Cal Poly Compost Chomper
Final Design Report

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Statement of Disclaimer

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Executive Summary

The purpose of this final design report is to detail the design, manufacturing, and testing of a bicycle powered compost cutter for use by the Captain Raymond Collin's Elementary school. Students in the garden program are tired of manually chopping up garden waste into small enough pieces to be composted effectively. Project Sponsor and Master Gardener, Susan Deogracias had the idea to create a pedal powered compost cutter which would save time and improve moral for the aspiring gardeners.

This report details the ideation process the team went through in defining the compost cutting system. Engineering methods are documented for the selection, design, and synthesis of the appropriate drive train, support structure, safety systems, and cutting mechanism. Important steps within the manufacturing process for the project have been recorded, including problems that were encountered. Results from testing performed on the final product to ensure the objectives were met are also recorded and analyzed. An operations manual is provided in the Appendix for reference.

This "Cal Poly Compost Chomper" device successfully takes in garden waste and cuts it into compost. It is now in the hands of Captain Raymond Collin's Elementary school and will be implemented by the garden program in the near future (circa 2017-2018 school year).

1.0 Introduction

The Captain Raymond Collins Elementary School has a spectacular garden under the direction of master gardener, Susan Deogracias. The garden teaches students valuable gardening skills, inspires a healthy lifestyle, and produces vegetables, herbs, berries, and some flowers which are shared within the community. With this produce comes a large amount of garden waste in the form of weeds, vines, stalks, and roots. These vines and other forms of garden waste are chopped up and made into compost to be used as fertilizer and show the students the full life cycle of the plants. The problem the students have is that the garden waste is very tedious and difficult to cut into compostable pieces using their current method of processing: chopping with shovels. A better method to process the garden waste is needed in order to save time and energy as well as keep the students engaged.

The goal of the California Polytechnic State University Compost Chomper (CP Comp Chomp) team is to design and build a device that will solve the Captain Raymond Collins Elementary school garden's problem of composting garden waste. Cal Poly Compost Chomper is comprised of three fourth-year Mechanical Engineering students: Joe McGill, Cory Parmenter and Anthony Jungquist. Each of us has a passion for learning and developing effective designs that we will apply to this project. This project is under the advisement of Sarah Harding of the Cal Poly Mechanical Engineering Department.

This final design report documents background research, the scope of the project, project objectives, plans for the achievement of these objectives, ideation and iterations, our final design for the project, the design process we went through, analysis to justify our design, manufacturing, and testing.

2.0 Background

Composting garden waste products like vines, leaves, roots, etc. provides an inexpensive method to create soil with high nutrition and teaches students important concepts of sustainability. The smaller the organic waste can be cut for compost, the quicker it will decompose and be ready for garden use. As waste is cut into smaller pieces, more surface area is created, allowing more opportunities for microorganisms to break down the material [1]. A common method for making compost is placing the organic waste in closed bins as it decomposes. Depending on the desired speed of composting, full or chopped plants can be put into the bins. For the Captain Raymond Collins Elementary school, small chopped compost is ideal to reduce composting time.

In order to get an idea of what designs work best for the needs of the school garden, benchmarking of some key existing product designs was performed. These products include existing composting systems, cutting devices, and any bicycle powered machines. The benefits and drawbacks of the various designs are discussed below.

2.1 Human-Powered Shredder

The Human-Powered Shredder (Figure 1 below) [2] is perhaps the best fitting pre-existing solution to the needs of the school garden.

Figure 1. Human-Powered Shredder [2].

This machine, designed for rural farm use by Peter Harrison, was the closest design we found to a pedal-powered compost shredder. Harrison’s design features a pedal-powered, chain-driven system that seats the operator flat on the ground with a steel frame supporting the shredding mechanism. While this design is promising for shredding compost, it still does not satisfy the needs of the Captain Ray Collins Elementary School. This design caters specifically to adults, with the seated position requiring more strength from the legs to pedal the shredder, as well as the lack of adjustable seating for different sized people and children. For children to be able to pedal with ease, a different design must be implemented. Harrison’s shredder also lacks any safety measures to prevent children from injuring themselves in the shredder or any other moving parts. This is a crucial flaw in its design and is one of the chief reasons that it cannot be implemented for use at an elementary school. The shredder also lacks a feeding system, such as a hopper, and has no built-in method of capturing the compost once it is shredded.

2.2 Filamaker Organic Waste Shredder

The Filamaker Organic Waste Shredder (Figure 2 below) is a European made industrial style shredder [3]. It takes a standard concept for shredding large and tough materials and scales it down for household use.

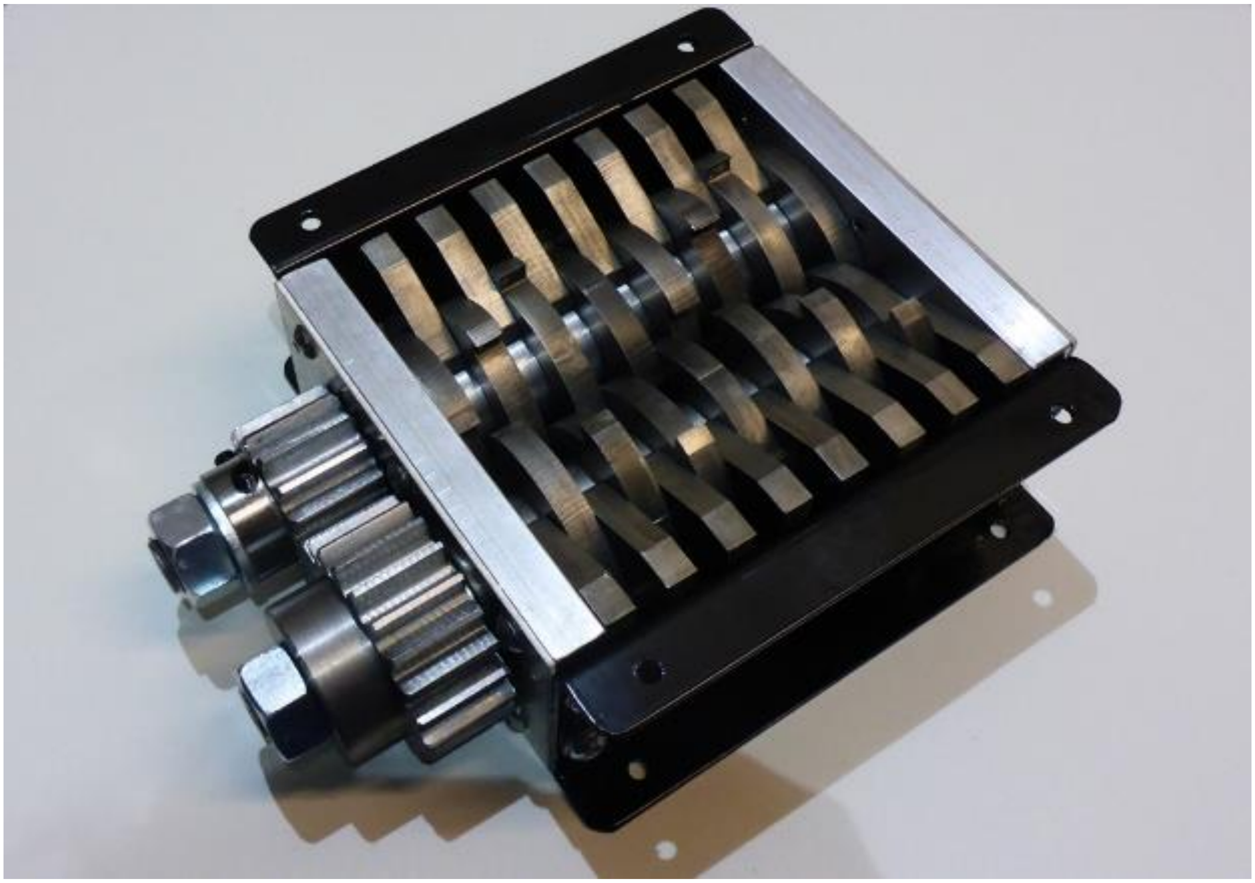


Figure 2. Filamaker Organic Waste Shredder [3].

The shredder is operated by a variety of methods: both hand cranked and motor driven. Hand crank models display great proficiency in shredding organic waste into approximately half-inch size but no videos of testing on stiff vines are available. This style of shredder is a proven design in industry but is fairly expensive at $900 and lacks the benefit of being pedal powered. This design holds some potential to be adopted to make a pedal powered version. On an additional note, this device has a 3D printed functional model, which could be made to test the potential of this design.

2.3 Gas Engine and Electric Motor Driven Shredders

Electric and gas-powered shredders do not fit the needs of the Captain Raymond Collins Elementary School Garden due to safety reasons and the fact that the device is intended to be pedal powered. However, they still serve as useful benchmarks with which to be compared. Bosch has a product line of three motor driven shredders, each with different cutting mechanisms which span a range of cutting torque, cutting speed, and power. Investigation into why these designs are different provides valuable information for choosing a cutting device.

The first model is the Bosch AXT Rapid 2200 (see Figure 3). This model requires the least amount of power out of the three and relies on sharp, fast moving, propeller shaped blades (similar to lawn mower blades) to cut through the material (see Table 1 for details). It also includes a handheld wedge that can be used to push the material into the blade without the user's hands getting in harm's way [4].

Figure 3. Bosch AXT Rapid 2200 cutting device [4].

The second model is the Bosch AXT 25 D (see Figure 4). This design utilizes a gear-like cutting drum which shears the material against a back-plate and provides a self-feeding feature by pulling the material in with its gear-like teeth. This blade design rotates much slower than the AXT Rapid 2200, but makes up for it in much higher torque. This model also has the highest processing rate out of the three (see Table 1 for details).

Figure 4. Bosch AXT 25 D cutting device [4].

The third model is the Bosch AXT 25 TC (see Figure 5). This design incorporates a blade pattern that looks similar to a turbine. It can take the largest diameter branches and is more resistant to jamming because the excess material is allowed to fall through the center of the blade array (see Table 1 for details).

Figure 5. Bosch AXT 25 TC cutting device [4].

Table 1 below contains data that was taken into account before choosing a cutting blade design. The data shows how existing shredders use either a high speed and low torque, or high torque and low speed combination. Further analysis is required to determine which is better for a pedal powered device, but these values can be used as a reference when designing a gear ratio which allows for acceptable pedaling torque and frequency requirements of the student(s).

Table 1. Product details of three Bosch motor driven yard shredders [4]. These values are approximate.

Model	Cutting Device Shape	Motor Power [hp]	Torque [ft-*lb*]	Cutting Speed [rpm]	Branch Diameter [in]	Process Rate $[\frac{lb}{hr}]$	Weight [lb]
AXT Rapid 2200	Straight	2.95	10	3650	1.6	198	26
AXT 25 D	Drum	3.35	479	41	1.6	386	69
AXT 25 TC	Turbine	3.35	479	41	1.8	230	67

Another shredding/chipping/mulching mechanism to consider is the DR Wood Chipper 11.5 Self-Feeding, Manual Start (Figure 6). This design is powered by a 1 cylinder, 250 cc overhead valve engine, which supplies 11.5 ft-lbf of torque [5].

Figure 6. DR Wood Chipper 11.5 Self-Feeding, Manual Start [5].

The manufacturer boasts that the chipper knife is attached to a 14" flywheel that spins at 101 mph and weighs 25 lb (Figure 7). This flywheel was an intriguing aspect to consider incorporating into our design in order to store pedaling energy in the form of a rotating mass. A flywheel has the potential to increase our cutting efficiency especially if the children pedal sporadically.

Figure 7. DR Wood Chipper 11.5 Self-Feeding, Manual Start flywheel and cutting blade [5].

A design that could potentially be more resistant to jamming on the cutting side is the weed whacker. The design shown in Figure 8 below is made by Toro and is powered by a 2-cycle, 25.4 cc gas engine [6]. The string cutting mechanism of a weed whacker could be advantageous because it is not rigid and therefore can bend instead of binding. However, the string cutters may not be strong enough to cut the thicker vines in the garden and may wear out quickly.

Figure 8. Toro 2-Cycle 25.4cc Attachment Capable Curved Shaft Gas String Trimmer [6].

This model allows for changing out the strings for other attachments like the one shown in Figure 9. This attachment has the advantage of rigid blades for more cutting strength but the blades are also on hinges so that they are free to pivot and avoid jamming.

Figure 9. Weed Warrior plastic (left) and metal (right) attachment blades for heavier duty cutting [7], [8].

The nature of these cutting devices requires high rpm, so it could be a significant safety hazard if a blade fell off while the device was spinning. However, if the cutting device was contained within walls, this hazard could be mitigated. A benefit of the weed whacker concept is that most blade inserts are fairly affordable and easy to replace. A plastic version of the weed warrior attachment blade is about $12 and a metal version goes for about $40 on Amazon.com [7], [8].

2.4 Child-Adult Tandem Bikes

In addition to implementing a standard bicycle design, we have also considered a tandem system. Most tandem bicycles are designed for adults and would need to be modified to accommodate children. However, some manufacturers do make tandem bikes designed with children in mind. An example of one of these products can be seen in Figure 10 below.

Figure 10. Child-Adult tandem bicycle [9].

These bicycles, designed and built by Brown Cycles in Grand Junction, Colorado, have specially designed pedals and seats for children. This particular model, the Standard Yellow, allows for one adult and one child to ride together. The adult sits in the back and has control over steering and gear shifting while the child sits in front. The child's seat features a lower seat, and shorter pedals.

3.0 Objectives

Students in the garden program at the Captain Raymond Collins Elementary School spend excessive time and energy manually chopping garden leftovers to make compost. The students need a safe, easy to operate, pedal-powered device which chops the material while encouraging a lifelong passion of gardening and engineering.

3.1 Needs List

After extensive conversation with our sponsor, Mrs. Deogracias, we determined the following list of needs that she and her students have for the device:

- Pedal Powered
- Cuts compost into reasonable sized chips
- Safe, restrict access to cutting blades
- Removable receptacle
- Wide hopper/ funnel for loading vines

- Adjustable quick release seat, must accommodate age 6 to adult
- Long lasting and serviceable
- Low cost (below $1000 + additional funding)
- Must be operable by 1st-5th graders (must be able to operate on their own under supervision)
- Transportable (slide/roll/ be able to be pushed in some way)
- Must fit in 40’x70’ grass area (better if it is long and skinny)
- Stable foundation, no tipping
- Must support an adult for demonstration purposes

From the needs list we developed a brief boundary sketch (Figure 11) that outlines the areas of the product we’ll be working on.

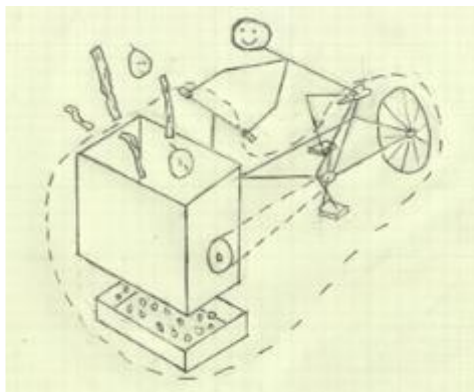


Figure 11. Boundary sketch diagram.

All areas within the dotted line on the above figure show aspects that we can control on our product. In this case the user and organic waste are two areas we can’t control, while the pedal-powered device and cutting mechanism are within our control. This along with our needs list control form the scope of our project.

3.2 Quality Function Deployment

Using the above list of needs, we determined a set of target specifications for our machine. These needs and specifications were then inputted into a Quality Function Deployment matrix (QFD) known as a “house of quality” in order to develop and refine the specifications. An excerpt from our QFD is included in Table 2 below; please see Appendix A for the full QFD matrix. Values for our target quantities were determined using information found in our background research.

Table 2. QFD Matrix for Compost Chomper Design.

WHAT: Customer Requirements (explicit & implicit) / HOW: Engineering Specifications	Torque Input	Input RPM	Torque Output	Blade rpm	Chip Size	Vine Size	Process Rate	Product Cost	Jam Frequency	Withstands Operator Weight	Product Weight	Footprint	Stability	Max Feed Volume	Height
Pedal Powered	●	●	●	●	▽		○	▽	▽		▽	▽	○		○
Unassisted Operation by Grades 1-5	●	●	○	○			▽		○				○		●
Cuts Material into Compostable Size	○	○	●	●	●	●	●		▽		▽	○			▽
Adjustable								▽		○	○	▽	▽		○
Safety	▽	▽	○	○			▽		○	●	○	▽	●		○
Able to support adults										●	○		●		○
Portable											●	●	○		●
No Electrical Power	●	●	●	●	▽		○	○	▽		○	○	○		
Engaging/Inclusive for Children	○	○	○	○	▽				○				▽		▽
Removable Receptacle					○		○	○				▽	▽		
Long Lasting/Maintainable	●	●	●	●	○	○	○	●	●	●	○	▽	▽		
Easy to Load						●	○					▽		●	
Fits into available storage space										▽	▽	●	○	○	●
Able to cut thick vines	○	○	●	●	○	●	○	▽	●		▽				
Efficiency	●	●	●	●	○	○	●		○			▽		●	▽

Relationships	
Strong	●
Moderate	○
Weak	▽

On the left, we can see the design requirements we interpreted from our sponsor and on top are the specifications developed by our team to meet those requirements. The symbols seen in this section of the QFD signify the correlation between the specification areas and the customer requirements that we determined. A dark circle represents a strong correlation between specification and requirement, meaning for us that the specification is something worth focusing on because it will satisfy a requirement well. In that same vein, a white circle represents a medium correlation, and a triangle a weak correlation, between

specification and requirement. This matrix gives us a guide into what specifications may require more attention and consideration when creating our design in order to best satisfy the requirements of our customer. A full detailed QFD can be found in Appendix A with comparisons to existing designs.

3.3 Engineering Specifications

Once the specifications were refined using the house of quality, we were able to create the specification table (Table 3). We used a weighted importance rating as a guideline for determining the "risk" of each individual specification parameter. The "risk" describes the amount of difficulty our team will have in meeting a specification. We also assigned four possible methods of determining specification compliance. These methods are analysis (A), test (T), similarity to existing products (S), and inspection (I).

Table 3. Engineering Specifications for the Compost Chomper.

Spec. #	Parameter Description	Target Quantity	Tolerance	Risk*	Compliance**
1	Torque Input	320 in-lbf	Max	H	A,T,S
2	Input RPM	60 rpm	Max	H	A,T,S
3	Torque Output	960 in-lb_f	Min	H	A,T,S
4	Cutter RPM	20 rpm	Min	H	A,T,S
5	Chip Size	1 in^3	Max	L	I
6	Vine Size	3 in diameter	Min	M	I
7	Process Rate	0.8 lb/min	Min	L	T
8	Jam Frequency	3 jams/hr	Max	M	T
9	Supports Operator Weight	300 lb	Min	H	A,T,S
10	Product Weight	500 lb	Max	M	A,T,I
11	Footprint	4'10" x 10'	Max	L	A,I
12	Stability	Will remain stable with 60lbs applied at highest point	Min	M	A,T,S
13	Feed Volume	2 ft^3	$\pm 0.5 ft^3$	L	A,I
14	Product Cost	$3000	Max	M	A
15	Height	4 ft	Max	L	I

* High (H), Medium (M) or Low (L) risk
**Analysis (A), Test (T), Similarity to Existing Designs (S), and/or Inspection (I)

For each specification, our reasoning for the target quantity is explained below:

1. Input Torque: we made an assumption of how much force a child could put on a recommended lever arm based on anthropometric data for the 5th percentile weight of a six-year-old child [10]. See Figure B.1 in Appendix B for supporting hand calculations.

2. Input RPM was based off of information on typical adult cyclist RPM and adjusted for children [11]. For clarity, it should be noted that the input torque and input RPM specifications have maximum tolerances because we are referring to the maximum torque and RPM we think the children will be able to supply; however, if the children were able to provide higher values than the specification, we would still consider those values within the specification. Another way to describe these specifications is the maximum input torque and RPM that our device can feasibly require of the students.
3. Output RPM was approximated by examining a video of the Filamaker Organic Waste Shredder, which is a cutting mechanism that is similar to one we plan on employing [12]. From this video we were able to visually estimate the RPM of the cutting blades to be about 20 rpm.
4. Output torque was determined by assuming that power input to our system, which is simply the angular velocity multiplied by the torque, is equal to power output from our system. This simple math (see Figure B.2 in Appendix B) shows us that our output torque should be approximately 960 in-lb_f. Because of this power relationship, the output torque value is essentially forced by specifications 1-3. Specifications 1-4 are all labeled as high risk because we anticipate difficulty in producing enough power to cut the material. If the pedal is too hard to crank or the cutter does not cut, then our device would be useless. All values in Table 3 are assuming only one child is pedaling; however, we will likely employ a tandem drive system which would allow two users to pedal at the same time, thus doubling the potential power input. We also plan to use a rapid-prototype model of the cutting device to assess early on if we have enough output torque to cut the material. If we find that the prototype is ineffective with the specified torque, we can add an additional user to supply more torque or modify the cutting device so it is more effective with the existing torque. We have also consulted documentation on the force required to cut branches using shears in order to get an idea of the order of magnitude of the forces we will require [13].
5. Our target chip size, that is the size of the individual pieces of compost being outputted, was created based off of our benchmarking research with products already built.
6. The target vine size that our composter should be able to handle was determined through discussion with our sponsor, Mrs. Deogracias, about the typical thickness of the vines and stalks that are grown and chopped in the garden.
7. Our process rate for the amount of garden material going into our machine was found by taking the lowest process rate from the different models of Bosch AXT Shredders, quartering that amount, and converting that process rate to pounds per minute in order to more accurately represent the process rate associated with the power a child provides to our system (see Table 1). From examining videos and qualitatively assessing the speed at which these shredders process the material, we estimate that it will still be acceptable if our process rate is at least a quarter of this [14].
8. Our jam frequency parameter was determined more on a qualitative level. Seeing as it is a difficult parameter to quantify, we aimed to set a target quantity that seemed reasonable for a composting mechanism (and the user) to endure. If the user (probably an adult supervisor) has to unjam the device more than three times per hour, he or she may get frustrated and more likely to get hurt.

9. The operator weight parameter was found by looking at data for the 95th percentile weight of a 20-year-old adult male which was about 225 lbs, and then bumping that up to 300lbs for added measure and setting that as our minimum amount that the machine must be able to support [15]. We consider this a high risk parameter because safety is a primary concern.
10. The product weight target was decided based on the need of portability for our device. In order for our device to be portable, it needs to be light enough that a group of four people can move it. The means by which the device can be moved has yet to be decided, but the weight of the product is crucial to the portability of the device.
11. Our footprint parameter for the machine was determined from a drawing provided to us by Mrs. Deogracias detailing the dimensions of the storage space in which the machine is meant to be kept (see Appendix C).
12. Our stability parameter was set based on some minor calculations concerning an adult leaning on the machine at its highest point, using rough estimates for leaning angle and average adult weight (see Figure B-3 in Appendix B).
13. Our feed volume parameter refers to the amount of garden waste that would be fed into a hopper or similar feeding mechanism before going into the cutting mechanism itself. We quantified this parameter by referring to pictures given to us by Mrs. Deogracias of the amount of garden waste created after an average harvest.
14. Product cost is set per the funding we are guaranteed by Mrs. Deogracias as well as the funding from the Baker-Koob Endowment, totaling 3000 dollars.
15. Lastly, the height of the machine we set at four feet maximum to allow for children to get onto the machine with relative ease.

3.4 Additional Design Considerations

Designing the product to last is very important to us, but we have no feasible way to test if our design is long lasting. The best that we can do is choose durable materials that are reasonably corrosion resistant. We will also apply fatigue analysis where we can in order to maximize the lifespan of critical parts. The ability of the machine to adjust to children and adults of varying heights and dimensions is also very important to our design, but is not something that we can quantify as a target, and so we will make sure that our device can accommodate a wide range of users. We also want the machine to be safe, of course; even though safety is not quantifiable we will make sure that the machine is as safe as we can design it. The hardest thing to gauge is how fun and engaging the device is for the children. We will try to channel our inner child so that we can design the device to be as fun as possible. We have visual and auditory feedback, competition, and aesthetics in mind for some fun and engaging aspects that can be incorporated.

4.0 Design Development

In the following section, the process used to develop our preliminary design is outlined. Throughout the process, the overall design was split into subsystems: cutting mechanism, driving mechanism, safety mechanism, and feeding mechanism. Once the ideas for each subsystem had been determined, the various advantages and disadvantages of each mechanism idea were weighed, and from this, the best ideas for each subsystem were chosen. These ideas were then combined to form a number of overall system ideas, and again the process of weighing the advantages and disadvantages of each idea was repeated to determine the best overall system to fit the project's needs.

4.1 Ideation

Our approach to this project has and will continue to follow the design process outlined in Appendix D. As the project progressed, a number of concepts were developed for the different crucial subsystems of the Compost Chomper. We focused on the development of conceptual designs for the cutting, feeding, driving, and safety mechanisms for our machine. We used a variety of ideation techniques to come up with a large selection of designs. These techniques included brainstorming (coming up with as many ideas as possible and writing them down in a short time period), brainwriting (modified brainstorming where each member draws an idea and then the ideas are traded between members to add to the original drawing), and SCAMPER (stands for Substitute, Combine, Adapt, Modify, Put to another use, Eliminate, and Reverse). An example of our ideation sessions can be seen in Figure 12 below.

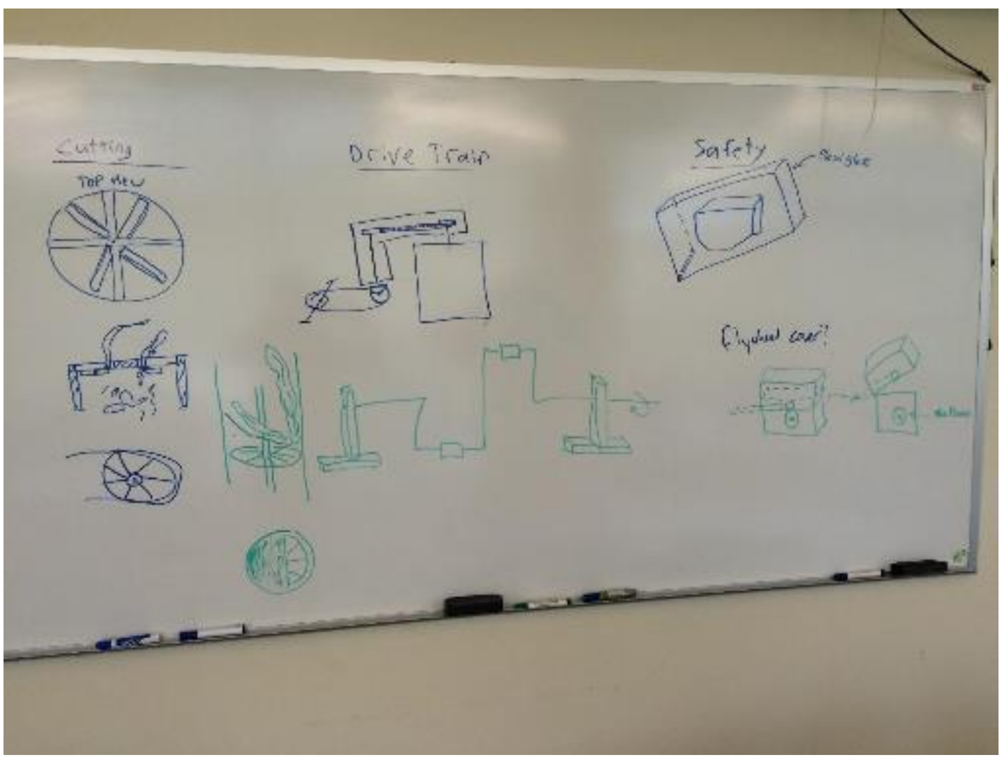


Figure 12. Excerpt from brainwriting ideation session focused on cutting, driving, and safety mechanisms.

After these ideation sessions, we produced rough concept prototypes for some select subsystems that would benefit us the most. We decided that the mailbox, weed whacker, standard shredder, and tapered worm would benefit the most from prototyping. The focus of these prototypes was more for getting an idea of the physical form of the subsystem rather than producing a fully functional model. Our rough prototype of a mailbox-inspired feeding/safety mechanism and standard shredder concept model can be seen in Figure 13 below.

Figure 13. Rough prototype of mailbox feeding/safety mechanism and standard shredder concept.

4.2 Idea Selection

Once we had concepts for these mechanisms, we used Pugh Matrices to weigh each concept against one another in order to determine which concept best satisfied the specifications applicable to it. On the matrices, the datum with which we compared all other concepts is listed as the left-most concept and has a "0" rating for all specification areas. A "-1" represents that a given concept performs worse than the datum in a particular specification area. A "1" represents that a given concept performs better than the datum in a particular specification area. Our specifications are weighted to represent their relative importance to each subsystem.

For our cutting subsystem, we were choosing between eight different concepts. Please refer to Figure 14 to see our Pugh matrix and the accompanying sketches. We chose the standard shredder as our

datum with which we compared all of our other concepts. As is apparent from the total scores of each of the concepts, the standard shredder proved to be our best concept for the cutting mechanism. The chief advantages of the standard shredder is that it requires a low rotational speed, which allows for higher torque and does not pose the risk of flinging debris while operating. The high torque associated with the standard shredder also allows for it to digest thick vines easier than other designs. Because we do not want to limit ourselves in terms of overall system creation, we considered the weed whacker and one-sided gear shear for implementation as well.

		Cutting Mechanism							
Spec	Wt.	Standard Shredder	Weed Whacker	One Sided Gear	Tapered Worm	Linear	Tangential	Oposing Tangential	Horizontal Worm
Easy to Power	3	0	0	-1	-1	-1	0	0	-1
Chip Size	2	0	-1	0	1	-1	0	0	0
Vine Size	1	0	-1	0	0	0	0	0	0
Process Rate	1	0	0	-1	1	0	0	0	1
Long Lasting/Maintainable	2	0	1	0	-1	-1	-1	0	-1
Jam Frequency	2	0	0	0	-1	-1	-1	0	0
Product Weight	1	0	1	0	0	0	0	0	-1
Footprint	1	0	0	0	-1	-1	-1	-1	0
Max Feed Volume	1	0	-1	0	0	0	0	0	0
Height	1	0	0	0	-1	0	0	0	0
Excitement	1	0	0	0	1	1	0	0	1
Safety	5	0	-1	0	0	0	0	0	0
Manufacturability	3	0	1	1	-1	-1	0	-1	-1
Totals		0	-3	-1	-8	-12	-5	-4	-7

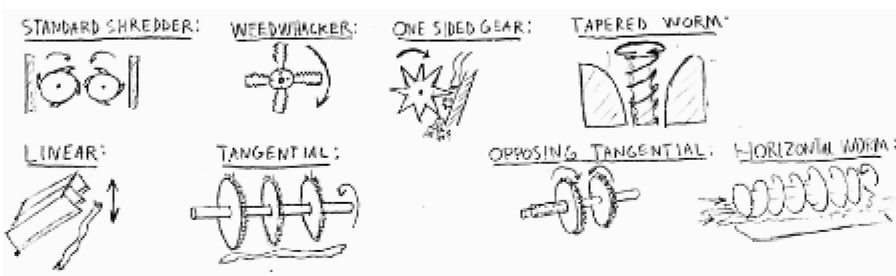


Figure 14. Decision matrix for cutting mechanism with brief sketches

For our safety mechanism, we had six concepts which did not necessarily need to be exclusive. Refer to Figure 14 to see the Pugh matrix. We went through with comparing different safety mechanisms with our datum mailbox system, and saw that our mechanical stopper won. The mechanical stopper refers to a system that would engage and disengage a pin in the cutting mechanism, stopping the cutting blades when the blades are accessible, and letting the blades rotate when they are not accessible. We realized after we had done the comparison that we could combine many of these systems to create an even safer machine.

	Safety Mechanism					
Spec	Wt.	Mailbox	Brushes	Plexiglass Cover	Mechanical Stopper	Pusher
Easy to Power	1	0	-1	0	0	0
Process Rate	1	0	1	-1	0	1
Maintenance Cost	3	0	-1	0	-1	1
Jam Frequency	2	0	-1	0	0	1
Product Weight	1	0	0	-1	1	0
Footprint	1	0	0	-1	1	0
Max Feed Volume	3	0	1	0	0	0
Safety	5	0	-1	-1	1	-1
Reduces Pinch Points	4	0	0	1	0	0
Totals		**0**	**-7**	**-4**	**4**	**1**

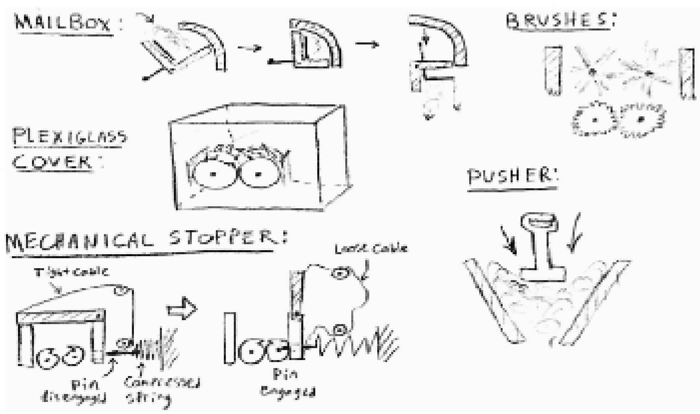


Figure 15. Decision matrix for safety mechanism with brief sketches

For our driving mechanism we had six mechanisms with which to compare. Please refer to Figure 16 for the Pugh matrix and accompanying sketches. The driving mechanism refers to the method with which the power will be provided to the system. We chose a standard bicycle foot pedal for our datum. The alternate concepts fared much more poorly compared to the standard bicycle and tandem bicycle driving systems. The tandem bicycle won overall due to its ability to create about twice as much power (if it is a two person tandem) than a standard bicycle system.

		Driving Mechanism					
Spec	Wt.	Upright Pedal	Tandem Upright	Horizontal Pedal	Hand Crank	Hand Pedal	Hand and Footpedal
Easy to Power	3	0	1	1	-1	-1	0
Adjustable	2	0	0	-1	0	1	0
Process Rate	1	0	1	0	-1	-1	0
Maintenance Cost	1	0	-1	-1	1	0	-1
Jam Frequency	1	0	1	0	-1	0	0
Withstands Operator Weight	1	0	0	1	1	1	0
Product Weight	1	0	-1	-1	1	0	-1
Footprint	1	0	-1	-1	1	0	-1
Stability	1	0	0	1	0	0	0
Height	1	0	0	1	0	-1	-1
Excitement	2	0	1	0	-1	0	1
Safety	5	0	0	0	0	0	0
Long Lasting	2	0	0	0	0	-1	-1
Manufacturability	2	0	0	-1	1	0	-1
Totals		0	4	-1	-1	-4	-6

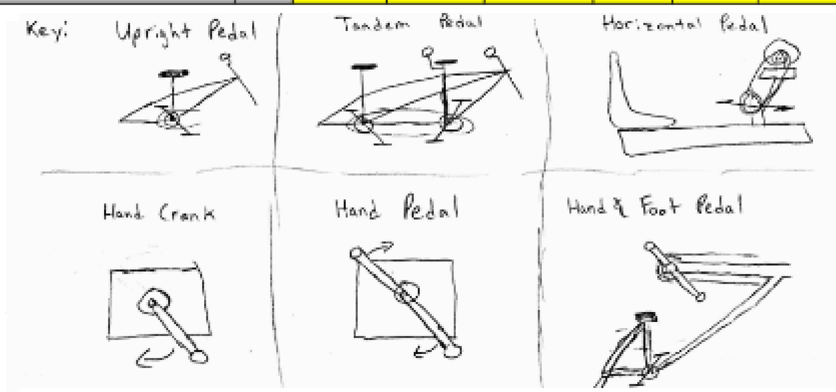


Figure 16. Decision matrix for driving mechanism with brief sketches

For our feeding mechanism, we came up with a number of unique designs. Refer to Figure 17 for the Pugh matrix accompanying sketches. Our datum was chosen to be an open shredder because we found that feeding by hand is the most basic feeding mechanism. The feeding mechanisms had some overlap with the safety mechanisms because in some cases they served both purposes. Our top choices that arose from our Pugh matrix were the sliding door, due to its simplicity, and the mailbox, due to its enhanced safety precautions.

		Feeding Mechanism							
Spec	Wt.	Open	Conveyor	Sliding Door	Brush	Hopper	Worm	Mailbox	Chop Block Box
Easy To Load	2	0	1	1	1	1	-1	0	0
Process Rate	1	0	1	0	1	0	0	-1	0
Maintenance Cost	2	0	-1	0	-1	0	-1	0	0
Jam Frequency	1	0	-1	0	-1	-1	-1	1	0
Ability to Force Load	2	0	0	0	1	-1	0	1	0
Product Weight	1	0	-1	0	0	-1	-1	-1	0
Footprint	1	0	-1	0	0	0	0	0	-1
Max Feed Volume	3	0	1	1	1	1	0	1	1
Height	1	0	0	0	0	-1	0	-1	0
Excitement	1	0	1	-1	1	1	1	1	0
Safety	5	0	0	1	0	1	0	1	0
Manufacturability	3	0	-1	0	-1	0	-1	0	0
Portability	2	0	-1	0	0	-1	-1	-1	0
Totals		0	-3	9	3	4	-10	7	2

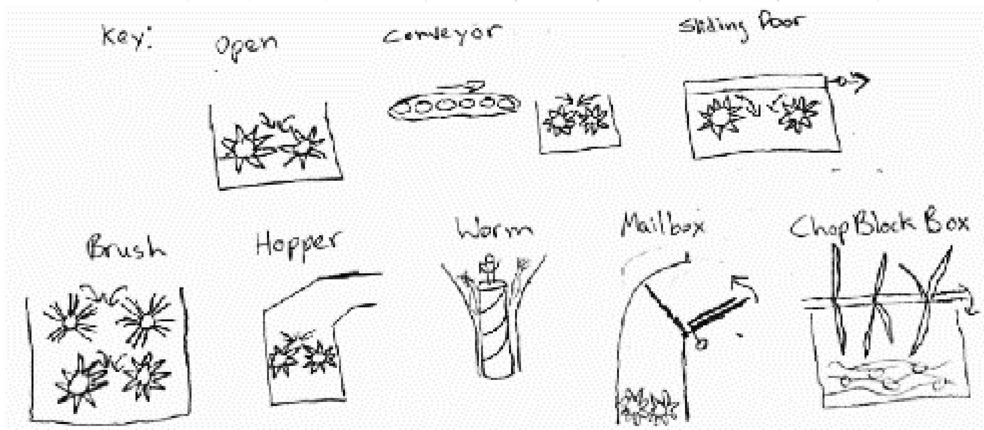


Figure 17. Decision matrix for feeding mechanism with brief sketches.

After looking through our Pugh matrices, we determined our top concepts for each subsystem. These top concepts for each subsystem were combined to create some designs for our entire machine. Included below (Figure 18) is a more detailed sketch of our standard shredder concept. This cutting mechanism design would be very similar to the Filamaker Organic Waste Shredder [3]. For the sake of brevity of the report, a compilation of the more detailed sketches of our top concepts that we combined to create our overall system concepts is included in Appendix E as Figures E-1 through E-7.

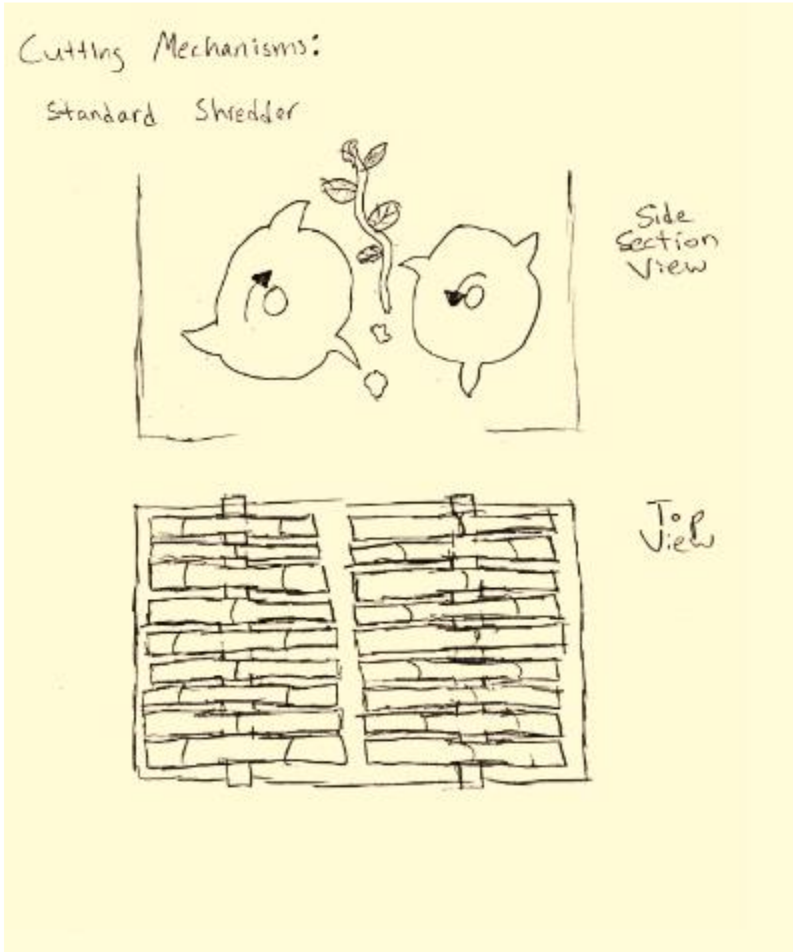


Figure 18. Sketch of Standard Shredder cutting mechanism

We then took the best of our subsystem designs and combined them to create another Pugh matrix with our overall system designs to once again determine which overall designs best satisfy our specifications. This overall system Pugh matrix is viewable in Figure 19.

Spec	Weight	System A	System B	System C	System D	System E	System F
Easy to Power	3	0	1	1	1	1	1
Long Lasting/Maintainable	2	0	0	1	-1	0	-1
Chip Size	2	0	0	-1	-1	-1	0
Vine Size	1	0	0	0	-1	-1	0
Safety	5	0	0	-1	0	0	1
Height	1	0	0	0	0	1	-1
Portable/Product Weight	3	0	0	0	-1	0	0
Engaging/Inclusive for Children	2	0	1	0	0	0	1
Easy to Load	2	0	0	-1	0	-1	0
Fits into available storage space	3	0	-1	0	-1	0	0
Able to cut thick vines	2	0	0	-1	-1	-1	0
Efficiency	2	0	1	0	1	0	0
Totals		**0**	**4**	**-6**	**-8**	**-3**	**7**

System Key	Subsystem			
System	Cutting	Driving	Feeding	Safety
A	Standard Shredder	Upright Pedal	Hopper	Mechanical Stopper
B	Standard Shredder	Tandem Upright	Hoper	Mechanical Stopper
C	Weedwhacker	Horizontal	Sliding Door	Mailbox
D	Onse Sided Gear	Tandem Upright	Brush	Pusher
E	Onse Sided Gear	Horizontal	Sliding Door	Mailbox
F	Standard Shredder	Tandem Upright	Mailbox	All

Figure 19. Whole system, weighted, decision matrix for top 6 subsystem combinations. "All" refers to mailbox, brushes, Plexiglas cover, mechanical stopper, and pusher.

As is apparent from our Pugh matrix above, System F is rated as the best system and is our overall system of choice. System F prevails over the other systems for a number of reasons. Firstly, it employs a tandem bicycle driving mechanism, which provides twice as much power as the standard singular bicycle. System F also uses the mailbox feeding system even though the sliding door scored higher in our feeding system Pugh matrix. This is because the Pugh matrix failed to represent that the mailbox is far safer than the sliding door. The mailbox feeding system also allows the operator(s) to apply pressure on the compost as it is being fed into the shredder without risking danger (the mailbox design has a plunger mechanism built into it). System F also features all of the safety mechanisms discussed in the safety mechanism Pugh matrix (mailbox, brushes, Plexiglas cover, mechanical stopper, and pusher), which allows the system to be safe for operation by curious elementary school students. Using all of the safety mechanisms is also beneficial because it introduces redundancies into the system; if one safety mechanism were to fail, it would be backed up by the other four. This benefit greatly outweighs the drawbacks of having a slightly more complex system.

4.3 Initial CAD and Design Considerations

Once we had determined the best overall subsystem, we created a rough solid model using SolidWorks to demonstrate the functionality of our concepts.

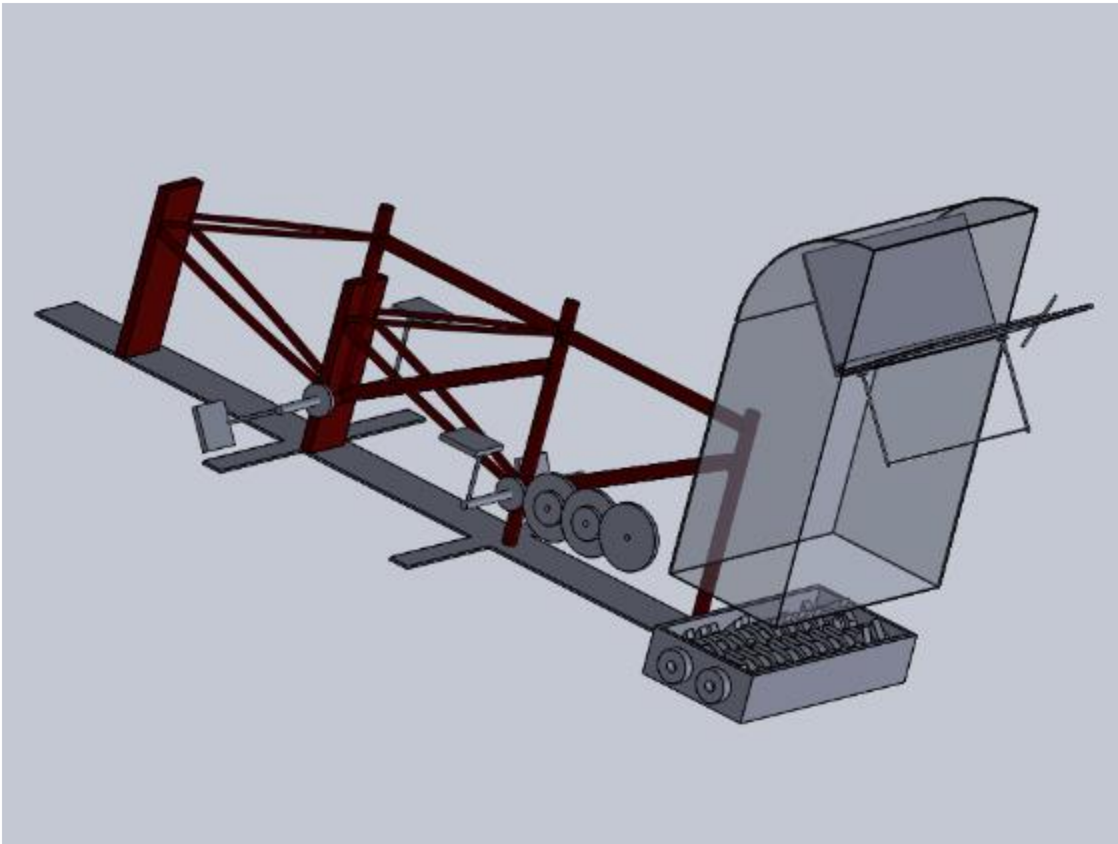


Figure 20. CAD Model of Compost Chomper.

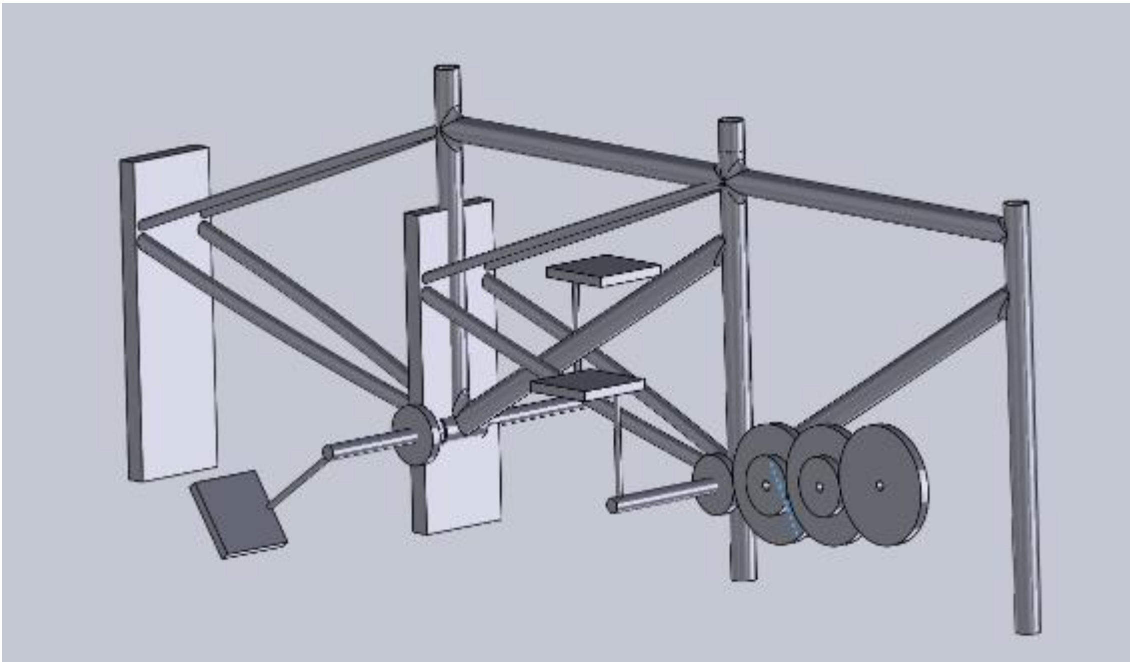


Figure 21. Frame and Drive-Train mockup.

With our preliminary design in Figure 20, we were confident we would meet all of the specifications and design considerations we set. While the dimensions and drive train were not yet fully designed, we know the gearing ratio we need in order to transmit the necessary torque and rotational speed to the cutting mechanism. For the preliminary design, this was a 6 to 1 reduction, meaning that the children would pedal six times faster than the cutters will rotate, thus increasing the cutting torque by 6 times that of the input torque. The gear placeholders visible in Figure 21 will form a full gear train in the final product, with the rear pedaling system connected to the front pedaling system and drive train via chain. Refer to Appendix B, Figure B-4 for sample calculations on the gear reduction we planned on implementing.

With the cutting mechanism we have set, we would be able to digest the target vine size into the target compost size at the process rate we set. At this phase of the design, the cutting system was either going to be purchased (if one was found within spec and price) or be machined by a contracted machinist because of the complex shape. The gears, represented by the discs in Figure 21, were to be purchased from a vendor to allow for easy maintenance and replacement. The dimensions of our mailbox were highly adjustable; and because of this, we were confident that our max feed volume and processing rate specifications could be met. The plunger on the mailbox would be able to limit the number of jams in the hopper shaft, and the low rotational speed and high torque of our cutting mechanism would make the system resistant to jamming as well. Although the framing for our machine was not designed at this point (the frames in Figure 21 are taken from an online source [16]), we were confident in our ability to design a structure that could support an adult's weight. Because the frame and cutting mechanism would need to be made of steel, our machine would be heavy, but with our material choices for the mailbox and other smaller systems, we were confident that we could achieve an overall weight lower than our specified

maximum of 500 lbs. This product weight (the majority of which being low to the ground) would also increase the ability of the machine to avoid being tipped over, which aided us in achieving the stability specification.

