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Assisted bottle opener

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CAPSTONE DESIGN

MIM 702

Technical Design Report

Assisted Bottle Opener

Final Report

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Abstract

In today's world more and more devices are being created to aid those that are handicapped and make their daily routines easier and their lives more independent. The focus of this design involves the opening of a medicine bottle for one-hand use and is targeted primarily to an audience that includes those who are disabled and have only the use of a single-functional hand. Design requirements of the device include being easy and safe to use, lightweight and having minimal assembly and maintenance requirements. In addition to opening the bottle cap, the cap must also be able to be put back on. The design must be flexible enough to incorporate different bottle styles, including over the counter, as well as prescription applications.

Through patent and market research it is apparent that there are few commercially available products that meet all of our design requirements. Patent research yielded a significant number of inventions that would facilitate the opening and closing of several pill bottles, but only a single design that came close to meeting the most crucial design requirement of being able to open a bottle with one hand. Market research generated similar results and provided limited products that would satisfy all of our design goals.

Targeting the specific bottle types incorporated into the design was a crucial first step in development. The three most widely used bottle types and the central focus of the design include the standard prescription bottle in which the user is required to push down and turn the bottle cap. Over the counter applications include bottles that have the user line up two arrows and pop a cap off, as well as push in two tabs and twist the cap off.

Incorporating these bottles led to a semi-automated device that met all of the design requirements. A centrally located shaft is driven by a DC motor and gear reduction assembly. Revolving at eight revolutions per minute, the shaft is connected to a non-slip base plate by a keyed connector and alignment bushings at the top and bottom. The base plate is recessed into the top of the unit allowing for an eighth inch of vertical displacement. The same displacement occurs in the shaft, which connects a circuit by depressing a ball switch and permits the motor to run. The motor can run in reverse through the use of a double pole double throw switch. From a cost and manufacturing standpoint, the semi automated unit is the optimal solution to the design requirements.

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1.0 Introduction

The primary goal of the design project is to devise a working prototype that will allow a user to be able to open and close a variety of medicine bottles with one hand. The medicine bottles consist of over the counter, as well as prescription style applications. The prototype design goals include having the model be easy and safe to use, low cost, lightweight, and require minimal maintenance and assembly. The device also needs to be marketable and visually appealing. The product is targeted toward those who are handicapped, having only the use of a single-functional hand. However, the device may also be used by any person who wants assistance opening a medicine bottle.

The initial step in prototype development involved researching existing designs currently available on the market that closely meet the design requirements. A similar search on registered patents to ensure an existing device will not be developed was conducted. These searches allowed knowledge to be gained from existing components and incorporated in a prototype design. In addition to pill bottle opening devices, information on manufacturers of pill bottles and the most popular applications on the market today was necessary to design progress and had to be incorporated into the prototype. Patent and market research are an essential part of a successful design.

Initial designs, composed of fully mechanical devices, proved not to be user friendly. A user friendly and marketable device would have to include more automation. The automated design considered includes four motors and a logic circuit to execute user input. The automated design, although extremely user friendly, would not be cost effective. A semi automated solution solves both the cost and user input problem. The semi automated design includes one motor driving a gear train. The gear train reduces the output to an appropriate revolving speed and increases the torque. The final gear drives a vertical shaft connected to a non slip platform. Placing the bottle on the platform displaces the ball switch, connecting the circuit and powering the motor. The semi automated approach provided the optimal solution to the design requirements and therefore was the design for our prototype.

The final prototype design incorporates an appropriate component break down. Research of gears, adequately powered motors, shaft design, and an enclosure case were amongst the most crucial components. Benchmarking of the Black and Decker Lids Off

product lent hands-on knowledge that applied directly to the design progress. A full cost analysis from both a prototype and manufacturing standpoint was a critical portion of final design development. In addition, child safety issues had to be addressed to ensure our device was used appropriately. Experimental testing involving material selection for a non-slip surface of the revolving pad and testing of the torque and pressure force required to open a multitude of medicine bottles set the design parameters for the unit.

2.0 Patent Research

Extensive research was done in order to see what patents regarding the design goals exist. This research provided more insight as to the pros and cons of each of the designs, as well as lending ideas to what will and won't work with design considerations. The following are the results of the patent research and descriptions of each of the five products that best fit our application. The pros and cons of each of these designs are analyzed in their respective descriptions.

2.1 United States Patent Number 6,393,947

US patent number 6,393,947 involves a method and apparatus for loosening a closure form container. In this case, closure form containers include medicine bottles, which incorporate a push and twist opening system [1]. This patent has similar design achievements to our project in that it will open medicine bottles while ensuring children won't be able to. The design is shown in Figure 2.1.

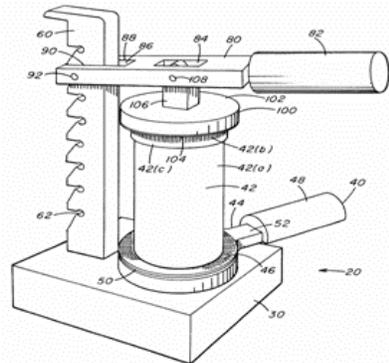


Figure 2.1 – United States patent number 6,393,947

The product includes a foundation with an adjusting platform embedded. This platform is attached to a handle that provides horizontal movement. A vertical post is mounted to the foundation with an adjustable attached arm for means of gripping and applying pressure to the top of the medicine bottle. The apparatus has simple mechanics, no electrical components, can adjust to various different bottle heights and is cost effective. For these reasons, the design is very sufficient; however, the flaw it possesses is the need for two hands to operate. Improvements to accommodate this patent to our design include combining the handles so that the bottle can be opened using a single-motion handle.

2.2 United States Patent Number 6,205,888

The one-handed childproof medicine bottle opener, US patent number 6,205,888, is a very simple design. The design includes a pill tray, which easily adapts to many different-sized medicine bottles by an array of rubber flaps that grip the medicine bottle. The bottle is kept centrally located on the non-slip mat inside of the product [2]. This apparatus is shown in Figure 2.2. A drawback with this patent is the size of the medicine

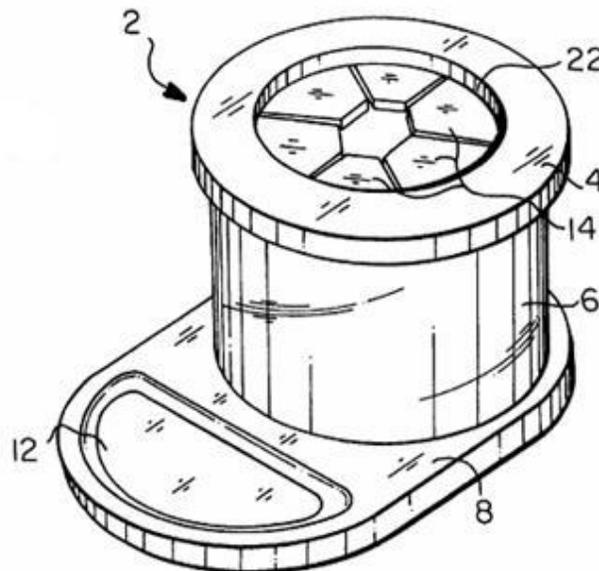


Figure 2.2 - United States patent number 6,205,888

bottle that the unit can open. Larger diameter bottles will not be able to fit into the apparatus and therefore will not meet design requirements. This is a very simple and inexpensive design, but it could be improved upon in order to assist a wider variety of people with different disabilities. A considered improvement is an added apparatus with a handle that would assist the person with pushing down the cap. Another improvement would be if the apparatus could rotate using the same handle or a motor in order to assist with the turning of the cap.

2.3 United States Patent Number 5,621,936

The Multi-Purpose Hand Tool US 5,621,936 shown in Figure 2.3 is a very versatile aid for people with limited hand functions. However, this device does not help the truly challenged. This tool assists with medicine bottle opening, cutting open letters, opening cans and unlocking doors [3]. This versatility also comes with a low market price of five dollars. The disadvantage of this device is that opening the medicine bottle requires the use of two hands. Similarly, the key assistance needs to be setup by someone with complete use of their hands. This device could be improved by adding a handle to give the user increased torque. The Multi-Purpose Hand Tool is only good for a limited number of disabled people.

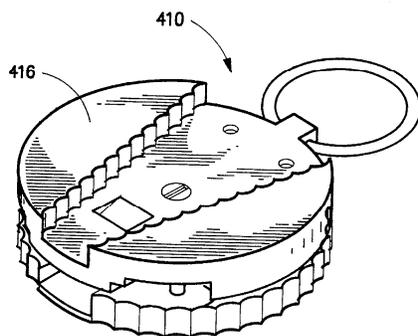


Figure 2.3 – United States patent number 5,621,936

2.4 United States Patent Number 6,263,761

A review of Patent No. 6,263,761 entitled Pill Bottle Opener filed on February 16, 2000 by John C. Ryder yielded a pertinent solution for opening medicine bottles. The design can be seen in Figure 2.4. The invention is very similar to a nutcracker, where the ends of the levers press and hold the bottle cap and the length of the invention provides additional leverage to assist in opening small bottles [4]. The invention is made of plastic, making it durable and very low cost.

