Adaptive Beach Walker

Team Sean

Jonathan Larsen
Christian Nuñez
Nicholas Simon
Jessica Smith

Sponsors:

J. Kevin Taylor, PhD   James Widmann, PhD   RAPD Grant
Department of Mechanical Engineering & Department of Kinesiology
California Polytechnic State University, San Luis Obispo

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Statement of Disclosure

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Nomenclature

Nomenclature	Description
δ	*Deflection in beam*
σ	*Bending stress*
τ	*Shear stress*
θ	*Angle of Deflection*
φ	*Angle of Twist*
σ_N	*Normal Stress*
F	*Force*
L	*Length of beam*
E	*Young's Modulus*
I	*Moment of Inertia*
y	*Distance from plane of action to neutral axis*
K_{ts}	*Shear stress concentration factor*
T	*Torque*
r	*Radius*
J_{net}	*Modified Polar moment of Inertia (based off of table A-16)*
G	*Modulus of rigidity*
F_B	*Buoyancy force*
V_d	*Volume of displaced fluid*
ρ_{df}	*Density of displaced fluid*
g	*Gravity*

Executive Summary

The RAPD program is a federal organization funded by the National Science Foundation that supports the development of technologies for new and improved devices or software for persons with disabilities; in the case of our project and our fellow classmates, the program provided grants to student projects that are designed to help persons with disabilities in participating and enjoying physical activity. Our project is directed with the help of Dr. Widmann and Dr. Taylor of the Mechanical Engineering and Kinesiology Departments respectively, at California Polytechnic State University, San Luis Obispo. Three students from the Mechanical Department and one student from the Kinesiology department have been tasked with the design of this unique mobility walker to assist a local 8-year old Special Olympian. The walker makes use of lightweight materials, specialized balloon beach tires, and a very rigid frame to ensure safety, longevity and overall aesthetic appeal.

This report details the idea generation, concept selection, calculations and design of a mobility walker for traversing the beach environment. The design that the team implemented is a direct influence from Sean's current beach walker, his general purpose walker and other existing designs that were researched. Our final design was fabricated at a total cost of approximately $850, which was significantly reduced due to generous donations from multiple suppliers. Despite the success of our final product, a few minor improvements could be made to the design. The pipe fittings used to connect the various components of the frame are slightly too big and result in a loose fit with the tube. A new clamp could be selected to help eliminate any clearance that may affect the overall function and strength of the walker. In addition, the weight could be reduced through the use of thinner wall aluminum tube and the caster could be fabricated by bending thicker aluminum as opposed to the welded design we produced. A final recommendation for improvement is making the foam padding more secure by fastening it directly to the frame to eliminate chances of slipping while Sean is in the water.

The primary features of the final design include:

1. High surface area, low pressure, polyurethane balloon tires that are specialized for beach environment are used to allow easy traverse across sand and other comparable terrain. In addition, they provide significant stability and buoyancy while in the water.
2. The handlebars can be adjusted to accommodate Sean's growth.
3. The frame is powder coated and fastened using corrosive resistant hardware to prevent rust from developing, increasing the life and overall functionality of the walker.
4. The front wheels utilize a caster and bushing assembly that makes turning and maneuvering through the sand easier.

Chapter 1: Introduction

1.1 Sponsor Background and Needs

Team Sean has been tasked with designing an improved beach walker for Sean, a central coast local Special Olympic Athlete. Sean is a highly active and energetic eight-year old, and though he is often challenged by balance issues stemming from cerebral palsy with ataxia, he eagerly wants to play at the beach and enter the water. Sean is currently in possession of a beach walker, which has served to provide a means to traverse the sand with relative success. However, upon entering the water, the current walker becomes unstable, and requires a greater effort from his mother to keep it upright. The frame has also begun to deteriorate over time due to the corrosiveness from the ocean water, leaving parts of the aluminum frame covered in rust. In short, while the current walker has served Sean's most immediate needs, it is not ideal as a long-term option for Sean. A multi-disciplinary team, consisting of three Mechanical Engineering students and one Kinesiology student, was tasked with designing an improved mobility walker to meet Sean's needs. Funding for the project was provided through the RAPD Grant awarded by the National Science Foundation.

Figure 1-A. Sean's Current Beach Walker.

