CHAPTER 17
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ADAPTATION OF A RIDING LAWNMOWER FOR A PERSON WITH PARAPLEGIA

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INTRODUCTION

The purpose of this project was to adapt a riding lawnmower (Simplicity 6200) so that a person with paraplegia could operate it, while still maintaining the standard operation for use by able-bodied family members. The clutch and seat were modified. A clutch lever arm assembly was designed and built to allow the client to depress the foot pedal using hand and arm movements instead of leg and foot movements. The seat was replaced to provide maximum support for the client's upper body and allow for easy transfer from a wheelchair.

SUMMARY OF IMPACT

A clutch lever arm assembly was designed, built and installed in a lawnmower to allow the client to operate it without use of his legs. This assistive device will allow this person to gain more independence in his daily living activities, thereby contributing to the improved quality of life for him and his family.

TECHNICAL DESCRIPTION

Operation of the lawnmower requires depressing a foot pedal (clutch pedal) to engage the brakes and simultaneously disengage the drive shaft. While the foot pedal is depressed, the gears can be changed. Releasing the foot pedal disengages the brakes and engages the drive shaft. Therefore, modifications of the clutch and seat were necessary to adapt this lawnmower for use by the person with quadriplegia.

CLUTCH LEVER ARM ASSEMBLY, DESIGN, AND INSTALLATION

The existing clutch is foot controlled, thereby eliminating the opportunity for a person with paraplegia to operate the lawnmower. A clutch lever arm assembly was designed, manufactured, and installed to allow the drive system of the lawnmower to be engaged and disengaged using the operator's hands and arms.

The drive system of the lawnmower is a variable speed pulley system. The distance the foot clutch will travel backward, as the drive system of the lawnmower engages, is contingent on the gear of the drive system. For example, if the drive system is in first gear, the return travel of the clutch will be approximately one inch. Accordingly, if the drive system is in second gear, the return travel of the clutch will be approximately two inches. In the highest gear of the lawnmower, the return travel will be equal to the total return travel of eight inches. The design of the clutch assembly must allow for the varied return travel distance of the clutch.

Design criteria included that:

- The modified clutch assembly provide a stopping time the same or better than that for the existing foot-controlled clutch;
- The drive system remain disengaged without assistance from the operator once the drive system is disengaged;
- Potential leg and foot obstructions for the operator be eliminated;

- the clutch assembly be easily removable, so family members can operate the lawnmower with the foot-controlled clutch;
- it be cost effective;
- The structural integrity of the original mower be maintained; and
- The new clutch assembly be safe.

Several possible solutions were considered, including a hydraulic cylinder assembly, a screw drive motor assembly, a cable and pulley system, and a clutch lever arm assembly with a bottom pivot or center pivot. The clutch lever arm with a bottom pivot was selected. A lever arm, pivoted at the bottom with a rod hinged through a hole approximately six inches above the bottom of the lever arm, was connected to the clutch pedal. The lever arm assembly, located on the clutch side of the lawnmower, was mounted on the footrest. Pushing the lever arm forward forced the hinged rod forward and in turn disengaged the clutch and drive system of the lawnmower.

The design and manufacture of the clutch lever arm assembly included three components: clutch lever arm, push pull rod, and clutch pedal. Each of these included design of new parts, modifications of existing parts, and calculations for critical design points.

CLUTCH LEVER ARM

The lever arm, purchased from McBride Equipment, Inc., is the same as that used to raise and lower the mowing deck. It has a spring-loaded locking system, which allows the operator to disengage the clutch and use both hands to shift gears. The lever arm comes with a 0.125-inch thick steel base plate to ensure secure mounting on the mower.

Three lever arm modifications were made. The first consisted of decreasing the width of the steel base 2.5 inches because the original width of the base was too wide and did not leave room for the operator to place his foot to the inside of the lever arm. This modification necessitated the removal of a large angular steel piece from the end of the rod through the lever arm base.

The second lever arm modification was a result of the first. Since the lever arm base had to be decreased, only two bolts could be used to support and to connect the base of the lever arm to the footrest of the lawnmower. The existing holes in the lawn mower footrest are 0.25 inches in diameter. Design calculations indicated that two 0.25 inch standard grade UNC-20 bolts would provide the required stability and strength needed for mounting. This required drilling an additional 0.25 inch diameter hole into the base of the lever arm. The location of the hole was determined through visual inspection and marked on site through the use of a scribe.

Figure 17.1.Modified Clutch Lever Arm.

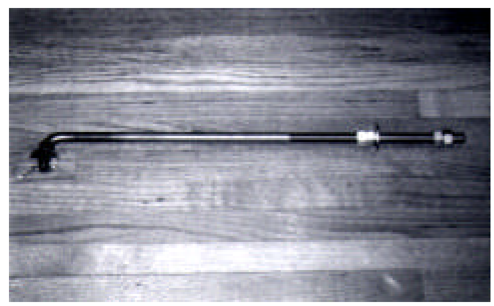

Figure 17.2. Push Pull Rod Assembly.

The third modification of the lever arm required relocation of the push pull rod hole. The original 0.625-inch diameter hole, six inches above the base of the lever travel distance of eight inches, was not sufficient for engagement and disengagement of the lever arm. A new hole was mounted 14 inches up on the lever arm. The lever arm is bottom pivoted, so the higher up

Figure 17.3. Clutch Pedal Before Modification.

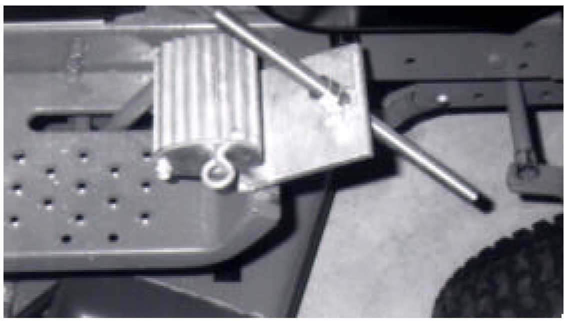

Figure 17.4. Clutch Pedal After Modification.

the hole is along its radius, the more travel distance the hole provides. To provide additional adjustment in travel distance, a 6" x 2" x 0.25" (length x width x thickness) bracket with three 0.625-inch holes spaced 1.5 inches apart were manufactured. The new bracket, shown in Figure 17.1, was welded to the lever arm with the bottom hole 14 inches above the base of the arm. Figure 17.1 shows the modified lever arm.