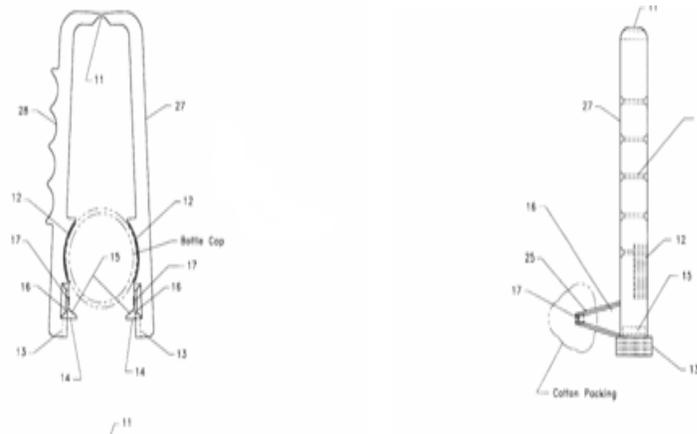


Figure 2.4 –United States patent number 6,263,761

This design is quite easy to store and, if needed, would even be able to be carried on an individual as an everyday item. This device also has small wedges on the base of the curved gripping section to pry up on bottle caps. A plastic blade is used to pierce the foil seal and assist in cotton removal. This device requires two-handed operation, one to hold the tool and one to hold the bottle from rotating. The unit requires a significant amount of hand strength to be able to apply enough friction force so the tool does not slip. This device is very limited to small bottles because of its innate small size. The actuation force and direction is very awkward to apply to the medicine bottle. Finally, this device cannot open child-proof or resistant medicine containers. These containers require a downward force, as well as force to turn the cap for removal. This design would not

meet the requirements for one-handed operation, but it could be used in conjunction with a separate hands free device to hold the medicine bottle from rotation while this device is used to rotate the bottle cap. Using a pad with a higher coefficient of friction on the curved gripping section would reduce the amount of force the operator would need to remove the medicine bottle cap.

2.5 United States Patent Number 6,651,531

Patent number 6,651,531 is a great example of a product built specifically to automate the opening and closing of a prescription pill bottle. This device, named Automated Pill Bottle Opener, uses an electric motor in conjunction with a gearbox in order to rotate the top of the pill bottle. This unit is initiated by the user placing the bottle on a lower gripping surface that is integrated into the device. A plunger assembly actuates the plunger downward until a top-gripping surface of the rotator assembly presses on the top of the bottle cap. Once the bottle is opened, a pressure sensitive triggering device reverses the direction of travel of the plunger so that the plunger is again raised to its original position. The bottle can also be resealed by placing the bottle on the lower gripping surface and setting the selector switch to the reverse direction. The bottle cap must be placed on top of the bottle before placing the bottle in the device. Putting the cap back on is identical to the forward motion, but the direction is reversed [5]. The patent cover page for the Automated Pill Bottle is shown in Figure 2.5.

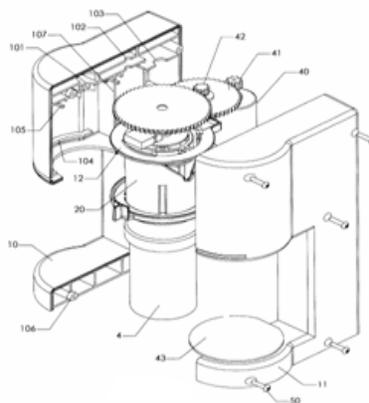


Figure 2.5 – United States patent number 6,651,531

3.0 Market Research

As with the development of any new product, a thorough evaluation must be done on the current products on the market. This evaluation determines the desirability of the proposed new product. Market research provided few products that would meet our design requirements. The following section focuses on commercially available products and assesses their abilities to meet the design requirements. Specific components that are applicable to the design are considered for the initial design recommendations.

3.1 Jaromatic Opener

The current market for container openers incorporates an assortment of products that ranges from cheap simple mechanics to expensive electrical devices. The Jaromatic Opener is automatic and motor driven. The device can be used either on a countertop or can be mounted on a wall. A picture of the Jaromatic Opener is shown in Figure 3.1. The



Figure 3.1 – Jaromatic bottle opener

Jaromatic simply involves placing the medicine bottle or jar in the device and pressing a button. A limitation in the design of the product is the size of the jar. The machine itself is five and a half inches wide, eleven and a half inches high and eight and a quarter

inches deep. The cost of the opener is twenty-nine dollars and ninety five cents per unit. The device is self adjusting to the bottle size and is safe and simple [6]. Medicine bottles that require the user to squeeze two tabs on the side will not be able to be open with this unit. Because electric components are introduced, failure of these components could happen - including, but not limited to, the power going out. This design, although somewhat pricy, is very well engineered and tackles most of our design goals. However, the unit does not allow the user to place the cap back on the medicine bottle and will not accommodate all varieties of medicine bottles.

3.2 The Purrfect Opener

The Purrfect Opener is a good example of an esthetically pleasing, simple, and handy design. This apparatus can be found in Figure 3.2. The product has a magnetic backing for easy storage on a refrigerator. This design is inexpensive and is easier, faster, and safer to use than most automated openers [7]. Some design disadvantages are that it doesn't adapt to very many different types of medicine bottles and isn't easily operated by people with certain disabilities like arthritis or missing appendages.



Figure 3.2 – The Purrfect Opener

3.3 Open Up Electric Jar and Bottle Opener

The Open Up Electric Jar and Bottle Opener in Figure 3.3 provides power to assist in opening of jars and bottles. The device has a cone at the top; while the motor spins the cone, the user holds the jar or bottle up into the cone. A major advantage to this device is that it helps with household jars and containers, a task that can be difficult for everyone, no matter what their physical ability [8]. The problem is it requires enough force to hold the jar into place to prevent it from rotating. This could be improved upon by a second cone on the bottom that would not spin, but rather push up on the jar and eliminate the need for the user to provide a resistive torque and upward force. Another disadvantage is the cost, which could be reduced by replacing the electric motor with a handle that force could be applied to by the user.



Figure 3.3 – Open Up electric jar and bottle opener

3.4 The Medication Bottle Opener

The Medication Bottle Opener first hit the market in the 1970s and was very successful. The Medication Bottle Opener, as seen in Figure 3.4, is very inexpensive at a price of two dollars and forty-nine cents. This efficient design is also very easy to manufacture. The design is ergonomic and effectively opens small bottles [9]. The product does require two-handed operation and would not be suitable for our design requirement of one-handed operation. Also, due to the very small leverage arms, it does not offer a significant advantage for opening bottles. The innately small size of the product greatly restricts the size of the bottle that can be opened. This product could be used in conjunction with another hands-free fixture that held the bottle section from rotating. The dome-shaped design has the potential to be an affective way to grip many varying bottle caps for a hands-free device.



Figure 3.4 – Medication bottle opener

3.5 The Pill Bottle Opening Tool

The Pill Bottle Opening Tool which can be seen in Figure 3.5 facilitates the opening and closing of pill bottles ranging from two inch diameter bottles to half inch diameter bottles. The tool works by gripping the sides of the bottle and adding a lever arm for mechanical advantage. The bottle opening tool also has a “bottle popper” to open bottles once the two arrows have been lined up. This device is a simple and low cost design at two dollars and ninety-five cents with no moving parts to wear or break [10]. One major disadvantage to this device is that two hands are needed in order to use it. One hand is needed to hold the bottle, and the other hand is needed to open the bottle. Another disadvantage is the awkward operation with having to push down on a bottle top and twist at the same time. Improvements to this design would be to make it more handicapped friendly, expand the use to greater than a few styles of bottles, and further automate it.

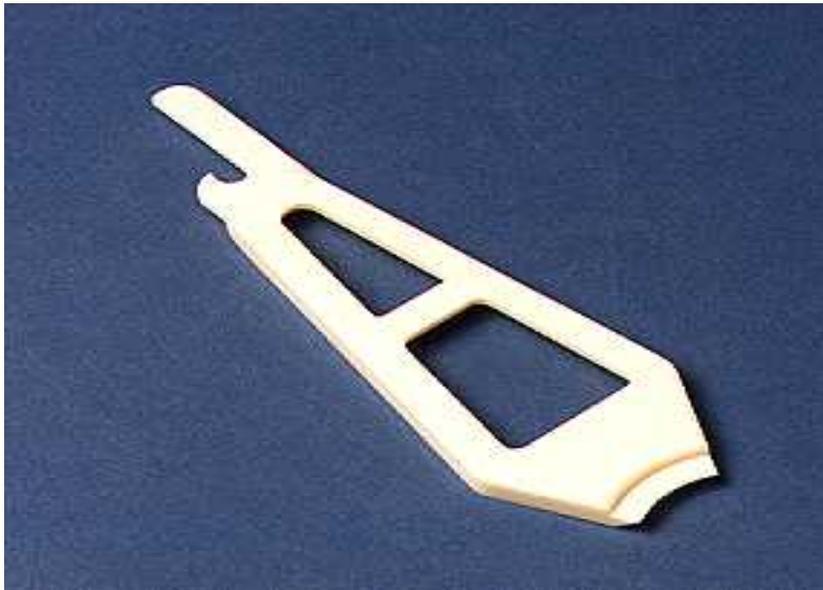


Figure 3.5 – Pill bottle opening tool

3.6 Medicine Bottle and Bottle Manufacturer Research

Our market research also focused on various types of existing medicine bottles. Research included targeting pharmacies, such as CVS and Walgreens. Going beyond the local pharmacy, we also targeted manufacturers that supply these pharmacies and found Kerr Manufacturing and Setco Bottles as the primary provider of an assortment of different styles of medicine bottles [11] [12]. These bottles included the most common style in which the operator has to push down and turn the cap and are most often found in the prescription drug market. Advil and other over the counter drug bottles consist of a cap that requires two tabs to be pressed in and then for the cap to be turned, while Tylenol requires two arrows to be lined up and the cap to be pressed off. Collection and testing of all these styles of bottles was an essential part of design development.

4.0 Design Considerations

Individual initial design considerations were compared and discussed. The design recommendations are born from patent research, market research, industrial technology, and engineering knowledge. The initial design recommendations provided further insight into the development of the semi automated prototype.

4.1 Mechanical Jackscrew and Slide

After a brainstorming session that involved component research, one possible preliminary design was sketched and analyzed. This design shown in Figure 4.1 involves a fixed mount foundation with an insert for a medicine bottle. Four fasteners with arced rubber pads on the end and jackscrew handles are used to center the bottle in the foundation. Two uprights are used and an adjustable top platform is attached with set screws. The top platform consists of a handle and gripper that applies both vertical pressure and horizontal motion to the top of the medicine bottle. The flaws in this design include the time to open one bottle and the challenge of doing it with just one hand. On the contrary, this design includes simple mechanics and would have no electrical

components, but would need to be mounted on a countertop for effective use. The design should be relatively inexpensive to construct.

