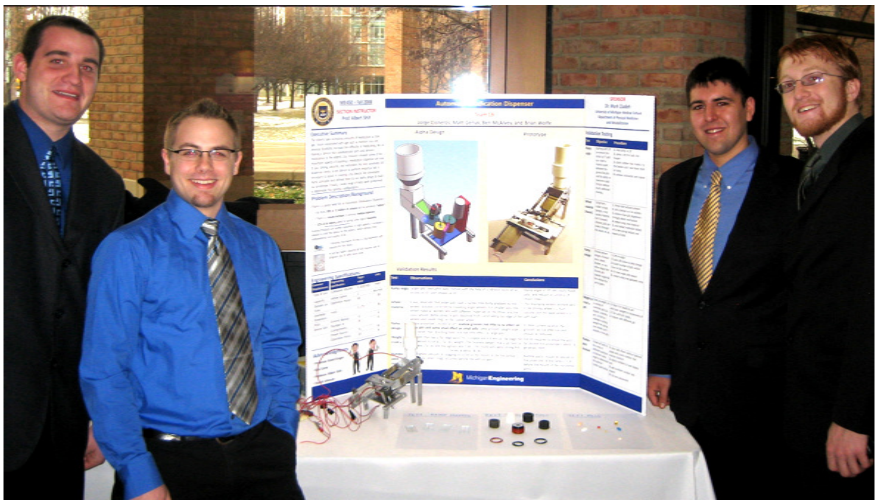
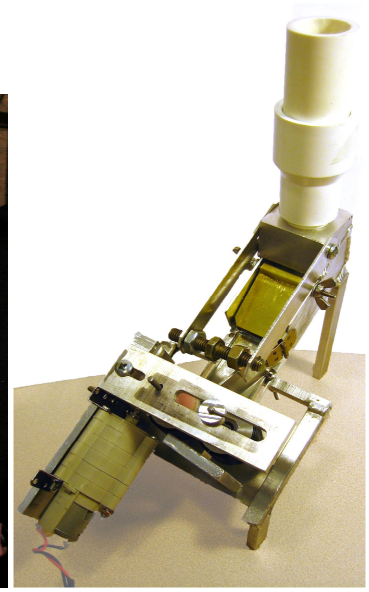
FINAL DESIGN REPORT

AUTOMATIC MEDICATION DISPENSER





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EXECUTIVE SUMMARY

The issue that we tried to resolve was the difficulty taking appropriate medication doses faced by the elderly. As people get older, they are generally prescribed more medication in varying doses and have trouble taking the correct amount. We designed and built a device that automatically sorts and delivers medication to the elderly person. From our research, some of the important aspects of building the medication dispenser are ease of use, security, and reminders. These aspects are important to the elderly because they easily forget when and how many pills they are supposed to take.

We developed a list of customer requirements, which are translated into different engineering specifications. (Table 1) We determined the values from table 1 based off of our benchmarks, and engineering sense. These requirements were based on discussions with Dr. Ziadeh and by conducting field research. The customer requirements are listed in order of importance. Their relationships to the engineering specifications can be seen by reviewing our QFD. (Appendix A)

TABLE 1: CUSTOMER REQUIREMENTS AND ENGINEERING SPECIFICATION

Customer Requirement	Engineering specification	Units	Target value
Easy to use	Container Volume	mm^3	3.50E+07
Capacity	Alert Audio	dB	90
Locks /			
Security	Alert Visual	lm	100
Delivers on			
Time	Material selection	ρ= g/cm^3	1.05
Overdose	Operation Noise	dB	40
Prevention	mass	kg	3.175
Price	Electric Backup	hr	10
Device Size	Number of Components	#	30
Reminder	Power Source	W	75
Warning			
Caregiver	Operation Force	N	4
	Timer	Days	7

There are devices already on the market that deliver pills at certain times; however, these devices simply deliver a container of pills, not individual pills. Our product will automatically sort and dispense pills reliably; some of our concepts can be seen in (Concept selection section). We have determined that our most difficult challenge will be to fit all of these aspects into a coffee machine size device.

To come up with our concept sketches we discussed the present designs out there and brainstormed to come up with the ideas. Using these techniques we developed three main concept ideas using different working principles to accomplish our goal. We came up with a hopper, a crane, and PEZ® like dispenser. We did some experimentation on the pills to help know what the bending strength, compression test, effect of moister contact, and simple friction test. To choose our final idea we used some criteria to rate our designs like variation of dispensable pills, low jamming possibility, and ease of manufacturing. We found that the PEZ® dispenser had the best rating but it didn't automatically dispense like we wanted it to. So we went with the hopper with the impinging wheel which was the best rated of the automatically dispensing concepts.

We performed analysis on our mechanism to verify what types of springs, motors, and strength of material for the pill dispenser. We used the CES program to determine which material to use for the parts. We determined that we were going to use mostly PVC except for the delicate parts which we will use aluminum. The manufacturing plan we will use mostly PVC and will be milling, drilling, and lathing to shape the parts.

A test device to perform empirical test is necessary to assist in creating a full device. We developed many concepts and refined them to our alpha design to build our prototype. Finally, a wide range of tests were performed to determine the optimal configuration.

ABSTRACT

Taking multiple medications becomes a daily activity as people age, requiring continuous sorting of pills, remembering to take medication, and facing a possibility of an accidental overdose. Developing a device that can automatically sort and dispense pills on time would greatly save the user time, money, and increase independence. With the assistance of Dr. Mark Ziadeh from the University of Michigan Medical Center, our team will focus on a mechanism to automatically sort and dispense medication while keeping in mind the whole design of a machine that will store and dispense medication in a safe and timely matter.

PROBLEM DESCRIPTION

Medication ingestion generally increases with age. Common health problems that arise with age are: muscles, tendons and joints lose flexibility and strength, eye sight problems, and nervous system deteriorate. [1] Muscular problems increase the difficulty of opening medication containers and sorting individual pills. Poor eye sight increases the difficulty of identifying different medications. Finally, memory loss from nervous system deterioration creates problems with taking medication on time, and potentially overdosing from forgetting what medication has been taken and when. [8] Working with Dr. Mark Ziadeh from the University of Michigan Medical Center, our team will design a machine that will automatically sort and reliably dispense medication. We will be focusing on a mechanism for sorting and dispensing various sizes of medication.

INFORMATION SOURCES

RESEARCH ON EXISTING PATENTS AND THEIR DESCRIPTIONS

Several patents are listed below with representative quotes from their abstracts or descriptions. The picture for each patent can be found in (Appendix D). Each patent comes from Google patent search. [10]

US Patent # **3921806**

A pill dispenser is useful for elderly patients having reduced muscular control and who must take a large number of pills each day. The dispenser includes 28 separate pill-receiving compartments, each at least 0.15 cubic inches in volume for each day of the week.

US Patent #**4674651**
An apparatus for dispensing pills where a rotating element includes a number of compartments for receiving pills. When a compartment is above an opening in the base, the pills fall into a chute and is dispensed. A pin is associated with each compartment and is placed in an activated position when pills are loaded into the compartment. When the compartment is above the dispensing opening, a pin engages a micro switch which activates audio and visual alarms.

US Patent #**4838453**
The disclosed pill dispenser is of the disc or carousel type and has a base provided with a flat top over which the disc is superimposed. The gate is timed with rotation of the disc on the basis of a predetermined number of dosage periods per day.

US Patent #**5176285**
An automatic pill dispensing apparatus is provided having a plurality of cartridges mounted on a common rotatable shaft within a housing. An alarm is sounded for the user when the cartridges are in position for dispensing medication. The use of a manually automated dispensing bar eliminates the possibility of over dosage by taking accumulated, unused medication.

US Patent #**5133478**
A pill dispenser particularly adapted for use by the physically or mentally infirm. The columns of the matrix correspond to days of the week, while the rows of the matrix correspond to times of the day. A removable cover is placed over the containers.

US Patent #**5178298**
The pills are loaded into cartridges and a actuator is used to push a pill forward dispensing it on time.

US Patent #**6510962**
A device that can be loaded with appropriate pills and programmed to automatically dispense the proper amount(s) and proper type(s) of pill(s) at the proper time(s) each day. The device includes a system for alerting the pill taker that pills have been dispensed, a system for providing voice messages to coach the pill taker to use the device and consume the pills, and a system for alerting an off-site caregiver when the pill taker has not responded as required or when there is a problem with the operation of the device.

BENCHMARKED DESIGNS:

1) E-pill Automatic Pill Dispenser (EA) [2]
2) Vibrating Five Alarm Pill Box (VFA) [9]
3) E-pill Monitored Automatic Pill Dispenser (EMA) [2]
4) E-pill CompuMed Tamper Proof Automatic Pill Dispenser (ECTP) [2]

We used these four products as benchmarks for our design. Unlike our design all of these devices require a presorting of the medications. The VFA was like a normal pill box but in a circle with an alarm. The EA is a bigger version of the VFA; it also includes locks that keep you from accessing the pills before the proper time. EMA and ECTP both have a wider range of alarms and monitoring. The first two bench marks are smaller cheaper and simpler than the other two. Our device will be built more around the EMA and ECTP engineering specifications. Our QFD (Appendix A) shows a side by comparison with a rating for each customer quality. They all include a wide variety of alarms and reminders, exactly like we plan to implement in our design, so they all ranked high for reminder. The audio reminders for these products are about 90 decibels or equivalent of a loud whistle. For easy to use, and price, VFA ranked the highest, it has the least features and simplest design. The other three products we comparable in rank to each other for: security, warning to caregiver, capacity, device size, overdose prevention, and delivers on time. It is hard to compare exact values for the engineering specifications of our bench marks to our own product, since none are fully sorting and dispensing automatically.

CUSTOMER REQUIREMENTS AND ENGINEERING SPECIFICATIONS

Our team conducted a broad field research, conducting discussions with Doctor Ziadeh, nursing home patients, staff, and pharmacists to identify nine customer requirements:

TABLE2: CUSTOMER REQUIREMENTS AND WEIGHTS

Requirement	Necessary?	Weight
Easy to use	Yes	5
Capacity	Yes	5
Locks / Security	Yes	5
Delivers on Time	Yes	5
Overdose Prevention	Yes	5
Price	Yes	4
Device Size	Yes	3
Reminder	Yes	2
Warning Caregiver	No	1

All the customer requirements are considered necessary, except for warning to caregiver. The weight for each category was determined using feedback each of research groups. It's self-evident from (Table 2) requirements to do with the proper function, and security, were the number one concerns. The last groups of the requirements were more desired requirements. Lower price and size would be ideal. Reminder and warning to caregiver are considered added bonuses.

TABLE 3: ENGINEERING SPECIFICATIONS AND TARGET VALUES

Engineering specification	units	Target value
Container Volume	mm^3	3.50E+07
Alert Audio	dB	90
Alert Visual	lm	100
Material selection	g/cm^3	1.05
Operation Noise	dB	40
mass	kg	3.175

Electric Backup	hr	10
Number of Components	#	30
Power Source	W	75
Operation Force	N	4
Timer	day	7

The customer requirements were then translated into engineering specs with target values seen in Table 3.

We determined the engineering specification values based off our benchmarks and common sense. The volume is about the size of an average coffee maker, and correlates to capacity and device size. This is so it fits well in the kitchen and is about the same size as existing products. The audio alert decibel level is that of a loud whistle, so it can be heard by hard of hearing. The visual alert we picked as bright as LEDs so they will be sure to have a high contrast and grab attention. Both alert values correlate to a reminder, and warning to caregiver. We planned to make as much of the machine out of plastic as possible, which has a density of about 1.05 g/cm^3, and correlates to price. We wanted to make sure the noise while operating was low, our machine will have several motors and shakers that will produce noise. We chose 40 dB or a little higher than a whisper for a good target with goals on minimizing. The mass is light enough that an elderly person can move the machine for any reason. There needs to be a 10 hour battery backup, which is equivalent to the benchmark competitors, we would like to maximize that value. To keep the device as simple and inexpensive as possible we made an educated guess for the number of components, 30 seems about enough to incorporate several hoppers, a motor or multiple, and slides gates. The power source will be for American 120V AC wall outlet. We choose 75 watts for the amount of power the machine should draw, this will make operational cost economical, and this value should be minimized. We asked Dr. Ziadeh for the average pushing force a geriatric could produce; his answer was about 4 Newton's, depending on whether it is a single finger or multiple [3]. Finally we picked a week timer or seven days so that the machine will dispenses the proper medication all week long.

A QFD (Appendix A) was developed from the requirements and specifications. It was determined that fitting all components into a coffee sized container will be the hardest engineering difficulty. This was followed in difficulty by operation force, and noise. The force of operation is particularly important to ease of use. Our machine needs to be small, easy to use, and reliable for it to be a success.

CONCEPT GENERATION

The primary concern of our product is to automatically separate one pill from many and dispense it. Individual brainstorming was first used to generate ideas to accomplish the goal. We discussed what to think about and in which order to maximize practical designs, our list was:

- Current automatic pill sorting mechanism
- Lateral sorting mechanisms

- Preloaded container based systems
- Extras

From the concepts developed through brainstorming we applied lateral thinking to see if any other ideas could be develop from other products that perform close to ours. At this point a Functional decomposition was created to determine all necessary components and actions that must be completed for our devise to function; it can be seen in (Appendix F).

Using these techniques we developed three main concept ideas using different working principles to accomplish our goal. Our first thought was of a hopper design using; a screw, impinging wheels, or separated conveyer belt system, to individualize the pills. The idea for impinging wheels was only thought of after considering a baseball pitching machine for dispensing mechanism as part of lateral thinking. Our second design is much like a crane machine using; a vacuum, claw, or crane to pick up isolate the pills. Our third design was a single hopper with a rotating divided carrousel and a camera to identify the pills and blow them off with a puff of air. Finally we had ideas for cartridge based pill dispenser, similar to a PEZ® dispenser, or a rotating carrousel with many pill containers. (Appendix B) With the cartridge designs we had several ideas for making them easy to load, and multiple dispensing mechanisms. Extras we thought of were; built in water dispenser, pill cutter, and easy load tube. All these devices would have a wide range of warnings and reminders, and a lock for security.

CONCEPT SELECTION

A Pugh chart, shown in (Appendix F), was used to determine which of our design concepts was best. The selection criteria used to rate each design came primarily from our QFD and included:

- Variation of dispensable pills
- Ease of manufacturing
- Low jamming possibility
- Size smallest
- Noise lowest
- Durability longest
- Aesthetics
- Cost lowest

The following designs illustrate a sample selection of the wide ranging designs that were initially considered and weighed against each other in the Pugh chart.

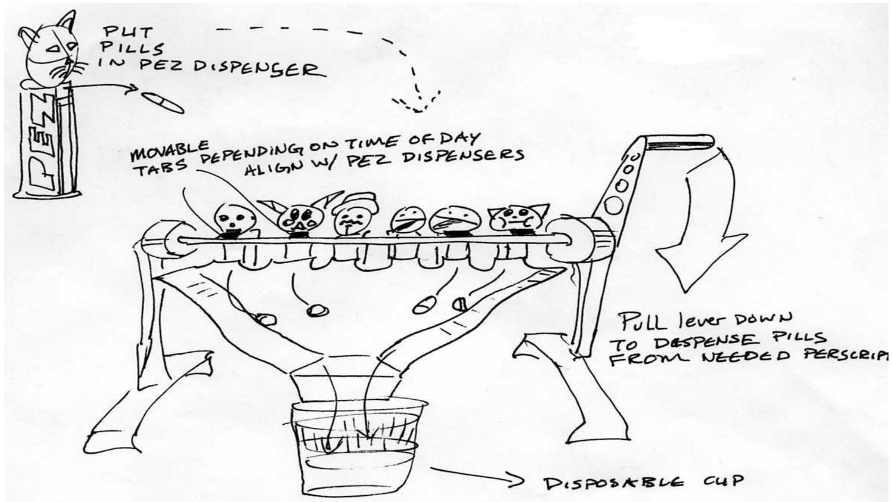


FIGURE 1: PEZ® STYLE DISPENSER

Each PEZ® -like container is adjustable for the dimensions of the particular prescription held inside. Once the head is tilted back, only one pill is dispensed at one time. The benefits of this design are the variety of pill sizes due to the adjustable nature of the pill holders along with the interactive nature and collectability of the PEZ® merchandise. The shortcomings of the design are the high setup time and the interaction required if different dosages are required at different times of the day.

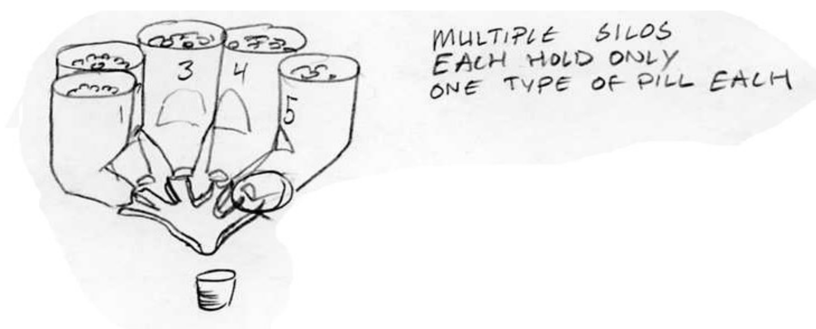


FIGURE 2: MULTI HOPPER DISPENSER

The multi hopper design has several hoppers each with a separate prescription which can be dispensed in any combination due to the isolation capabilities of the mechanism. The pros of the hopper design are the high capacity and therefore less caregiver involvement. The potential drawback would be the size of the pill-station. A closer inspection of the actual isolation mechanism showcases 3 distinct ideas for separating pills to be dispensed individually.

FIGURE 3: IMPINGING WHEELS

The impinging wheels rely on a slow rotation rate and to guide the pills through the mouth of the mechanism allowing only one pill to drop from the mouth at one time. The benefits of this concept allow for a large variety in pill size without having to adjust any aspect of the wheels themselves. The main drawback would be getting the pills to enter the wheels simply by gravity feed.

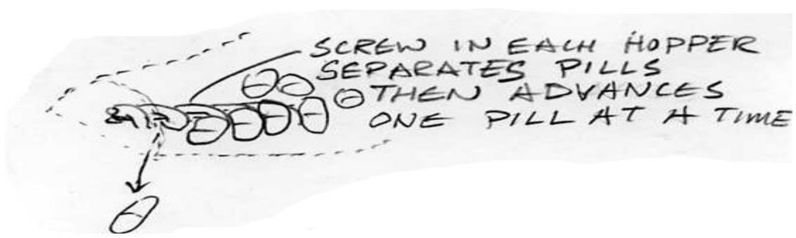


FIGURE 4: SCREW MECHANISM

The screw design uses the idea that a stationary screw will draw the pills through a region which both skims extra pills away from the entrance and isolates the pills in the grooves. Under these two principles all that is requires to dispense a single pill is to rotate the screw a fixed amount depending on the specific pill prescription contained inside. The benefits of this design are the exact nature that involves a single pill, a simple rotation. One of two major drawbacks is the higher possibility of pill breakage or wear because grinding that may occur between screw and pill. The second is that designing a screw and tube that would account for 95% of pill sizes on the market would be very difficult while still maintaining the isolation of each pill relative to its neighbor.

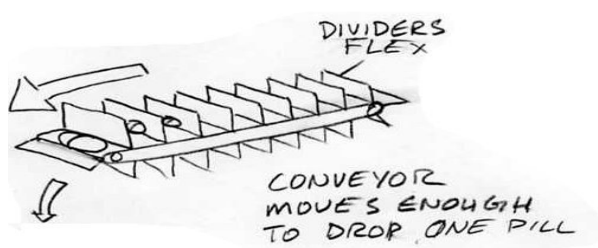


FIGURE 5: DIVIDED CONVEYER BELT MECHANISM

The conveyer belt operates on the principal that pills would be isolated by the flexible dividers so when the conveyer reaches the end of the track, only one pill will be dispensed. The benefits of this mechanism are the set distance between dividers, and therefore, the set progression the conveyor undergoes. Several drawbacks are the complexity of the conveyor and the one-size-fits-all requirement for the distance between the dividers.

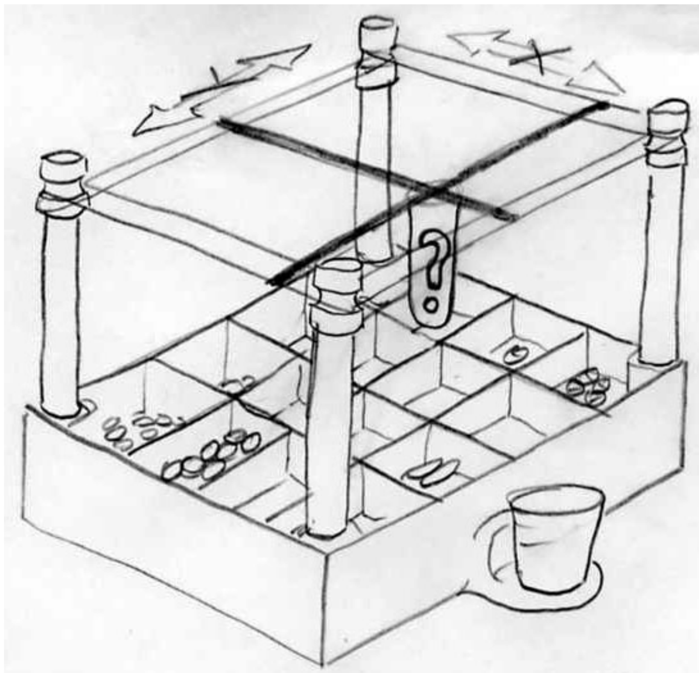


FIGURE 6: CRANE STYLE DISPENSER

The crane dispenser operates in the same way as many types of coin-operated games or vending machines. The grabber device moves along two axes until it is above the coordinates of a specific prescription. After selecting just one dose, the crane returns to the origin and deposits the medication. The advantages to this device are that it can handle a very wide variety of pills and it should not jam. The disadvantage of the crane design is it's overly complicated making the device costly, and has a lower durability. A closer inspection of the actual crane mechanism showcases 2 distinct ideas for selecting pills individually.

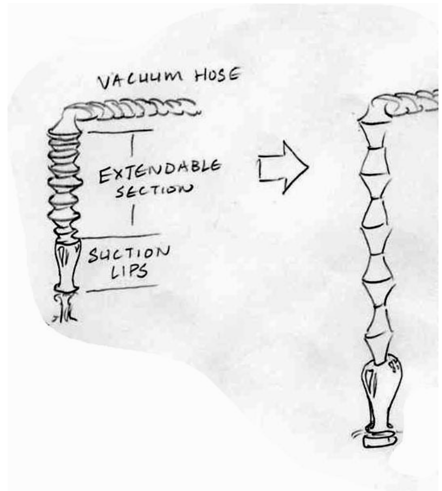


FIGURE 7: VACUUM HOSE

A vacuum hose design would ideally have the hose position above the prescription and descend to suck up only one pill. Advantages of this design are its inability to overdose and high capacity along with the ability to account for many types of pill size and shape. The main disadvantage is the very complex vacuum system which would be the source of many problems.

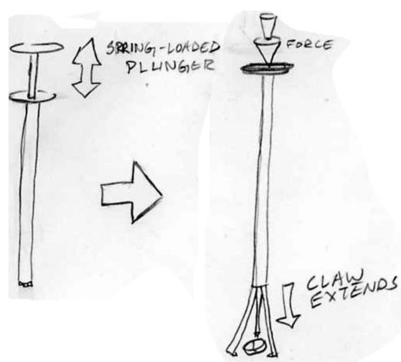


FIGURE 8: CLAW

The claw mechanism is meant to be able to pick up a wide array of pills thanks to the three prongs. This is its chief advantage. Disadvantages to this mechanism are that it would have high possibility of pill breakage and it's not guaranteed to always grab one pill.

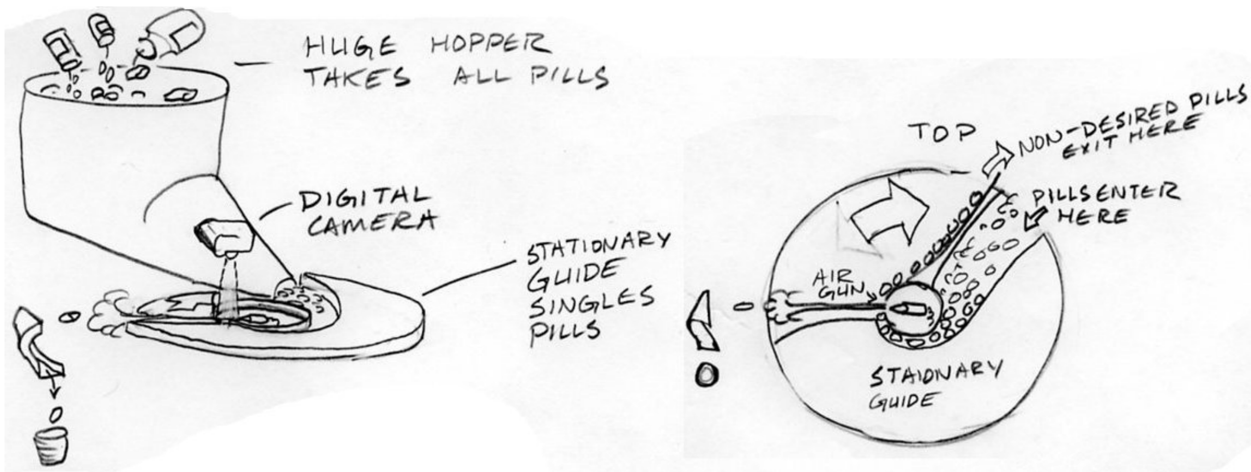


FIGURE 9: SINGLE HOPPER WITH CAMERA

The single hopper concept works like modern day assembly lines with cameras. Instead of using compressed air to shoot away the defected products, this device would use compressed air to collect the desired prescriptions. The advantages are that the user would be able to mix all their prescriptions together into one container and in a high capacity manner. The drawbacks to such a design are the large scale nature required to make it cost-effective along with the high complexity and programming needed. This design was the least feasible for many reasons and scored the lowest on the Pugh chart.