The footprint was well within our allowable footprint, with our width slightly over two feet and our length slightly over seven feet. Our machine's height was just over two feet, so again well within acceptable ranges. With our design as it stood, we anticipated difficulty staying under our one-thousand-dollar budget. However, we applied for the Baker-Koob Grant, which when accepted, added an additional $2000 of funding. We found out this grant proposal had been accepted on December 5th.

Having developed a solid outline of our design, we began some additional analysis on the capabilities of our design. We wanted to get a better idea of what the power output of the tandem design might be, so we developed a code in MATLAB (Appendix F) to model it. Two pedal orientations where analyzed: first with both pedals synched in the same phase and second with the pedals 90 degrees out of phase. Figure 22 below illustrates the two orientations.

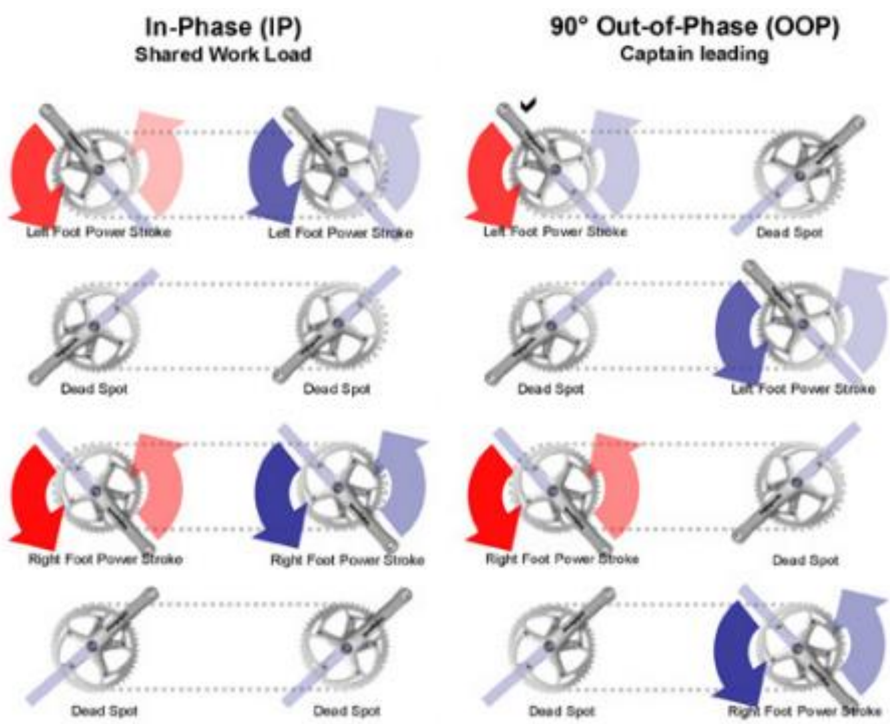


Figure 22. In and out of phase pedal orientations [17].

The power plots were generated from the MATLAB code displayed the power output plotted over a given timeframe. The resulting plots can be see below in figures 23 and 24.

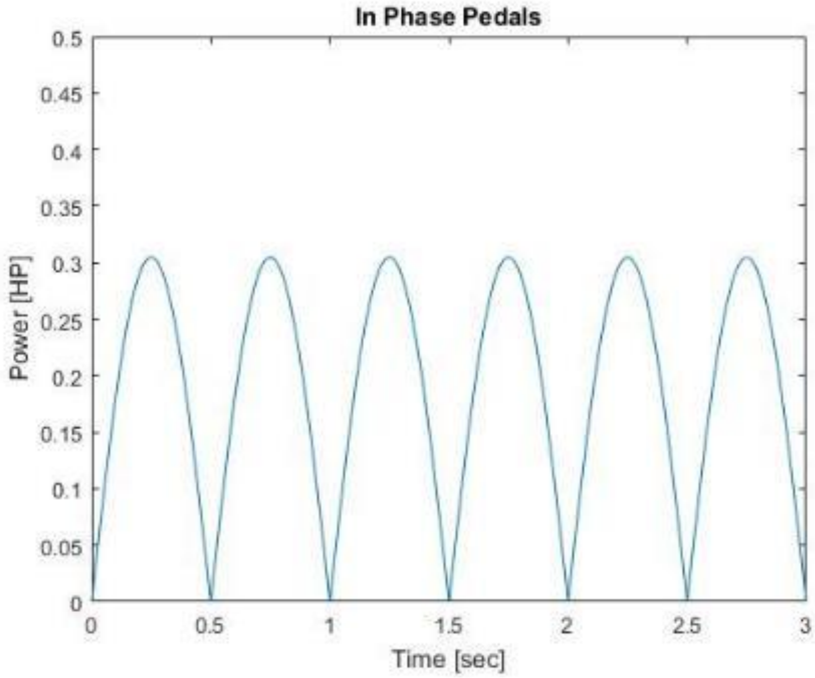


Figure 23. In phase tandem power output in horsepower.

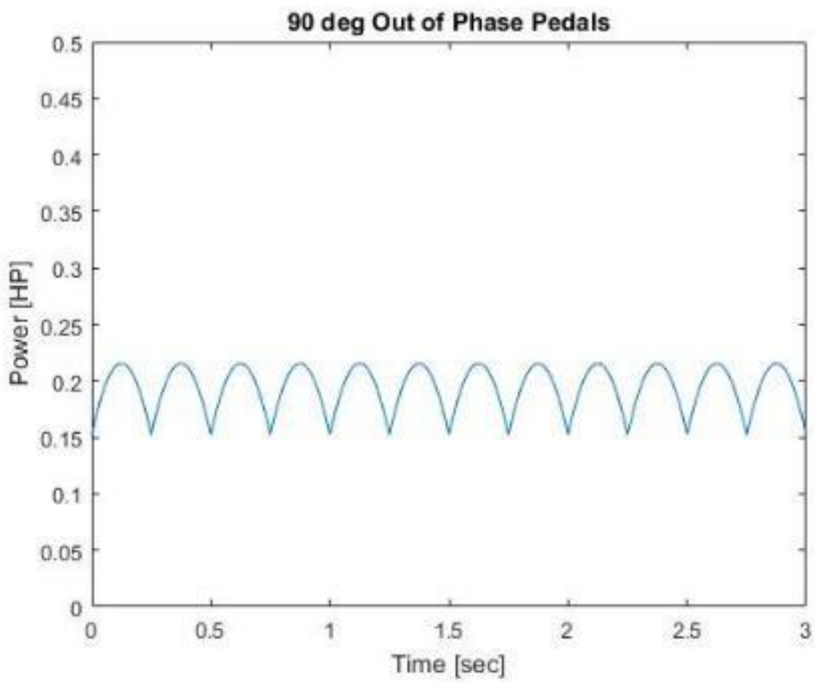


Figure 24. Out of Phase tandem power output in horsepower.

We can see that in the in phase design the peak power output is significantly higher than the out of phase, with peak values of 0.305 horsepower and 0.215 horsepower respectively. The drawback of the

in phase design however, is that it has periods of extremely low/no power. The out of phase design on the other hand maintains a min power of 0.152 horsepower. The periods with no power in the in phase design could make it prone to frequent jams but the out of phase design may lack adequate power. Changing the phasing of our pedals is an extremely easy task because it only requires that we remove the chain the rotate the pedal, so this is a design area we can easily test to determine the best set up. Additionally, 90 degrees is not the only option for out of phase, any number of degrees can be chosen which may yield an even better design. Alternative phasing will also be experimented with during the construction/testing phase.

Testing would involve experimentation with gear meshing and power output. We planned on using rapid prototyping techniques in order to quickly and cheaply produce models of our cutting mechanism and gears that we can test and use to measure and more accurately determine the forces needed to cut compost. We planned on calculating all forces within our gear train, performing stress analysis and fatigue strength analysis on our gears and cutting mechanism. This would allow us to determine how long our design can operate before failing and allow us to plan and adjust accordingly. Manufacturing our design as it stood would be a challenge; the volume of steel involved and number of cutting blades involved will make producing our compost cutter expensive, time-consuming, and heavy. One of our goals was to determine where and how we can save time, money, and weight with our cutting mechanism. This required us to purchase cutting blades if it is cheaper than contracting a machinist and buying the steel. Our overall design also needed reevaluation in order to determine where we could change materials or reduce dimensions in order to save weight.

With some of the initial design concepts completed we, generated a brief Design Hazard Checklist found in Appendix G. This checklist helped ensure that all of our safety concerns are dealt with appropriately.

5.0 Final Design

5.1 Functional Description

In order to reach the final design of the Compost Chomper, a number of decisions had to be made with the direction of the design. Foremost of these decisions was to select a cutting mechanism and obtain a bike frame from donations. Our team was able to obtain an adult tandem steel bicycle (Figure 25) as well as a flywheel (Figure 26) among various other bicycle components at no cost through a donation from Jail Enterprises, a subsidiary of the Los Angeles County Jail. This donation was crucial in that it saved our team a large amount of money and also provided a reliable frame on which we could base our driving mechanism and support frame designs.

Figure 25. Bike Frame acquired from Jail Enterprises.

Figure 26. Flywheel acquired from Jail Enterprises.

Our team decided to purchase the Organic Waste Shredder from Filamaker [3] (Figure 27) to use as our cutting mechanism. Buying the cutting mechanism drastically reduced the complexity of

manufacturing the final product and guaranteed a certain quality of cutter that otherwise our team may not have been able to achieve through manufacturing.

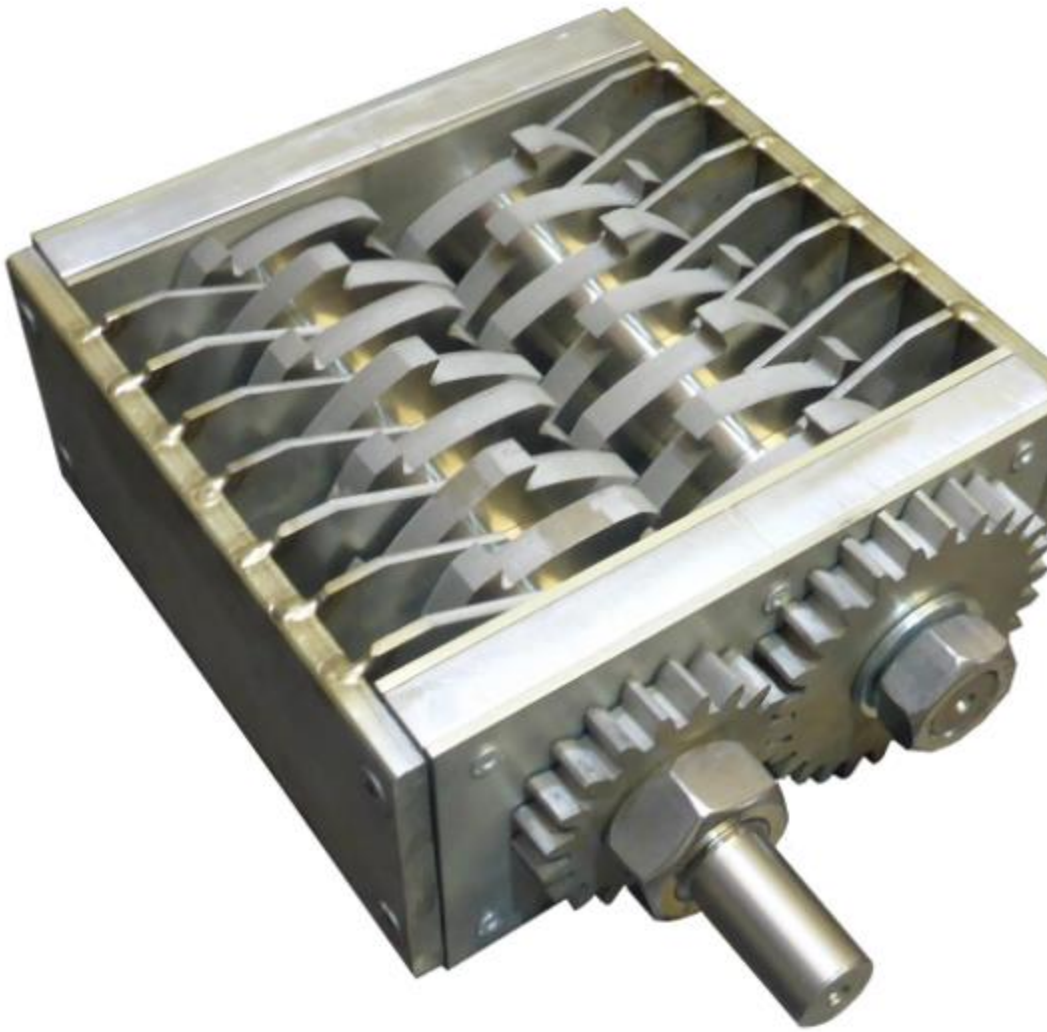


Figure 27. Filamaker Organic Waste Shredder

Since the Filamaker shredder suited our needs for cutting organic material into compostable bits and was the basis of our preliminary design cutting mechanism, the decision to buy from Filamaker was a natural one. We were also able to get a significant discount from Filamaker in support of our cause. Additionally, it is beneficial to buy the Filamaker because it is made from stainless steel and will therefore be corrosion resistant and easy to clean, Using the purchased shredder, however, affected our design quite drastically due to the fact that our preliminary design cutting mechanism had much larger dimensions than the Filamaker shredder. This large reduction in dimensions of our cutting mechanism thus constrained our feeding mechanism, making the preliminary feeding/safety mechanism of the mailbox chute (Figure 20) insufficient and obsolete. A chute the size of the Filamaker would not have been able to make use of the mailbox design.

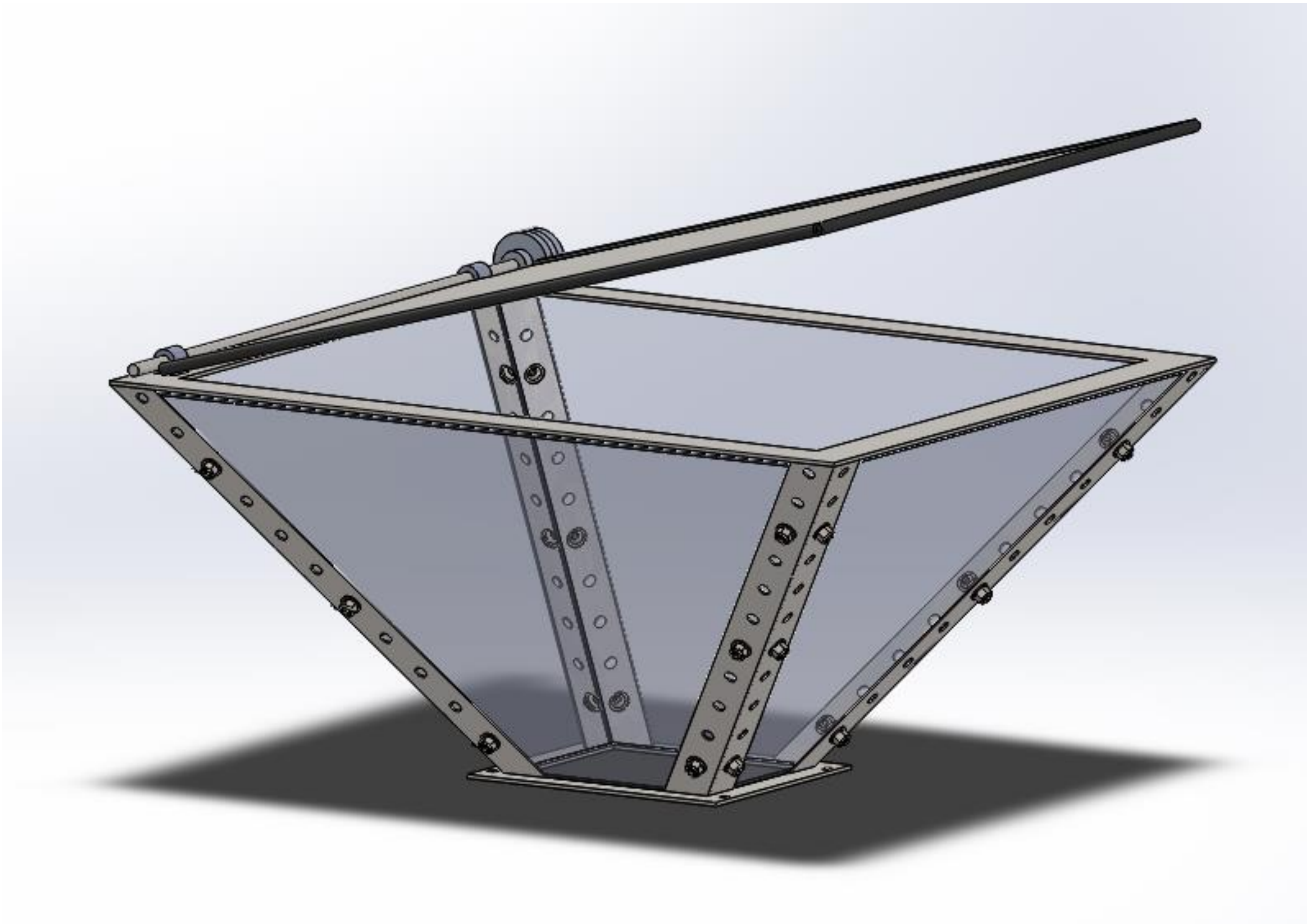


Figure 28. Redesigned Hopper Feeding Mechanism

For this reason, the chute had to be redesigned entirely. Our new chute (Figure 28) functions as a funnel with a lid, with the narrow section of the funnel fastened to the cutting mechanism. The lid will serve as a part of the primary safety mechanism. Attached to the shaft that the lid will rotate on is a cam (Figure 29).

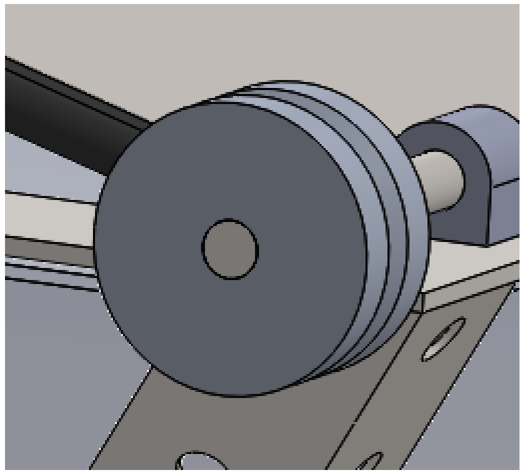


Figure 29. Cam Attached to Shaft Of Hopper Lid

This cam has a brake line attached to it that runs to a bicycle rim brake that acts upon the flywheel of the drivetrain. When the lid is opened, the cam will rotate, pulling the brake line and engaging the brake on the flywheel in order to stop the cutting mechanism from rotating when the lid is open (Figure 30). This will prevent children from harming themselves when they have access to the cutter. While the hopper will prevent the children from injuring themselves, it will not prevent them from being able to see what's going on inside the shredder, because we will make the side panels out of clear acrylic.

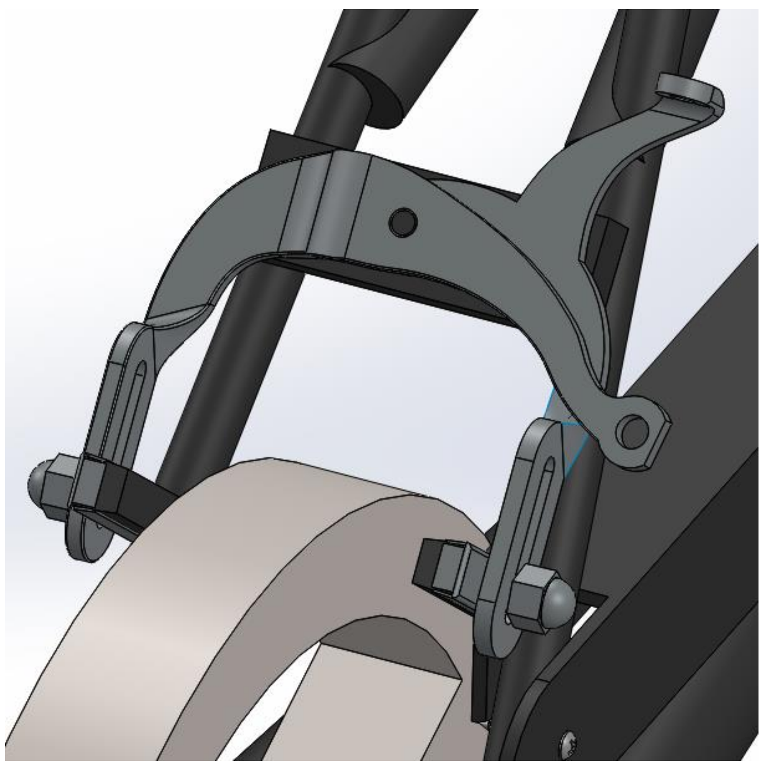


Figure 30. Rim Brake Disengaged On Flywheel

The drive train makes use of the sprockets already on the bicycle frame, with a chain connecting the two sprockets on each pedaling shaft. A chain also runs from the rear pedaling shaft to a sprocket on

the shaft of the flywheel, providing power from both sets of pedals to the flywheel. The sprocket on the flywheel shaft is considerably smaller than the sprockets on the pedaling shafts in order to increase the rotational speed of the flywheel and thus store more rotational energy in the flywheel. Having a high rotational speed at the flywheel is beneficial because the increased rotational energy will allow for smoother pedaling. Yet another chain runs from the small sprocket on the flywheel shaft to a large sprocket on the shaft of the cutting mechanism. This provides power from the drivetrain to the cutting mechanism. The large size of the sprocket on the cutting mechanism allows for increased torque to the cutter while also decreasing the rotational speed of the cutter to a reasonable level. For added safety, the drivetrain is covered with a chain protector. The full drivetrain can be seen in Figure 31.

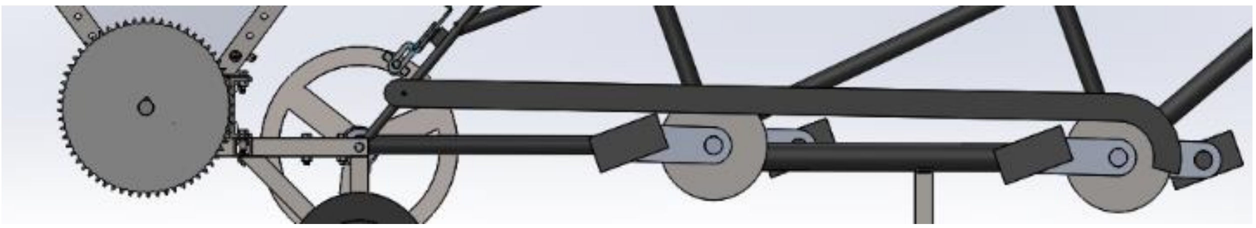


Figure 31. Drive Train

The support frame (Figure 32) supports the entire machine and fits with wheels to allow for easy transport. It connects to the bike frame at three locations in a way that will allow the bike frame to be detached from the support frame.

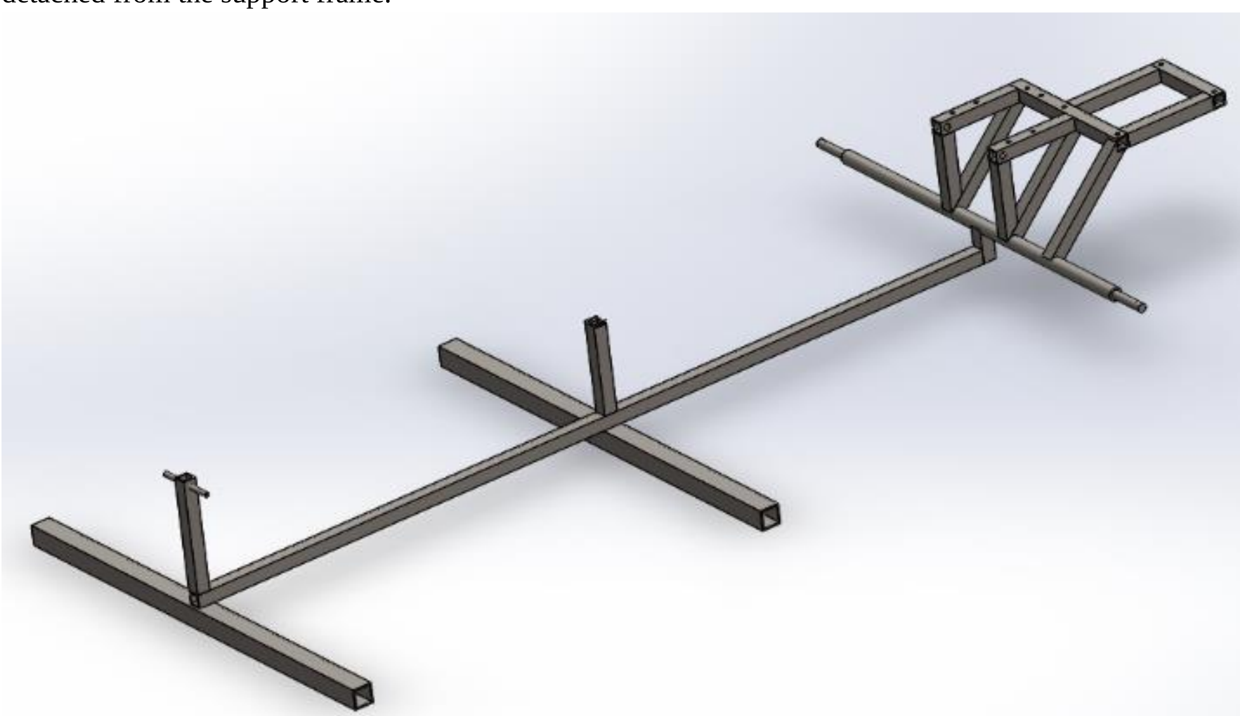


Figure 32. Support Frame

In the front of the bike frame, the support frame attaches to the bike frame by means of a bicycle skewer. The skewer fastens the front fork to the support frame, and the handlebars will be welded in position to prevent the front of the bike frame from moving in relation to the support frame. In the middle

of the bike frame, the support frame connects to the bottom bar of the bike frame by means of a support beam flush with the bottom bar. Perpendicular to the bike frame at this location is a slot machined through the support beam on the support frame, where a strap can be threaded through and around the bottom of the bike frame and cinched down, attaching the bottom of the frame to the support beam. At the rear of the bike frame, a shaft is put through the flywheel and rear drop-outs that will attach the back of the bike and flywheel to the support frame. This shaft is a modified version of the bearing shaft already part of the flywheel donated to us, lengthened to be able to be fixed to the support frame. The support frame also supports the cutting mechanism and hopper and features bars that run perpendicular to the length of the bike in order to prevent it from tipping and provide stability to the riders. Based on component grouping, the Compost Chomper was divided up into 3 sub-assemblies (Figure 33): Support Frame, Bike Frame and Hopper.

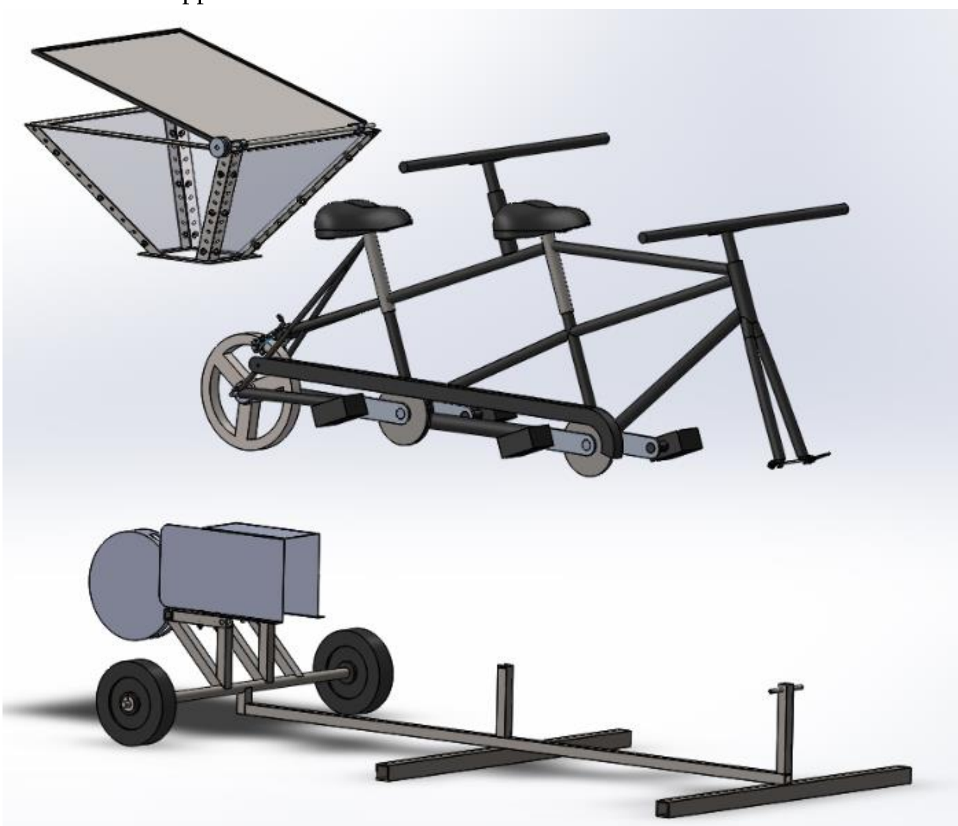


Figure 33. Disassembled Bike Frame and Drive Train, Support Frame and Cutting Mechanism (Not Visible), and Hopper.

Each sub-assembly can be easily removed for repair and maintenance, with the goal of creating a long lasting design. Sheet metal shielding was added to the support frame to protect the large sprocket and flywheel for any students accidentally accessing it. Additional safety measures may be imposed after further review and testing. The full assembled design can be seen in Figure 34.

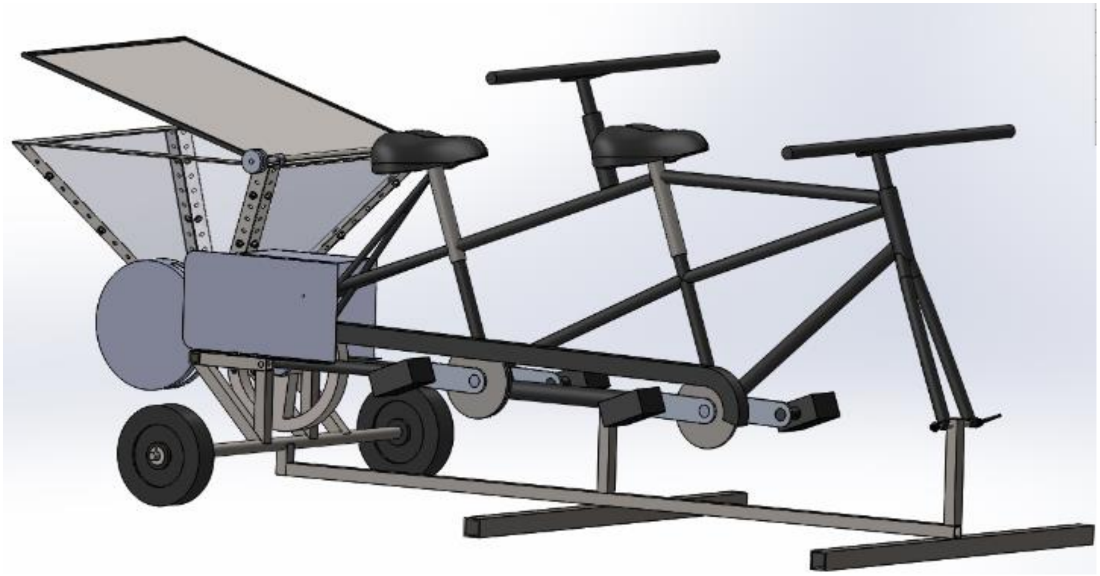


Figure 34. Final design.

With each sub-assembly put together and fasteners secured the final design was estimated to be 200lbs based off solid molding material weights.

5.2 Supporting Analysis: Satisfaction of Specifications

At this stage in our design, we can safely say that we are able to meet all of our specifications listed in Table 3 with the "A" Compliance designation. The first four of these specifications concern the drivetrain of the machine and are very closely related to each other. Our background research lead to our torque [10] and RPM input [11] estimates. Refer to Figure B-1 for input torque calculations. Based on the video of the Filamaker Organic Waste Shredder [12] we were also able to approximate a reasonable output RPM. With an ideal input RPM and torque as well as an ideal output RPM, our team was able to design a drivetrain based around the sprockets already on the tandem bicycle frame. The addition of the flywheel to the drive train, while complicating the system, provides valuable rotational energy storage, allowing for easier pedaling while grinding the garden waste. One of the largest considerations during our drive train design process was the rotational speed of the flywheel. The higher the rotational speed of the flywheel, the more energy it stores and the smoother the pedaling will be. In order to reach high rotational speeds however, a small sprocket must be connected with a chain to a large sprocket. This is because, when two sprockets are connecting by a chain in a drive train, rotational speed and size of the sprocket are inversely proportional. For a look at how our team decided on the selection of a chain for our drive train, please refer to Figure G-10. This idea of gearing ratios complicates the design of the drive train because the largest possible step-up (that is, going from the largest sprocket to the smallest possible sprocket) requires unique sprocket sizes in order to achieve the highest possible rotational speed at the flywheel, and thus more unique sprocket sizes in order to step the RPM of the sprockets back down to a reasonable level for the cutting mechanism. Because of this complication that is created by introducing a high RPM component like a flywheel to our drive train, we came up with two drive train designs. Refer to Figures G-7, G-8, and G-9 for drive train sketches, power verification, and our optimization spreadsheet. Initially, our team was in favor of our drive train design that featured a two-step reduction in RPM from the

flywheel to the cutting mechanism. This design allowed the system to store about 2.67 times more energy by powering the flywheel at a higher rotational speed, at the cost of being more complicated, featuring more sprockets, and operating our cutting mechanism at a half of our ideal rotational speed. After careful review, we decided to go with our drive train design that featured a one-step RPM reduction between the flywheel and cutting mechanism, which allowed us to use the sprockets already on the bike while using less sprockets and chains overall. This came at a cost of operating our flywheel at a lower rotational speed, but considering that we are able to achieve both our input and output specifications for RPM and torque using this drive train design, the loss in stored rotational energy is acceptable.

Our next specification that required analysis of our system involved making sure that our machine could sustain a total operator weight (between two people in the case of our tandem frame) of 300 lbs. Our design meets this specification given the assumption that the bicycle frame that we obtained from Jail Enterprises is safe to ride. Because the frame we obtained is a commercial-grade steel tandem frame, the assumption that it is safe to ride is a reasonable assumption to make, as bicycles made available to the public feature large factors of safety so that the frames can support a variety of users. This same idea was applied to our support frame; because our support frame is made out of carbon steel, and therefore has a very high elastic modulus and yield strength, the three vertical supports that connect to the bicycle frame will be able to take the load of the operator with extremely small deflections and with extremely high factors of safety, making the integrity of the support frame material itself an area of least concern. For a look at how our team calculated deflection for the wheel axle, please refer to Figure G-2. The area of most concern, however, lies in where our stress concentrations will be highest, which is at our weld joints. We identified the areas of critical concern on our support frame using our engineering judgement, and performed stress calculations using worst-case scenarios involving a 500 lb operator load as well as the loads from the weights of all other components. Using worst-case scenarios, however impossible or unlikely, allow our designs to be as conservative and safe as possible. Please refer to Figures G-3, G-4, and G-5 for our in-depth calculations at our points of critical concern. Once our stress calculations were performed, we found that our welds had factors of safety of 31, 40, and even in the most extreme case, 6.8. These factors of safety tell us that our frame is many times over-designed, making it very safe for even the heaviest loads.

The weight of our product is also of concern due to the fact that it needs to be moved into and out of storage. Our specifications set our maximum weight as 500 lbs, and after modeling our total machine assembly in SolidWorks, a Computer Aided Design software, we were able to estimate our total weight at around 200 lbs. This puts our design well within our specification, and will allow two to three people to easily tilt and roll the machine to and from storage.

Our device's footprint, that is the area it takes up on the ground, had to be a maximum 4 feet and 10 inches wide and 10 feet long in order to fit within the storage area at the Captain Ray Collins Elementary School. Including all parts of our design, our machine's dimensions are 7.5 feet long and 3 feet wide, so well within the allowable footprint. The extra space that we have left within the allowable footprint will make getting around the machine when moving it into and out of storage much easier.

The stability of our machine is yet another critical specification that warrants analysis before we continue with manufacture. While our specification describes that our machine will remain stable with a 60 lb force applied to the highest point of its side profile, as we finished our design our concerns grew to consider that our device may tip backward, pivoting on the wheel axis due to the weight of the cutting

mechanism and hopper. Analysis was performed for both cases, please refer to Figures G-1 and G-6 for in-depth analysis. In either case, we found that our machine would not tip.

Our machine's feed volume, that is the volume that the hopper can store while the lid is closed, needs to be 2 cubic feet plus or minus 0.5 cubic feet. The volume of our hopper comes out to be slightly less than 2.5 cubic feet, putting our design just on the upper limits of our specifications. Please refer to Drawing #403 in Appendix K for exact dimensions of the hopper.

Since our Senior Project Team was awarded $2000 from the Baker-Koob Endowment, our total budget was increased to $3000 during this phase of the design. Thus, our total cost for the design could not exceed $3000. Our cost was estimated to be around $1600, well within our budget. Please refer to our Section 5.7 Cost Analysis as well as our Bill of Materials in Appendix J for a detailed breakdown of our project's costs.

5.3 Design Safety Considerations

The Compost Chomper is designed to be operated by children from first to sixth grade, making safety a major concern in our final design. The most design intensive features of our final product were in fact the safety features. Outlined in the following sub-section are our safety features included in the device.

As seen in Figure 31 and 34 a guard was fastened over the chain to prevent students from getting any articles of clothing caught in the drivetrain while operating or easily putting and appendages in the drivetrain. At this time the guard exists on the top of the drivetrain only, but if necessary a guard that encompasses more of the drivetrain could be purchased or manufactured such as the guard seen in Figure 35.

Figure 35. Schwinn Town & Country Tandem Bike- Chrome Chainguard [18]

To prevent the flywheel and cutter drive sprocket from potentially causing injury some form of shielding needed to be implemented. Figure 36 shows the rear section of the drivetrain with the designed safety shielding.

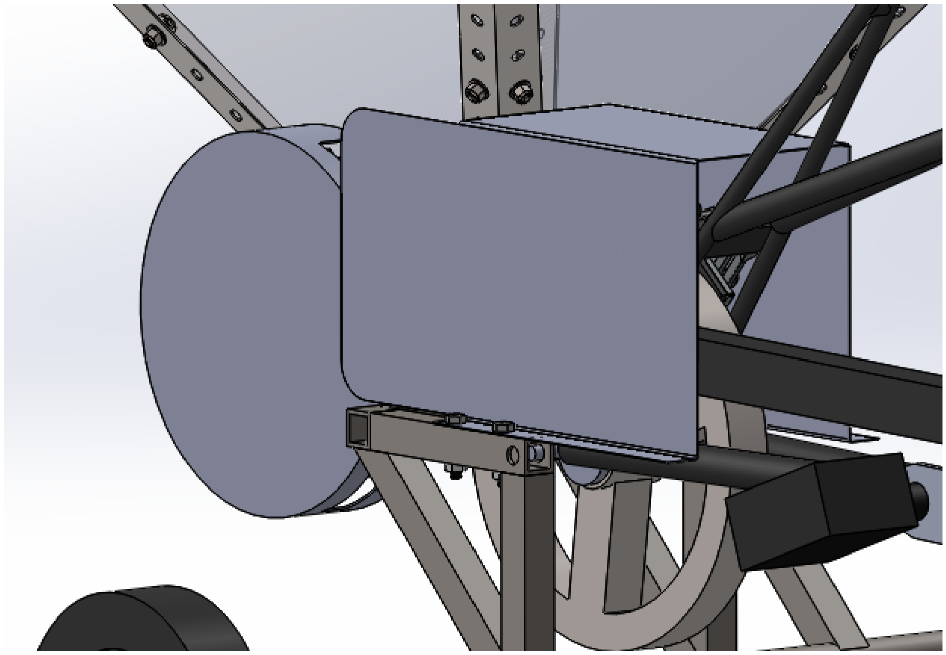


Figure 36 Sheet Metal Safety Shielding for The Rear Drive Train

If deemed necessary, a guard for the lower flywheel could be designed, but the current design prevents easy access to moving components from the top and sides. This design limits the amount the students can see, which is unfortunate for their enjoyment of the design but provides a level of safety the is crucial to this project.

The hopper of the Compost Chomper is the key safety system to preventing access to the spinning blade of the shredder as well as preventing the device from operating while it is being loaded. Figures 28 and 29 show these systems in detail. This hopper allows for viewing into the shredding area while preventing any interaction with the blades.

To prevent tipping and provide a stable ride for the students the supporting frame was designed with 3ft long support bars and a wide wheelbase (Figure 37).

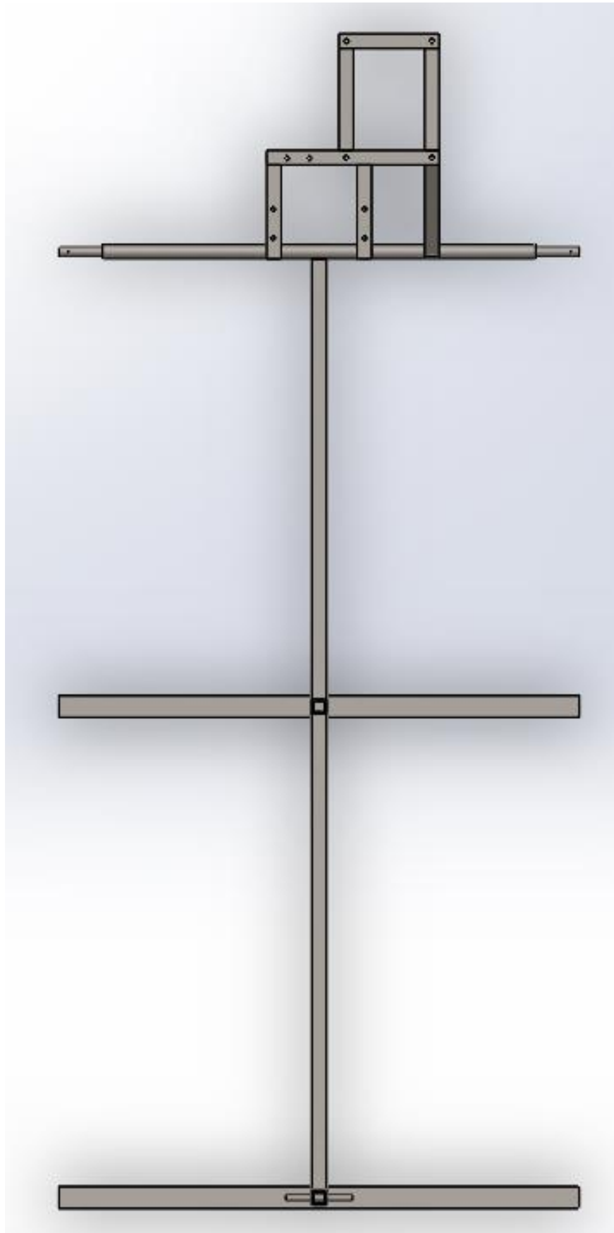


Figure 37. Top view of supporting frame showing support feet.

As outlined in section 5.2, the length of the support feet allows for large forces to be applied at the highest point of the device without it tipping. Additionally, the wide feet will prevent excessive rocking of the device on uneven ground. Sharp exposed edges on the device will be ground down and all exposed tube-ends will be capped off with rubber plugs. Painting or powder coating the frame will prevent exposed rust.

5.4 Material Selection and Justification

When selecting material for the Compost Chomper, three main considerations were taken into account: manufacturability (machine, weld, bend, etc.), corrosion resistance and strength properties. Due to the healthy budget, of our project cost was not a major concern in a material selection. Assistance for

material selection was provided by David Otsu with the Materials Engineering Student Society, mainly for the hopper panels. David's report suggested we use a clear UV resistant breed of acrylic. The acrylic selected (Appendix H) offers strength properties that fit well within our model but still allow for viewing of the shredder as seen in Figure 38.

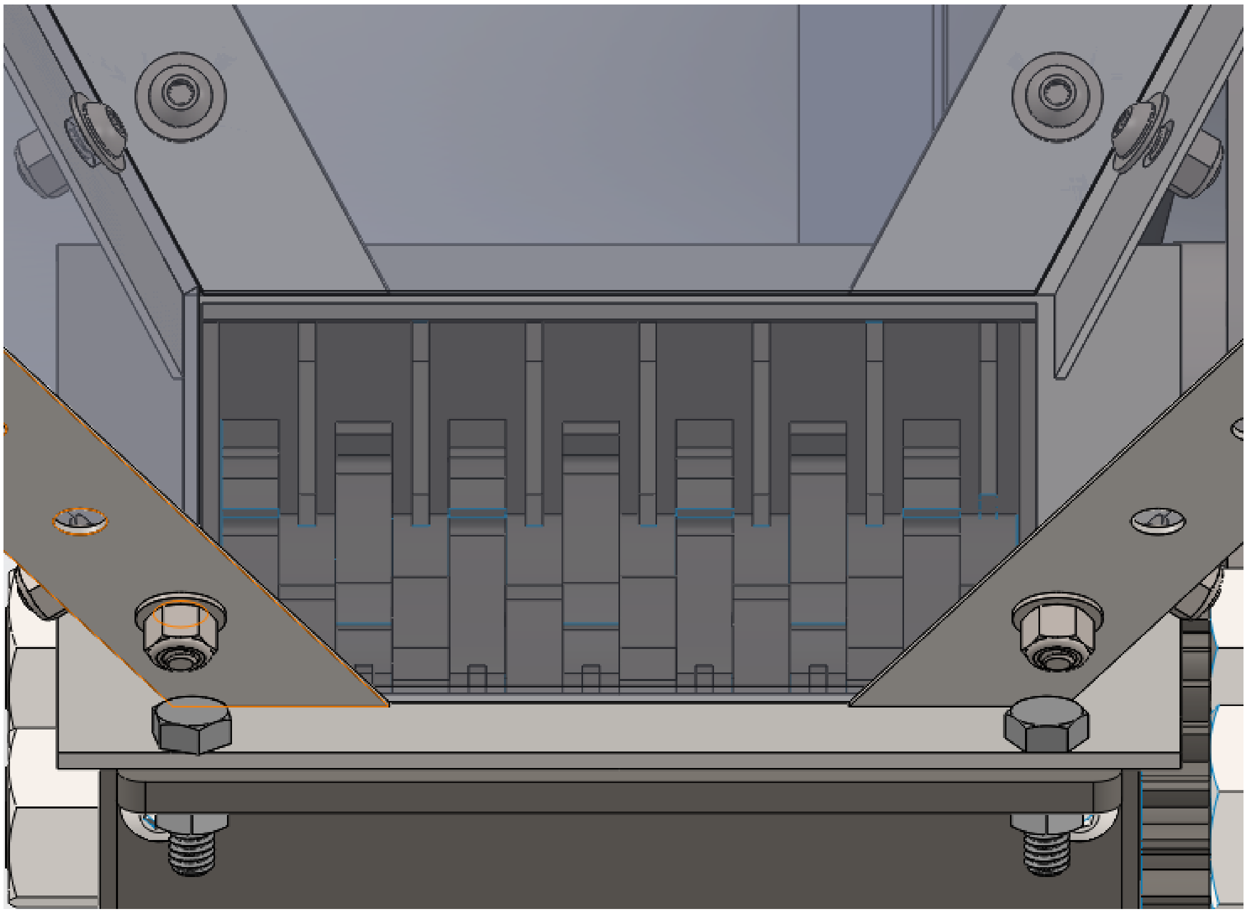


Figure 38. Acrylic see-through panels allow for prime shredding entertainment.

The supporting frame system is made entirely from low carbon steel square tubing. Low carbon steel offers great weldability and strength properties, at the cost of poor corrosion resistance. Left untreated, the frame would corrode and possibly become a hazard. To mitigate this, the frame will be painted or powder coated with corrosion resistant material to ensure longevity of the device. The axel portion of the supporting frame was also selected to be low carbon steel for its weldability.

The tandem frame and supporting parts of the bike were donated to the project so they did not have a specific material selection process. We sought steel parts to be donated for their weldability and strength but the components we received varied between aluminum and steel. The materials we received however proved to be well within workable limits. The stainless steel chain will be one of the few purchased parts that goes on to the bike. Chains often are one of the first parts to fail/lose functionality on a bike so using a stainless steel chain allows for better life and fewer repairs.

The flywheel guard and rear guard show in Figure 36 will be made out of stainless steel sheet metal. Stainless steel will provide great corrosion resistance and strength. The downside of using stainless steel is that the rear guard will likely require a paid fabricator to weld it, due to the skill required to weld. It also has a relatively high cost but well within our budget.

All fasteners were selected to have high corrosion resistance. This meant the material for the parts was stainless steel and typically coated with zinc or galvanized. These parts were selected so that they can outlast the even the device itself.

5.5 Manufacturing and Assembly Instructions

We have designed our system such that it can be manufactured and assembled in the Cal Poly machine shops. However, there are some parts that we will contract professionals to manufacture. Details on the intended manufacturing and assembling process for each subsystem are listed below. The actual manufacturing process is described in Section 6.

5.5.1 Bike and Drive Train Manufacturing and Assembly

Thanks to the donations from Jail Enterprises, we will be using a complete tandem frame as the basis of our drive train assembly. This frame already has sprockets mounted to the two pedal axles, and we plan to use these existing sprockets in the final design (shown as N2, N3, and N4 in Figure G-8). We will attach two 12 tooth sprockets purchased from McMaster-Carr (shown as N5 and N6 in Figure G-8) to the flywheel axle using either welding or brazing. The flywheel will be mounted in place of the back wheel using the existing dropouts on the forks. We will use an existing keyway on the Filamaker drive shaft to attach a 60 tooth sprocket with a setscrew also purchased from McMaster-Carr (N7 in Figure G-8). We will purchase new chains for each pair of gears and attach them using a bike chain tool. After the chains are in place, we tension them with the derailleur and chain tensioners. The bike frame will be attached to the support frame at three points: the front dropout, the center of the down tube, and the rear dropout. The front and rear dropouts will be mounted to axles in the support frame and secured using quick release skewers as if they were being attached to a regular wheel. The center of the down tube will rest in a groove cut into the middle column of the support frame and will be cinched down using a draw strap attached to the middle column. Finally, we will use MIG or TIG welding to weld the front handlebars to the post so the structure is more secure.