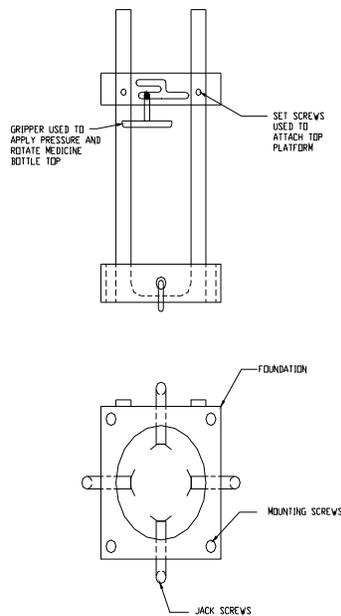


Figure 4.1 - Mechanical jackscrews and slide

4.2 Electrical-Mechanical Conical Gripper

An additional design involves an automated bottle opener that is adaptable to a wide variety of bottles. This apparatus can be found in Figure 4.2 and will look similar to a coffee maker. There is a non-slip surface most likely made of rubber on the bottom, and a conical hard rubber piece that will contact the bottle. The conical piece is on a sliding rod that will be spring loaded and pushed down by the user. The motion of pushing down will activate the motor inside that will rotate the rod/conical piece system after a specified time, which will unscrew the lid on the bottle. This design, though not simple, will be easy for anyone to use. It can be set on a counter with either high-friction feet or suction cups underneath or even permanently mounted with screws. This apparatus will operate by a one hundred twenty volt AC power source.

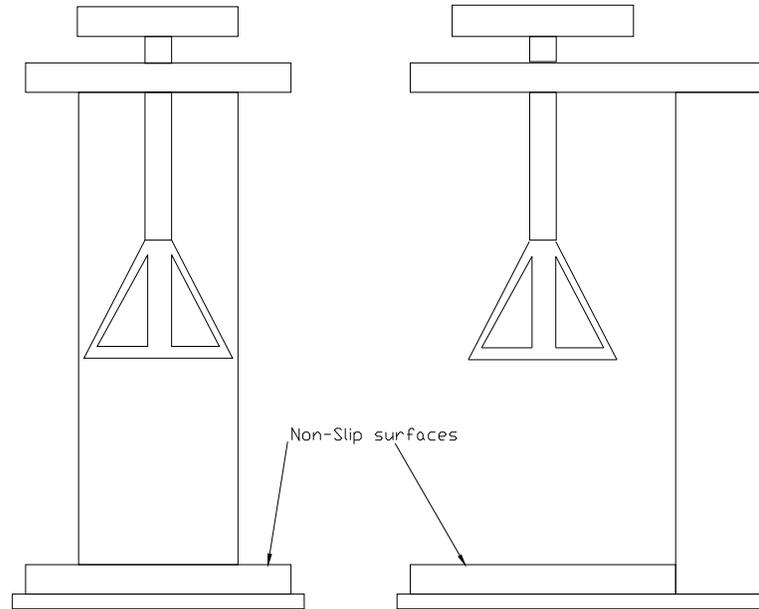


Figure 4.2 – Electrical-mechanical conical gripper

4.3 Interchangeable Cone and Ratchet

The bottle opener in Figure 4.3 incorporates the cone idea from the Open Up product. However, it uses two similar cones, one at the top and bottom. It also reduces cost by eliminating the electric motor. The motor is replaced by a handle that provides a mechanical advantage for the user to open the bottle. The device is operated by placing the bottle in the bottom cone. Next the user lowers the top cone by pushing down on the handle. The handle must be turned to remove the top of the jar or bottle. The device is made more versatile by making the cones interchangeable. The interchangeable cones will come in sets having varying diameters. This device could even be used to open a two liter bottle of soda by putting the large cone in the bottom, and the smallest on the top. The versatility and low cost of this device are its greatest assets.

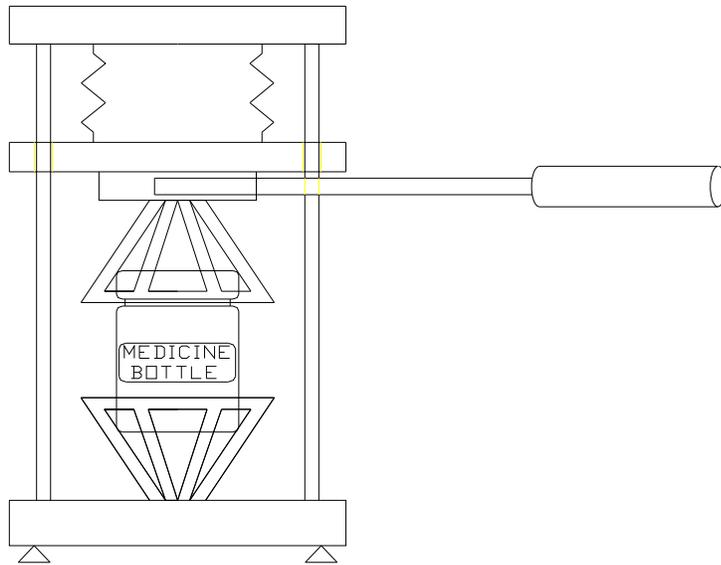


Figure 4.3 – Interchangeable cone and ratchet

4.4 Pressure Clamp

A standalone medicine bottle opener that can be operated with one hand and limited strength was considered. The design utilizes the domed-gripping device to grasp the medicine bottle cap. The medicine bottle is fixed from rotation by a conical friction section as shown in Figure 4.4. The clamping pressure needed to maximize the friction force to eliminate slipping is provided by a long lever and a carriage that locks in place by gear teeth. Next, a second lever on a bearing surface rotates the domed-shaped gripper, while applying a downward force from the carriage and removes the medicine bottle cap. After, the clamping pressure can be released by lifting the locking lever and carriage. In order to reseal the medicine bottle, the process can be reversed.

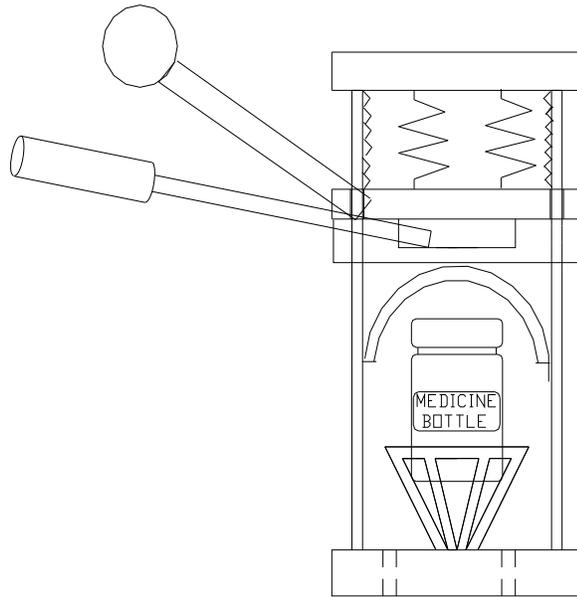


Figure 4.4 – Pressure clamp

4.5 Power Screw Clamp

Using a power screw to raise and lower an arm, which has a gripping surface on the end facing down towards the bottle top, was an additional design considered. This design can be seen in Figure 4.5. The bottle is placed on a lower gripping surface and the upper arm is lowered until the bottle top has been depressed. Once depressed, the lever arm can be rotated and the bottle top will now be unlocked. The arm can be raised and the bottle removed. By placing the bottle on the lower gripping surface with the cap on top of the bottle, the cap can be rotated on the bottle by reversing the steps. With interchangeable heads, the device will be able to open a multitude of bottle designs. The advantages to this design are that it can be used by the elderly and the handicapped, it opens many different bottles and is cheap. The disadvantages to this design are that it is not automated, and it will take extra time to change out the heads for different bottles.

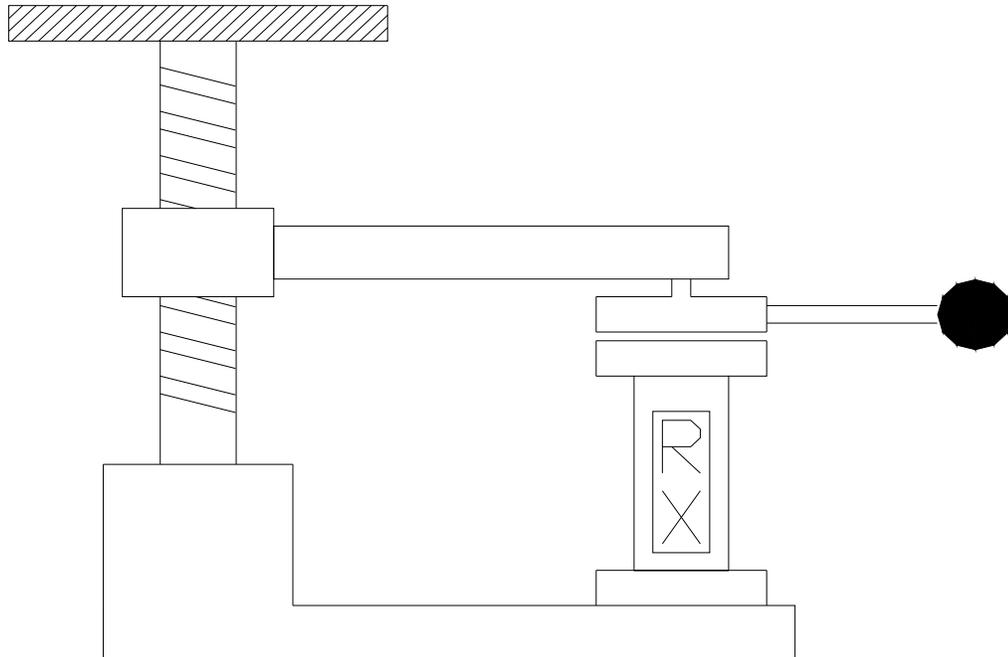


Figure 4.5 – Power screw clamp

Our research into patents and current market products shows that there is a need for a one-handed, limited strength device. With the preceding five design ideas, the design criterion was met, but the most adequate approach is the semi automated unit presented in section 9.0.