PUSH PULL ROD

The push pull rod of the Clutch Lever Arm Assembly transmits the motion of the lever arm to the clutch pedal. It consists of a 0.5 inch diameter steel rod 20 inches in length with a two-inch bend on one end, as shown in Figure 17.2. The straight end of the push pull rod is threaded up 8.375 inches from its end for 0.5inch UNC-13 nuts. On the two- inch bend end of the push pull rod, there is a 0.125 inch through hole for a standard cotter pin.

The bend end of the push pull rod goes through one of the three holes of the lever arm bracket, with a 0.5inch washer between the lever arm and cotter pin. There is also a 0.5 inch nylon bushing that attaches to the bend end of the push pull rod after it has been put through the lever arm bracket hole and before the cotter pin and washer are installed. This nylon bushing decreases the slack between the 0.5-inch-diameter rod and the 0.625-inch diameter bracket holes.

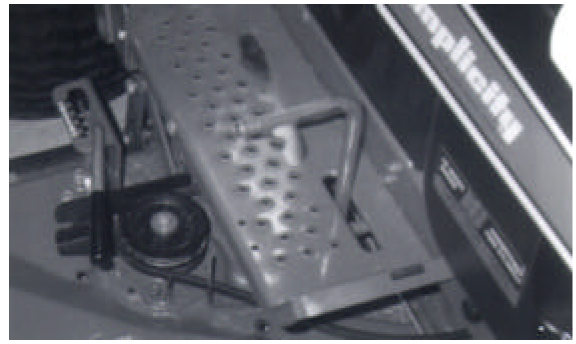

Figure 17.5. Clutch Bar Before Phase 1 Installation.

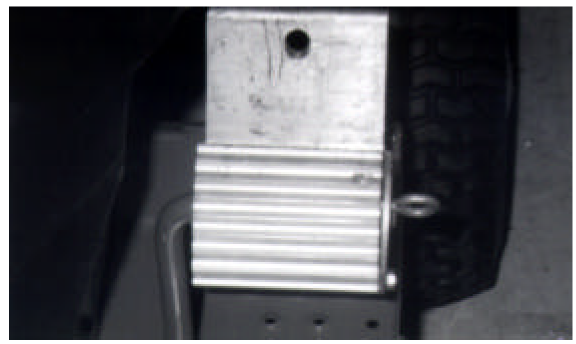

Figure 17.6. Modified Clutch Pedal Mounted On Clutch Bar After Phase 1 Installation.

The cotter pin and washer secure the push pull rod to the lever arm. On the threaded end of the push pull rod, there are two 0.5inch UNC-13 nuts snugly tightened against each other. On the rod end side of the nuts, there is another 0.5 inch washer that goes between the nuts and the aluminum angle on the clutch pedal, through which the push pull rod is inserted. On the other side of the aluminum angle are two more 0.5 inch UNC-13 nuts tightened to snug tight condition against each other for safety.

CLUTCH PEDAL

The existing clutch pedal was modified so that it would not have to be removed with either clutch assembly in place. Figures 17.3 and 17.4 show the clutch pedal before and after modification, respectively. An aluminum angle was welded to the lip on the backside of the pedal. A 0.5625-inch diameter hole was located on the top side of the 3.75" x 3.5" x 0.25" angle in which the push rod would be inserted.

Figure 17.7. Clutch Lever Arm Attached To The Footrest.

Figure 17.8. Clutch Lever Arm Assembly Fully Installed

The corners of the top part of the angle were rounded to remove the sharp edges and to provide a finished look.

FINAL ASSEMBLY

Figure 17.5 shows the initial lawnmower clutch. The modified clutch pedal was reinstalled onto the existing clutch bar as shown in Figure 17.6. The lever arm was then installed. Two 0.25-inch diameter UNC-20 bolts with corresponding nuts and washers were used to attach the base of the lever arm to the footrest of the lawnmower as shown in Figure 17.7. The bolts were tightened to snug tight condition using a hand ratchet wrench. Loctite™ bolt sealant was applied for final assembly. The sealant keeps the bolts from coming lose due to vibration during operation.

Finally, the push pull rod was installed. The push pull rod was screwed on to the rod using two 0.5-inch UNC-13 nuts approximately six inches up the thread from the end. A 0.5-inch washer was added behind the two UNC-13 nuts. Next, the threaded end of the push pull rod was inserted through the 0.5625-inch

Figure 17.9. Existing Lawn Mower Seat.

Figure 17.10. New Lawn Mower Seat.

diameter hole in the aluminum angle on the clutch pedal. The 2-inch bend end of the push pull rod was then inserted into the middle hole of the bracket welded onto the lever arm. A 0.5-inch nylon bushing was placed onto the 2-inch bend end of the push hole.

Next, another 0.5-inch washer was placed onto the 2-inch bend end of the rod, past a 0.125inch cotter pull rod, and into the middle bracket pin hole. A cotter pin was then inserted into the hole. Two other 0.5inch UNC-13 nuts were screwed onto the threaded end of the rod, approximately two inches away from the backside of the aluminum angle.

The two 0.5-inch UNC-13 nuts on the front side of the aluminum angle were adjusted to meet the comfort and accessibility needs of the operator. Finally, all four of the 0.5-inch UNC-13 nuts were tightened to snug tight condition against each other, ensuring security and safety. Figure 17.8 shows a picture of the fully assembled clutch lever arm assembly.

SEAT MODIFICATIONS

The existing seat of the riding lawn mower did not have a seatbelt and provided no support for the upper body. Without support and a seatbelt, the user could possibly be thrown from the lawnmower. A new seat and a seatbelt were added. The new seat met the following criteria:

- Universal mounting to allow for easy installation and minor modifications to existing equipment;
- Fold-up arms that allow for easy entry and exit;
- High backrest and armrests to provide support and security; and
- Comfort for other operators.

A seat from Northern Hydraulics was acquired and modified to attach a seatbelt. The backrest on the new seat is 16.5 inches, which provided an additional 3.5 inches of support. Two foam-cushioned armrests provide additional side support. During transfer, the armrests can be folded up to allow the user to slide onto the seat.

The seat was constructed of a steel frame, used for seatbelt attachment. Figures 17.9 and 17.10 show pictures of the existing and new seats, respectively.