5.5.2 Support Frame Manufacturing and Assembly

The entire support frame will be manufactured and assembled in the Cal Poly machine shop with the exception of the chain and flywheel guards, which we will contract out to a local sheet metal shop. We will use tube notches to notch tubing in order to fit together for welding. The frame will be welded using the MIG and TIG welders in the shop. We will create the rear support frame axle by turning down the ends of a 1” diameter bar to a diameter of 5/8”. This axle will then be welded to the rest of the frame and wheel burrow wheels will be fastened to the axle using cotter pins. Using a press or hand drill, holes will be drilled in the support columns to mount the front and rear bike axle rods, and additional bolt holes will be drilled to fasten the Filamaker to the support frame. A notch will be cut in the middle support column for the bike frame down tube to rest in, and a slot will be cut using a small diameter handheld

circular saw below the notch to allow straps to be secured around the bike frame. The chain and flywheel guards will be fastened to the frame once the bike and drive train are in place.

5.5.3 Hopper Manufacturing and Assembly

The hopper will get its rigidity from a welded steel frame on which the acrylic siding panels can be bolted. The top and bottom of the frame will be welded into rectangles from 1/8" steel bars. In order to create the corners of the frame, we will bend McMaster-Carr's bolt-together framing from 90 degrees to 109 degrees using the sheet metal bender in the Cal Poly machine shop. The ends of these pieces will be cut at an angle in order to fit to the top and bottom bars. We will need to grind away the zinc plating from the ends of the framing in order to safely weld the framing to the top and bottom bars. To cut the acrylic panels, we prefer to use the laser cutter to get very accurate angles and easily and precisely locate bolt holes; however, if the laser cutter is not available, we can use a table saw and drill press to create the panels. The panels will then be bolted to the hopper frame. The lid will be cut from a sheet metal panel (or possibly other material such as expanded steel), then welded to a rod. In order to mount the lid, we will machine bearings that slide over each end of the rod and can be fastened to the hopper frame. We will then machine the safety cam which will be attached to the rod on the lid. We will thread a brake line through a hole in the safety cam and attach the other end to the existing brake calipers on the bike frame so that when the lid opens, the cutter cannot rotate. Lastly, rubber stripping will be added to the edges of the lid to ensure good contact with the frame and reduce pinch points.

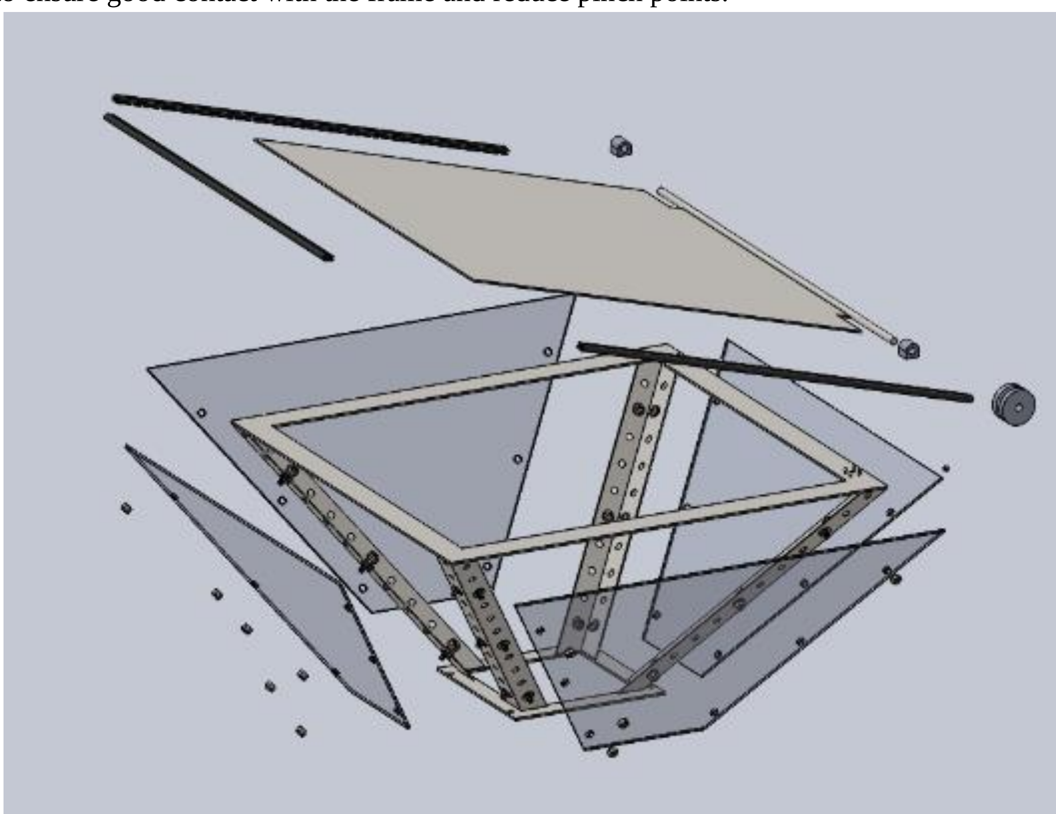


Figure 39. Exploded view of hopper assembly.

5.6 Maintenance Considerations

Maintenance for the Compost Chomper is similar to that of a standard bike with a few additions. Regular cleaning of the chain should occur whenever any sign of corrosion or debris is present. Cleaning consists of using a chain cleaning device and oiling the chain with any available chain oil or chain lubricant. Sprockets can be cleaned with a gear brush or any brush with stiff plastic bristles. The drivetrain may be hosed down to be clean as long as water is not left standing on parts.

The hopper and Filamaker shredder should be hosed down after each use to ensure maximum life. Leftover plant residue could contain chemicals that accelerate any corrosion in the hopper and shredder. In the case that the shredder cannot be adequately cleaned with a hose alone, the hopper can be removed and a small scrubber brush can be used to clean the shredder. The hinge of the hopper should be lubricated once a year to ensure easy opening. Additionally, attention should be paid to the brake line, looking for corrosion or signs of wear. If the line looks at all fatigued it may require replacement.

If chains and sprockets become corroded or worn, they may need to be replaced. The chains can be split off and replaced with the corresponding part from the Bill of Materials (Appendix J). Sprockets can be replaced with related parts found on most standard bikes. Local bike shops will be capable of ordering compatible parts if sourcing parts online or off the shelf is difficult

5.7 Cost Analysis

With the Baker-Koob Endowment and the funding guaranteed to us by our sponsor Susan Deogracias, our project has a total budget of $2500, down from the $3000 originally promised. Below is a brief summary of our costs per each subassembly. For a more comprehensive list of costs and materials, please refer to our Bill of Materials in Appendix J.

Table 4. Cost Analysis

Cost Analysis		
Sub-Assembly	Cost	Weight
Fasteners	$170.80	~7 lbs
Hopper	$307.75	~35 lbs
Support	$1,035.46	~100 lbs
Bike Frame	$410.03	~55 lbs
Total	$1,924.04	197 lbs

As our project stands, having completed the finished product, we have about $500 leftover in our budget. Note that the costs shown in the cost analysis above and the Bill of Materials in Appendix J have been adjusted for shipping and tax fees once orders have been placed. Should our team have decided at any time that an aspect of manufacturing our project was out of our skill range, we had enough money to contract a machinist or Cal Poly Shop Tech.

5.8 Testing Timing and DVP

Once the system was built, we planned to be able to start testing. Refer to the DVP in Appendix I or Figure 58 above for a comprehensive list of the timing for the tests we performed. We planned to use our tests to verify that the Compost Chomper indeed performs how we expected it to and to ensure that it is safe to use.

In order to perform these tests effectively, we needed the right equipment. We expected that we would require a series of torque wrenches to measure the input torque required to operate the Filamaker and would be able to borrow or purchase these for little or no cost. To measure the RPM, we planned to either purchase a tachometer or use slow-motion video. We would use rulers and tape measures to measure the physical dimensions of the system. To measure the total weight of the system, we would likely break it down into subsystems and put them on the shop scale. To test if the structure supports the operator weight, we would sit on it ourselves. Finally, to measure the stability of the device, we would try pushing on it on the highest point of the broad side and see if it tips. To get a more accurate reading of the forces involved in the process, we planned to use masses and pulleys.

6.0 Manufacturing

Manufacturing the Compost Chomper was very time intensive and took the team to nearly every corner of the Cal Poly machine shops. The design of the Compost Chomper required a variety of systems effectively working together, which meant that each system needed to be manufactured carefully so as not to interfere with others. The final assembled design can be seen in Figure 40.

Figure 40. Compost Chomper, fully assembled.

The following sections detail the manufacturing of various sub-systems of the Compost Chomper

6.1 Support Frame

The support frame makes up the base for the Compost Chomper and all systems are attached to it. This made it the natural place to begin manufacturing. The axle of the support frame was the first part to be manufactured. The axle was made from a 3ft long 1in diameter steel rod. The ends of the rod were turned down on a lathe to accommodate the wheels and holes drilled for the cotter pins. The completed axle with the wheels mounted can be seen in Figure 41.

Figure 41. Axle assembly that allows the Compost Chomper to be easily moved.

To make the support legs, two 3ft long 1.5in wide steel squaring tubing sections were attached normal to a 5ft section of 1in square tubing by MIG welding the sections. Perpendicularity of the legs was checked using a square before welding. The base for the Filamaker was made from the same 1in tubing used for the spine of the base. Sections of tubing were cut on a steel chop saw and necessary holes made on a drill press. Once each section of tubing was ground to ensure a good fit, the base was tacked and welded together. After the base was confirmed to fit the Filamaker the rest of the rear support frame was welded together and attached to the axle seen in Figure 42.

Figure 42. Rear support frame tacked together preparing for welding.

To attached the rear support frame to supporting leg section, the rear was clamped to a piece of scrape metal and a level was used to ensure the Filamaker would sit parallel to the ground. Once the fit was confirmed the frame was welded and can be seen in Figure 43.

Figure 43. Completed Support Frame

During testing, it was discovered that the back portion of the frame saw a large amount of deflection when the device was shredding. To remedy this two support bars were added which can be seen in the lower back part of the frame in Figure 43.

6.2 Bike and Drivetrain

To use the flywheel acquired from the LA county jail, sprockets needed to be mounted to accommodate the bike chain and the machine chain used to drive the Filamaker. The thick sprocket needed to be fixed to the flywheel but the chain would not fit if mounted directly to the face. To fix this a custom spacer was manufactured on the lathe using a piece a scrap bar stock found in the Cal Poly machine shop. Turning and facing the steel spacer was a straightforward process, but parting the section off proved to be a lengthy operation. The parting tool provided by the shop was likely dull but no replacements could be found.

With the spacer completed, the sprocket needed to be welded on. Fixing to sprocket required carefully welding inside a small 1/2in gap using a TIG welder. The stick on the TIG gun was pulled out to allow the tip to reach but this came at the cost of a more erratic arc due to turbulent gas flow. Despite this the sprocket was successfully mounted and after some grinding with a Dremel fit the chain comfortably. Securing the sprocket assembly to the flywheel would mean closing of access to the bearings inside the flywheel. In order to allow for potential servicing to sprocket assembly was tacked multiple times instead of fully welded so that the tacks could be ground off if necessary. The thick sprocket and flywheel assembly can be seen in Figure 44.

Figure 44. Picture of flywheel and thick sprocket assembly.

To fix the sprocket that would run to the pedals, the shaft that originally held the spin bike drive belt was used. The shaft inserted into the flywheel allowing the flywheel to freely spin but still be driven by the pedals like a normal bike. To modify the shaft for the bike sprocket, it was turned down on a lathe to a standard size of 1.25in. A collar with a face mount was fixed to allow for the sprocket to attach. A sprocket was found from the bike graveyard, which was drilled to fit to the shaft and collar. This assembly was placed into the flywheel assembly. During testing, the sprag clutch inside the flywheel failed, taking away the ability of the flywheel to spin freely. To fix this the shaft was welded in place, which fixed the full drivetrain together. Although this raised some concerns about the flywheel "bucking" riders further testing proved this to not be an issue. The final flywheel drive assembly can be seen in Figure 45.

Figure 45. Final flywheel drive assembly with all parts welded together.

During testing, some chain slip was occurring in both the sprockets attached to the flywheel. To fix this tensioners where purchased and welded as seen in Figure 46.

Figure 46. The rear tensioner on the left and front tensioner on the right.

In order to stop the flywheel on command, a braking system was attached. A 1.5in steel metal plate was welded directly to the bike frame and a standard road bike brake was fixed seen in Figure 47.


Figure 47. Flywheel braking system

6.3 Hopper

Manufacturing of the Hopper occurred concurrently with the drivetrain. To start the hopper, one large and one small steel rectangle was made from 1.5in wide 1/8in thick steel bars. The bars were cut on the steel chop saw and MIG welded together. To form the pyramid shape of the hopper, 90 degree bolt-together framing was used. The 90 degree bend needed to be changed to 110 degrees to accommodate the plexiglass so a bending jig was created using a piece of wood and a vice seen in Figure 48.


Figure 48. Bending jig created to achieve 110 degree angles in framing

Once the framing was bent, it was cut to size with an angle grinder. One of the challenges in using the framing was that it was galvanized steel, which when welded can release toxic fumes. To weld the framing the galvanized layer had to be ground off any area exposed to the heat of the welder. The framing was put in place with the rectangles and MIG welded together. During welding a fume hood was placed directly over the work area to ensure that any toxic fumes developed were quickly moved out of

the area. Holes were then drilled in the hopper frame to allow for it to be fixed to the Filamaker and for the lid hinges.

To make the lid another large rectangle was manufactured but now with one side missing, making a “U” shape. Inside the “U” a sheet of expanded steel was MIG welded. The structure was then attached to a steel bar that ran through the hinges. Rubber trimming was placed on all the edges of the hopper lid for safety. The fully assembled hopper can be seen in Figure 49.

Figure 49. Fully assembled hopper.

6.4 Safety

As was previously mentioned in the Drivetrain section, a handbrake was installed so that the drivetrain could be stopped with relative ease. Additionally, a cam and follower system, visible in Figure 50, was created so that when the hopper lid was open, the cam would move the follower, pulling a brake line attached to the same brake calipers around the flywheel as the handbrake so that the drivetrain could not move while the hopper was open. This braking system acts as an automatic safety feature to prevent the children from having access to the moving blades.

Figure 50. Cam braking system attached to hopper lid shaft

To prevent the children from accessing the other moving parts of the Compost Chomper, sheet metal covers were designed and then manufactured by Paladin Sheet Metal in Paso Robles at no cost to the team. The covers are viewable in Figure 51, and served to prevent the children from accessing the chains around the pedals, the flywheel, and the chain running from the flywheel to the large sprocket at the cutter.

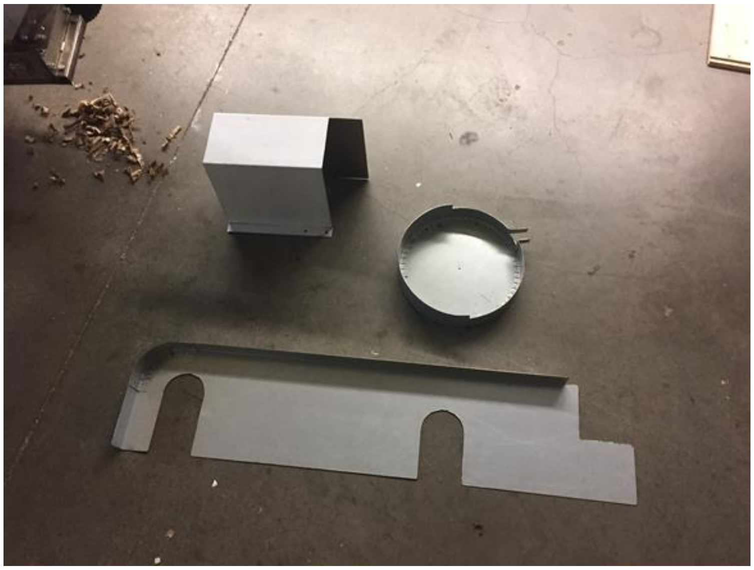


Figure 51. Sheet metal covers for chains, flywheel, and large sprocket

Two locks were also purchased so that the pedals of the Compost Chomper could be locked together and the hopper locked closed when not in operation.

6.5 Final Assembly and Painting

Once all of the various components had been manufactured and assembled, we took apart the Compost Chomper so that it could be painted. Painting the Comp Chomp is important because the paint will act as a protective anti-corrosion layer on our steel. Even while being manufactured, many of our carbon steel parts began to show signs of rust, so it was crucial that an outdoor project like ours be coated with paint. We decided to use Rust-Oleum spray paint because of its superior corrosion resistance. After grinding off the layer of rust on the carbon steel parts of the bike frame, support frame, and hopper, we began painting. We chose to paint the ground frame red, viewable in Figure 40, so that it matched the Collins School colors, and painted the hopper blue because we thought the children would enjoy it. The bike frame had spots of rust and chipping paint which we touched up with black paint. The final assembly, after being painted, can be seen in Figure 41.

7.0 Testing

The majority of the tests to verify that Compost Chomper met its specifications were go/no-go tests. Testing was carried out according to our DVP. Table 5 summarizes our testing results.

Table 5. Testing result summary

Parameter Description	Target Quantity	Test Result
Torque Input	160 in-lbf	160 in-lbf ✓
Input RPM	60 rpm	60 rpm ✓
Torque Output	960 in-lb_f	721 in-lb_f ×
Cutter RPM	10 rpm	13 Rpm✓
Chip Size	1 in^3	0.62 in^3 ✓
Vine Size	3 in diameter	Pass ✓
Process Rate	0.8 lb/min	2.7 lb/min ✓
Jam Frequency	3 jams/hr	Fail ×
Supports Operator Weight	300 lb	340 lb ✓
Product Weight	500 lb	170 ✓
Footprint	4’10” x 10’	3’ x 7’6” ✓
Stability	Will remain stable with 60lbs applied at highest point	Pass ✓
Feed Volume	8 ft^3	1.5 ft^3 ×
Product Cost	$1,000	$2000 ×
Height	4 ft	3 ft ✓

7.1 Test Summaries

Torque Input/Output Testing:

Torque testing was done by using luggage scales and knowing the length of our pedal shafts. We were able to match our input torque specification, but when that torque was applied at the pedals we measured the torque at the large sprocket on the cutter. Knowing the dimensions of the cutter, we were able to calculate what the output torque was, unfortunately falling below what our target was. We believe this discrepancy can be attributed to the fact that during manufacturing, we used a sprocket with a different number of teeth than what was designed on our flywheel shaft running to one of the pedal shafts. This was because it was the only bicycle sprocket we had that could fit our flywheel shaft and was close to our designed sprocket size.

Input/Cutter RPM Testing

RPM testing was done by counting how many revolutions we had at both the input and the output within a given time frame. We were able to operate the compost cutter at 60 RPM pedaling speed, so we considered that a passing score. When pedaling at 60 RPM, we counted approximately 13 RPM at the cutter, which is above our 10 RPM minimum speed, so we considered that a passing score as well. As was previously mentioned, the discrepancies in speeds from what our design specifications were can be attributed to the small change in sprocket size that we used.

Chip Size

Chip size was tested thoroughly so that we could perform statistical analysis on the results. We shredded seven different kinds of garden waste: Vinca, Lavender, Centrathus Ruper, Alder Tree branches, Privet Tree branches, Pepper Tree branches, and Rose bushes, seen in Figure 52. These samples varied in diameter and level of dryness as well as material density.

Figure 52. From left to right: Vinca, Lavender, Centrathus Ruper, Alder Tree branches, Privet Tree branches, Pepper Tree branches, and Rose bushes.

Figure 53. Shredded chips of sample mixture from Figure 51.

This test was done concurrently with our test for Process Rate, Jam Frequency, and Vine size. We found that chip size depended greatly on the kind of garden waste put into the Comp Chomp, with the longer, skinnier vines creating longer chips more often than the thicker, shorter stalks of garden waste. Running the chopped compost a second time through the grinder produces even smaller chip sizes if that is desired. A histogram of our chip size data is provided in Figure 54.

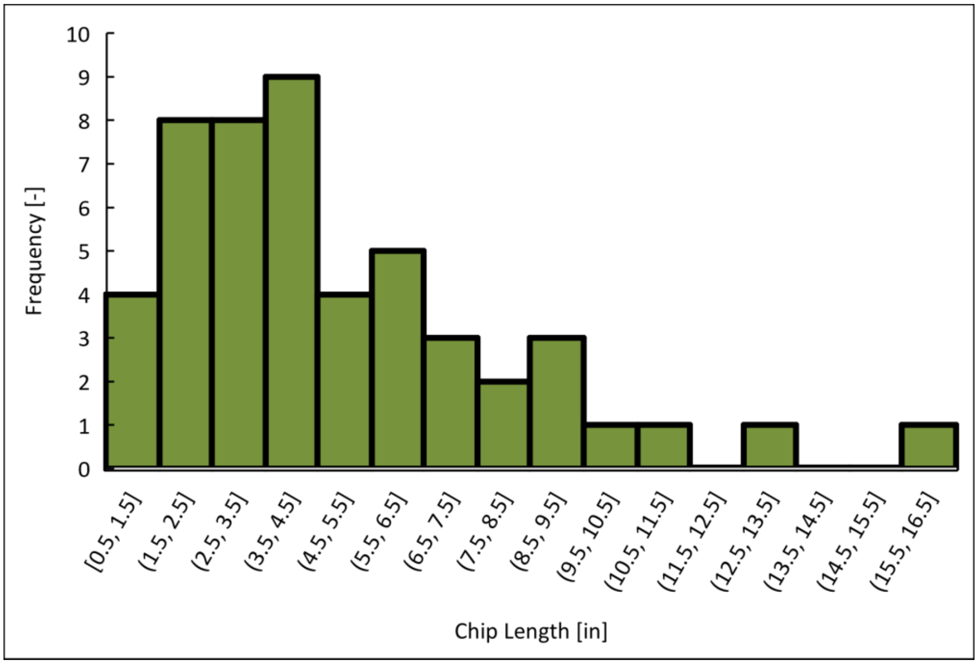


Figure 54. Histogram of 50 chip length samples randomly selected from chips collected during 8 trials with mixed material.

From visual interpretation of the histogram, it could be loosely determined that this data is probably normally distributed. Further analysis would be required to conclude this with confidence, but for our purposes, we will assume that the data is in fact normally distributed. We believe that a reason the data appears to be slightly skewed to the left is that it was difficult to select a purely random sample from the chip population. The larger pieces were more prominent and thus more were grabbed than the smaller pieces which tended to sink to the bottom. In reality, we expect there to be a similar pattern as the right side of the histogram mirrored on the left side.

Using normal distribution as an assumption, we performed an uncertainty analysis to determine the expected next measurement and mean value of the chips with 95% confidence. The resolution uncertainty was root-sum-squared with the statistical uncertainty (calculated with a student T variable) in order to get a final uncertainty. The result was an expected next value of approximately 5 ±5 in and an expected mean of 5±1 in. This makes sense because most of the measurements we saw fell within that range.

Additionally, a statistical process control chart was created to visualize the patterns of results from each chip size test (Figure 55). This time, the chip sizes are represented by the maximum size per trial and are in units of volume.

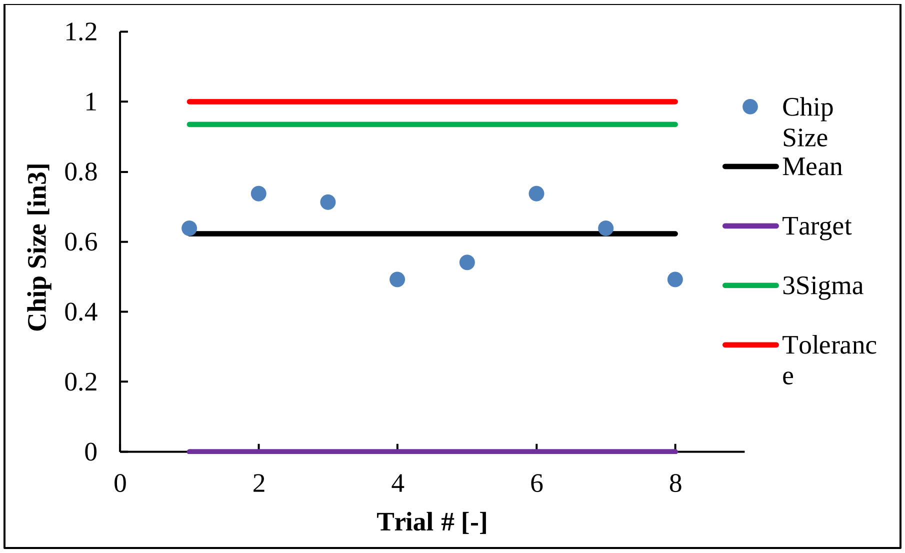


Figure 55. Statistical Process Control Chart displaying maximum chip volume of each of the 8 trials.

According to the chart, our process is performing well for chip volume. There have been no failures (measurements past the red tolerance line) and the 3sigma uncertainty range is also below the red tolerance line (meaning future failures are not likely).

Vine Size

Our vine size specification was set to be 3 inches in diameter maximum for a vine based on information our sponsor told us about her garden. While testing how well the Comp Chomp ground the garden waste, we were able to pick out the widest piece we had, at just over 3 inches in diameter, and we were successfully able to grind it.

Process Rate

Process rate was tested by creating a thorough mix of all of our plant material and weighing a small, uniform, amount of it. Then the mixture of garden waste was thrown into the hopper to be shredded, and the amount of time it took to completely grind away the waste was recorded. Based on this data, we were able to determine if the Comp Chomp was able to grind compost in a timely manner. We were consistently above the minimum process rate of 0.8 pounds per minute with an average of about 2.7lbs of compost ground per minute, thus satisfying our specification.

Jam Frequency

Concurrently with our Process Rate, Vine Size, and Chip Size tests, we were also testing for Jam Frequency. We considered jams in the hopper and jams in the cutter to be separate categories, with jams in the cutter being the main issue of focus. After testing multiple batches of garden waste, we found that our grinder did jam fairly often with drier, thicker material, and so while our tests only lasted 30 seconds each, a single jam in that time would put us over our 3 jams per hour specification. It seems that our specification in this case was too ambitious for a compost grinder.

Statistical process control charts for the feed jam frequency and the feed frequency can be seen in Figures 56 and 57 below.

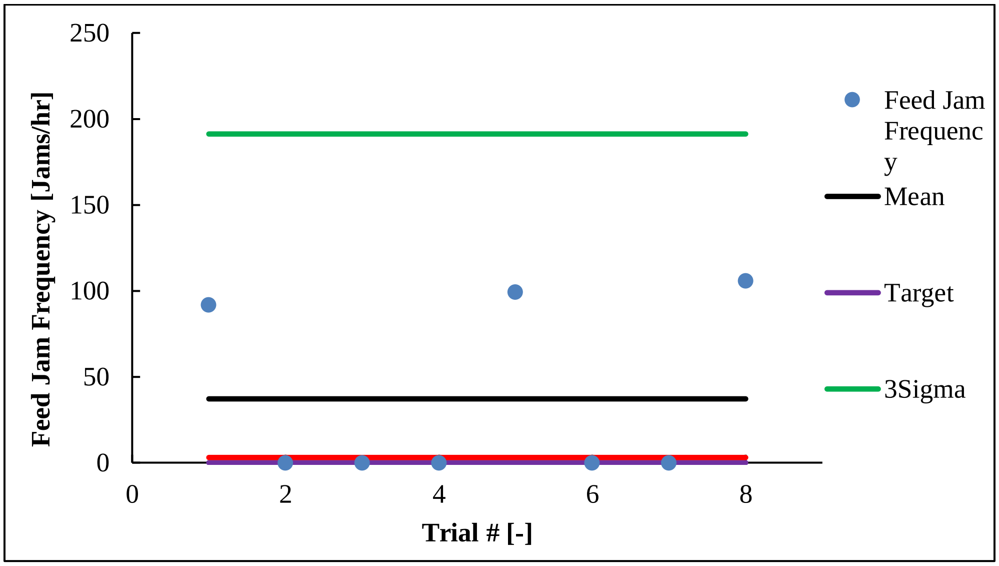


Figure 56. Feed jam frequency for 8 trials of operating the device.

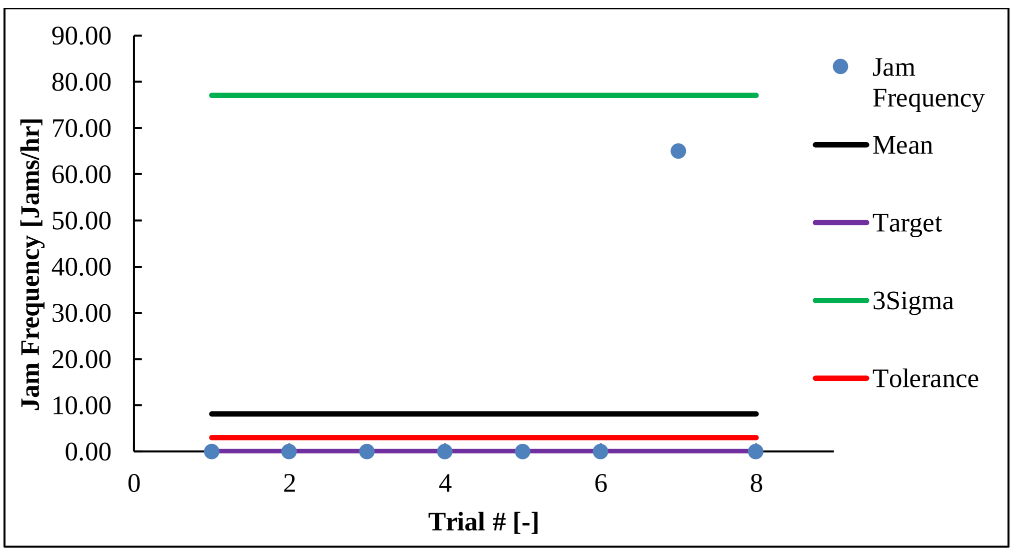


Figure 57. Jam frequency for 8 trials of operating the device.

Unlike the chip size SPC chart, the jam frequency SPC charts show processes that are operating far outside of the desired range. There are multiple failing measurements and the 3sigma uncertainty ranges exceed the tolerance by orders of magnitude. Although the data looks bad, this could be due to a poorly thought out specification. A jam/minute spec would have probably been more appropriate than jam/hr and would have likely shown less dramatic failures due to the nature of our testing. We are confident that the jams experienced by the device will not hinder successful operation although they may just be a slight inconvenience.

Operator Weight

Operator Weight was a fairly easy test to complete, as when any combination of the three of our team members were operating the Compost Chomper we were above 300 lbs of operator weight already and the system showed no signs of failure.

Product Weight

Product Weight was again a simple test. With 500 lbs being our maximum, it was fairly easy to tell that we were well underweight when two of our team members could pick up the Comp Chomp. We estimate our weight to be around 140 lbs, and when tilted onto its rear wheel the Compost Chomper becomes very easy to move.

Footprint

The footprint of our project was important because it needs to fit within the storage space our sponsor has available. Using a measuring tape, we were able to determine that our ground footprint was around two feet less in both width and length than our maximum dimensions.

Stability

The stability specification for our project was determined based off of approximations for the amount of force someone would put onto the Comp Chomp while leaning on it. We leaned on the project in many directions and even tried to tip it over, but the weight of the project allows it to stay very stable.

Feed Volume

Feed volume refers to the volume of our hopper. Due to the small size of the Filamaker shredder we had to downsize the volume of our hopper, and so our hopper volume fell out of tolerance of our specification.

Project Cost

Our project cost specification stems from the original amount of budget that we had to work with. Once we were granted Baker-Koob funds, it quickly became apparent that keeping the entire project under $1000 when the shredder alone cost $600 was not possible. In the end, our project cost nearly $2000, twice our original budget.

Height

Height is an important characteristic of our project because if the project is too tall then children will not be able to operate it. The maximum height we set was four feet, and we came a foot under that at three feet, satisfying our specification.

8.0 Management

To facilitate successful completion of project tasks, we assigned specific responsibilities to each team member. Anthony is our communication head, meaning that he was responsible for sending and responding to the bulk of the team emails and reaching out to our various contacts. He also dealt with any manufacturing considerations and was be the main authority on prototype fabrications. Anthony was

primarily responsible for the frame and overall structure of the device. Joe was in charge of documentation, which entails preparation of weekly status reports with our advisor and recording all important project progress. Joe was also the main CAD modeler and will be primarily responsible for the cutting mechanism. Cory was assigned the task of treasurer, which includes monitoring funds, handling spending and material acquisition, and applying for grants. He was also in charge of test planning, and analysis. The subsystem of the device that Cory was primarily responsible for was the gear train.

In order to stay organized and on track, we composed a Gantt chart, seen in Figure 58. This chart shows estimated completion times and due dates for various key project components.

Build	**60 days**	**Fri 2/10/17**	**Tue 5/2/17**	
All Parts Ordered	0 days	Tue 2/14/17	Tue 2/14/17	
Cut Support Frame Parts	14 days	Tue 2/14/17	Fri 3/3/17	22
Assemble Support Frame	14 days	Mon 3/6/17	Thu 3/23/17	22,2
Cut Hopper parts	14 days	Mon 3/6/17	Thu 3/23/17	22,2
Assemble Hopper	7 days	Fri 3/24/17	Fri 3/31/17	25
Assemble Filamake	7 days	Fri 3/3/17	Mon 3/13/17	
Spring Break	7 days?	Sat 3/25/17	Mon 4/3/17	
Attach Filamker	7 days	Tue 4/4/17	Wed 4/12/17	24,2
Assemble Full Design	14 days	Thu 4/13/17	Tue 5/2/17	29
Operator's Manual	0 days	Thu 3/9/17	Thu 3/9/17	
Test	**11 days?**	**Wed 5/3/17**	**Wed 5/17/17**	**21**
Torque Input/Output	2 days	Wed 5/3/17	Thu 5/4/17	
Input/Output RPM	1 day	Fri 5/5/17	Fri 5/5/17	33
Chip Size	3 days	Mon 5/8/17	Wed 5/10/17	34
Vine Size	3 days	Mon 5/8/17	Wed 5/10/17	34
Process Rate	3 days	Mon 5/8/17	Wed 5/10/17	34
Jam Frequency	3 days	Thu 5/11/17	Mon 5/15/17	34,3
Operator Weight	1 day?	Tue 5/16/17	Tue 5/16/17	35,3
Product Weight	1 day?	Tue 5/16/17	Tue 5/16/17	38
Footprint	1 day?	Tue 5/16/17	Tue 5/16/17	38
Stability	1 day?	Tue 5/16/17	Tue 5/16/17	38
Feed Volume	1 day?	Wed 5/17/17	Wed 5/17/17	42
Height	1 day?	Wed 5/17/17	Wed 5/17/17	42
Compile Final Report and Board	12 days	Thu 5/18/17	Fri 6/2/17	32
Final Design Review/Expo	0 days	Fri 6/2/17	Fri 6/2/17	

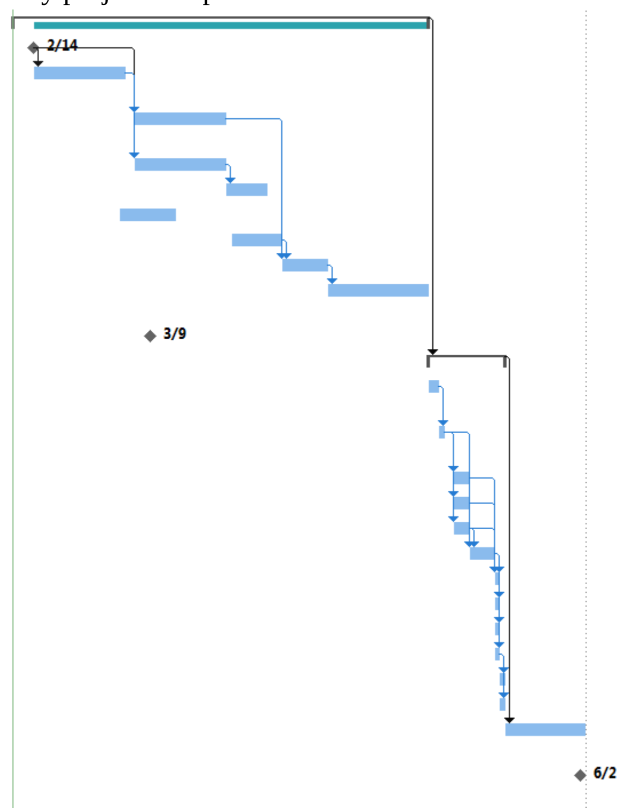


Figure 58. Gantt chart with currently planned tasks.

This gantt chart reflected our planned completion dates as of CDR. The actual schedule that we ended up following can be found in Figure 59.

Task Name	Duration	Start	Finish
Build	**83 days**	**Fri 2/10/17**	**Fri 6/2/17**
Frame Parts Ordered	6 days	Tue 2/14/17	Tue 2/21/17
Cut Support Frame Parts	7 days	Sat 3/25/17	Mon 4/3/17
Assemble Support Frame	5 days	Tue 4/11/17	Mon 4/17/17
Hopper Parts Ordered	0 days	Mon 4/3/17	Mon 4/3/17
Cut Hopper parts	2 days	Tue 4/11/17	Wed 4/12/1
Assemble Hopper	7 days	Thu 4/13/17	Fri 4/21/17
Assemble Filamaker	7 days	Mon 4/3/17	Tue 4/11/17
Spring Break	7 days?	Sat 3/25/17	Mon 4/3/17
Attach Filamker	7 days	Fri 5/5/17	Mon 5/15/1
Assemble Full Design	14 days	Tue 5/16/17	Fri 6/2/17
Operator's Manual	0 days	Mon 5/29/1	Mon 5/29/1
Test	**23 days**	**Wed 5/3/17**	**Fri 6/2/17**
Torque Input/Output	2 days	Wed 5/3/17	Thu 5/4/17
Input/Output RPM	1 day	Wed 5/17/1	Wed 5/17/1
Chip Size	3 days	Tue 5/23/17	Thu 5/25/17
Vine Size	4 days	Mon 4/10/1	Thu 5/25/17
Process Rate	3 days	Tue 5/23/17	Thu 5/25/17
Jam Frequency	3 days	Fri 5/26/17	Tue 5/30/17
Operator Weight	5 days?	Wed 5/17/1	Tue 5/23/17
Product Weight	6 days	Mon 5/15/1	Mon 5/22/1
Footprint	1 day?	Wed 5/31/1	Wed 5/31/1
Stability	1 day?	Wed 5/31/1	Wed 5/31/1
Feed Volume	1 day?	Thu 6/1/17	Thu 6/1/17
Height	1 day?	Thu 6/1/17	Thu 6/1/17
Compile Final Report and Board	10 days	Mon 5/22/17	Fri 6/2/17

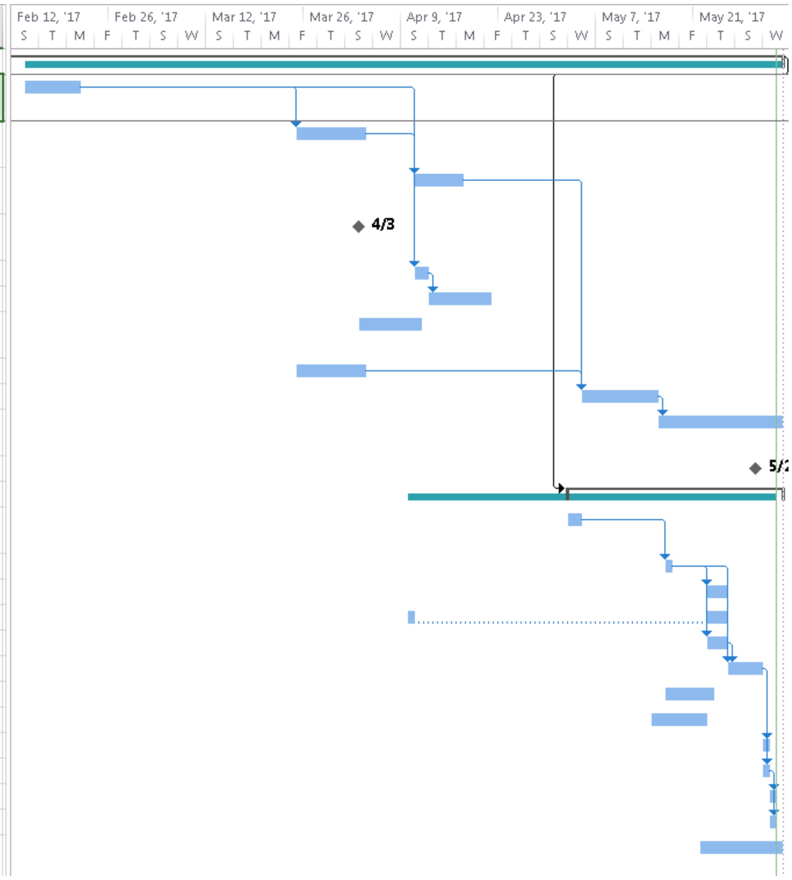


Figure 59. Updated Gantt chart to reflect actual dates

The actual completion dates ended up being significantly later in almost all areas of the gant chart. The building and assembly of the total design continued right up until expo with testing occurring concurrently to the build.

9.0 Conclusion

The goal of this document has been to take the needs of the Captain Raymond Collins Elementary School Garden and translate them into engineering specifications that can be used to produce a successful device. In order to produce accurate, competitive specifications, we have done comprehensive research on existing products related to the needs. We have generated design ideas and selected the best configuration to meet our specifications. Based of those specifications we have developed our final design. Our machine has been thoroughly tested and meets all crucial criteria, and for that reason we believe it will meet the needs of our client well. For an operations manual, please refer to Appendix M at the end of the report. This final design is the product of 30 weeks of work, and we hope that this final design proves to be satisfactory for all of the Captain Raymond Collins Elementary School Garden's goals.

Works Cited

[1] "Guide to Small Batch Composting." Urban Garden Center. N.p., 2014. Web. 20 Oct. 2016. <http://www.urbangardencenter.com/how-to-compost/how-to-compost.html>.
[2] "Human-Powered Shredder for Urban Farmers." Design Society Development DESIS Lab. Faculty of Art, Design & Architecture, University of Johannesburg, South Africa, n.d. Web. 15 Oct. 2016. <http://www.designsocietydevelopment.org/project/human-powered-shredder>.
[3] "Organic Waste Shredder." *Filamaker*. N.p., n.d. Web. 08 Nov. 2016. <http://filamaker.eu/product/organic-waste-shredder/>.
[4]"Shredders by Bosch Garden Tools | Bosch." Garden Tools from Bosch. N.p., n.d. Web. 25 Oct. 2016. <https://www.bosch-garden.com/gb/en/garden-tools/garden-tools/shredders-199967.jsp>.
[5] "DR Wood Chipper." *DR Power*. N.p., n.d. Web. 16 Nov. 2016. <http://www.drpower.com/power-equipment/chippers/wood-chippers/self-feeding-wood-chipper-11-5-manual-start.axd?ctm_id=CPR11AMN&src=AW90375XE3663309&gclid=CLnL656OpNACFcNhfgodrfMKow>.
[6] "Toro 2-Cycle 25.4cc Attachment Capable Straight Shaft Gas String Trimmer-51978 - The Home Depot."*The Home Depot*. N.p., n.d. Web. 17 Nov. 2016. <http://www.homedepot.com/p/Toro-2-Cycle-25-4cc-Attachment-Capable-Straight-Shaft-Gas-String-Trimmer-51978/202071363>.
[7] "Weed Warrior Light Blade Trimmer." *Amazon.com*. N.p., n.d. Web. 16 Nov. 2016. <https://www.amazon.com/Warrior-Light-Blade-Timmer-59600/dp/B002ATMWU0/ref=pd_sbs_86_t_1?_encoding=UTF8&psc=1&refRID=1DK5M5VDKD58RY4E00F9>.
[8] "Weed Warrior Timmer Head." *Amazon.com*. N.p., n.d. Web. 16 Nov. 2016. <https://www.amazon.com/Weed-Warrior-Trimmer-Head/dp/B002YKM6DS/ref=sr_1_fkmr0_4?ie=UTF8&qid=1478993816&sr=8-4-fkmr0&keywords=weed+warrior+heavy+duty+attachment>.
[9] "Brown Cycles of Grand Junction, Colorado." *Browncycles.com*. N.p., n.d. Web. 18 Nov. 2016. <http://browncycles.com/bc/kidz-tandem/>.
[10] "2 to 20 Years: Boys Stature Weight-for-age Percentiles." www.cdc.gov. CDC, 30 May 200. Web. 21 Oct. 2016. <https://www.cdc.gov/growthcharts/data/set2clinical/cj41c071.pdf+>.
[11] "How Cycling Cadence Works." *HowStuffWorks*. N.p., 14 July 2010. Web. 15 Oct. 2016. <http://adventure.howstuffworks.com/outdoor-activities/triathlons/training/cycling-cadence1.htm>.
[12] Thymark. "Making Salad with FilaMaker Organic Waste Shredder." *YouTube*. YouTube, 23 July 2016. Web. 14 Nov. 2016.< https://www.youtube.com/watch?v=TfqV_HdRUMQ&t=51s>.
[13] Crossland, P., G. Murphy, G. Martin, and M. Dean. *Energy and Force Requirements for Six Pruning Shear Designs* (n.d.): n. pag. 1997. Web. 1 Nov. 2016. <http://www.nzjf.org/free_issues/NZJF42_3_1997/76E76EA5-2923-4DAD-9212-BC3AAA82C69E.pdf>.
[14] Ducci, Vincent. "Broyeur Rapid AXT Rapid 2200 Bosch Pour BRF." *YouTube*. YouTube, 02 Oct. 2014. Web. 30 Oct. 2016. <https://www.youtube.com/watch?v=gXGsP8Z06dk>.
[15] "95 Percentile Person." *95 Percentile Person*. N.p., n.d. Web. 17 Nov. 2016. <http://members.shaw.ca/gnat/95.html>.

