CHAPTER 4
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Reacher Arm for Quadriplegics

Designer: Tracee Lancaster
Client Coordinafors: Mike White and Donnie Prissock
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INTRODUCTION

The limited use of the arms and hands of C5 quadriplegics makes retrieving dropped items difficult. A motorized reacher arm was developed to aid in this task. This device (see Figure 4.1) attaches to a wheelchair and is designed to be capable of retrieving up to two pounds from a variety of positions. Upon activation of one switch, the arm rotates to the position of the item (usually the ground). Pressing another switch clasps the item. The arm is then returned to a position where the user may retrieve the item by activating the first switch again. Should the item not be directly beside the wheelchair, the mounting device acts as a hinge allowing the arm to be rotated away from the side of the chair.

SUMMARY OF IMPACT

This device allows quadriplegics a more independent life style. Previously, the retrieval of a dropped item from a wheelchair required the aid of another person. Through the use of this device, a person is able to retrieve items in front of the arm. The range of motion and the arm strength of the user determines the distance from the side of the chair to which the arm will be able to retrieve items.

TECHNICAL DESCRIPTION

The design considerations include:

- the user would have little or no pinching force in hands
- the user would have limited arm strength and control
- the physical restrictions of the user would vary with person
- the mechanical arm must be compact
- the arm must be able to lift two pounds (average weight of a typical textbook)

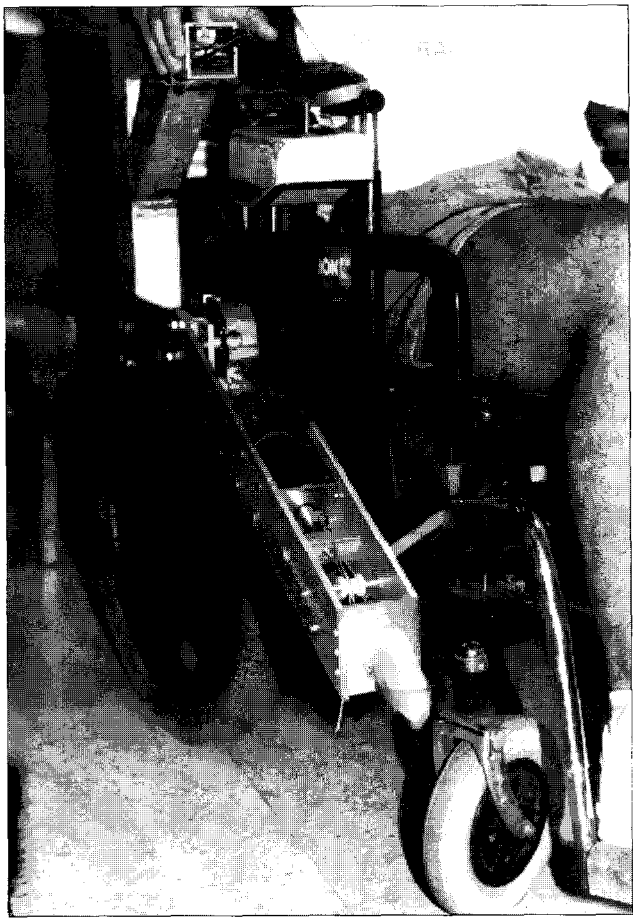

Figure 4.1. Side View of Reacher Arm Attached to Wheelchair.

An electrical device is utilized because it would be usable by more than one quadriplegic. The device is made from 2” wide aluminum square tubing, and attaches directly to the wheelchair. The device also uses the wheelchair’s battery. The motor, from an automotive power window system, is mounted 15" from the arm rest of the device. The motor rotates a 13" arm with a CAPP terminal device (prosthetic hand attachment by Hosmer Dorrance Corporation) attached. A Ledex solenoid (model TDS 16B) is used to open the hand. A momentary toggle switch is used for the control of the rotational motor while an on/off push button is used for activation of the solenoid.

Problems encountered with the device involved the use of the selected motor in that it did not have sufficient torque capacity. A modification in future models should include a gear box to increase the applied torque.

Device mounting is through an aluminum plate that fits around the supports for the wheelchair arm rest. This plate maintains a 4" distance for the toggle switch used to control the wheelchair. The mounting device acts as a hinge, allowing the arm to be rotated away from the side of the wheelchair. This angle is determined by the arm strength of the user.

Including the distance maintained for the wheelchair control switch, the entire device is only six inches wide and weighs 15 pounds.