5.0 Medicine Bottle Selection

Market research yielded three different bottle styles that encompass the majority of the prescription and over the counter plastic medicine containers. Settling on these bottle styles involved contact with Kerr Manufacturing, the leading manufacturer of prescription and over the counter medicine bottles [12]. Talking with Kerr allowed us to obtain engineering samples of the most popular medicine bottles on the market and enabled a better final design concept in our testing phase.

5.1 Standard Prescription Bottle

The first medicine bottle considered, which is one of the most popular prescription bottles, is of the push down and turn style. This bottle style is shown in Figure 5.1 and consists of a series of tabs on the cap that lock into a series of grooves onto the top of the container. By pushing down on the cap, the tabs are released from the grooves on the top of the bottle and turning the cap allows for it to spin off. By having this procedure to open this bottle, it becomes more difficult for children to open the bottle.



Figure 5.1 – Standard prescription bottle

5.2 Lining Up of Arrows Bottle

The standard Tylenol bottle is the second bottle of interest and is found more often in over the counter applications. This bottle requires lining up two arrows allowing the cap to be released from the bottle. Figure 5.2 shows the Tylenol bottle, which consists of a lip all the way around the top of the medicine bottle, except for one small region where there is a break in the lip. The cap, sometimes called a snap cap, is composed of a tab that locks underneath the circumferential lip. The cap can be released when it is pushed up as it enters the small region where there is no longer a resistance from the lip

on the top of the bottle. This snap cap bottle style also acts as an effective child safety locking device.



Figure 5.2 – Lining up of arrows bottle

5.3 Two-Tab Bottle

The third bottle design incorporated in our final design concept involves the standard Advil, Aleve and Nyquil bottles. This over the counter medicine bottle entails two tabs located one hundred eighty degrees apart, which need to be pushed in to release the bottle cap when turned. This application is shown in Figure 5.3. Two stops on the top of the bottle prevent the cap from coming off. By pressing the tabs in, the stops are cleared allowing the cap to be turned off the bottle. Settling on designing our fixture around these three bottle styles was necessary for the further development of the design. It was now possible for us to propose our final design concept around these parameters.



Figure 5.3 – Two-tab bottle

6.0 Bench Marking of Black and Decker Unit

Continuous market research over time revealed a new product that used a semi-automated approach to open household jars and bottles. The Black and Decker Lids off jar opener wasn't able to put the cap back on and specifically was not designed for medicine bottles; therefore, not meeting design requirements. However, the product was so similar to a design consideration that bench marking the unit led to an extremely important insight on the functionality of components. The unit requires a user to place a bottle on a rotating base plate that has two chucks on it. A collapsible top platform has a similar two-chuck system that requires the user to level the top platform with the top of the jar by lifting on a handle. The user then has to press an on and off button that activates the motor and engages the rotation of the top and bottom. In addition to rotation, the chucks at the top are allowed to move in and adjust to the lid of the jar providing sufficient torque to loosen the cap. The bottom chucks move in and provide support for the jar. Figure 6.1 shows the unit in operation. A rotating base, adjustable chucks and the motor and gear assembly driving them are crucial components that could be adapted to open medicine bottles. By carefully disassembling the unit and documenting component layout and functionality, a better understanding of the unit was established.



Figure 6.1 – Black and Decker Lids Off unit

6.1 Motor and Switch Analysis

By removing the top of the Lids Off Unit, it was possible to clearly see the motor and gear system. After removing the top half of the gear box, a 120 volt DC Johnson Electric motor that was driving the gear box was clearly exposed. A simple circuit consisting of four diodes was used to convert AC power to DC power. A switch activated by pushing down on the large gray button shown in Figure 6.1 will start the motor and be turned off when the switch is depressed. Surprisingly, the motor was not mounted very securely and relied heavily on a small metal bracket attached to a drive shaft and small mold in the compact gear box. Figure 6.2 and Figure 6.3 display the motor and diode converter circuit, respectively.

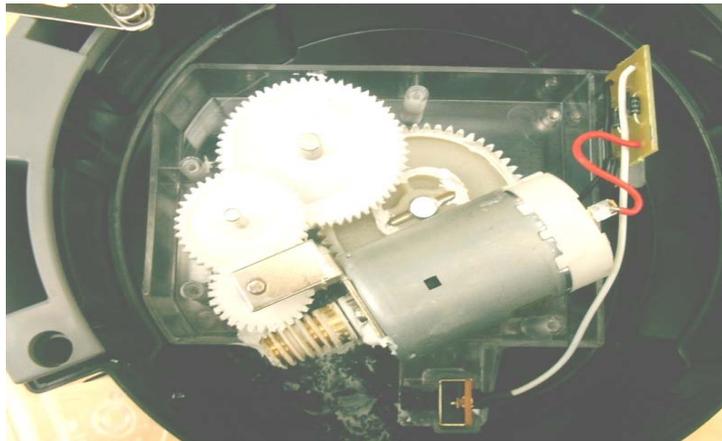


Figure 6.2 – Motor and gear assembly



Figure 6.3 – AC to DC converter circuit

6.2 Gearing and Gear Track Analysis

When the top platform has been adjusted to the top of the jar and the gray button is pressed activating the motor, the gear assembly begins rotating the chucks. A worm gear attached to the motor drives the first of four gears used to reduce the speed of the motor. The final gear attaches to a drive shaft that provides rotation of the top unit. The shaft has an eight- point-steel gear on the end that is used to drive a gear track. The gear track on the base, shown in Figure 6.5 after disassembly of the unit, allows for securing the bottom of the jar. A very similar gear track is used in the bottom platform. The bottom gear track relies on the top motor rotation and weight of the top platform pushing down to rotate the base. There is no motor in the base of the unit, just the simple mechanical gear track allowing the chucks to move in and out. Figure 6.4 shows the top gear track that is used for rotation of the jar and securing the lid. The collapsible plastic legs are also clearly shown in this figure allowing for the adjustment to the various different jar sizes.



Figure 6.4 – Top platform gear track



Figure 6.5 – Base gear track after disassembly

6.3 Developmental Benefits of Bench Marking

Black and Decker has developed a relatively simple system and effective unit with the lids off semi automated jar opener. Having only to use one motor is a clear advantage when trying to keep the cost low. The bench marking of this unit revealed components that were not used in design considerations, including using simple gear tracks to operate chucks. One of the extremely valuable components revealed in bench marking was the simple AC to DC converter circuit. Previous to disassembling the unit, there was limited knowledge that this type of circuit even existed. Valuable information from the bench marking of the Lids Off Unit was gained and similar components are found in the final design.

7.0 Bottle Torque and Force Testing

Testing of current bottles for opening torque and force to overcome child safety mechanisms was crucial to the final design. Torque data was needed in the selection of the proper motor and gear train required for outputting the necessary torque to overcome the frictional resistance in the threads. A selection of too much torque would make the device costly, and knowing the max torque necessary allowed for an optimization of the

design. The data of the force pushing down was also vital in understanding what a reasonable amount of downward force the device would see. This data was used in the structural design of the device.

7.1 Torque and Force Testing Apparatus

The torque required to open the bottle was gathered by fixing a bottle in a vise, and using a vise grip wrench to secure the cap. With substantial weight applied to the cap, the wrench was turned using a spring scale as shown in Figure 7.1. The perpendicular distance from the center of the bottle cap to the point where the spring scale is applied was measured. The torque then can be easily calculated by multiplying the force times the perpendicular distance. The weight on the cap exceeded the minimal value in order to assure this torque load was the maximum necessary.

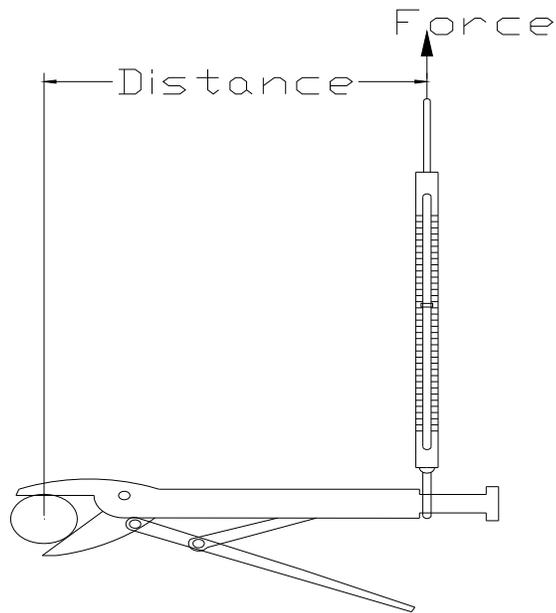


Figure 7.1 – Bottle and torque testing diagram

This test was performed to a variety of pushdown and turn-style bottles. The test was not performed to other styles of bottles, because the other bottles require far less torque.

In order to find the minimal amount of force to push down, measured weights were placed on top of a pushdown and turn prescription bottle. While those weights were

added, an observer watched to see when the threads lined up to allow the cap to turn. By looking closely at the cap, the observer could see through an opening and watch the position of the threads.

7.2 Torque and Force Testing Results

The testing of a variety of over the counter and prescription bottles, including the three major bottles the unit is to open as discussed in section 5.0, revealed that the standard prescription bottle is the hardest to open. To open this bottle, a calculated torque of sixteen inch-pounds and a downward force of twenty pounds was necessary. With this information, safety factors were applied to the torque and force requirements.

8.0 Design Development

Initial design considerations consisted of largely mechanical devices that overlooked and made assumptions on some of our most important design goals. Our design is to be safe and easy to use, cost effective, lightweight, and require a minimum amount of maintenance and assembly. Most initial design considerations strayed from the core requirements, largely in the area of the ease of use requirement. A more automated approach, which includes electronics, will aid in meeting the ease of use requirement. As the design progressed, keeping in mind the products' target audience, their needs and abilities were necessary.