[16] Jamerson, Shane. "GrabCAD - CAD Library." *GrabCAD - CAD Library*. N.p., 15 Jan. 2015. Web. 14 Nov. 2016. <https://grabcad.com/library/bike-19>.
[17] "Off-set Crankarm Positions." *Off-set Crankarm Positions. - Bike Forums*. N.p., n.d. Web. 17 Nov. 2016. <http://www.bikeforums.net/tandem-cycling/299299-off-set-crankarm-positions.html?styleid=6>.
[18] "Rare 1950 Arnold Schwinn Town & Country Twinn Tandem Bike-chrome Chainguard." *Terapeak*. N.p., n.d. Web. 09 Feb. 2017. <http://www.terapeak.com/worth/rare-1950-arnold-schwinn-town-country-twinn-tandem-bike-chrome-chainguard/111760558872/>

Appendices

Appendix A - Quality Function Deployment Matrix

QFD: House of Quality
Project: Compost Chomper
Revision: 1.0
Date: 10/24/16

Correlations	
Positive	+
Negative	−
No Correlation	

Relationships	
Strong	●
Moderate	○
Weak	▽

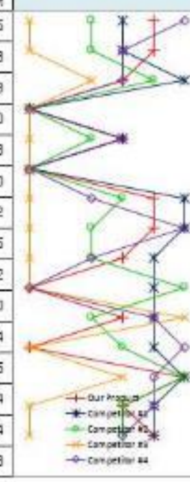
Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼

WHO: Customers

HOW: Engineering Specifications / WHAT: Customer Requirements (explicit & implicit)

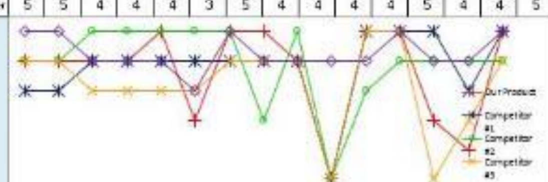
Row #	Relative Weight	Importance	Maximum Relationship	Column # →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	One Side Gear Shear	Fitmaker (Standard Shredder)	Wood Chipper	Weed Wacker	Seated Shredder	Row #
					Torque Input	Input RPM	Torque Output	Blade rpm	Chip Size	Vine Size	Process Rate	Product Cost	Jam Frequency	Withstands Operator Weight	Product Weight	Footprint	Stability	Max Feed Volume	Height						
1	7%	7	9	Pedal Powered	●	●	●	●	▽		○	▽	▽		▽	▽	○		○	4	3	2	0	5	1
2	8%	8	9	Unassisted Operation by Grades 1-5	●	●	○	○			▽		○				○		●	4	3	2	0	3	2
3	8%	8	9	Cuts Material into Compostable Size	○	○	●	●	●	●	●		▽		▽	○			▽	3	5	4	2	3	3
4	7%	7	9	Adjustable								▽		○	○	▽	▽		○	0	0	0	0	0	4
5	8%	9	9	Safety	▽	▽	○	○			▽		○	●	○	▽	●		○	3	3	2	0	3	5
6	6%	6	9	Able to support adults										●	○		●		○	0	0	0	0	0	6
7	6%	6	9	Portable											●	●	○		●	4	5	3	0	2	7
8	7%	7	9	No Electrical Power	●	●	●	●	▽		○	○	▽		○	○	○			4	5	2	0	5	8
9	7%	7	9	Engaging/Inclusive for Children	○	○	○	○	▽				○				▽		▽	3	4	2	0	2	9
10	8%	8	9	Removable Receptacle					○		○	○				▽	▽			0	4	5	0	0	10
11	7%	7	9	Long Lasting/Maintainable	●	●	●	●	○	○	○	●	●	●	○	▽	▽			3	4	2	5	4	11
12	6%	6	9	Easy to Load						●	○					▽		●		0	4	3	0	5	12
13	8%	8	9	Fits into available storage space										▽	▽	●	○	○	●	5	5	5	3	4	13
14	6%	6	9	Able to cut thick vines	○	○	●	●	○	●	○	▽	●		▽					3	4	3	0	4	14
15	6%	6	9	Efficiency	●	●	●	●	○	○	●		○			▽		●	▽	4	4	3	0	3	15

NOW: Current Product Assessment - Customer Requirements



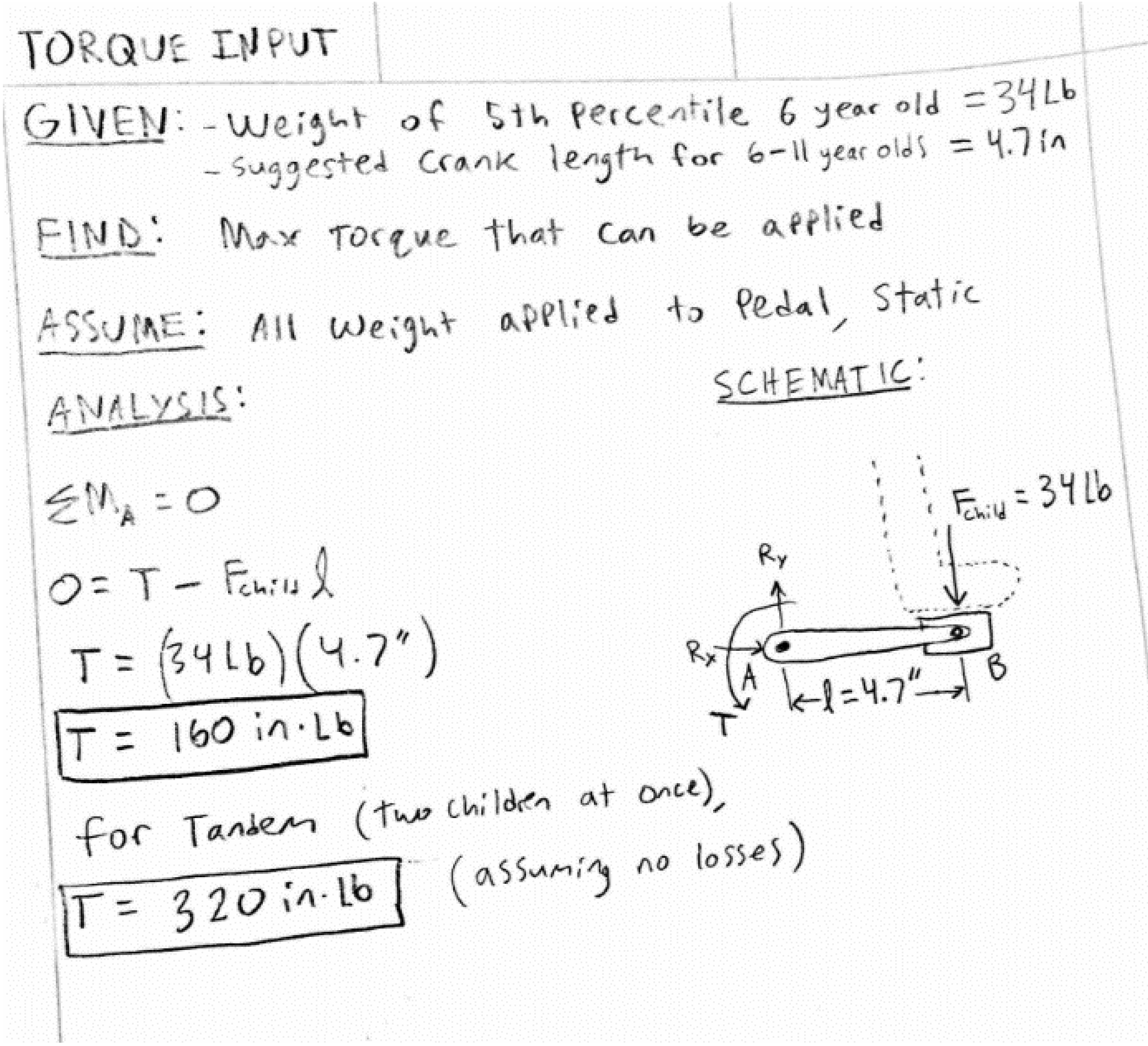
Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
HOW MUCH: Target	180 ft*lb	60 rpm	900 ft*lb	10 rpm	1 in²	3 in diameter	0.8 lbs/min	$1,000	3 Jams/hr	300 lb	60 lb	4' x 3' x 2'	100% Applied at Highest Point	1.6 ft³	4ft
Max Relationship	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Technical Importance Rating	365	365	416	416	164	207	251	121	216	214	180	205	257	125	289
Relative Weight	10%	10%	11%	11%	4%	5%	7%	3%	6%	6%	5%	5%	7%	3%	8%
Weight Chart															
One Side Gear Shear	4	4	4	4	5	2	5	5	4	0	5	5	2	1	5
Fitmaker (Standard Shredder)	3	3	4	4	4	4	4	4	4	0	5	5	5	3	5
Wood Chipper	4	4	5	5	5	5	5	2	5	0	3	4	4	4	4
Weed Wacker	4	4	3	3	3	3	4	4	4	0	5	5	0	2	4
Seated Shredder	5	5	4	4	4	3	5	4	4	4	4	5	4	4	5

Current Product Assessment - Engineering Specifications



Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Appendix B – Hand Calculations



TORQUE INPUT

GIVEN: - Weight of 5th percentile 6 year old = 34 Lb
- Suggested crank length for 6-11 year olds = 4.7 in

FIND: Max Torque that can be applied

ASSUME: All weight applied to pedal, static

ANALYSIS:

$\Sigma M_A = 0$

$0 = T - F_{child}\,\ell$

$T = (34\,\text{Lb})(4.7'')$

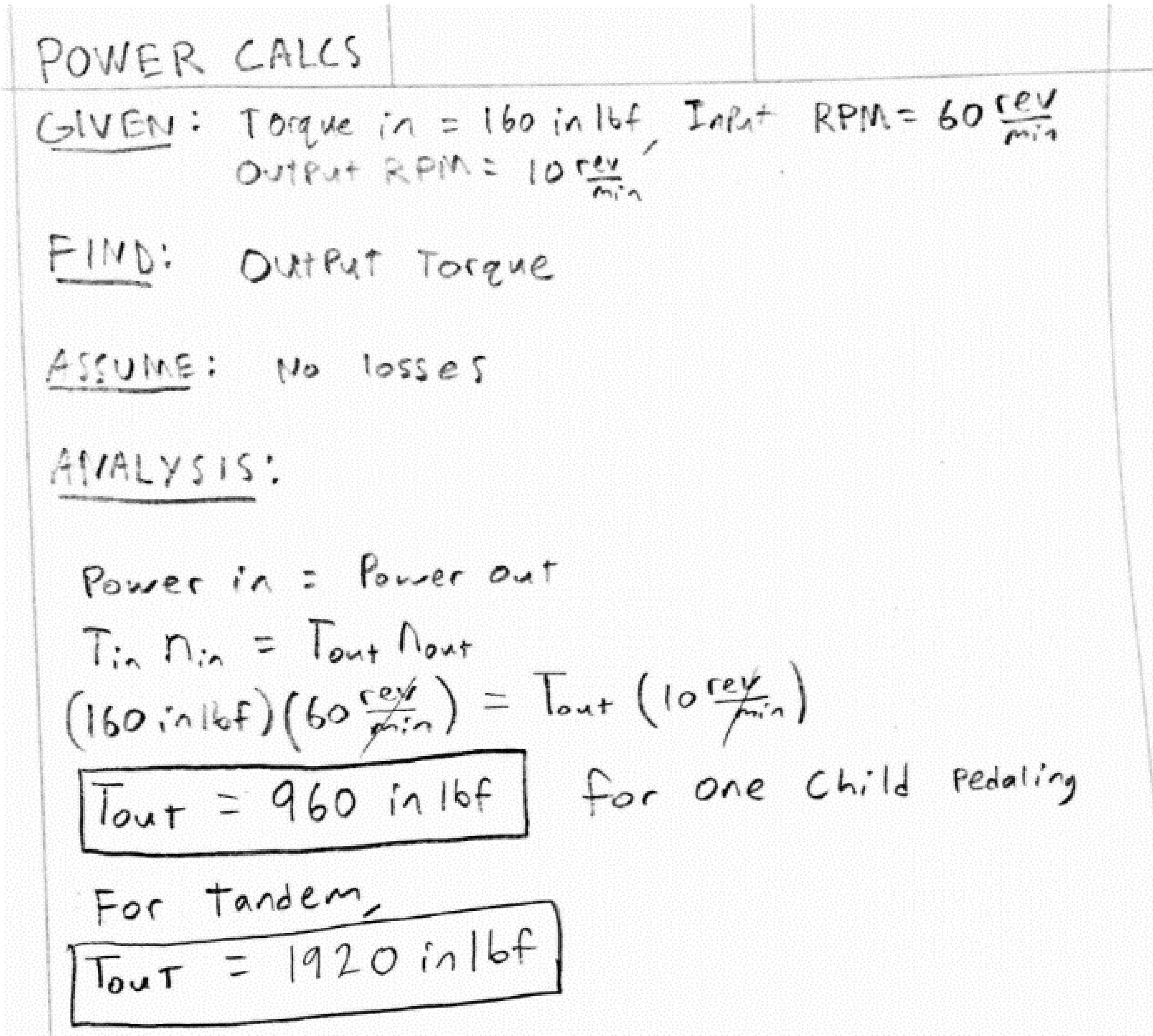
$T = 160\ \text{in}\cdot\text{Lb}$

for Tandem (two children at once),

$T = 320\ \text{in}\cdot\text{lb}$ (assuming no losses)

SCHEMATIC:

Figure B-1. Torque input calculations for single and 2 person tandem pedaling.



POWER CALCS

GIVEN: Torque in = 160 in lbf, Input RPM = 60 $\frac{rev}{min}$, Output RPM = 10 $\frac{rev}{min}$

FIND: Output Torque

ASSUME: No losses

ANALYSIS:

Power in = Power out

$T_{in} n_{in} = T_{out} n_{out}$

$(160 \text{ in lbf})(60 \frac{rev}{min}) = T_{out} (10 \frac{rev}{min})$

$T_{out} = 960 \text{ in lbf}$ for one Child pedaling

For tandem,

$T_{out} = 1920 \text{ in lbf}$

Figure B-2. Power calculations for single and 2 person tandem pedaling.

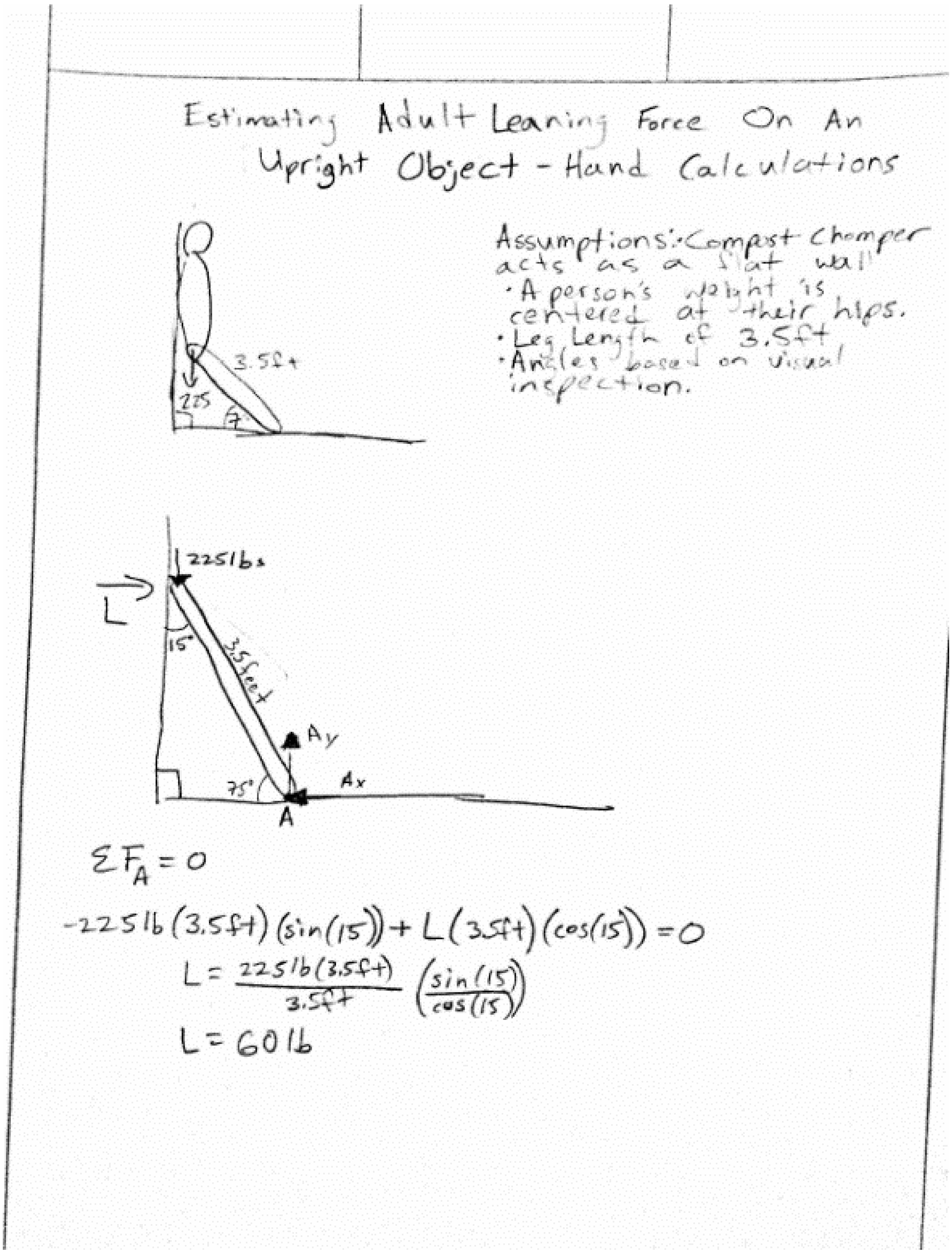


Figure B-3. Estimating leaning force of an adult leaning on the Compost Chomper.

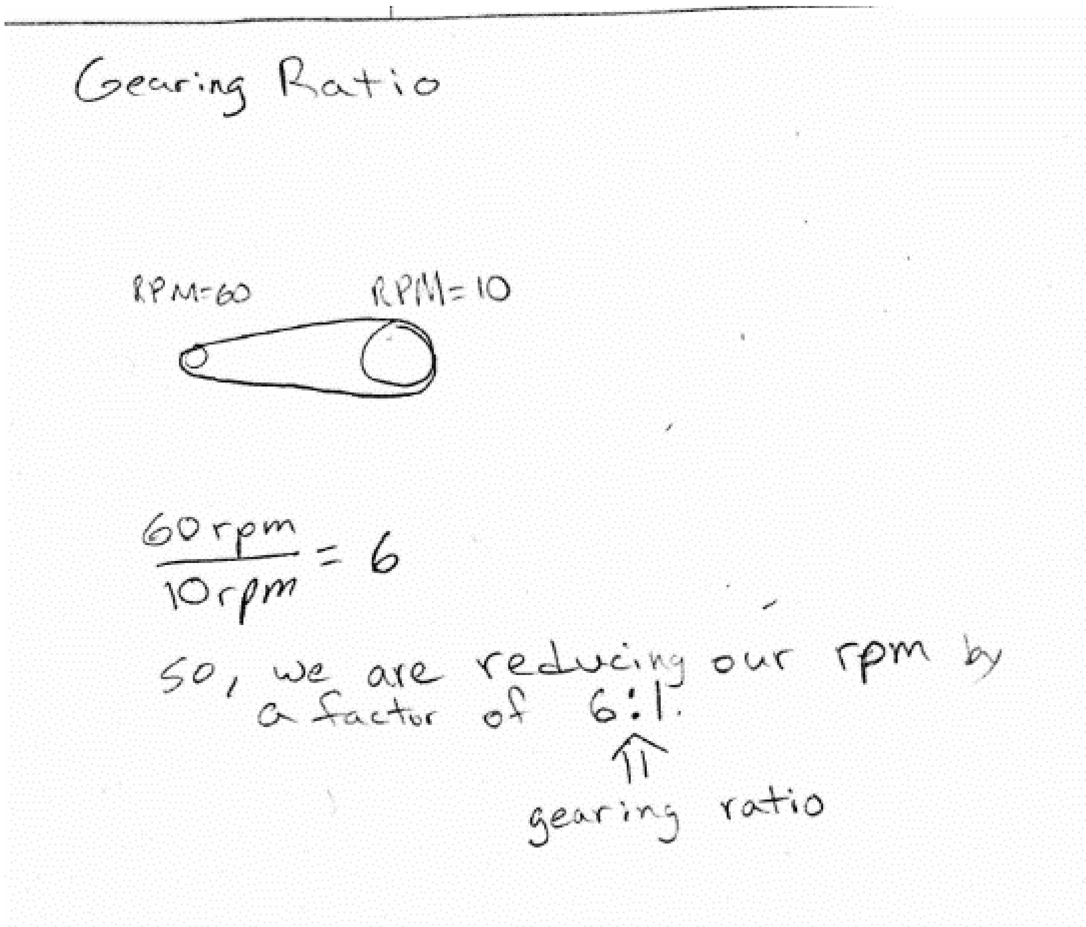
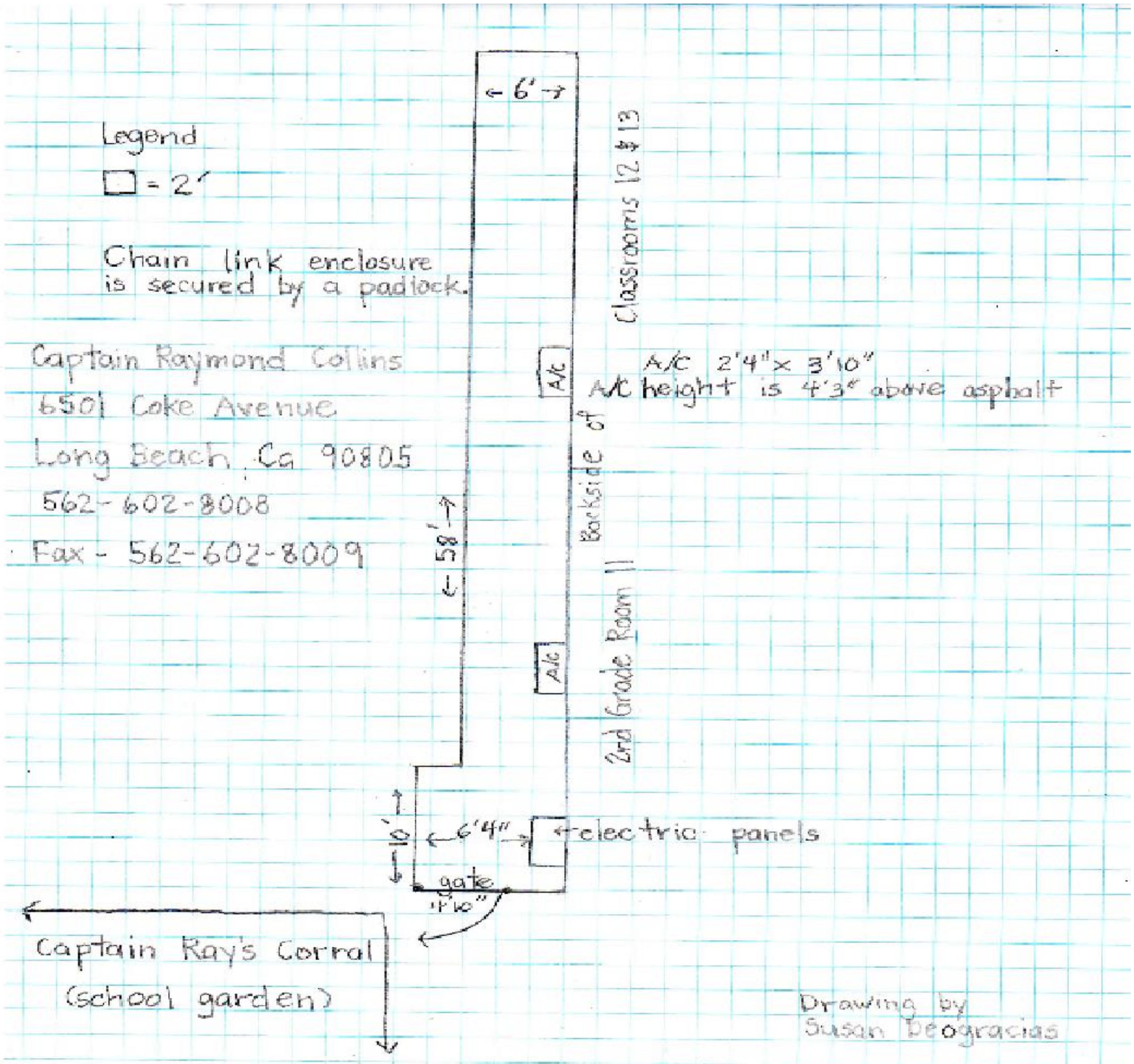
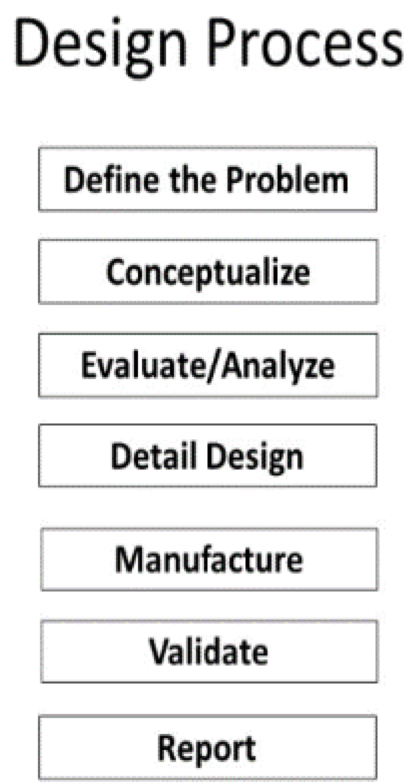


Figure B-4. Gear ratio calculations for drive train.

Appendix C – Storage Space Floor Plan



Appendix D – Design Process Flowchart (from Professor Schuster's 2016 Senior Project lecture)



Appendix E – Top Subsystem Concept Sketches

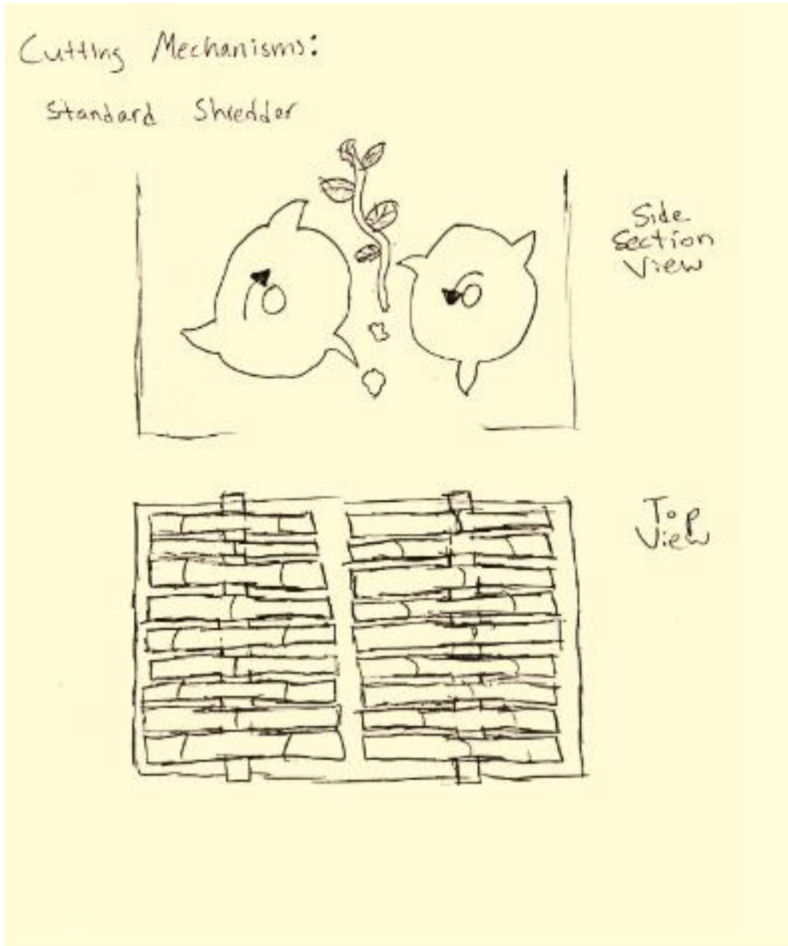


Figure E-1. Standard Shredder cutting mechanism

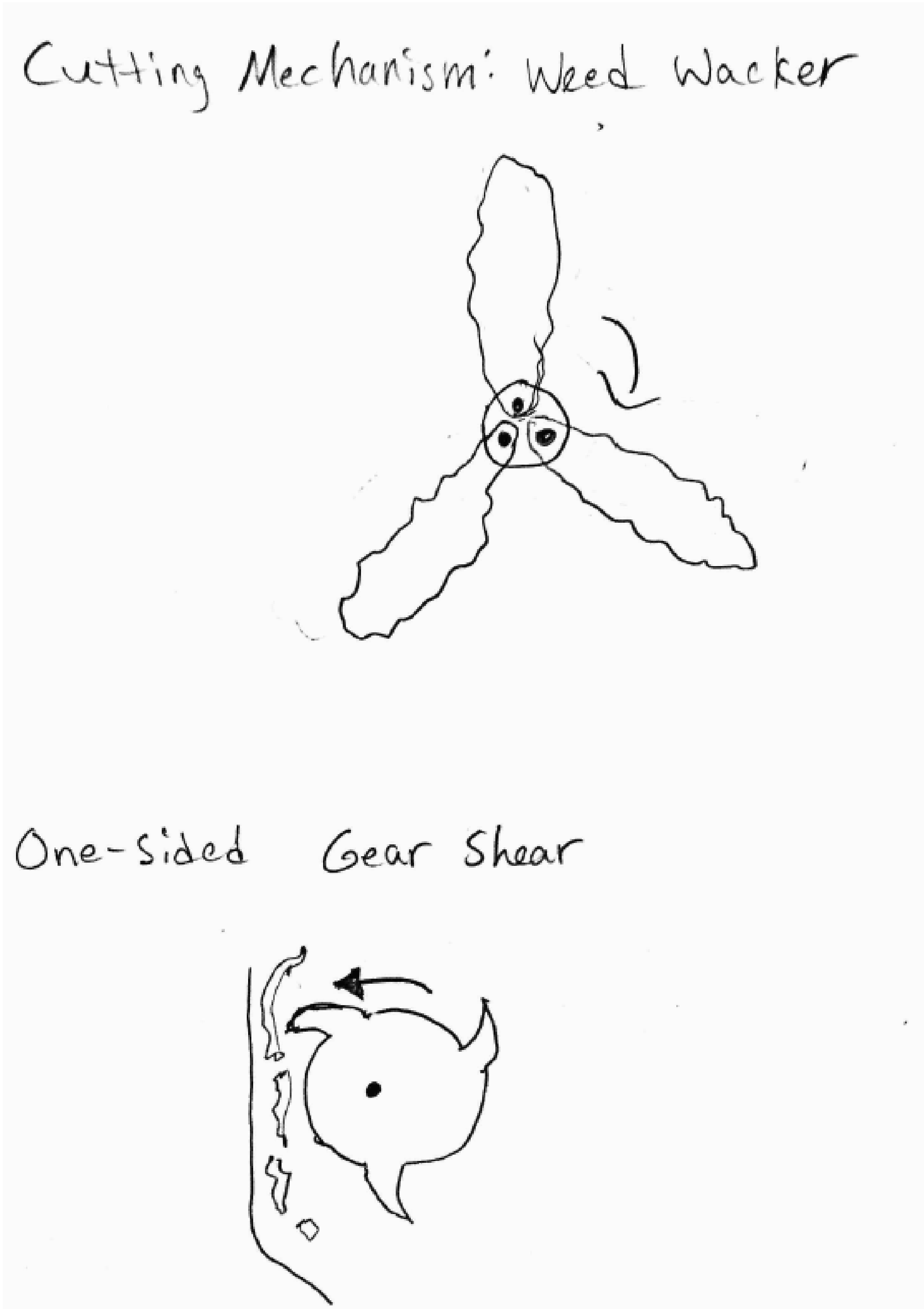


Figure E-2. Weed whacker and One-sided Gear Shear cutting mechanisms

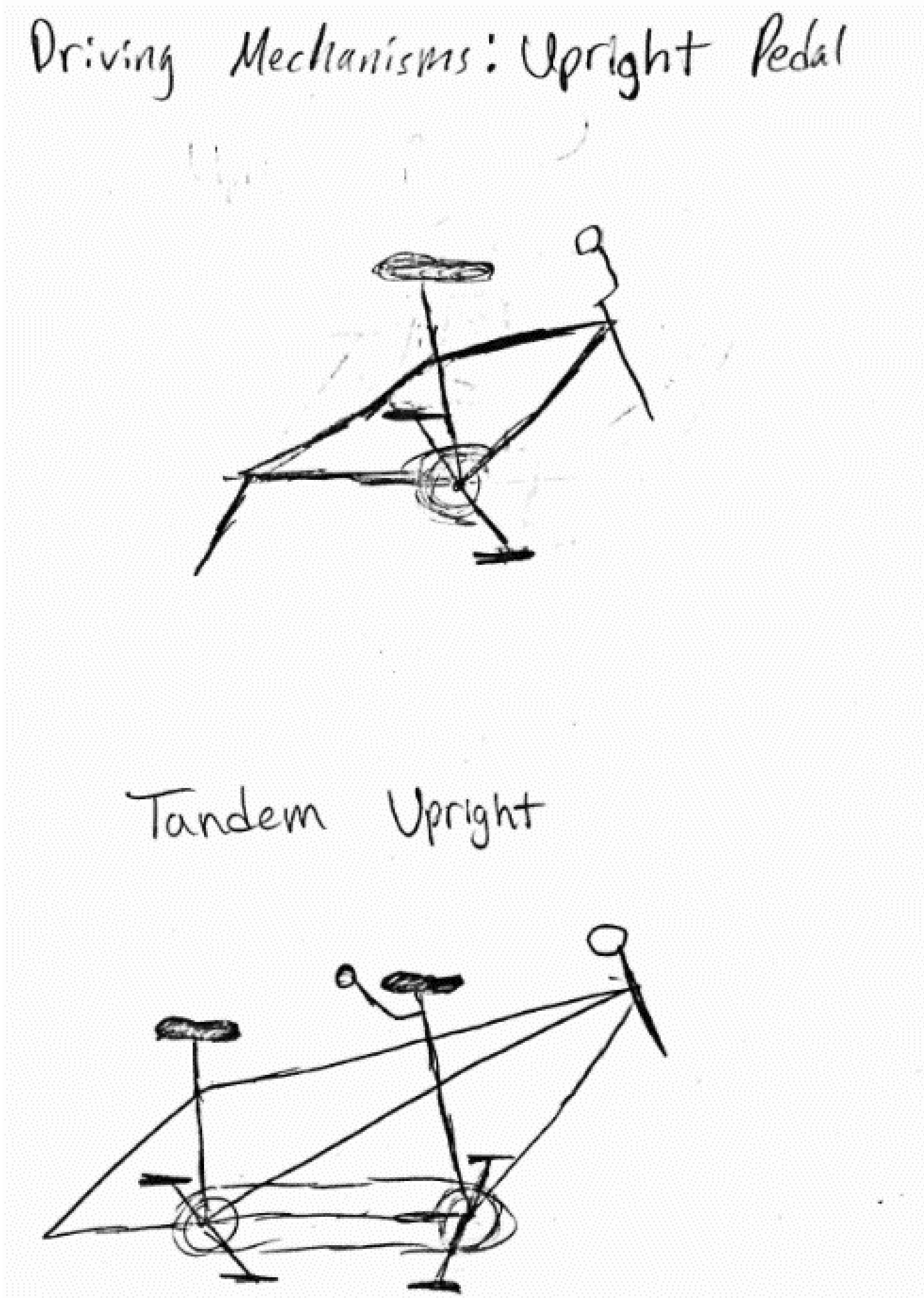


Figure E-3. Upright Pedal and Tandem Pedal Driving Mechanisms

Figure E-4. Horizontal driving mechanism

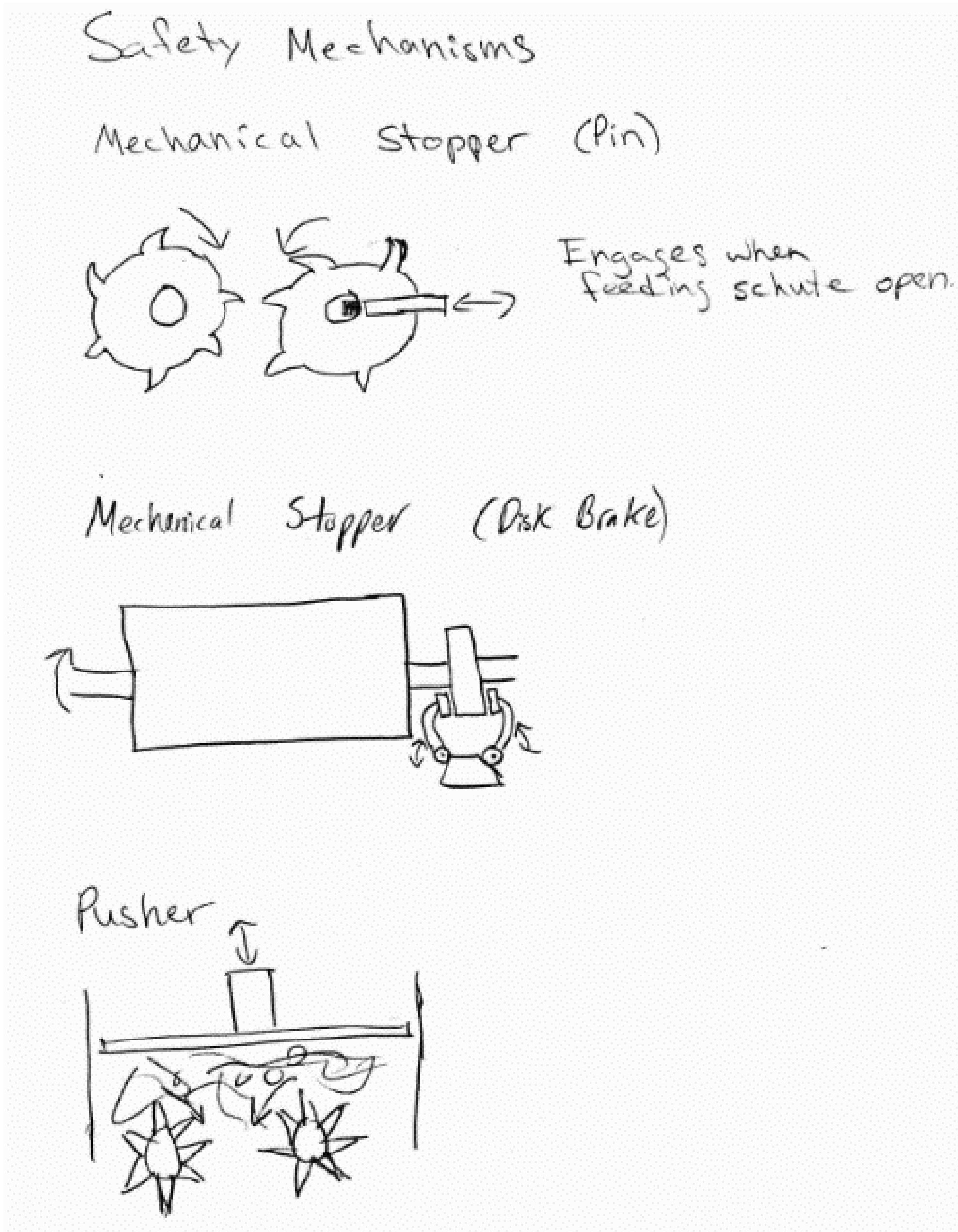


Figure E-5. Mechanical stopper and Pusher safety mechanisms

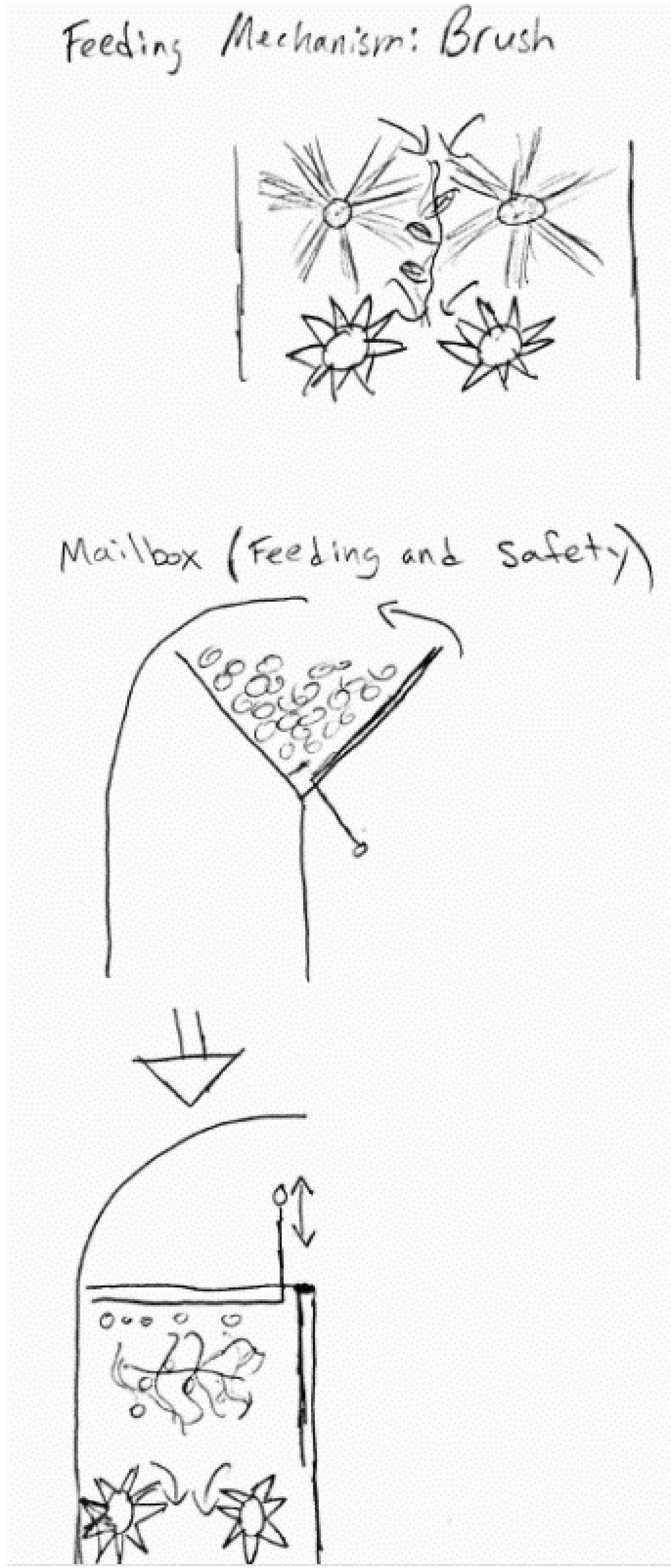


Figure E-6. Brush and Mailbox feeding mechanisms

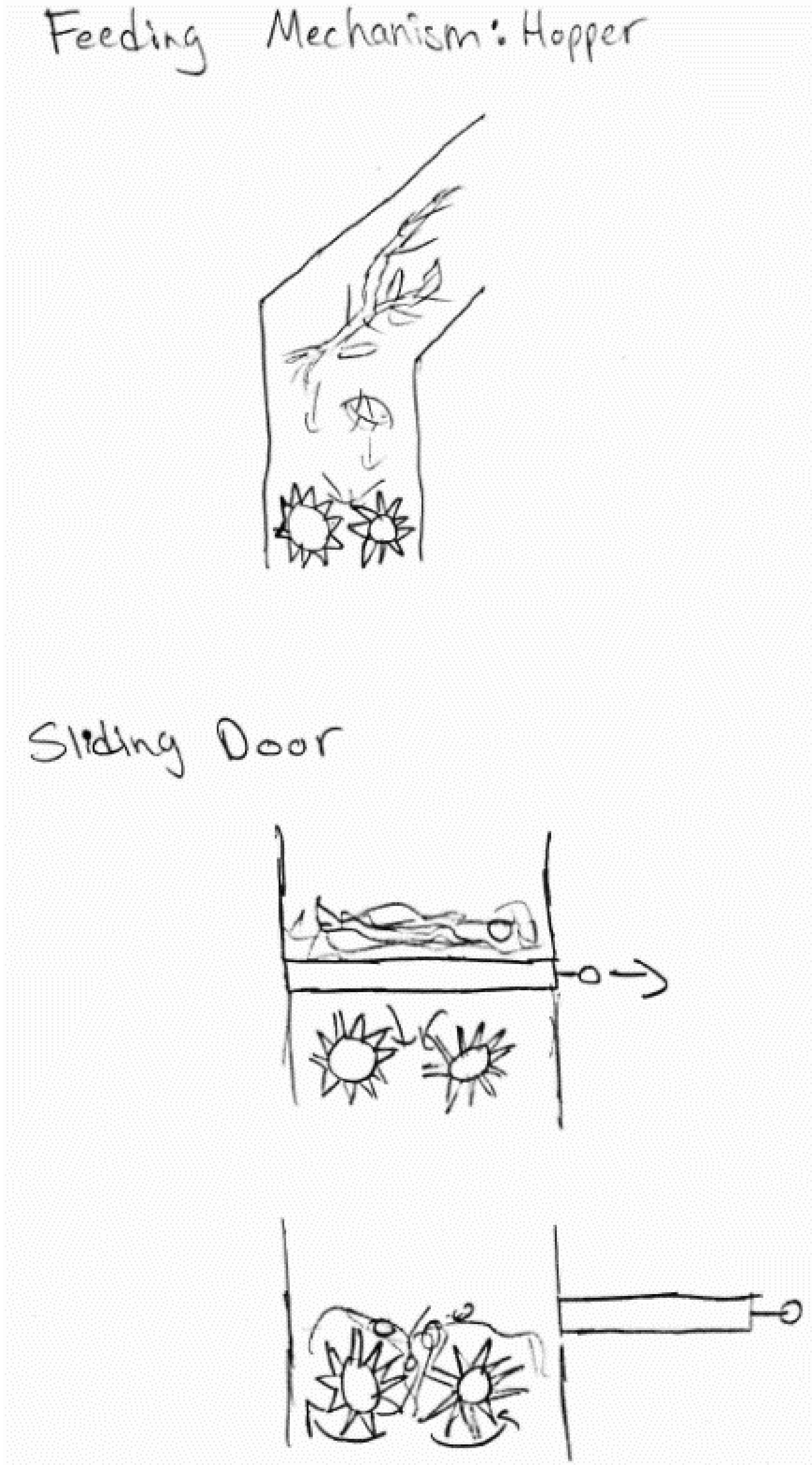


Figure E-7. Hopper and Sliding Door feeding mechanisms

Appendix F – Tandem Power MATLAB Code

Tandem Power

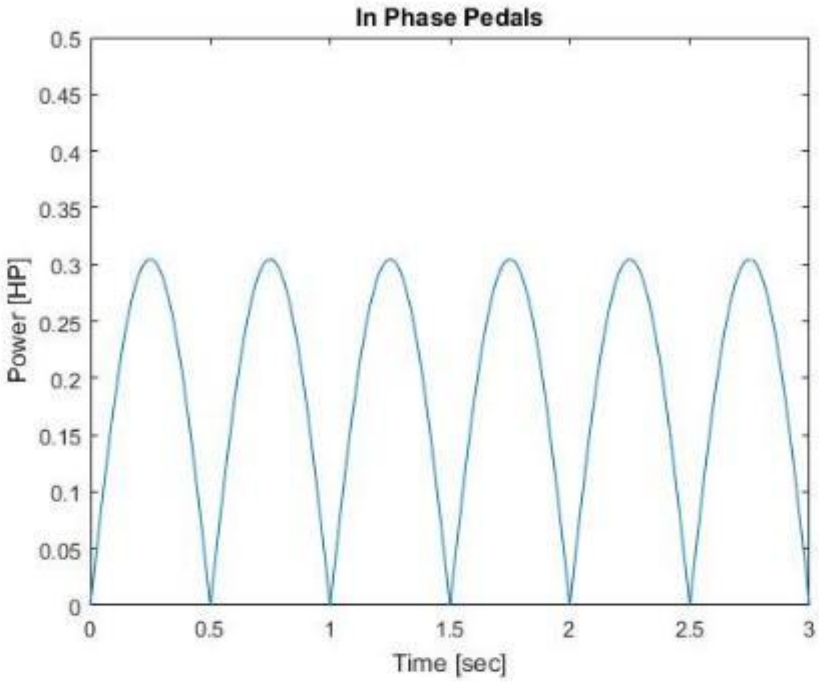
This file provides projected power output plots for a tandem bicycle.

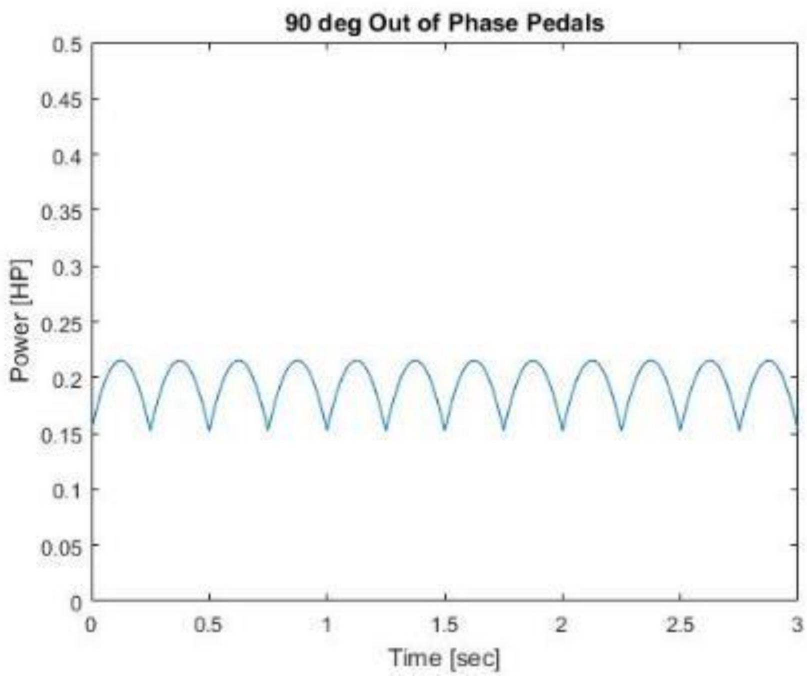
```
clear
clc

Tmax=160;    %in-lbf max torque created by one student
RPM=60;      %rpm of a student riding a bike, this will be assumed to be constant
w=2*pi*RPM/60;      %frequency in rad/s


% For in phase pedaling
syms t
figure(1)
%plots power in horsepower for in phase
fplot((Tmax*RPM/12/5252)*abs(sin(w*t))+(Tmax*RPM/12/5252)*abs(sin(w*t)),[0 3])
title('In Phase Pedals')
ylabel('Power [HP]')
xlabel('Time [sec]')
axis([0,3,0,.5])

% For 90 deg out of phase
figure(2)
%plot power in horsepower for out of phase
fplot((Tmax*RPM/12/5252)*abs(sin(w*t))+(Tmax*RPM/12/5252)*abs(cos(w*t)),[0 3])
title('90 deg Out of Phase Pedals')
ylabel('Power [HP]')
xlabel('Time [sec]')
axis([0,3,0,.5])
```


In Phase Pedals
Power [HP]
Time [sec]
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.5
1
1.5
2
2.5
3


90 deg Out of Phase Pedals
Power [HP]
Time [sec]
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.5
1
1.5
2
2.5
3

Appendix G – Specification Satisfaction Calculations

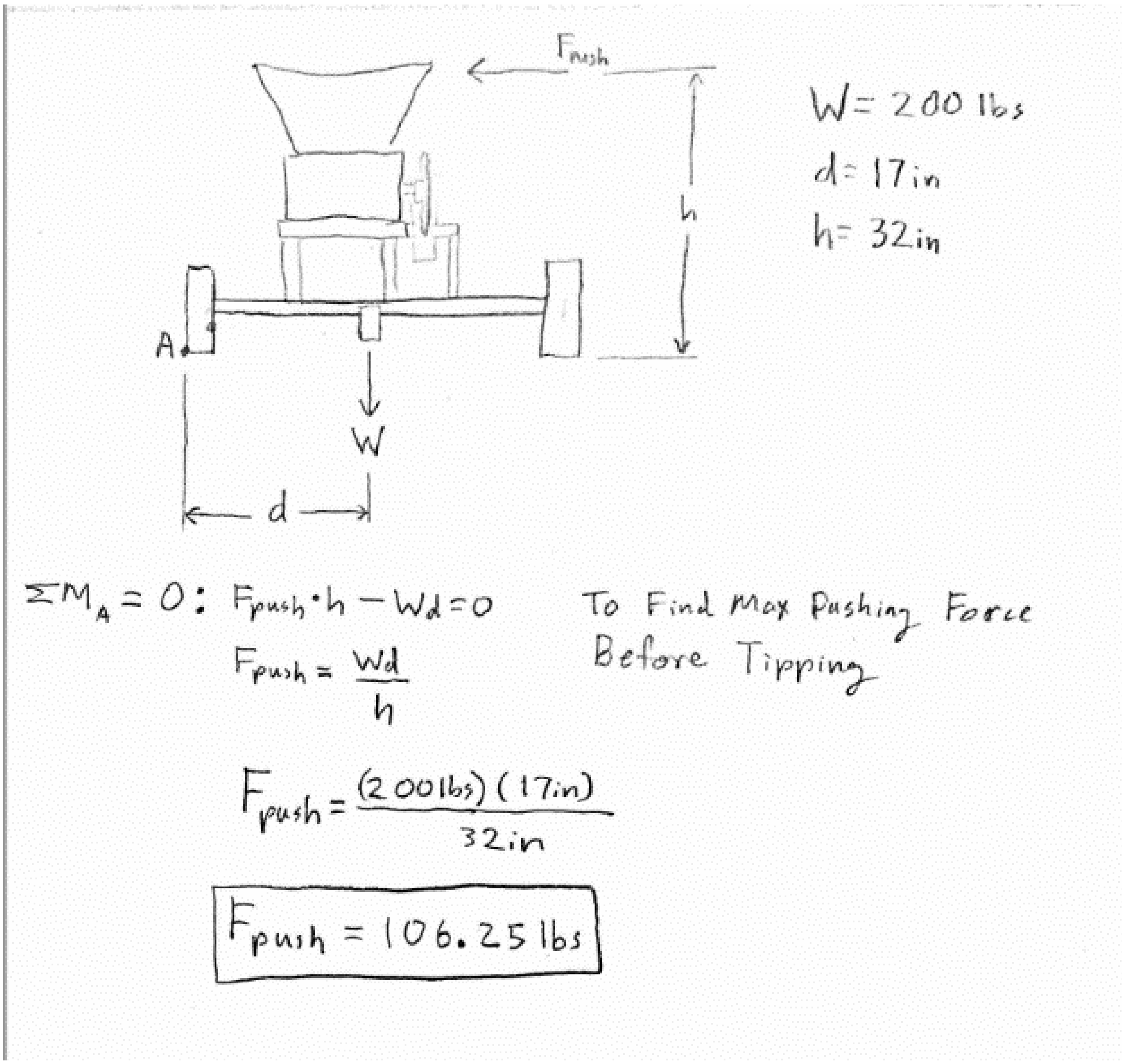
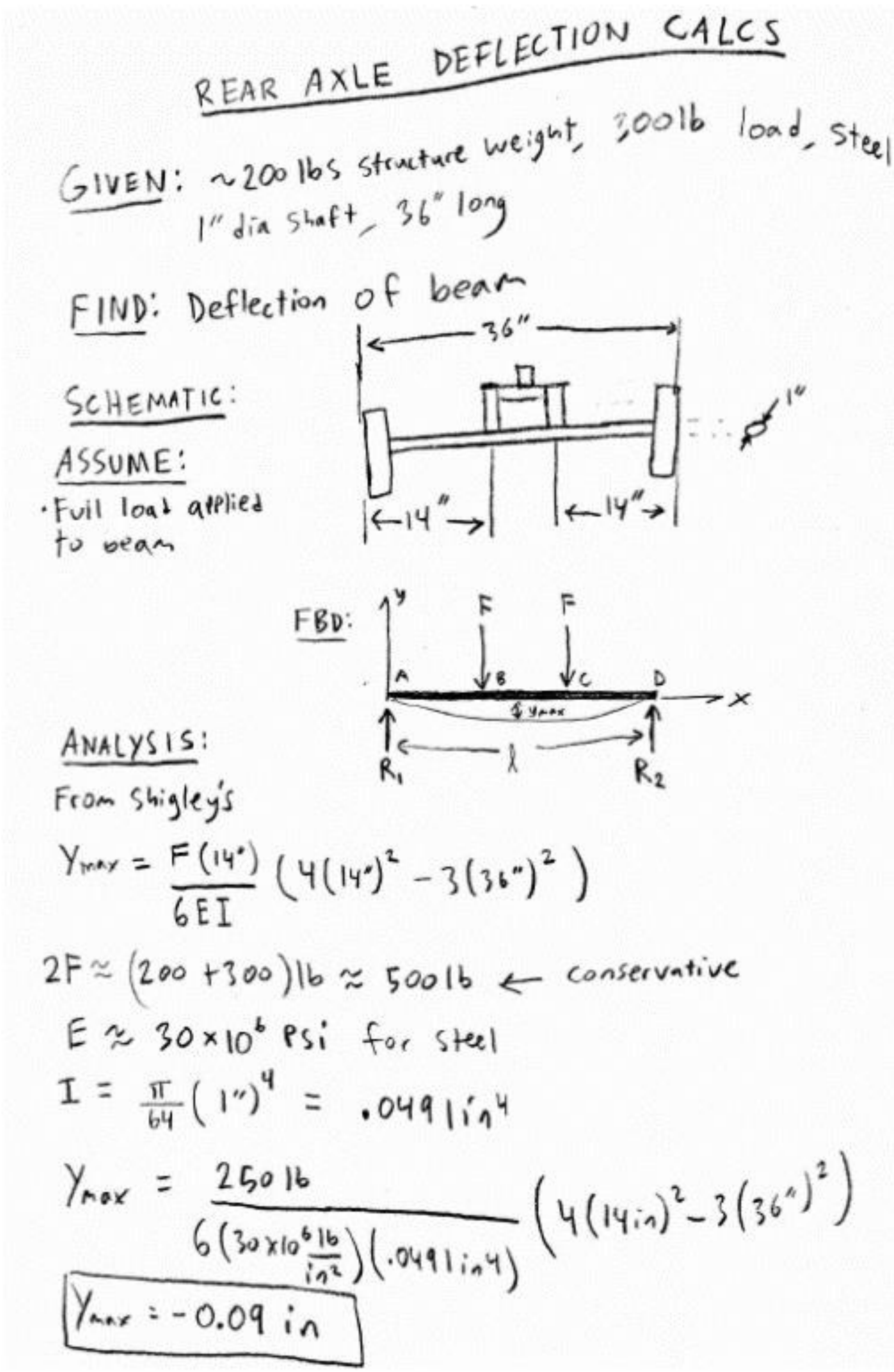