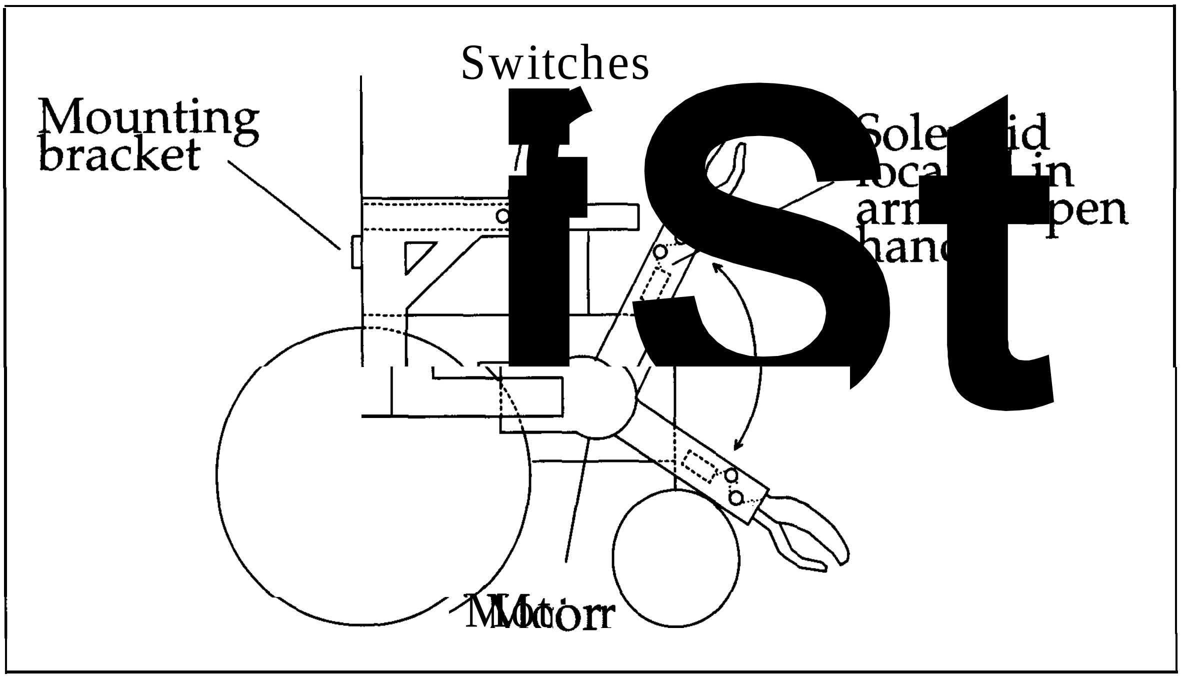

Figure 4.2. Schematic of the Reacher Arm.

Paraplegic Exercise Bike

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INTRODUCTION

The Paraplegic Exercise Bike (Figure 4.3) was designed for a paraplegic student at Mississippi State University. The purpose of building the bike is to provide a safe form of exercise for the student. The basic idea for the project is the conversion of a linear force produced by the upper extremities into a rotational motion implemented upon the lower extremities. The feet are strapped into pedals as in a normal bicycle. The back and forth action of the arms turns an upper sprocket which, through a chain, turns the peddles of a lower sprocket and exercises the paralyzed legs. The bike is usable from a wheelchair and is adaptable for different user sizes.

SUMMARY OF IMPACT

The Paraplegic Exercise Bike offers several advantages to the user. The bike provides physical therapy without outside help and improves self-confidence. It improves circulation to the lower extremities and prevents spasms and atrophy.

The bike is versatile in that it can be completely disassembled and easily moved. It can be used both indoors and outdoors from the wheelchair. Once the individual's feet are strapped to the pedals, upper and lower body exercise (active and passive) can proceed.

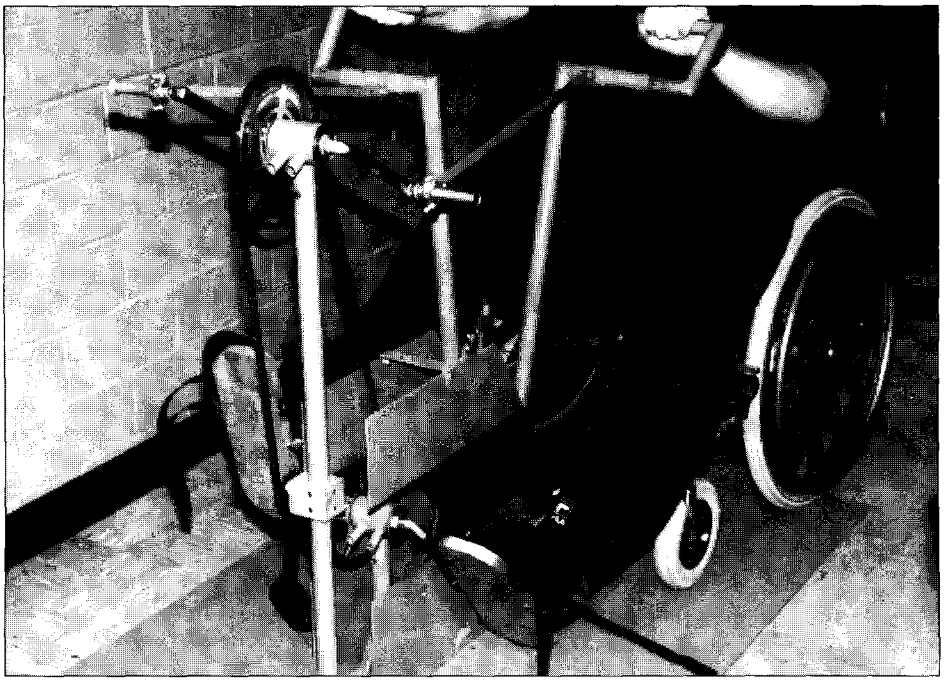

Figure 4.3. Paraplegic Exercise Bike

TECHNICAL DESCRIPTION

There are a number of concepts around which the Paraplegic Exercise Bike was built. The bike needed to be non-mobile, usable from a wheelchair, resistive to the lower extremities, adaptable for different user sizes, and able to be operated from push/pull upper extremity motion.

The design (Figure 4.4) was based on that of an ordinary bicycle. Five basic components were incorporated into the design: (1) heavy steel base plate, (2) wheelchair as counterweight, (3) pedals with straps, (4) upper sprocket and chain enclosed, and (5) lower sprocket connected with base supports. The upper sprocket and lower sprockets were roughly the same size. The upper sprocket has connecting rods on either side that extend to handles. This can be seen in Figure 4.3. The user in the wheelchair pushes and pulls alternately on the handles to create the rotary motion of the sprocket. The lower sprocket is driven by the connecting chain and thus the feet (strapped to the pedals) and legs are forced into a typical motion required when operating a bicycle.