In scoring our designs using a Pugh chart, all of our devices had low rankings for; cost, ease of manufacturing, and smallest size. These criteria did not affect the total rank much, they are less important criteria.

Each concept was rated on a scale of 1-5, where 5 were most desirable. Each of our design concepts were rated for each selection criteria, with weights for more important futures receiving higher numbers, such as; variation of pills, low jamming, and durability. The result of the table from best design to worst is:

1. PEZ® type pill dispenser
2. Hopper with impinging wheels
3. Hopper with divided conveyer belt
3. Crane with claw
4. Crane with vacuum
5. Hopper with screw
6. Single Hopper with Camera

The PEZ® type (Fig. 1) ranked the highest, it has a very low jamming possibility, and would be straightforward to manufacture. Its downfalls are limited capacity, and no multi dispensing or automation.

Due to the fact that the reference product was not fully automatic, concepts with this ability scored much higher. This makes the hopper with impinging wheels the best design. We strongly believe the hopper with impinging wheels is the best design. It has high numbers for; variety of dispensable pills, low jamming, and durability. It is also easier to manufacture than other hopper designs. The other hopper separating devices would require more parts, have a higher possibility of jamming, and wouldn't handle as wide a variety of pills.

SELECTED CONCEPT

ALPHA DESIGN

We selected the concept that has multiple hoppers that flow down to an impinging wheel mechanism. (Fig 2-3, Pg.12-13) The hopper will have a square outlet with beveled bottom walls, or a round outlet.

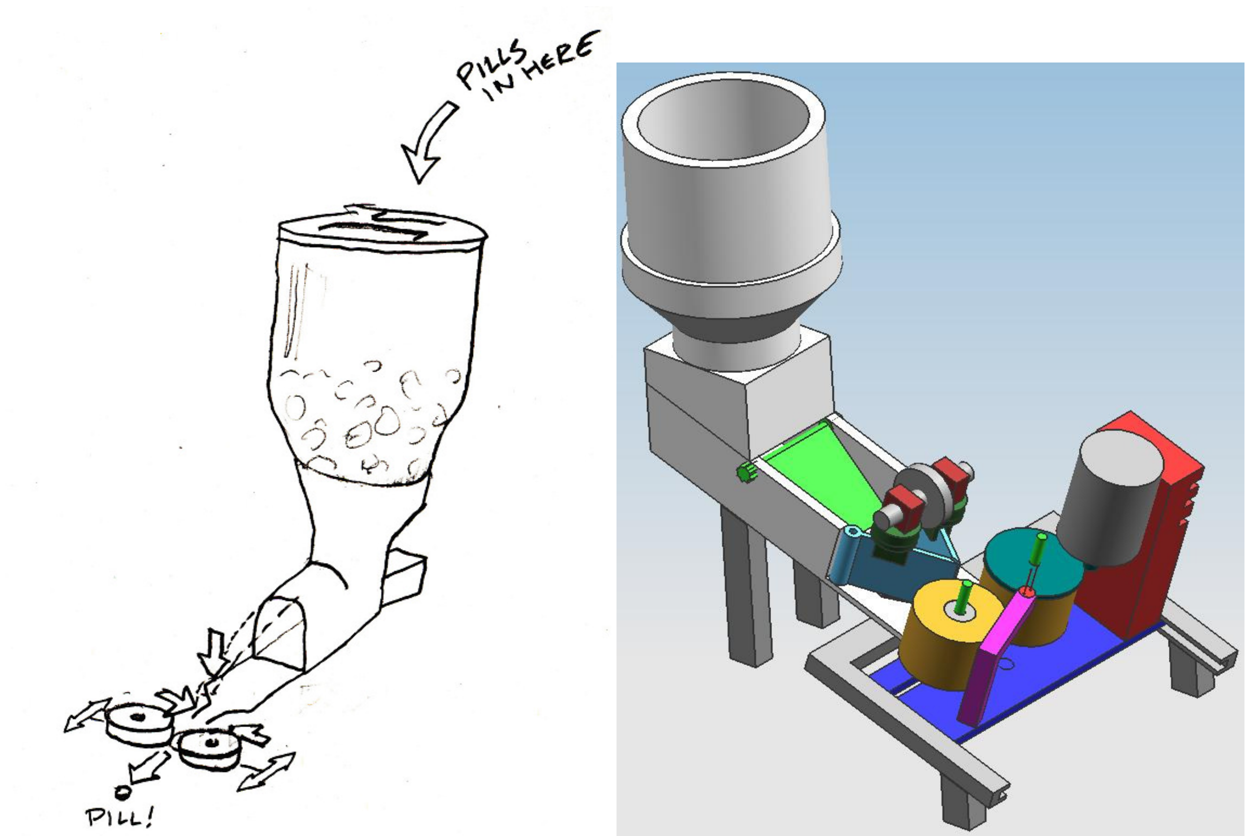


FIGURE 10: HOPPER WITH IMPINGING WHEELS

Due to the fact that our group seeks to produce a prototype that can be tested on a variety of aspects involving pill isolation, capacity, and size, multiple concepts for each aspect of our design were considered. This second level of iteration in the concept generation process allowed for the entire team to become comfortable with alpha design and to flush out problems before they could occur in the fabrication and testing stages. Figure 11 shows the multiple rumble devices which would be attached to the pill dispenser in order to unclog jams that are inevitable in a gravity-fed process. Our group chose to use the rumble pack due to its small size, wide availability, and ease of integration into any existing system.

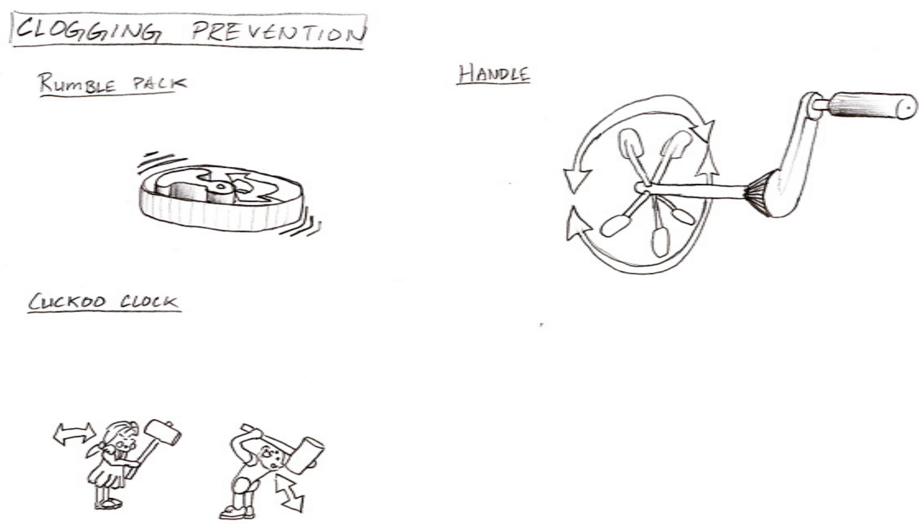


FIGURE 11: VIBRATION DEVICES

In order to restrict the flow of pills from a large cross sectional area into a single file line, a system of multiple gates was devised along with the way in which the gate aperture would be changed. Because jams are less likely to occur when restricting one axis at a time, the gate system on the left in figure 12 was chosen for the alpha design.

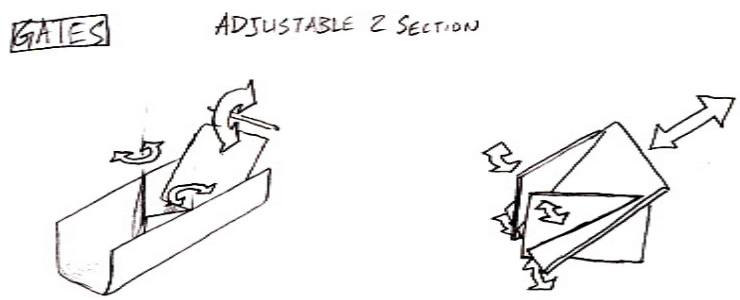


FIGURE 12: GATE DESIGN FOR RAMP

Prescription will not vary within the hopper but the need to initially set the gate aperture is still a necessity. Because vibrations will affect any gate chosen, the spring and screw gate was chosen for its ability to withstand vibration and not move.

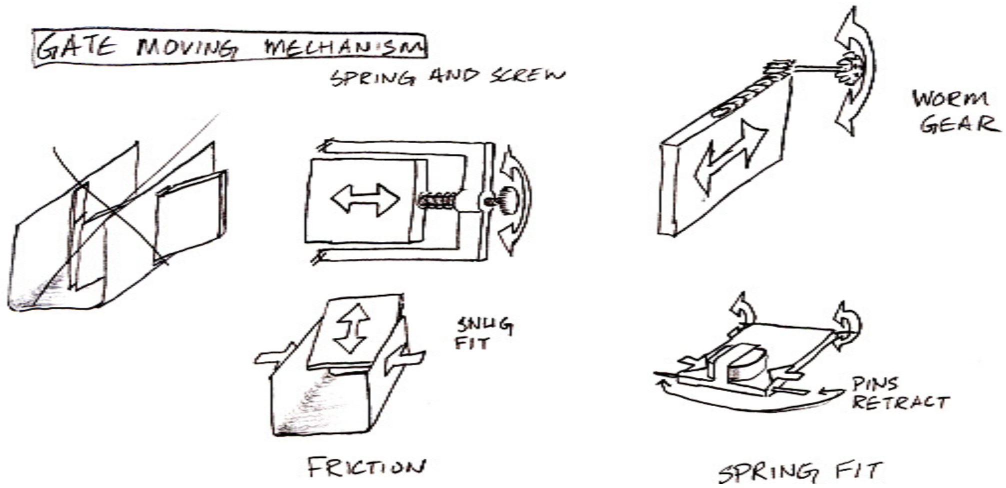


FIGURE 13: DESIGN FOR GATE MOVEMENT

In order to further funnel the pills towards the impinging wheel mechanism, the ramp near the gates can either be smooth or have grooves which promote a single file line. Our group selected the design with groves to further help account for multiple pill size.

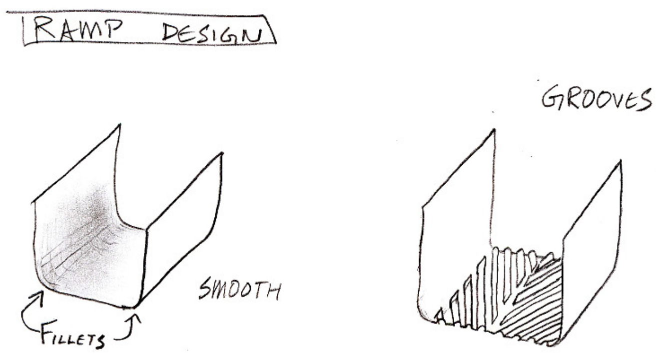


FIGURE 14: RAMP DESIGNS

The two wheels will dispense the pills in the same way as a football or baseball pitching machine but at a much slower velocity. The wheels will rotate slowly so only one pill is dispensed at a time. These wheels will be driven by a motor using gears, or pulleys. (Fig. 15) Both wheels can be driven, or there can be one drive wheel with a slave wheel in tension. Or group selected the driver, slave combination (top of figure 15) because this allows for the wheels to expand as they pass a pill between them yet still keep tension.

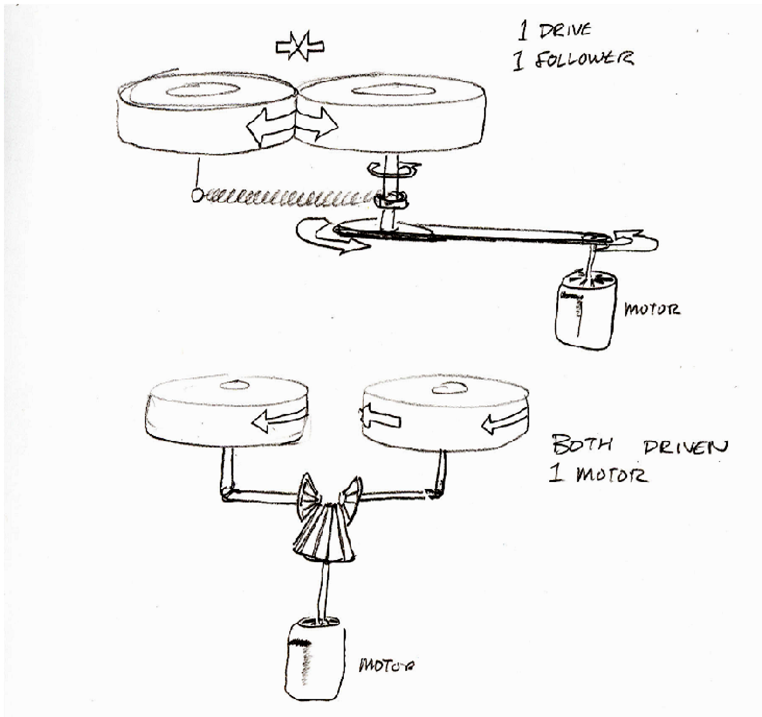


FIGURE 15: WHEEL DRIVE DESIGNS

The type of material used for the wheels themselves is important because of nature of the surface of pills. The tension of the springs holding the drive wheel to the slave wheel must also allow for the surface of the wheels to draw in the medication. We decided to use a rubber gel surface of hard silicone because this would be more sanitary and rigid.

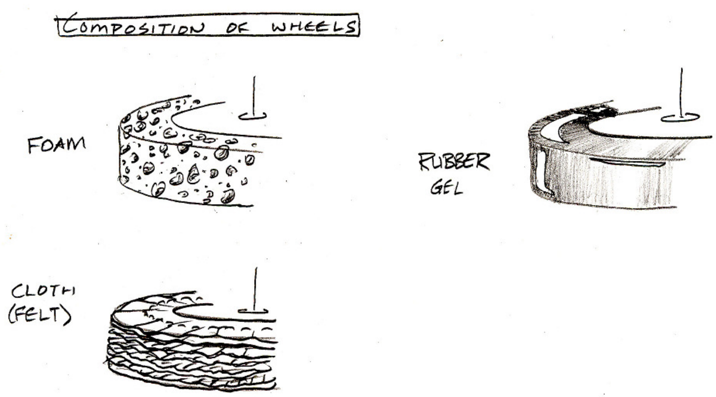


FIGURE 16: WHEEL MATERIAL POSSIBILITIES

Due to the nature of the gate system and the fact that prescription size will change, the aperture of the gates will vary. In order to insure pills have no other course but into the cleavage of the impinging wheels the entire wheel assembly needs to be able to move towards and away from the gates themselves. We selected the screw and spring wheel mount on the left in figure 17 because this would allow for both wheels to move as a unit.

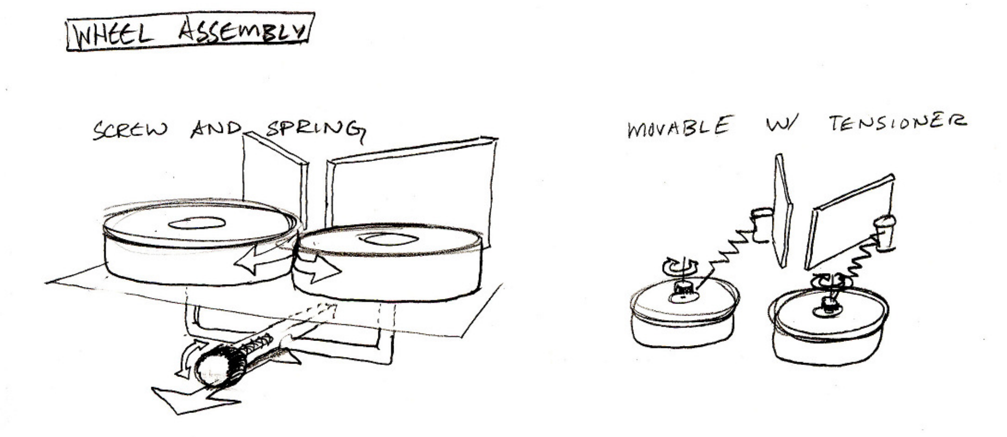


FIGURE 17: WHEEL ASSEMBLY DESIGN

The last aspect of the Alpha design is the counting mechanism to control how many pills are dispensed. We will address this by having a sensor that stops the wheel when the pill activates the sensor. These are the basic subsystems of our device necessary to automatically separate and dispense pills. Aspects of our design that are vital include timing mechanisms, alarms, and locks. These lay beyond the scope of this semester's projects and must be addressed in the next iteration of the project.

ANALYSIS

Engineering analysis was performed on critical components of our device to ensure proper functioning. These components where: the hopper, springs for the wheels and wheel assembly, and motor design analysis.

HOPPER

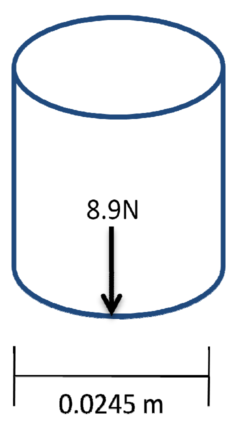


FIGURE 18: HOPPER

The bottom outlet for the hopper was modeled as a cylinder with a diameter of 0.0245 meters. We assumed a force of 8.9N or about 2 lb-ft, by considering the density of typical medication and the volume of our hopper and calculating a rough estimate on a full container. We then found the area (Equation 1) and calculated the stress (Equation 2) [11] to ensure it would not yield.

(Eq. 1)

– (Eq. 2)

A= Area (m^2)

σ_y= Stress Yield (Pa)

F= Force (N)

This analysis was performed to find the area where maximum stress would occur, which we figured was at the outlet of the hoper. This area would also have a 20^o slope which we have assumed to be zero here. This value is used later to help determine the material our machine should be built from. The normal yield strength values for plastics and metal are measured in MPa, so any material we select should be more than strong enough, and have an adequately high safety value.

SPRING WHEEL

With the exact distances for our machine determined, we can find the correct spring for our spring loaded wheels. We found the spring needed an initial length of 1.25", and expand to 2.25". Using Hooke's law (Equation 3) [12] we found the force from expansion. By adding that force to the initial force we determined the overall force and check to make sure it was not over the max loaded before plastic deformation. We found a spring from Grainger [13] with initial length of 1.25", a spring constant k=0.03 lb/in, and initial load of 0.11lb. The maximum load this spring can take is 1.18lb.

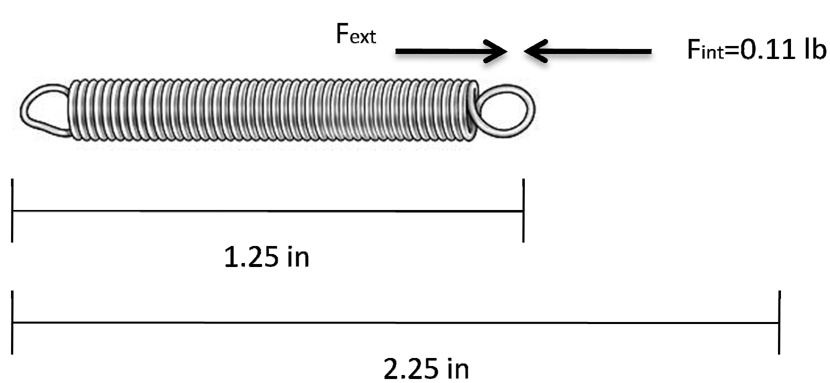


FIGURE 19: SPRING

(Eq. 3)

—

(Eq. 4)

x= difference in length

F_{ext}= Force from extension (lb)

k= Spring constant (lb/in)

F_{int}= Initial force in the spring

F_{max}= maximum force in spring before plastic deformation

The analysis predicts that this spring is more than adequate for this purpose.

The maximum firmness of the foam for the wheels is 2.05psi with the maximum area of contact area on the pill of 0 .1 in^2. The max force from the foam (Eq. 5) on the pill is 0.205lb.

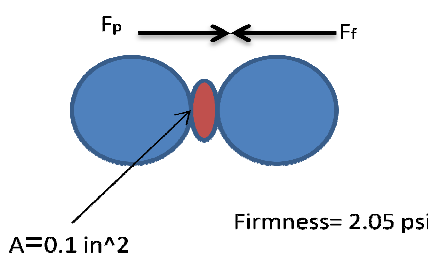


FIGURE 20: IMPINGING WHEELS

F_f= force foam

F_p= force pill

A= area

This force counteracts the force from the extension springs, and is well below our measured force to crush a pill.

This force counteracts the force from the extension springs, and is well below our measured force to crush a pill.

SPRING WHEEL ASSEMBLY

This analysis is the same as before, except we need a spring with initial length of 1" and needs to expand to 2.25". We found a spring from Grainger [14] with initial length of 1", a spring constant of 0.87 lb/in, initial load of 0.14 lb, and max load of 1.55 lb.

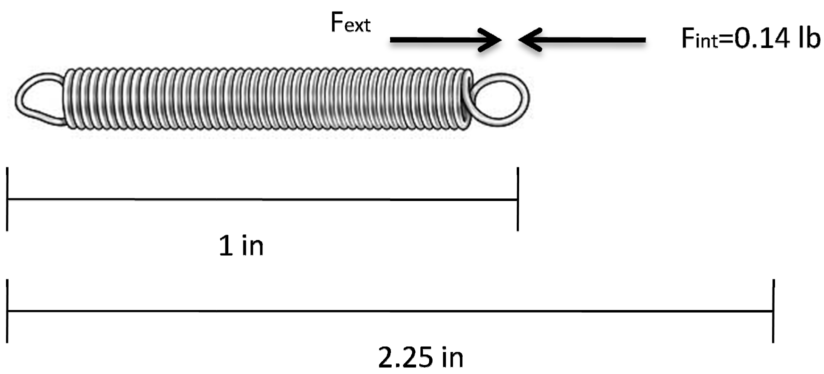


FIGURE 21: SPRING

(Eq. 5)

—

(Eq. 6)

This analysis shows that this spring is appropriate for this application.

MOTOR

To calculate the power requirements for our motor we had to calculate the torque the motor would be required to turn. We made some assumptions to simplify the problem: First we considered the bearing to be frictionless and the rotating portion of the bearing to be mass less since this should be insignificant compared to the size of our wheel. Second the mass of the; rubber tires of the wheels, and the large gear connected to the wheel, was considered insignificant. Finally we considered the rolling resistance from tire deflection to be insignificant force. We want the wheels to turn slowly, so through actual trials we determined the angular acceleration to be 2 Rev/min^2, which converted to 1.9X10^{-5} rad/sec^2. With those assumptions we calculated the volume and the mass of the aluminum wheel (Equation 7, 8). We found a typical density for aluminum on Wiki answer. [15]

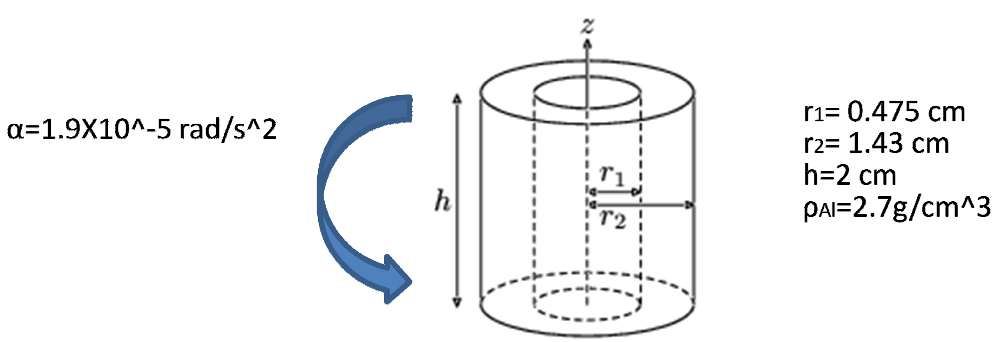


FIGURE 22: MOTOR

$$V = h\pi(r_2^2 - r_1^2) = 2cm \times \pi(1.43^2 - 0.475^2)cm^2 = 11.43cm^3 \quad \textbf{(Eq. 7)}$$

$$m = V \times \rho = 11.43cm^3 \times 2.7\tfrac{g}{cm^3} = 30.86g = 0.0309Kg \quad \textbf{(Eq. 8)}$$

V=Volume (cm^3)

h=Height (cm)

r=Radius (cm)

m=Mass (Kg)

Using the mass we found the moment of inertia (Equation 9) [16] on the x y plane. Finally the torque required to drive the wheel was calculated. (Equation 10) [17]

$$I = \frac{1}{12}m[3(r_1^2 + r_2^2) + h^2] = \frac{1}{12}(0.0309Kg)[3(0.475^2 + 1.43^2)cm^2 + 2^2cm^2] = 0.0278Kg\ cm^2 = 2.78 \times 10^{-6}Kg\ m^2 \quad \textbf{(Eq. 9)}$$

$$\tau = \alpha I = 1.9 \times 10^{-5}\frac{rad}{s^2} \times 2.78 \times 10^{-6}Kg\ m^2 = 5.28 \times 10^{-11}N \cdot m = 5.28 \times 10^{-5}mN \cdot m$$

(Eq. 10)

I= Moment of inertia on xy plane (Kg cm^2)

α=Angular acceleration (rad/s^2)

This is the torque to drive one wheel and because we are driving two wheels we need double that value, so 1.056 X 10^{-4} *mN m*. This value is still insignificant to the 17.7 *mN m* stall torque of the motor we chose. [18] Speed is not a factor for our selection, since we want the wheels to rotate slowly. We will use a reducing gear ratio of 400:1, this will reduce the speed of the motor and the torque to the motor by a factor of 400.

DESIGNSAFE

Designsafe 3.0 was used to determine what systems might fial on our device (appendix I). The analysis shows our deive is in no danger of failiure. We have already shown in our analysis, that all forces our device is subjected to are insigificant.

SEMIPRO

SemiPro was used to predict the environmental impact of our device (appendix J). Our device is mostly aluminum, which requires a high amount of energy to produce. The graph of the environmental impact showed raw material is the largest factor of our device on the environment. The next highest effect was on the air (Figure 23). In the future our device will ideally be manufactured from PET plastic, which has a very different environmental impact.