The new seat had to be slightly modified for secure attachment to the lawnmower. The new seat had four, 0.25-inch diameter pre-drilled holes. However, the rear two holes did not line up with the existing mounting bracket. To remedy this, two additional 0.25inch-diameter holes were drilled through the steel frame of the seat. The seat was then attached to the existing mounting bracket using four 0.25-inch diameter bolts. To attach the seatbelt to the new seat, two, 3/8 inch-diameter holes were drilled through the steel frame of the backrest. The seatbelt was attached to the new seat using two, 3/8 inch-diameter bolts.

OPERATION AND EVALUATION OF THE ADAPTED LAWNMOWER

The operation of the clutch lever arm assembly begins when, using his or her right arm, the operator firmly pushes forward on the lever arm of the assembly to bring the mower to a full stop and to lock the clutch into disengagement. Force is transmitted from the arm of the operator to the assembly lever arm. Federal regulations require that the clutch assembly provide a mechanical advantage for the operator. The maximum force needed to disengage the drive system (or conversely, engage the brakes) should not be greater than 50 pounds. It was found that the force that needs to be supplied by the arm of the operator to the assembly lever arm is approximately thirty pounds, which is less than the maximum force allowed by the federal regulations. From the assembly lever arm, the force is transmitted through the bracket to the push pull rod. The force is then transmitted along the length of the push pull rod and applied to the clutch pedal as a result of the two nuts pushing against the front side of the aluminum angle.

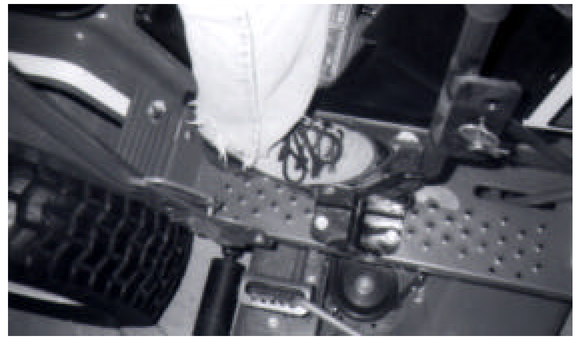

Figure 17.11. Foot Clearance With Clutch Lever Arm.

Figure 17.12. Hand Clearance Between Lever Arms Assembly Attached.

To release the clutch pedal, the operator pushes in the button at the top of the lever arm, releasing the spring-loaded locking system and slowly allows the clutch pedal to travel back and engage the drive system. The lever arm is forced back by the spring-loaded clutch pedal. The force from the pedal is transmitted through the angle on the pedal pushing against the two front side nuts.

Each component was evaluated while simulating the operation of the lawnmower by a person with paraplegia. This test was recorded on a standard VHS video and included the following tasks:

- Folding the arms;
- Securing the operator with the seatbelt;
- Checking clearance between the operator's foot and the clutch lever arm assembly;
- Checking clearance between the mower deck lever arm and clutch lever arm assembly;
- Locking the clutch lever arm assembly to disengage the drive shaft;
- Changing gears;
- Releasing the clutch lever arm assembly to engage the drive shaft; and
- Simulating normal stopping using the clutch lever arm assembly and recording stopping times.

The test adequately displayed the effectiveness of the clutch level arm assembly and the new seat. The operator is provided ample body support, and the seatbelt effectively secures the operator to the seat. With the clutch lever arm assembly attached, the operator still has sufficient dearance to place his/her foot on the footrest, as shown in Figure 17.11. Also, the clutch lever arm assembly does not interfere with the normal operation of the mower deck lever arm. Figure 17.12 shows the distance between the clutch lever arm assembly and the mower deck lever arm. The clutch lever arm assembly can be locked in the forward position, disengaging the drive shaft, as shown in Figure 17.8. This allows the operator to use both hands to change gears. Finally, using the clutch lever arm assembly does not negatively affect the stopping time. Stopping times using the clutch lever arm assembly were compared to stopping times using the existing foot pedal and foot-activated stopping. The stopping times for the two methods were almost equivalent on average to 1 sec.

The total costs of the material were $240.00. The price of the seat was $97.52, and the lever arm was purchased for $95.00. These costs do not include machining costs of cutting, drilling and welding.

DRINKING SYSTEM FOR PERSONS WITH QUADRIPLEGIA

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INTRODUCTION

The purpose of this project was to develop a system that allows patients with quadriplegia to drink water independently while in bed when no assistance is available. The prototype can be mounted to any hospital bed. The unit includes an adjustable, flexible extension arm that ends with a mouthpiece. The arm is welded to a sleeve into which a main support post slides. Such a post is typically located near the head of most hospital beds. Water bottles and a waterline are also supported by this post. The prototype mounted on a hospital bedpost is shown with the arm extended in Figure 17.13 and with the arm partially retracted in Figure 17.14

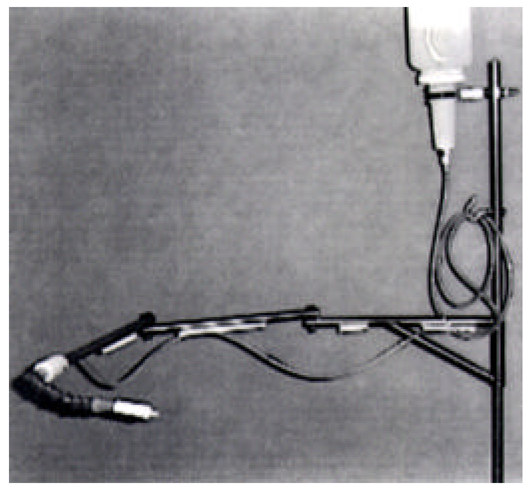

Figure 17.13. Drinking Unit Mounted on a Hospital Bedpost with Arm Extended.

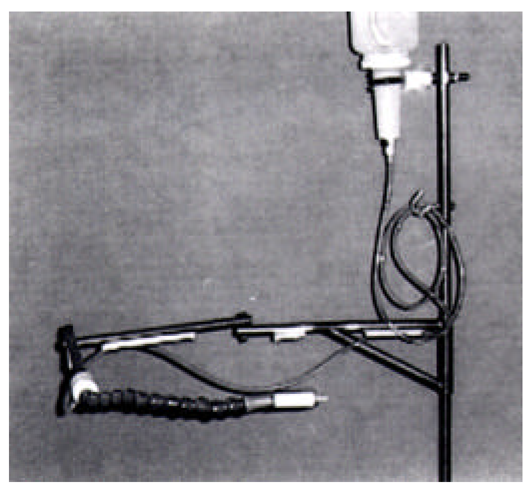

Figure 17.14. Drinking Unit Mounted on a Hospital Bedpost Post with Arm Partially Retracted.

