or use of special tools.

Rationale. This requirement is necessary because of the examples of inaccessible maintenance components seen on the evaluated lifts. For example, one lift had a grease fitting "looking" directly at a structural member approximately 1/2 in. away. Another lift had a housing around the gear drive unit, which was good protection from moving parts, but a special screwdriver was needed to remove the housing in order to check the grease level. One hydraulic lift had a horizontal fluid filler fitting, requiring a long flexible funnel to avoid spills. A thorough maintainability analysis by the manufacturers would help to eliminate such situations.

4.2.7. *Tests.*

4.2.7.1. *Visual Inspection.* A visual inspection shall be made to determine the inclusion of a Maintenance Manual and its compliance with Section 4.2.3. and of the inclusion of documentation as required by Section 4.2.4.

4.2.7.2. *Maintainability Test.* The maintenance procedure prescribed by the manufacturer shall be performed to ascertain compliance with Sections 4.2.5. and 4.2.6.

5.0. *Identification and Inspection by the Manufacturer.*

5.1. *Identification.* Each lift manufactured for sale shall bear a model number, a serial number, and the name and address of the manufacturer. This identification may be engraved or placed on a permanently affixed tag which will remain visible after lift installation in the vehicle.

Rationale. Identification of consumer products and industrial equipment is a common practice and should be applied to wheelchair lifts. Such an identification system will not only aid the lift owner in contacting the manufacturer in the event of product failure, but will also aid the manufacturer in many ways: retorfitting (if neccssary), design change identification, component traceability, and others.

5.2. *Manufacturing Inspection.* In view of the implied seriousness of in-service failures, quality control inspections made by the manufacturer shall be 100 percent on every lift which is commercially sold. Evidence of quality assurance shall be included with every lift sold and can be in the form of a seal, inspection stamp, tag, or any other legible identification. Uninspected lifts shall be returned to the manufacturer.

Rationale. It is imperative that manufacturers carefully conduct quality control inspections on their lifts. The procedure and timing for conducting the inspections must be developed by the manufacturers and while there is no effective way to test compliance with this section, the requirement of the inspector's tag will help to force recognition of this essential program.

5.3. *Warranty.* A statement of warranty shall be provided with each lift device assuring the quality of materials an workmanship of the product for at least one (1) year from the date of delivery to final consumer. The warranty shall state that if defects are found during the warrnaty period, the device will be repaired, replaced, or a refund made by the seller or his authorized agent.

Rationale. The one year warranty is comparable to that of many other consumer products. Having such a warranty will encourage manufacturers to improve their designs, require high quality from component manufacturers, and improve the overall quality of their product.

5.4. *Claims Made.* Advertising literature shall reveal the adaptive equipment manufacturer's name and address. All claims of approval by private groups, local, state or federal government shall be specific as to the approving agency and the acceptance test protocol. Such claims shall be documentable on request. Furthermore, all claims of scientific merit shall be clearly stated and documentable on request.

Rationale. It is well known that advertising claims are sometimes more self-laudatory than true. This requirement concerning claims is intended to protect the VA and the public from claims of approvals or performance which cannot be substantiated.

5.5. *Liability Claims.* Although lifts may be certified by the VA as having conformed to the requirement of this standard, the VA assumes no liability for any claim arising from the use of the lift.

Rationale. This disclaimer statement is inserted as a protective measure against claims primarily from non-veteran users.

5.6. *Annual Inspection.* In the interest of long-term safety, the VA recommends an annual inspection of all wheelchair access systems. The inspection should include checks for wear, deterioration, proper adjustment, loose fasteners, etc. as well as a performance test. The manufacturer is urged to include annual inspections in the maintenance proceudre and to encourage such inspections by proper support to distributors and/or installing agencies.

Rationale. This statement is not intended as a requirement but is included to urge the manufacturer to prescribe such inspections in his maintenance procedure and to assist distributors/installers as necessary to conduct the inspections.

5.7. *Visual Inspection.* Each lift shall be inspected for the inclusion of the required identification tag, evidence of manufacturer's quality control inspection, and for inclusion of the required Warranty Statement.

6.0. *Test Procedures.* This section brings together under one heading all tests specified in the standard and in the approximate sequence of testing.

3.1.12.1. *Receiving Inspection Test.* A receiving inspection shall be conducted and shall include:

a. Weighing the wheelchair lift.
b. Assessment of installation method and required vehicle alterations.
c. Assessment of battery power supply, connections, and charging method.

3.1.12.2. *Dimensional Test.* Upon installation of the lift on a test fixture according to manufacturer's instructions, measurements will be taken to determine compliance with dimensional requirements of Section 3.1.10.