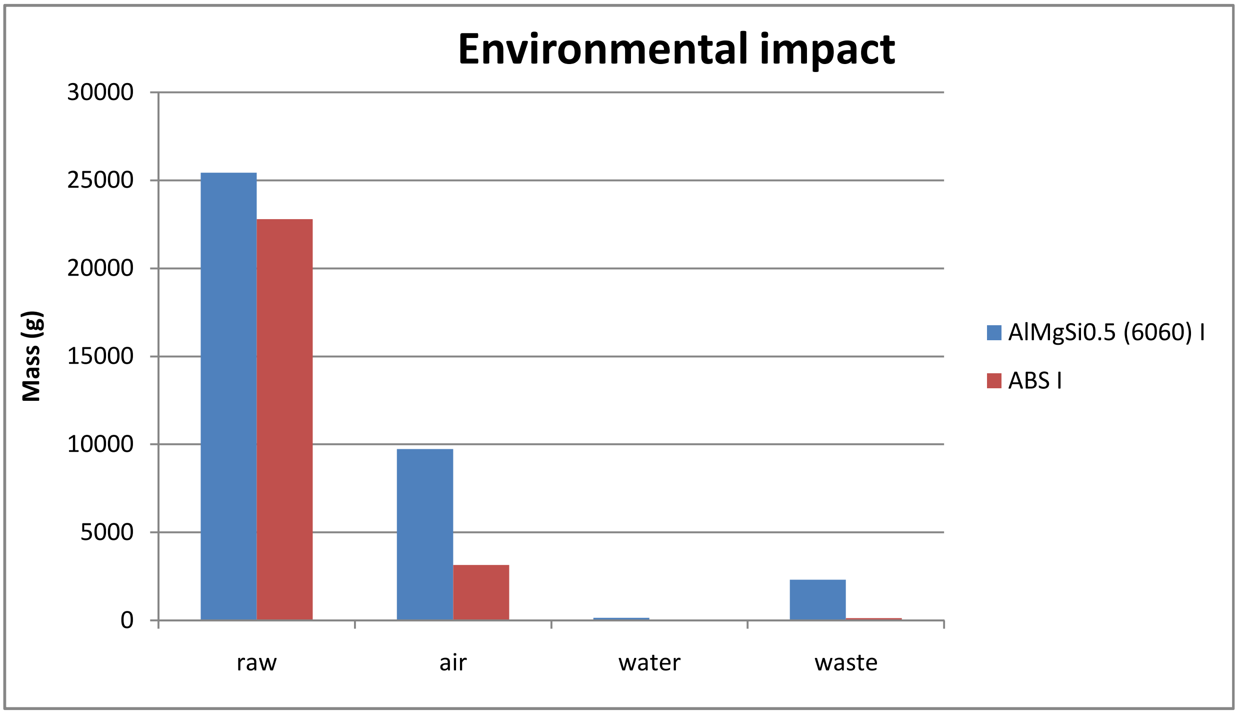


FIGURE 23: GRAPH OF THE ENVIRONMENTAL IMPACT FROM SEMIPRO

ADDITIONAL CONSIDERATIONS

Stress strain analysis could be performed on the door flaps on the ramp. The result would be the conclusion that the stress on those parts is insignificantly small compared to the strength of the materials they will be built from.

Bending analysis can be conducted on the axels of the wheels. These parts are made of steel and are significantly stronger than the forces being subjected to them.

The stand legs for our hopper will be under compressive force. Analysis could be done but this would definitely result in the legs being well over engineered.

All the motors will be hot glued in place provide much more holding force than necessary. We determined this experimentally with our mock up model.

The jack screw set up for the two front doors, will also be overly strong to handle the forces of opening and closing. This will really not be a load bearing part, and the screw we have to use will be much larger than what is necessary.

Our finally consideration is the forces on the wheel assembly slide from the expansion spring. Simple 3 point bending could be used to determine if the cross beam would yield. This would lead to the conclusion that the strength of the part is much greater than necessary.

MATERIAL SELECTION - CES

To begin the material selection process for the main body of our mechanism our team preformed a basic force analysis of the medication dispenser hopper. The resultant maximum force that could be applied to hopper was found to be 4,391 Pa, the result details can be seen in the analysis section of this report. Based on these results it was determined that nearly any material readily available to us would sufficiently work, therefore we determined based on cost of material and ease of use that PVC plastic would be sufficient for a majority of the device. Further material consideration was necessary for the gate mechanisms to simplify manufacturing of these parts. Though PVC would suitably meet the required engineering specification for the gates we felt that due to the small size and thickness a more versatile material would be optimal, thus Aluminum was chosen. To further verify our material selections we ran a CES simulation based on a yield strength of 0.00628 MPa and fracture toughness of 4 Mpa*$m^{1/2}$ that satisfied the force requirements. The fracture toughness we used is the minimal value for a material to remain rigid. To further refine our selection we limited the price per kilogram to a range of 1-10 USD/Kg and set density range of 800-4000 kg/m^3. The density range was determined from the graphs to eliminate the heaviest materials. Figure 24 below shows the materials that fit within the defined constraints; both PVC and aluminum are suitable materials.

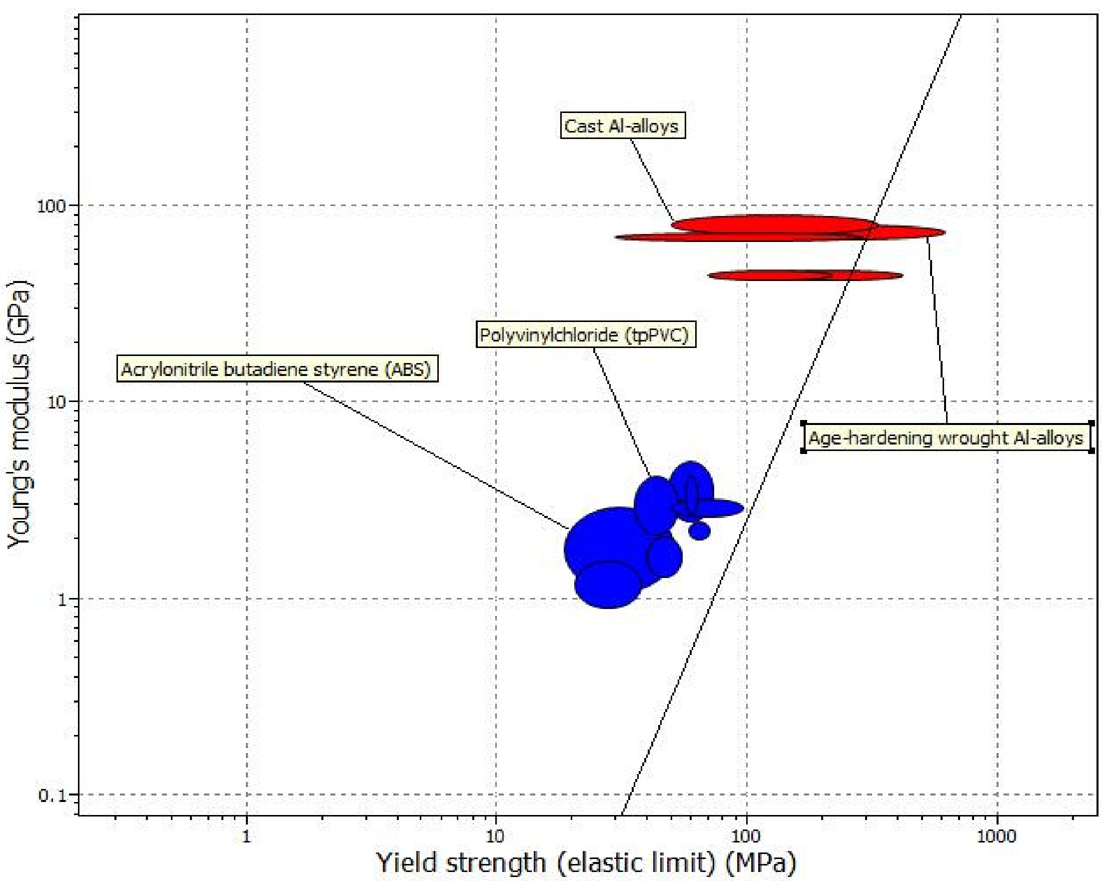


FIGURE 24: CES GRAPH OF THE BODY OF THE MECHANISM

We used a material index (Equation 11) [20] to find the optimal material for yield strength and cost. The equation was log to linear the terms to each other and we found the slop to be 3/2 (Equation 12) for our material index.

$$M = (\sigma_y^{2/3})/(\rho C_m) \quad \textbf{(Eq. 11)}$$

$$\log(\sigma_y) = (3/2)\log(\rho C_m) + (3/2)\log(M) \qquad \text{with slope} = 3/2 \quad \textbf{(Eq. 12)}$$

A separate material selection process was done for the wheel mechanisms. The contact surfaces on the wheel needed to be pliable enough to grab pills but stiff enough to capture pills one at a time. Based on our previously developed mockup and experiments, we knew that the material needed to be harder then soft foam as this allowed for pills to slip under the wheels. Materials with higher hardness values were found to provided an increased chance of pill breakage and therefore undesirable for our device. With this in mind we determined that the hardest material we should consider would be rubber. Using engineering charts we determined that the maximum yield strength of 5 Mpa and a maximum hardness of 51 HV would produce materials that could safely select pills. Figure 25 below shows the result produced by CES based on our constraints.

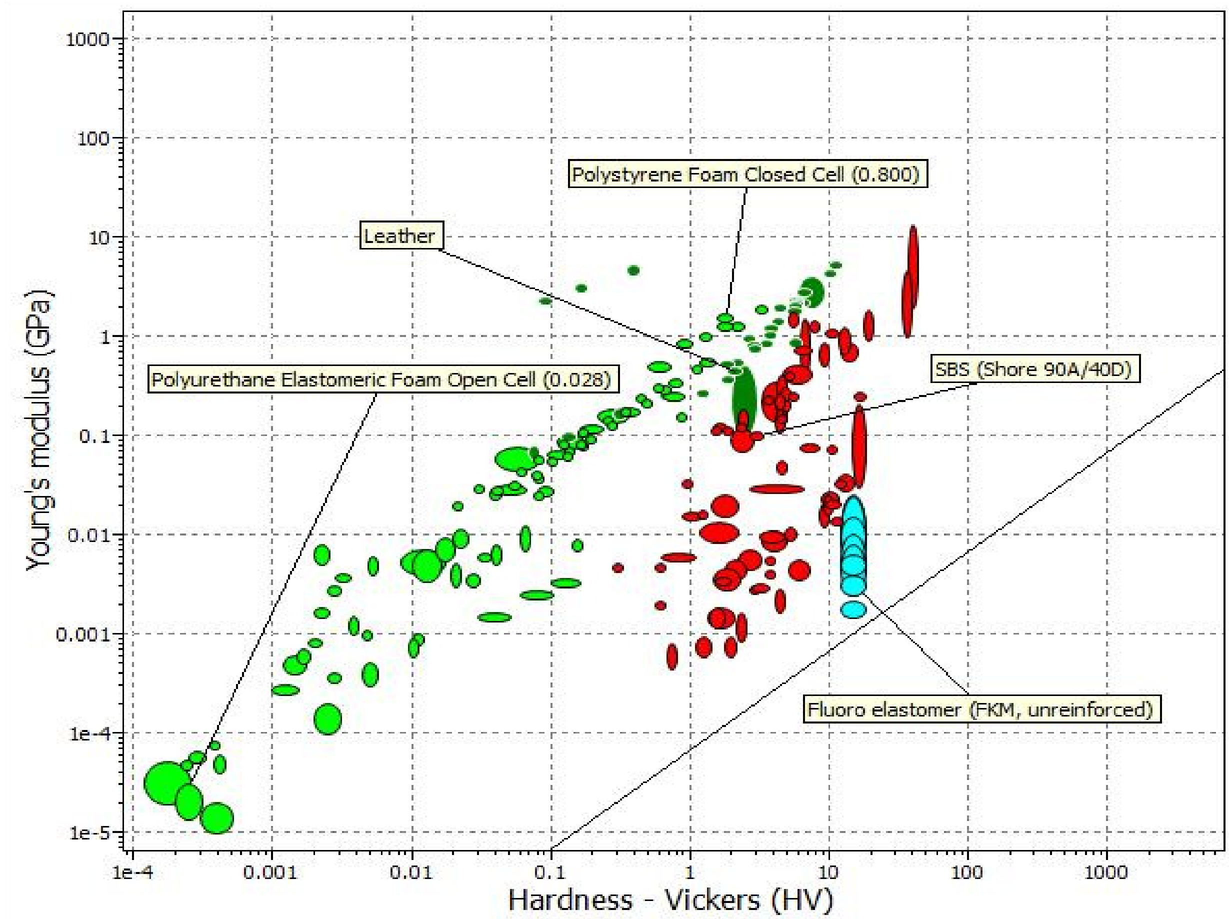


FIGURE 25: CES GRAPH OF THE WHEEL MATERIALS

As can be seen above CES produced a wide range of acceptable materials therefore further reduction was necessary. A material index based on Young's modulus to cost per-density was used. [20] Our group determined that price was a suitable constraint and based our material selection upon that. Fluoro elastomer (FKM, unreinforced) is the material used to make standard O-rings, we decided that due to the cost and availability of O-rings that the Fluoro elastomer was a sufficient material for our impinging wheel surfaces. . Other possible wheel materials for testing from our CES search included:

TABLE 4: WHEEL MATERIALS

Material	Firmness (PSI)
Polyamide foam	1.3
Low density Polystyrene foam	1
Polyurethane	2.05
Vinyl foam	1.6

FINAL DESIGN

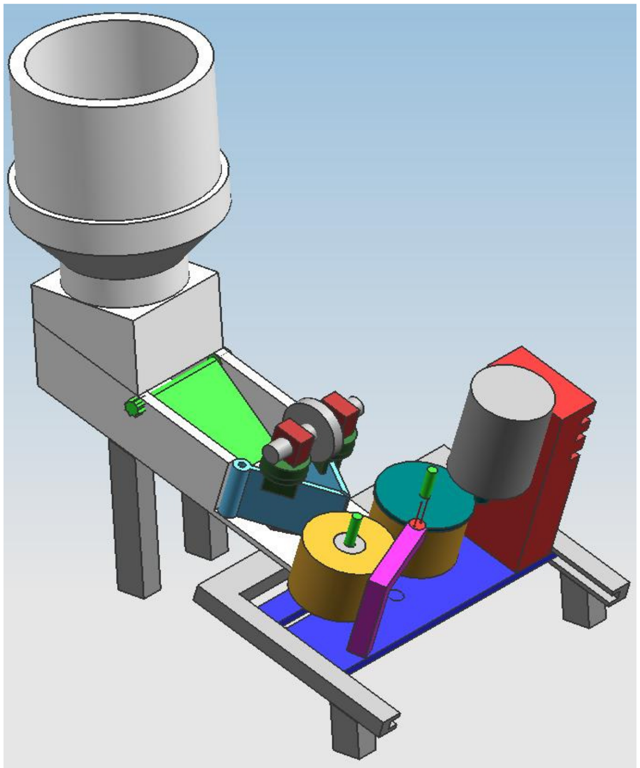


FIGURE 26: FINAL DESIGN CAD DRAWING

The final CAD model for our prototype has been completed. (Fig 26) There are a few differences between our alpha and final design. We added pivoting jack screw assembly to the two front gates. We finalized our optical sensor and mount. We finalized our motor, gear ratio, and rumble pack.

Engineering drawing can be found for each individual part in Appendix H. Our device has several main assemblies that are compiled into the fully functioning machine.

There is the hopper assembly, (Fig 27) which consists of; the hoper, the constrictor, the adapter, the ramp, the vertical door, and the two horizontal doors.

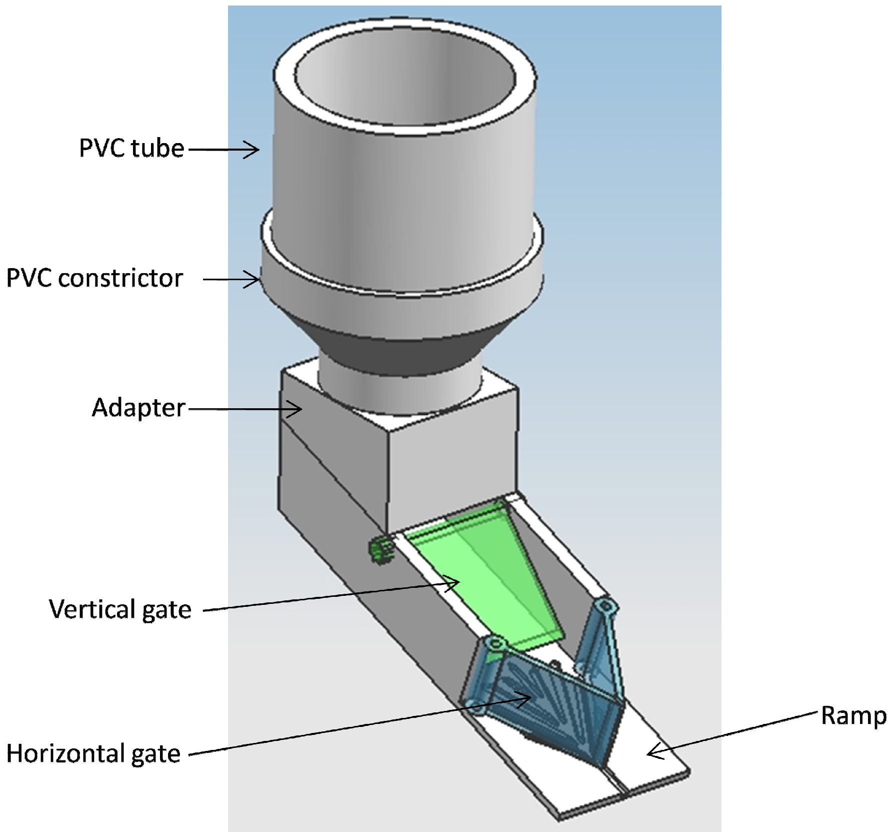


FIGURE 27: FINAL HOPPER ASSEMBLY

There will be two vibration motors glued to the back of the constrictor. The vertical door is held in place by a thumb screw, with a lock washer and nut on the other side. This way the pressure can be reduced and the door can swing then locked in place. The two horizontal doors are will be loosely bolted to the ramp. There is a Jack screw assembly (Fig 28) that fit over the horizontal doors and allows them to open and close at the same rate and hold their position during light shaking. Swivel assembly

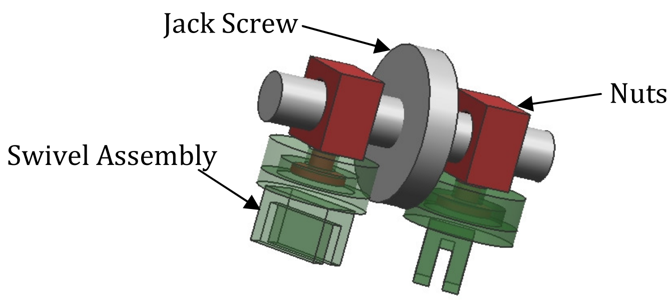


FIGURE 28: JACK SCREW ASSEMBLY

The screw has right and left handed threading (Fig 29) which accomplishes the goal of same opening and closing rate. [18] The nut for the screw can also swivel inside the lower portion to change as the screw expands and contracts

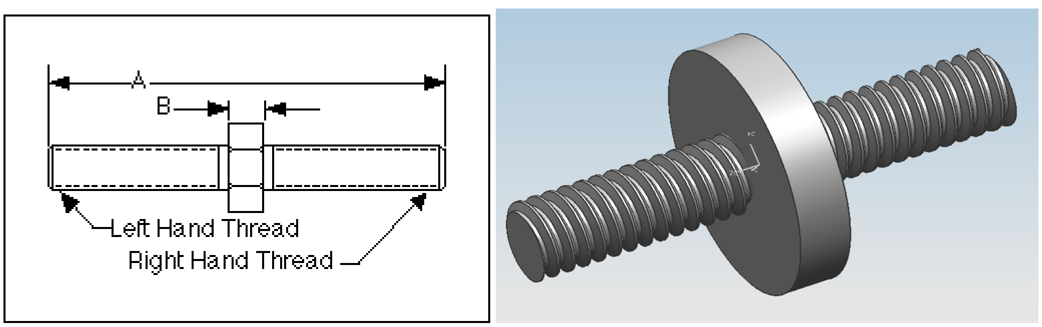


FIGURE 29: SCREW HAS RIGHT AND LEFT HAND THREAD

The next portion of our machine is the wheel assembly. This consists of: the main wheel plate, wheel assembly slide, wheels, wheel shaft, bearings, motor and motor mount, large and small gear, optical sensor and mount, and set screw.

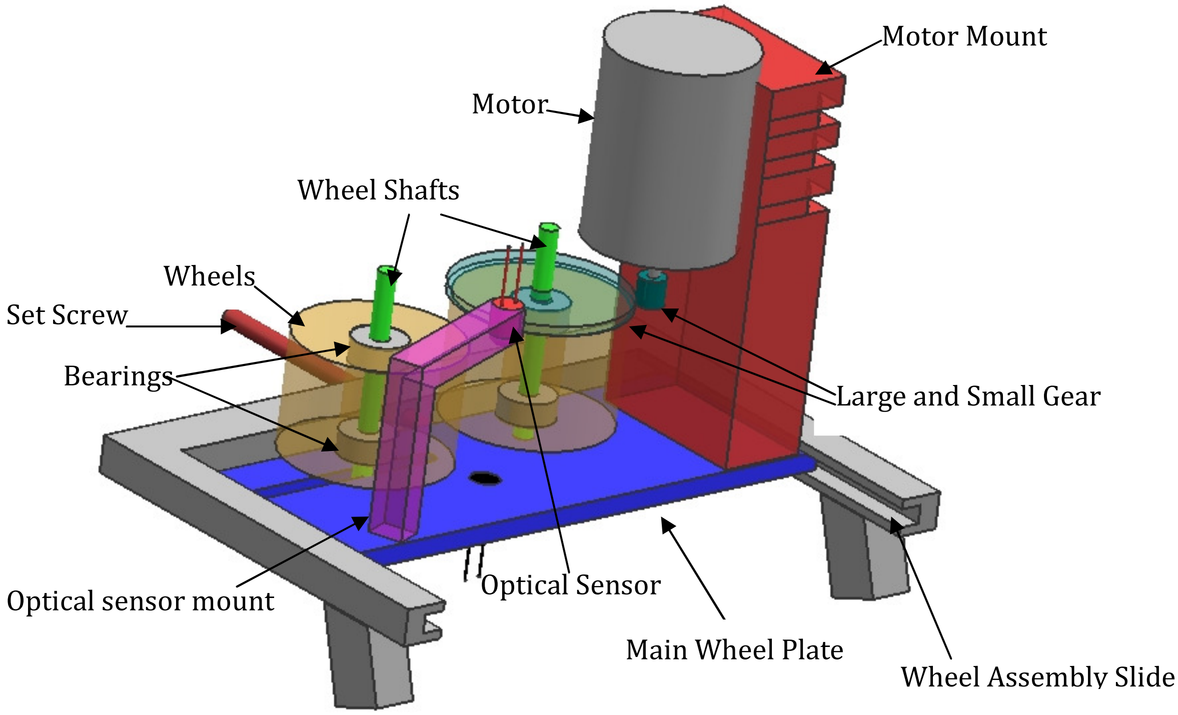


FIGURE 30: FULL MOTOR ASSEMBLY

The Slider assembly (Fig 31) is made up of: the main plate, the slider guide, and a set screw. Tension for the set screw is provided by a spring not modeled here. There is a groove for one wheel to slide, and a whole in front of the wheels where the photodiode will go.

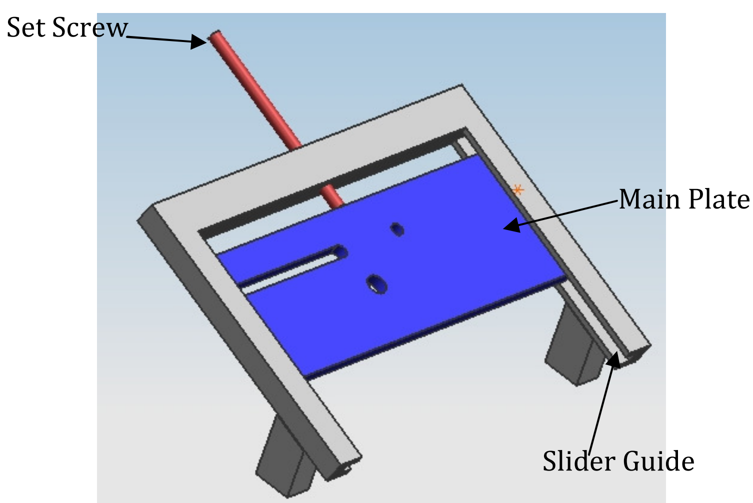


FIGURE 31: THE SLIDER ASSEMBLY

The wheels (Fig 32) consist of: wheel shafts, Wheels, rubber o ring, bearings, and large gear. The bearings are fixed to the shafts and the wheel side snugly over. There are rubber o rings around the wheel hub that are not pictured here. The large gear is attached to the drive wheel. There will also be two springs stretching across the top and bottom of the shaft to tension the wheel together.