SUMMARY OF IMPACT

Patients with quadriplegia have little or no control of the body below the neck. This makes it impossible for them to get a drink of water independently. Dehydration becomes a problem when such individuals are without assistance.

Users are able to use this system and attain water by adjusting the mouthpiece location using only neck movement, provided the mouthpiece is placed by the user's head. This design is also effective for patients with limited use of one arm, as they do not need the mouthpiece by their heads all the times.

TECHNICAL DESCRIPTION

Designs with and without motorized arms were considered. The motorized option was dismissed because of safety aspects. If a system failure were to occur, the user would be unable to move out of the path of the arm and may suffer further injury. The prototype consists of three main parts: the main support post, the water bottle, and the extension arm.

The main support post is typically made of 3/4-inch stainless steel tubing and slides into a sleeve located near the head of most hospital beds. The water bottle is supported from the top of the post with a bottle-holding gripper. The post also supports the excess water line, necessary for height adjustment, with a support hook, as shown in Figures 17.13 and 17.14. Additionally, the main post supports the extension arm by a 1-inch steel sleeve with two inline holes. Hand retractable plungers that fit these holes are used to adjust the position of the sleeve along the post, setting the height of the arm at the desired location.

The water bottle contains a machined hard plastic disc that seals its lower end. A quick disconnect valve is threaded into this disc, allowing the bottle to be easily removed for filling. Soft ¼-inch plastic tubing is used as water line and is attached to the lower end of the disconnect. This water line is connected to a check valve that prevents leakage. The check valve is mounted at the end of the extension arm. The mouthpiece is connected to the check valve and consists of a short 1/4-inch tubing. All non-plastic components that come in contact with water are made of corrosion resistant material.

The extension arm is welded to the steel sleeve of the main support post. The arm consists of four sections. The first section is a stay-put flexible PVC coolant hose (hard plastic tubing), 15 inches in length. The check valve is attached to one end of this tubing, while the other end is threaded into a 14-inch stainless steel tube (OD = 0.75 inch, ID = 0.68 inch) that represents the second section of the arm. The flexible hard plastic tubing forming the first section of the extension arm allows adjustment of the location of the mouthpiece connected to the check valve. The third section of the extension arm is made of an identical tube (14 inches in length) that is hinged to the second section.

The fourth and last section of the extension arm is the arm support truss and consists of two members, as shown in Figures 17.13 and 17.14. The first member is a 15-inch stainless steel tube hinged at one end to the second section of the arm and welded at the opposite end to the post's sleeve.

The second member of the arm support truss is welded, at 30 degrees, to the first member. This member is also welded at its opposite end to the post's sleeve. Shoulder bolts, washers, lock nuts, and tubing caps were employed at all hinges. Self-adhesive Velcro was used to hold the water line to the extension arm.

Assistance is required to adjust the position of the extension arm on the hospital bedpost and for the removal, refilling, and reattachment of the bottle. Assistance is also required to position the mouthpiece for patients with no arm movement. A sterilization solution should be processed through the system at least once a week to ensure a clean water flow from the mouthpiece. This piece should be thoroughly and frequently washed.

On a mass production scale, the plastic disc that seals the bottle would be more efficiently produced by a casting operation instead of machining.

ASSISTIVE DEVICE TO START A PULL-START LAWNMOWER

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INTRODUCTION

The purpose of this project was to develop an assistive device that allows a person with a physical disability to independently start his pull-start lawn mower. This person has weakness in his grip strength and in his arms and shoulders. The device includes a pulley that redirects a downward force assisted by gravity to an upward pulling force. The pulley is attached to a small metal frame housing wheels that roll on top of one of the beams inside the client's barn as shown in Figure 17.15. Starting the lawn mower requires him to pull down on a handle bar attached to a rope that wraps around the pulley and attaches to the pull start handle of the lawn mower.

SUMMARY OF IMPACT

A unit was designed and built to allow a farmer with a physical disability to independently start his pull start lawn mower. This individual cannot control the strength of his grip and cannot pull up on a cord with adequate speed using his arms and/or shoulders. The unit was safely tested and operated by the client to his satisfaction.

Figure 17.15. Assistive Lawn Mower Starter.

TECHNICAL DESCRIPTION

This assistive device is used to redirect the typically strenuous upward pulling force to a simple downward force that is assisted by gravity. The initial design consisted of a large frame that would hold a pulley approximately eight feet above the top of the lawn mower. This frame was also to restrict the body of the lawn mower to keep it from lifting off the ground when the cord was pulled upward. However, it was decided to use the client's existing barn as the frame, which reduced costs.

Figure 17.16 shows a close-up of the prototype. It includes a pulley attached to a small metal frame that houses wheels that roll on top of a single beam in the ceiling of the client's barn. The frame is made of 0.25 inch steel plates. It consists of two vertical plates, 2 inches apart, welded to a horizontal rectangular plate (2.5 inches x 7.5 inches). The two vertical plates were not rectangular in shape, each plate having a total height of 14.25 inches and a total width of 7.5 inches.

A sheave (pulley for small diameter wires and/or fibrous ropes) rated at 1400 lbs. was used. The pulley had a bronze bushing and an outside diameter of five inches. The pulley was secured between the vertical plates using two pulley spacers, each being an ultra-high molecular weight polyethylene (UHMWP) rod, 1.25 inches in diameter and 0.625inches in length. Each pulley spacer was drilled through to allow the insertion of a 0.75inch-diameter drill rod that was two inches in length (which was equal to the separation distance between the two vertical plates). Each end of the drill rod was drilled creating 3/8inch-diameter holes. The two pulley spacers and the sandwiched sheave were mounted on the drill rod, which was attached to the two vertical plates of the unit frame using 3/8-inch shoulder screws.