Special design was also required for the pedals since this would be the one area of uncontrolled contact between the user and the device. The pedals were made of aluminum to allow for maximum support without compromising strength from excessive wear. The pedals need nylon straps with Velcro in order to obtain easy access and maximum security. A heel support is required in order to allow easy placement of the extremity onto the pedal.

The overall weight of the exercise bike is between 170 and 200 pounds. The cost of the bicycle is $500.

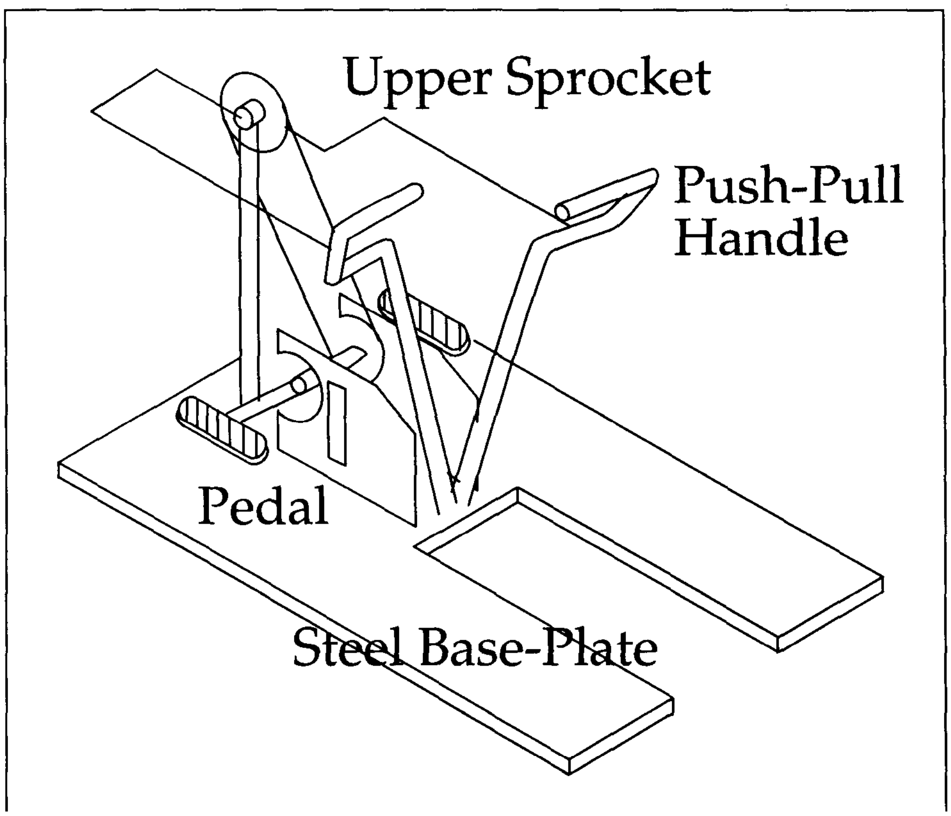

Figure 4.4. Schematic of the Paraplegic Exercise Bike.

Convertible Top for Wheelchair

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INTRODUCTION

Many wheelchair bound people cannot easily use umbrellas. At times they may need both hands to operate the wheelchair, or sometimes, they might have difficulty holding an umbrella in violent weather. A convertible wheelchair top is designed as a "hands free" method to keep people in wheelchairs dry in the rain (Figure 4.5). The design consists of four major parts: the mounting bracket, the arm mount/swing arm assembly, the canopy frame, and the canvas cover. The entire apparatus does not need any tools for assembly or disassembly. The bracket is attached to the wheelchair back. The arm mount slides into the top of bracket. The swing arms connected to the arm mount are linked to the canopy frame, and the canvas cover goes over the canopy. The canvas cover is easily removable for cleaning or replacement. Once the top is attached to the back of the wheelchair, the canopy can be either kept in the lowered position or lifted and locked into the raised position. The convertible wheelchair top is usable for a wide range of different sized people, and attaches easily to most wheelchairs.

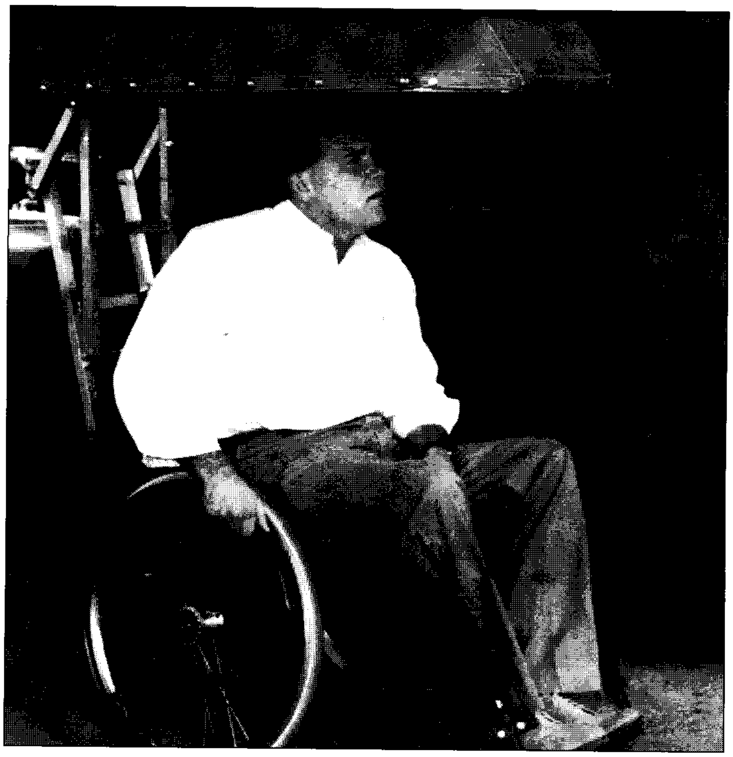

Figure 4.5. Convertible Top Mounted on a Wheelchair.