1.2 Formal Objective

The objective of this project is to design and build an improved walker that will allow Sean to experience the beach with more independence and also provide the means for him to continue to improve his muscular strength. The following is a list of customer requirements that were finalized after receiving feedback from his mother on our initial project proposal presented at the beginning of Fall Quarter 2013. Optional preferences are also included

1.3 Objectives/Specifications Development

The goals of the project are as follows:

- Design and produce a new walker that will allow Sean to traverse the sand with safety and with ease.
- Design a walker that maintain a Least Restrictive Environment for Sean, as any design that hinders his ability to move as he pleases would be counterproductive.
- Maximize Sean's independence in the beach environment.
- Design to be light-weight, so that it could be easily lifted by one person, and easy to transport within the space restrictions of Sean's Mother's car.
- Utilize buoyant light-weight wheels that would provide floatation and stability in the water.
- Treat the aluminum frame so that it is resistant to corrosion caused by the corrosive salt water beach environment.

The requirements set forth by the customer are as follows:

- Allow Sean to independently traverse the sand/beach
- Can float in water without tipping
- Frame should be open in front and should not restrict Sean's mobility
- Lightweight
- Must be able to maneuver through standard ramps, doorways, and hallways according ADA guidelines.
- Materials must be resistant to corrosion caused by the beach environment
- Must be durable
- Adjustable to fit Sean's growth

Table 1-A. Formal Engineering Requirements with Risk and Compliance Assessment

Specification	Parameter Description	Requirement or Target (units)	Tolerance	Risk	Compliance
1.	Dry/Wet Sand	100% (all sand conditions)	max	L	T, S, I
2.	Overall Width	30 inches	max	M	A, I
3.	Overall Height	36 inches	max	M	A, I
4.	Overall Depth	50 inches	max	M	A, I
5.	Submergibility	5.5 inches	+/- 2	H	A, T, S, I
6.	Adjustable Grip Range	5 inches	+/- 1	M	A, T, S
7.	Weight	15 lbs.	+/- 3.5 lbs.	H	A, I
8.	Operational Volume	50 ft^3	+/- 5 ft^3	M	A, I
9.	Factor of Safety	2	Min	H	A, S, I
10.	Corrosion Resistance	5 years	Min	H	A, T, S, I
11.	# of Attachments	4	Min	L	I
12.	Customer Satisfaction	100%	Min	H	T, I, S
13.	Total Cost	$999	+/- $150	L	A

Process of meeting specifications:
A-Analysis, T-Test, S-Similarity to existing designs, I-Inspection
Difficulty (Risk) of meeting specifications: L-Low, M-Medium, H-High

A Quality Function Deployment (QFD) table, found in Appendix A, was made for Sean's walker using the objectives of the project, the customer requirements and engineering requirements. Along with adjusting our QFD table, we reevaluated our formal engineering requirements, seen in Table 1-A above. This table quantifies the requirements with a desired value and tolerance. It also evaluates the risk associated with meeting the desired value. The requirements that are considered "high risk" are critical in our design and need to be closely evaluated and documented. The submergibility requirement is one of our largest design characteristics because we have to ensure stability in the water to prevent Sean from tipping out of his walker. The weight of the walker is also important due to the limited strength Sean possesses and the fact his mother needs to be able to move the walker in and out of her vehicle. We have also assigned a high risk value to the corrosion resistance of our walker, due to the design requirement that the walker last up to 5 years. The beach environment is very corrosive and will quickly reduce the lifespan of our walker, if not properly accounted for. We have also considered the factor of safety of 2 as a high risk item. It is critical that our design is safe for Sean. The design requirements will be assessed for compliance using analysis, testing, comparison to similar designs, and inspection.

1.4 Team Management

The team was managed according to the Team contract, found in Appendix H. A brief description of each team member's responsibilities can be seen below.

1. Communications Officer - Jessica Smith
    a. Be main point of communication with sponsor and customer
    b. Facilitate meetings with sponsor and customer
2. Team Treasurer - Christian Nunez
    a. Maintain team's travel budget
    b. Maintain team's materials budget
    c. Relay purchase order information to ME dept. office
3. Secretary/Recorder - Jonathan Larson
    a. Maintain information repository for team (e.g. team binder, google docs site, etc...)
    b. Master note taker
4. Coordinator/Facilitator - Nicholas Simon
    a. Arrange team meetings and travel details
    b. Task and schedule manager

In addition to the weekly meetings held with our advisor, our team met at a minimum once per week to discuss the current progress of the project along with to-do items. To help facilitate the outside of class meetings our team maintained a chat group in which all matters regarding the project could be discussed. This chat group was able to streamline communication between the members of our group. Manufacturing of the project was scheduled to occur on Tuesdays and Saturdays during spring quarter. Other deadlines for this project were set and completed as seen in the Gantt chart in Appendix G.