Figure G-1. Tipping Force Analysis



REAR AXLE DEFLECTION CALCS

GIVEN: ~200 lbs structure weight, 300lb load, steel
1" dia shaft, 36" long

FIND: Deflection of beam

SCHEMATIC:

ASSUME:
- Full load applied to beam

36"
1"
14"
14"

FBD:
y
F
F
A
B
C
D
x
y_{max}
R_1
l
R_2

ANALYSIS:
From Shigley's

$$Y_{max} = \frac{F(14")}{6EI}\left(4(14")^2 - 3(36")^2\right)$$

$2F \approx (200 + 300)\,lb \approx 500\,lb$ ← conservative

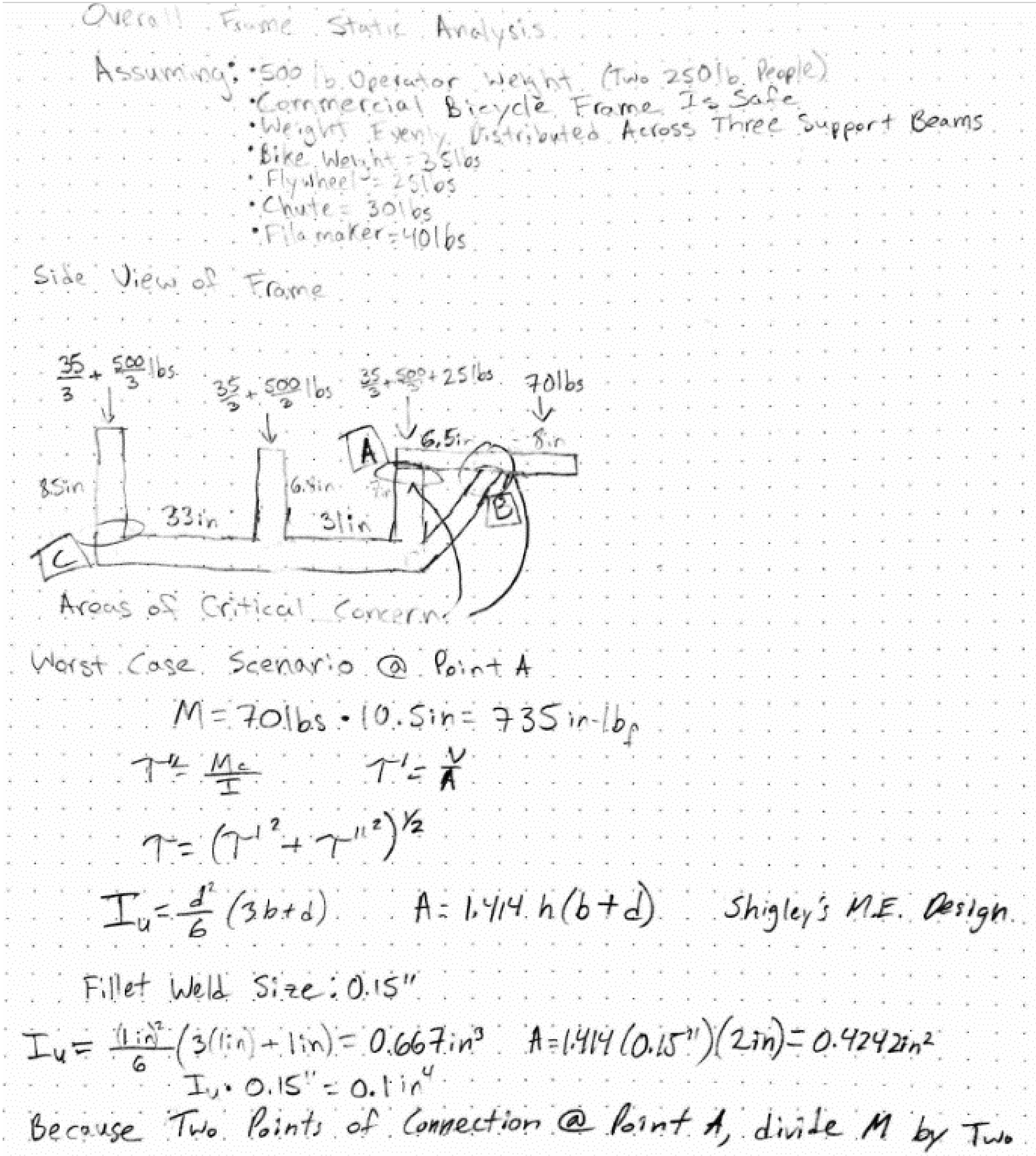
$E \approx 30 \times 10^6$ psi for steel

$$I = \frac{\pi}{64}(1")^4 = .0491\,in^4$$

$$Y_{max} = \frac{250\,lb}{6\left(30 \times 10^6 \frac{lb}{in^2}\right)(.0491\,in^4)}\left(4(14\,in)^2 - 3(36")^2\right)$$

$Y_{max} = -0.09$ in

Figure G-2. Rear Axle Deflection Calculations



Overall Frame Static Analysis

Assuming:
- 500 lb Operator Weight (Two 250 lb People)
- Commercial Bicycle Frame Is Safe
- Weight Evenly Distributed Across Three Support Beams
- Bike Weight = 35 lbs
- Flywheel = 25 lbs
- Chute = 30 lbs
- Filamaker = 40 lbs

Side View of Frame

Areas of Critical Concern

Worst Case Scenario @ Point A

$$M = 70\,lbs \cdot 10.5\,in = 735\,in\text{-}lb_f$$

$$\tau'' = \frac{Mc}{I} \qquad \tau' = \frac{V}{A}$$

$$\tau = (\tau'^2 + \tau''^2)^{1/2}$$

$$I_u = \frac{d^2}{6}(3b+d) \qquad A = 1.414\,h(b+d)$$ Shigley's M.E. Design

Fillet Weld Size: 0.15"

$$I_u = \frac{(1\,in)^2}{6}(3(1\,in) + 1\,in) = 0.667\,in^3 \qquad A = 1.414(0.15")(2\,in) = 0.4242\,in^2$$

$$I_u \cdot 0.15" = 0.1\,in^4$$

Because Two Points of Connection @ Point A, divide M by Two

Figure G-3. Critical Weld Stress Analysis Part 1

@ Point B

$\tau' = \frac{V}{A}$ $\tau'' = \frac{Mc}{I}$

Worst Case Scenario

$M = 70\,lb_f \cdot 4\,in$

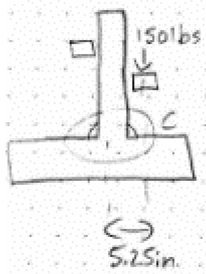
$M = 280\,in\text{-}lb_f$

$I = 0.1\,in^4$

$$\tau'' = \frac{(280\,in\text{-}lbs)(0.5\,in)}{0.1\,in^4} = 1400\,lb_f/in^2$$

$$\tau' = 70\,lb_f / 1.414(0.15)(2) = 165.02\,lb_f/in^2$$

$$\tau_B = \left((1400\,lbs/in^2)^2 + (165.02\,lb_f/in^2)\right)^{1/2} = 1409.7\,lb_f/in^2$$



Case: 150lbs on one pedal at each seat
Total Loading 300lbs at pedal location
Pedal is 5.25in from center of support beam

Worst case: All bending caused by loading on one weld joint (in reality will be split between the three weld joints on the support beams)

$\tau' = \frac{V}{A}$

$A = 0.707(0.15)(1") = 0.10605\,in^2$

$\tau'' = \frac{Mr}{J}$ $M = 300\,lb_f \cdot 5.25\,in = 1575\,in\text{-}lb_f$ $r = 0.5\,in$

$J = \frac{4}{6} \cdot 0.15$ Shigley's

$J = 0.1$

$$\tau'' = \frac{1575\,in\text{-}lb_f \cdot 0.5\,in}{0.1\,in^4} = 7875\,lb_f/in^2$$

$$\tau' = \frac{300\,lb_f}{0.10605\,in^2} = 2828.9\,lbs/in^2$$

$$\tau_C = \left((2828.9\,psi)^2 + (7875\,psi)^2\right)^{1/2} = 8367.7\,psi$$

Figure G-4. Critical Weld Stress Analysis Part 2

According to Shigley's ME Design Textbook:

Tensile Yield Strength: 57 kpsi

Factors of Safety:

Point A: $\frac{57\text{ kpsi}}{1844.7} = 30.9 = n_A$

Point B: $\frac{57\text{ kpsi}}{1409.7} = 40.43 = n_B$

Point C: $\frac{57\text{ kpsi}}{8367.7} = 6.8 = n_c$

Even in most extreme case, which is impossible due to the other two support beams, we still have a factor of safety of 6.8.

Frame Is Safe For Design Loads

Figure G-5. Critical Weld Stress Analysis Part 3

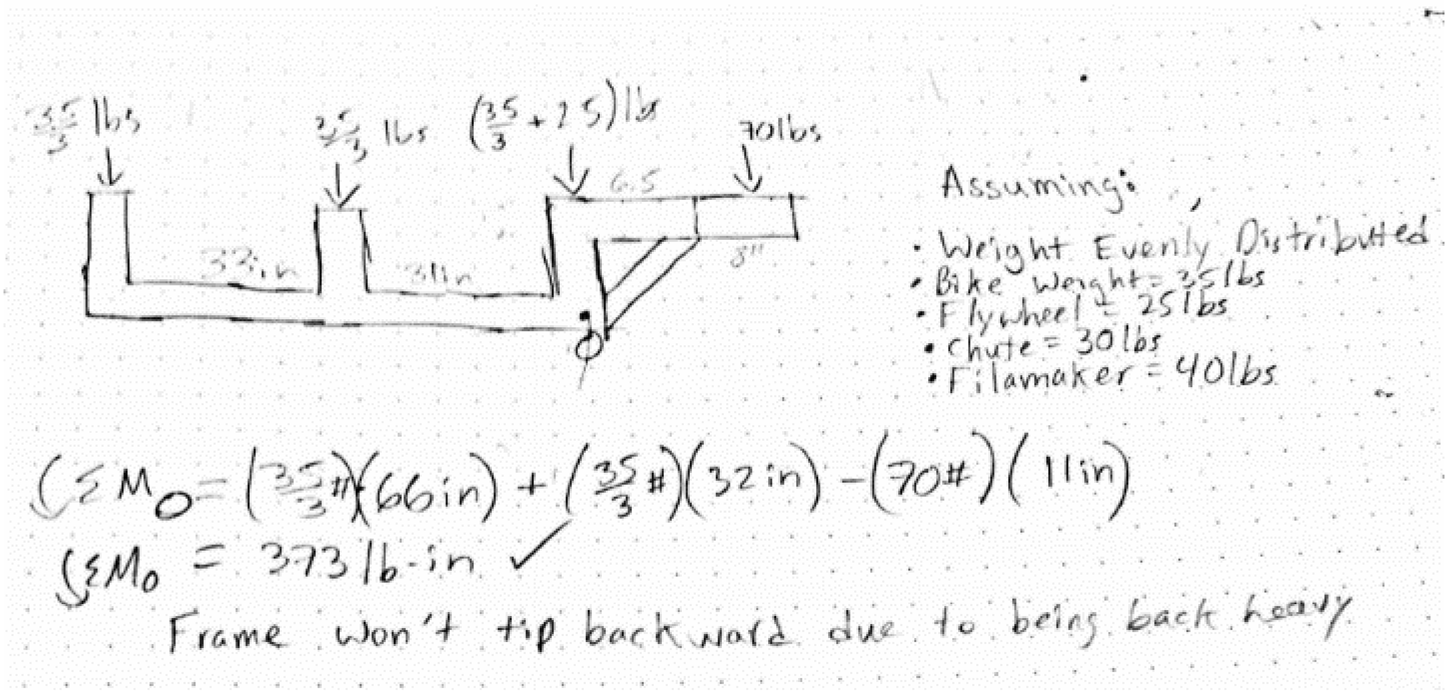


Figure G-6. Frame Tipping Due to Imbalance Calculations

Variables	Values	Units	Constraint		Equations	Values	Units	Constraint	
One Step After Bike									
N6	20	Teeth	11<=N_6<=60		e=(N_6*N_14)/(N_7*N_15)	0.3333	-	1/3<=e<=1/2	
N7	12	Teeth	11<=N_7<=60		N_6/N_7	1.66666666	-	<=6	
N14	12	Teeth	11<=N_14<=60		N_15/N_14	5	-	<=6	
N15	60	Teeth	11<=N_15<=60		(N_6/N_7)^2	2.77777777	-	Max	
					Input RPM	60	rev/min		
					Output RPM	20	rev/min		
					Flywheel RPM	100	rev/min		
Two Steps After Bike									
N_4	30	Teeth	11<=N_6<=60		e=(N_4*N_12*N_14)/(N_5_11*N_13*N_15)	0.1833	-	0.1666666667	
N_5_11	11	Teeth	11<=N_7<=60		N_4/N_5_11	2.72727272	-	<=6	
N_12	11	Teeth	11<=N_14<=60		N_13/N_12	5.45454545	-	<=6	
N_13	60	Teeth	11<=N_15<=60		N_15/N_14	2.72727272	-	<=6	
N_14	11	Teeth	11<=N_15<=60		(N_4/N_5_11)^2	7.43801652	-	Max	
N_15	30	Teeth	11<=N_15<=60		Input RPM	60	rev/min		
					Output RPM	11	rev/min		
					Flywheel RPM	163.636363		2.67768595	x more ener

Figure G-7. Bicycle Drive Train Sprocket Tooth/RPM Optimization Spreadsheet; Refer to Figure G-8 For Accompanying Sketches

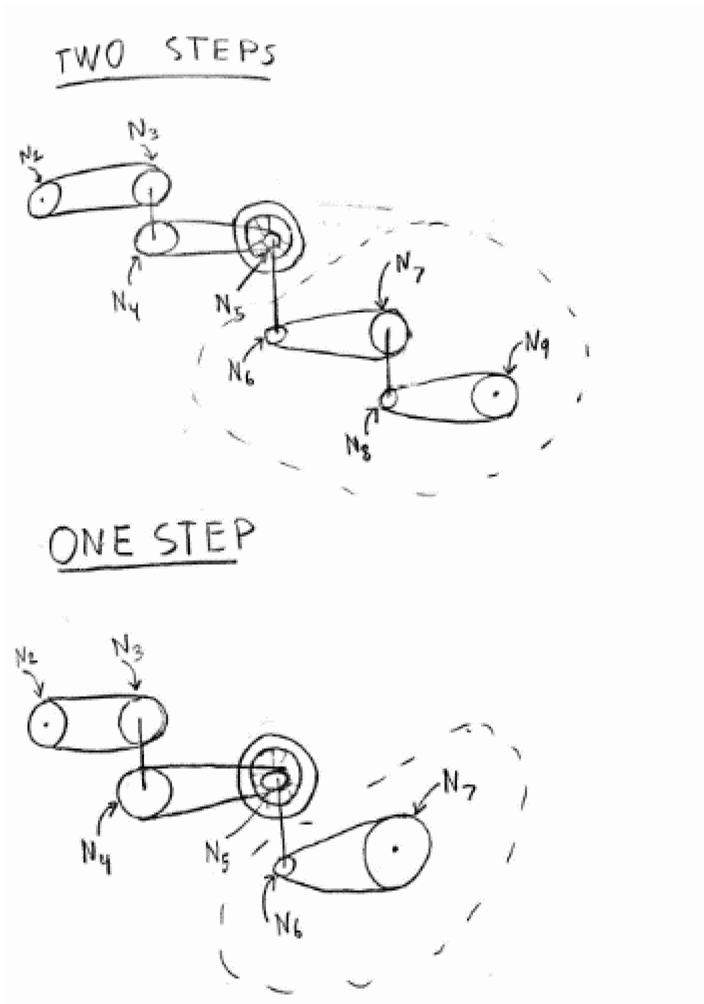


Figure G-8. Drive Train Considerations; Refer to Figure G-7 For Accompanying Optimization Spreadsheet

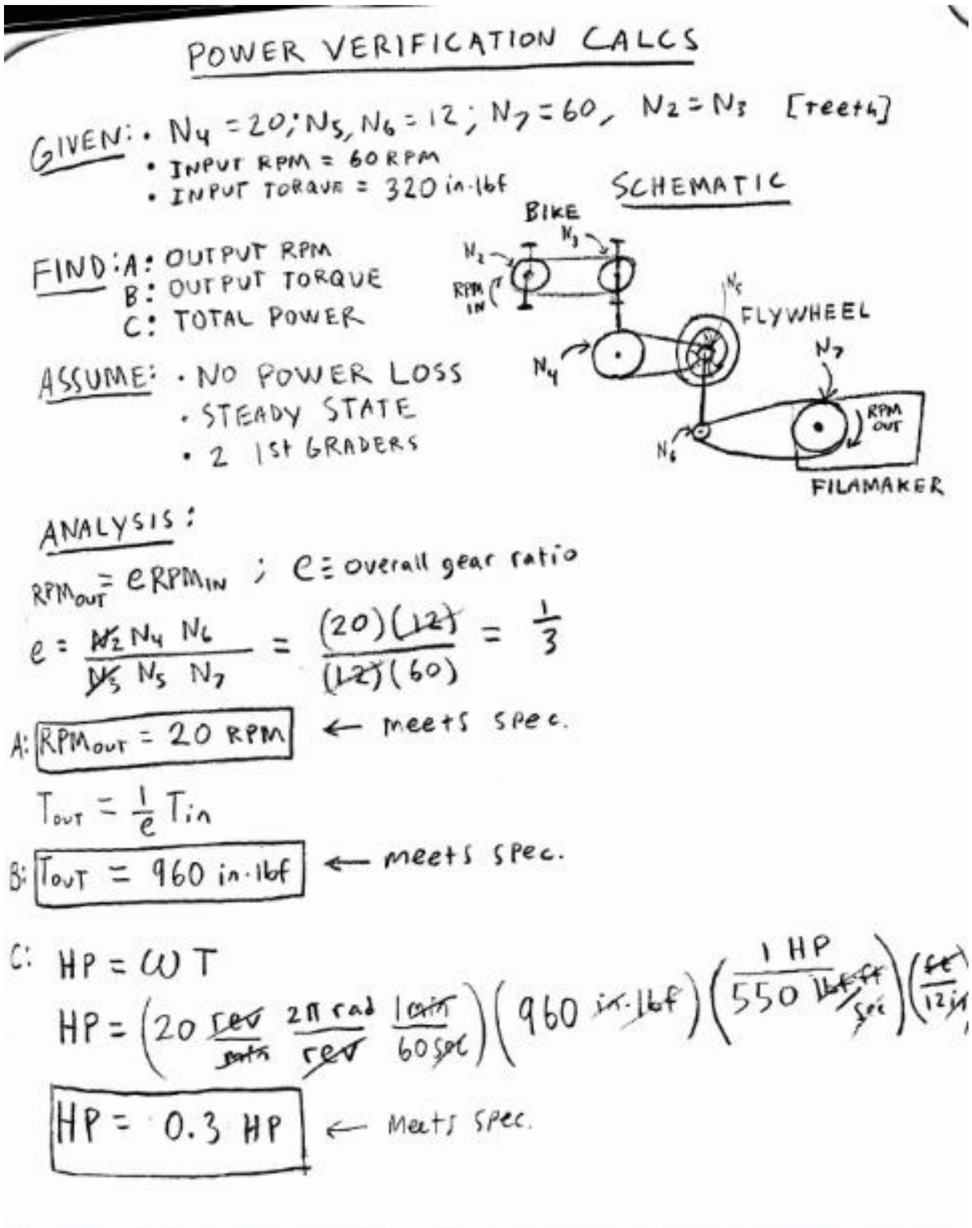
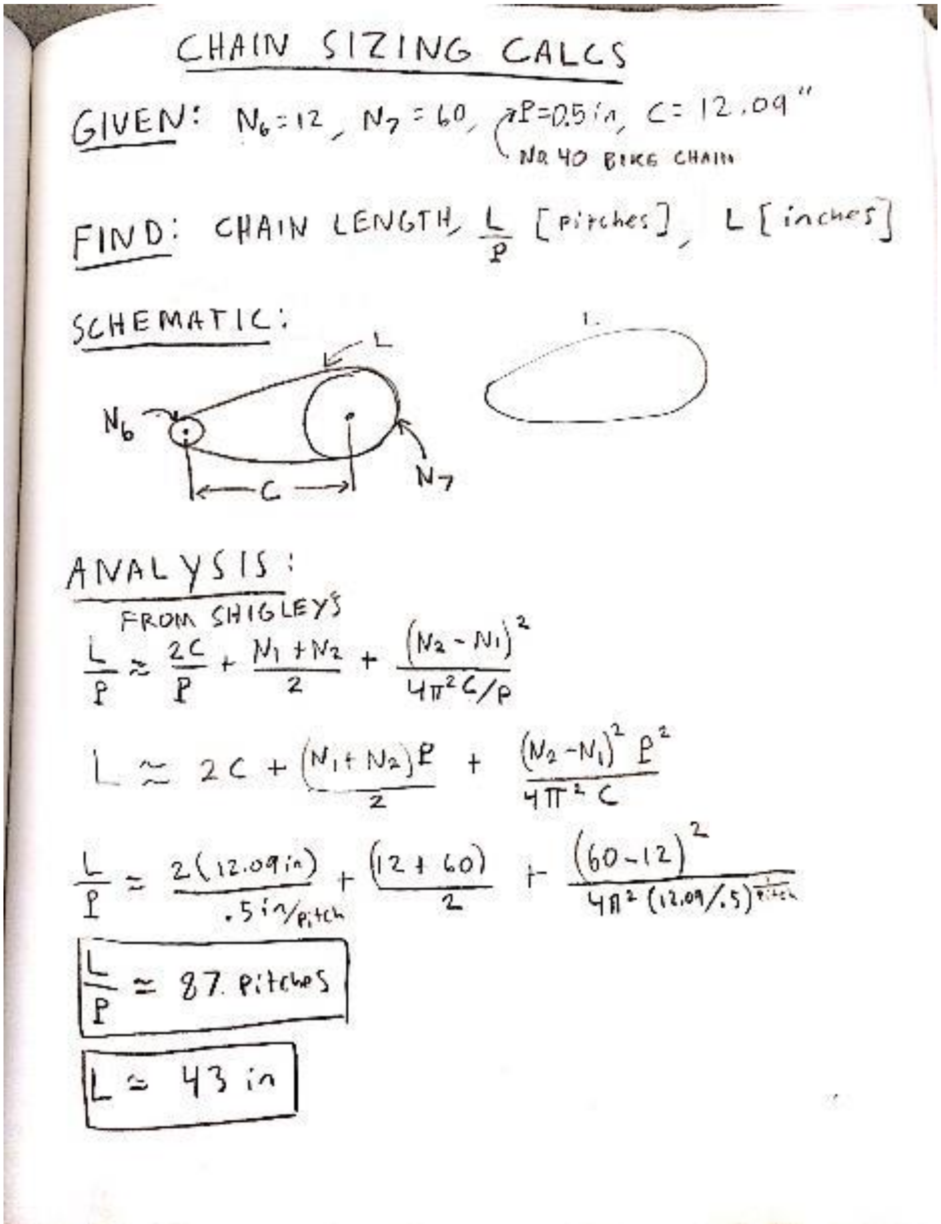


Figure G-9. Power Verification for Given Sprocket Sizes



CHAIN SIZING CALCS

GIVEN: $N_6 = 12$, $N_7 = 60$, $P = 0.5$ in (NO 40 BIKE CHAIN), $C = 12.09''$

FIND: CHAIN LENGTH $\frac{L}{P}$ [pitches], L [inches]

SCHEMATIC:

ANALYSIS:

FROM SHIGLEYS

$$\frac{L}{P} \approx \frac{2C}{P} + \frac{N_1 + N_2}{2} + \frac{(N_2 - N_1)^2}{4\pi^2 C/P}$$

$$L \simeq 2C + \frac{(N_1 + N_2)P}{2} + \frac{(N_2 - N_1)^2 P^2}{4\pi^2 C}$$

$$\frac{L}{P} \approx \frac{2(12.09\text{ in})}{.5\text{ in/pitch}} + \frac{(12+60)}{2} + \frac{(60-12)^2}{4\pi^2(12.09/.5)_{\text{pitch}}}$$

$$\frac{L}{P} \approx 87 \text{ pitches}$$

$$L \approx 43 \text{ in}$$

Figure G-10. Chain Sizing Calculations for Flywheel to Filamaker.

Appendix H - Design Hazard Checklist

DESIGN HAZARD CHECKLIST

Team: CP Compost Chomper Advisor: Sarah T. Harding

Y	N	
[x]	[ ]	1. Will any part of the design create hazardous revolving, reciprocating, running, shearing, punching, pressing, squeezing, drawing, cutting, rolling, mixing or similar action, including pinch points and sheer points?
[ ]	[x]	2. Can any part of the design undergo high accelerations/decelerations?
[x]	[ ]	3. Will the system have any large moving masses or large forces?
[ ]	[x]	4. Will the system produce a projectile?
[x]	[ ]	5. Would it be possible for the system to fall under gravity creating injury?
[ ]	[x]	6. Will a user be exposed to overhanging weights as part of the design?
[x]	[ ]	7. Will the system have any sharp edges?
[ ]	[x]	8. Will any part of the electrical systems not be grounded?
[ ]	[x]	9. Will there be any large batteries or electrical voltage in the system above 40 V?
[ ]	[x]	10. Will there be any stored energy in the system such as batteries, flywheels, hanging weights or pressurized fluids?
[ ]	[x]	11. Will there be any explosive or flammable liquids, gases, or dust fuel as part of the system?
[ ]	[x]	12. Will the user of the design be required to exert any abnormal effort or physical posture during the use of the design?
[ ]	[x]	13. Will there be any materials known to be hazardous to humans involved in either the design or the manufacturing of the design?
[ ]	[x]	14. Can the system generate high levels of noise?
[x]	[ ]	15. Will the device/system be exposed to extreme environmental conditions such as fog, humidity, cold, high temperatures, etc?
[x]	[ ]	16. Is it possible for the system to be used in an unsafe manner?
[ ]	[x]	17. Will there be any other potential hazards not listed above? If yes, please explain on reverse.

For any "Y" responses, add (1) a complete description, (2) a list of corrective actions to be taken, and (3) date to be completed on the reverse side.

Description of Hazard	Planned Corrective Action	Planned Date	Actual Date
Cutting mechanism will have moderate speed cutting blades.	Design a safety mechanism that prevents blades from spinning while device is being maintained and a safe loading mechanism during operation.	2/7/17	2/7/17
Cutting mechanism may be a relatively large rotating device.	See above action.	2/7/17	2/7/17
System could tip if enough force is applied to the side.	Design a stable base that allows for a large adult to lean on device with tipping.	2/7/17	2/7/17
Cutting blades will have sharp edges.	See first action	2/7/17	2/7/17
Device will be stored outdoors in a humid area where rust could form.	Paint device with corrosive resistant paint and use stainless steel parts wherever possible.	2/7/17	2/7/17
Device could be used to shred objects that should not be shredded.	Require adult supervision when device is in use and inform adults about what products can and can't be shredded.	2/7/17	2/7/17

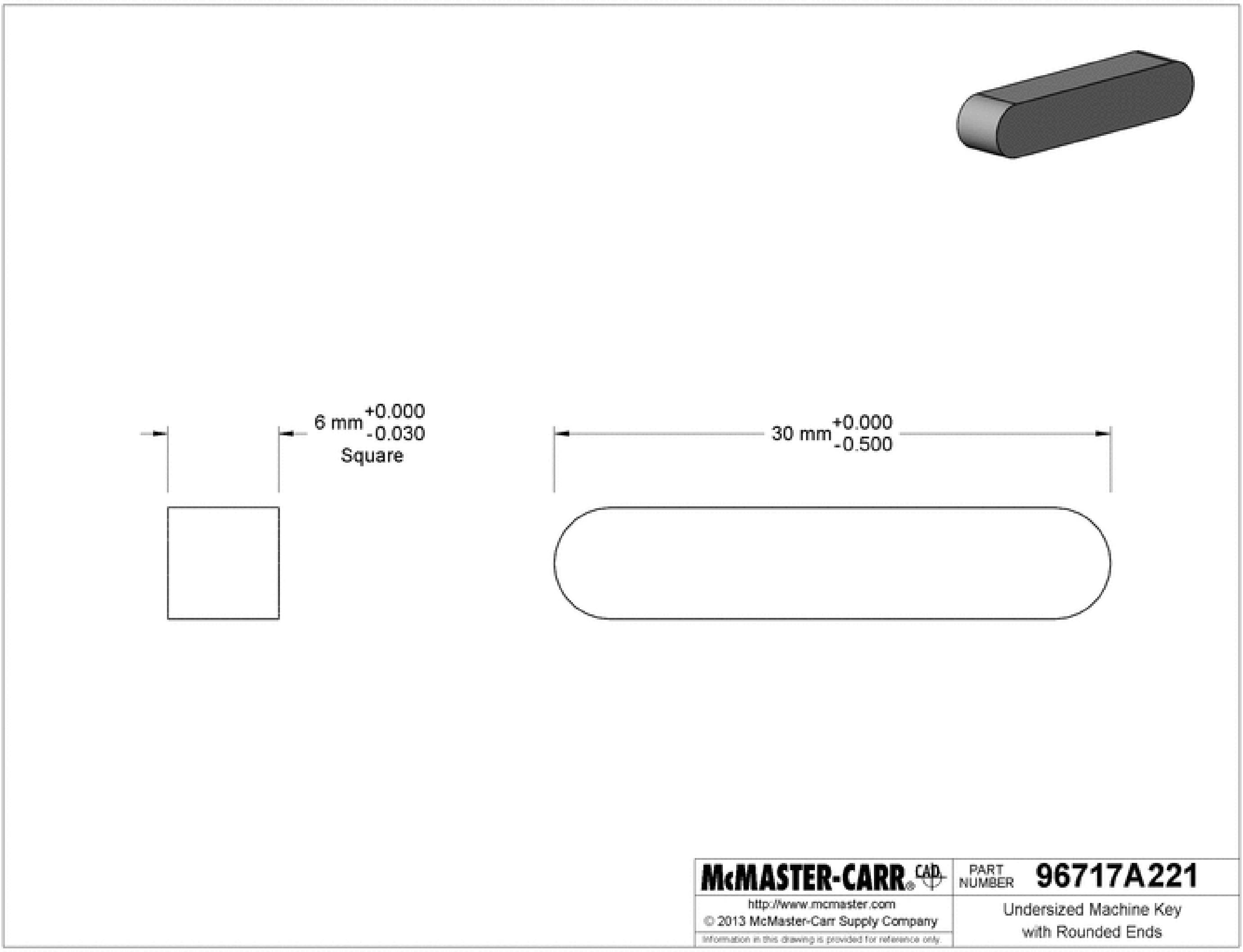
Appendix I -- DVPR

ME428 DVP&R Format								
Date		Sponsor						Component/A
TEST PLAN								
Specification or Clause Reference	Test Description	Acceptance Criteria	Test Responsibility	Test Stage	SAMPLES TESTED		TIMING	
					Quantity	Type	Start date	Finish date
Torque Input	Torque Wrench	320 in-lbf Max.	Anthony	CV	5	A	5/3/2017	5/4/2017
Input RPM	Slo-mo video and position marker	120 rpm Max.	Cory	CV	5	A	5/5/2017	5/6/2017
Torque Output	Weights and lever arm	1920 in-lbf Min.	Joe	CV	5	A	5/5/2017	5/6/2017
Cutter RPM	Slo-mo video and position marker	20 rpm Min.	Anthony	CV	5	A	5/5/2017	5/6/2017
Chip Size	Ruler	1 in^3 Max.	Cory	DV	5	B	5/6/2017	5/10/2017
Vine Size	Ruler	3 in diameter Max.	Joe	CV	5	A	5/6/2017	5/10/2017
Process Rate	Weigh material cut/time period	0.8 lb/min Min.	Anthony	PV	5	C	5/6/2017	5/10/2017
Jam Frequency	Count jams per given time period	3 jams/hr Max.	Cory	PV	5	C	5/6/2017	5/10/2017
Supports Operator Weight	Put weights on seat	300 lb Min.	Joe	DV	5	B	5/10/2017	5/11/2017
Product Weight	Industrial scale	500 lb Max.	Anthony	PV	1	C	5/10/2017	5/11/2017
Footprint	Tape measure	4'10"x10' Max.	Cory	PV	2	C	5/10/2017	5/11/2017
Stability	Pulley and weights (highest point)	60 lbs Max.	Joe	PV	5	C	5/10/2017	5/11/2017
Feed Volume	Tape measure	8ft^3 +/- 6 ft^3	Anthony	DV	2	B	5/10/2017	5/11/2017
Product Cost	Accounting	$3000 Max.	Cory	DV	2	B	5/10/2017	5/11/2017
Height	Tape measure	4 ft. Max.	Joe	PV	2	C	5/10/2017	5/11/2017

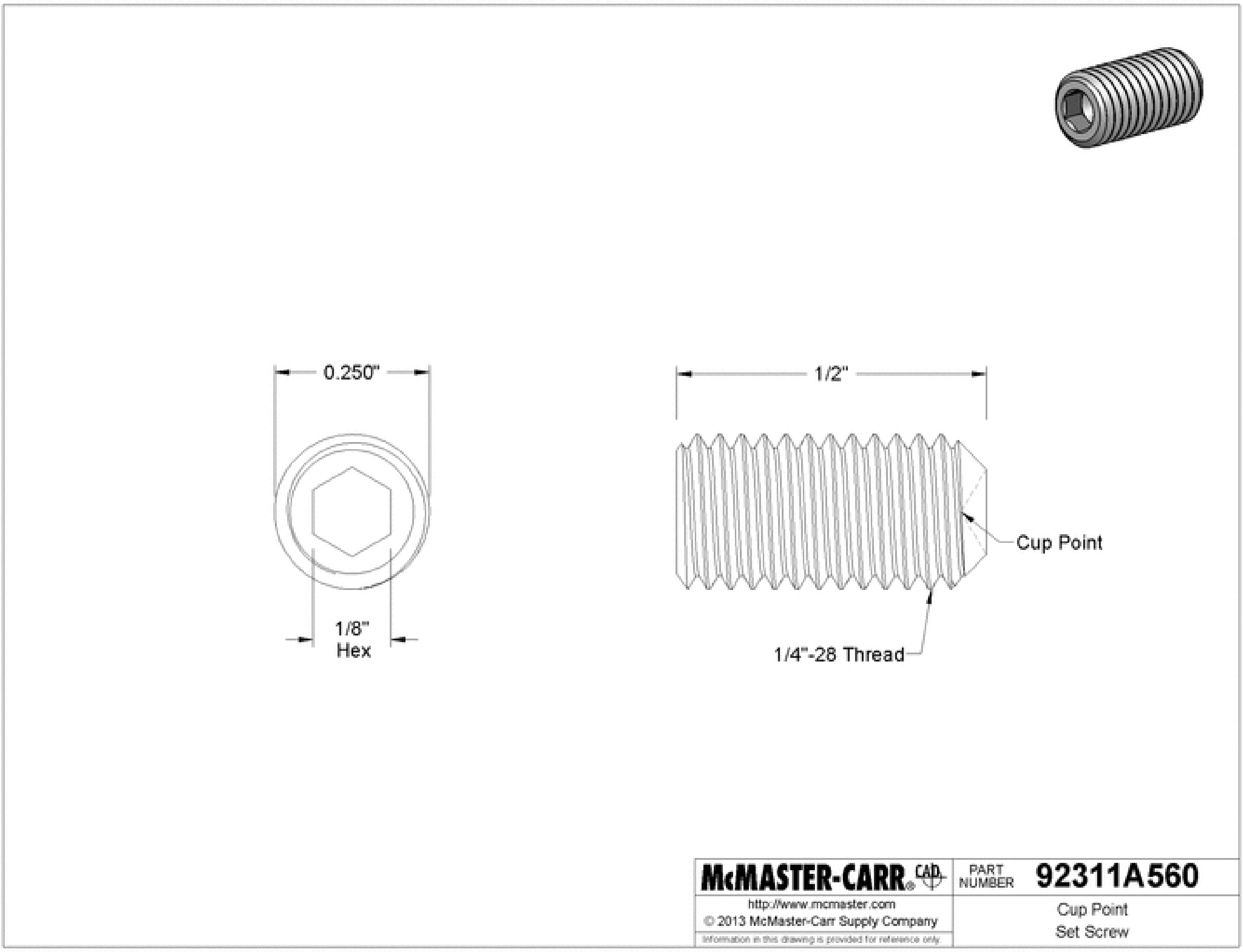
Appendix J – Bill of Materials

Compost Chomper Bill Of Materials					
Part Number	Sub Assembly				
500	**Fasteners (Approx. 7lbs)**	Material	Qty	Unit Cost	Total Cost
501	Phillips Rounded Head Screws for Sheet Metal 50 pack	18-8 Stainless Steel, Number 5 Size, 3/4" Long	1	15.14	15.14
502	Hex Drive Rounded Head Screw 25 pack	316 Stainless Steel, 1/4"-20, 5/8" long	2	9.01	18.02
503	Cup-Point Set Screws 25 pack* Slotted Set Screws Ordered - 10 pack for 5.50	316 Stainless Steel, 1/4"-20, 1/4" long	2	3.28	6.56
504	Phillips Rounded Head Screws 50 pack	316 Stainless Steel, 4-40, 1/4" long	1	3.73	3.73
505	Nylon-Insert Locknut 50 pack	316 Stainless Steel, 1/4"-20	1	12.61	12.61
506	Hex Drive Flat Head Screw 10 pack	316 Stainless Steel, 4-40, 3/8" long	1	2.27	2.27
507	1/4" Washer 100 pack	316 Stainless Steel	1	14.45	14.45
508	Cotter Pin, 100 pack	316 Stainless Steel, 1" length	1	12.05	12.05
509	5/8" Washer, 10 pack	316 Stainless Steel	1	17.06	17.06
510	Ultra-Corrosion Resistant Hex Head Screws	Alloy 20 Stainless Steel, 5/16"-18, 1" long	1	10.63	10.63
511	Hex Nut 50 pack	316 Stainless Steel, 5/16"-18	1	15.31	15.31
512	Ultra-Corrosion Resistant Hex Head Screws	Alloy 20 Stainless Steel, 5/16"-18, 1.5" long	3	14.73	44.19
514	Cup-Point Set Screws 10 pack	316 Stainless Steel, 1/4"-20, 0.5" long	1	12.96	12.96
515	Steel Phillips Rounded Head Screws, 100 pack	Zinc-Plated Steel, 5-40, 5/16" long	1	16.43	16.43
				subtotal	221.551
400	**Hopper Assembly (Approx. 35lbs)**				
401	Small Panel	Acrylic	2	41.09	82.18
402	Large Panel	Acrylic	2	41.09	82.18
403	Hopper Frame	1.5X1.5 Bolt-Together Framing, 1/8X1.5" Steel Bar	1	120.72	120.72
404	Shorter Rubber Edge Trim	Rubber	1	34.55	34.55
405	Safety Brake Cam	Aluminum 6061	1	33.23	33.23
406	Lid	Expanded Steel 24"X24", 4130 Alloy Steel Round Tube 3/8" Dia	1	53.78	53.78
407	Hopper Bearing	Aluminum 6061	2	18.76	37.52
				subtotal	488.576
300	**Support Frame Assembly (Approx. 100 lbs)**				
301	Support Frame	1.5" and 1" Square Tube Steel	1	92.42	92.42
302	Filamaker	Stainless Steel	1	600	600
303	Machinable-Bore Sprocket 60 Tooth1/2" Pitch	Steel	1	75.85	75.85
304	Fly Guard	Stainless Steel Sheet	1	0	0
305	Rear Guard	Stainless Steel Sheet	1	0	0
306	Wheels	(2 Wheels) Rubber, 4130 Alloy Steel, Rod 1" Diameter	1	72.58	72.58
				subtotal	924.935
200	**Bike Frame (Approx. 55 lbs)**				
201	Chain Guard	Stainless Steel Sheet	1	0	0
202-205	Various Donated Parts	Various	1	0	0
206	Flywheel	Steel	1	0	0
207	Tandem Bike Frame	Corrosion-Resistant Steel #40 Roller Chain, 1/2" Pitch, 6ft; #40 1/2" Pitch Connecting Link	1	261.65	261.65
				subtotal	267.815
				Total Cost	1924.04

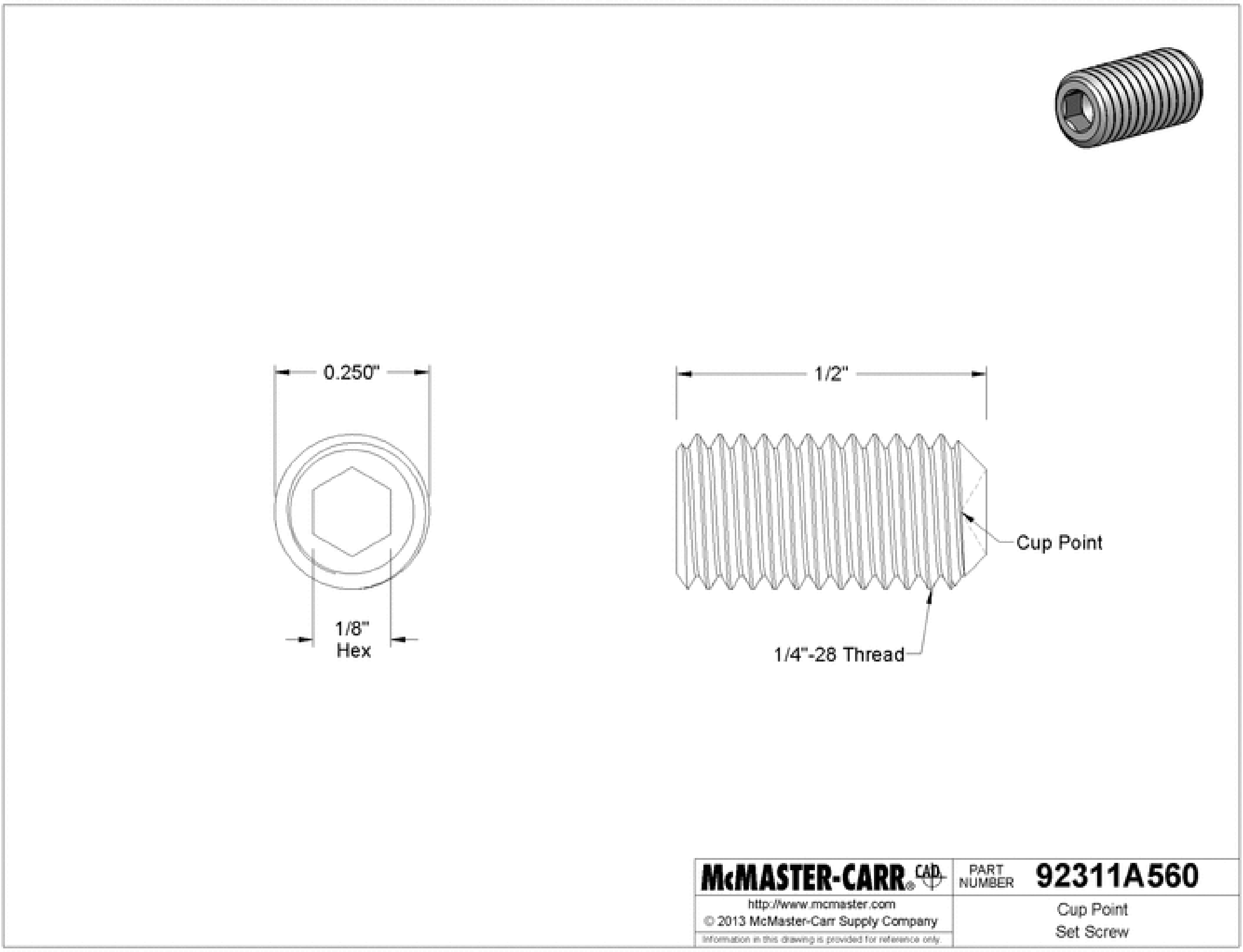
Appendix K – Component Specification Sheets



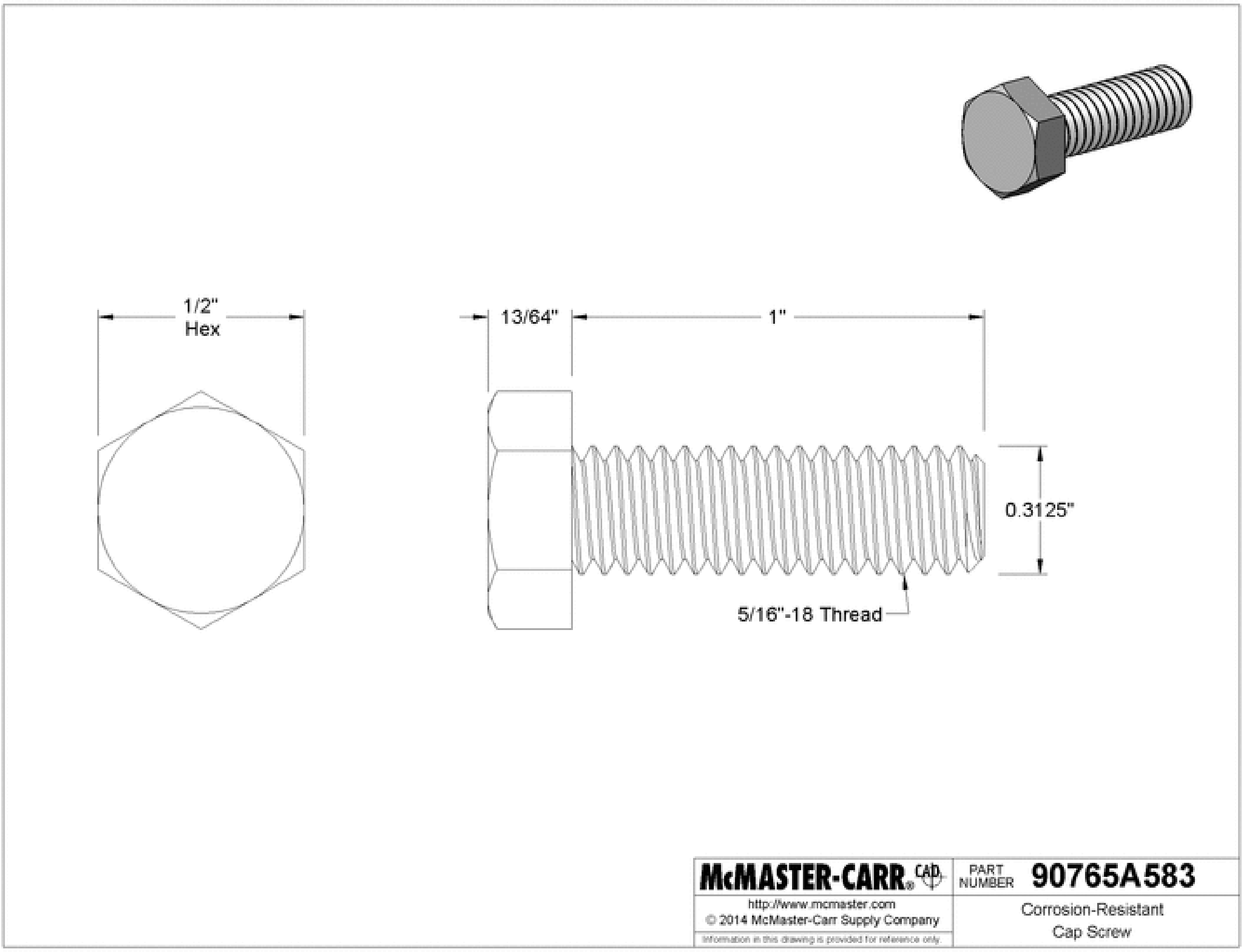
Metric Machine Key, Stainless Steel, 6mm Square, 30mm Length