SUMMARY OF IMPACT

The convertible wheelchair top provides people in wheelchairs with effective coverage in the rain. People can use their hands freely in rainy weather and still have the same protection that an umbrella provides. One possible improvement for this device is to reduce the size of the apparatus. As it is, the device is a little bulky. This can be a problem when the user maneuvers through narrow passageways, needs to transport the device, or needs to assemble it quickly.

TECHNICAL DESCRIPTION

The first consideration in the design of the convertible wheelchair top is its dimensions. The device needs to be high enough to allow a tall person to fit under it comfortably and low enough for a short person to raise the canopy to the inclined position. Anthropometric data obtained from "Designing for the Disabled" by Seldwyn Goldsmith is used to set the dimensions. The maximum height and eye level are set for the 95th percentile, and the minimum reach is set for the 5th percentile.

As stated previously, the design consists of four major parts, as illustrated in Figure 4.6. The mounting bracket is attached to the back of the wheelchair. The attachment or removal of the bracket is done with a threaded rod and requires no tools. The arm mount/swing arm assembly slides into the mounting bracket. The swing arms are the mechanism for raising or lowering the canopy. The arm mount/swing arm assembly is arranged in a way that prevents interference between the apparatus and the wheelchair wheels, while it still accommodates the anthropomorphic data. The swing arms attach to the canopy frame. When the top is raised, a spring lock is used to maintain the device in its position. The canvas covering goes over the canopy frame. The cover is fastened with heavy duty buttons in the rear and Velcro in front. The Velcro easily releases to keep the wheelchair from being blown over in heavy winds. The buttons keep the covering from flying off completely. The covering can be easily removed either for cleaning or replacement.

The design fits most wheelchairs, but, if the diameters of the vertical bars on the wheelchair back are greater then 1", or the back leans at too great an angle, then the design won't fit. This can be easily corrected by re-designing the mounting bracket. No other parts need modification.

Stress analysis done on the design revealed the weakest point in the structure is the mounting bracket. The factor of safety at this point is 103.5; this safety factor is more than enough to handle high winds or collisions.

The majority of the design is made of 16 gauge aluminum tubing and $\frac{1}{4}$" steel plate. The total cost of this project is $120.82.

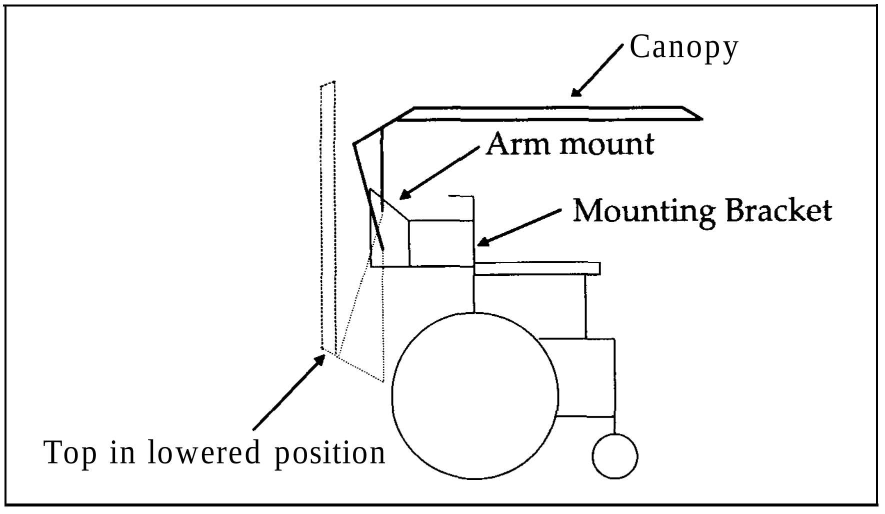

Figure 4.6. Schematic of the Convertible Top Showing Raised and Lowered Positions.

Increasing the Stability of a Hand-Powered Tricycle for Disabled Children

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INTRODUCTION

The Telephone Pioneers of America produce hand-powered tricycles for physically handicapped children with leg disabilities. The Children's Rehabilitation Clinic in Jackson, Mississippi purchased a number of these tricycles, and has experienced problems with many of them. Some of the children who use the tricycles have under-developed legs and are top heavy. This top heavy condition places the center of gravity relatively high for the given supported area of the tricycle. Consequently, the high center of gravity results in a tendency for the tricycles to tip over when used. This tipping tendency is a particular problem because many of the children at the rehabilitation center are more frail than average children.

To improve stability, the tricycle's frame was redesigned. The front wheels and rear wheel base were extended to expand the supported area, and the seat placement was changed to relocate the center of gravity. The chain assembly was altered and the hand pedals were repositioned to compensate for the modifications in the frame. Existing parts were used when possible to minimize expenses. The modified tricycle is shown in Figure 4.7.