8.1 Review of Design Considerations

Initial designs relied heavily on mechanics that required the user to either be pushing or pulling handles which would be difficult with the use of a single-functional hand. Some designs included removable fixtures to fit an assortment of bottles contributing to assembly time and making it more difficult for the operator. These early designs required a large amount of time to open a bottle and were rather bulky units. To eliminate some of the cons of early design concepts, components such as motor driven

gears and switches that will allow the operator to just press a button rather than switch a fixture in and out were beneficial. When taking into account an electric or automatic approach, the ease of use and the appearance of the unit are two very positive aspects. However, going electric increases prototype development cost and will be more complex to design. By taking a more automated approach the product is more marketable and visually appealing than a mechanical device consisting of aluminum plates, levers and fixtures.

8.2 Assembly and Component Concepts

Initial design of the unit looked at the top and bottom halves as separate entities with both the top and bottom of the device having separate functions. The bottom clamps the bottle and rotates it while the top provides movement up and down and clamps the bottle cap.

8.3 Base Assembly Conceptual Model

There is extensive movement in the base of the pill bottle opener. The fastening mechanism is a four point chuck that is opened and closed via an electric motor mounted underneath the bottom plate. The power from the motor is transferred to the chucks through two gear boxes utilizing perpendicular gear sets as shown in Figure 8.1.

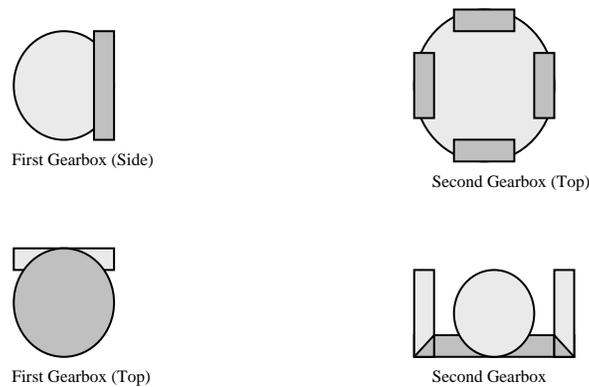


Figure 8.1 – Base gearing assembly

Each chuck runs on a separate power screw to keep the bottle centered on the bottom plate. In using power screws, it is possible to keep pressure on the bottle without using a brake in order to keep the motor from spinning in reverse when the power is shut off. The rotation of the bottom plate is powered by a separate electric motor geared directly with the edge of the bottom plate.

8.4 Top Assembly Conceptual Model

The top section of the pill bottle opener is responsible for the vertical motion and also for securing the bottle top. The top assembly of the unit is shown in Figure 8.2. The vertical motion is handled by two power screws on opposing sides of the top platform. The screws which move the top are powered by a DC electric motor connected to a gear box which transfers power to each screw. The top platform has two threaded holes, which the power screws use to create the vertical movement. The power screws are fixed at the bottom of the enclosure with bearings. A switch is used to control the movement of the top platform. When the switch is tripped it sends a signal to stop the motor driving the power screws. There will be instances where the vertical motion will have to depress the bottle by a certain distance before it can twist it off. This motion is handled by the logic chip and the selector switch on the unit.

The securing of the bottle top is a crucial part of the design and is handled through the use of a two jaw chuck system. The jaws are moved in and out on slots with a power screw system that is driven off of a DC electric motor connected to a gear box. The two-point chuck system is designed so that it secures the push down and turn bottle, the line up the arrows bottle and the two tabs and twist bottle. Once the jaws have been moved into place they hold their position until the bottle has been closed. Once closed, the motor driving the jaws reverses and the jaws now allow the bottle to be removed from the unit.

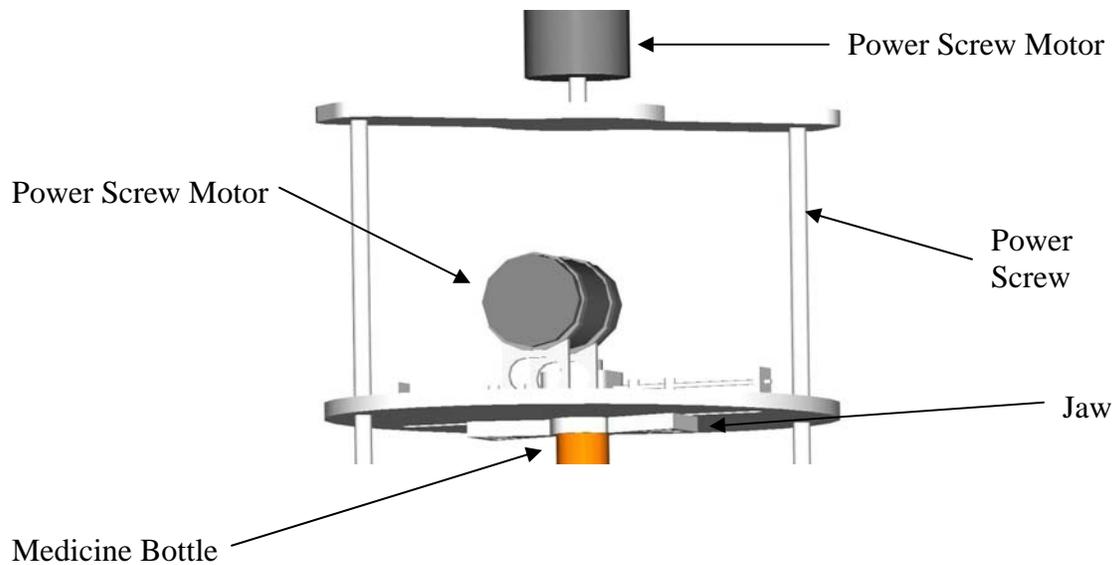


Figure 8.2 – Top assembly

8.5 Operating Procedure

Though complex, the pill bottle opener completes the very simple task of removing and replacing a bottle cap. There is a two-position switch for the user to choose between. The first position is for the type of bottle that opens by pushing down and turning. The user places the bottle in the center of the bottom plate, selects the correct switch setting, and presses the start button. The four-point bottom chuck closes around the bottle, and then the top apparatus moves down until the top of the cap touches the top plate and places pressure on the top of the bottle. The two point chuck on the top closes around the bottle cap and the bottom assembly rotates and unscrews the cap. The top apparatus then raises and removes the bottle cap, but without releasing the cap. The user then takes their pills and places the bottle back in the center of the bottom plate. The cap is replaced in the reverse order that it was removed.

The second switch position is for the bottles that require either pushing in of the tabs, or the lining up of arrows and prying off. The user places the bottle in the center of the bottom plate with the arrows or tabs aligned correctly, selects the correct switch setting, and presses the start button. The four-point bottom chuck closes around the bottle, and then the top apparatus moves down until the top of the cap touches the top plate. The two-point top chuck then closes around the bottle cap and the bottom

plate/chuck assembly rotates and unscrews the cap while applying a tensile force. For the bottles that require pushing in tabs and twisting, the tensile force does not affect how the bottle opens. Bottles requiring the lining up of arrows, the rotation and tensile force together pry off the lid when the arrows are aligned. The unit is shown as a working model below in Figure 8.3 and as an encased unit as it would look like after manufacturing in Figure 8.4, respectively.

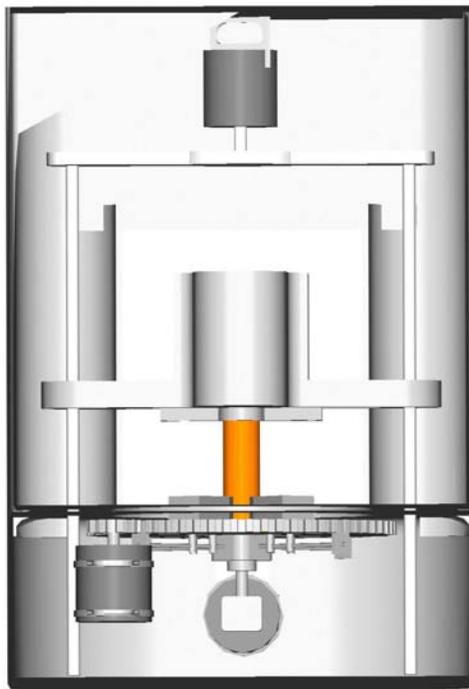


Figure 8.3 – Working prototype model

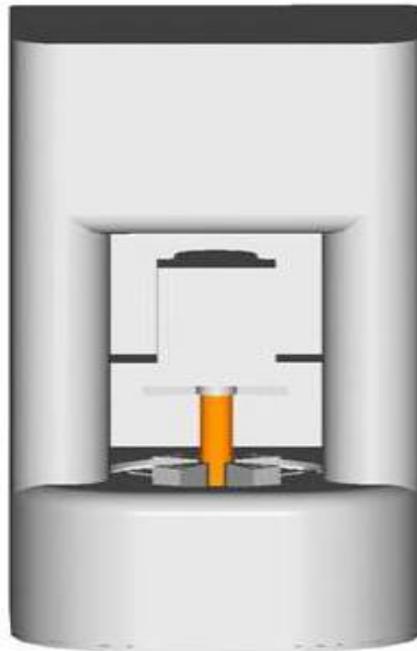


Figure 8.4 – Completed assembly after manufacturing

9.0 Final Design Concept

The development of our design was beneficial to the layout of components in a three dimensional model format geared towards medicine bottles. In many ways the unit described in the previous section overshoot the simplicity of the design goals and did not meet others with an emphasis on being cost effective. Settling on a final design concept was a crucial step and, realistically, the unit as is in the design development section isn't the most efficient product. A variation of this unit that is semi automated, using many of the same components, suits the design goals more appropriately. To settle on a final design, careful analysis of the design requirements with respect to a fully automated design and a semi-automated design aided in a decision.