Four solid rubber wheels with hard tread and self-lubrication were used to allow the steel frame to roll on top of a single ceiling beam in the barn. Each rubber wheel was two inches in diameter and 15/16 inch in width. Each rubber wheel was secured between the two vertical plates of the steel frame using two spacers of UHMWP rod, 0.625 inch in diameter and 0.5 inch in length. Each rubber wheel spacer was drilled through to allow the insertion of 0.25 inch-diameter socket-head shoulder screws. Each of the four sets of three rubber wheel spacers was thus mounted on a 0.25-inch diameter screw that attached the unit to the vertical plates of the frame. The solid rubber wheels, the sheave, and the UHMWP were ordered from McMaster-Carr Supply Company.

A one-inch diameter, 10-inch long aluminum rod was used as a handle; this allowed two hands to fit on the rod as shown in Figure 17.15. A 0.312 inch through hole was drilled in the middle of the handle to allow for rope attachment. A 0.25 inch rope was used. The rope was attached to the handle, passed around the

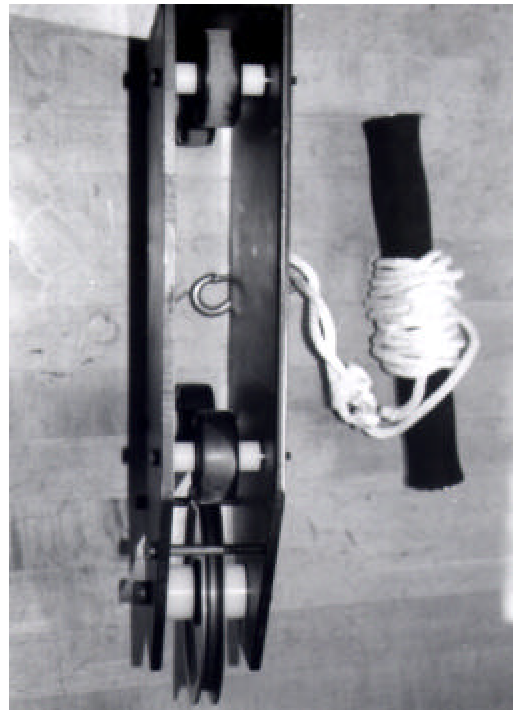

Figure 17.16. Pulley and Rollers.

pulley, and then connected to the lawnmower's pulling cord using a hook.

The prototype was assembled and tested successfully at the client's barn under the supervision of his physician. The total material cost was $80.00.

ASSISTIVE DEVICE TO OPEN AND CLOSE LARGE JARS

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INTRODUCTION

An assistive device was developed to allow a person with a physical disability independently to open and close jars of various sizes. The prototype consists of a strap wrench with a handle machined to allow it to slide into a metal block welded to a metal base, as shown in Figure 17.17. The base is bolted to a table-top for support. During operation, the handle slides into the block and opens jars, as shown in Figure 17.18. When the handle is turned around and inserted in the block in the opposite direction, it closes jars. Using the strap as the clamping mechanism allows the prototype to be used on jars of different sizes, regardless of height or diameter.

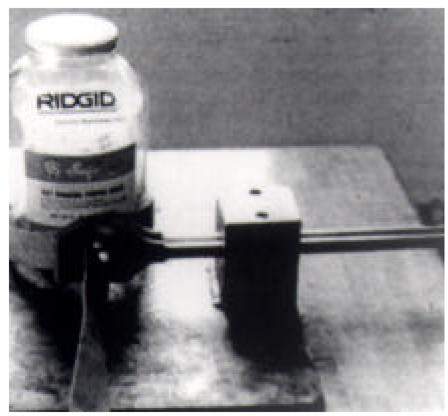

Figure 17.17. Assistive Device to Open and Close Jars.

SUMMARY OF IMPACT

The client, a farmer, had lost sensation in his fingers due to a spinal cord injury. This device will assist him in canning produce grown in his garden or provided to him by neighbors, as is the custom where he resides. The device is universal in that any person with a weakened or atrophied upper body may find it useful.

Figure 17.18. Device in Use by Client.

TECHNICAL DESCRIPTION

The tightening/removal torques of commonly encountered jars were determined by consulting with Owens-Brockway research and development laboratory in Perrysburg, Ohio. Two items were picked at random from a grocery store: a salsa jar and a pickle jar. At Owens' laboratory, the jars were tested in a torque tester consisting of a steel jaw that gripped the base of the jar. The jaw was connected to a torque gauge that read both tightening and removal torques. Torque was applied directly to the lid, as one would when opening a jar. For both jars, the average tightening torque was measured as 75 in-lbs. The average removal torques was 40 in-lbs. and 49 in-lbs. for the salsa and pickle jars, respectively. These results were consistent with the commonly used design guidelines indicating that the tightening torque is related to the diameter of the lid. A 70 in-lbs. torque is required to tighten a 70-mm metal lid. Conversely, it takes only 2/3 of the tightening torque to remove the lid; that is 46.7 in-lbs. to remove a 70-mm lid.

A survey of the heights of typical grocery store jars was then conducted to determine the height of the smallest typical jars that could be encountered. This was to determine whether the device needed a variable height adjustment to accommodate large and small jars. Based on 24 samples, it was found that common jars have an average height of 6.2 inches (± 1.4 in.) with a minimum height of 3.9 inches and a maximum height of 10.4 inches. Using these data, it was determined that only one height was needed to clamp all the jars surveyed.

The jar-clamping device consists of a Ridgid brand strap wrench manufactured by Ridge Tool Company, Elyria, Ohio. A steel block with a 3 x 3-inch base and 4-inch height, was used to support the wrench. The handle of the wrench was machined to enable the can to slide into the steel block.

Because it was difficult to drill a hole through the steel block that allows the machined handle to slide into it, the block was divided into two equal small blocks, each with a height of two inches. Each of these small blocks was then machined such that when attached together, a through hole was created with a cross-section matching that of the machined handle.

Once the handle was inserted between the two small blocks, they were secured together using two 0.375-inch bolts. The bottom small block was welded to a steel base plate that was bolted to a tabletop using four 0.25-inch bolts. The base plate was made from 0.25-inch steel and was square in shape (16 x 16 inches). Figure 17.17 shows a picture of the unit. Figure 17.18 shows a schematic illustrating the machining details of the two small blocks.