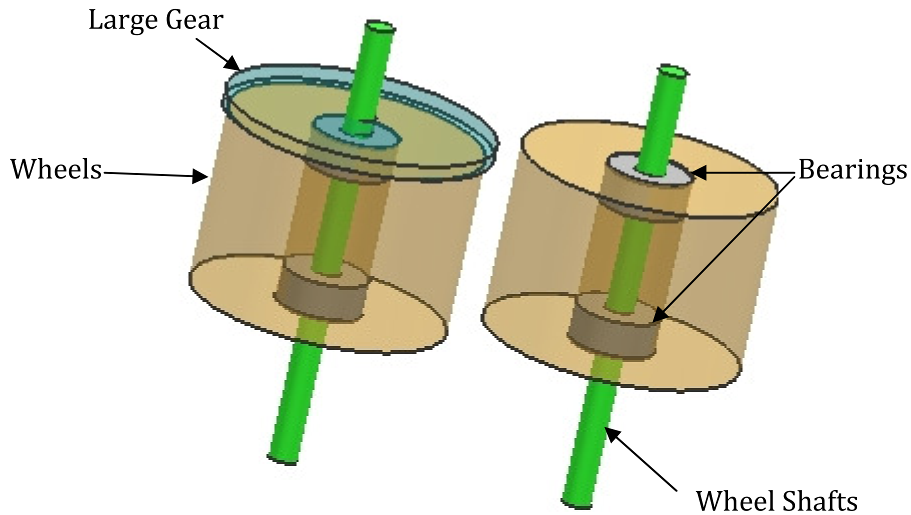


FIGURE 32: WHEELS ASSEMBLY

The main drive wheel is driven by a smaller gear attached to the motor. (Fig 33) The motor is held in place by the motor mounts. The motor will be zip tied to the mount and hot glued in place.

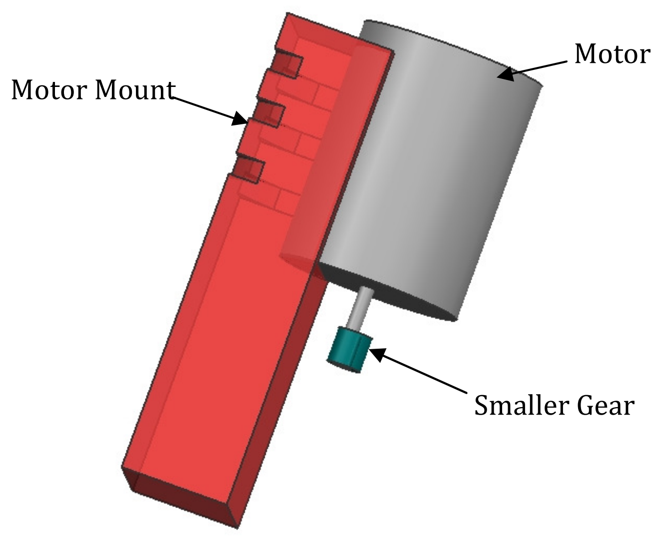


FIGURE 33: MOTOR MOUNT WITH SMALLER GEAR ATTACHED

The final sub assembly of our device is the optical sensor. (Fig 34) The sensor consists of: infra-red LED, LED mount, and infra red photodiode. The mounting bracket allows the senor to be the proper position without interfering with the expansion of the wheels. The senor will be connected as shown in the Circuit diagram below. (Fig 35) [19] Once the beam from the LED to the photodiode is broken we can set the change in voltage as the single to stop the motor, this will require a computer controller.

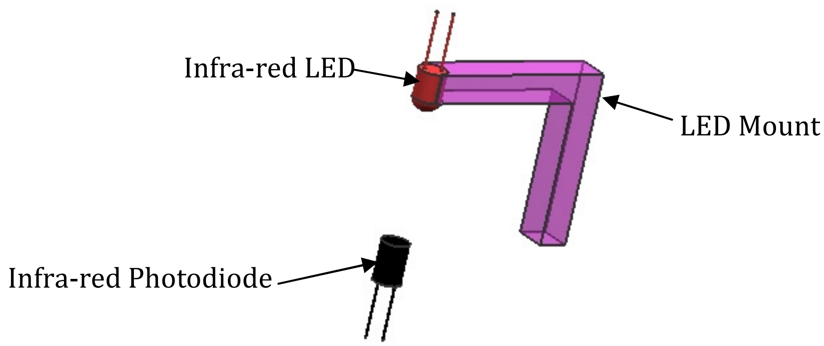


FIGURE 34: LED SENSOR

ENGINEERING CHANGE NOTICE

MOTOR MOUNT AND WHEEL STABIZLER

WAS: Figure 33, pg 33

IS:

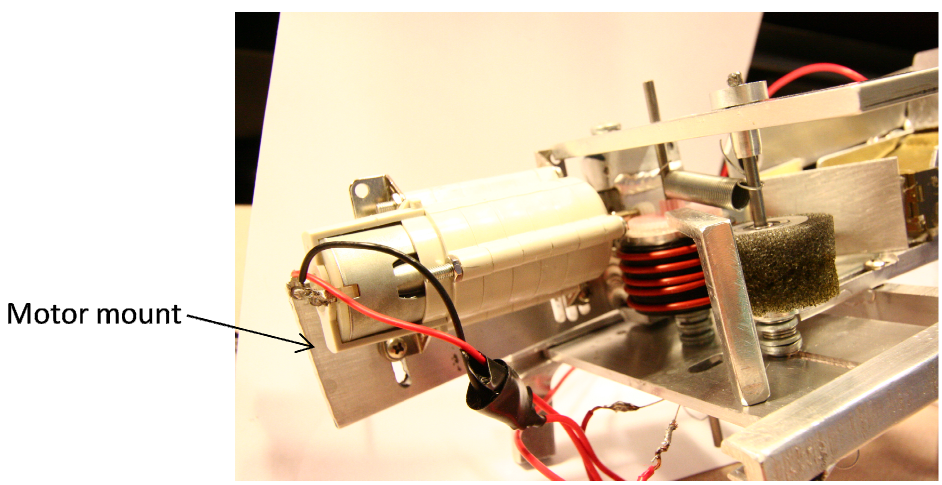


FIGURE 35: REDESIGN MOTOR MOUNT

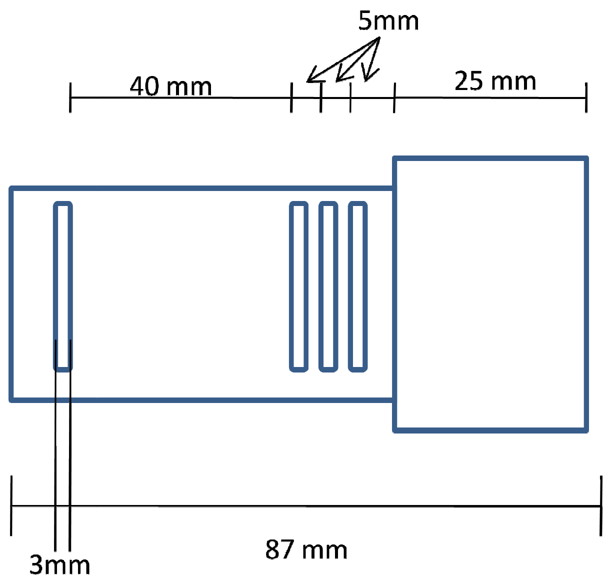


FIGURE 36: MOTOR MOUNT ENGINEERING DRAWING

Changes Made:

1. Rotated motor mount sideways
2. Added height piece
3. Wheel axel stabilizer
4. Slide stabilizer
5. Stop added to slide axel

Reasons for Change:

1. The wheel axels needed stabilization
2. Stabilize drive wheel
3. Slide helps stabilize slide wheel torque

Date of Changes Made: 11/25/2008

Changes Authorized By: Albert Shih

SWIVEL MECHANISM

WAS: Figure 28, pg 31

IS:

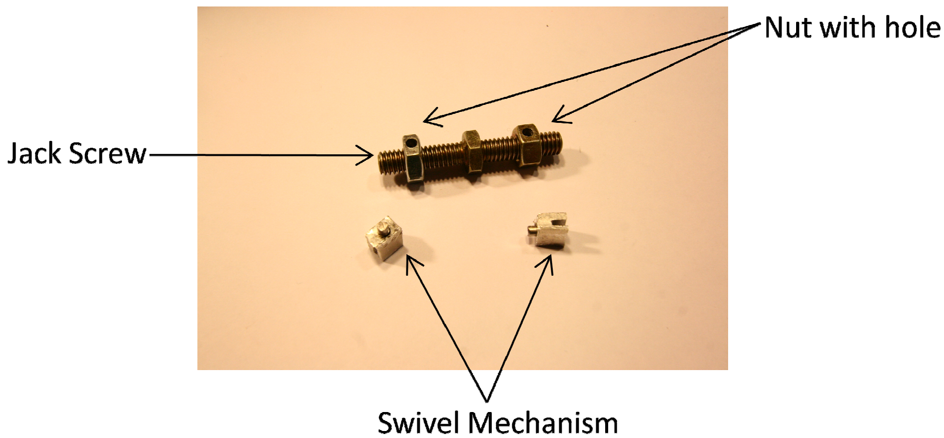


FIGURE 37: SWIVEL MECHANISM

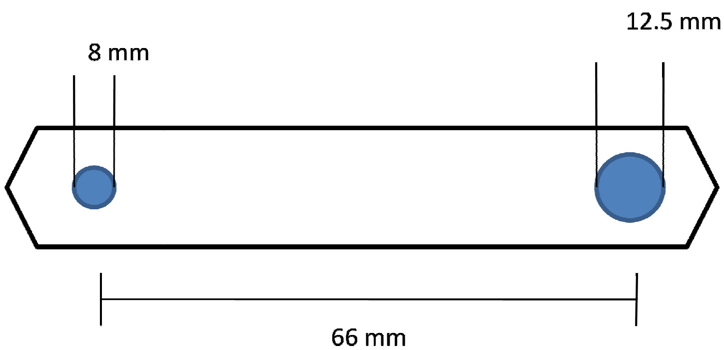


FIGURE 38: SWIVEL STABILIZER

Changes Made:

1. Holes and pegs instead of complex joint
2. Stabilizer arm

Reasons for Change:

1. Simpler design
2. Stabilize the mechanism

Date of Changes Made: 11/10/2008

Changes Authorized By: Albert Shih

GROOVED PLATE SPACE

WAS: Figure 27, pg 30

IS:

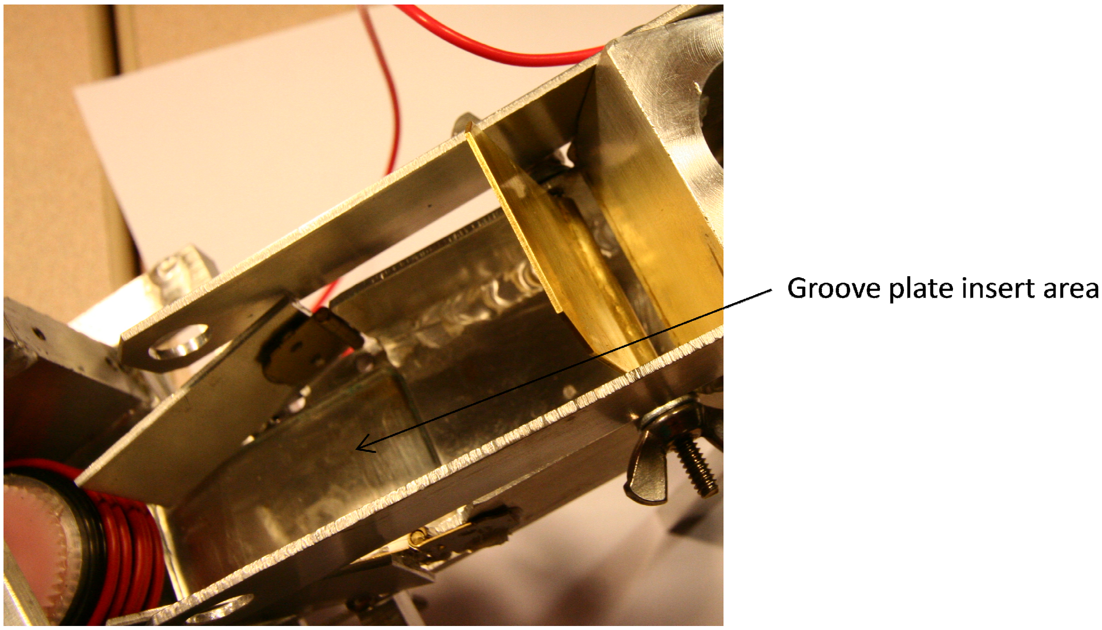


FIGURE 39: GROOVE PLATE AREA

Changes Made:

3. Groove added at bottom of ramp

Reasons for Change:

3. Try different Groove plates

Date of Changes Made: 11/10/2008

Changes Authorized By: Dan Johnson

VIBRATING MOTOR

WAS: 5mm diameter vibrating motor

IS: 18mm diameter Vibrating motor

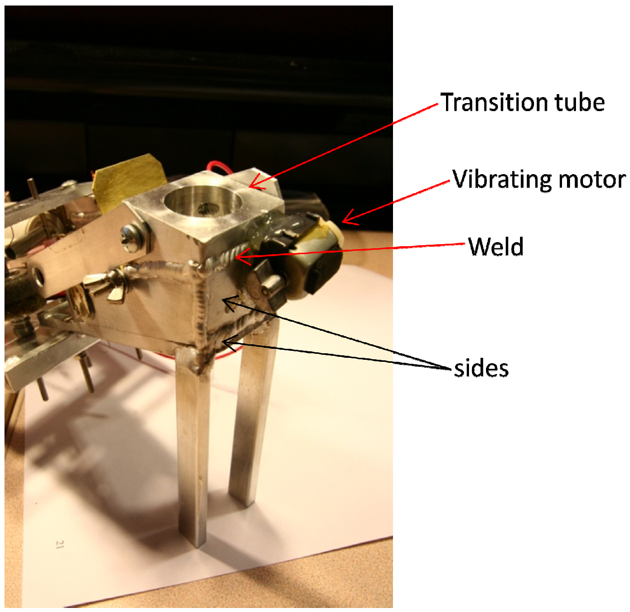


FIGURE 40: REAR ATTACHED VIBRATING MOTOR

Reasons for Change:

1. Higher vibrations

Date of Changes Made: 11/25/2008

Changes Authorized By: Dan Johnson

DOOR HINGE

WAS: Figure 27, pg 30

IS:

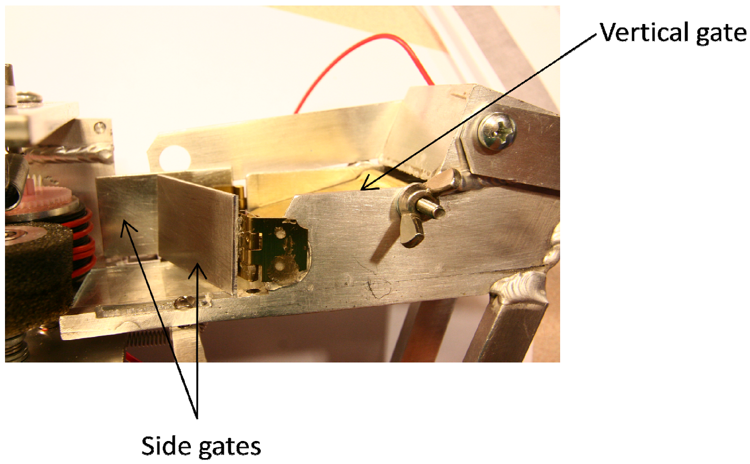


FIGURE 41: SIDE AND VERTICLE GATE

Changes Made:

1. Door hinge instead of screw hinge for side gates

Reasons for Change:

1. Increase door stability

Date of Changes Made: 11/25/2008

Changes Authorized By: Dan Johnson

MANUFACTURING PLAN

We used conventional machining techniques to manufacture our prototype. These included: lathe, mill, band saw, sheet metal stamp, drill press, and Tig welder.

The hopper (Figure 41, pg 39) was made of aluminum sheet metal. The side walls were stamped out of 0.03” sheet aluminum, and holes were drilled for the top gate. The base and legs were sawed from ¼” sheet aluminum, then smoothed, grooved, and drilled using a mill at high speed. The transitional tube was sawed from 1.5" aluminum block, drilled with a 1" bit, and drilled and taped for a 10-24 screw. All these parts were Tig welded together.

The side gates (Figure 42, pg 40) were stamped from 0.03" sheet aluminum, and secured to the side walls via 1" brass hinge, with hot glue. The vertical gate was stamped from .03 sheet brass, and was hand forged around a 2" 6-32 stainless machine screw.

The swivel mechanism (Figure 38, pg 37) was sawed from ¼" sheet aluminum, sawed halfway to create the door slot, and drilled with a 1/8" bit for the swivel pegs. The pegs were hand sawed from 1/8" steel rod, and filed to a round edge. The left and right hand thread nuts were drilled with a 1/8" drill bit. The swivel mechanism stabilizers where stamped from 0.03" sheet aluminum, drilled with ½" bit, and grooved with ¾" end mill bit.

The wheel assembly slide (Figure 43) was cut from ¾" sheet aluminum, grooved with 1/8" end mill, the middle section was drilled and taped for 6-32 screw, and drilled on top with 1/8" bit to connect with hopper. This was all welded together with 2 more feet made earlier. The wheel assembly plate was sawed from 1/8" aluminum sheet metal, drilled, and grooved by a 1/8" end mill bit.

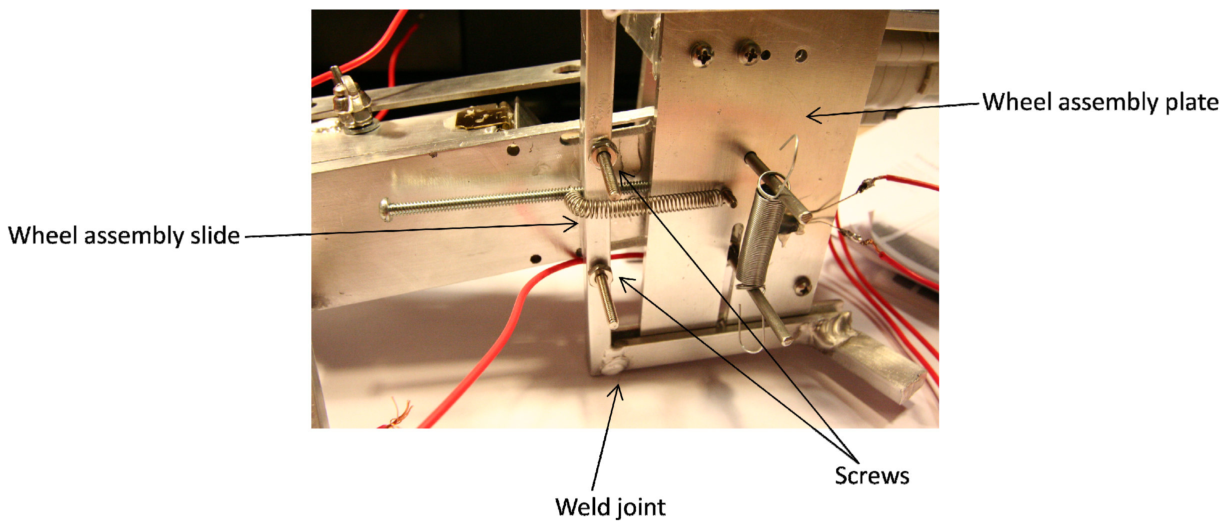


FIGURE 42: WHEEL SLIDE ASSEMBLY

The motor mount bottom was sawed from ½" aluminum block, and top from ¼" aluminum sheet. The bottom was drilled and taped for 4-40 screws on one side, and 10-24 on the other. The top part was grooved with a 1/8" end mill bit. These were welded together.

The LED mount was sawed from ¼" aluminum sheet, and taped for 4-40 screw.

The top stabilizer was sawed from ¼" sheet aluminum, drilled and slotted with ¼" end mill, and drilled for the wheel axel with 1/8" bit.

The slide wheel T collar was lathed and bored to the correct size and shape.

The wheel axels were cut from 1/8" steel rod. The sliding axel was drilled with a 1/16" bit. The top stop was hand sawed from 1/16" steel rod.

The wheels were lathed from aluminum round stock to the different specified dimensions, while on the lathe the centers were drilled and bored for press fit of the bearings.

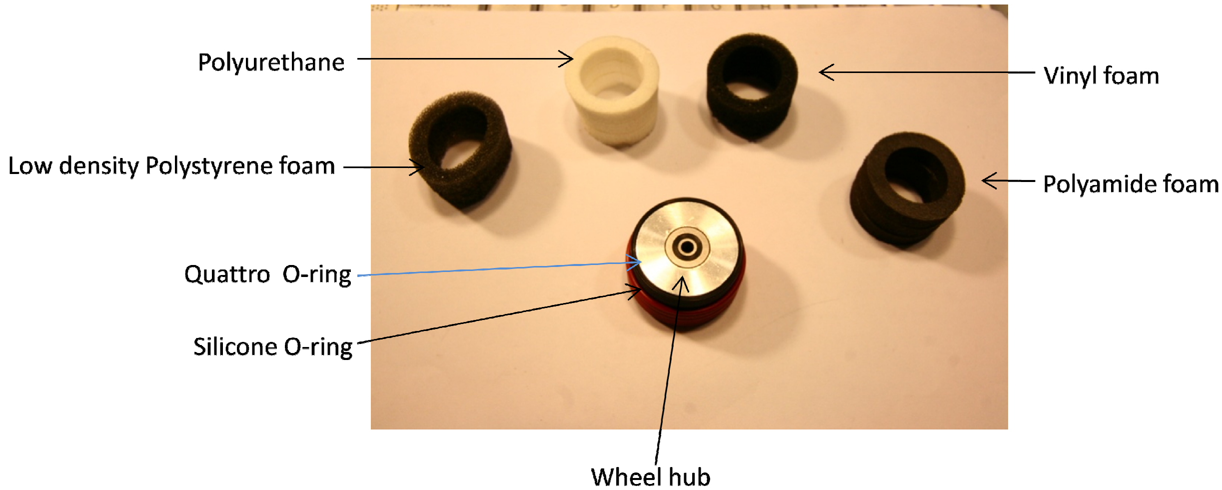


FIGURE 43: WHEEL HUB AND MATERIALS

The Wheel material and grooved inserts were laser cut from different foam sheets, and Plexiglass. This required designing the shape in bob CAD setting the laser level and placing the material in the laser bay.

The bread board for our project is shown below, with labels where connection wires go. Connect the red wires to the positive locations, and red wires with black tape to the ground locations. The parallel cable is connecting to our controlling computer. Professor Kruger can be seen for help with the electronics.

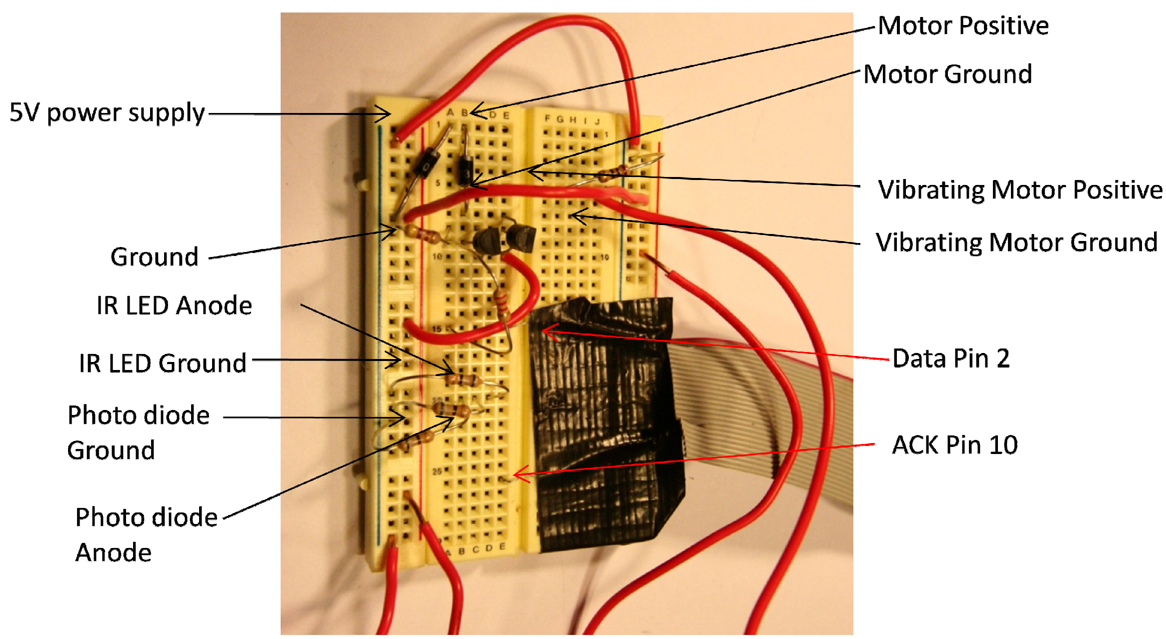


FIGURE 44: LED SENSOR CIRCUIT DIAGRAM

ASSEMBLY DIRECTIONS

The top gate is screwed together with wing nuts and washers on each side, and a lock washer on one side. The hopper is bolted to the wheel assembly. The door swivel pieces are placed on the door with the screw and nuts. The stabilizers are then placed over and screwed to the transition piece.

The motor mount is screwed to the wheel assembly plate. The motor is screwed to the mount with two 4-40 washers for spacers. The driven wheel axel is places in the wheel assembly plate and washers are used till the height is over the ramp, then the wheel is inserted. The slide stabilizer is assembled by putting the stop axel with the slider collar through the slot, then the spring is hooked through the axel, the wheel was slid on, and finally spacer washers. This is all carefully hooked together the spring to the driven wheel axel, and the slide stabilizer screwed down. A spring was hooked around the bottom of the axels. The wheel assembly plate is slid in the wheel slide and attached via a spring hooked around the side adjuster screw.