9.1 Fully-Automated Versus Semi Automated Design Analysis

Listing out the design requirements and developing a matrix to select the most optimal design, led to the semi automated approach as the final design concept. Table 9.1 shows the matrix which helped make this decision. The design requirements are listed in

the left-hand column and the two devices are located in the other two columns showing whether the units fully meet the requirements. The two deciding factors that made the final design a semi automatic approach were the maintenance and cost effectiveness of the unit. The fully-automated unit consisted of four motors and would have required much more maintenance, and the cost of the unit would have been extreme. Also, contributing to the cost of the fully-automated unit was the programmable logic circuit, which has been eliminated with the semi automated approach.

Design Requirements from Project Description	Fully Automated	Semi automated
Simple Device To Use	Yes	Yes
User Can Open With One Hand	Yes	Yes
Accommodate Prescription + OTC Applications	Yes	Yes
Safe To Use	Yes	Yes
Easy To Operate	Yes	Yes
Lightweight	Yes	Yes
No Maintenance	No	Yes
No Assembly Requirement	Yes	Yes
Cost Effective	No	Yes

Table 9.1 – Design requirement selection matrix

9.2 Pros and Cons of Fully-Automated and Semi Automated Units

Further solidification the semi automated approach dealt with weighing out the pros and cons of the two units. The pros and cons of the two devices are shown in Table 9.2. The fully-automated approach was appealing to the elderly, as pushing down on the bottle would not be necessary. The deciding factor to go with a semi automated approach revolved around the cost of the unit. The fully-automated approach went far beyond the design requirements, had the potential to be a bulky unit and complex to design. Taking a lesson from Black and Decker, we felt low cost and simplicity of components would sell.

Semi Automated Pros	Fully Automated Pros
Meets Design Requirements	Appeals To Elderly Individuals
Low Cost	Fully Automated
Less Moving Parts	
More Reliable	
Saves Space	

Semi Automated Cons	Fully Automated Cons
Relies More on User Ability	High Cost
	Time and Risk Involved in Learning New Technology
	Goes Beyond the Design Requirement
	Potential To Be a Bulky Unit

Table 9.2 – Pros and cons of fully and semi automated designs

9.3 Semi Automated Design Concept

The semi automated design approach is a simple design consisting of only a single motor. A DC motor with a worm gear on the end is used to drive a series of gears that reduces the speed. The final gear drives the primary drive shaft, which provides the rotation for the top plate. The top plate is connected to the shaft through a square drive and bolted into the square drive on the shaft. The top plate consists of a non-slip surface, upon which the medicine bottle is placed. When the user places a medicine bottle on the top plate, the plate allows for approximately an eighth of an inch vertical displacement. This displacement of the shaft allows for the shaft to depress a normally open ball switch that engages the motor and, in turn, driving the unit and providing rotation of the top plate to open the medicine bottle. The ball switch is threaded into a bottom plate made out of steel. The combination of the downward force provided by the user and the rotating plate allows for the bottle to open. Because a DC motor is being used, reversing the motor is a simple task by using a double pole double throw switch to reverse the polarity of the motor. The user will activate the switch, as shown on the prototype in Figure 9.3, to reverse the direction of the rotating plate. Figure 9.1 and Figure 9.2 show the motor and gear assembly and a cut through of the unit respectively.

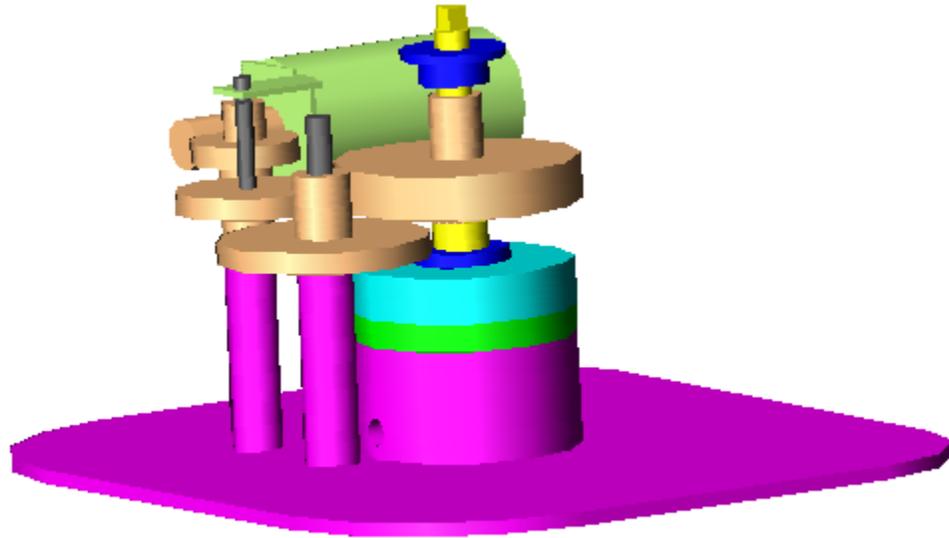


Figure 9.1 – Motor and gear assembly

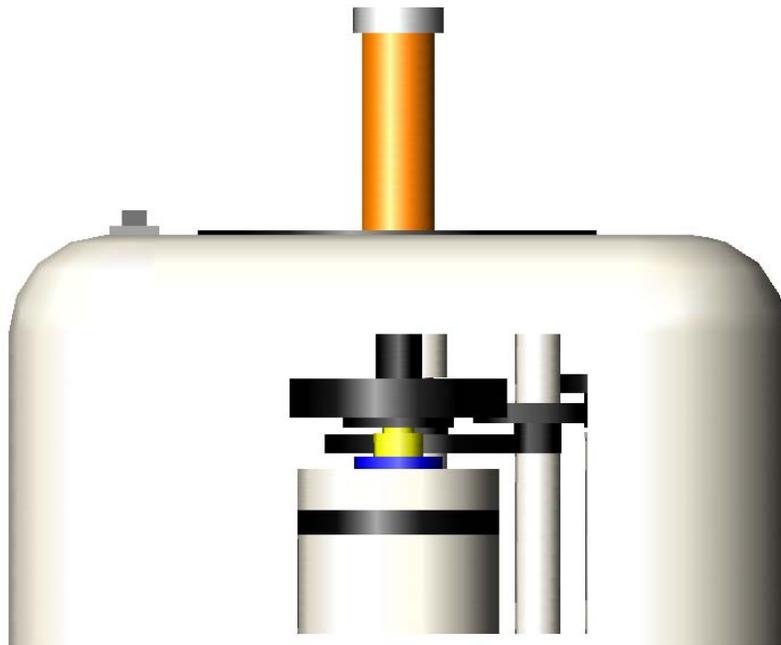


Figure 9.2 – Cut through of semi automated unit



Figure 9.3 – Prototype

9.4 Operating Instructions

A one handed person holds the top of a medicine bottle as is necessary to release the childproof tabs or locks. They will then proceed to place the bottle on the non-slip surface that begins to spin as the bottle is pressed down onto it by the user. The spinning and gripping of the surface eliminates the need for a second hand to perform those tasks. When the bottle needs to be closed, the user moves the switch to the “close” position and reverses the process.

10.0 Ball Switch Mounting Plate Analysis

The bottom plate, or switch mount, performs one main function: holding the ball switch in place. The ball switch is threaded up into the bottom plate using a 9/16 – 18 UNF-2A thread. The shaft that is connected to the top platform rests on the ball switch

and when a user applies a downward force on the platform, it is transferred to the switch body itself. The plate is connected to an integrated ABS plastic boss at the bottom of the case which, in turn, transfers all the force to the base of the unit. With the downward force having to be transferred from the switch to the plate, the connection between the two becomes the effective area. The 9/16 – 18 UNF-2A thread provides this connection. The arrows in Figure 10.1 represent the downward force applied by the user, the red lines show the contact area between the threads, and the dotted lines show the effective shear area.

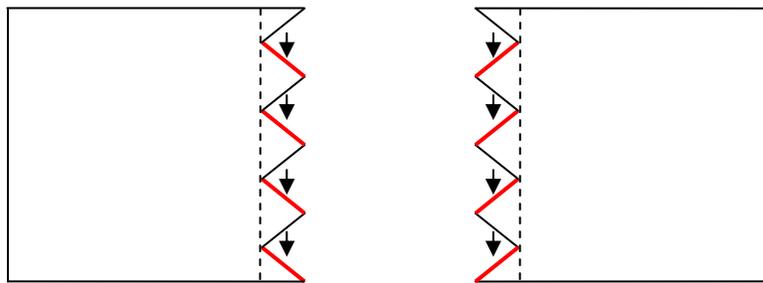


Figure 10.1 – Effective areas of bottom plate

The shear area can be analyzed by approximating higher than average downward forces that will be applied by the user. To approximate these forces, a five-person independent study was performed. The results of this study showed an average force of thirty-five pounds when the participants were asked to push “harder than normal” to open the bottle. With this force, the shear force on the bottom plate was found to be seventy-nine pounds per square inch when using a quarter inch thick plate [13]. This shear force was then compared to the maximum allowable shear forces of several common materials including: ASTM-A36 steel, 6060-T6 aluminum, and ABS plastic. The calculations regarding thread information and the shear area of the bottom plate are located in Appendix A [14].

10.1 Switch Mounting Plate Material Factor of Safeties

The ABS was selected as a material to compare because of the three dimensional printer's ability to mold parts using it. The allowable shear stresses were found to be twenty-one ksi for the steel, and twenty ksi for the aluminum. No allowable shear stresses were available for the ABS, but a conservative estimate of allowable shear stress is fifty percent of the material's yield strength in tension, which calculates to be 2,145psi. Using these allowable limits, the factor of safety for each material is: 265 for steel, 253 for aluminum and twenty-seven for ABS. The calculations regarding the factors of safety are also shown in Appendix A [14].

11.0 Gear Analysis

The gear train consists of a 120 Volt DC motor directly driving a worm gear mated with four other gears as seen in Figure 10.2.