3.3.2.6.2. *Water Spray Test.* The exposed portions of electrical components intended for installation external to the vehicle will be subjected to a five minute, fine droplet water spray test in which the droplets contact the components both vertically and horizontally. The wetted components will be allowed to air dry for approximately three (3) minutes and then the circuits will be electrically checked for successful operation.

3.3.2.6.3. *Electrical Current Test.* Electrical current flow will be measured for each lift movement. The ammeter used will be of laboratory quality with appropriate shunts. Only steady-state current, ignoring momentary surges, will be recorded.

3.4.1.1. *Weldment Test.* A close visual inspection shall be made of all welds to detect (1) structural flaws such as undercutting, cracking, poor penetration, and surface defects, and (2) dimensional flaws such as warpage, incorrect weld size or profile, and incorrect joint spearation. Other nondestructive testing using radiographic, ultrasonic, dye penetrant, or other methods may be conducted if deemed necessary by the testing agency. Significant defects shall disqualify the lift from acceptance.

3.4.3.2. *Platform Angle Test.* The lift shall be installed on a rigid structure. Measurements shall be taken to determine the lift platform angle at the van floor position.

3.4.4.3. *Finish Coating Test.* An inspection of the coating shall be made to include, but not be limited to, overall appearance and existence of a dull, matte surface finish. Measurements of film thickness shall be made in at least three locations using a dial comparator or dial indicator as described in ASTM D 1005-51 (R1972), Measurement of Dry Film Thickness of Organic Coatings. [20] A subjective evaluation of coating adherence will be obtained in at least three locations as follows: use a machinist's scribe to scribe a single line approximately one inch long with sufficient force to penetrate to the base metal. Lay on a strip of transparent mending tape and burnish the scribed area for approximately 15 seconds with a smooth-ended metal tool. Pull the tape off with a quick, perpendicular motion. A very thin line of coating particles is indication of good adhesion. Upon completion of the Accelerated Life Cycle Test, Section 3.3.1.3.1. and the Operational Safety Test, Section 3.6.9.4., another inspection will be made to determine long-term wear and use characteristics of the coating.

3.5.1.7.1. *Control Inspection Test.* Inspection of controls in accordance with principles and recommendations in the referenced volume (Section 3.5.1.2.).

3.5.1.7.2. *Acceleration Test.* Accelerations will be measured by means of accelerometers in the head or chest cavity of an anthropometric dummy which is seated in a wheelchair on the platform. The wheelchair and dummy weight will be supplemented to a total weight of 400 pounds (1780 N). Accelerometer readings will be taken for all lift motions on which an occupant is carried.

3.5.1.7.3. *Slope Dimension Test.* The empty platform will be lowered to the ground position with the ramp, if any, at its entry/exit position. Linear measurements of rise and run will be made. Likewise, any step over which the wheelchair must roll will be measured.

3.5.3.1. *Visual Inspection.* A visual inspection shall be made as to the inclusion of the required Operating Instructions and the suitability of the contents.

3.6.9.1. *Occupant Hazards Test.* The fully assembled and installed wheelchair lift shall be carefully inspected with regard to safeguards, sharp edges, projections, and dirty or greasy surfaces with which the occupant might come in contact during normal operation of the lift.

3.6.9.2. *Slip Resistance Test.* The wheelchair platform shall be inspected for utilization of slip-resistant surfaces on which the wheelchair rolls. Slip-resistant characteristics will be observed in these cases when the platform is at ground and at floor level: occupant in manual wheelchair onto/off of dry and wet platform; occupant in electric wheelchair onto/off of dry and wet platform.

3.6.9.3. *Platform Opening Test.* The platform will be positioned at ground level and at van floor level, and all openings therein will be tested with a metal ball of 3/4 inch (19.1 mm) diameter for oversize dimensions.

3.6.9.4. *Operational Safety Test.* The fully assembled and installed wheelchair lift shall be operated by both able-bodied and disabled persons, in the manner specified in the Operating Instructions, and observations made as to whether the lift can be operated safely, with minimum potential to injury. Observation shall be made as to a requirement for an on-platform turning movement of the wheelchair. Observations shall be made of the floor level stop position as to safe entry/exit of the wheelchair into/out of the van.

3.6.9.5. *Wheelchair Retaining Test.* Test equipment will be constructed to fit each wheelchair retaining device. The equipment will apply a static load of 1600 pounds at a height of three (3) inches above and parallel to the wheelchair ground plane, evenly distributed over the full width of the roll stop device. The load will be applied for at least five (5) seconds with the lift platform at the van floor level and also will be applied as the wheelchair ground plane moves down (or up). A load of 400 pounds will be on the lift during the test if the wheelchair retaining operation is dependent on such a load for its proper operation.

4.1.2.4. *Visual Inspection.* A visual inspection will be made as to the inclusion of required Installation Manual and the suitability of its contents and of the existence of the necessary installation hardware.