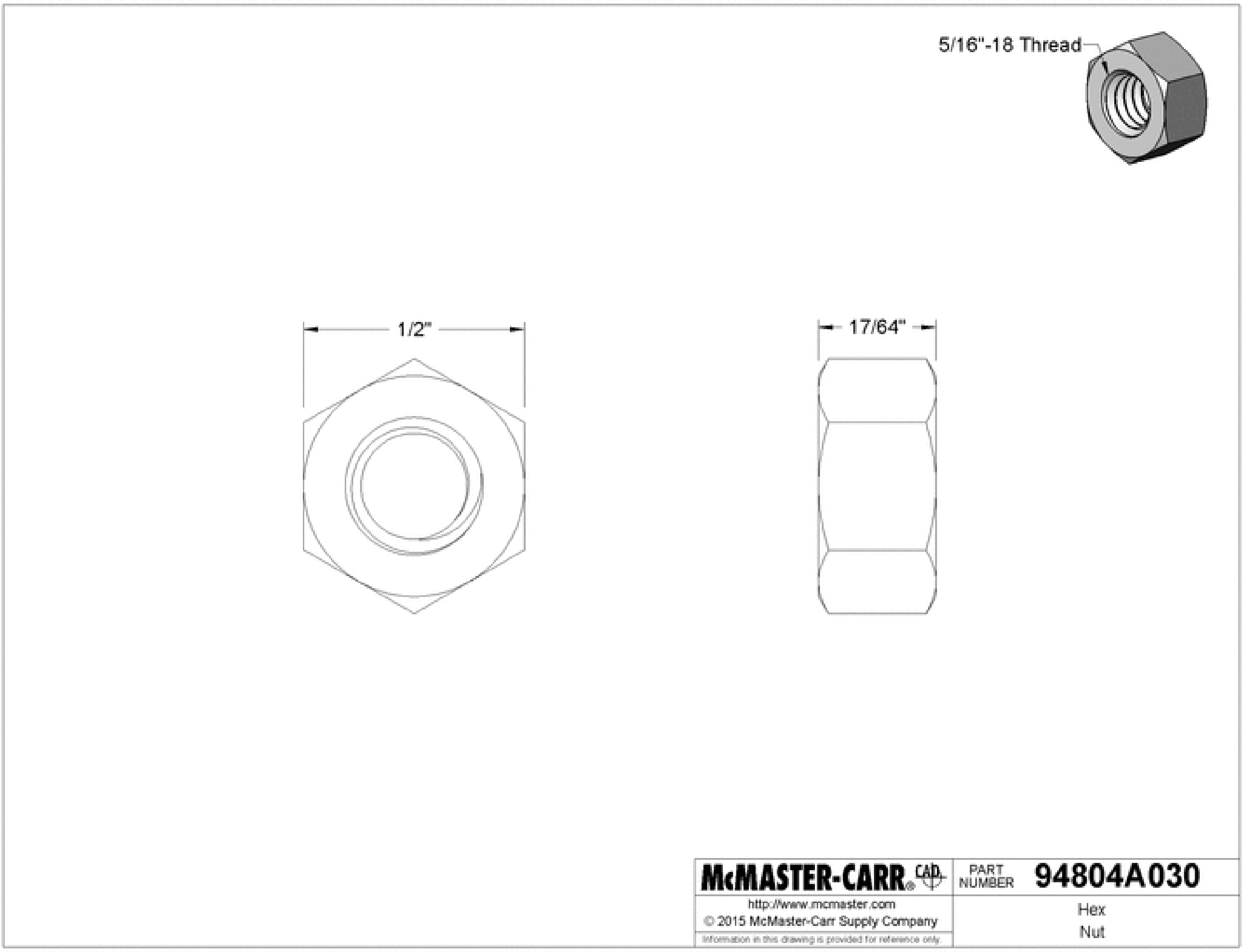
Type 316 Stainless Steel Slotted Cup Point Set Screw, 1/4"-20 Thread, 1/2" Length



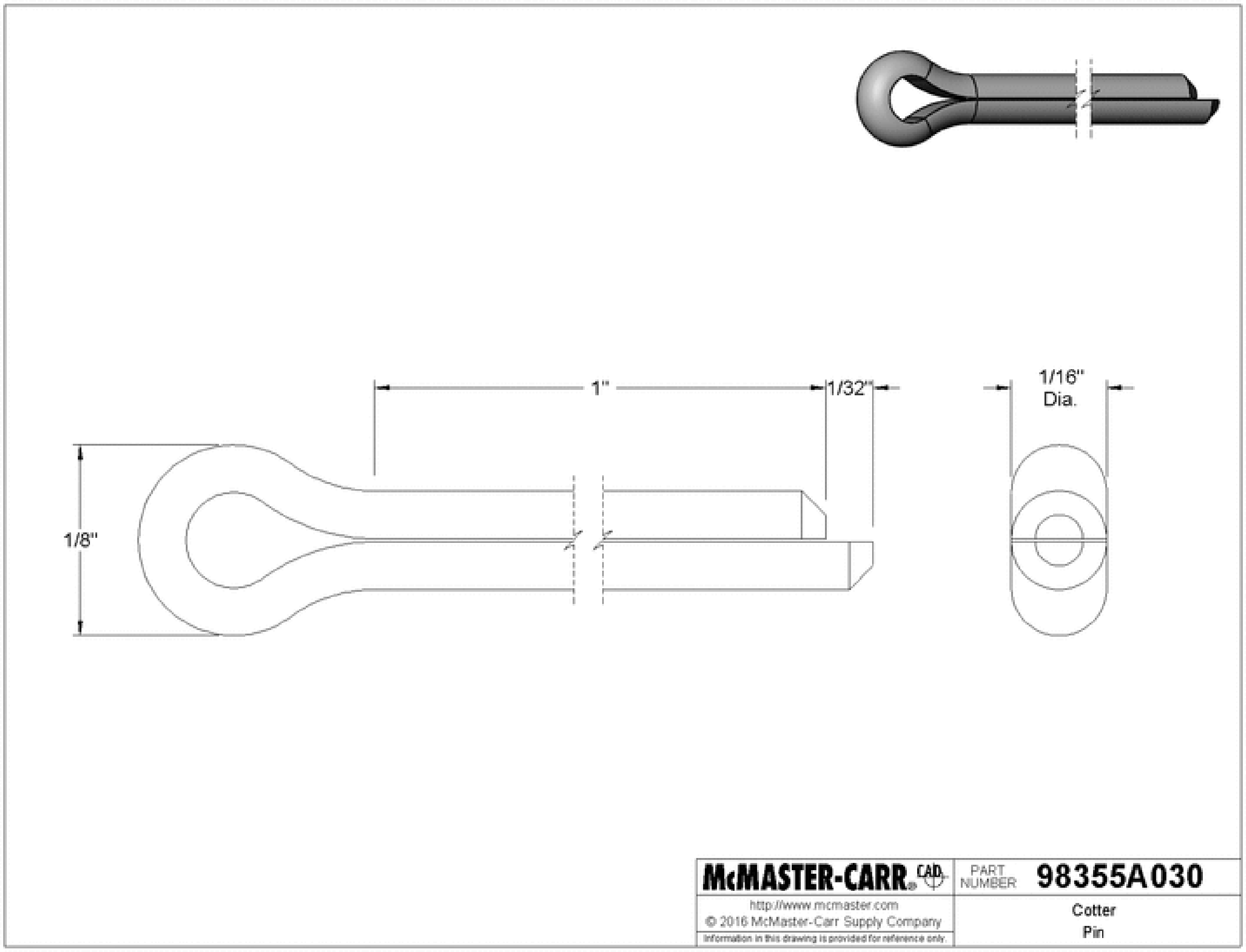
Ultra-Corrosion-Resistant Hex Head Screw, Alloy 20 Stainless Steel, 5/16"-18 Thread Size, 1-1/2" Long (bag of 25)



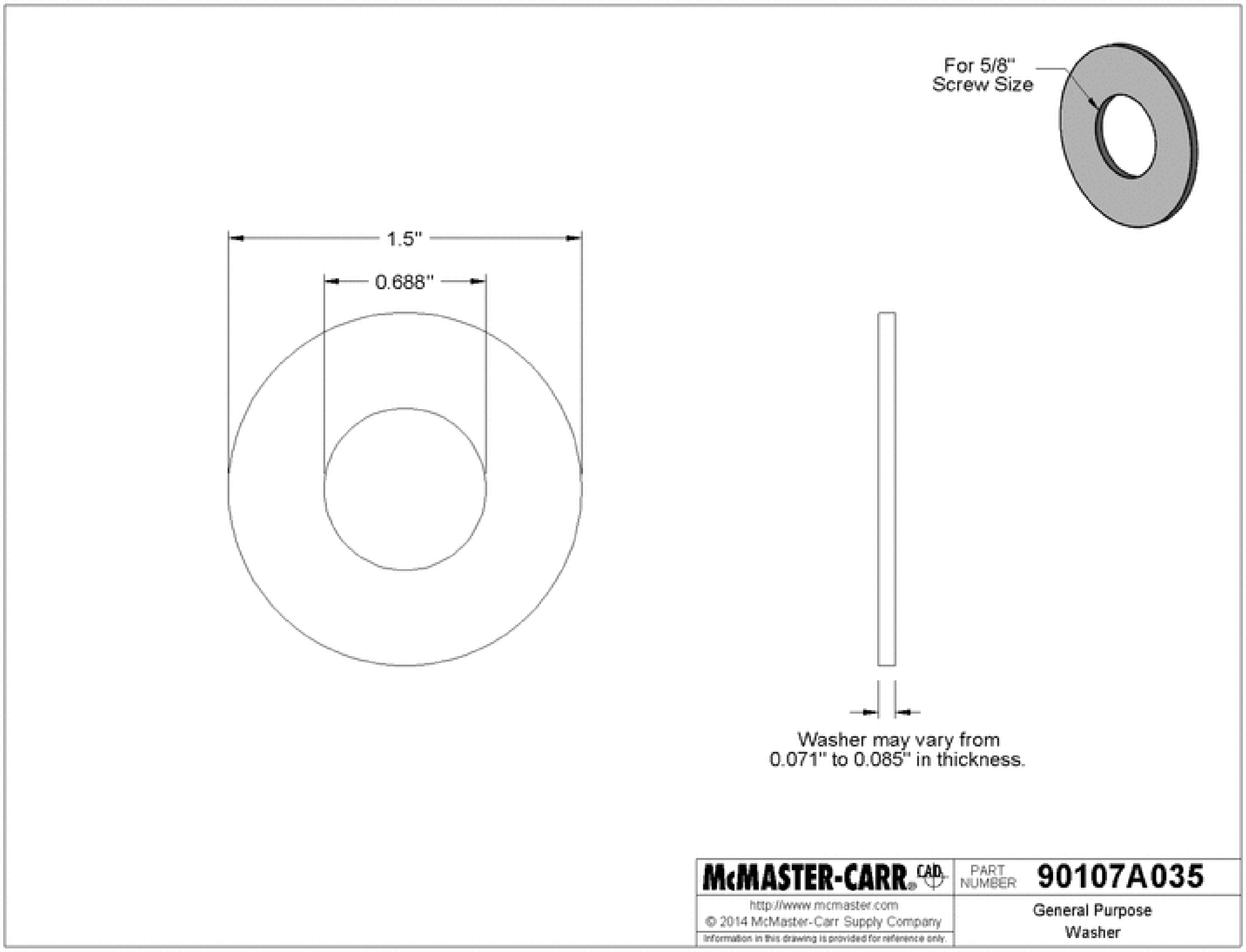
Ultra-Corrosion-Resistant Hex Head Screw, Alloy 20 Stainless Steel, 5/16"-18 Thread Size, 1" Long (bag of 25)



Super-Corrosion-Resistant 316 Stainless Steel Hex Nut, 5/16"-18 Thread Size (bag of 50)



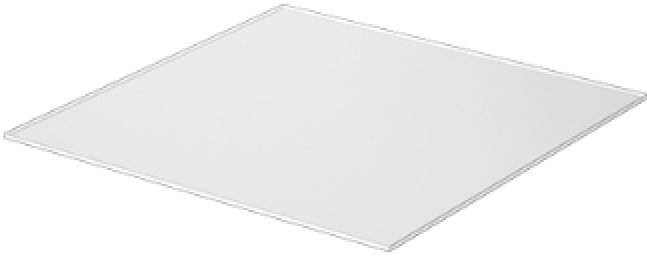
Type 316 Stainless Steel Cotter Pin, 1/16" Diameter, 1" Length (bag of 100)



316 Stainless Steel Washer for 5/8" Screw Size, 0.688" ID, 1.5" OD (bag of 10)

Strengthened UV-Resistant Acrylic Sheet

1/8" Thick, 24" x 24"



Each

ADD TO ORDER

In stock
$21.09 Each
4615T94

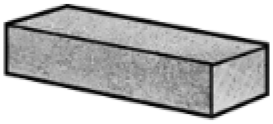
Material	Acrylic Plastic
Fabrication	Extruded
Cross Section Shape	Rectangle
Construction	Solid
Texture	Smooth
Color	Clear
Clarity	Clear
Thickness	1/8"
Thickness Tolerance	-0.013" to +0.013"
Tolerance Rating	Standard
Width	24"
Width Tolerance	-1/8" to +1/8"
Length	24"
Length Tolerance	-1/8" to +1/8"
Backing Type	Plain
Hardness	Rockwell M70
Hardness Rating	Hard
For Use Outdoors	Yes
Temperature Range	32° to 170° F
Impact Strength	0.30 ft.-lbs./in.
Impact Strength Rating	Poor
Tensile Strength	8,100 psi
Tensile Strength Rating	Good
Specifications Met	UL 94HB
Density	0.043 lbs./cu. in.
Coefficient of Friction	Not Rated
Dielectric Strength	430 V/mil
Water Absorption	0.30%
Coefficient of Thermal Expansion	3.5×10^{-5} in./in./°F
Additional Specifications	More About Plastics
RoHS	Compliant

Modified to be stronger than standard acrylic, these sheets also resist damage from UV light. Use them for skylights, windows, and signs.

Strengthened UV-Resistant Acrylic Sheet 1/8" Thick, 24" x 24", clear

Low-Carbon Steel Rectangular Bar

1/8" Thick, 1-1/2" Width



Length
- 1/2 ft.
- 1 ft.
- 2 ft.
- 3 ft.
- 6 ft.

Each

ADD TO ORDER

8910K398

Grade	1018
Shape	Rectangular Bar
Finish	Unpolished
Thickness	1/8"
Thickness Tolerance	-0.006"
Width	1 1/2"
Width Tolerance	-0.006"
Yield Strength	54,000 psi
Hardness	Medium (Rockwell B70)
Specification Met	ASTM A108
Construction	Cold Drawn
Material Composition	
Carbon	0.13-0.20%
Manganese	0.30-0.90%
Silicon	0.15-0.30%
Phosphorus	0.04% Max.
Sulfur	0.50% Max.
Iron	98.06-99.42%
Nominal Density	0.283 lbs./cu. in.
Electrical Resistivity	15.9 microhm-cm @ 32° F
Thermal Conductivity	29.4 Btu/sq. ft./ft./hr./°F @ 212° F
Coefficient of Thermal Expansion (Text)	6.7-7.5 × 10^{-6}
Elongation Range	10-36%
RoHS	Compliant

One of the most widely used types of steel, low-carbon steel is weldable, machinable, and can be surface hardened by heat treating. It is suitable for a variety of applications, such as structural and power transmission components.

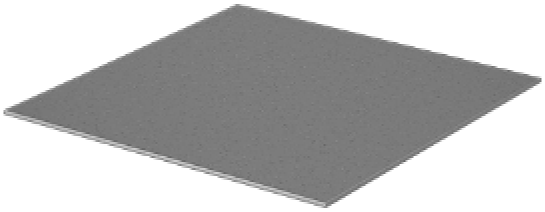
Warning: Physical, mechanical, and chemical properties are not guaranteed and are intended only as a basis for comparison.

Material is 1018 carbon steel. Thickness and width tolerances are -0.006" for 1/8" to 4" wide bars; they are -0.010" for 4 1/2" to 6" wide bars; and they are -0.013" for bars 7" and wider. Length tolerance is ±1/8" for 1/2-ft. lengths, ±1" for 1-ft. lengths, ±2" for 2-ft. lengths, ±3" for 3-ft. lengths, and ±6" for 6-ft. lengths.

1/8 x 1.5 x 6'and 2' bar

Easy-to-Weld 4130 Alloy Steel Sheet

with Material Certification, .125" Thick, 24" x 24"



Each

ADD TO ORDER

In stock
$98.64 Each
4459T268

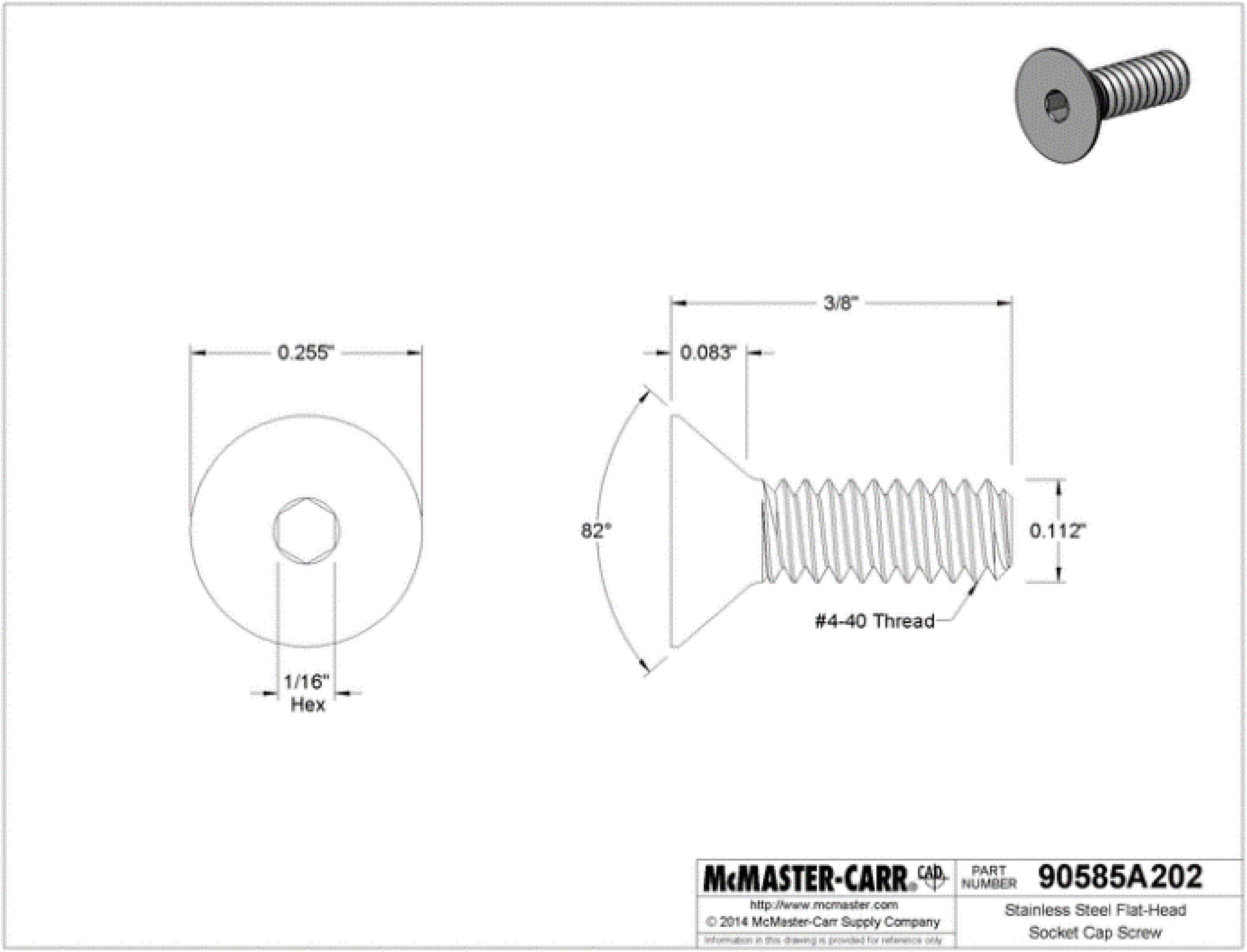
Grade	4130
Shape	Sheet
Finish	Unpolished
Thickness	0.125"
Thickness Tolerance	±0.009"
Yield Strength	50,000 psi
Hardness	Medium (up to Rockwell B85)
Specifications Met	AMS 6350-6351
Construction	Cold Rolled
Material Condition	Annealed
Material Composition	
Carbon	0.27-0.34%
Manganese	0.35-0.60%
Silicon	0.15-0.40%
Phosphorus	0.011-0.035%
Sulfur	0.002-0.04%
Chromium	0.80-1.15%
Molybdenum	0.15-0.25%
Vanadium	0-0.035%
Aluminum	0.039%
Copper	0-0.25%
Hydrogen	0-2 ppm Max.
Nickel	0-0.25%
Niobium	0.05% Max.
Titanium	0.03% Max.
Iron	94.53-98.23%
Nominal Density	0.283 lbs./cu. in.
Electrical Resistivity	22.3 microhm-cm @ 68°F
Thermal Coefficient of Expansion per °F	7.6×10^{-6} (68° to 752° F)
Elongation Range	25-28%
Feature	WITH MATERIAL CERTIFICATION
Width Tolerance	±1/16"
Length Tolerance	±1/16"
Width	24"
Length	24"
RoHS	Compliant

Its carbon content is low enough for good weldability but high enough to give this steel abrasion and impact resistance. 4130 is often used for gears, fasteners, and structural applications.

Warning: Physical, mechanical, and chemical properties are not guaranteed and are intended only as a basis for comparison.

Meet AMS 6350-6351. Each sheet comes with a traceable lot number and material test report. All sheets are annealed. 0.025" to 0.125" thick sheets are cold rolled. Width and length tolerances are ±1/16".

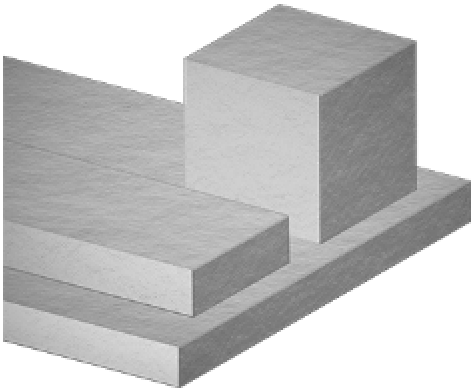
Easy-to-Weld 4130 Alloy Steel Sheet with Material Certification, .125" Thick, 24" x 24"



10x 4-40 screws

Multipurpose 6061 Aluminum

Rectangular Bar, 1" x 1"



Length, ft.
1/2
1
2
3
6

Each

ADD TO ORDER

9008K14

(Web) System of Measurement	Inch
Material	6061 Aluminum
Cross Section Shape	Rectangle
Construction	Solid
Thickness	1"
Thickness Tolerance	-0.012" to 0.012"
Tolerance Rating	Standard
Width	1"
Width Tolerance	-0.014" to 0.014"
Yield Strength	35,000 psi
Fabrication	Heat Treated
Temper	T6511
Temper Rating	Hardened
Hardness	Brinell 95
Hardness Rating	Soft
Heat Treatable	Yes
Appearance	Plain
Temperature Range	-320° to 300° F
Specifications Met	ASTM B221
Straightness Tolerance	Not Rated
Magnetic Properties	Nonmagnetic
Density	0.1 lbs./cu. in.
Surface Resistivity	25 Ohm-Cir Mil/ft
Melting Point Temperature	1080° F
Modulus of Elasticity	10.0 ksi × 10^3
Thermal Conductivity	1,160 Btu/hr. × in./sq. ft./°F @ 75°
Elongation	12.5%
Material Composition	
Aluminum	95.1-98.2%
Chromium	0.4-0.8%
Copper	0.05-0.4%
Iron	0-0.7%
Magnesium	0.8-1.2%
Manganese	0-0.15%
Nickel	0-0.05%
Silicon	0.4-0.8%
Titanium	0-0.15%
Zinc	0-0.25%
Zirconium	0-0.25%
Other	0.15%
Length Tolerance	-1" to 1"
RoHS	Compliant

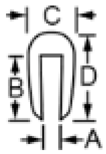
Often fabricated into vehicle parts, pipe fittings, and containers, 6061 is stronger and offers better corrosion resistance than MIC6 and 2011. It's also nonmagnetic, heat treatable, and resists stress cracking.

6061 Aluminum block for hopper bearing

Rubber Edge Trim

1/8" Inside Width, 15/32" Inside Height

Length, ft.	Each
10	ADD TO ORDER
25	
50	
100	1-99 Ft. $1.40
Other	100 or more $1.05
	8507K16



Inside	
Width (A)	1/8"
Height (B)	15/32"
Outside	
Width (C)	23/64"
Height (D)	5/8"
Color	Black
Additional Specifications	Standard—Style 5
RoHS	Compliant

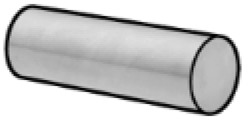
Cover exposed or unfinished edges. Trim pushes into place and its tight grip holds it on the edge. Materials are medium-hard with a 45A-70A durometer.

Standard trim is neoprene rubber and offers good fuel, water, and ozone resistance. It can be used outdoors; temperature range is −40° to 155° F. Material is nonmarking.

Rubber Edge Trim, 1/8" Inside Width, 15/32" Inside Height, 10ft. Length

Easy-to-Weld 4130 Alloy Steel

Rod, 3/8" Diameter



Length
1 ft.
3 ft.
6 ft.

Each

ADD TO ORDER

8673T39

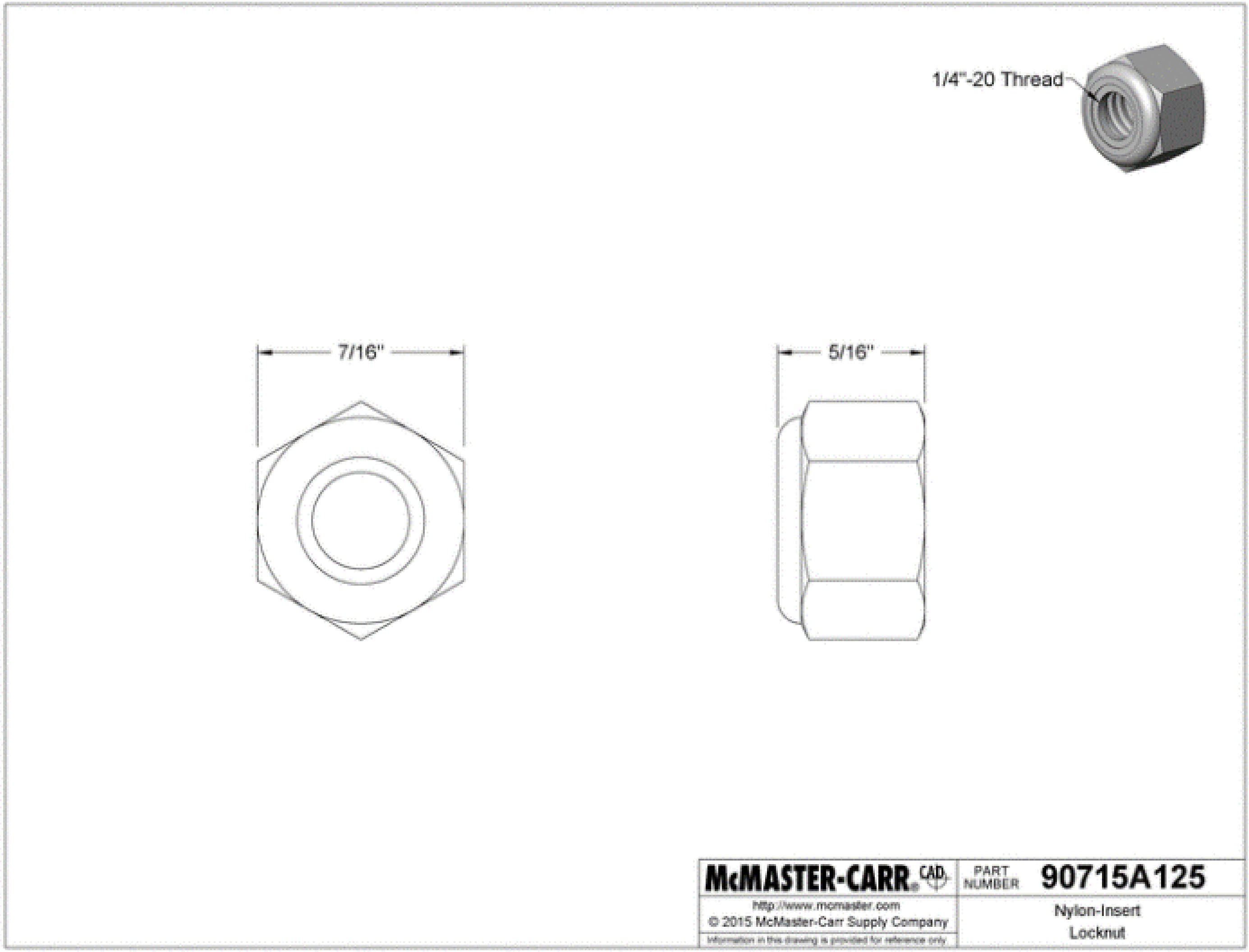
Grade	4130
Shape	Rod
Diameter	3/8"
Diameter Tolerance	-0.005"
Yield Strength	Not Rated
Hardness	Hard (Rockwell C20)
Specifications Met	ASTM A108, AMS 2301, AMS 6348
Construction	Cold Drawn
Material Composition	
Carbon	0.27-0.34%
Manganese	0.35-0.60%
Silicon	0.15-0.40%
Phosphorus	0.011-0.035%
Sulfur	0.002-0.04%
Chromium	0.80-1.15%
Molybdenum	0.15-0.25%
Vanadium	0-0.035%
Aluminum	0.039%
Copper	0-0.25%
Hydrogen	0-2 ppm Max.
Nickel	0-0.25%
Niobium	0.05% Max.
Titanium	0.03% Max.
Iron	94.53-98.23%
Nominal Density	0.283 lbs./cu. in.
Electrical Resistivity	22.3 microhm-cm @ 68°F
Thermal Coefficient of Expansion per °F	7.8 × 10^{-6} (68° to 752° F)
Elongation Range	25-28%
RoHS	Not Compliant

Its carbon content is low enough for good weldability but high enough to give this steel abrasion and impact resistance. 4130 is often used for gears, fasteners, and structural applications.

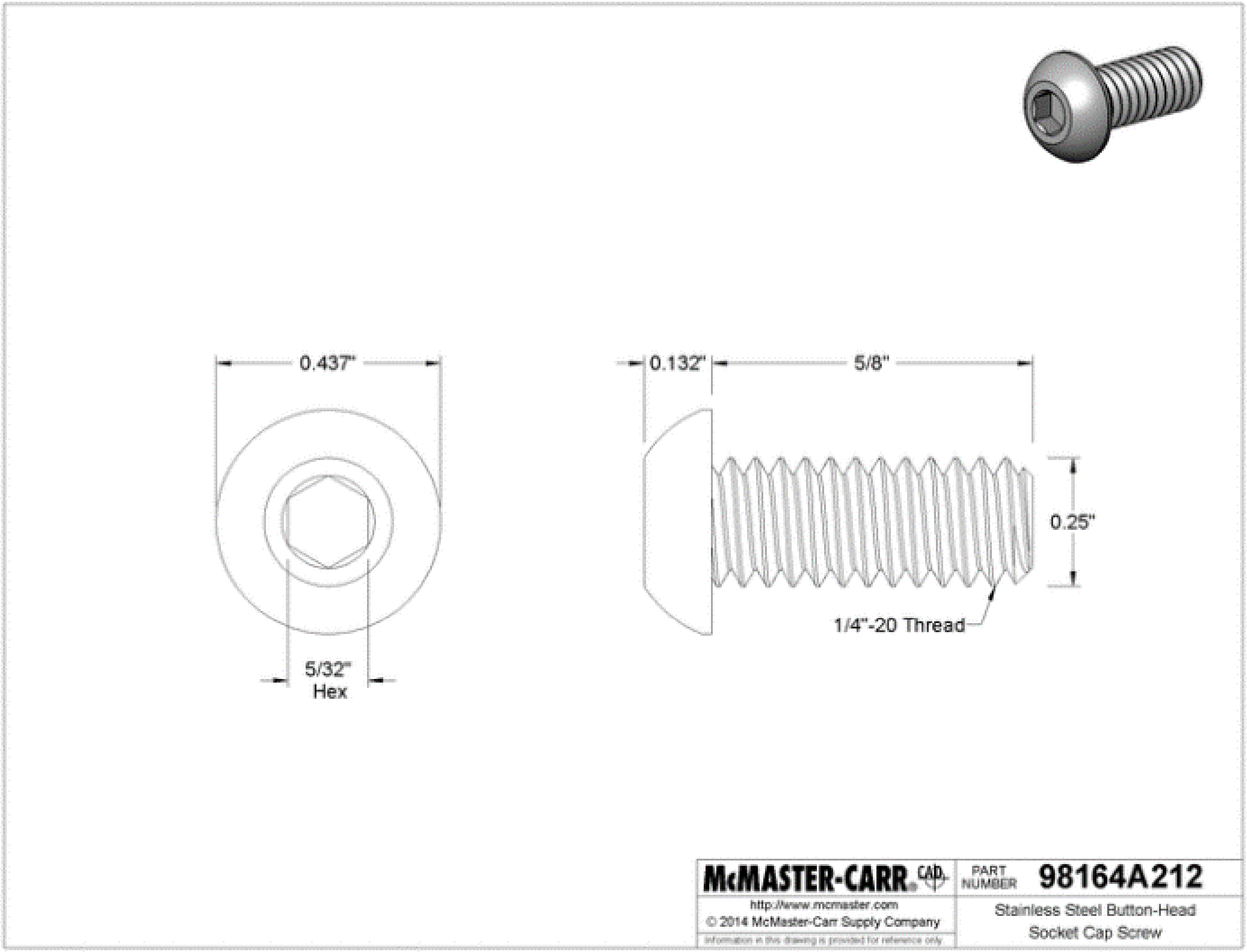
Warning: Physical, mechanical, and chemical properties are not guaranteed and are intended only as a basis for comparison.

Meet AMS 2301 and AMS 6348. These rods are normalized for consistent hardening and machining. They are turned and polished, except 3/8" and 3/4" dia. rods are cold drawn. Length tolerance is ±1" for 1-ft. lengths, ±3" for 3-ft. lengths, and ±6" for 6-ft. lengths.

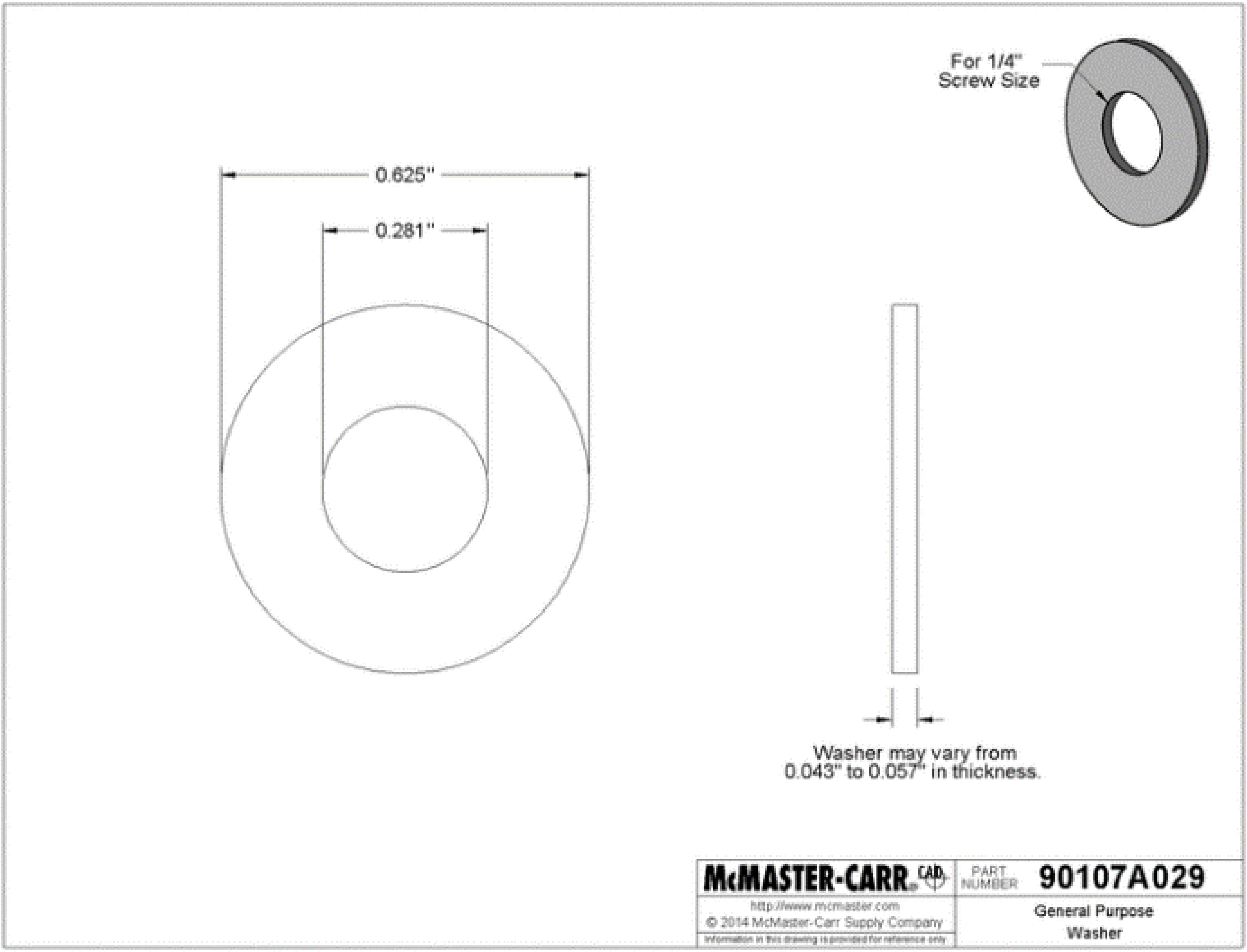
Easy-to-Weld 4130 Alloy Steel Round Tube 3/8" Dia



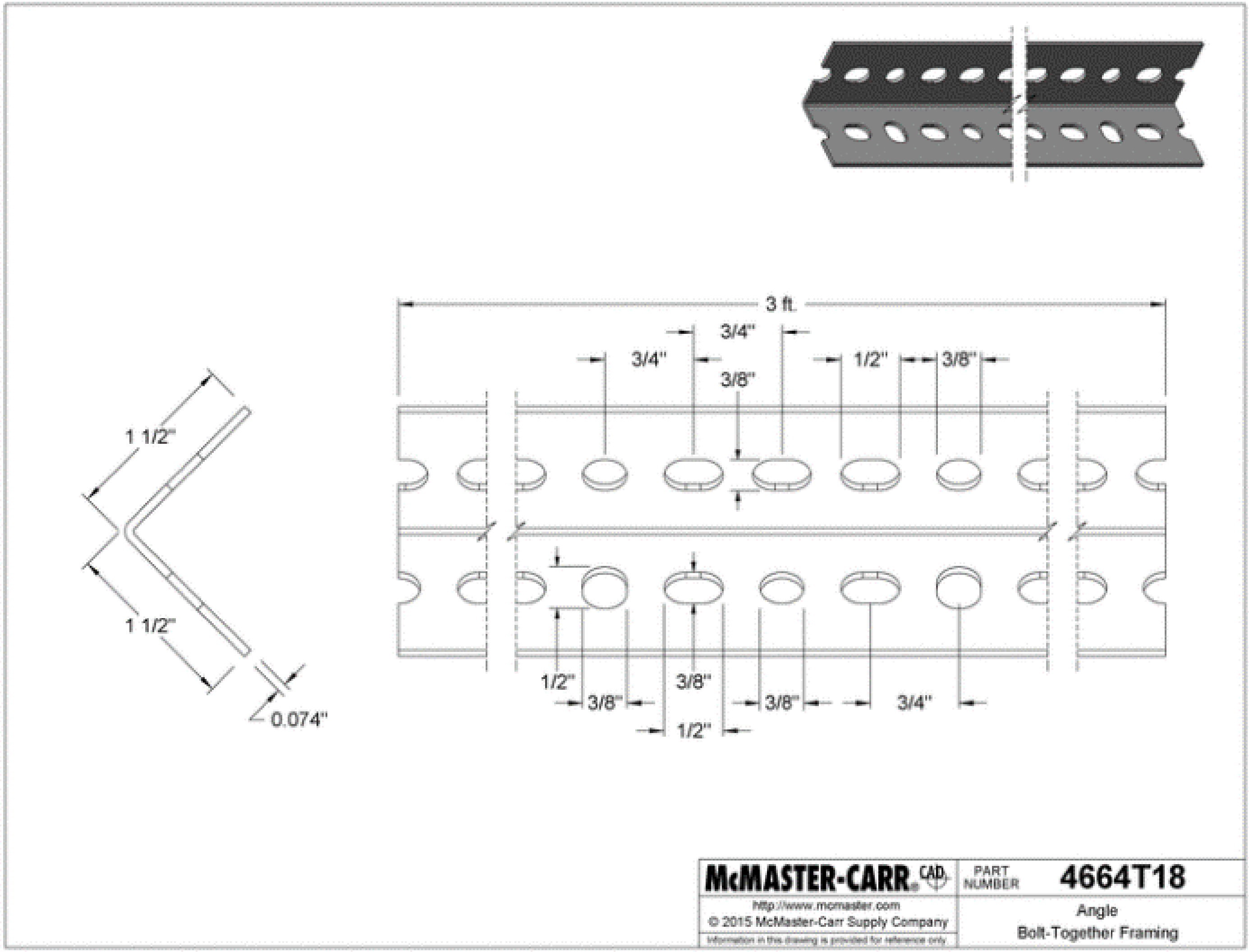
1/4 20 lock nut for hopper panels



1/4 20 5/8 screw for hopper panels



1/4 washer for hopper panels



Bolt together Framing 3ft each

Cinching Strap

Includes 30' of 1" Polypropylene Webbing, 6 Buckles

Each

ADD TO ORDER

In stock
$12.49 Each
8846T49

Width	1"
Length	30 ft.
Number of Buckles	6
Additional Specifications	Polypropylene Webbing
RoHS	Compliant

Cut rolls to length and add the included no-sew buckles. Webbing and rubber are black. Buckles are black plastic.

Polypropylene webbing is lightweight, economical, and moisture resistant. Comes with feed-through buckles, which are easy to thread quickly.

Cinching Strap, Includes 30' of 1" Polypropylene Webbing, 6 Buckles

Organic waste shredder

850.00€

1 Add to cart

Category: shredders Tag: organic waste

Description

Product Description

This shredder is made only for organic waste.

It is build 100% out of stainless steel to prevent rusting or contamination of shredded waste.

Shredder chamber size is 170mm wide and 140mm long (14 blades with 10mm thickness)

If you need shorter or longer shredder then this one. Download this PDF file to start your custom order.

This shredder can work under water and can be used up to 100°C temperature. It's dishwasher proof.

Ideal for compost machines, farmers, Fisherman's, animal food processing and much more.

Not for wood thicker than 10mm or branches thicker than 20mm

Not for bones from cows, pigs, horses, and other big animals.

We offer free shipping all over the world. But Australia, Japan, and other islands need to go with 20€ international shipping.

We are the manufacturer and we can take up to 3 weeks to manufacture and test your unit. (One week is common)

If you need a hand crank from us, you need to write it with your order.

For payment, we have stopped supporting payment through PayPal, because of disagreement with new Policy Terms of Use valid from 19. November 2016 (If you still want to use PayPal or credit card please process through PayPal partner "Xoom" and wire the funds to our bank account.)

Polypropylene Core with Cushion Rubber-Tread Wheel

8" x 2", 5/8" Axle, Side-Mount Hub/Ball Bearing, 450 lb Capacity

Each

ADD TO ORDER

In stock
$16.45 Each
2839T66

Wheel	
Diameter	8"
Width	2"
Axle Diameter	5/8"
Hub Length	2 1/4"
Capacity Each	450 lbs.
Additional Specifications	Solid Tread with Polypropylene Core
	Side-Mount Hub with Easy-Roll Bearings

Thick rubber treads offer more cushion than standard rubber treads, and unlike air-filled tires there's no chance of flats. Treads are ribbed black rubber, unless noted.

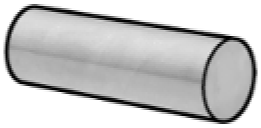
Solid tread with polypropylene core has a soft tread (80A durometer). Temperature range is -22° to 212° F. Side-mount hubs are offset for extra clearance between the wheel and your equipment.

Easy-roll bearings have steel balls and require less effort to start rolling.

Polypropylene Core with Cushion Rubber-Tread Wheel, 8" x 2", 5/8" Axle, Side-Mount Hub/Ball Bearing, 450 lb Capacity

Easy-to-Weld 4130 Alloy Steel

Rod, 1" Diameter



Length	Each
1 ft.	
3 ft.	
6 ft.	

ADD TO ORDER

6673T27

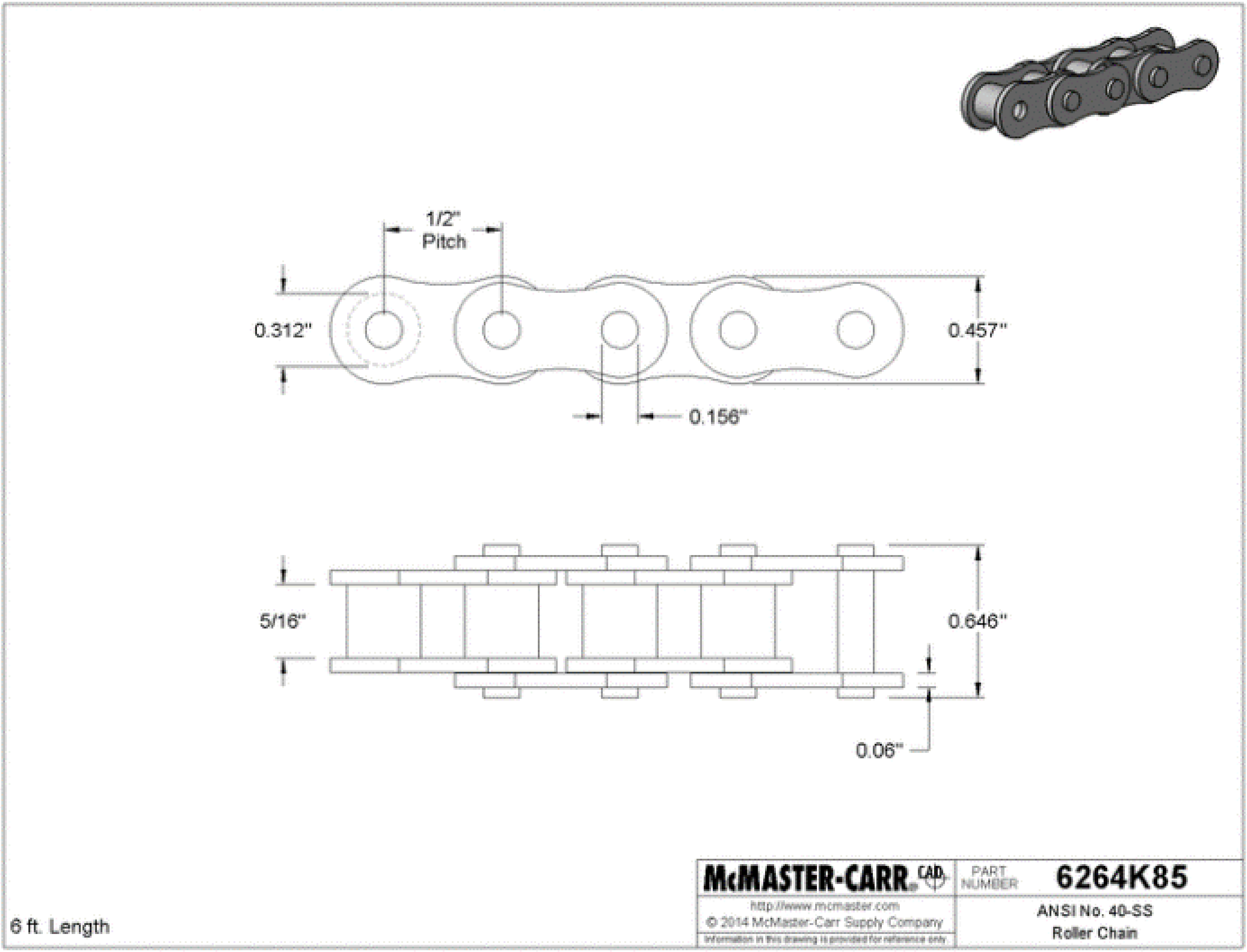
Grade	4130
Shape	Rod
Diameter	1"
Diameter Tolerance	-0.005"
Yield Strength	Not Rated
Hardness	Hard (Rockwell C20)
Specifications Met	ASTM A108, AMS 2301, AMS 6348
Material Composition	
Carbon	0.27-0.34%
Manganese	0.35-0.60%
Silicon	0.15-0.40%
Phosphorus	0.011-0.035%
Sulfur	0.002-0.04%
Chromium	0.80-1.15%
Molybdenum	0.15-0.25%
Vanadium	0-0.035%
Aluminum	0.039%
Copper	0-0.25%
Hydrogen	0-2 ppm Max.
Nickel	0-0.25%
Niobium	0.05% Max.
Titanium	0.03% Max.
Iron	94.53-98.23%
Nominal Density	0.283 lbs./cu. in.
Electrical Resistivity	22.3 microhm-cm @ 68°F
Thermal Coefficient of Expansion per °F	7.6×10^{-6} (68° to 752° F)
Elongation Range	25-28%
RoHS	Not Compliant

Its carbon content is low enough for good weldability but high enough to give this steel abrasion and impact resistance. 4130 is often used for gears, fasteners, and structural applications.

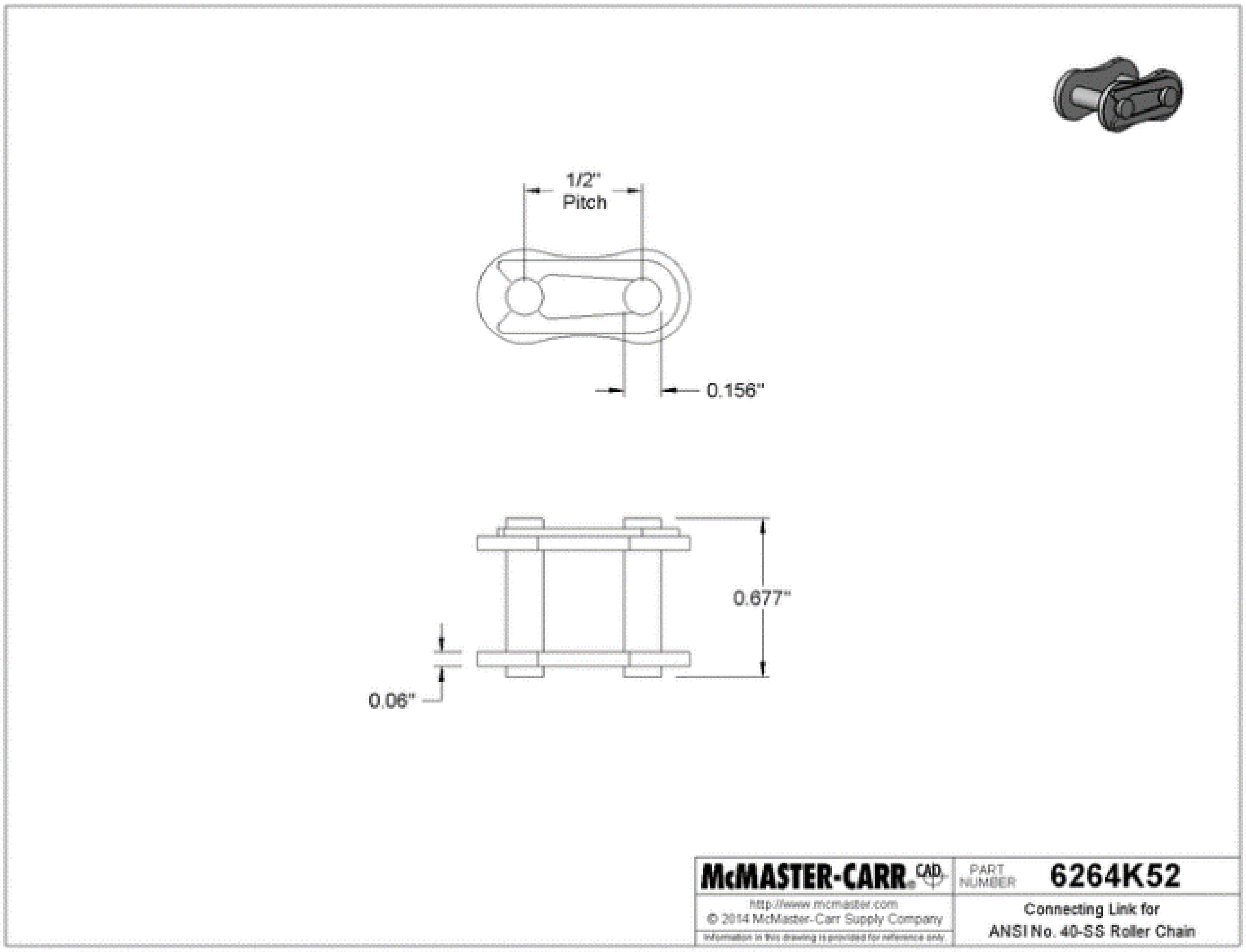
Warning: Physical, mechanical, and chemical properties are not guaranteed and are intended only as a basis for comparison.