BILL OF MATERIALS

Component	Material	Manufacturer	Cost
IR LED	N/A	Hobby Engineering	$1.25
Spring 1 ¼ ext	steel	Grainger	$4.83
Spring 1 ext	steel	Grainger	$5.62
Sealed Bearing 1/8 inner bore X 4	N/A	Grainger	$5.60
N64 rumble motor	N/A	Masuto	Donated
Aluminum	Aluminum	Machine Shop	Donated
Axle	Steel	Machine Shop	Donated
Jack screw	steel	Midwest Machine	$4.65
50 pack O rings	Buna N	Grainger	$20.00
50 Pack O rings	Silicone	Grainger	$20.00
50 Pack Quattro O rings	Buna N	Grainger	$20.00
Tube	PVC	Carpenter brother	$1.65
Adapter	PVC	Carpenter brothers	$2.58

4-40 screw X 10	Stainless steel		$0.11
6-32 screw X 3	Stainless steel		$0.13
50 X 40-40 washers	Stainless steel		$0.07
10 X 6-32 washer	Stainless steel		$0.09
2 X 6-32 wing nut	Stainless steel		$0.13
Connection wire	Copper	Radio Shack	$7.00
Bread board	N/A	Radio Shack	$18.00
Foam	Foam	Scrap box	$2.50
Groove plates	Plexiglass	Machine shop	Donated
Circuit components	N/A	Kruger	Donated
Computer	N/A	Kruger	$300
Power supply	N/A	Gateway	Donated
10-24 screw	Steel	Machine shop	Donated
Vertical gate	Brass	Machine shop	Donated
IR receiver	N/A	Hobby engineering	$3.50
Gears	Nylon	Ryder hobby shop	$20.00

VALIDATION PLAN AND TEST RESULTS

Validating our prototype was an important aspect of assessing whether or not our prototype was a success. We subjected our pill dispenser prototype to five different tests in an effort to test pill control and interaction. The tests we conducted concerned ramp angle, wheel material, ramp design, weight to crush a pill, and rumble pack locations. The following section presents our setup along with results and conclusions.

TEST: RAMP ANGLE

Objective: At high angles, the pills will rush down the ramp and seize up at the mouth of the impinging wheels. At low angles the pills won't slide down the ramp without aid of a vibrator. This test seeks to find an angle that balances the gravity fed nature of pills with the least amount of seizing.

Procedure:

1. Hold ramp at 10°
2. Dump 25 of pills into hopper
3. Observe how pills clog and their ability to overcome static friction on their own
4. Increase inclination and repeat

Observations:

TABLE 5: Ramp angle tests

Ramp incline	Large Pills	Small Pills
10^0	Overcame friction and moved slowly with aid of vibrator	Very little movement when vibrator applied
20^0	Little vibration needed to move pills	Pills unstuck easily with vibrator and move steadily
30^0	Pills take a constant vibration to move	Little vibration needed to move pills
40^0	Pills seized tightly. Vibration doesn't affect at all.	Longer bursts of vibration needed but pills still move well

Larger pills overcame static friction with the help of a vibrator easily at an incline of 10°, and smaller at 20°.

Conclusion: A ramp angel of 20° will easily move pills, and reduce occurrence of major clogs.

TEST: WHEEL MATERIALS

Objective: Using foam, rubber o-rings, sponge, or any squishy material in combinations, test if ramped, vibrated, pills can make it through the wheel set up.

Procedure:

1. Wrap foam around wheels
2. Set a tension on the wheels
3. Observe how pill progresses through wheel mechanism
4. Repeat using new material
5. Once wheel materials tested, set a new spring tension and repeat all tests

Observations:

TABLE 6: Wheel materials

Driving wheel material	Slave wheel	Observation
Buna N X rings	Buna N X rings	• Works with small pills • Insufficient friction to grab large pills
Buna N rings	Buna N rings	• Works with small pills • Insufficient friction to grab large pills
Silicon rings	Silicon rings	• Works with small pills • Insufficient friction to grab large pills
Polystyrene foam	Polystyrene foam	• Insufficient friction to grab pills
Polyamide foam	Polyamide foam	• Insufficient friction to grab pills
Polyurethane foam	Polyurethane foam	• Insufficient friction to grab pills
Vinyl foam	Vinyl foam	• Insufficient friction to grab pills
Buna N X rings with silicone ridges	Buna N X rings	• Insufficient friction to grab large pills • Can handle small pills
Buna N X rings with silicone ridges	Buna N X rings with silicone ridges	• Small pills work • Insufficient friction to grab large pills
Buna N X rings with silicone ridges	Polystyrene foam	• Works with small pills • Works with large pills
Buna N X rings with silicone ridges	Polyamide foam	• Works with small pills • Works with large pills
Buna N X rings with X ridges	Polyurethane foam	• Works with small pills • Trouble with large pills
Buna N X rings with X ridges	Vinyl foam	• Works with small pills • Trouble with large pills
Buna N X rings with X ridges	Polyurethane foam	• Works with small pills • Trouble with large pills
Buna N X rings with X ridges	Polystyrene foam	• Works with small pills • Trouble with large pills

It was observed that larger pills have a harder time being grabbed by the current diameter wheels. For smaller pills, the wheel material worked best with different materials on the driver and the slave wheels.

Conclusion: The impinging wheels worked best if the driving wheel is a hard silicone and the slave wheel is covered in soft foam. A larger diameter wheel could allow for a wider selection of wheel materials to grab pills.

TEST: RAMP DESIGN

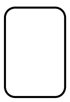
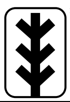
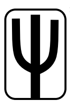
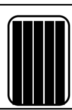
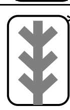
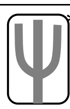
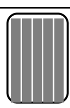
Objective: To determine whether or not adding grooves to the ramp affects the flow of pills we will choose groove designs of bacon pans, leaves, broilers, or any other design that funnels pills towards single-file line without the use of gates.

Procedure:

1. Set an angle of 20^0
2. Pour pills down a ramp design
3. Observe flow of pills towards gate section
5. Repeat using new grooved ramp

Observations:

TABLE 7: Ramp Design

Insert Design	Large Pills	Small Pills
Blank 	Slid towards wheels smoothly as directed by gates and walls	Slid towards wheels smoothly as directed by gates and walls
 *	Adjusted the orientation of the pills adversely at points where vertical groove meets with side grooves	Fell into cracks and got stuck constantly.
 *	Adjusted the orientation of the pills adversely at points where vertical groove meets with side grooves	Fell into cracks and got stuck constantly.
 *	Adjusted the orientation of the pills adversely at points where vertical groove meets with side grooves	Fell into cracks and got stuck constantly.
 *	Pills jam where straight grooves lines pass beneath gates	Fell into cracks and got stuck constantly.
 **	No effect was seen on pills by grooves to help direct towards gates	Helped to direct pills towards gates.
 **	No effect was seen on pills by grooves to help direct towards gates	Helped to direct pills towards gates.
 **	No effect was seen on pills by grooves to help direct towards gates	Helped to direct pills towards gates.
 **	No effect was seen on pills by grooves to help direct towards gates	Helped to direct pills towards gates but some jamming occurred where gates pass over ramp

* Solid black lines are deep grooved ramp inserts
** Solid grey lines are shallow grooved ramp inserts

Shallow grooves had little to no effect on large pills and some small effect on small pills. Deep grooves caught large pills rather than directing them and had little effect on large pills.

Conclusion: In their current location the grooves we not effective and should be removed.

TEST: WEIGHT TO CRUSH A PILL

Objective: Test a variety of common pills (i.e. Aspirin, vitamins, etc.) to find an average crushing weight the spring and wheels can't exceed on the pills

Procedure:

1. Place 6 lb board on pill and stack weights in increments of 2.5 lbs until pill cracks.
2. Repeat with different pill

Observations:

TABLE 8: Weight to crush a pill

Pill Type	Flat force to cracking (lbs)	On-edge Force to cracking (lbs)
Loratadine	250	5
Centrum	26	31
Trimethobenzamide(capsule)	18.5(bends)	31 (breaks)
Compazine	28.5	31
Amox	18.5	26

The pills that had a flat edge were the strongest but if it was on the edge the pills would break at a far less weight. The heaviest weight that a pill held up to was 250 lbs and the lightest was 5 lbs. The round pills were strong but broke at about 30 lbs.

Conclusion: Forces required to break the pills far exceed the prototype's ability to generate them

TEST: RUMBLE PACK LOCATION

Objective: Create pill jams in the ramp in order to find a location for the rumble pack which would best unclog the most types of jams.

Procedure:

1. Pour pills down ramp at 20^0 until clog
2. Apply rumblers to ramp until pills are free
3. Try new placement and repeat

Observations:

TABLE 9: Rumble pack locations

Rumble pack location	Big rumble pack effect	Small rumble pack
Below ramp	All pills were unclogged	No effect
Hopper holder	All pills were unclogged	No effect
Side of ramp	All pills were unclogged	No effect
Below gates	All pills were unclogged	No effect

Legs of prototype	All pills were unclogged	No effect

Conclusion: The small rumble packs had no effect and the large rumble pack was effective regardless of location.

DISCUSSION

There are several revisions to our design that we most likely would have implemented. First, the gates were hot-glued to the frame which made them fall off when assembling but it worked for the mechanism because there wasn't much force on the gates. The wheel rod on the bottom of the mechanism didn't have a roller like the top. This caused the rod to sometimes have a torque on it causing it to get stuck and the spring not being able to expand to enable the pills to come out. To fix this we would probably add a roller to the bottom as well to limit the friction and torque on the axle. A more powerful sensor would be preferable because the current model only had enough sensitivity to work at 5 mm and we needed to reach about 25 mm to have the pill cross, be sensed by the system, and stop the mechanism. Currently we have a 5.715 mm of foam on the wheel. If we increased the thickness to about 12 mm it would make it easier to dispense larger pills. We would have added thicker foam on the follower wheel because we found that the materials that worked best were one hard rubber on the driver and soft foam on the follower. So if the follower wheel is softer it will be able to take in the larger pill and the harder rubber will push the pill into it. This would help because some of the larger pills would be able to press into the foam to get through.

RECOMMENDATIONS

Further recommendations for the automatic pill dispenser can be broken into two separate categories, those that pertain to what has already been designed and those that pertain to the project's future. The main issues with the current concept is its size, because each hopper system can only hold one type of prescription, multiple systems will be required to account for the majority of patients. As a result it is recommended that size reduction is needed, specifically in the impinging wheel system and mount. A majority of the reduction can be obtained simply by purchasing more compact and precise components, items like the motor and gearbox can easily be upgraded with a moderate increase in overall cost. By reducing these key components the size of the motor mount can also be decreased. It must also be noted that in the current design the power of the LED sensor is too small for the desired distance, either the power must be significantly increased or a redesign of the pill exit must be conducted. This can be achieved by adding a small shoot at the end of the ramp that allows pills to drop into the impinging wheels. Improvement of the wheel design and/or material is also recommended, based on our observations a material of foam rubber would be ideal as well as a wheel with permanent spacing would allow for better pill seizure. Another area of the current design that needs further improvement is the spring system. Through testing it was observed that though the design functioned it did not perform as well or as reliably as desired. Larger pills proved much more difficult than originally thought, therefore the tension of the spring must be adjusted or the spring mechanism itself needs to be improved. One of the issues that arose during fabrication was the meshing of the motor gear and the drive wheel; it is recommended that a gear shaped pattern be etched into the wheel itself to increase the chances that the motor gear contacts and drives the wheel. It is recommended that the horizontal gate system be redesigned. The stability of the system is less than ideal and therefore must be increased. By adding a cover for the pill shoot the horizontal doors will have two connection points, which should dramatically increase the system's stability.

As the main goal of this device is to accurately dispense correct medication dosages it is also recommended that the safety precaution be increased. By implementing more systems the likelihood of an overdose is further reduced: more accurate LED sensors, weight sensors, and even video sensors will all but eliminate incorrect dosing. Another aspect of the overall design that needs to be reworked is the hopper shape and dimensions. Because the device is intended to be one of several, the shape and tolerance must be tight to allow for snug fitting joints between the other contained devices.

PROJECT PLAN

September 11	Research on an Aging Society
September 13	Researching Patents and Other Companies Designs
September 17	Meeting with Dr. Mark Ziadeh
September 21	QFD Completed
September 25	Final Concept sketches
September 30	Report 1 (completed)
October 1	Slide Show Presentation for DR 1 (completed)
October 2	Design Review 1 Presentation
October 6	Review Concept Designs
October 7	Thorough Brainstorming (completed)
October 8	Engineering Specifications Presentation/Report (completed)
October 9	Meeting with Dr. Mark Ziadeh to review and expound (completed)
October 13	Choose a Design
October 13	Slide Show Presentation for DR#2 (completed)
October 14	Report For DR#2 (completed)
October 16	Presenting DR#2
October 16	Visiting the Pharmacy with Dr. Mark Ziadeh
October 20	Finalize Concept to Start Prototype
October 23	Start on Deciding the Material to Use
October 26	Start Machining the Prototype
October 27	Work on FMEA
November 1	Work on Report
November 3	Work on Presentation

November 4	DR#3
November 6	Meet with Bob Coury to Discuss Prototype
November 7	Start Manufacturing the Prototype
November 10	Work on Timeline to Complete Prototype by the Expo
November 15	Start Working in the Machine Shop Making Parts
November 17	Work on Report for DR #4
November 21	Work on Slide Show for DR #4
November 23	Make Sure our Design is a Working Prototype
November 25	DR#4
November 27-29	Thanksgiving Break
December 1	Finalize Machining
December 2 & 3	Experiments
December 4	Design Expo
December 7	Work on Final Report
December 9	Final Report Due

Appendix K details our schedule in depth. Here, we have shown three intermediate deadlines to help complete the Preliminary Design. First, Review the concept designs, by considering the input of our instructor and sponsor. Second, do more research and further analysis on how to make the best design. Third, we will choose a single design by Monday, October 13th, and, finally, the report and presentation for that design will be completed by October 14th and 16th, respectively. We will start the prototype on October 26 and continue to work on it until DR#3. Our report and presentation will be completed by November 6.

PROBLEM ANALYSIS

Primary research on existing products, and medication use and size, was performed first. Next field research was conducted to identify our customer requirements. With the help of Dr. Ziadeh, various nursing homes, other medical professionals, and brainstorming session we developed a QFD. The requirements for our machine in order of priority are: automatically sort medication, dispense reliably, security, ease of use, and reminder / warning.

- Automatic medication sorting is the main purpose of our machine, we need to design a mechanism that will take a jumble of medications and order them and individually dispense them.
- The dispensing of the medication needs to be reliable; it must be released on time, and without extra medications. This is necessary so the user receives their proper medication and no accidental over dose.
- Security for this machine is to ensure no tampering with the medications. This is to prevent either the user or other parties from potential over dose and theft.

- Ease of use is particularly important. This machine will be used by independent elderly. It needs to be very simple to operate, and require very little force to use.
- Finally a reminder system will be important to ensure the user is remembering and taking their medication. The reminder needs to be both audio and visual, with the possibility of a wireless reminder. Also warning to guardian in case of emergency.

The largest difficulty of this machine will be the sorting mechanism, examples of our concepts can be found in (Appendix C). There is an enormous variation in pill size, so a design that can handle most will be necessary. Once a mechanism is settled on reducing the size and fitting it into a coffee sized machine will be our next hardest task. Current automatic pill dispensers still require pre sorting of the pills, but have array of helpful reminders. These can be improved on by creating a faster loading method or an automatic sorter.

Our machine uses many elementary engineering fundamentals to accomplish our goal. Dynamics are used in the form of rotating wheels to dispense the pills, rotating off set weight to shake hopper, or wheel in tension with a spring. We will model a single pill on an incline and determine the minimal force to break the static coefficient of friction. The device will also need systems and controls to make sure it operates correctly and on time. We have started performing tests with models of hopper designs, and variable pills, to find potential problems with our design. We also preformed a range of tests on pills to see there; bending strength, compression test, effect of moisture contact, simple friction test. We measured a wide range of pill sizes to have a better idea of the range of size for the hopper design.

We also constructed some prototype models of the hopper. We were able to better design the bottom cone of the hopper and the gates with these models. They were tested by loading them with various pills of different sizes, and observing any problem that occurred while flowing out of the container. We later added a rumble pack motor to the model to test the effect of shaking on the pills. Finally a wheel mount was set up to test for problem with that device. We found that the material need to be stiff or the pills will get stuck underneath the material, or if the wheel speed is to fast it will cause the pills to break.

CONCLUSION

Our challenge was to automatically sort and dispense medication reliably. Our prototype successfully dispenses pills one at a time which decreases the amount of time needed for medication sorting and alleviates the hardships associated with old age. From our initial concept, ideas, and models, we narrowed the possibilities to a few designs that could feasibly be built. Using a comparison chart we further narrowed the design to one. Our final prototype was a multi hopper impinging wheel concept. We designed a CAD model with exact specifications of our design and preformed engineering analysis on vital components to determine necessary parts, and proper materials. Manufacturing plans were drawn up for each fabricated component. We conducted several experiments to test the validity of our prototype and develop recommendations for future engineering teams. Through these tests, research, and brain-thought, all customer requirements and engineering specifications were met by our final prototype.

TEAM HEALTH

Each team members share responsibility for the design generation and engineering work. Our specific tasks are as follow:

Jorge Cisneros	Facilitator, Futurist
Matthew Genyk	Researcher, Treasurer
Ben McAlvey	Scheduler, Liaison
Brian Wolfe	Artist, Notebook Keeper

Our team chemistry is great. Each member of the team works hard and contributes equally. We have a good time bouncing both practical and humorous ideas off each other. We are all excited to do this project and believe it has endless possibilities.

BIOGRAPHIES

JORGE CISNEROS

Jorge is a senior in Mechanical Engineering. His hometown is Ann Arbor, MI. His reason for interest in this project stems from his grandmother lived to be 92 years old. During her later year she struggled with all problems associated with old age. One such problem was a daily medication regiment for years. She also lived independently till she passed. Due to this he has thought previously on assistive devices for her.

MATTHEW GENYK

Matt is a senior Mechanical Engineering. His hometown is Ypsilanti, MI. He was actually born at U of M hospital. He was home schooled up until high school and then in high school went to Fr. Gabriel Richard H.S. He played football and baseball in high school. He also works at his church high school youth group as a group leader. He decided upon this project because he had a great aunt live with him and his family and she needed to take pills and it was difficult for her. They had to take care of her for 3 years before she passed away.

BENJAMIN MCALVEY

Ben is a senior in Mechanical Engineering. His hometown is Lansing, MI. His father was diagnosed with Lou Gehrig (ALS) when he was a senior in high school. For the next few years his family was forced to watch as the disease took all of his functional control. As he lost his motor control he was forced to turn to additive devices to help with communication and mobility. The GADS projects appealed to him on these grounds as he saw a huge need for redesign/improvement of the current market devices.

BRAIN WOLFE

Brian is a senior in Mechanical Engineering. His hometown is Dexter, MI. For the past two years he's worked with kids with cerebral palsy and muscular dystrophy at a week-long barrier-free camp. He was able to facilitate the campers' desires to participate in many activities they would not otherwise be able to do. He sees many cross applications with people with disabilities and the elderly. He's passionate about working towards goals that will directly benefit someone.

ACKNOWLEDGEMENTS

Dr. Albert Shih, for helping us with the designing of our prototype.

Dan Johnson, for meeting with us whenever we needed help.

Dr. Mark Ziadeh, for sponsoring us and helping us know the needs of patients.

Bob Coury, for helping us with machining of our parts and welding most of our parts.

Marv Cressey, for helping us with machining of our parts

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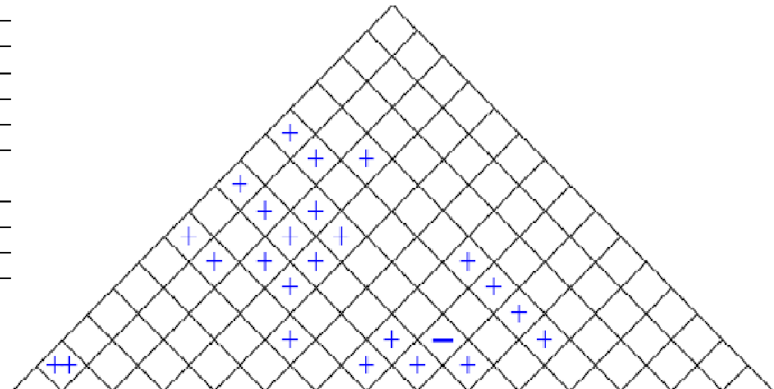
APPENDIX A

Title: GADS - Automatic Medication Dispenser
Author: Group 19 - Jorge C., Matt G., Ben M., Brian W.
Date: 10/2/2008
Notes:

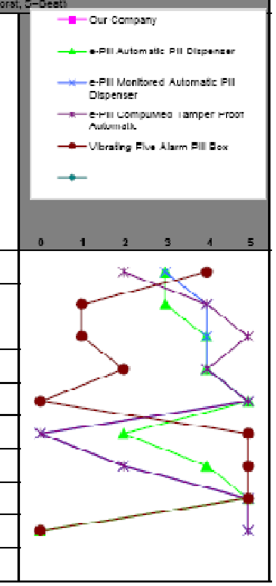
Legend

Symbol	Meaning	Value
⊙	Strong Relationship	9
○	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlation	
+	Positive Correlation	
—	Negative Correlation	
▼ (blue)	Strong Negative Correlation	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
X	Objective Is To Hit Target	



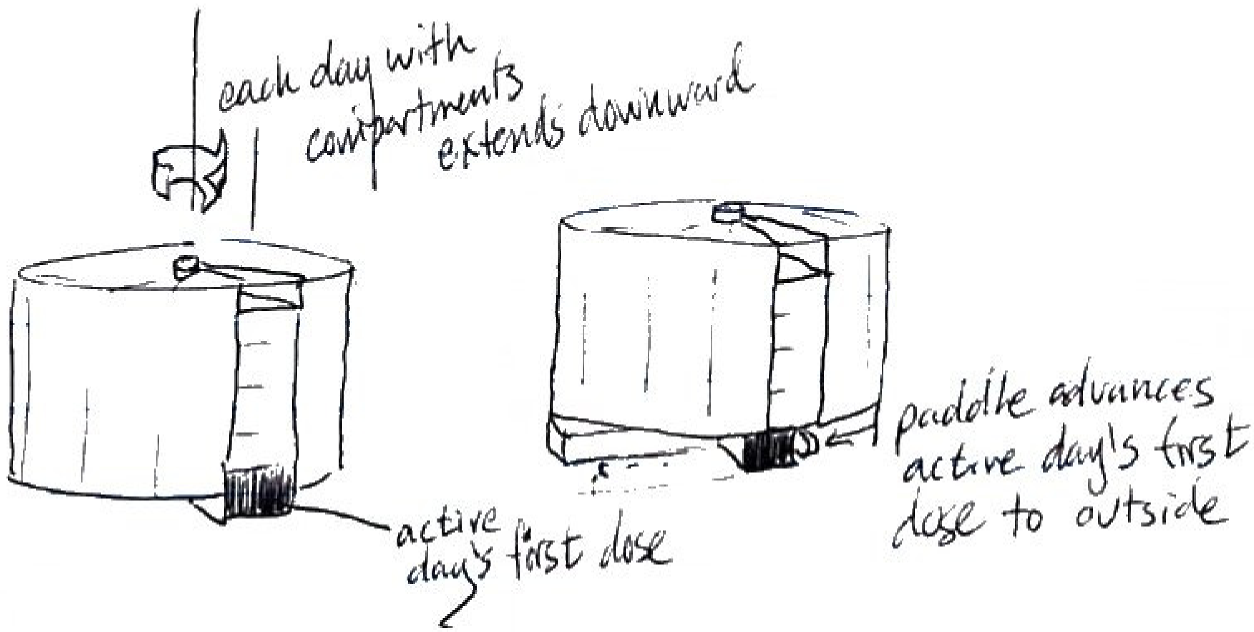
Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Demanded Quality (a.k.a. "Customer Requirements" or "Whats") / Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	1 Lid Design	2 Container Type / Volume	3 Alert Audio	4 Alert Visual	5 Material Selection	6 Operational Noise	7 Mass	8 Electric Backup	9 Number of Parts	10 Power Source	11 Operational Force	12 Timer	13	14	15	Our Company	e-Pill Automatic Pill Dispenser	e-Pill Monitored Automatic Pill Dispenser	e-Pill CompuMed Tamper Proof Automatic	Vibrating Five Alarm Pill Box
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (X)	▼	▼	▲	X		▼	▼	X	▼	X	▼	X								
1	9	14.3	5.0	Easy to Use	○	▲					▲	○	○	▲	⊙	▲					3	3	2	4
2	9	14.3	5.0	Capacity	▲	⊙			▲		▲		▲			▲					3	4	4	1
3	9	14.3	5.0	Looks / Security	⊙	▲	▲	▲	○			▲									4	4	5	1
4	9	14.3	5.0	Delivers on Time			▲	▲				▲		▲		⊙					4	4	4	2
5	3	14.3	5.0	Overdose Prevention			○	○													5	5	5	0
6	9	11.4	4.0	Price		▲			⊙	⊙	▲	▲	⊙	⊙							2	0	0	5
7	9	8.6	3.0	Device Size		○			○		⊙		○	▲							4	2	2	5
8	9	5.7	2.0	Reminders			⊙	⊙						⊙		⊙					5	5	5	5
9	9	2.9	1.0	Warning to Caregivers			⊙	⊙								○					0	5	5	0
10																								
				Target or Limit Value	304 mm	35E6 mm^3	90 dB	1000 lm	1.05 g / cm^3	40 dB	3175 kg	9 V	30 Parts	75 W	4 N	24 hr								
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	0	9	3	3	4	6	5	2	5	2	6	1								
				Max Relationship Value in Column	9	9	9	9	9	3	9	3	9	3	9	9								
				Weight / Importance	186.7	194.3	148.6	148.6	186.7	34.3	117.1	82.0	186.7	88.6	128.6	217.1								
				Relative Weight	10.8	11.3	8.7	8.7	10.8	2.0	6.8	4.8	10.8	5.2	7.5	12.6								