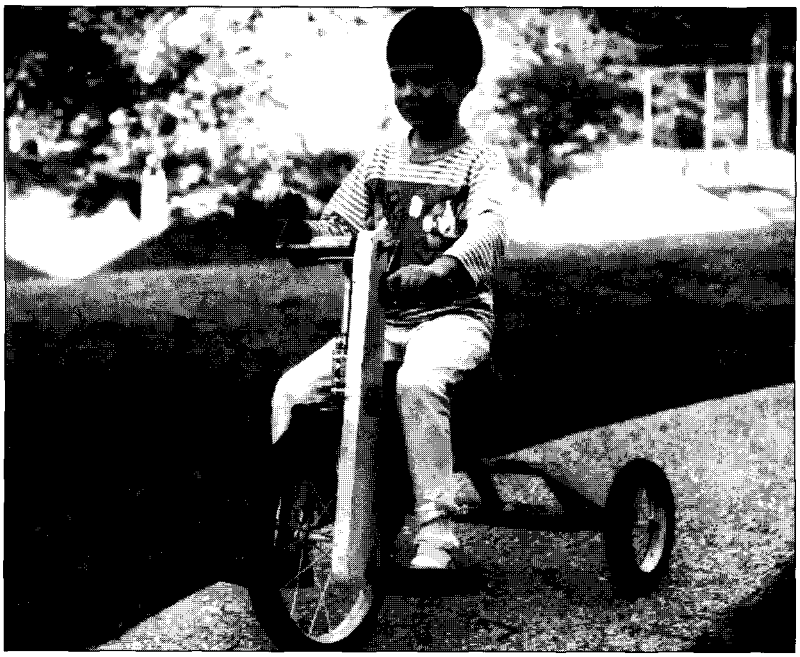

Figure 4.7. Hand-Powered Tricycle.

SUMMARY OF IMPACT

The original concept of a hand-powered tricycle by the Telephone Pioneers of America has many benefits. The tricycle is a useful recreational outlet for physically disabled children. It is a good opportunity for either outdoor or indoor recreation, while it supplies the benefits of enjoyable exercise. The tipping tendency, however, is a problem.

Some of the children who are in physical rehabilitation are physically more fragile or less coordinated than normal children. Because of these conditions, the tricycle's lack of stability is a particular problem. The tricycle with the modified design is definitely more stable than the original version. The center of gravity has been shifted downward by 3%, and the base of support has been increased by 51% as shown in Figure 4.8. Although it is still possible to tip the tricycle over, the modified tricycle is safer and, therefore, an improved form of recreation for disabled children.

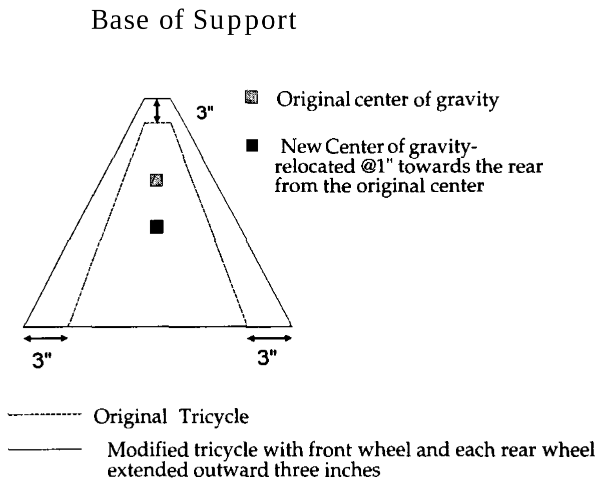

Figure 4.8. Schematic of Supported Areas.

TECHNICAL DESCRIPTION

The reason why there is an instability in the tricycle is the center of gravity is too high for the tricycle's provided supported area. Therefore, the tricycle can be made more stable by both repositioning the center of gravity and expanding the supported area.

The new frame bar on which the seat is mounted has been modified. It has been lengthened, and the new seat mounting is lower and nearer to the rear wheel base than in the original tricycle. These changes lower the center of gravity by about 0.96 cm and move it towards the back of the tricycle by about 2.54 cm.

The new frame bar extends the front wheel by 7.6 cm. The new rear wheel axle is 15.24 cm longer than the original axle. The frame supporting the axle is modified to sustain these changes. These extensions increase the stability of the tricycle by expanding the supported area as shown in Figure 2. The chain assembly and hand pedal are altered to compensate for the frame modifications.

Calculations were made to determine the attainable angular velocities for operation without tipping for the original and modified tricycles. The tricycles were assumed to be traveling along a curve having a fixed radius. The attainable angular velocities show the modified tricycle to have an increase in stability over the original tricycle by more than twenty-five percent. In other words, the modified tricycle can attain an angular velocity twenty-five percent greater than the original tricycle can.

Stress analyses show the weakest point due to the tricycle's alterations is in the elongated rear wheel axle. The maximum stress due to bending in this piece is 11157 psi. This stress value is far below the allowable value that is 100 ksi for steel. Costs were kept to a minimum by using existing parts from the tricycle whenever possible. The only new materials were for the extended frame bar, rear wheel support frame, and the new rear axle. The total cost of the project was approximately $35.

Elevator Button Pusher

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INTRODUCTION

The Elevator Button Pusher was designed to aid disabled Mississippi State University students in opening elevator doors without assistance (Figure 4.9). Many wheelchair bound students are incapable of reaching the buttons used to control elevators. One of the users of this device has shortened limbs due to osteogenic imperfecta and literally cannot reach beyond the confines of her wheelchair. The Elevator Button Pusher allows this student and others to perform the task of operating an elevator without reaching for the buttons.