4.2.7.1. *Visual Inspection.* A visual inspection shall be made to determine the inclusion of a Maintenance Manual and its compliance with Section 4.2.3. and of the inclusion of documentation as required by Section 4.2.4.

4.2.7.2. *Maintainability Test.* The maintenance procedure prescribed by the manufacturer shall be performed to ascertain compliance with Sections 4.2.5. and 4.2.6.

5.7. *Visual Inspection.* Each lift shall be inspected for the inclusion of the required identification tag, evidence of manufacturer's quality control inspection, and for inclusion of the required Warranty Statement.

3.3.1.3.1. *Accelerated Life Cycle Test.* An accelerated life cycle test will be performed by repeating the wheelchair lift use cycle 4400 times. The time between each cycle shall be not less than six minutes. Ambient temperature shall be between 50° F and 90° F (10° C and 32° C). Alternating cycles of loaded and unloaded platform configuration will be simulated by applying a 400 pound (1780 N) load for 100 cycles, then removing the load for 100 cycles. Periodic visual inspection without disassembly of the lift will be made in intervals of 550 cycles and changes in alighment, component wear, loosening of fasteners, and the like will be recorded. Failure mode analyses will be performed and a decision will be made based on those analyses. Preventive maintenance will be performed in accordance with the manufacturer's instructions.

3.3.2.6.1. *General Electrical Test.* Electrical components and wiring shall be considered integral parts of the lift system and shall be tested for failures during the performance of Accelerated Life Cycle Testing, Section 3.3.1.3. Any failure or any hazardous condition caused by an electrical component during test shall disqualify the entire system from acceptance.

3.3.3.2. *Chain Drive Test.* Chain drive components shall be considered integral parts of the lift, and shall be tested for failures during the performance of the Accelerated Life Cycle Test, Section 3.3.1.3., and inspected for conformance to the above standards. Discrepancies in conformance or failures during the test shall disqualify the lift from acceptance.

3.3.4.3. *Hydraulic Components Test.* Hydraulic components shall be considered integral parts of the wheelchair lift and shall be tested for failures during the performance of the Accelerated Life Cycle Test, Section 3.3.1.3. Any failures, including significant leaks, shall disqualify the lift from acceptance. A significant leak is defined as seepage or leakage which produces one or more droplets (e.g., a teardrop, approximately 0.1 cc) in ten (10) complete cycles of the wheelchair lift.

3.3.5.4. *Wire Rope System Test.* An inspection of the wire rope system shall be made and shall include measurement of the nominal diameters of rope, sheaves, and drum. The fleet angle between the lead sheave and drum and between sheaves at all platform positions shall be measured. Attachments and fittings shall be inspected for conformance to Section 3.3.5.3. The travel of the rope during all lift movements shall be followed to observe possible rope contact with structural members.

3.4.2.3. *Fastener Tests and Inspection.* Fasteners shall be considered as integral parts of the lift system and shall be tested for wear, integrity, and resistance to loosening or loss through vibration or use conditions. Such testing and inspection will be done during the Accelerated Life Cycle Test, Section 3.3.1.3.1.

3.3.6.5. *Power Screw Tests.* The threads on the power screw shall be inspected to ensure that Acme screw threads (or equivalent) are used and that the system transmits power in both directions.

3.3.1.3.2. *Static Load Test.* A static load of 2400 pounds (10676 N) shall be applied through the centroid of a test pallet placed at the centroid of the platform when the platform is positioned at van floor level. The length and width dimensions of the test pallet shall be 23" length X 23" width to correspond to the approximate outer dimensions of a wheelchair "footprint". The load shall remain on the platform not less than two (2) minutes. After the load is removed, an inspection shall be made to determine if fractures have occurred. An equivalent test shall be performed on lifts which do not have a platform. The Static Load Test shall be performed after the Accelerated Life Cycle Test.

APPENDIX 1 – METRICATION

The use of SI (metric) units is in conformance with SAE J916a, Rules for SAE Use of SI (Metric) Units. Examples of conversion to SI units are given below.