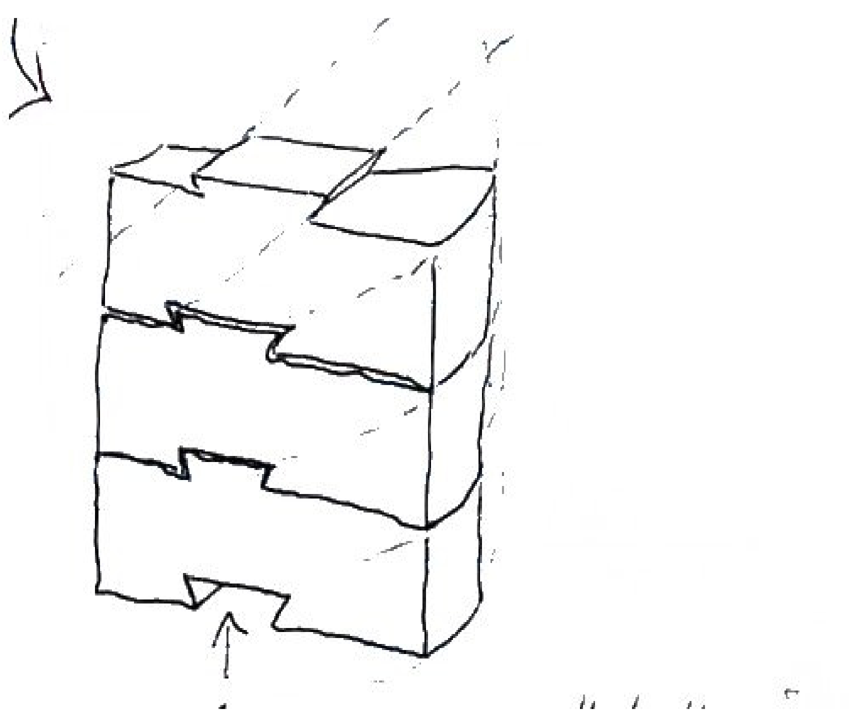
Competitive Analysis (0=Worst, 5=Best)



Powered by QFD Online (http://www.QFDOnline.com)

APPENDIX B

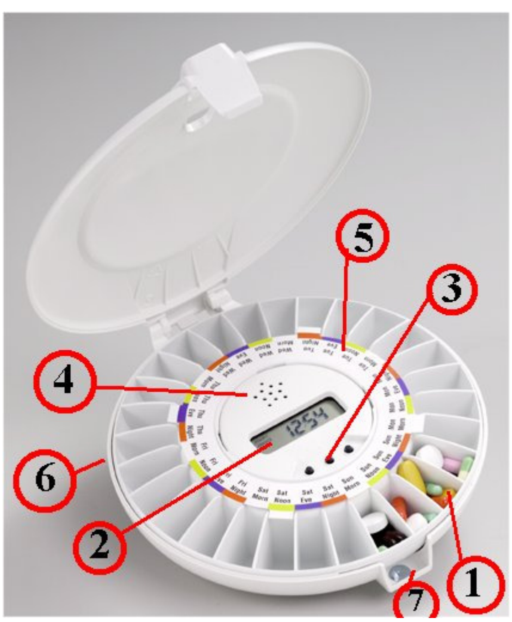

each day with
compartments
extends downward
active
day's first dose
paddle advances
active day's first
dose to outside



APPENDIX C

Monitored Automatic Pill Dispenser

e-pill Automatic Pill Dispenser Med-Time

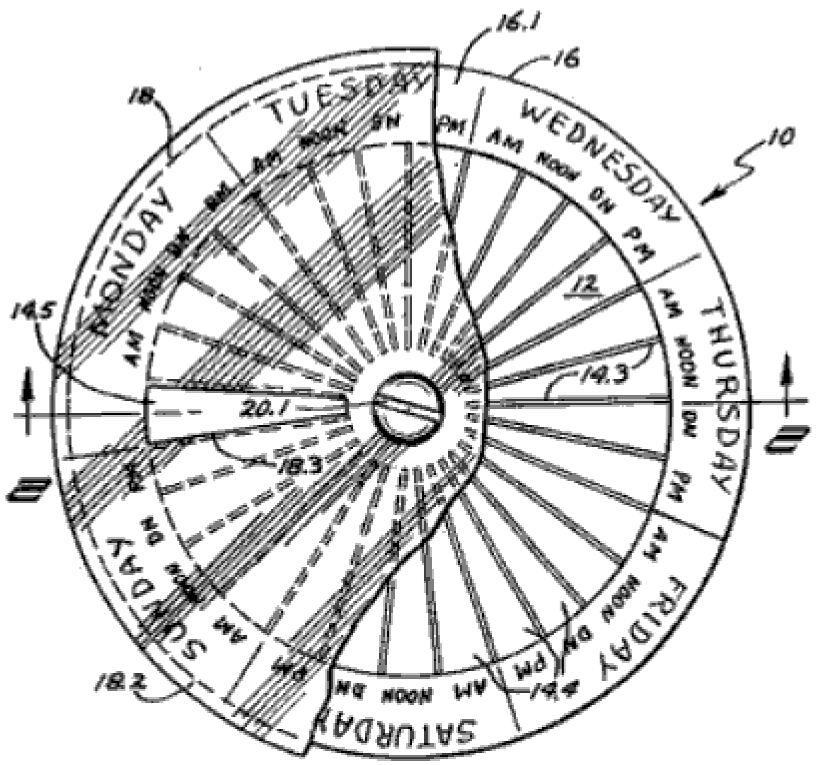


CompuMed Automatic Pill Dispenser

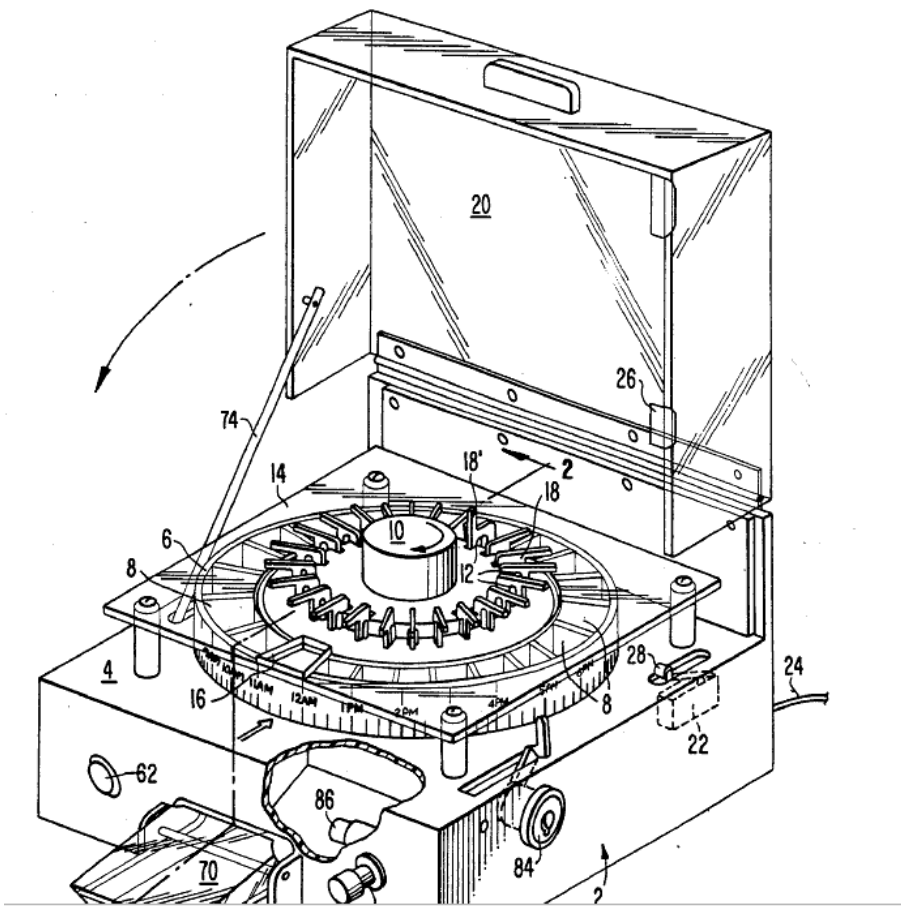
Vibrating Five Alarm Pill Box

APPENDIX D

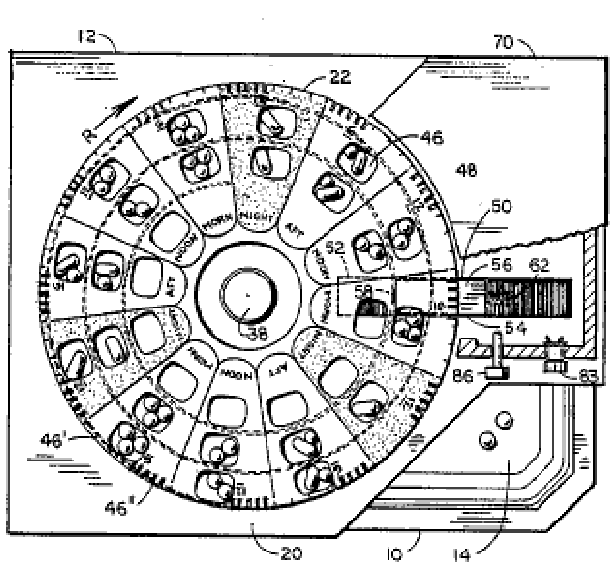
US Patent #3921806



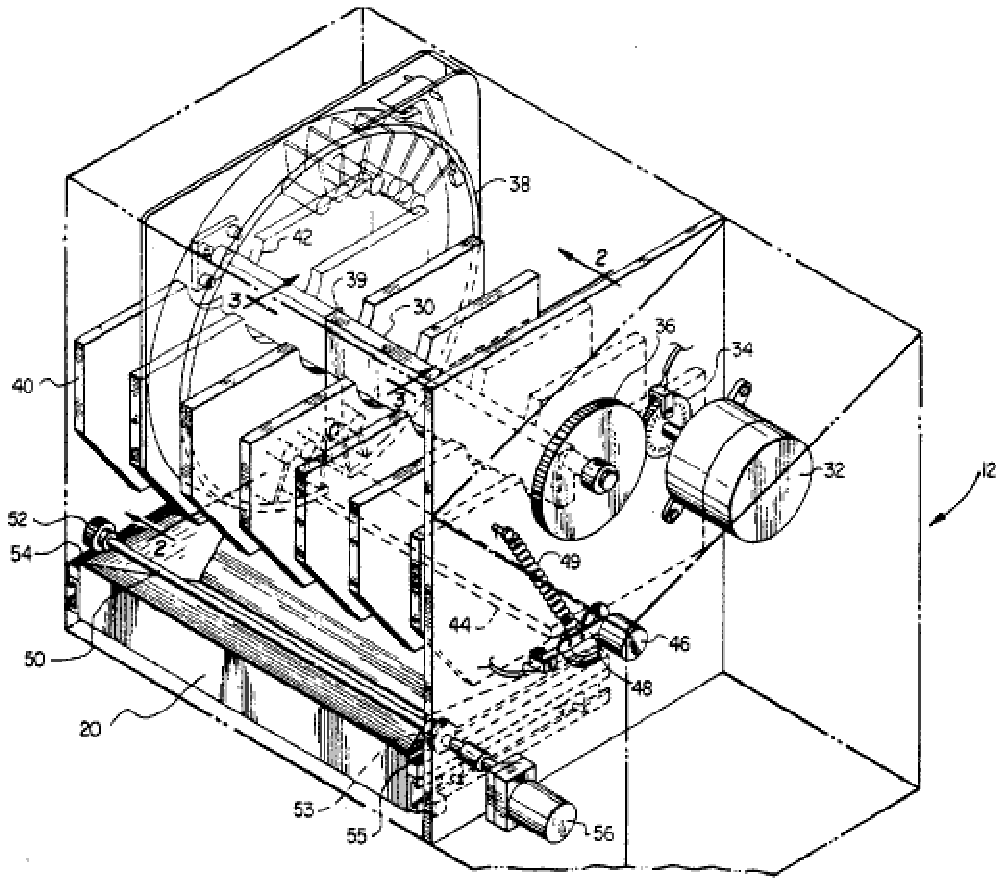
US Patent #4674651



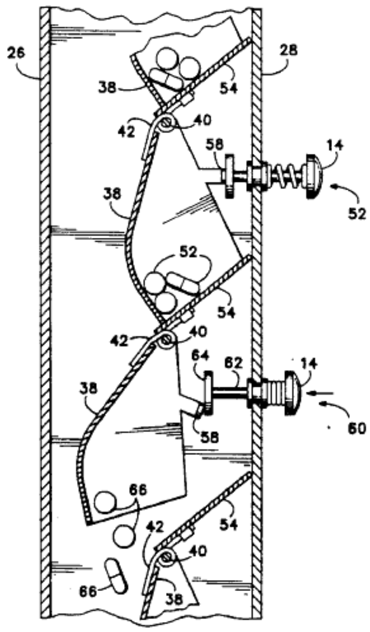
US Patent #4838453



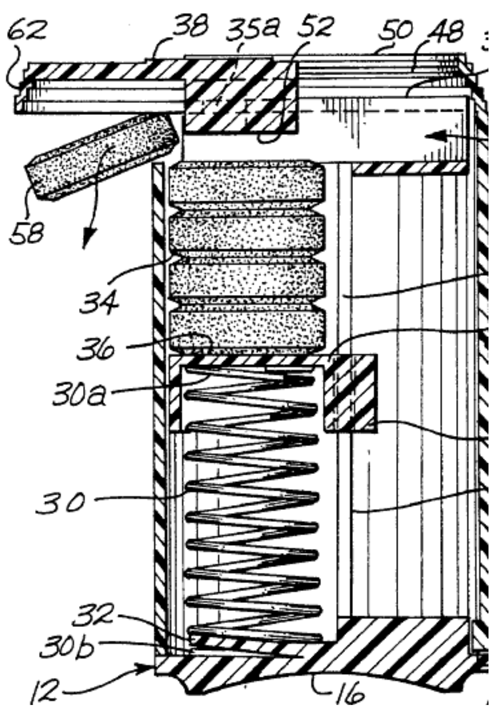
US Patent #5176285



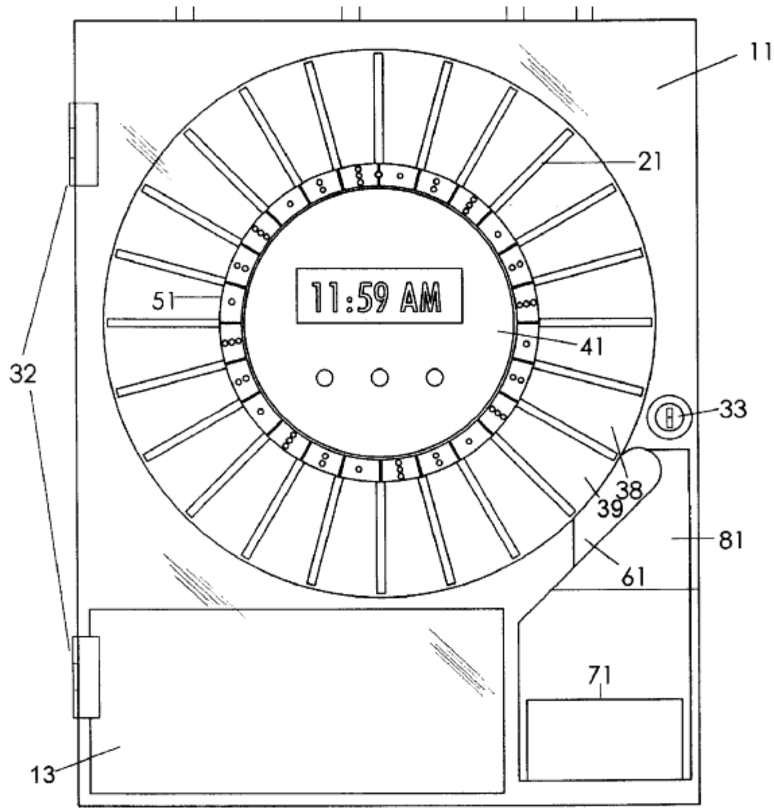
US Patent #5133478



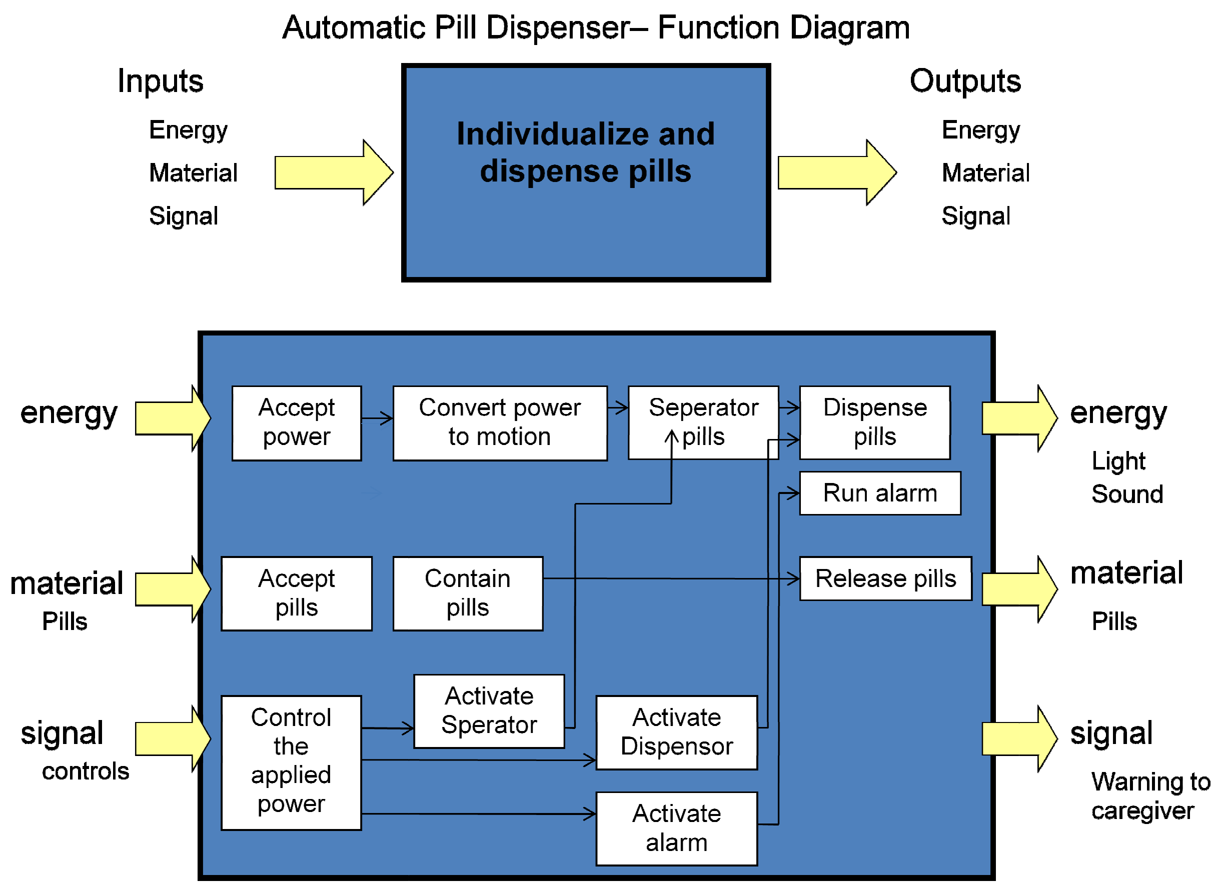
US Patent #5178298



US Patent #6510962



APPENDIX E


Automatic Pill Dispenser– Function Diagram
Inputs
Energy
Material
Signal
Individualize and dispense pills
Outputs
Energy
Material
Signal
energy
Accept power
Convert power to motion
Seperator pills
Dispense pills
Run alarm
energy
Light
Sound
material
Pills
Accept pills
Contain pills
Release pills
material
Pills
signal
controls
Control the applied power
Activate Sperator
Activate Dispensor
Activate alarm
signal
Warning to caregiver

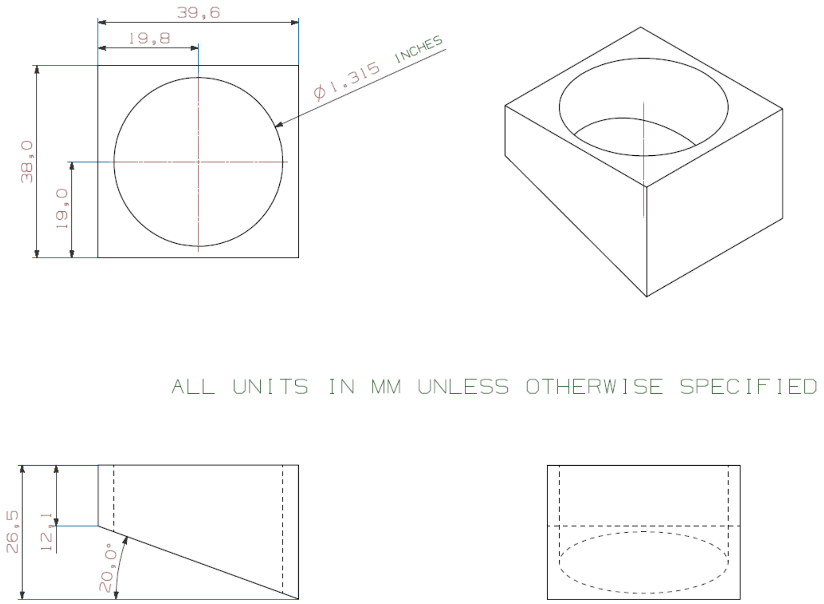
APPENDIX F

Subfunction Pugh Chart for Directional Control

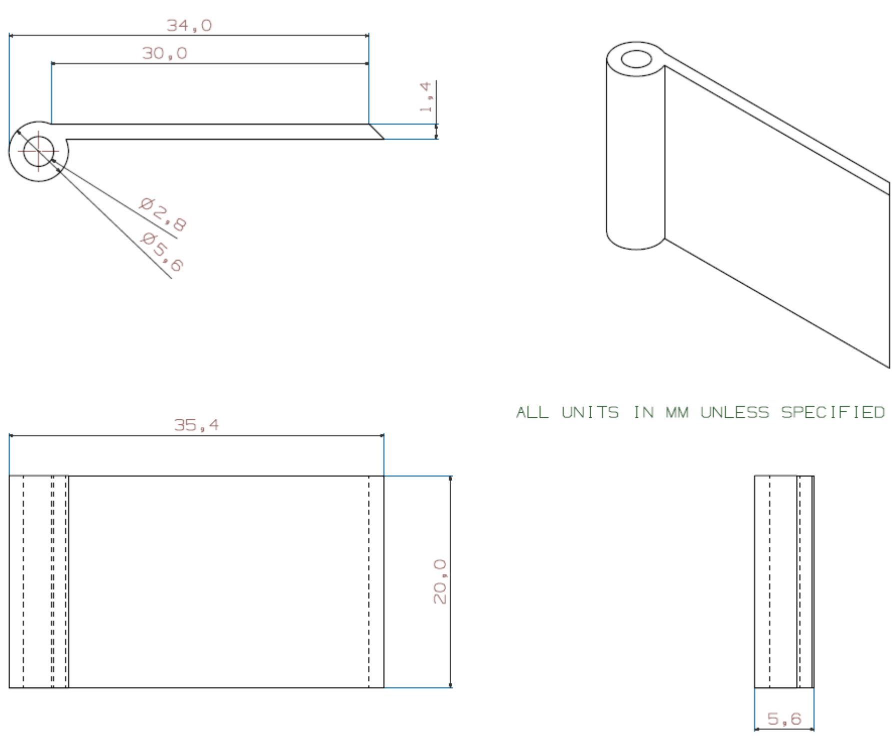
	Concept Variants							
Selection Criteria	Hopper with screw	Hopper with impinging wheels	Hopper with separated conveyer belt	Crane machine with claw	Crane machine with vacuum	PEZ® type pill dispenser	Single hopper with camera	Reference (e-pill automatic)
Variation of dispensable pills	3	4	4	3	5	3	5	5
Ease of manufacturing	1	2	1	1	0	3	0	3
Low jamming possibility	2	4	4	5	5	5	5	5
Size smallest	1	2	1	3	3	4	0	3
Noise lowest	3	3	3	4	0	5	0	5
Durability longest	4	4	4	2	3	5	2	5
Aesthetics	4	4	4	4	5	5	4	4
Cost lowest	1	2	1	0	0	2	0	1
Automatic	5	5	5	5	5	0	5	0
Net	24	30	27	27	26	32	21	
Rank	5	2	3	3	4	1	6	
Continue?	No	Yes	No	No	No	Yes	No	