SUMMARY OF IMPACT

The Elevator Button Pusher was tested by several clients and found to work well for its intended purpose. The users felt that the device was an acceptable weight and easy to handle in both the vertical and horizontal positions. The device was found to be useful for opening doors that have handicap easy door handles. Several other disabled students have requested one of these devices; Mississippi State University is complying with their request.

Figure 4.9. Elevator Button Pusher.

TECHNICAL DESCRIPTION

The project was designed to meet five basic objectives. The device was to be: 1) lightweight, 2) collapsible, 3) sturdy, 4) easy to operate, and 5) affordable.

The device (Figure 4.10) that was constructed utilized a telescoping design of approximately thirty inches in length. The device was to consist of three sections, each approximately ten inches in length. The major problem in the design project involved joining the three sections. A lever-button locking mechanism was chosen. For practical purposes, the locking mechanisms are placed on the outside, rather than inside the sections. When the lever is depressed, the round, irregular shaped portion of the lock exerts a force against the sections, thereby locking them into place. When unlocked, the small flat portion of the mechanism is exposed, which allows the sections to move freely.

Since the construction of the telescoping mechanism is difficult to fabricate from basic components, a standard camera tripod is utilized. The tripod is light-weight aluminum and has locking tabs. The tripod has a maximum extension of thirty-five inches and is collapsible to fourteen inches. Due to cost and weight consideration, a photographic tripod is more appropriate than a video tripod. The Slik 500GFL is used in the device since it is light weight and has quick release lever locks. These locks are aligned in a row so that they may be released with one hand and can be locked at any length. A soft rubber hand grip is mounted at the proximal end for ease in handling.

Compression test results for the device establish that it can withstand 37.25 pounds before slippage. This was more than sufficient for the intended task.

The major cost in constructing the device is the cost of the tripod. The hand grip was generously donated by GripWorks of St. Louis. The total cost of the device is approximately $30. However, since three devices can be assembled from one tripod, the individual cost is approximately $10.

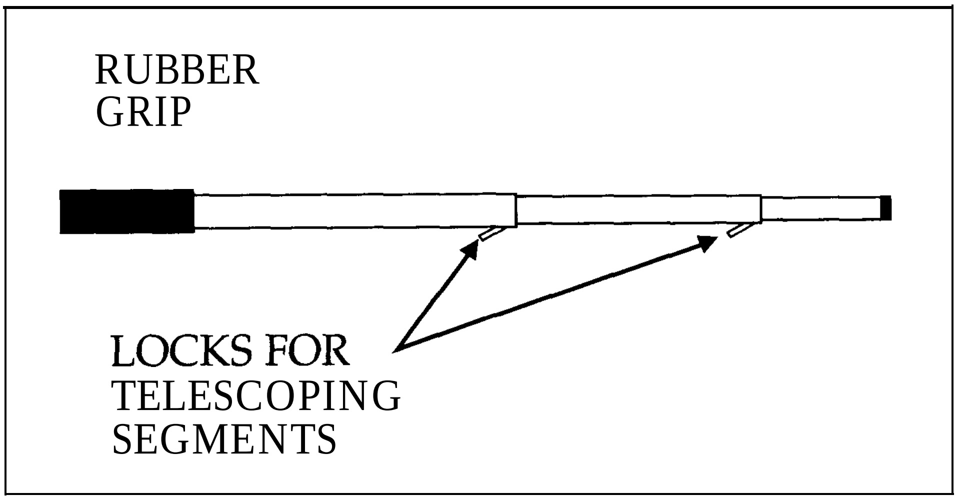

Figure 4.10. Schematic of the Elevator Sutton Pusher.

Backyard Waterfall for Physically Disabled Children

Designers: Philip E. Towles, Elizabeth Welch
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INTRODUCTION

After visiting the children's physical rehabilitation clinic at the University of Mississippi Medical Center, we felt the playground needed some equipment with which the children could have fun. After discussing several ideas with Dr. Graves, a pediatrician at the clinic, we decided to design a waterfall system (Figure 4.11). The idea was to build a structure to allow the children to get only their hands and arms wet. We came up with the idea of modules at different heights for different size wheel chairs that would allow the children to simply roll their wheelchair up to a module and play in the water. Water, pumped from a reservoir, runs from the tallest module to the shortest and back to the reservoir where the water is again recycled to the tallest module. The water in each module is held in a removable pan that can eventually be replaced if needed, and each module was built so that it could be easily removed from the ground if necessary.

SUMMARY OF IMPACT

For many physically handicapped children, there is little playground equipment that they can use safely. In fact, it is difficult to get the children to be active outdoors. We decided water would be a relatively harmless toy that could provide lots of fun. The children who encountered our design as we were installing it were ecstatic. One of the children proclaimed, "Water!". When we were finished installing the design, we felt that possibly a larger pan could be designed for the modules for future design projects, but as for the design as a whole, we felt that the design worked very well.