Meet AMS 2301 and AMS 6348. These rods are normalized for consistent hardening and machining. They are turned and polished. Length tolerance is ±1" for 1-ft. lengths, ±3" for 3-ft. lengths, and ±6" for 6-ft. lengths.

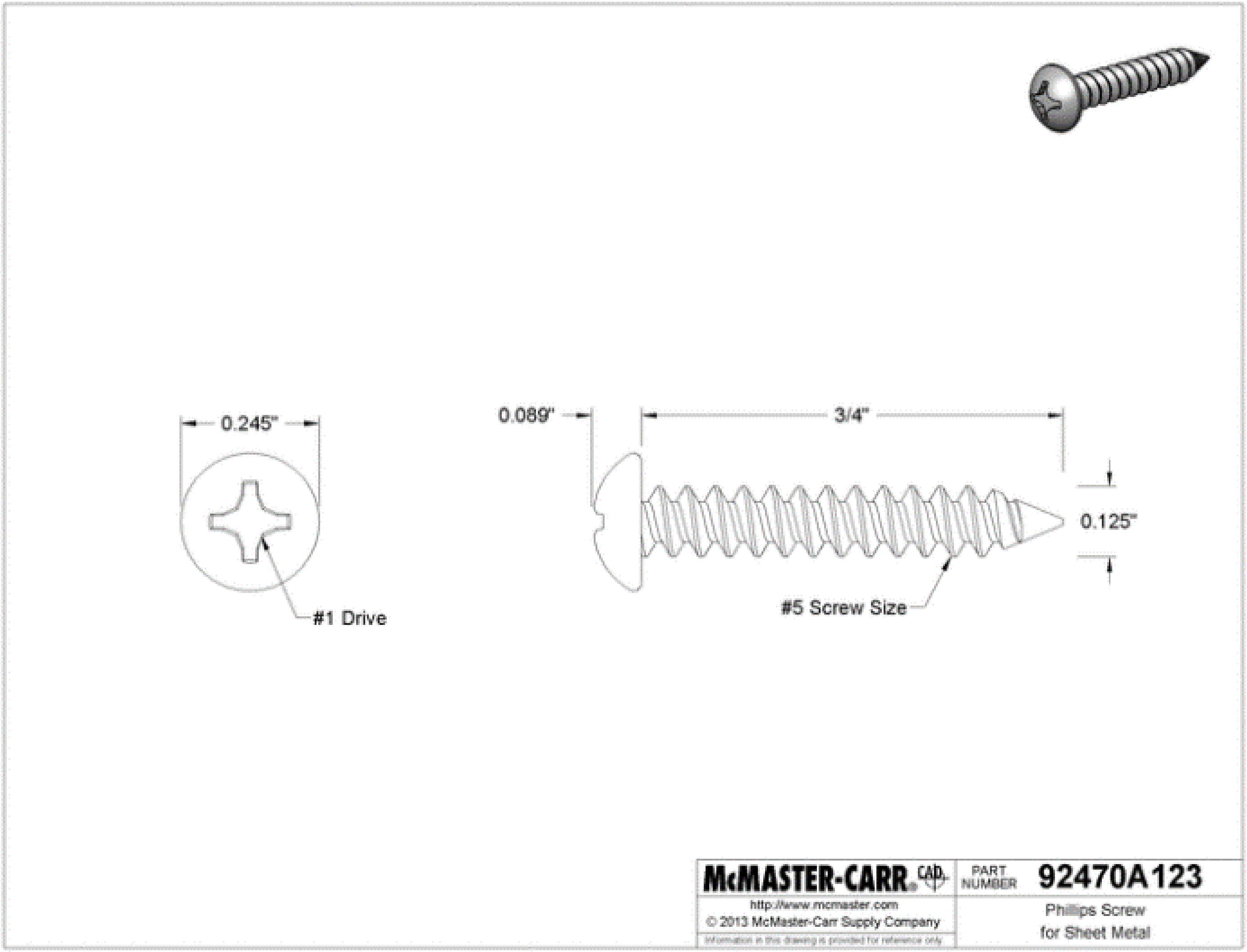
Easy-to-Weld 4130 Alloy Steel, Rod, 1" Diameter



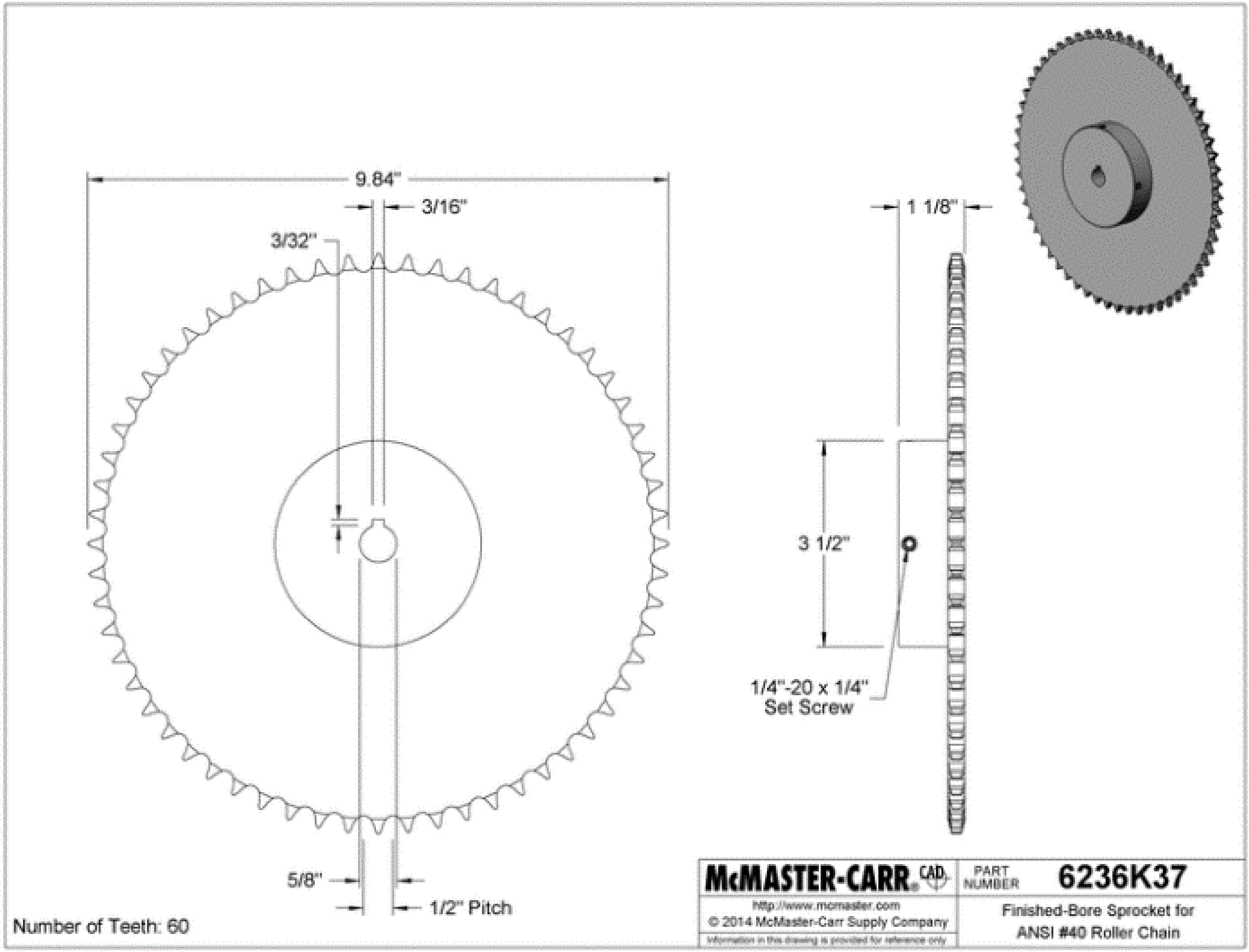
Highly Corrosion-Resistant Roller Chain, 304 Stainless Steel, ANSI Number 40-SS, 1/2" Pitch, 6ft



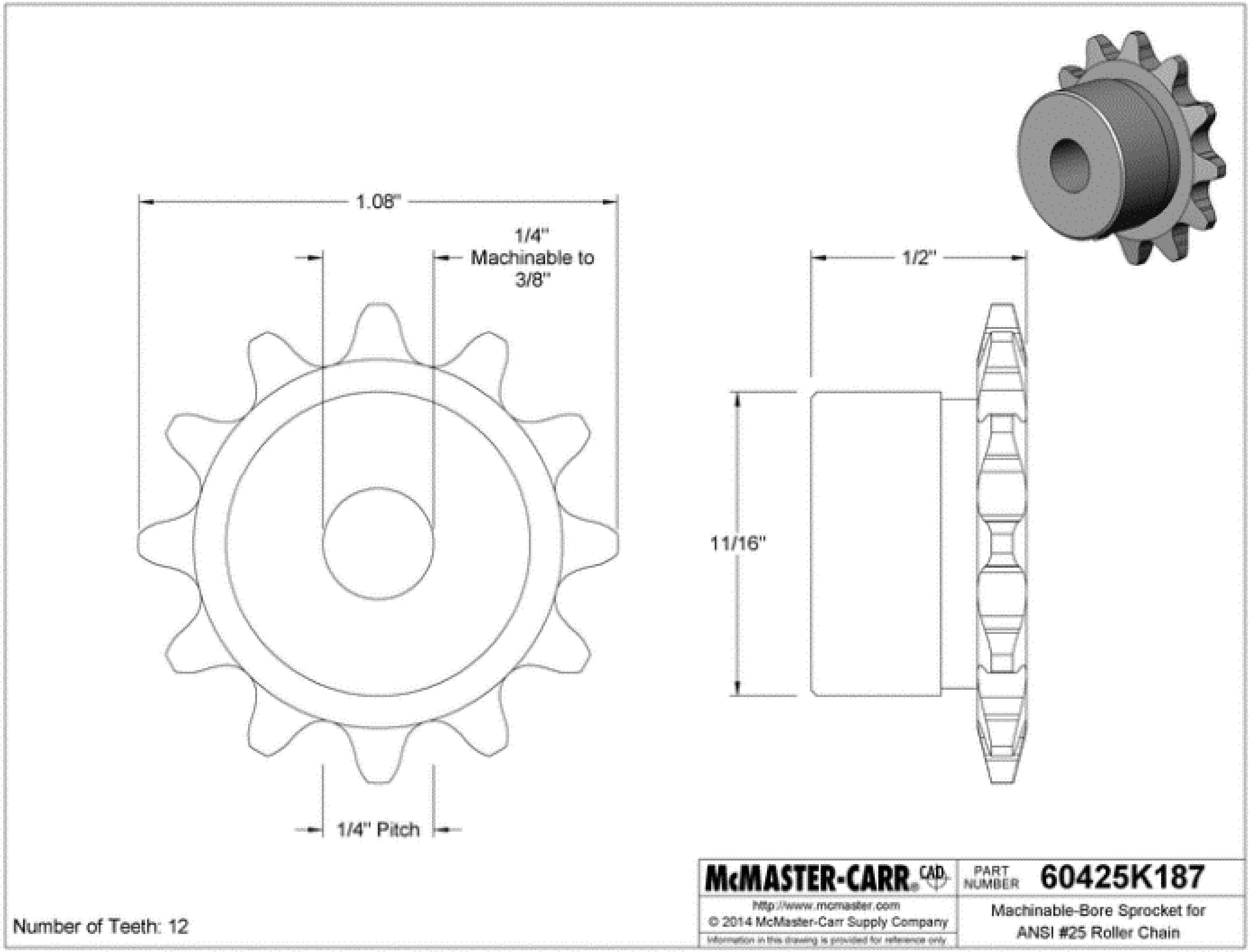
ANSI Number 40-SS Connecting Link for 304 Stainless Steel Highly Corrosion-Resistant Roller Chain



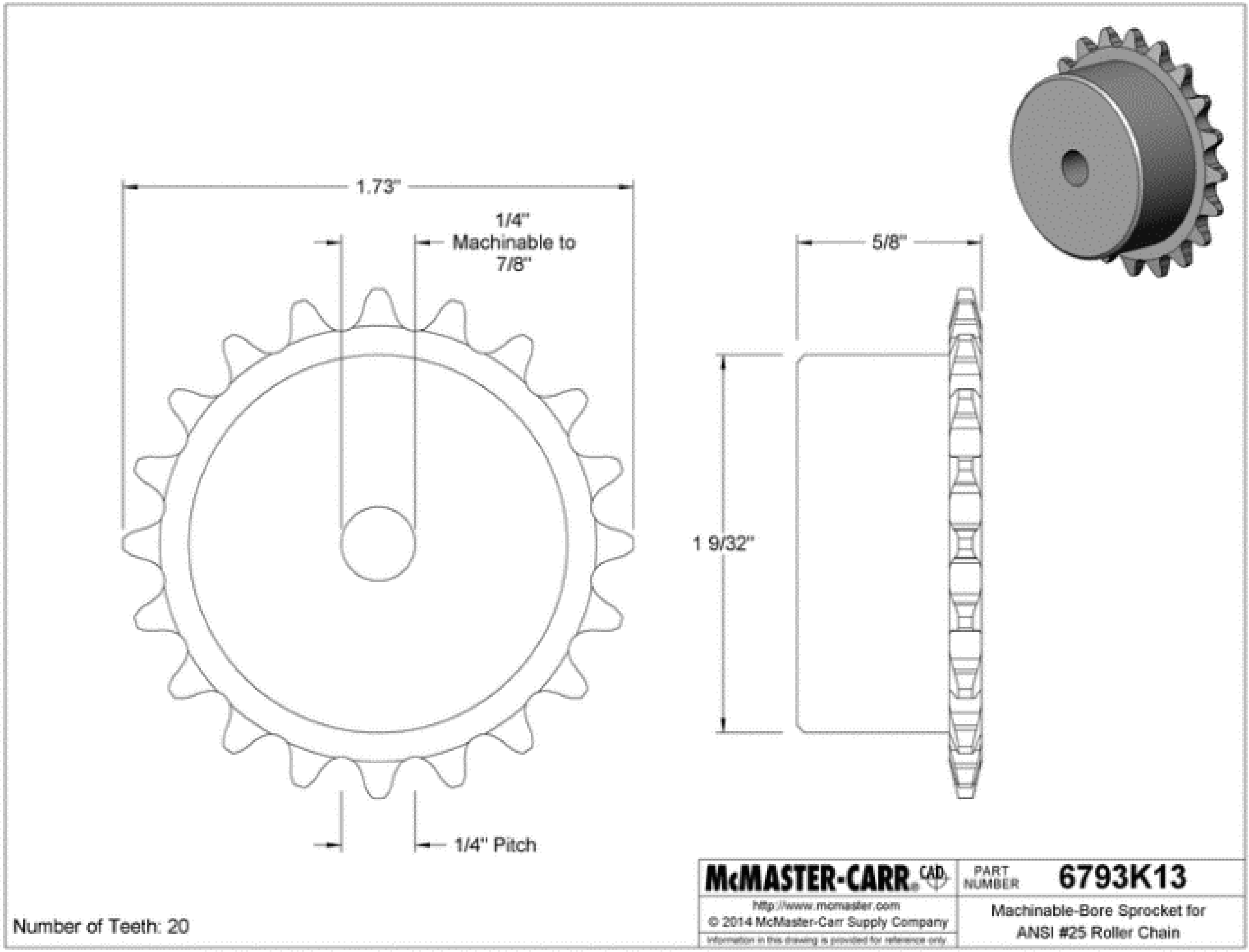
Phillips Rounded Head Screws for Sheet Metal, 18-8 Stainless Steel, Number 5 Size, 3/4'' Long (bag of 50)



Steel Machinable-Bore Sprocket for ANSI Number 40 Roller Chain, 1/2" Pitch, 60 Teeth



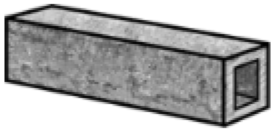
Steel Machinable-Bore Sprocket for ANSI Number 40 Roller Chain, 1/2'' Pitch, 12 Teeth



Steel Machinable-Bore Sprocket for ANSI Number 40 Roller Chain, 1/2" Pitch, 20 Teeth

Low-Carbon Steel Square Tube

1" Wide, 1" High, .120" Wall Thickness



Length
1 ft.
3 ft.
6 ft.

Each

ADD TO ORDER

6527K364

Grade	1005-1026
Shape	Square Tube
Finish	Rough
Wall Thickness	0.120"
Wall Thickness Tolerance	±0.012"
Width	1"
Height	1"
Width/Height Tolerance	±0.030"
Straightness Tolerance	1/16" per 3 ft.
Yield Strength	46,000 psi
Hardness	Not Rated
Specification Met	ASTM A500
Construction	Hot Rolled
Material Composition	
Carbon	0.13-0.20%
Manganese	0.30-0.90%
Silicon	0.15-0.30%
Phosphorus	0.04% Max.
Sulfur	0.50% Max.
Iron	98.06-99.42%
Nominal Density	0.283 lbs./cu. in.
Electrical Resistivity	15.9 microhm-cm @ 32° F
Thermal Conductivity	29.4 Btu/sq. ft./ft./hr./°F @ 212° F
Coefficient of Thermal Expansion (Text)	6.7-7.5 × 10^{-6}
Elongation Range	10-36%
RoHS	Compliant

One of the most widely used types of steel, low-carbon steel is weldable, machinable, and can be surface hardened by heat treating. It is suitable for a variety of applications, such as structural and power transmission components.

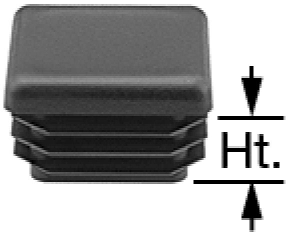
Warning: Physical, mechanical, and chemical properties are not guaranteed and are intended only as a basis for comparison.

Material is 1005-1026 carbon steel. Straightness tolerance is 1/16" per 3 ft. of length. Length tolerance is ±1" for 1-ft. lengths, ±3" for 3-ft. lengths, and ±6" for 6-ft. lengths.

0.120" thick 1" square tubing 6' long

Square Finishing Plug for Tubing

Ribbed, Fits 1" Tube OD and 0.72"-0.84" Tube ID



Packs of 100

ADD TO ORDER

In stock
$12.29 per pack of 100
9565K52

Shape	Ribbed Square
Fits Outside Tube Size	1"
Fits Inside Tube Size	0.72"-0.84"
Height	7/16"
Color	Black
Material	Polyethylene
RoHS	Compliant

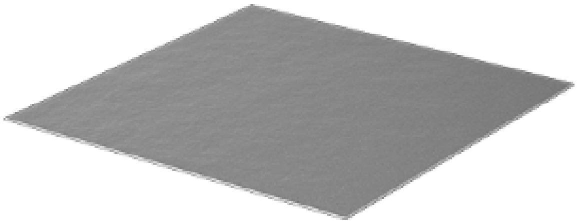
Finish the ends of your square and rectangular tubing with these plugs. Plugs are polyethylene with a durometer of 41D-54D. Maximum temperature is 150° F. Color is black.

Ribbed plugs have flexible ridges that allow them to fit a range of tubing sizes.

Square Finishing Plug for Tubing, Ribbed, Fits 1" Tube OD and 0.72"-0.84" Tube ID

Multipurpose 304 Stainless Steel Sheet

.060" Thick, 36" x 36"



Each

ADD TO ORDER

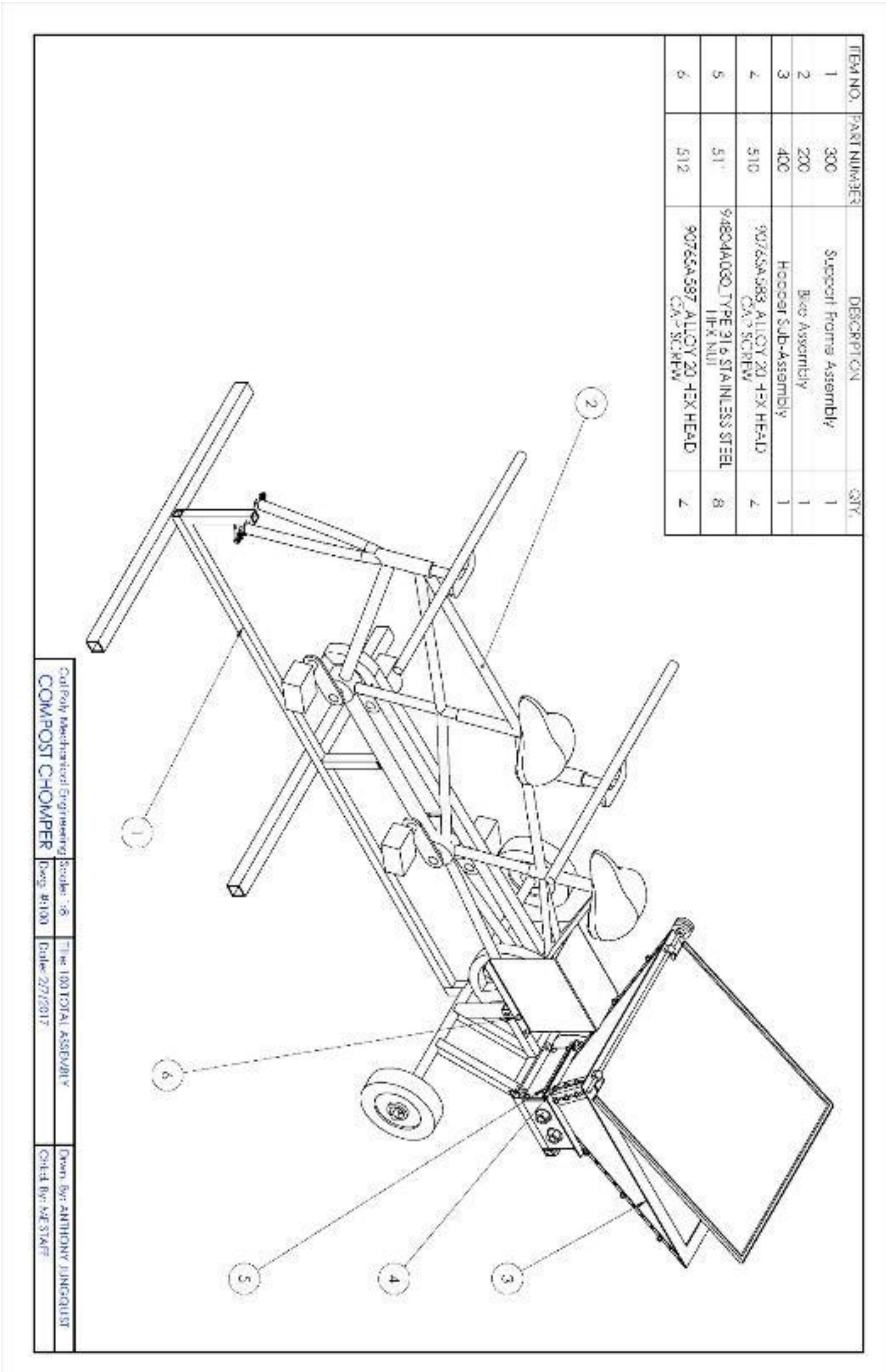
In stock
$99.89 Each
8983K335

Material	304 Stainless Steel
Cross Section Shape	Rectangle
Construction	Solid
Appearance	Plain
Thickness	0.06"
Thickness Tolerance	-0.004" to 0.004"
Tolerance Rating	Standard
Width	36"
Width Tolerance	-1/8" to 1/8"
Length	36"
Length Tolerance	-1/8" to 1/8"
Yield Strength	30,000 psi
Fabrication	Cold Worked, Heat Treated
Hardness	Rockwell B80 (Medium)
Temper Rating	Softened
Heat Treatable	No
Minimum Temperature	Not Rated
Maximum Temperature	1500° F
Specifications Met	ASTM A240
Flatness Tolerance	Not Rated
Density	0.29 lbs./cu. in.
Surface Resistivity	469 ohm-cir. mil/ft.
Melting Point Temperature	2400° F
Modulus of Elasticity	28 ksi × 10^3
Thermal Conductivity	100 Btu/hr. × in./sq. ft./°F @ 212° F
Elongation	50%
Material Composition	
Iron	53.48-74.5%
Carbon	0-0.08%
Chromium	17.5-24%
Cobalt	0-0.29%
Copper	0-1%
Manganese	0-2%
Molybdenum	0-2.5%
Nickel	8-15%
Nitrogen	0-0.1%
Phosphorus	0-0.2%
Silicon	0-1%
Sulfur	0-0.35%
RoHS	Not Compliant

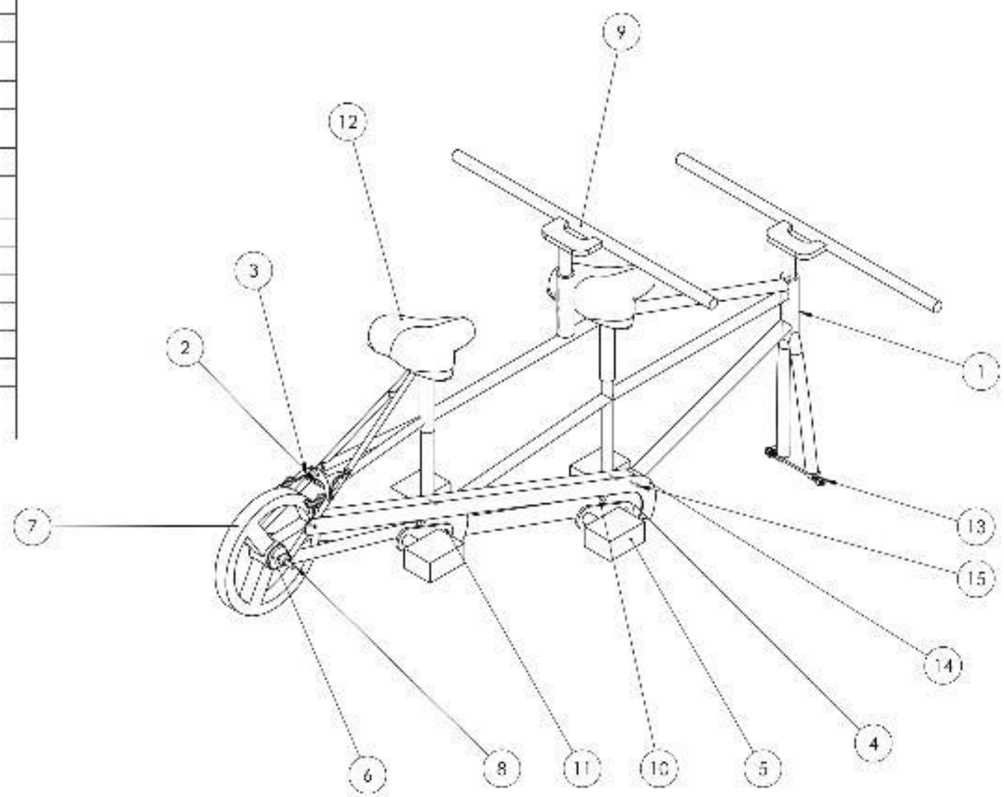
From cookware to chemical-processing equipment, 304 stainless steel is a good all-around choice for a wide range of applications. It maintains its corrosion resistance in temperatures up to 1500° F.

Multipurpose 304 Stainless Steel Sheet, .060" Thick, 36" x 36"

Appendix L – CAD Drawings

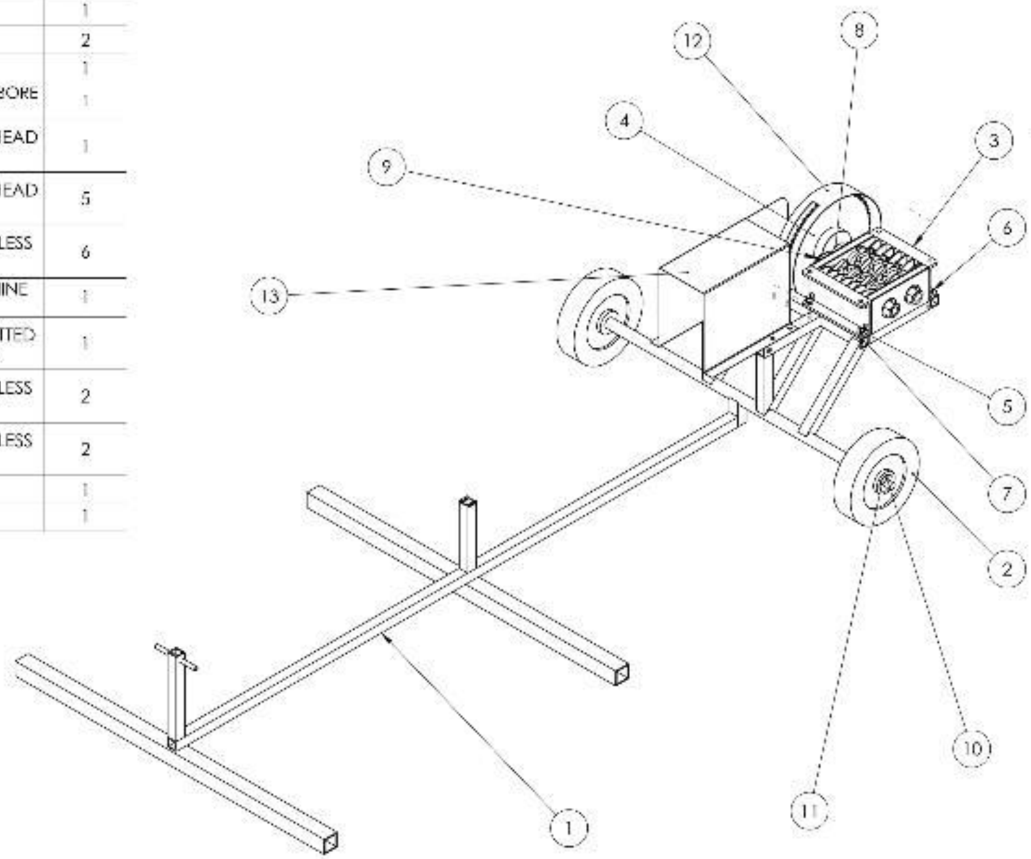


ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	207	Tandem Bike Frame	1
2	203	Brake Attachment	1
3	212	Brakes	1
4	202	Crude Big Sprocket	3
5	205	Crude Pedal	4
6	211	Crude Small Sprocket	1
7	206	Flywheel	1
8	213	Front Drop In Pin	1
9	214	Handlebar	1
10	204	Pedal Crank Arm	4
11	210	Pedal Shaft	2
12	209	Seat	2
13	208	Skewer	1
14	201	Chain Guard	1
15	501	92470A123 PAN HEAD PHILLIPS SCREW FOR SHEET METAL	4

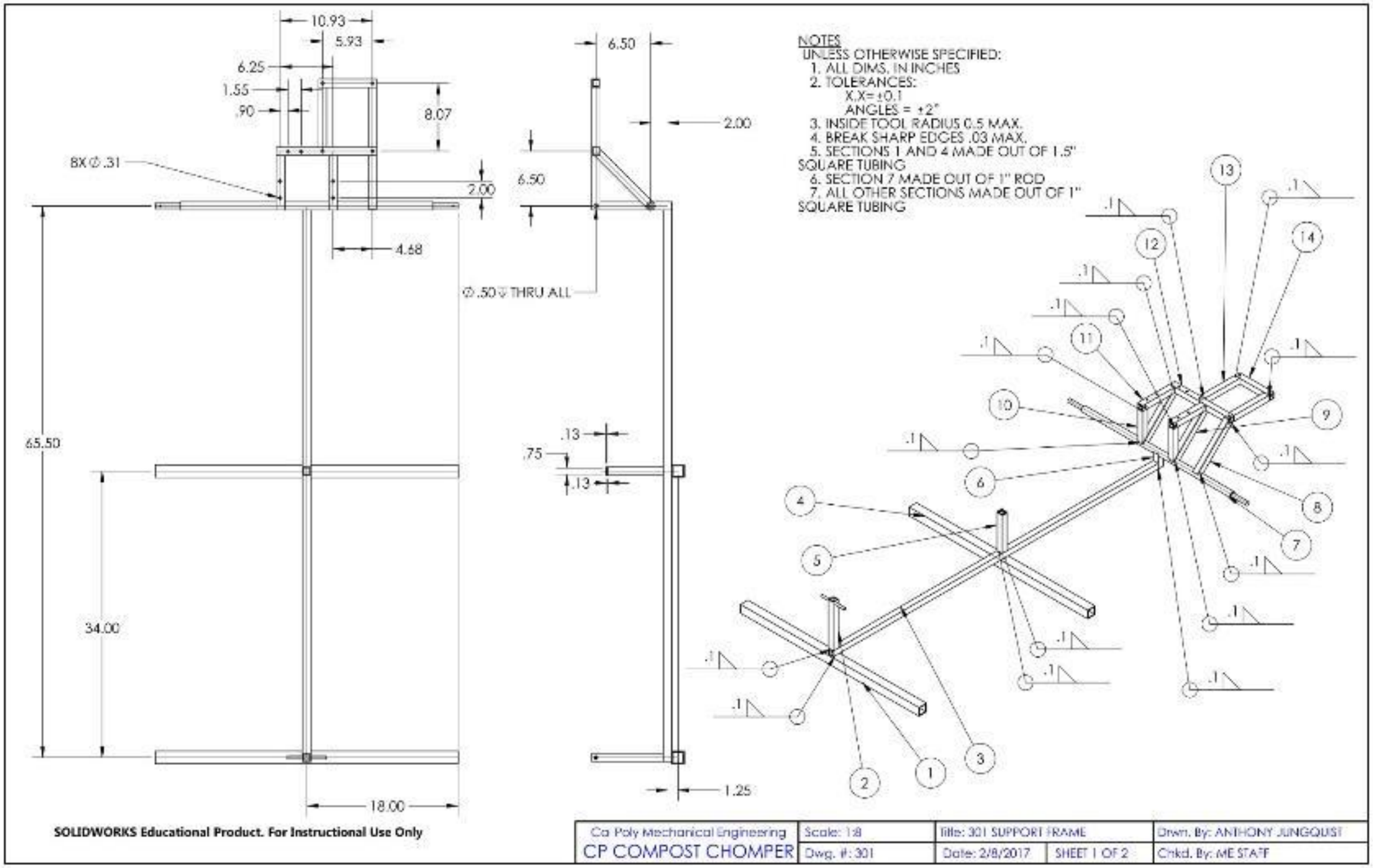


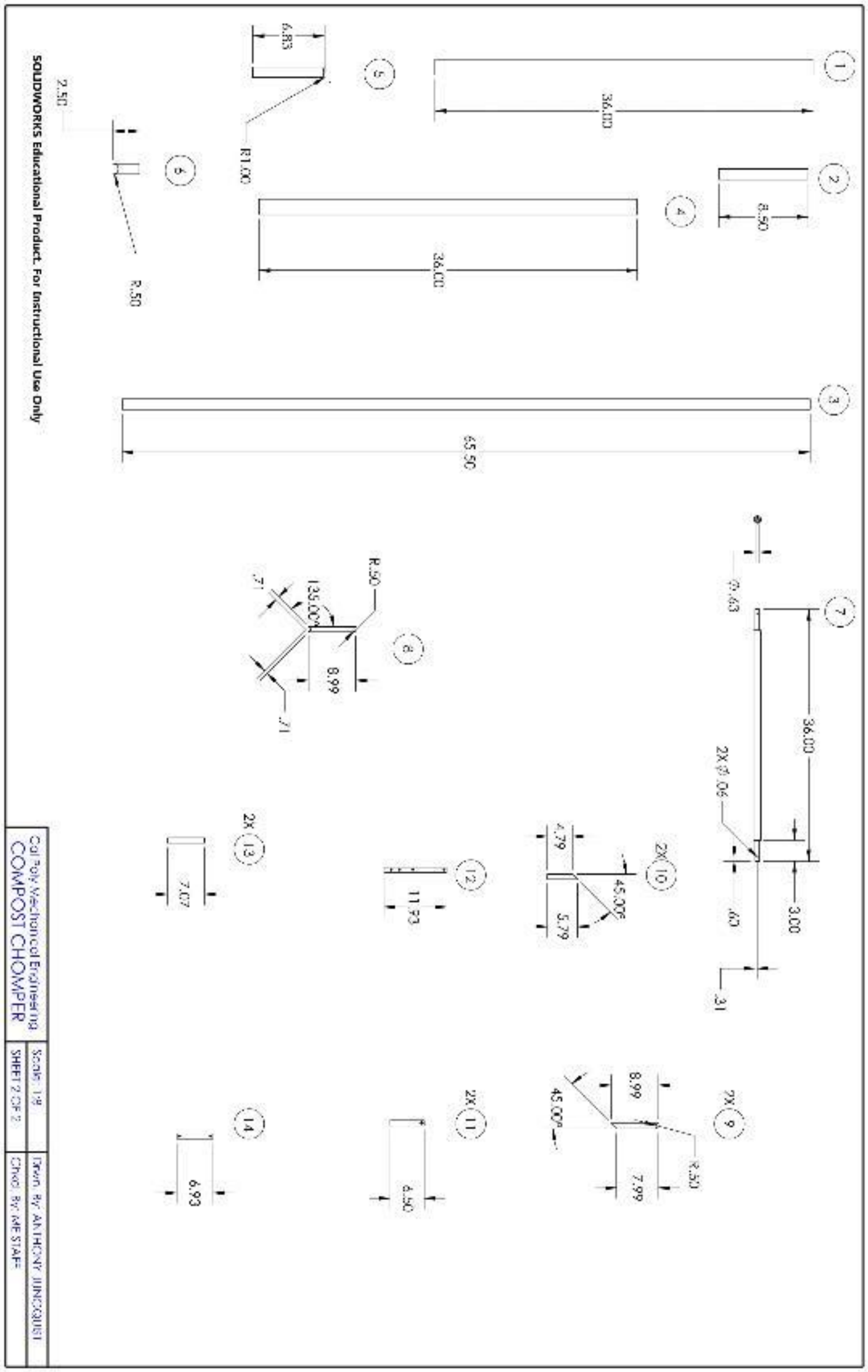
Cal Poly Mechanical Engineering	Scale: 1:8	Title: 200 BIKE ASSEMBLY	Drwn. By: ANTHONY JUNCQUIST
COMPOST CHOMPER	Dwg. #: 200	Date:2/1/2017	Chkd. By: ME STAFF

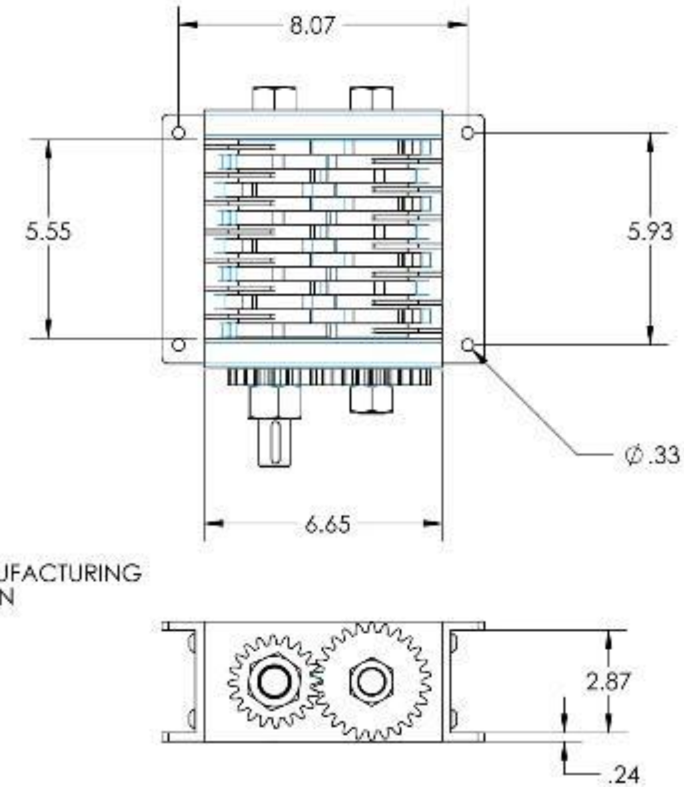
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	301	Support Frame	1
2	306	Wheel	2
3	302	Filamaker	1
4	303	6793K163 STEEL MACHINABLE-BORE SPROCKET	1
5	510	90765A583_ALLOY 20 HEX HEAD CAP SCREW	1
6	512	90765A587_ALLOY 20 HEX HEAD CAP SCREW	5
7	511	94804A030_TYPE 316 STAINLESS STEEL HEX NUT	6
8	513	96717A221_METRIC MACHINE KEY	1
9	514	98057A663_TYPE 316SS SLOTTED CUP POINT SET SCREW	1
10	508	98355A030_TYPE 316 STAINLESS STEEL COTTER PIN	2
11	509	90107A035_TYPE 316 STAINLESS STEEL FLAT WASHER	2
12	305	Read Guard	1
13	304	FlyGuard	1



Cal Poly Mechanical Engineering	Scale: 1:8	Title: 300 SUPPORT FRAME	Drwn. By: ANTHONY JUNCQUIST
COMPOST CHOMPER	Dwg. #:300	Date: 2/3/2017	Chkd. By: ME STAFF

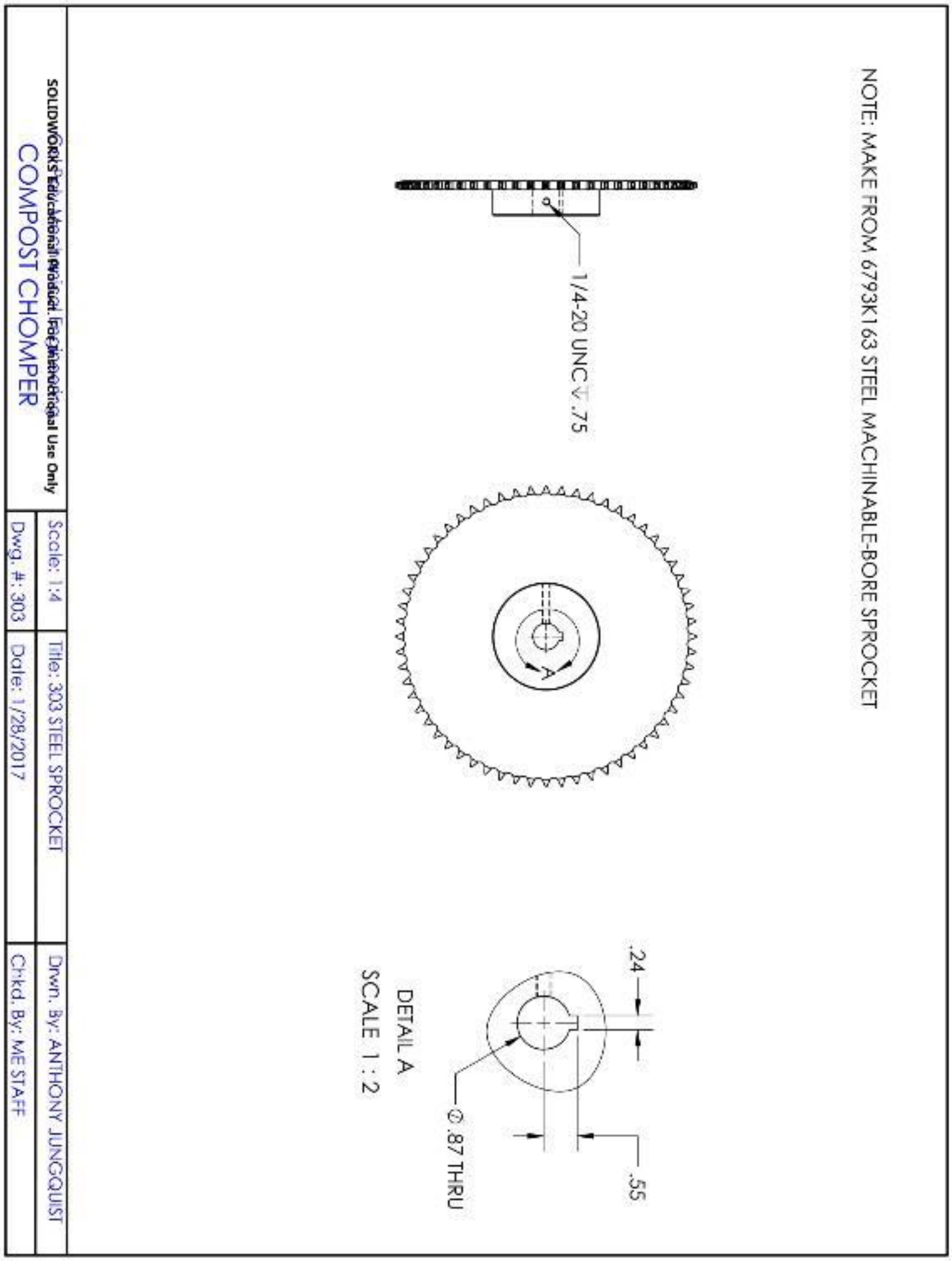

10.93
5.93
6.25
1.55
.90
8.07
8X ∅ .31
2.00
6.50
4.68
65.50
34.00
18.00
∅ .50 ⇩ THRU ALL
.13
.75
.13
1.25
NOTES
UNLESS OTHERWISE SPECIFIED:
1. ALL DIMS. IN INCHES
2. TOLERANCES:
X.X= ±0.1
ANGLES = ±2°
3. INSIDE TOOL RADIUS 0.5 MAX.
4. BREAK SHARP EDGES .03 MAX.
5. SECTIONS 1 AND 4 MADE OUT OF 1.5" SQUARE TUBING
6. SECTION 7 MADE OUT OF 1" ROD
7. ALL OTHER SECTIONS MADE OUT OF 1" SQUARE TUBING
SOLIDWORKS Educational Product. For Instructional Use Only
Ca Poly Mechanical Engineering
CP COMPOST CHOMPER
Scale: 1:8
Dwg. #: 301
Title: 301 SUPPORT FRAME
Date: 2/8/2017
SHEET 1 OF 2
Drwn. By: ANTHONY JUNGQUIST
Chkd. By: ME STAFF

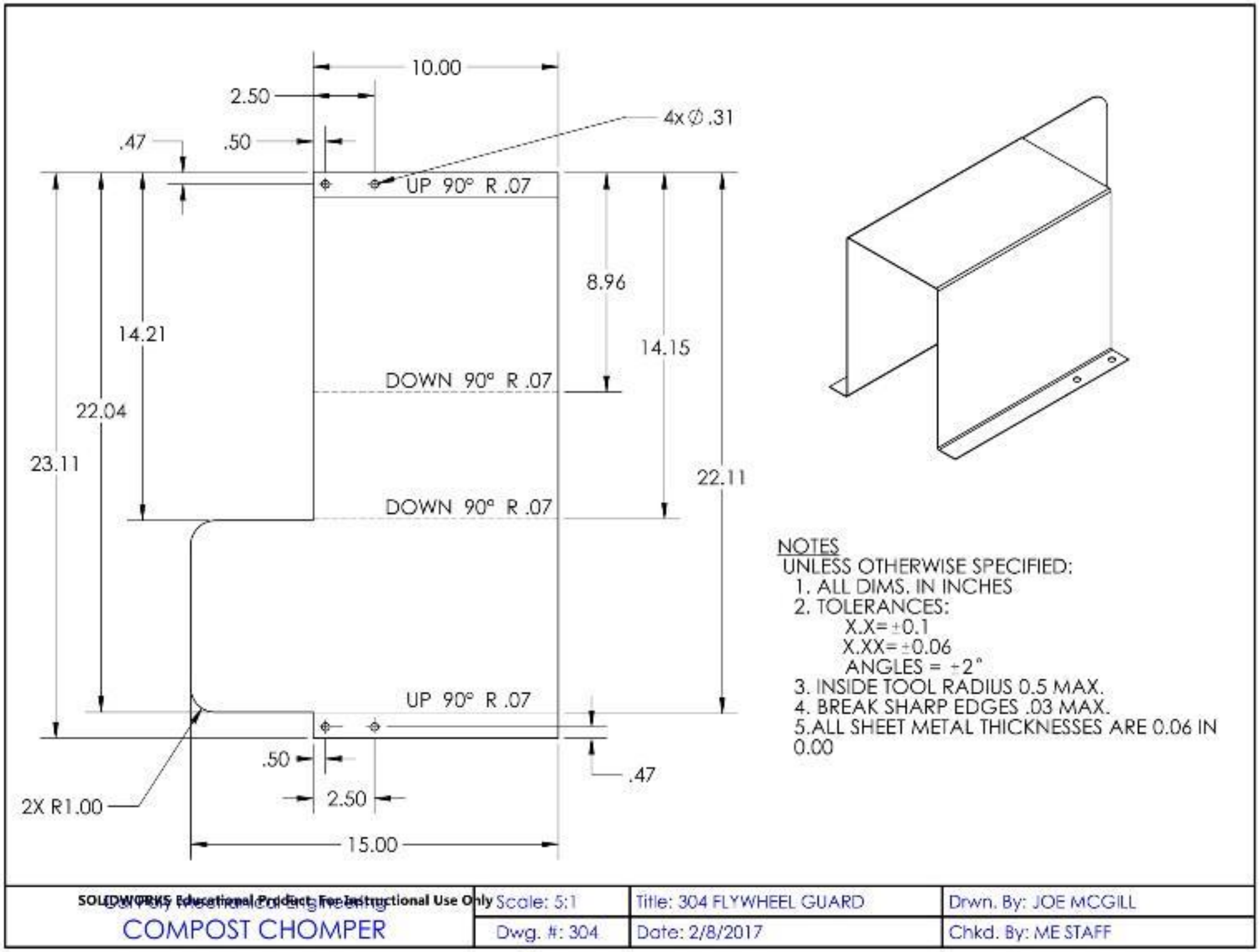

SOLIDWORKS Educational Product. For Instructional Use Only
Cal Poly Mechanical Engineering
COMPOST CHOMPER
SHEET 2 OF 2
Chkd. By: ME STAFF