During operation, the strap of the wrench is tightened around the jar, generating a friction force that inhibits jar movement. To open a jar, it is placed within the strap with its bottom resting on the base plate. Pulling the loose end of the strap causes the strap to be pulled tightly around the jar. With the jar in the strap, the user places his hand on the lid and turns it, making the strap tighten further and causing the lid to be removed.

The device is also used to close jars when the handle is removed, turned around, and inserted between the two small blocks in the opposite direction.

The total cost of the unit including machining, parts, and dissemination material, was $180.00.

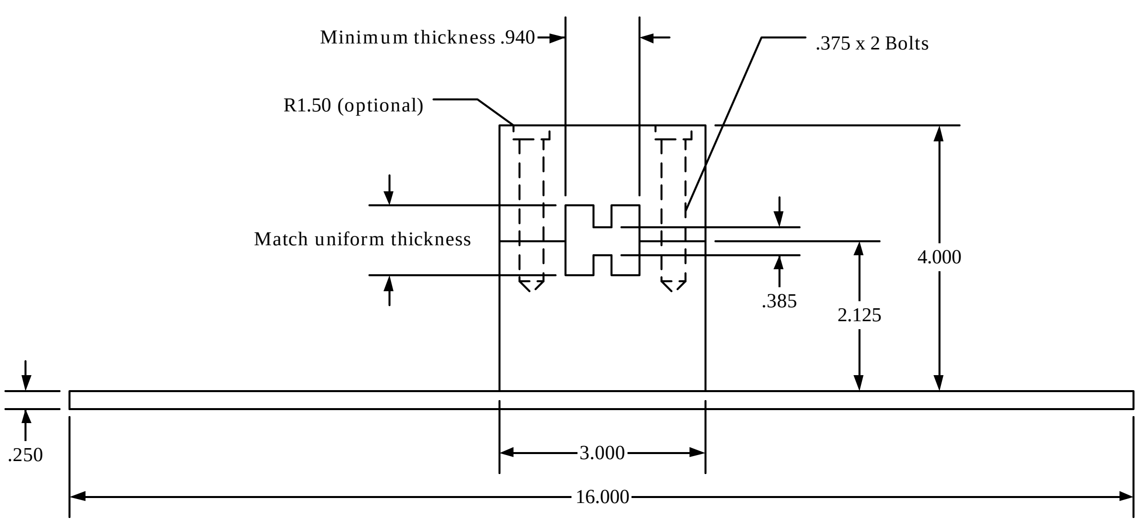

Figure 17.19. Schematic Showing the Machining of the Fixation Blocks Allowing Insertion of the Machined Handle (Dimensions in Inches).

REACHER DEVICE

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INTRODUCTION

A heavy-duty reaching device was designed to allow persons with paraplegia or people with limited reaching capabilities to grasp an object from 6-8 inches in diameter and up to 25 pounds in weight. The unit consists of a hollow aluminum shaft, a nylon cable noose, a ratcheting lock grip handle, and two lock releases, one at the handle and one at the noose end. The reacher extends 5.5 feet away. Figures 17.20 and 17.21 show the device being used by an individual with paraplegia in his garage.

SUMMARY OF IMPACT

A device was designed and built to allow an active person with paraplegia to reach and grasp heavy and large objects independently. Previously, his means of obtaining those objects was to knock them off the shelf with a rake, which was impractical and dangerous. The reacher prototype allows him to reach those objects in a more convenient and safe manner. Many people have difficulty reaching up to a cabinet, or picking an item up off a shelf. Currently, the available selection of reachers on the market is limited to those for grasping small, light objects from a short reach. The most common design in the market supports objects up to 4 pounds and widths of up to 4.5 inches. This reacher supports objects that are up to 25 pounds and has an adjustable noose capable of carrying objects 2 to 10 inches in diameter with an extended reach of 5.5 feet.

TECHNICAL DESCRIPTION

Several design concepts were considered including jaw, telescoping, reel, and noose designs. Criteria included that the unit be lightweight, stable, safe, and easy to use. The noose design was found to be most

Figure 17.20. Reacher in Use.

Figure 17.21. Reacher in Use.

versatile. It better accommodates the needs of a greater number of consumers due to its better grasping ability.

The noose consists of a 12-foot long cable, which wraps around any object being picked up. The cable tightens around the object, locking into position once it has secured a specific tightness. The shaft of the reacher is made of aluminum 3003, providing enough stability not to bend once the object has been removed from the floor or the shelf. The shaft has an OD of 1.5 inches and a thickness of 0.065 inch. Its length was predetermined to be 5.5 feet long, to provide the greatest amount of benefit for household use. Once tightened, the ratcheting lock-grip handle, which remains tight. This allows the user's hands to remain free when they are retrieving the object from the noose end. The lock-grip design incorporates two releases. The first release is by the handle, which makes releasing an object from a distance easier. Also, this facilitates placing an object on a shelf and changing from one object to another. The second release is at the noose end. This release allows the users to get the object once it has been lowered in front of them. A quick grip bar clamp from the American Tool Company, shown in Figure 17.22, was modified to make the handle and trigger assembly. The clamping ends were removed. The upper surface of the grip was milled down. The clamping part was inverted on its shaft, as shown in Figure 17.23. The shaft required machining. A hole was cut for the lock-grip handle to be inserted, and holes were tapped into the shaft for screws to secure the handle. A V-shaped rubber stop assembly was also mounted to the shaft at its grasping end. This portion was added to the shaft to support objects while they are gripped.

The handle operates on a sliding rod mechanism. The rod, which extends a distance of 12 inches from the back of the handle, slides through the top of the handle. As the handle is compressed, two metal strips that lie flat with the handle are tilted at an angle. Simultaneously, the strips grab the rod and pull it. The end of the rod in front of the handle is welded to a disk that slides along the diameter of the shaft. The disk, which is located in between the handle and the noose, is attached to the cable with lynch nuts. The other end of the rod is bent upward, perpendicular to the shaft. This bent portion acts as a handle to adjust the noose when it has not been secured.

Figure 17.22. Quick Grip Bar Clamp.

Figure 17.23. Quick Grip Bar Clamp After Modification

The prototype was tested and evaluated by a person with paraplegia, as shown in Figures 17.20 and 17.21, under the supervision of his physician. Operating instructions were clearly explained to the client before he attempted to use the device.