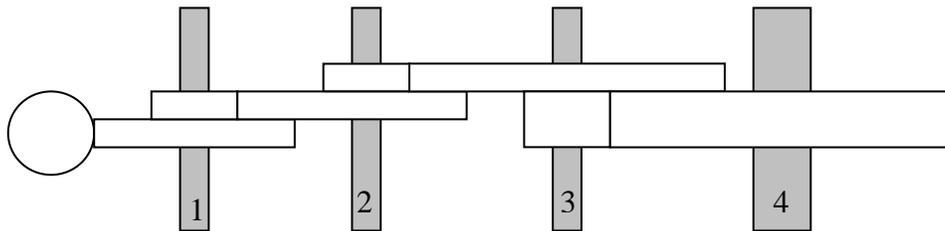


Figure 10.2 – Gear train layout

This gear train reduces the rotation from the motor's 4600 RPM to the final drive speed of about eight revolutions per minute. The measured torque needed to remove a medicine bottle cap is sixteen inch-lbs and this gear train easily obtains this final torque with a large factor of safety [13].

11.1 Tangential Forces and Stresses in Gear Teeth

Assuming a worst-case scenario of only one tooth from each gear transferring the power, it is possible to calculate the tangential forces and the stresses in the individual

teeth. Table 11.1 shows the formulas used to calculate the tangential forces in each of the gears, as well as a table displaying these forces. F_n is the normal force acting on the gear due to the torque, F_t is tangential force acting on the gear, F_r is the radial force acting on the gear, T is torque in the gear, ϕ is the pressure angle due to gear manufacturing, and r is the radius of the gear [13].

$F_n = T/r$ $F_t = F_n \cos \phi$ $F_r = F_n \sin \phi$

Gear Characteristics			Forces Between Gears		
Gear #	T_{gear} in-lbs	ϕ (°)	F_n (lbs)	F_t (lbs)	F_r (lbs)
worm					
1	0.224	25	0.46	0.455953	0.060882
2	0.95	25	1.473	1.460042	0.194954
3	3.8	25	3.98	3.944987	0.52676
4	16	25	14.545	14.41704	1.925056

Table 11.1 – Tangential forces between gears

In looking at the forces in the gears, there are virtually negligible radial forces acting on the shafts. For the tangential forces, there is slightly more force, but in dealing with the failure of the gears, there is almost no need for concern. These small forces should not result in the failure of these gears and the analysis done to prove this makes the following assumptions:

1. A full load is applied to the tip of a single tooth.
2. The radial load component is negligible.
3. The load is distributed uniformly across the full-face width.
4. The forces due to tooth sliding friction are negligible (grease).
5. The stress concentration in the tooth fillet is negligible.

11.2 Bending Stress: Lewis Equation

When taking these assumptions into consideration, it is possible to develop the basic Lewis equation. This equation and the results can be seen in Table 11.2. σ is the stress, P is the diametric pitch, N is number of teeth, d is pitch diameter, Y is the Lewis form factor, and b is the relationship between the tooth thickness, t , and the tooth height, L . (Note: a is the larger and b is the smaller half of each gear)

$b = 6F_t(L/t^2)$ $\sigma = (F_t P)/(bY)$

Gear #	L (in)	t (in)	Ft (lbs)	b	Y	d (in)	N	P	σ (ksi)
1a	0.065	0.075	0.456	31.613	0.425	0.965	30	31.088	1.0550
1b	0.065	0.075	1.460	101.230	0.307	0.482	14	29.046	1.3646
2a	0.065	0.075	1.460	101.230	0.457	1.292	40	30.960	0.9771
2b	0.065	0.075	3.945	273.519	0.307	0.478	14	29.289	1.3760
3a	0.065	0.075	3.945	273.519	0.491	1.928	60	31.120	0.9142
3b	0.1	0.1	14.417	865.023	0.227	0.528	12	22.727	1.6687
4	0.1	0.1	14.417	865.023	0.489	2.285	60	26.258	0.8950

Table 11.2 – Basic gear stress analysis

While analyzing the data in Table 4, it is proved that the nylon gears, having a tensile strength of nine ksi at yield, will definitely hold up to the task of opening a medicine bottle with a safety factor of 5.4; this analysis is assuming the load is carried by one tooth. The small stress in the gears shows that it would be possible to make them out of a weaker, less-expensive material, or even to make the gears smaller in order to save space [15].

11.3 Gear Design Concerning Motor Stall

In designing for the gears to hold up to the torque of motor stall, it was calculated that the gear train must hold an output of 105.6 in-lbs (8.8 ft-lbs). Examining the gear train shows that two teeth are in the tip-load condition as analyzed before, and one tooth is in full contact, resulting in the largest force near the middle of the tooth. In order to calculate shear stress, the face width of the gears had to be measured. Knowing the height

and thickness of the gears this could be calculated. These values can be seen in Table 11.3. The maximum shear stress seen by a gear tooth at motor stall is about 3.5ksi, giving a factor of safety of 2.6 assuming that the load is handled by one tooth [13].

Gear #	T (in-lb)	d (in)	Ft (lbs)	t (in)	w (in)	τ (psi)
1a	11.721	0.965	24.292	0.075	0.200	1619.49
1b	11.721	0.304	38.556	0.075	0.300	1713.60
2a	24.907	1.292	38.556	0.075	0.200	2570.41
2b	24.907	0.478	52.107	0.075	0.300	2315.88
3a	50.231	1.928	52.107	0.075	0.200	3473.81
3b	50.231	0.528	95.135	0.100	0.575	1654.52
4	105.600	2.220	95.135	0.100	0.400	2378.38

Table 11.3 – Gear shear stress

11.4 Contact Ratio of Gears

In order to show exactly how many teeth are in contact, the contact ratio needed to be calculated. The contact ratio, m_p , is defined as the length of contact, Z , divided by the base pitch, p_b . For the calculations, r is pitch radius, a is the addendum, c is the center distance, ϕ is the pressure angle, and p is the circular pitch. Table 11.4 shows the contact ratio of the gears.

$$\begin{aligned}
 p &= \pi/P \\
 p_b &= p \cdot \cos(\phi) \\
 m_p &= Z/p_b
 \end{aligned}$$

Gear #	P	p	ϕ (rad)	p_b	a	r	c	Z	m_p
1a	31.088	0.101	0.436	0.091586	0.03	0.48	0.965	0.13	1.419424
1b	29.046	0.108	0.436	0.098027	0.03	0.15	0.80	0.12	1.224157
2a	30.960	0.101	0.436	0.091966	0.03	0.65	0.89	0.12	1.304828
2b	29.289	0.107	0.436	0.097213	0.03	0.24	1.20	0.14	1.440134
3a	31.120	0.101	0.436	0.091492	0.03	0.96	1.23	0.14	1.530196
3b	22.727	0.138	0.436	0.125279	0.04	0.26	1.37	0.175	1.396883
4	26.258	0.120	0.436	0.108433	0.04	1.11	1.37	0.175	1.613904

Table 11.4 – Contact ratio of gears

After calculating the individual contact ratios for the gears, all of the values are between about 1.22 and 1.61. This shows that the stresses previously calculated are conservative calculations, in that they assume each tooth takes the entire load, rather than splitting up the load with other teeth [13].

12.0 Electrical Circuitry

The electrical system, as seen in Figure 12.1, for the bottle opener utilizes a 120V AC input that can be found in any home.

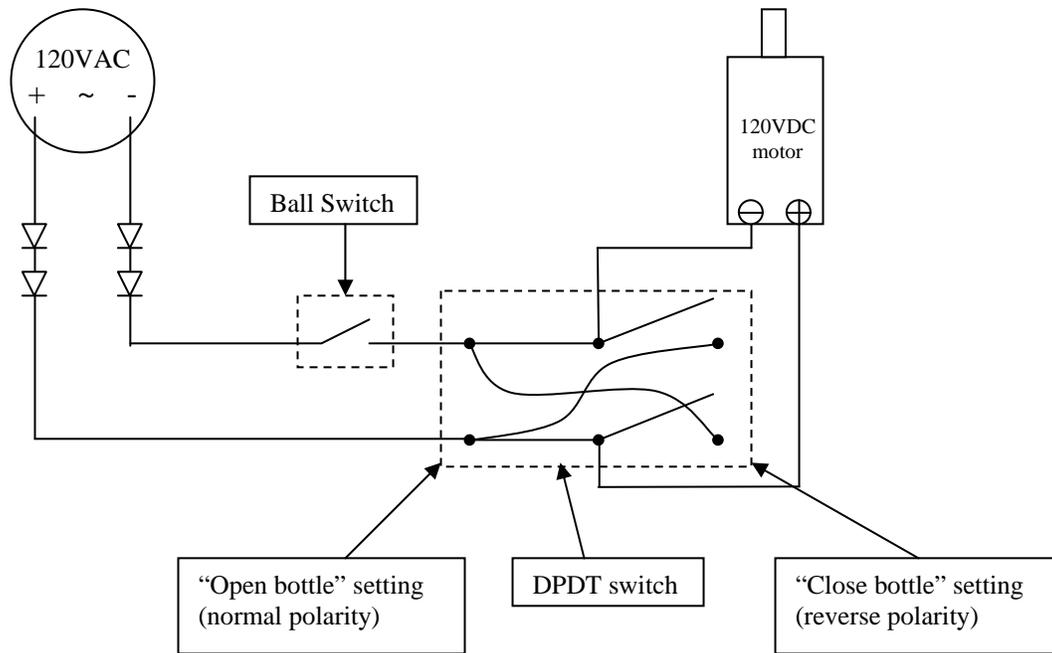


Figure 12.1 – Electrical wiring diagram

The motor for the unit is a DC motor, as opposed to an AC motor, because the ability to run in both directions is necessary, which a DC version provides. In order to convert the AC power to DC power, the positive side and the negative side of the AC input will pass through two diodes each that will create a pseudo 120V DC signal. This signal is sufficient for our application and will provide the DC signal we need to run our motor in both directions. Once the power has been converted into a DC signal, it is then fed to a

double pole, double throw (DPDT) switch which allows the reversing of the polarity when needed. The DPDT switch's output is connected to the motor to deliver the power. In order to keep the power off until the platform has been depressed, a normally open ball switch is between the diodes and the DPDT switch. When the switch is in its normal open state and the platform is not being depressed, the switch is not allowing the circuit to be closed. However, when the platform is depressed and the ball switch is pushed down, the circuit is closed and the motor is powered [16]. The DPDT switch is located on the top of the unit and will be controlled by the user. The switch has two positions, "Open Bottle" and "Close Bottle".