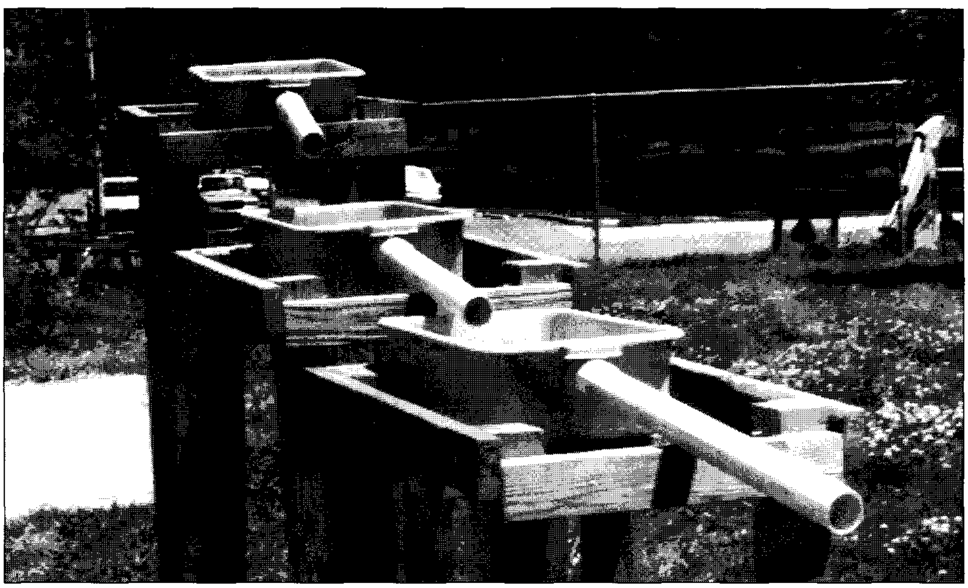

Figure 4.1 1. Backyard Waterfall for Handicapped Children

TECHNICAL DESCRIPTION

Three modules, all of different heights, were built for the design (Figure 4.12). Treated lumber was used to make each module, which was connected together with nuts, bolts and nails. The four supports, 4×4's, of each module were buried approximately one foot in the ground. The 2x4's bolted on the outside and top of each support formed a frame for each module. Three additional 2×4's, the supports for the pan, were nailed to the bottom of the 2x4's that created the frame.

For the reservoir, a plastic trash can was used. A hole was cut into the trash can for the submersible pump; the pump was secured to the bottom of the trash can and then the hole was sealed. A hose was then connected to the pump, and a screen was installed to prevent trash from clogging the pump. The reservoir is first filled from a water faucet. A minimum of three gallons of water must be in the reservoir at all times for safe operation.

The three pans used are all made of plastic. A hole was cut out of one end of each pan, and PVC pipe was placed in each hole. A short piece of PVC pipe was cut and placed in the hole of each pan so that half of the short pipe hung out of the inside and outside of the pan. Then two couplings, one on the inside and one on the outside of the pan, were placed on either end of the short piece of PVC pipe and pushed onto the pipe. This allowed the couplings to pinch the side of the pan with the hole in it and give support to the pan when the longer piece of PVC was added to the outer coupling. With the pans installed, the PVC pipe allowed the water to run relatively slow and splash free to the next pan with no leaking. The pump has a relatively low output velocity so the children can play in relatively still water.

The final cost of the design had to be estimated since the shop in the department actually built the wooden modules. The estimated cost was $250 for the entire design.