The client indicated he will use the device often and that the reacher will be a tremendous aid to him. Since some parts may become worn over time, it is suggested that the cable and the bolt connecting the rubber stopper assembly to the shaft be replaced after an extended period of use. It is also noted that the reacher's shaft is made of aluminum and will be become slippery if exposed to oil or water. The total cost of parts was $70.34. With mass production, the reacher's price would be almost half the cost of this prototype. The rubber stopper assembly could be molded into the shaft, which could be made of thinner aluminum or plastic composite.

WHEELCHAIR BICYCLE-TYPE ATTACHMENT

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INTRODUCTION

A bicycle-type attachment was designed for use by a person with paraplegia in a wheelchair. The client has normal control of his arms and upper body. The objective was to allow him to use his arms to propel himself by hand pedaling the attachment unit when it is temporarily connected to his wheelchair. During operation, the front wheels of the wheelchair are off the ground, thus making the structure, composed of the wheelchair and attachment unit, function as a tricycle. Operating this tricycle structure allows the patient to exercise different muscle groups in his arms.

SUMMARY OF IMPACT

This prototype was constructed for a person with paraplegia who is very active and enjoys outdoor activities with his family. Persons with paraplegia confined to wheelchairs often have limited opportunities to enjoy outdoor activities. Often, these patients cannot engage in public recreational activities because of the cost and availability of appropriate sporting equipment, such as racing wheelchairs. Using an affordable bicycle-type attachment unit that is easily connected to a wheelchair transforms it readily to a recreational hand pedaled tricycle.

TECHNICAL DESCRIPTION

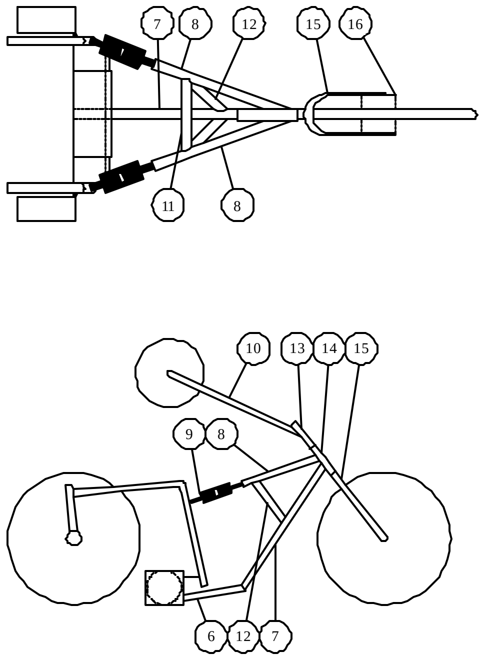
A bicycle-type attachment unit was designed to satisfy the requirements that it have no permanent attachments to the wheelchair, allow the user to propel himself using hand pedals, lift the small front wheels of the wheelchair off the ground during operation, and be safe, lightweight, and user-friendly, allowing the user to attach and detach the unit independently.

Figure 17.24. Tricycle in Use by a Client with Quadriplegia.

Figure 17.25 shows the different parts of the attachment unit and its connections to the wheelchair. The attachment unit incorporates a regular 24-inch bicycle wheel (not labeled in Figure. 17.25), a three-speed coaster brake, a front wheel bicycle fork, a steering arm, a crank-drive assembly (not labeled in Figure 17.25, but consisting of hand pedals, crank arms and a drive sprocket), a drive chain (not shown in Figure 17.25) and a connecting frame made from one-inch nominal steel tubing.

The front wheel bicycle fork has to be custom-fit to the three-speed-coaster brake hub, which usually provides a rear wheel drive in most bicycles. The crank drive assembly drives the chain, which drives the three-speed-coaster brake that provides three forward speeds and allows the user to decelerate by using a reverse rotation motion of the drive sprocket.

The steering arm was welded to a headset that rotates within the steering tube, causing the front wheel fork



Description of parts:

6 lower support structure to base plate
7 lower support structure to steering tube
8 upper support structure to steering tube
9 turnbuckle
10 steering arm
11 reinforcement of upper structure
12 reinforcement for upper and lower support structures
13 headset going into steering tube
14 steering tube
15 front wheel fork
16 wheel hub (3-speed coaster brake)

Figure 17.25. Bicycle type attachment

to rotate also within the steering tube. A bracket was attached to the headset to provide a guide for the drive chain. Hence, the chain path is from the drive sprocket to the guide bracket to the three-speed coaster hub and back around to the drive sprocket. This path was selected to allow the chain to avoid contact with the fork and the connecting frame at all times.

The design allows the attachment to be connected to the wheelchair using clamps located on the connecting frame and secured to the wheelchair on each side of its supporting frame, just below the patient's knees. These clamps were coated to prevent damage and/or slippage while attached to the wheelchair. They also have a cam-locking device to prevent them from becoming loose. Also, the design allows the front wheels of the wheelchair to be supported by the attachment unit using two racks located on the bottom part of the connecting frame. The two racks, made of fourteen-gauge steel, were connected with a schedule forty steel channel.

During the attachment process, the user rolls the front wheels of his wheelchair into the two racks that provide a stop. He then secures the front wheels in place by inserting a set of two pins in each rack. The user then turns down two screwjacks, one attached to each rack, to lift the racks housing the front wheels, producing a slight backward tilt of the wheelchair. These hand-operated screwjacks allow for a clearance up to two inches off the ground. The user then extends the upper part of the connecting frame using two turnbuckles, thus allowing the clamps to be secured to the supporting frame of the wheelchair. Finally, the user turns up the screwjacks, converting the attachment unit and the wheelchair into a tricycle type structure.

Figure 17.24 shows the patient sitting in his wheelchair with the attachment unit connected. During final testing, the patient was able to steer and drive the tricycle structure comfortably. It has been recommended to the patient to avoid high-speed turns to prevent turning over, as he has limited control of his torso movements. The patient indicated that while connecting the attachment unit to the wheelchair, turning down the screwjacks becomes difficult as the ground resistance increases. Screwjacks can be replaced with pneumatic jacks, but this will compromise the simplicity of the design. Total expenses for materials and supplies were $625.00 with the bicycle wheel assembly (wheel and coaster brake) being the most expensive item, costing $150.00.