13.0 Non-Slip Surface Testing

The top plate, or friction plate, is extremely important to the user's perception of quality. The top plate is the first and only user interface while using this product. There are additional requirements beyond the primary functions of the top plate because it is the sole-user interface. The friction plate optimizes the coefficient of friction, durability, elasticity, cost, and needs to be ergonomic and aesthetically pleasing. Minimizing the required input force will be critical to the quality of the medicine bottle opener. Maximizing the coefficient of friction yields the minimum required input force required to remove / replace a medicine bottle cap. The material is designed to facilitate prescription medicine bottles of the push down and turn style as a mating surface. The plastics from most medicine bottles are very similar and produce similar coefficients of friction with the friction pad. The torque required to open the bottle is fixed and the normal force on the bottle cannot be changed or assisted mechanically; the coefficient of friction is the only variable [15].

13.1 Rubber Padding and Knurled Surface Solutions

There are two characteristics of the non-slip surface that had to be evaluated in order to select the optimal material. First, use a material with a very high coefficient of friction, such as rubber or a "rubber-like" material. Second, a material with a lower

coefficient of friction, but very durable and can be machined or manufactured to create a high coefficient of friction through a very rough surface finish. One such material that is commonly knurled to create a high friction coefficient and is used in similar applications is aluminum. Aluminum is lightweight, very strong, durable, and relatively inexpensive. Using a rough surface finish like this may be an effective way to create enough friction force to open a bottle. However, this surface would be far less aesthetic, might mark the bottle, may create sharp surfaces or edges on the friction plate, and would be more expensive to machine.

13.2 Initial Material Selection

A rubber or “rubber-like” material will combine a high coefficient of friction with a low elastic modulus to create a larger high-friction area. Through experimentation it was found that a material that could fill in the voids and also partially surround the outside base of the medicine bottle had a great advantage over the materials that were too stiff and would not allow the bottle to press into the friction pad. When the bottle is pressed into the friction pad, the sections of the pad in contact with the cylinder’s outer diameter “pinch” against the side of the bottle and greatly reduce the normal force input from the user.

13.3 Testing of Materials

The gripping surface not only has to hold the bottle in place while the plate is spinning, but will also need to survive for at least 14,600 uses (14,600 uses corresponds to eight uses/day for 5 years). Some materials, such as the pure gum rubber and the neoprene, showed significant wear after only a few cap removals. The santoprene, polyethylene, and polyurethane did not provide enough grip to keep the bottle from spinning. The latex/natural rubber provided the best combination of grip and durability. This material was further tested in varying thicknesses including 1/16”, 1/8”, and ¼”. The 1/8” thick latex proved to be the optimal solution because of its ability to contour to each of the bottle’s bottom surfaces.

13.4 Adhesive Bondage of Rubber Padding

During friction material testing, the adhesive was found to be as critical to the performance of the friction pad as the friction material itself. Different spray adhesives were used to fasten the material to the prototype. Some of these spray adhesives were not strong enough, or were not rigid enough to make an effective bond between the bottle and the pad. Also, some of the adhesives caused the friction material to be uneven or wrinkle. This severely impacted the performance of the friction material and also caused the material to tear in many cases. A double sided 3M tape provided the best solution for adhering the rubber to the plate. The tape is applied to the cleaned aluminum top plate and the latex is laid on top of the tape. This 3M product provides a cost effective and strong adhesion solution.

14.0 Addressing Child Safety Concerns

The final prototype unit is designed for an adult with the use of a single functional hand needing assistance with the opening of a medicine bottle. By providing the torque to open the bottle we only ask the user to provide the downward force, pushing in of tabs or lining up of arrows to open and close the bottle. By doing so the unit makes opening a medicine bottle easier for the appropriate user, however in no way is it intend to make opening bottles for children easier. In the production phase literature regarding safe use of the device will be provided. In this literature suggested areas to place the unit, to store medicine bottles, awareness statistics on child safety and medicine bottles and numbers to call in case of an emergency would be included with the sale of the unit.

The first step in prevention of a child using the device to open a medicine bottle is to place the unit far away from the medicine bottles it opens. It is suggested that the device be placed on a countertop in the kitchen area where a child will not be able to get to. Every year 25,000 children under the age of five are killed from swallowing medicines and household cleaning substances [17]. These deaths could be easily avoided should the user of the bottle follow a safe storage practice for medicines and substances.

Medicine bottles should be kept far out of reach and sight of children preferably in a locked cabinet.

To operate the unit the user should obtain their medicine bottle from the secure cabinet and bring it to the device. While at the unit, the user should follow the standard instructions to open and close the bottle and then return the bottle to the out of reach or locked cabinet where a child could not obtain the medication. Medications shouldn't be left on tables or in handbags when young children are present as these are extremely accessible places for children to get to obtain medication. The unit developed helps adults overcome child resistant locks, but it doesn't in any way alter the bottle. It is the user's responsibility to properly store their medications and realize that medicine bottles although being child resistant are not child proof.

15.0 Financial Analysis

The medicine bottle opener development and prototyping costs are extremely low. The major costs to design the prototype can be found in the Table 14.1. The most expensive item was the Black and Decker® Lids-Off™ Automatic Jar Opener. The Lids-Off™ is a similar counter top appliance used to open various jars. The jar opener was used as a benchmark to investigate the typical industrial styling and craftsmanship used in home appliances. The medicine bottle opener prototype was designed to accommodate the electric drive motor, electric cord, as well as other small components to significantly reduce the prototyping costs (as seen in the table below). The total prototyping cost was significantly under budget at forty seven dollars and ten cents.

Fifteen dollars is the approximate cost to manufacture, assemble, and sell the medicine bottle opener. The final design manufacturing costs are assumed on a moderately high volume of approximately 50,000 units per annum. Each component cost is outlined in the chart below. The manufacturing costs of the major components top cover, base, switch mount, and gears, as well as, the electrical components will realize a significant reduction in cost from high production. The machined metal top plate could be molded from plastic to greatly reduce the cost leaving the main shaft the only

machined metal component. The small DC electric motor is the most expensive component in the medicine bottle opener design.

The sales and production numbers are conservative estimates when looking at the current market. The *Amputee Coalition of America* (ACA®) estimates there are over 1,285,000 persons living in the United States with the loss of a limb. Less than 4% of the target market would generate the estimated sales in the United States. Furthermore, a gross profit percentage greater than 25% will be achieved by meeting these sales projections at a suggested retail price of \$19.99. This profit percentage would be much higher than the small appliance industry average and more than double that of the industry leader.

Component	Black and Decker Lids-Off	Cover	Base	Gears	DPDT Switch	Cord	Motor	Ball Switch	Machined Parts	Rubber
Prototype Cost	39.99	In-House	In-House	N/A	4.60	N/A	N/A	Donated	In-House	2.50
Production Cost	N/A	1.00	0.50	0.50	1.00	1.00	4.00	2.00	3.00	0.50

*All Prices are in USD

** Production Costs Assume 50,000 units / annum

Table 14.1 – Prototype and production costs

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Appendix A

Calculations:

Thread information:

Thread size and type: 9/16 – 18 UNF-2A

$$d_{major} = 0.5625 \text{ "}$$

$$\frac{threads}{inch} = 18$$

$$\frac{inch}{thread} = 0.0625 \text{ "}$$

$$\begin{aligned}\tau_{area} &= \frac{inch}{thread} \times \pi \times d_{major} \\ &= 0.0625 \text{ "} \times \pi \times 0.5625 \text{ "} \\ &= 0.1104 \frac{in^2}{thread}\end{aligned}$$

Shear area of bottom plate:

Bottom plate thickness (t_{plate}) = 0.25"

Number of threads in bottom plate (N_t) = 4

$$N_t = \frac{t_{plate}}{\frac{inch}{thread}} = \frac{0.25 \text{ "}}{0.0625 \text{ "}} = 4$$

Effective shear area of bottom plate:

$$A_{effective} = N_t \times \tau_{area} = 4 \times 0.1104 \text{ in}^2 = 0.4416 \text{ in}^2$$

Factors of safety with different materials:

1. Steel (ASTM–A36):

$$\tau_{allowable} = 21 \text{ ksi}$$

Max Operating Force (V) = 35lb

$$\tau_{threads} = \frac{V}{A_{effective}} = \frac{35lb}{0.4416 in^2} = 79 psi$$

$$\tau_{threads} \ll \tau_{allowable}$$

$$79 psi \ll 21,000 psi$$

Factor of Safety (steel):

$$F_s = \frac{21000 psi}{79 psi} = 265$$

2. Aluminum (6061-T6):

$$\tau_{allowable} = 20ksi$$

Max Operating Force (V) = 35lb

$$\tau_{threads} = \frac{V}{A_{effective}} = \frac{35lb}{0.4416 in^2} = 79 psi$$

$$\tau_{threads} \ll \tau_{allowable}$$

$$79 psi \ll 20,000 psi$$

Factor of Safety (aluminum):

$$F_s = \frac{21000 psi}{79 psi} = 253$$

3. ABS plastic:

$$\tau_{allowable} \approx \frac{S_y}{2} = \frac{4290 psi}{2} = 2145 psi$$

Max Operating Force (V) = 35lb

$$\tau_{threads} = \frac{V}{A_{effective}} = \frac{35lb}{0.4416 in^2} = 79 psi$$

$$\tau_{threads} < \tau_{allowable}$$
$$79 \text{ psi} < 2145 \text{ psi}$$

Factor of Safety (ABS):

$$F_s = \frac{2145 \text{ psi}}{79 \text{ psi}} = 27$$