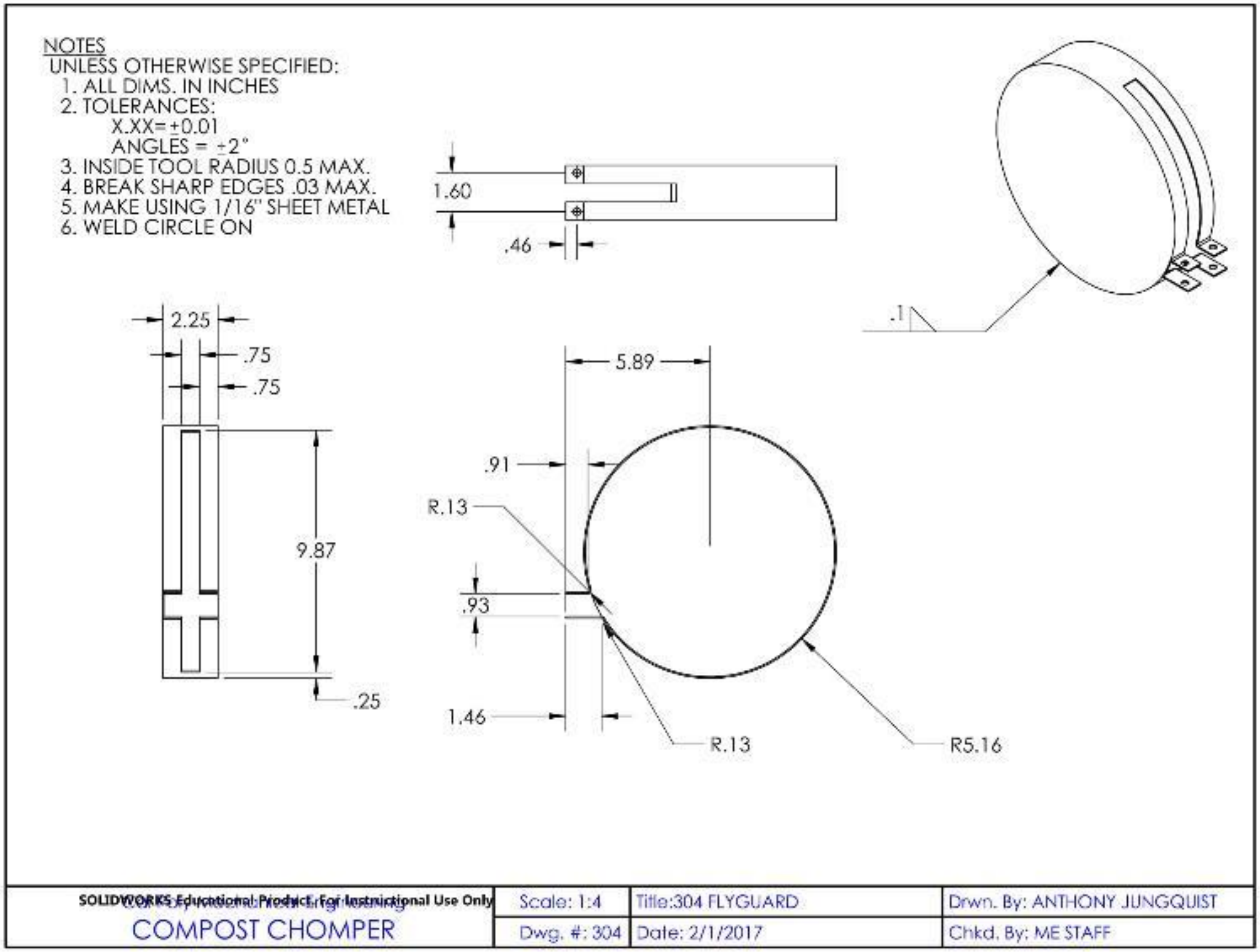


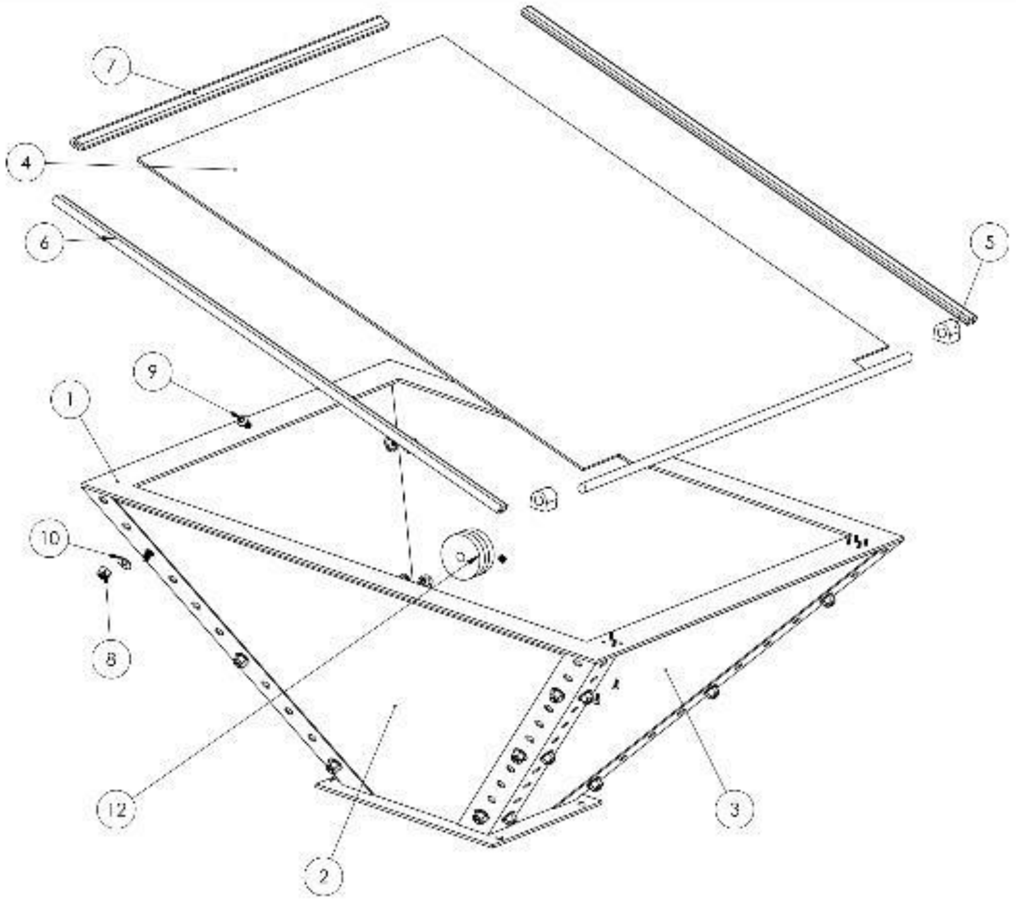
NOTE: DRAWING NOT FOR MANUFACTURING
DRAWING SHOWS HOLE PATTERN
AND BASIC DIMENSIONS

SOLIDWORKS Educational Product. For Instructional Use Only	Scale: 1:8	Title: 302 FILAMAKER	Drwn. By: ANTHONY JUNGQUIST
COMPOST CHOMPER	Dwg. #: 302	Date: 1/26/2017	Chkd. By: ME STAFF


NOTE: MAKE FROM 6793K163 STEEL MACHINABLE-BORE SPROCKET
1/4-20 UNC ⊽ .75
A
.24
.55
⌀ .87 THRU
DETAIL A
SCALE 1 : 2
SOLIDWORKS Educational Product. For Instructional Use Only
COMPOST CHOMPER
Scale: 1:4
Title: 303 STEEL SPROCKET
Drwn. By: ANTHONY JUNGQUIST
Dwg. #: 303
Date: 1/28/2017
Chkd. By: ME STAFF

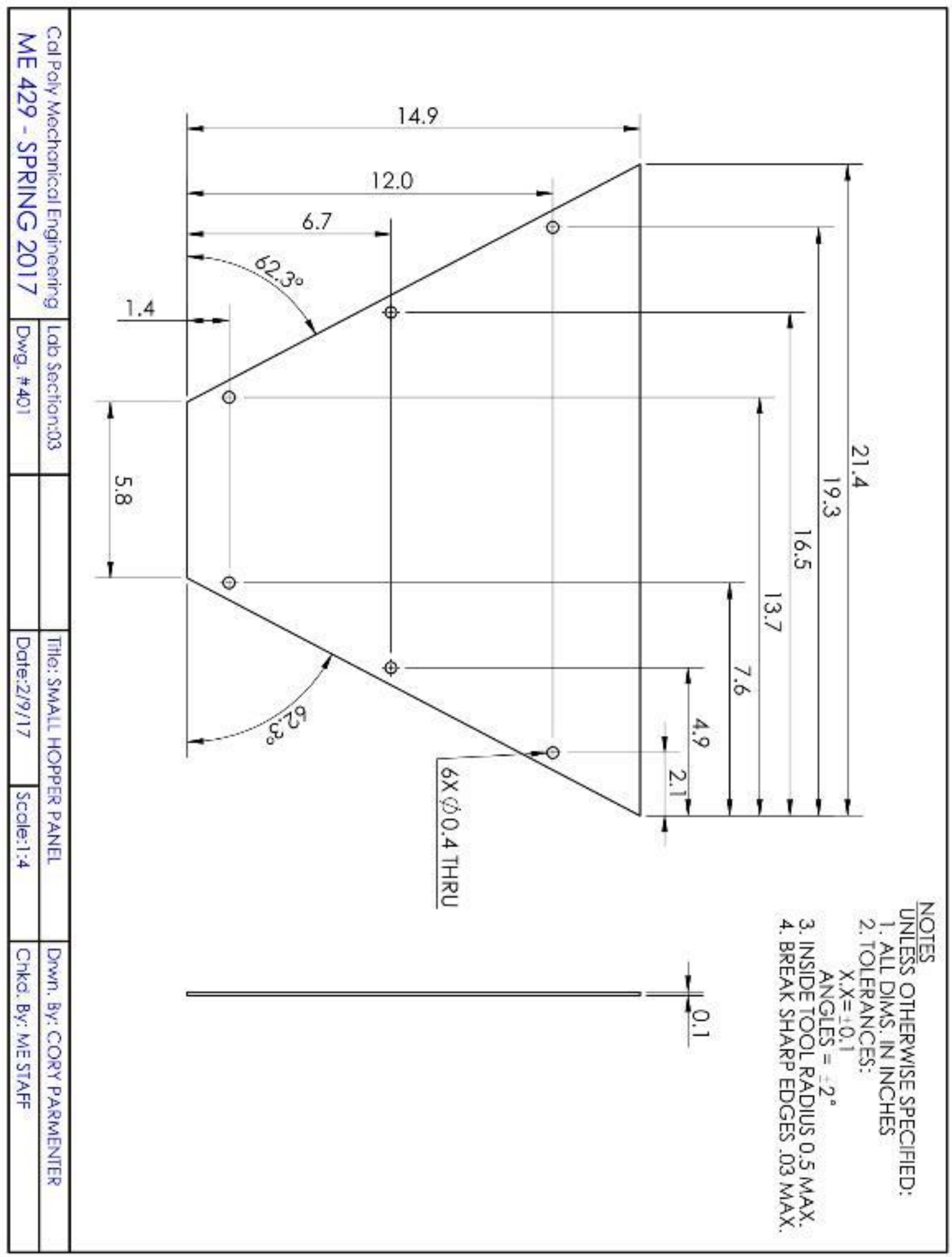

10.00
2.50
.47
.50
4x ∅ .31
UP 90° R .07
8.96
14.21
14.15
DOWN 90° R .07
22.04
23.11
22.11
DOWN 90° R .07
UP 90° R .07
.50
2.50
.47
2X R1.00
15.00
NOTES
UNLESS OTHERWISE SPECIFIED:
1. ALL DIMS. IN INCHES
2. TOLERANCES:
X.X= ±0.1
X.XX= ±0.06
ANGLES = ±2°
3. INSIDE TOOL RADIUS 0.5 MAX.
4. BREAK SHARP EDGES .03 MAX.
5.ALL SHEET METAL THICKNESSES ARE 0.06 IN
0.00
SOLIDWORKS Educational Product. For Instructional Use Only
Scale: 5:1
Title: 304 FLYWHEEL GUARD
Drwn. By: JOE MCGILL
COMPOST CHOMPER
Dwg. #: 304
Date: 2/8/2017
Chkd. By: ME STAFF

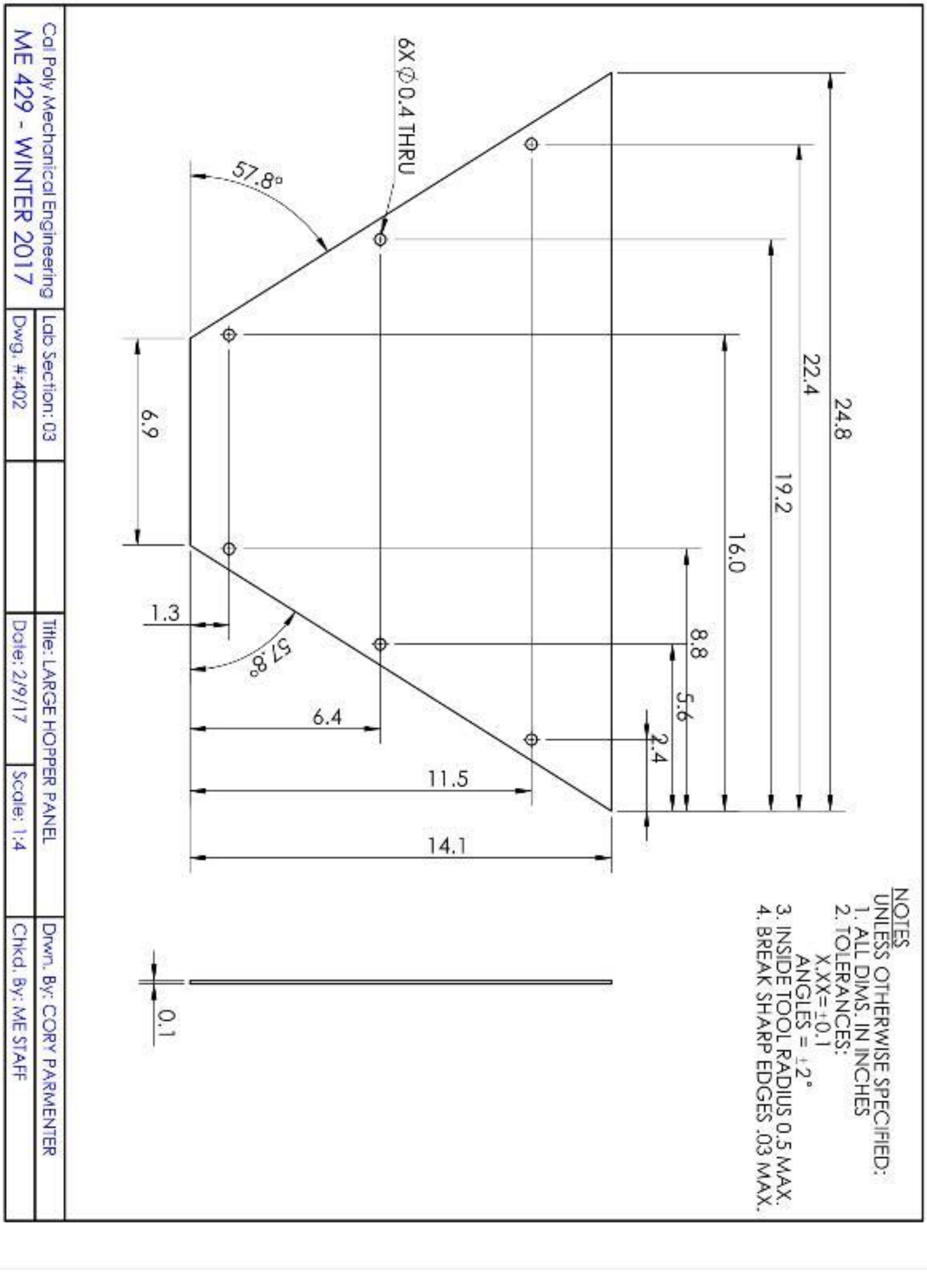

NOTES
UNLESS OTHERWISE SPECIFIED:
1. ALL DIMS. IN INCHES
2. TOLERANCES:
X.XX=±0.01
ANGLES = ±2°
3. INSIDE TOOL RADIUS 0.5 MAX.
4. BREAK SHARP EDGES .03 MAX.
5. MAKE USING 1/16" SHEET METAL
6. WELD CIRCLE ON
1.60
.46
2.25
.75
.75
9.87
.25
5.89
.91
R.13
.93
1.46
R.13
R5.16
.1
SOLIDWORKS Educational Product. For Instructional Use Only
COMPOST CHOMPER
Scale: 1:4
Dwg. #: 304
Title:304 FLYGUARD
Date: 2/1/2017
Drwn. By: ANTHONY JUNGQUIST
Chkd. By: ME STAFF



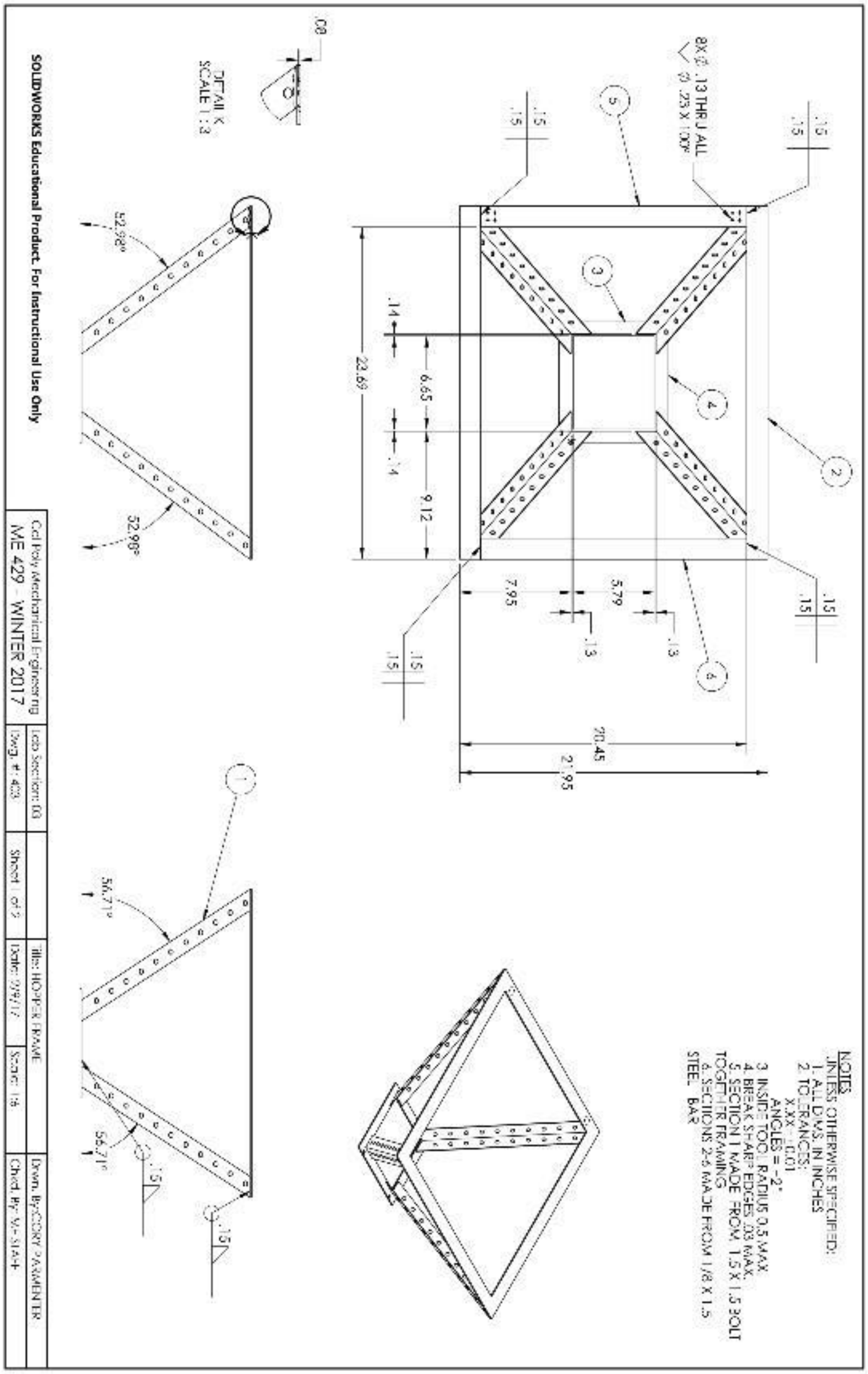
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	403	Hopper Frame	1
2	402	Large Panel	2
3	401	Small Panel	2
4	406	Lid	1
5	407	Hopper Bearing	2
6	415	Rubber Edge Trim	2
7	404	Shorter Rubber Edge Trim	1
8	505	90715A125_TYPE 316 STAINLESS STEEL NYLON-INSERT LOCKNUT	24
9	502	98164A212_TYPE 316 SS BUTTON-HEAD SOCKET CAP SCREW	24
10	507	90107A029_TYPE 316 STAINLESS STEEL FLAT WASHER	49
11	506	90585A202_TYPE 316 SS FLAT-HEAD SOCKET CAP SCREW	8
12	405	Safety Brake Cam	1
13	503	92313A533_TYPE 316 SS CUP POINT SET SCREW	1

Cal Poly Mechanical Engineering	Lab Section: 03	Title: HOPPER ASSEMBLY		Drwn. By: CORY PARMENTER
ME 429 - WINTER 2017	Dwg. #: 400	Date: 2/9/17	Scale: 1:4	Chkd. By: ME STAFF

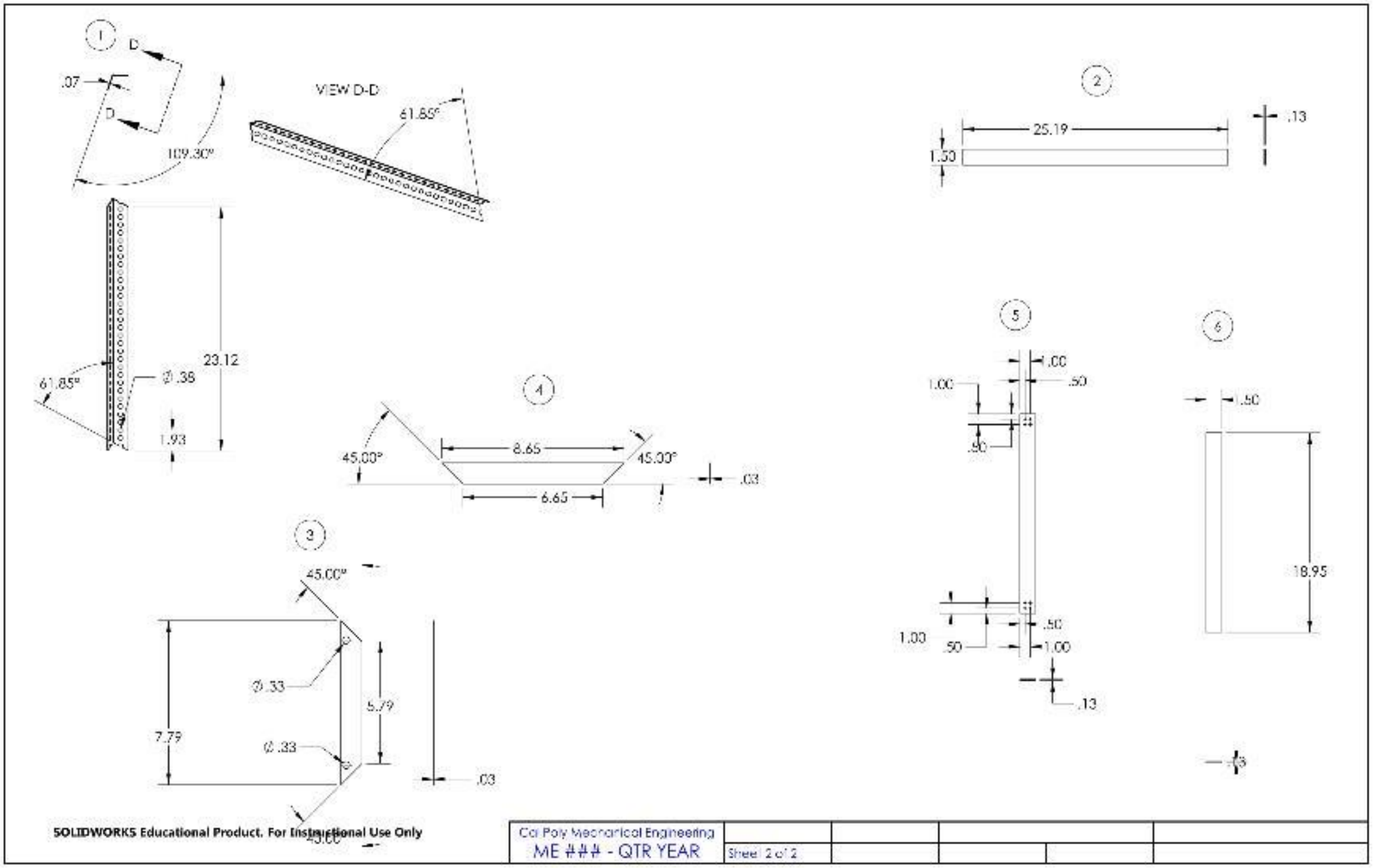

Cal Poly Mechanical Engineering
ME 429 - SPRING 2017
Lab Section:03
Dwg. #401
Title: SMALL HOPPER PANEL
Date:2/9/17
Scale:1:4
Drwn. By: CORY PARMENTER
Chkd. By: ME STAFF
14.9
12.0
6.7
62.3°
1.4
5.8
62.3°
6X ⌀0.4 THRU
21.4
19.3
16.5
13.7
7.6
4.9
2.1
0.1
NOTES
UNLESS OTHERWISE SPECIFIED:
1. ALL DIMS. IN INCHES
2. TOLERANCES:
X.X= ±0.1
ANGLES = ±2°
3. INSIDE TOOL RADIUS 0.5 MAX.
4. BREAK SHARP EDGES .03 MAX.



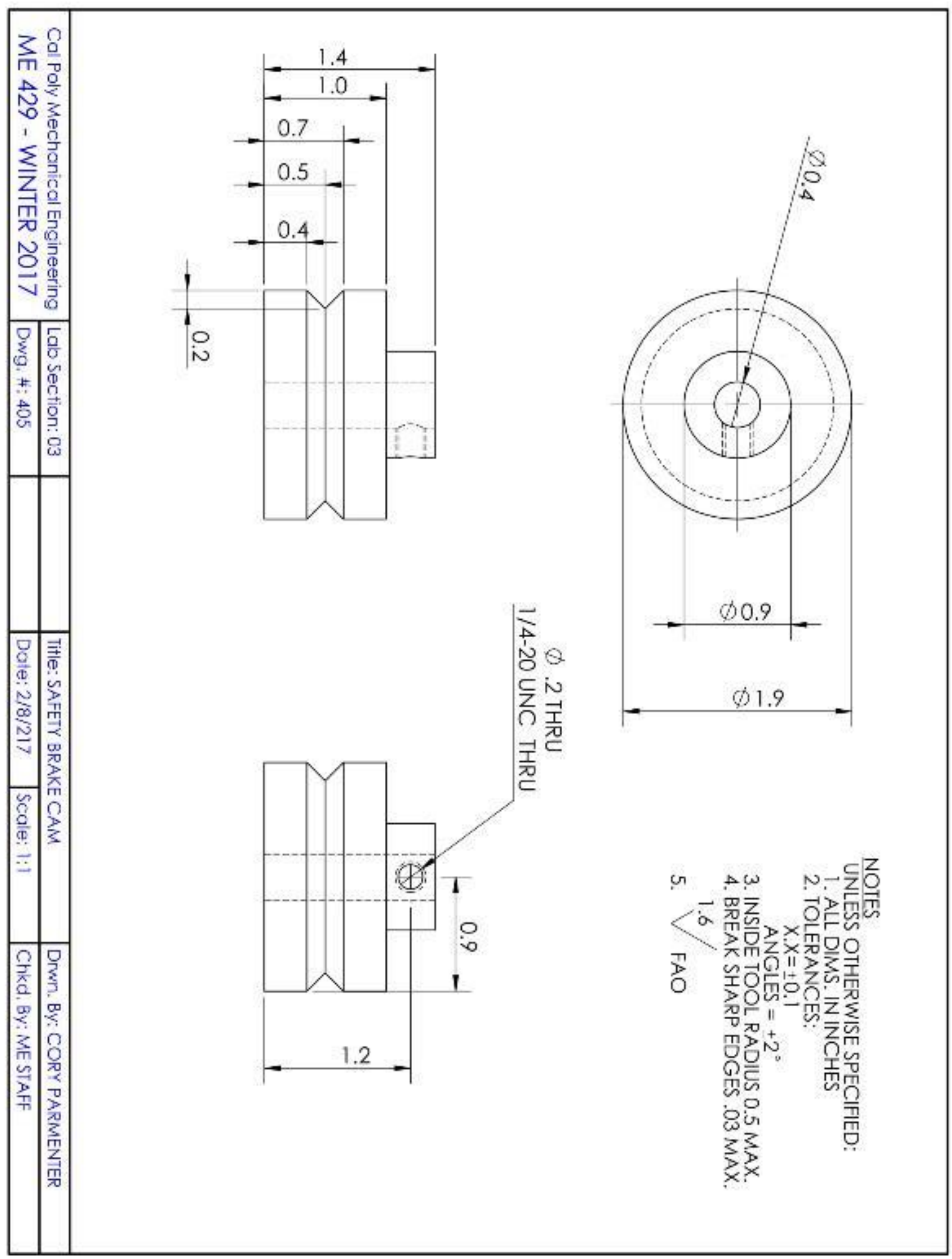
Cal Poly Mechanical Engineering
ME 429 - WINTER 2017
Lab Section: 03
Dwg. #:402
Title: LARGE HOPPER PANEL
Date: 2/9/17
Scale: 1:4
Drwn. By: CORY PARMENTER
Chkd. By: ME STAFF
6X Ø0.4 THRU
57.8°
57.8°
24.8
22.4
19.2
16.0
8.8
5.6
2.4
6.9
1.3
6.4
11.5
14.1
0.1
NOTES
UNLESS OTHERWISE SPECIFIED:
1. ALL DIMS. IN INCHES
2. TOLERANCES:
X.XX= ±0.1
ANGLES = ±2°
3. INSIDE TOOL RADIUS 0.5 MAX.
4. BREAK SHARP EDGES .03 MAX.

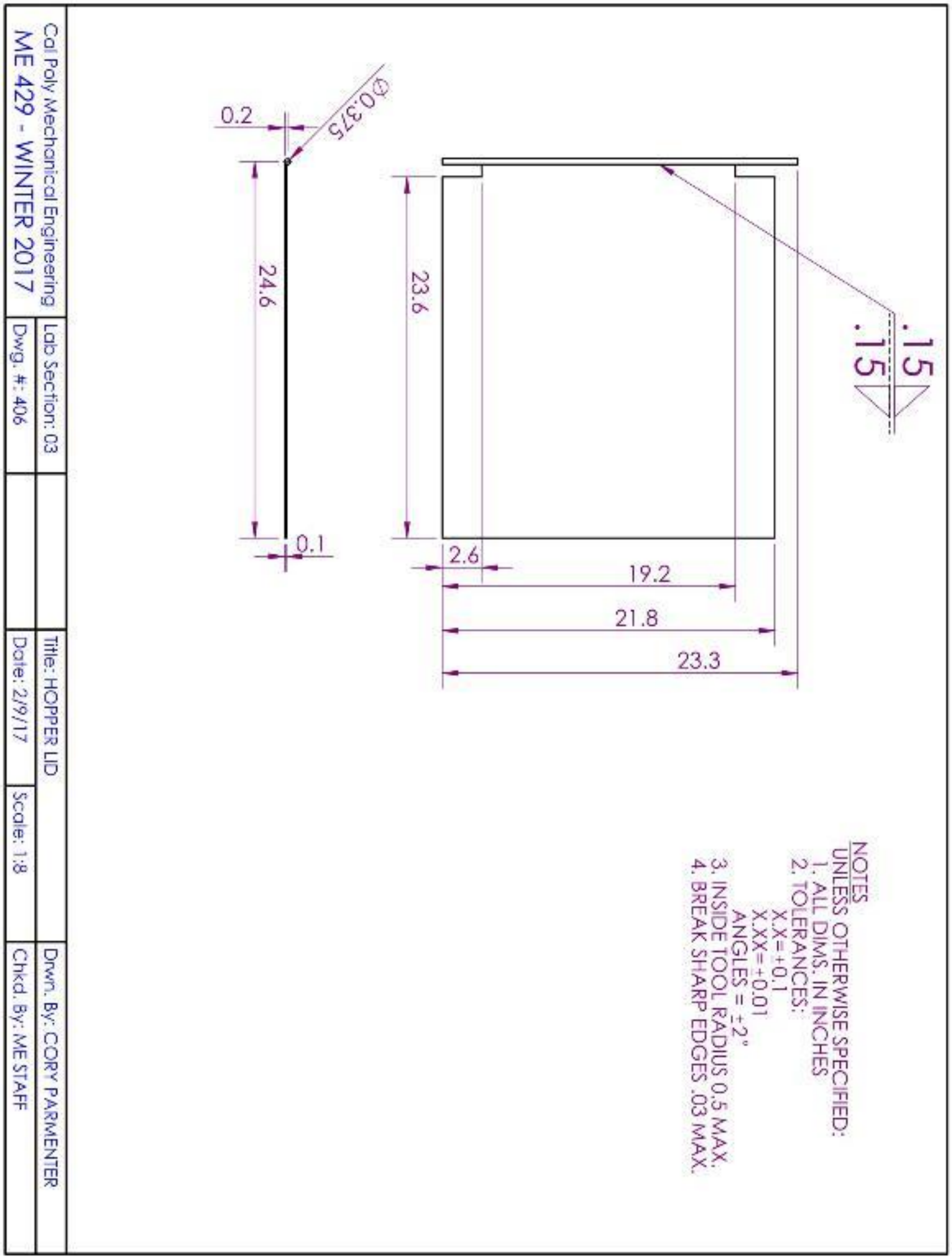


NOTES
UNLESS OTHERWISE SPECIFIED:
1. ALL DIMS IN INCHES
2. TOLERANCES:
X.XX ±0.01
ANGLES = ±2°
3. INSIDE TOOL RADIUS 0.5 MAX
4. BREAK SHARP EDGES .03 MAX.
5. SECTION 1 MADE FROM 1.5 X 1.5 BOLT TOGETHER FRAMING
6. SECTIONS 2-6 MADE FROM 1/8 X 1.5 STEEL BAR
8X ⌀ .13 THRU ALL
⌀ .25 X 100°
DETAIL K
SCALE 1 : 3
22.69
6.65
9.12
.14
7.95
5.79
.13
20.45
21.95
.15
.08
52.98°
56.71°
SOLIDWORKS Educational Product. For Instructional Use Only
Cal Poly Mechanical Engineering
ME 429 - WINTER 2017
Lab Section: 03
Dwg. #: 403
Sheet 1 of 3
Title: HOPPER FRAME
Date: 2/9/17
Scale: 1:6
Drwn. By: CORY PARMENTER

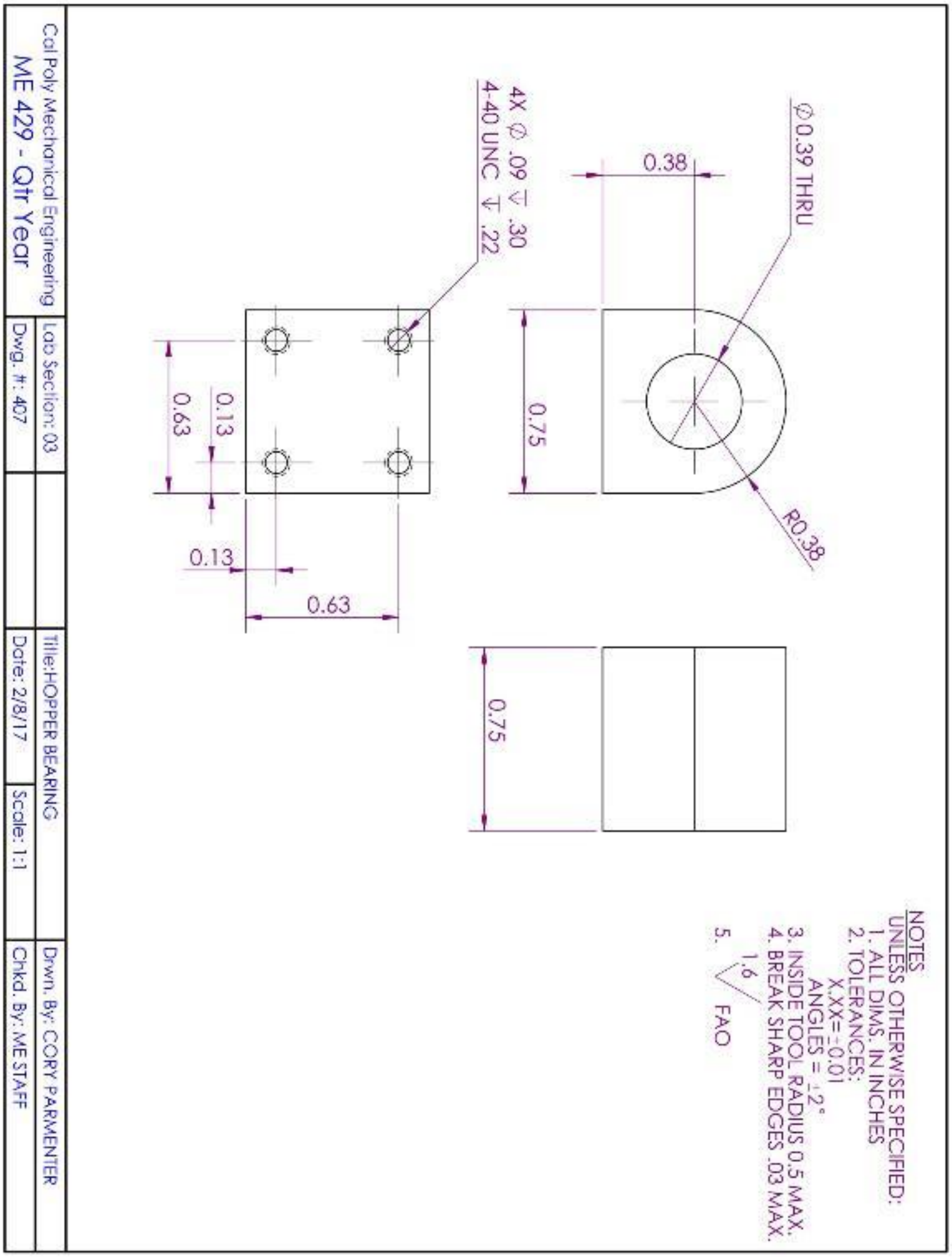


1
D
D
.07
109.30°
VIEW D-D
61.85°
61.85°
∅.38
23.12
1.93
2
25.19
1.50
.13
4
8.65
6.65
45.00°
45.00°
.03
3
45.00°
∅.33
∅.33
5.79
7.79
.03
5
1.00
1.00
.50
.50
.50
1.00
1.00
.50
.13
6
1.50
18.95
SOLIDWORKS Educational Product. For Instructional Use Only
Cal Poly Mechanical Engineering
ME ### - QTR YEAR
Sheet 2 of 2


Cal Poly Mechanical Engineering
ME 429 - WINTER 2017
Lab Section: 03
Dwg. #: 405
Title: SAFETY BRAKE CAM
Date: 2/8/217
Scale: 1:1
Drwn. By: CORY PARMENTER
Chkd. By: ME STAFF
NOTES
UNLESS OTHERWISE SPECIFIED:
1. ALL DIMS. IN INCHES
2. TOLERANCES:
X.X = ±0.1
ANGLES = +2°
3. INSIDE TOOL RADIUS 0.5 MAX.
4. BREAK SHARP EDGES .03 MAX.
5. 1.6 FAO
Ø .2 THRU
1/4-20 UNC THRU
Ø0.4
Ø0.9
Ø1.9
1.4
1.0
0.7
0.5
0.4
0.2
0.9
1.2



Cal Poly Mechanical Engineering
ME 429 - WINTER 2017
Lab Section: 03
Dwg. #: 406
Title: HOPPER LID
Date: 2/9/17
Scale: 1:8
Drwn. By: CORY PARMENTER
Chkd. By: ME STAFF
0.2
Ø0.375
24.6
0.1
23.6
2.6
19.2
21.8
23.3
.15
.15
NOTES
UNLESS OTHERWISE SPECIFIED:
1. ALL DIMS. IN INCHES
2. TOLERANCES:
X.X=±0.1
X.XX=±0.01
ANGLES = ±2°
3. INSIDE TOOL RADIUS 0.5 MAX.
4. BREAK SHARP EDGES .03 MAX.


∅0.39 THRU
0.38
R0.38
0.75
4X ∅ .09 ↧ .30
4-40 UNC ↧ .22
0.13
0.63
0.13
0.63
0.75
NOTES
UNLESS OTHERWISE SPECIFIED:
1. ALL DIMS. IN INCHES
2. TOLERANCES:
X.XX= ±0.01
ANGLES = ±2°
3. INSIDE TOOL RADIUS 0.5 MAX.
4. BREAK SHARP EDGES .03 MAX.
5. 1.6 FAO
Cal Poly Mechanical Engineering
ME 429 - Qtr Year
Lab Section: 03
Dwg. #: 407
Title:HOPPER BEARING
Date: 2/8/17
Scale: 1:1
Drwn. By: CORY PARMENTER
Chkd. By: ME STAFF

Appendix M – Testing Procedures

Test #1: Torque Input Part: Drivetrain Location: Bonderson 110 Goal: Measure input torque of single rider Equipment: Digital Scale	Testing performed: Ensure that the fully assembled device is positioned on flat ground. One rider will stand on the front pedals (Joe, Cory or Anthony). The rear pedals will have a digital scale measuring the force from the rear. From this the input torque can be calculated
Problems Testing: Finding Scales that were accurate enough for our range of forces.	Successes Testing: Luggage scales worked well.

Test #2 Input/Flywheel RPM Part: Drive Train Goal of testing: Verify that design speeds for the drive train are feasible and find out how system performs under different speeds. Equipment: Materials: Tachometer, Fully-assembled drivetrain, including cutter.	Testing performed: Counting number of pedaling cycles per minute for each operator, test different pedaling speeds and how system handles. Riders will pedal with a steady cadence in increments of 20 RPM per test. We will also use this opportunity to calibrate the tachometer. We will use the data from the above procedure to verify that the tachometer displays the same values.
Problems Testing: Pedalling at exactly the right cadence was a challenge initially.	Successes Testing: Using a metronome and a cheap tachometer allowed for more accurate testing.

Test #3: Cutter RPM	Testing performed:
Part: Cutter Location: Bonderson 110 Goal: Measure cutter rpm Tools/Devices: iPhone, Marker	A tooth will be marker with permanent marker on the large cutter sprocket. With one rider pedaling a slow motion video will be taken to count RPM.
Problems Testing: Counting the RPM of the cutting blades was difficult to make accurate.	Successes Testing: Running multiple tests and using a marker to mark the blades assured that our measurements were reasonable.

Test #4: Chip Size Part: Cutter Location: Bonderson 110 Goal: Measure average chip size leaving the cutter Tools/Devices: Ruler	Testing performed: Have two riders pedal full assembly with vines/sticks in the shredder. Once the shredder has come to a full stop, measure the longest length of any chip. This test will be repeated 10 times and statistical analysis will be performed to predict the size of a chip.
Problems Testing: Some of the longer, viny, garden waste did not get shredded as well as we wanted.	Successes Testing: Running the garden waste through a second time helped shred the compost more.

Test #5: Vine Size Part: Cutter Location: Bonderson 110 Goal: Measure largest vine size shredder is capable of shredding Tools/Devices: Ruler	Testing performed: Have two riders pedal full assembly with increasingly large vines in the shredder. Once the riders are unable to pedal or have overly frequent jams the max vine size has been reached.
Problems Testing: Cutter had trouble with thicker, drier vines.	Successes Testing: The cutter was better at cutting wetter material at the same thickness than it was cutting drier material.

<table>
<tr>
<td>Test #6: Process Rate

Part: Cutter

Location: Bonderson 110

Goal: Measure process rate capability of the compost chomper

Tools/Devices: Stopwatch</td>
<td>Testing performed:

Fill the hopper with approximately 1lb of garden waste. Have two riders power the device. As soon as the riders begin to pedal a timer will start. Once all the contents of the hopper are gone the timer will stop. From this the process rate will be calculated.</td>
</tr>
<tr>
<td>Problems Testing: Making sure our amounts of garden waste for each test were even was difficult.</td>
<td>Successes Testing: We were able to shred a relatively even amount of compost in a fairly consistently short time.</td>
</tr>
</table>

Test #7: Jam Frequency Part: Cutter Location: Bonderson 110 Goal: Measure Jam frequency during operation Tools/Devices: Stopwatch	Testing performed: During the chip size test above, the number of jams that occur will be recorded and a jam frequency will be calculated from it.
Problems Testing: Hard to define what a “jam” is.	Successes Testing: Separating the definition of jam into a hopper jam and a cutter jam made it easier to classify how many jams we had per second.

Test #8: Operator Weight Part: Frame Location: Bonderson 110 Goal: Ensure structure holds up under weight of users. Tools/Devices: Weights	Testing performed: Two operators (Joe, Anthony, or Cory) will sit on the two seats to ensure the structure does not fail. The weight of the operators will be measured and if their combined body weight is not enough to meet the 300 lb spec, they will hold additional weights while seated. Caution will be taken to ensure the operators do not get hurt if the structure fails.
Problems Testing: N/A	Successes Testing: Frame successfully held our weight, which together is over 300 pounds.

Test #9: Product Weight Part: Whole assembly Location: Hangar Goal: Test total weight of assembly Tools/Devices: Shop scale	Testing performed: The whole assembly will be placed on a shop scale and measured. If the assembly does not fit in one piece, components will be detached and measured individually, and the total weight will be calculated as the sum of the parts.
Problems Testing: Finding a scale to weigh the bike was hard.	Successes Testing: Testing was straight forward.

Test #10: Footprint Part: Whole assembly Location: Bonderson 110 Goal: Test total footprint Tools/Devices: Tape measure	Testing performed: Measure the dimensions of the virtual rectangle of space that the device occupies on the ground.
Problems Testing: N/A	Successes Testing: N/A

Test #11: Stability Part: Frame/Whole assembly Location: Bonderson 110 Goal: Test device's resistance to tipping. Tools/Devices: Weight	Testing performed: Push perpendicularly on broad side of device at the highest point. Pushing will be performed by either Joe, Anthony, or Cory (whoever is strongest). Pushing force will be calibrated at the gym to ensure the pusher is able to apply the specified 60 lbs of force.
Problems Testing: N/A	Successes Testing: We purposefully tried to tip the machine over and we were not able to. Accidentally tipping the machine over would be next to impossible.

Test #12: Feed Volume Part: Hopper Location: Bonderson 110 Goal: Test hopper's capacity. Tools/Devices: Tape measure	Testing performed: Measure the dimensions of the inside of the hopper and calculate the volume. Verify that the volume is within spec.
Problems Testing: Measuring volume of the hopper was difficult because of the geometry.	Successes Testing: Using known quantities of volume we were able to estimate how much the hopper could fit.

Test #13: Height Part: Whole assembly Location: Bonderson 110 Goal: Test max height of device Tools/Devices: Tape measure	Testing performed: Measure the normal distance from the ground to the highest point of the assembly. Verify that the height is within spec.
Problems Testing: N/A	Successes Testing: Testing was straightforward.

Appendix N – Operator Manual

Operating the Compost Chomper

The Compost Chomper is built to be easy to use but has a number a safety measures that must be acknowledged to ensure proper use. To begin, load the hopper with garden waste before any riders have mounted the bike. To fill the hopper, unlock the lid and lift it open. When filling the hopper some materials may need to be bent to fit inside the lid. At the same time material should be oriented as vertically as possible to facilitate feed into the shredder. Do not pack the hopper tightly. This increases the risk of a feed jam (material not feeding into the Filamaker). Before loading any garden was into the Compost Chomper be sure to check that no rocks are caught. Very small rocks do not pose a large threat to the shredder but larger ones could chip a shredder tooth. Tougher materials should be done individually or with as little material as possible.

Once the garden waste is loaded into the hopper, the rider(s) may mount the bike. One to two riders may power the device at a time, however, one rider may not be able to provide adequate power. Riders can adjust the seat height to their liking as well as add pedal blocks if the pedals are too far away. Each rider should be aware of the other and be on the lookout for issues or if another rider’s foot slips. If a jam occurs during operation, riders should dismount the Compost Chomper until the issue has been resolved. Fixing a jam may require pedaling backwards or pulling on the jammed material within the shredder. It is crucial that while this unjamming process is taking place that hands are kept away from moving parts and that if meddling with the shredder is necessary, that all riders have dismounted and are away from the machine. Only adults should un-jam the device.

Maintenance Considerations

It is possible that the thick machine chain or the bicycle chain(s) may hop off of their sprockets during operation. If this occurs, rider(s) should dismount the bike and an adult should remount the chains on the sprockets. Chain and sprocket life can be extended by the occasional use of chain lubricant around the chains. Brake line lubricant can be applied to the brake lines to maintain a smooth braking motion when the lines are pulled. Cleaning the shredder can be done with a hose, or if additional cleaning is required, the hopper can be taken off the shredder and, using a brush, debris can be scrubbed off the shredder.

If, however unlikely, the bearing on the flywheel needs maintenance, the tack welds that hold the flywheel assembly together can be easily ground off with an angle grinder with a cutoff wheel blade. Once that is done, the bearing may be easily accessed or replaced.

Safety Considerations

While the hopper lid is open NO RIDER MAY PEDAL OR TOUCH THE PEDALS. The hopper has a safety mechanism and the front rider has access to a handbrake, but these may be overcome with enough force which could result in bodily harm if any hands are near the shredder. Therefore, the braking systems on the machine should not be relied upon alone to provide safety. The use of clear verbal cues is recommended to communicate when the hopper is being loaded and when the hopper lid is closed and it is safe to pedal.

While the sheet metal guards make it more difficult to access moving parts on the machine, it is still possible that sprockets and chains and flywheel may still be accessed. It is crucial that the safety labels and warnings are heeded, and it is necessary that all operators are made aware of the dangers of touching the moving parts before operating the machine. BEWARE OF PINCH POINTS.

Hands should be kept away from the bottom of the shredder. The blades are still exposed on the bottom but are harder to see so under no circumstances should hands or feet be by the bottom of the shredder during operation.