TEMPERATURE CONTROL SHOWER UNIT

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INTRODUCTION

The purpose of this project is to design and develop a temperature controlled shower unit to be used by a person with paraplegia who has little or no motor or sensory function below his arms. The unit allows the client to interactively select and set his preferred water temperature in the shower. The design of this unit incorporates a thermal mixing valve that provides optimum temperature control, and a proportional-integral-differential (PID) controller that ensures a constant water temperature throughout usage. The valve is operated by a motor, which permits mixing cold and hot water within its body. A thermocouple measures the temperature of the mixed water and feeds it to the controller, which provides a feedback input to the motor allowing valve rotation. An anti-scald valve was also incorporated to prevent burns caused by scalding hot water that may result from system failure.

SUMMARY OF IMPACT

A loss of sensation puts individuals risk for unknowingly injuring themselves with scalding water. Persons with motor and sensory loss may need assistance to adjust the water to keep a constant temperature while washing, and while seated at the back of a bathtub on a tub bench, using a long handled shower head. With the use of a temperature controlled shower unit mounted inside the shower's walls, patients can independently determine water temperature and take a shower comfortably and safely.

TECHNICAL DESCRIPTION

The proposed design incorporates a thermal mixing valve that combines the output from hot and cold water supply lines into a single outlet stream having a specified temperature. A unit composed of a PID controller, a direct-coupled actuator, and a thermocouple, allows temperature control via an adjustable mixing valve.

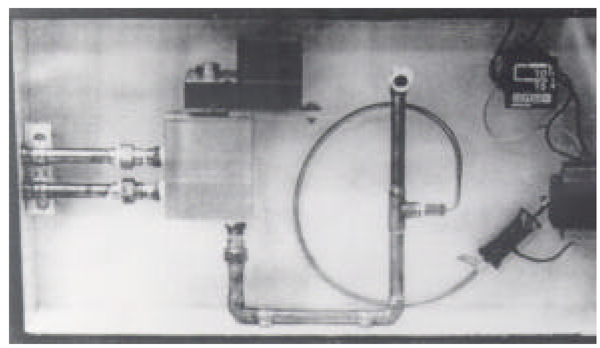

Figure 17.26. Temperature Control Shower Unit. The System Includes: (1) Motor; (2) Mixing Valve, (3) Thermocouple, (4) PID Controller, (5) Transformer, (6) Hot Supply Line, (7) Cold Supply Line.

Due to the wet environment, it was necessary for the control unit to operate at 24 volts and reduced amperage. This required using a transformer to step down the power from the standard 110-volt service to 24 volts. The system and its components are shown in Figure 17.26

The thermal mixing valve was designed to sustain up to 75 psi of water pressure and to operate between 45 and 200 degrees Fahrenheit, which accounts for all possible conditions present in a typical household water system, whether it is supplied municipally or by a well with a pump. For simplicity, the system was designed to operate with a single motor where hot and cold streams are mixed within the body of the thermal valve. The valve is composed of body, stem, three o-rings, and a stem-retaining nut. The stem is a 0.75inch-diameter rod with two 0.5-inch holes drilled through perpendicular to each other and offset axially 1.5 inches. The effect of the offset of the holes is to allow the motor to rotate the stem within the body of the valve 90 degrees. This allows the mix of the two inlet streams to vary from 100% cold flow to 100% hot flow with adjustable mixtures of hot and cold between the extremes.

The stem diameter is reduced to 0.5-inches to allow for a retaining nut to hold the stem in position inside the valve body. The stem-retaining nut is made of aluminum and has a 0.50-inch hole through the center to slide over the stem. The retaining nut is threaded on the outside edge and threads into the valve body to prevent the valve stem from moving in the axial direction. Three nitrile o-rings (operating temperature between -65 and 275 ^{0}F) were employed to seal the opening where the stem exits the body of the valve, thus requiring three o-ring grooves to be machined into the valve stem. Two o-rings were used to prevent water from leaking out along the valve stem, and one o-ring to prevent leakage between the hot and cold streams.

A Watlow Series 965 PID controller was employed to regulate the temperature. The motor was selected to allow for slow rotation, which was required to reduce temperature fluctuation about the set point. A direct-coupled actuator, manufactured by Honeywell, with a stroke range of either 45^o, 60^o or 90^{o,} was used. To measure the temperature of the mixed water, a T- type thermocouple with a working range of 32^{o}F to 662^{o}F was selected. Flexible romex wiring and connectors were employed in the final set-up. The thermocouple measured the temperature of the mixed water, and fed it to the controller, which subsequently compared it to the set temperature, and acted accordingly. The controller caused the motor to turn in one direction or the other, depending on whether more hot or more cold water was required in order to match the measured temperature with the set one.

A commercially available chrome plated brass anti-scald valve was added to the system. Since this valve is small, it can be installed at any point between the gooseneck pipe and the hand held showerhead. The valve is designed to automatically shut off the water when the temperature reaches 114 ±5^{o}F. A red reset button on the anti-scald valve can be pushed once the showerhead is directed away from the body to flush the hot water from the pipes.

The system was tested to determine the time required to respond to a significant temperature change. Two types of tests were conducted. In both tests, the valve stem was oriented to 100% cold water flow, approximately 67^{o}F. In the first test, the PID input temperature was set at 215^{o}F. The system responded by rapidly adding hot water. In 90 seconds, the water was shut off when it reached an average of 111.5^{o}F for two trials, which was within the designated rating of 114^{o}F ± 5^{o}F. In the second test to demonstrate how the PID controller determines the rate of temperature change and prevents temperature overshooting, the PID input temperature was set at 110^{o}F. As the measured temperature approached the set temperature, the rate of temperature change decreased. In about 90 seconds, the system stabilized with an average 2.15 seconds per degree over two trials.

The temperature control shower unit can be used with a standard long handled showerhead while the patient is seated on a tub bench at the back of the tub. One limitation of this system is that the mixing valve was designed to operate as a thermal-mixing valve only; isolation or shutoff valves were not included in the design of the prototype. The system can be improved if isolation valves are to be used for both hot and cold supply lines to start and stop flow. Furthermore, some improvements could be achieved if the 60° (instead of 90^o) range of rotation of the motor were selected and if the orientation of the holes in the valve stem were altered. If the valve stem holes were less than 90° apart, the mixture would change more rapidly and would speed the response time of the entire system.

The total cost for materials and supplies was $500. The controller and motor were the most expensive items, costing $266.00 and $96.26, respectively.