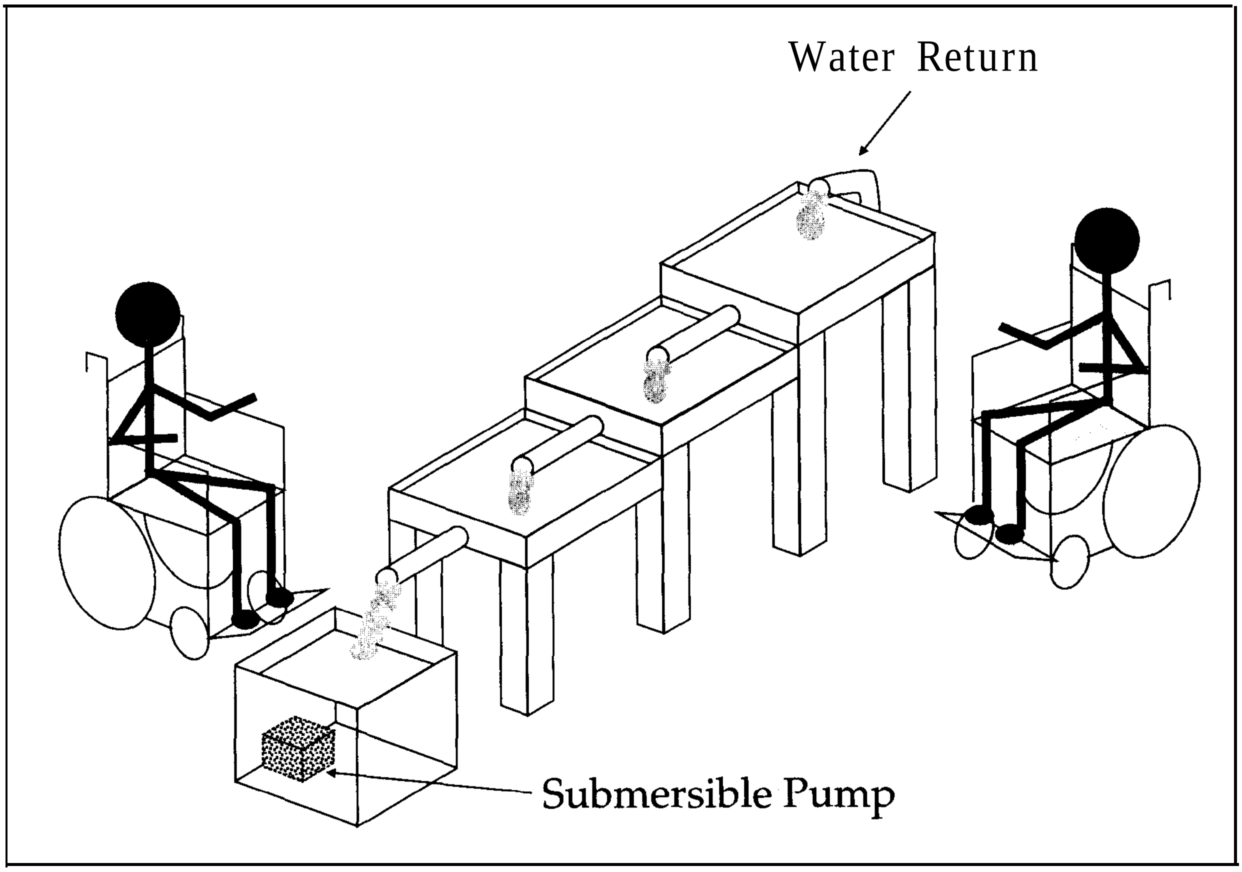

Figure 4.12. Schematic of the Backyard Waterfall.

A Pump Assist Device

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INTRODUCTION

The idea for a pump assist device came from Wanda Mills, a physically disabled student. Wanda is afflicted with osteogenesis imperfecta, which means brittle bones. Other characteristic features of this disease include dwarfism and muscle atrophy. As a consequence, Wanda has limited hand strength. She is unable to use spray bottles because of the finger strength and coordination required. However, she is capable of a gripping motion by using her whole hand. A pump assist device is important to Wanda because she uses products contained in these bottles on a daily basis. This device allows Wanda to be more independent instead of relying on other people to help her with simple tasks.

SUMMARY OF IMPACT

A device was designed to accommodate spray pump bottles so that a hand gripping motion would depress the pump piston on the top of the bottle as shown in Figure 4.13. Wanda tested the device on several bottles. She found that the device did work on several different sized bottles such as hair spray bottles and throat spray bottles. With either hand, she was able to squeeze the handles together without problem. In addition, she was able to remove the device from empty bottles and place it on other bottles without assistance.

Figure 4.13. Pump Assist Device Being Used by Client.

This type of device makes it possible for Wanda to use a wide variety of spray bottles without assistance, and use several different types of products that she never used before. She now uses cleaning products, personal care products, and air fresheners without having to depend on assistance from someone else.

TECHNICAL DESCRIPTION

The main design factors to consider are that the device be adjustable to fit a variety of different sized bottles and that it be easy for Wanda to use. The device needed to be large enough to fit over the tallest pump, but still depress the shortest pump enough so that it would spray. The device must also be large enough to fit around the bottle with the widest neck, but still be able to hold smaller bottles firmly in place.

The device, shown in Figure 4.14, is constructed from aluminum because it is easy to work with and is not damaged by the chemicals in the products used by Wanda. The top piece fits over the bottle and will deflect a minimum of $\frac{1}{4}$" to depress the pump. The bottom part of the device slips around the neck of the bottle to hold the device in place. Both of these pieces are attached to handles. A spring in tension is used to straighten the handles after they have been squeezed. The force of the spring is very small so that Wanda can squeeze the handles without difficulty. The top piece of the device has a screw located $\frac{1}{2}$" from the left side. This makes the device adjustable so that it can be used for bottles of various heights. This piece is connected to a long handle by a No. 8 screw.

The bottom part of the device consists of two pieces. The bottom part is $\frac{1}{8}$" thick, except for a $\frac{1}{32}$" rim on the inner surface. This piece was designed to be thin enough to slip under the cap of the pump without first having to loosen the cap. However, due to the thinness of this piece, it is not sturdy enough to support a handle. The semicircular piece has a larger inside radius and the same outer radius as the thin piece. These two pieces are attached by two screws with the thin piece below the thicker piece. The screws are countersunk in the thin piece to keep from adding extra thickness preventing the piece from sliding under the cap. The ends of the screws protrude above the surface, and are useful when dealing with smaller bottles because a rubber band can be fastened between them.

The materials needed to make the device cost under $20. In addition, several hours of machinery time were involved in the construction of the device.

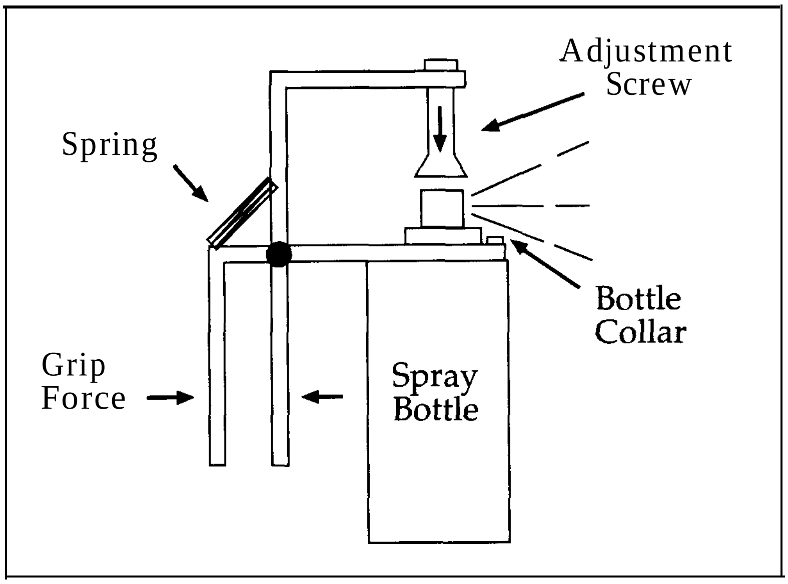

Figure 4.14. Schematic of the Pump Assist Device.