APPENDIX G

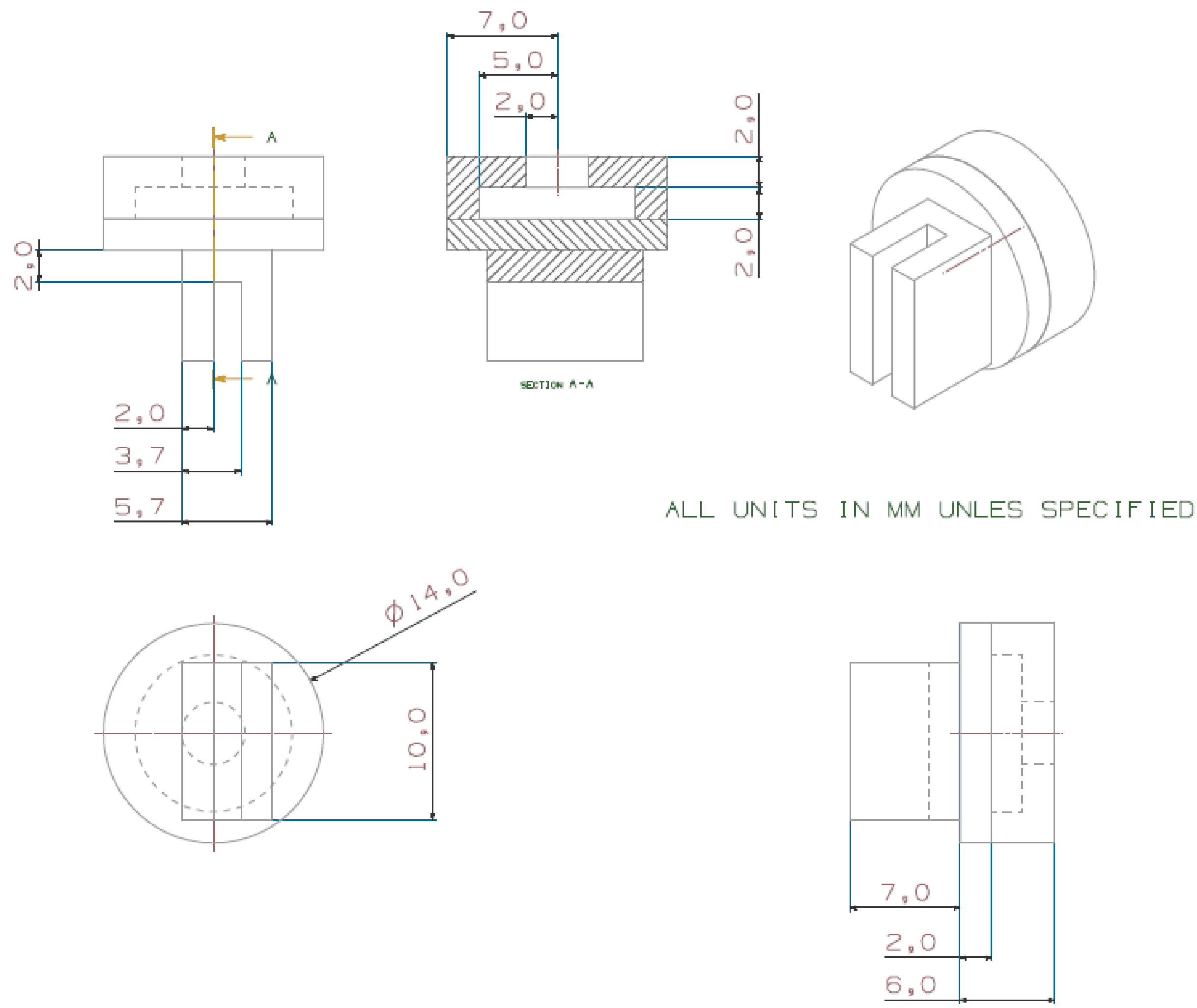
Hopper Holder



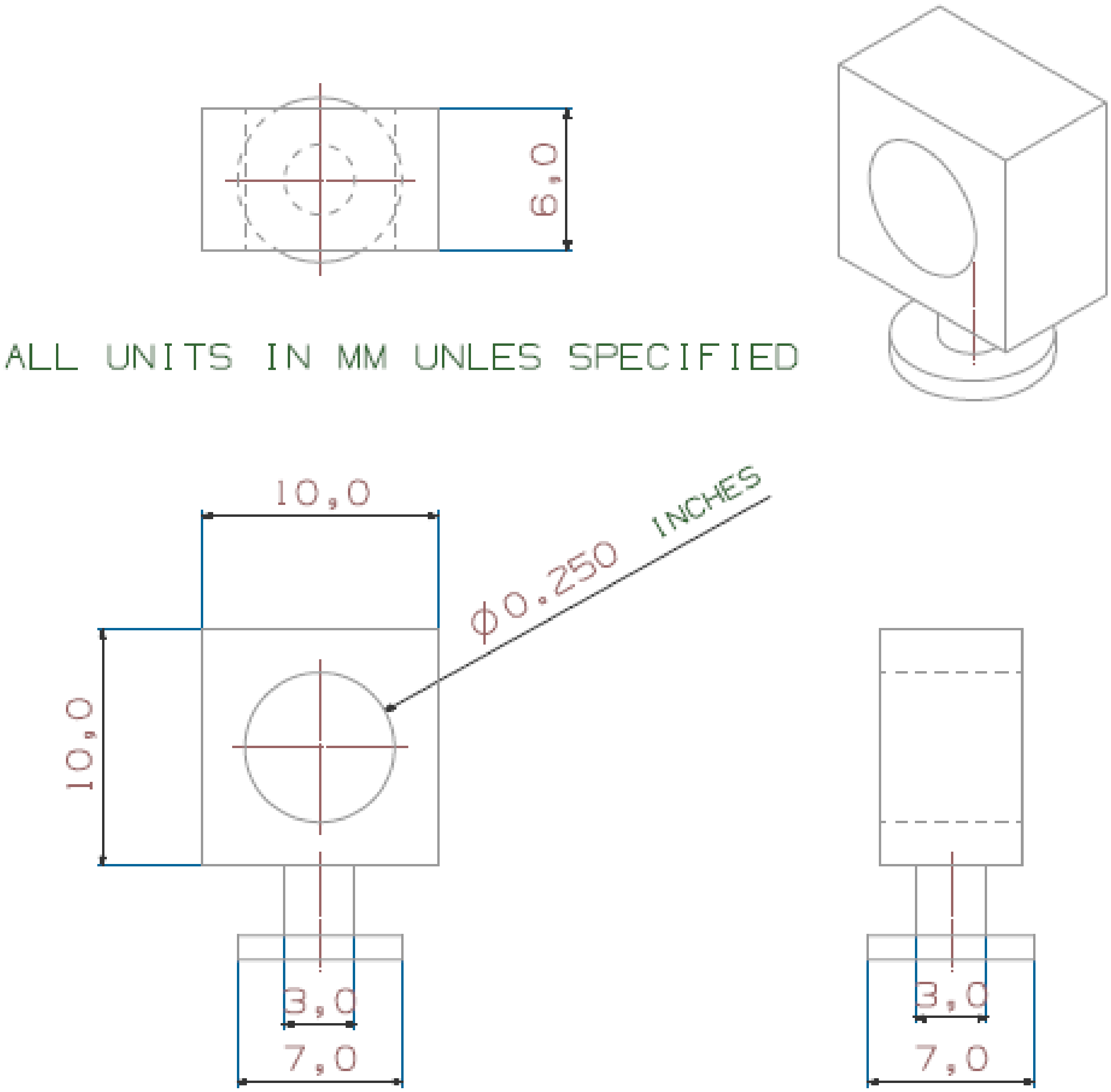
Horizontal Gate



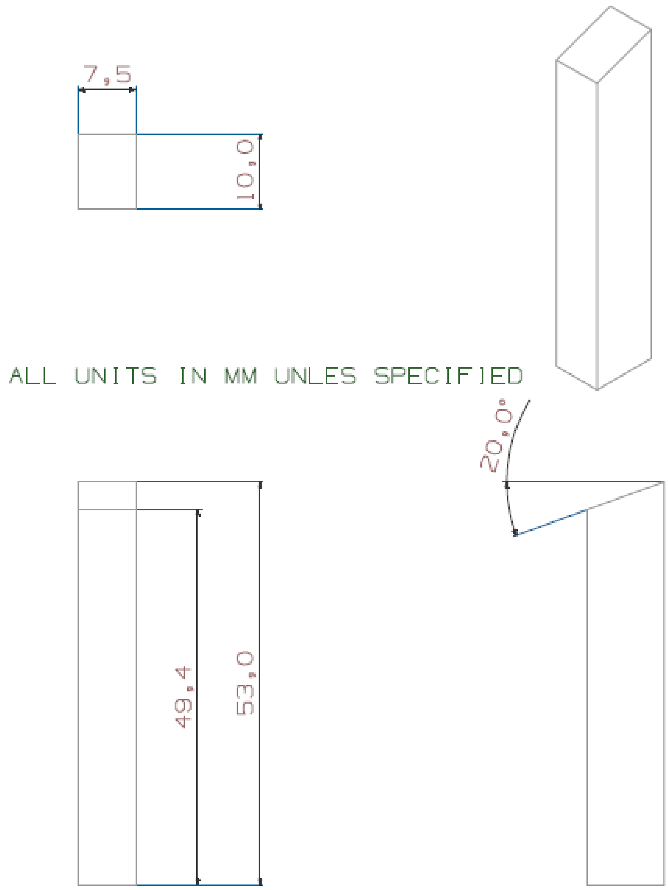
Screw Swivel Bottom



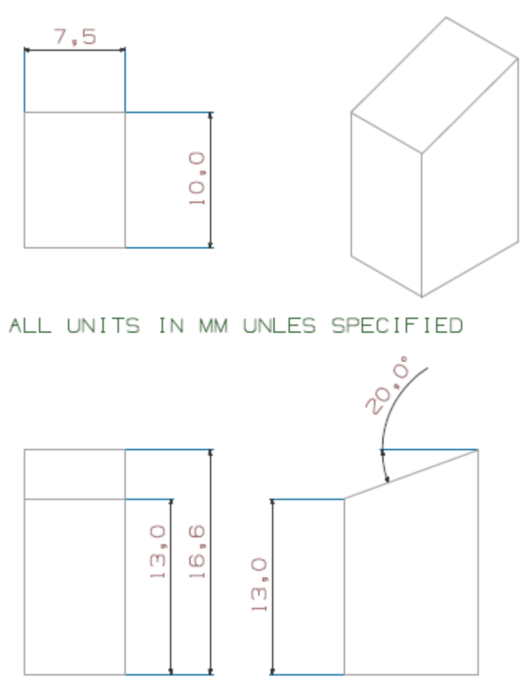
Screw Swivel Top



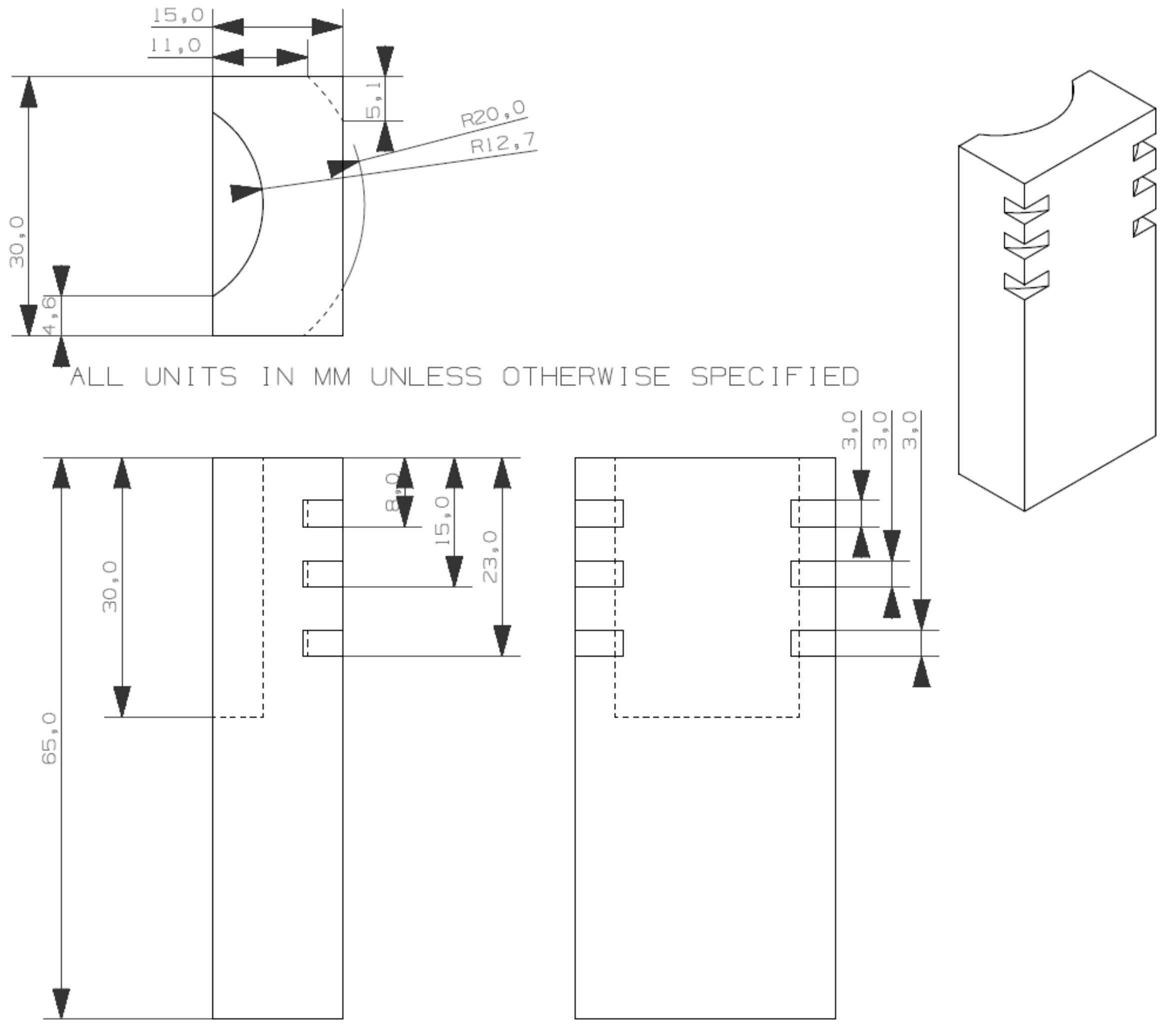
Long Support Leg



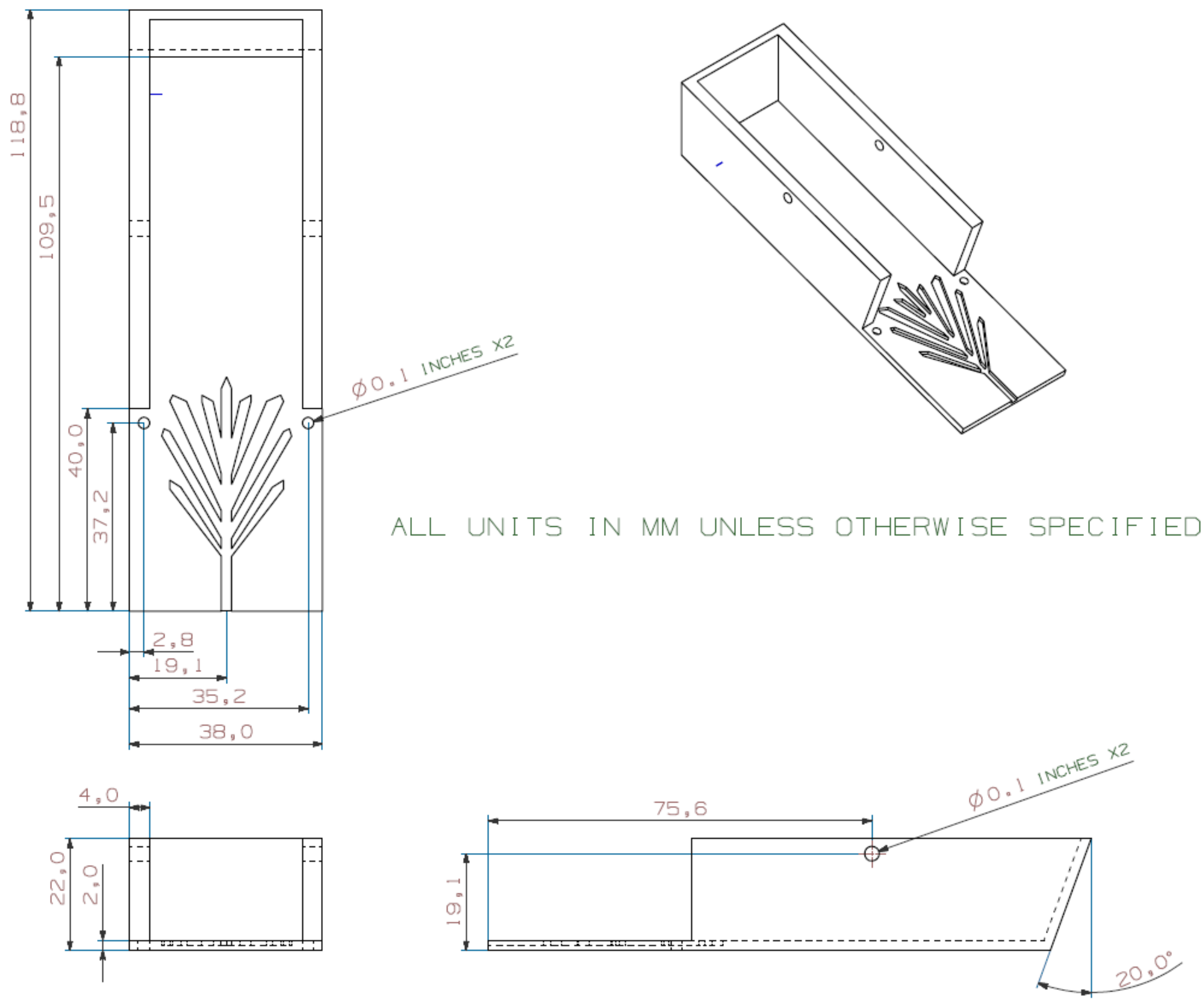
Short Support Leg



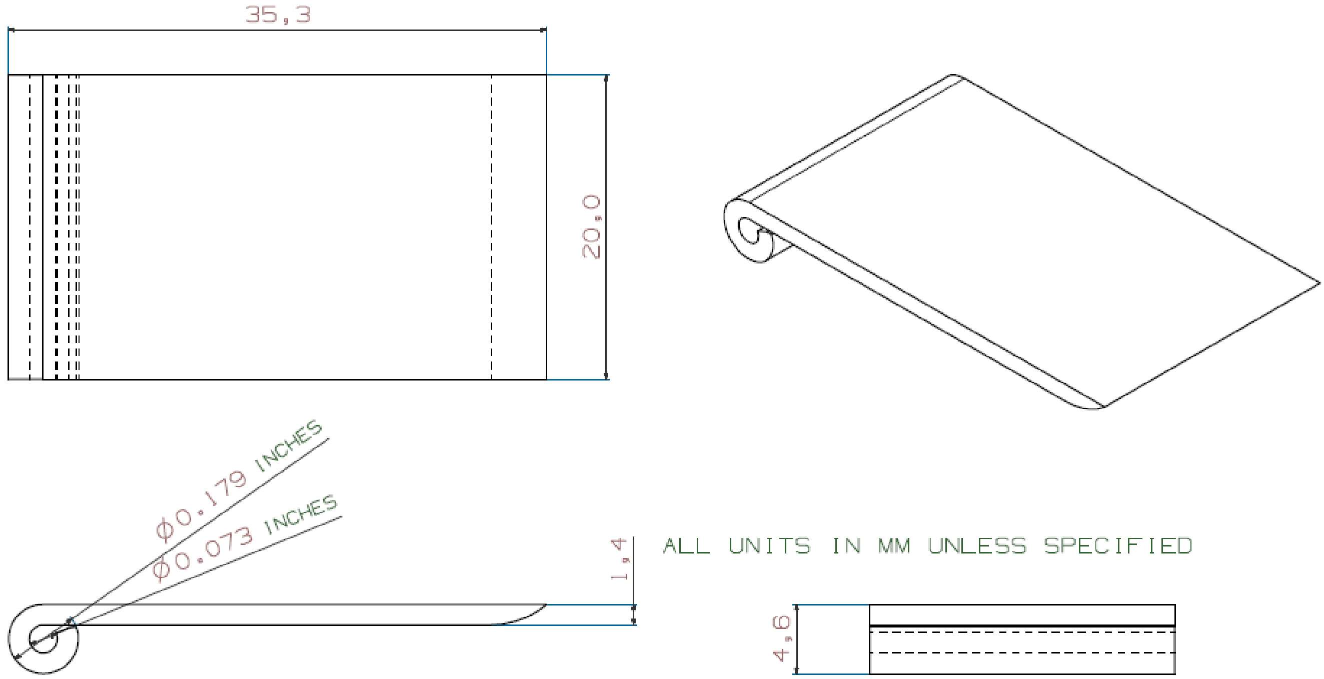
Motor Mount


15,0
11,0
5,1
R20,0
R12,7
30,0
4,6
ALL UNITS IN MM UNLESS OTHERWISE SPECIFIED
8,0
15,0
23,0
30,0
65,0
3,0
3,0
3,0

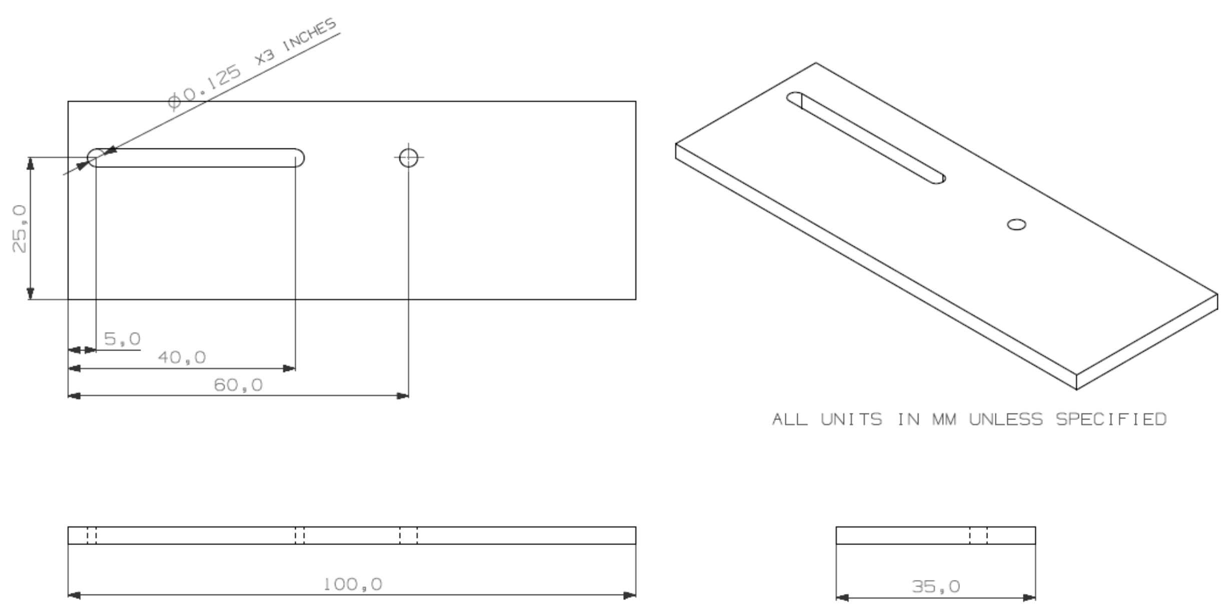
Ramp


118,8
109,5
40,0
37,2
Ø0.1 INCHES X2
2,8
19,1
35,2
38,0
ALL UNITS IN MM UNLESS OTHERWISE SPECIFIED
4,0
22,0
2,0
75,6
19,1
Ø0.1 INCHES X2
20,0°