1. From Section 3.1.3., related to lift speed fo four (4) inches per second. Convert to centimetres per second (cm/s).
   a. Estimate the implied precision of the value to be ± 0.1 inch per second. Then Total Implied Precision (TIP) = 0.2 inch per second.
   b. Convert values to metric units

$$\frac{4 \text{ inches}}{\text{sec}} \times \frac{2.54 \text{ cm}}{\text{inch}} = 10.16 \text{ cm/s}$$

$$\frac{0.2 \text{ inch}}{\text{sec}} \times \frac{2.54 \text{ cm}}{\text{inch}} = 0.508 \text{ cm/s}$$

   c. Choose the smallest number of decimals to retain, such that the last digit retained is in units equal to or smaller than the converted TIP. In this example use 0.1 cm/s since it is the next unit smaller than 0.508 cm/s.
   d. The converted, rounded value is then given as 10.2 cm/s.
2. From Section 3.1.7., related to a weight of 275 lb. Convert to newtons (N).
   a. Estimate implied precision as ± 5 lb. Then TIP = 10 lb.
   b. Convert values to metric

$$275 \text{ lb} \times \frac{4.448222 \text{ Newtons}}{\text{lb}} = 1223.26105 \text{ N}$$

$$10 \text{ lb} \times \frac{4.448222 \text{ N}}{\text{lb}} = 44.48222 \text{ N}$$

   c. Use 10 N for rounding
   d. Then 275 lb = 1220 N

APPENDIX 2 – REFERENCES

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B. Testing

1. *Upper-Limb Components*

a. *Internal Elbow Assembly.* Tests have been performed on the Internal Elbow Assembly submitted for annual compliance testing by Hosmer Dorrance, Inc., Campbell, California (BPR 10-27, page 117). The test sample complied with *Tentative Specifications for Adult Size Elbow, Artificial, Internal, Alternating, for Above-Elbow Amputees.*

b. *APRL Voluntary Closing Hook.* Tests have been performed on the APRL Voluntary Closing Hook submitted for annual compliance testing by Hosmer-Dorrance, Inc., Campbell, California (BPR 10-27, page 117). The test sample complied with *Tentative Standards for Hook, Mechanical, Voluntary Closing, for Upper-Limb Amputees.*

2. *Stump Socks*

Special shrinkage tests were completed of stump socks submitted by Knit-Rite, Inc., Kansas City, Mo., and the Ohio Willow Wood Co., Mt. Sterling, Ohio. All items tested complied with current requirements.

3. *Wheelchairs*

a. Two Everest and Jennings (E & J) "Premier" model (No. P8ULD 260-770) wheelchairs; one Invacare "Elite" model wheelchair with pneumatic tires; and two LEM Power Wheelchairs were tested and evaluated. The E & J and Invacare wheelchairs complied with current specifications. The LEM wheelchairs were laboratory tested and the results were sent to our Clinical Evaluation Service at the VAH, Castle Point, New York.

b. A wheelchair transfer attachment submitted by Icarus Health Aids, Ltd., Netanya, Israel, and a wheelchair shock absorber submitted by National Handicrafters, Inc. of Decatur, Georgia, were tested. The results were sent to our Clinical Evaluation Service at the VAH, Castle Point, New York.

III. THE VAPC CLINIC TEAM

The statistical breakdown (Table 1) of the veterans treated by our clinic team for the first half of 1978, represents a typical 6-month case load similar to those presented in previous BPR reports. Of the total treated, 8 were World War I veterans, 474 were World War II veterans, 14 were Korean War veterans, and 152 were Vietnam War veterans. Treatment of 480 was for service-connected injuries, and 168 were non-service connected. In addition, 10 Israeli and 2 Canadian veterans, and 4 non-veterans were treated.

TABLE 1.—*Statistical Breakdown of Patient Disabilities: January 1, 1978 to June 30, 1978*

Area of involvement	Specific level of involvement	Number of patients
	Amputation	
Lower-limb unilateral	Below-Knee	189
	Above-Knee	130
	Transmalleolar (Syme's)	14
	Hip (Disarticulation)	12
	Mediotarsal (Chopart)	1
Lower-limb bilateral	Below-Knee	16
	Above-Knee/Below-Knee	3
	Above-Knee	6
	Transmalleolar (Syme's)	3
Upper-limb unilateral	Below-Elbow	9
	Above-Elbow	4
	Hand	1
	Wrist Disarticulation	1
Upper-limb bilateral	Above-Elbow	2
	Below-Elbow	2
	Shoulder Disarticulation	1
Triple	Above-Knee/Below-Knee/Below-Elbow	1
	Above-Knee/Below-Knee/Above-Elbow	1
	Above-Knee/Below-Elbow/Below-Elbow	1
	Below-Knee/Above-Elbow/Hip Disarticulation	1
	Below-Knee/Below-Knee/Below-Elbow	1
		399 Total
	Neuromuscular or Skeletal Impairment	
Lower-limb unilateral	Ankle-Foot	134
	Knee-Ankle-Foot	19
	Knee	11
Lower-limb bilateral	Ankle-Foot	9
	Knee-Ankle-Foot	4
	Ankle-Foot/Knee-Ankle-Foot	1
Upper-limb unilateral	Arm-Elbow-Forearm; Wrist-Hand	10
Trunk	Lumbosacral spine	9
Miscellaneous	Varied (Wheelchairs, shoes, etc.)	52
		249 Total