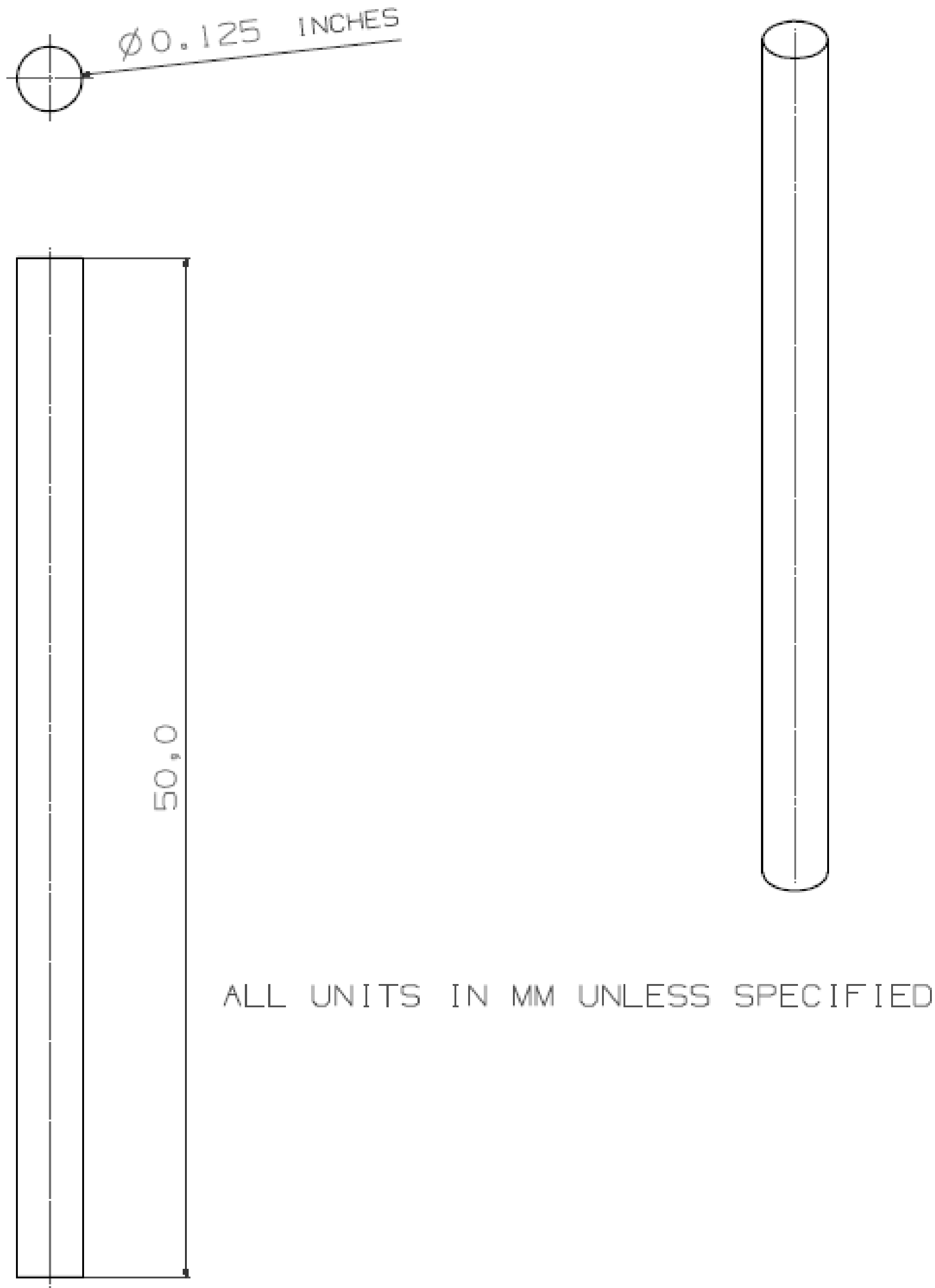
Vertical Gate



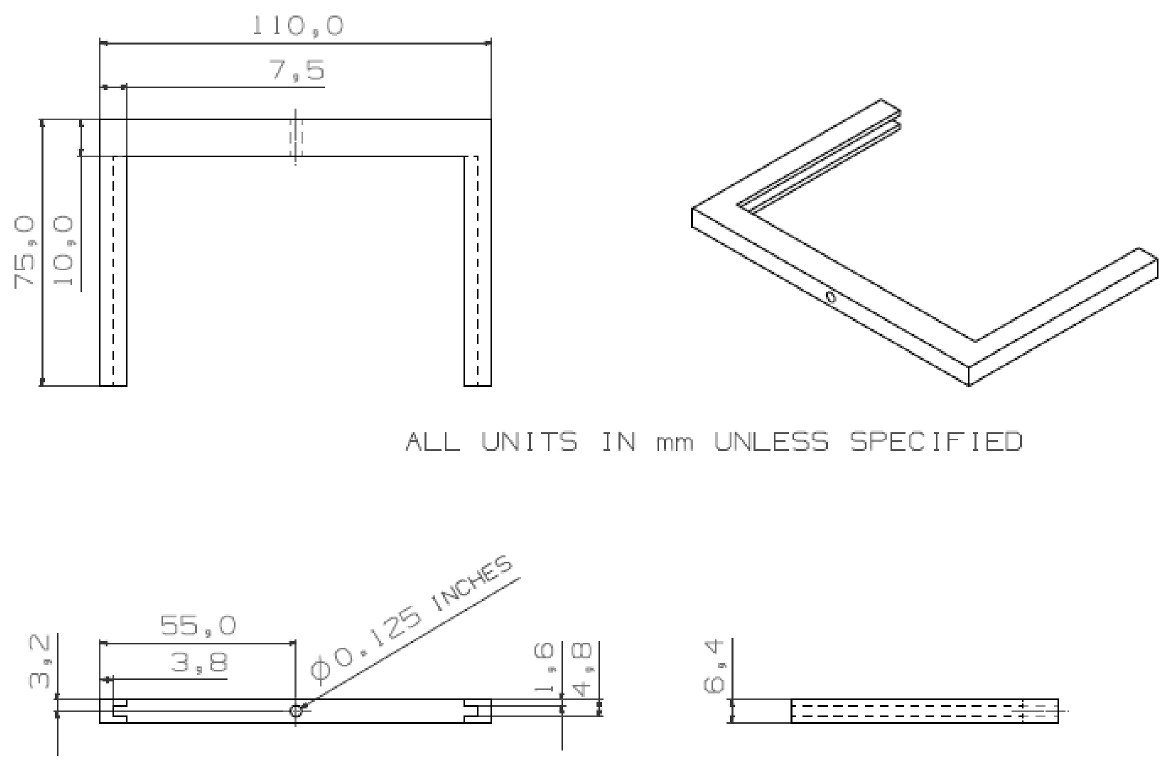
Wheel Plate



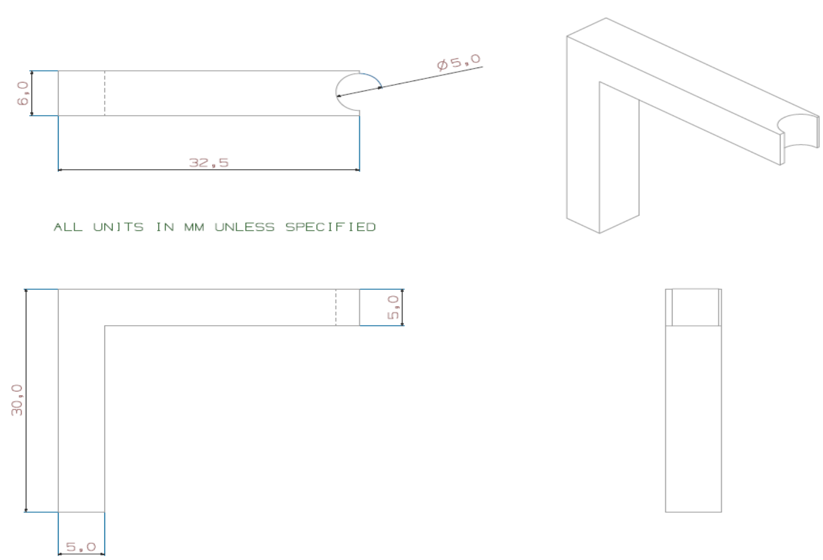
Wheel Shaft



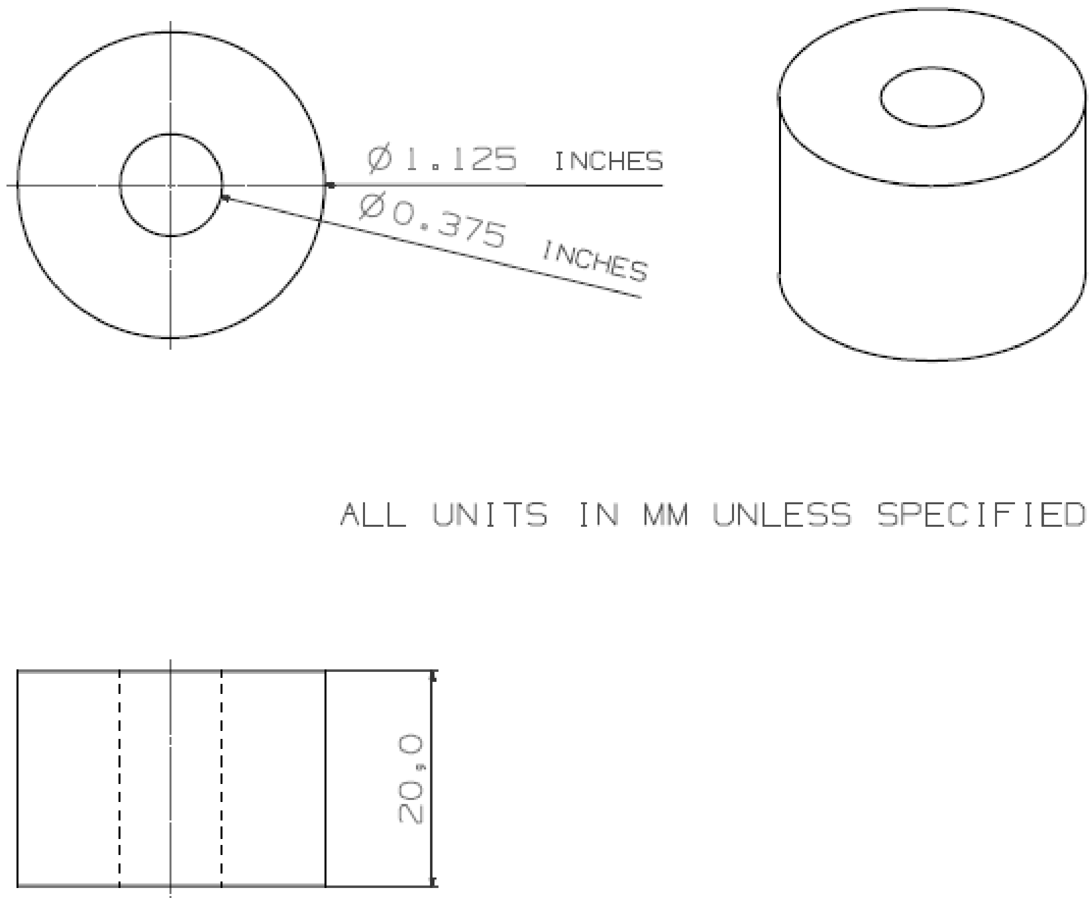
Wheel Slide



IR Sensor Mount



Wheel


Ø1.125 INCHES
Ø0.375 INCHES
ALL UNITS IN MM UNLESS SPECIFIED
20,0

APPENDIX H

Pill Name	Diameter (mm)	Thickness (mm)	Length (mm)	Width (mm)	Shape	Pill Name	Water Test
Excedrin	11.2141	6.1976	N/a	N/a	Cicular	Excedrin	Quickly dissolves gets sticky and breakable
Loratadine	6.4389	2.54	N/a	N/a	Cicular	Loratadine	Quickly dissolves gets sticky and breakable
RX 286769	9.017	3.4798	N/a	N/a	Cicular	RX 286769	Quickly dissolves gets sticky and breakable
Compazine	6.5532	3.175	N/a	N/a	Cicular	Compazine	Quickly dissolves gets sticky and breakable
Centrum	N/a	7.8613	19.4437	8.76808	Elliptical	Centrum	Quickly dissolves gets sticky when drys
Amox	N/a	7.0231	17.0688	10.0711	Elliptical	Amox	Quickly dissolves gets sticky
Trimethobenzamide	N/a	6.096	17.0688	6.096	Elliptical	Trimethobenzamide	Caseing begins to dissolve
Vitamin E	N/a	8.3058	14.3002	8.3058	Elliptical	Vitamin E	Sticky after it drys

Max	11.2141	8.3058	19.4437	10.0711
Min	6.4389	2.54	14.3002	6.096

Pill Name	Dry Test	Bending	Compression
Excedrin	Physical force applied caused breakage*	Strong	Strong
Loratadine	Physical force applied caused breakage*	Strong	Strong
RX 286769	Physical force applied caused breakage*	Moderate	Strong
Compazine	Physical force applied caused breakage*	Strong	Strong
Centrum	Physical force applied caused breakage*	Weak	Strong
Amox	Physical force applied caused breakage*	Weak	Strong
Trimethobenzamide	Physical force applied caused breakage*	Strong	Strong
Vitamin E	Light/Moderate physical force caused breakage*	Weak	Weak

*Force applied by group member holding pill bottle and hands

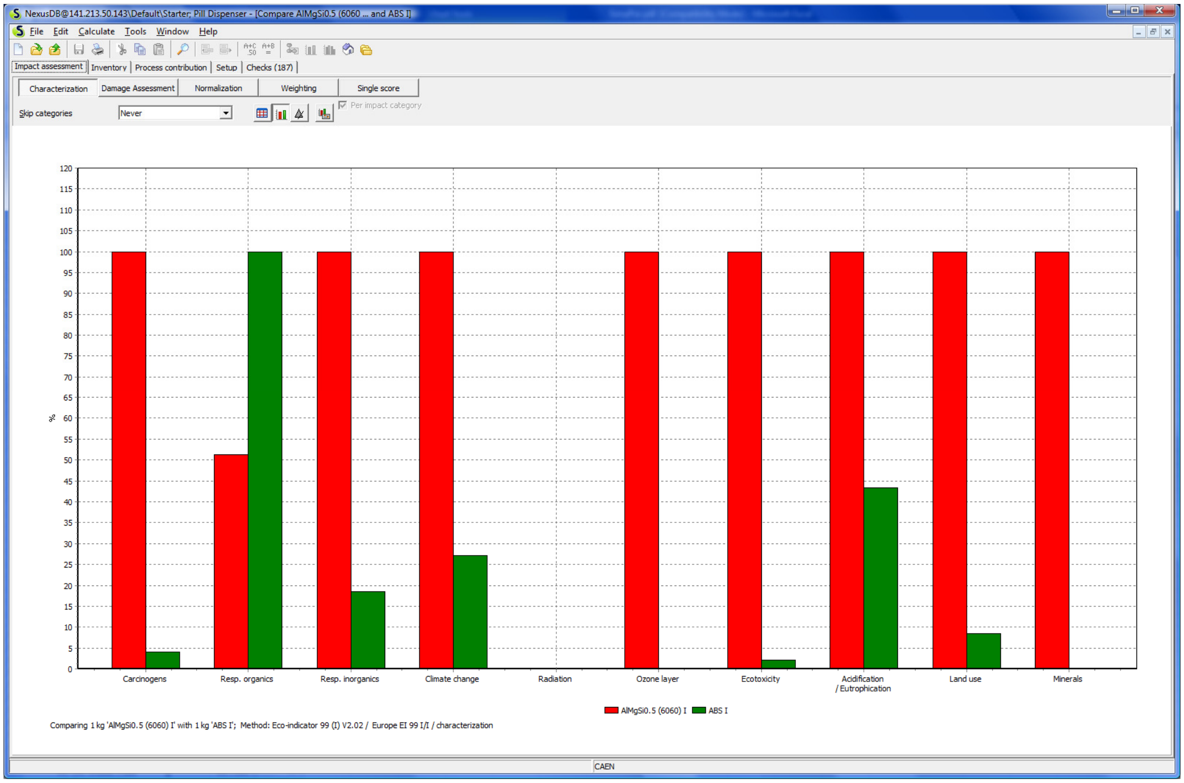
APPENDIX I

User	Task	Hazard Category	Hazard
All Users	All Tasks	mechanical	drawing-in / trapping / entanglement
All Users	All Tasks	mechanical	fatigue
All Users	All Tasks	electrical / electronic	water / wet locations
All Users	All Tasks	electrical / electronic	software errors
All Users	All Tasks	ergonomics / human factors	duration
All Users	All Tasks	ergonomics / human factors	human errors / behaviors
All Users	All Tasks	noise / vibration	noise / sound levels > 80 dBA
All Users	All Tasks	environmental / industrial hygiene	corrosion

Cause/Failure Mode	Severity	Exposure	Probability	Risk Level
if the pills get caught up in the rotating wheels	Slight	Occasional	Unlikely	Moderate
as the machine gets old it may fatigue	Minimal	Remote	Unlikely	Low
if water gets into the machine it ciould hurt our software	Catastrophic	Remote	Possible	High
we have the wheels controlled by computer software to control the speed	Slight	Remote	Unlikely	Low
during the lifetime of the machine it could have wear in the components	Minimal	Remote	Negligible	Low
Someone has to put the height and width of the pill to be able to have it released	Serious	Occasional	Possible	High
there is an alarm which will make loud noises	Minimal	Remote	Probable	Moderate
metal materials can corrode with time	Minimal	Remote	Unlikely	Low

Reduce Risk	Severity	Exposure	Probability	Risk Level
the material of the wheels because they won't get caught as easily	Minimal	Remote	Unlikely	Low
use O rings on the outside to keep water from getting in	Slight	Remote	Unlikely	Low
get a program to review, debug, and correct code	Minimal	None	Negligible	Low
making sure they have a caregiver set up the machine	Slight	None	Negligible	Low
using plastics	Minimal	None	Negligible	Low

APPENDIX J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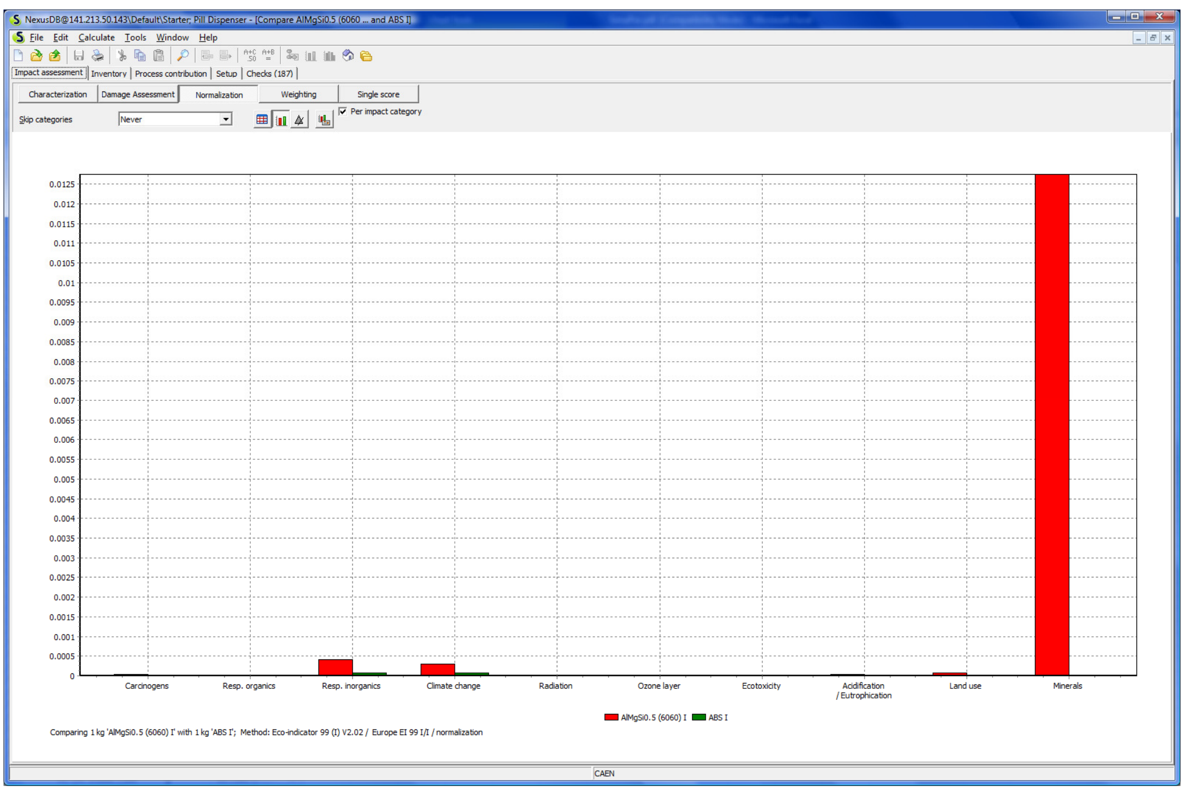
Impact assessment | Inventory | Process contribution | Setup | Checks (187)
Characterization | Damage Assessment | Normalization | Weighting | Single score
Skip categories Never
%
Carcinogens
Resp. organics
Resp. inorganics
Climate change
Radiation
Ozone layer
Ecotoxicity
Acidification / Eutrophication
Land use
Minerals
AlMgSi0.5 (6060) I
ABS I
Comparing 1 kg 'AlMgSi0.5 (6060) I' with 1 kg 'ABS I'; Method: Eco-indicator 99 (I) V2.02 / Europe EI 99 I/I / characterization
CAEN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Impact assessment | Inventory | Process contribution | Setup | Checks (187)
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Skip categories Never
Per impact category
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Resp. inorganics
Climate change
Radiation
Ozone layer
Ecotoxicity
Acidification / Eutrophication
Land use
Minerals
AlMgSi0.5 (6060) I
ABS I
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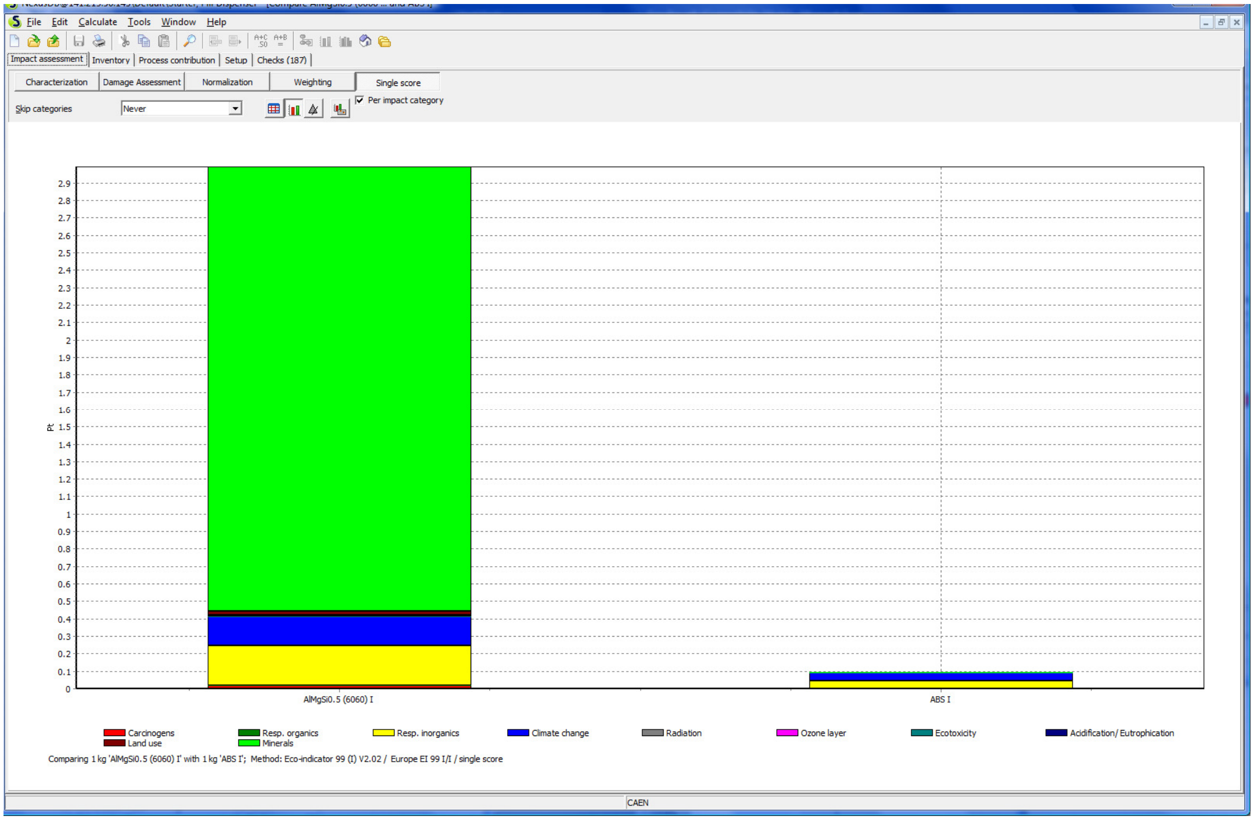
CAEN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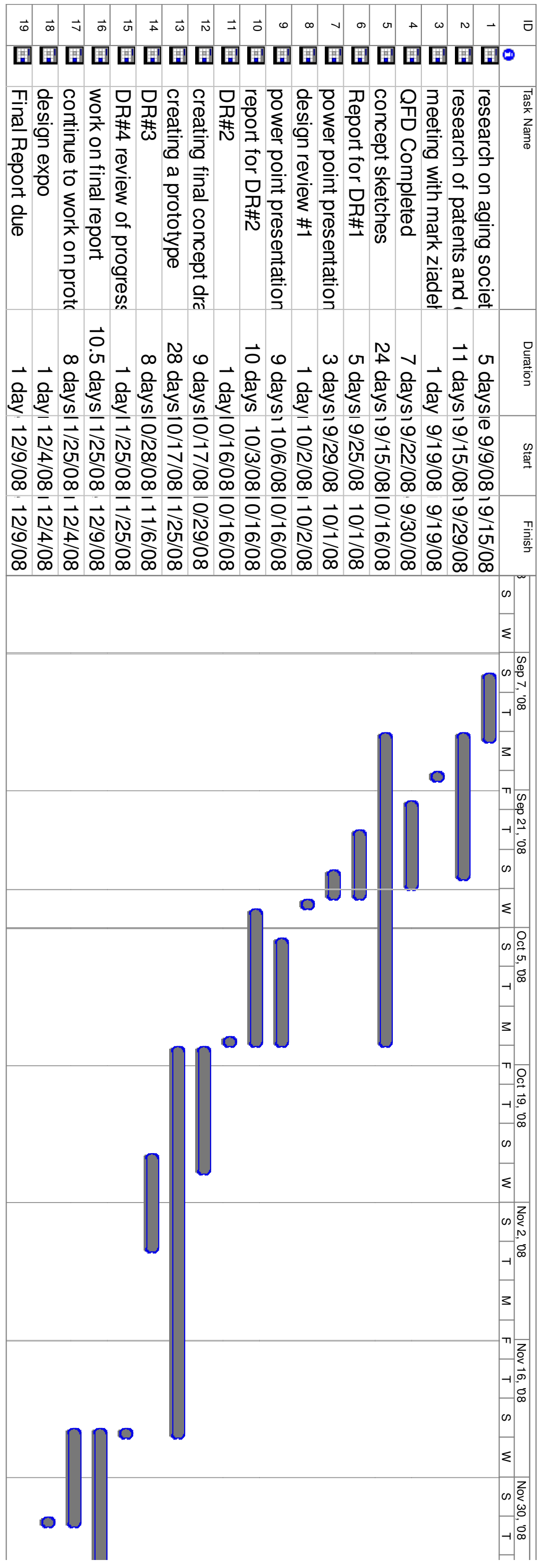
Impact assessment
Inventory
Process contribution
Setup
Checks (187)
Characterization
Damage Assessment
Normalization
Weighting
Single score
Per impact category
Skip categories
Never
Pt
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
AlMgSi0.5 (6060) I
ABS I
Carcinogens
Land use
Resp. organics
Minerals
Resp. inorganics
Climate change
Radiation
Ozone layer
Ecotoxicity
Acidification/ Eutrophication
Comparing 1 kg 'AlMgSi0.5 (6060) I' with 1 kg 'ABS I'; Method: Eco-indicator 99 (I) V2.02 / Europe EI 99 I/I / single score
CAEN

APPENDIX K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Task Name
Duration
Start
Finish
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2 research of patents and 11 days 9/15/08 9/29/08
3 meeting with mark ziadel 1 day 9/19/08 9/19/08
4 QFD Completed 7 days 9/22/08 9/30/08
5 concept sketches 24 days 9/15/08 10/16/08
6 Report for DR#1 5 days 9/25/08 10/1/08
7 power point presentation 3 days 9/29/08 10/1/08
8 design review #1 1 day 10/2/08 10/2/08
9 power point presentation 9 days 10/6/08 10/16/08
10 report for DR#2 10 days 10/3/08 10/16/08
11 DR#2 1 day 10/16/08 10/16/08
12 creating final concept dra 9 days 10/17/08 10/29/08
13 creating a prototype 28 days 10/17/08 11/25/08
14 DR#3 8 days 10/28/08 11/6/08
15 DR#4 review of progress 1 day 11/25/08 11/25/08
16 work on final report 10.5 days 11/25/08 12/9/08
17 continue to work on protc 8 days 11/25/08 12/4/08
18 design expo 1 day 12/4/08 12/4/08
19 Final Report due 1 day 12/9/08 12/9/08
Sep 7, '08
Sep 21, '08
Oct 5, '08
Oct 19, '08
Nov 2, '08
Nov 16, '08
Nov 30, '08