Chapter 2: Background

2.1 Sean's Current Mobility Walkers

In order to start developing a better understanding of the specific needs of our customer, we analyzed his current beach walker and his general purpose walker. The beach walker, shown in Figure 2-A below, is a completely custom design and is a combination of various mobility equipment and hardware. This walker had many features that were brought into the final design. Unfortunately we were unable to bring the current walker back to the shop for a detail analysis. In order to better understand how effective the walker actually was at the beach, videos and pictures were carefully analyzed throughout the entire design process. A lot of helpful information was collected from the videos and pictures in regards to comfort, ease of use, and overall size.

Figure 2-A. Sean using his original walker on the first beach day

In addition to analyzing Sean's beach walker, we carefully researched the design details of his everyday walker. The Nurmi Neo walker, shown below in Figure 2-B., is a youth mobility walker designed by a German company named Ottobock. This walker is collapsible, features minimal frame material, has adjustable handlebars, and has caster wheels in the front to enable turning. Sean is very comfortable using this walker, so our final design was closely modeled after many of the features that make this walker suitable for Sean's needs. A data sheet of the primary dimensions of this walker was obtained from the manufacturer's website in order to ensure that our final design was a comfortable transition for Sean.

Figure 2-B. Nurmi Neo Gait Trainer by Ottobock

2.2 Competitor Information

To begin our research we looked for any companies that offer a walker that meets our design goals. We found that, currently there is no competitor for the product we are designing. There are many walkers that have been adapted to traverse the beach, but none that are also meant to be used in the water as floatation device for riding small waves. As far as similar systems, as previously mentioned, there are a plethora of devices that have been developed to help people that require minor assistance when walking on the beach. Some of those devices are pictured below. Figure 2-C shows a picture of a homemade beach walker, it is constructed from a simple PVC frame and off-the shelf wheels designed for a wheelbarrow or utility cart. This particular picture was designed for a child approximately 6 years of age. Figure 2-D shows a picture of a walker with balloon tires, the inflatable wheels allow the user to cross soft terrain with ease. The frame is constructed of corrosion-protected aluminum tube and is collapsible for transportation and storage.

Figure 2-C. Homemade beach walker

Figure 2-D. J.O.B Walker by Neatec.

In addition to looking at walkers that were designed for the beach, we also took a look at walkers that have been ergonomically enhanced to allow for a better user interface. Below, a figure from a patent search is included. Figure 2-E shows an upright walker, the image on the left shows a standard walker design where the image on the right shows the design described in the patent. The overall height is taller to encourage an upright posture and also includes armrests with handles to help with forward motion.

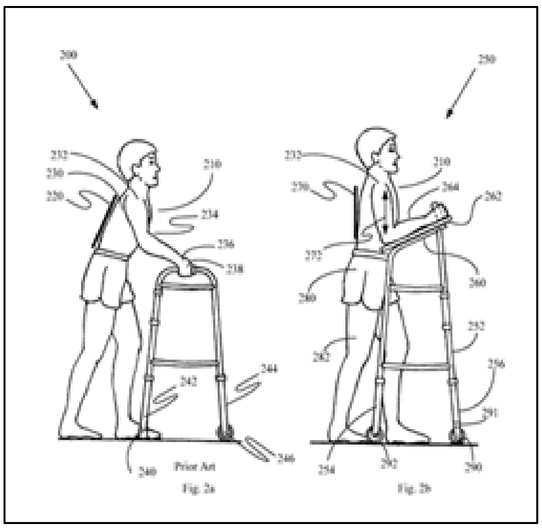


Figure 2-E. Up-right walker.

We also explored the possibilities of a collapsible design. Figure 2-F and 2-G below show images from patent on a collapsible walker that we found doing a patent search through Google patents. Although there are many advantages to a collapsible design, in the end we felt that it was not applicable to our project. This was a decision made by taking our sponsor's preferences into account, noting the pinch hazards for the user of the device and the increased risk of the walker malfunctioning. The image on the left shows the device in operational form where the user walker forward with an open front. The supporting frame is behind the user, providing the least restrictive environment. The image on the right shows the design in its collapsed form.

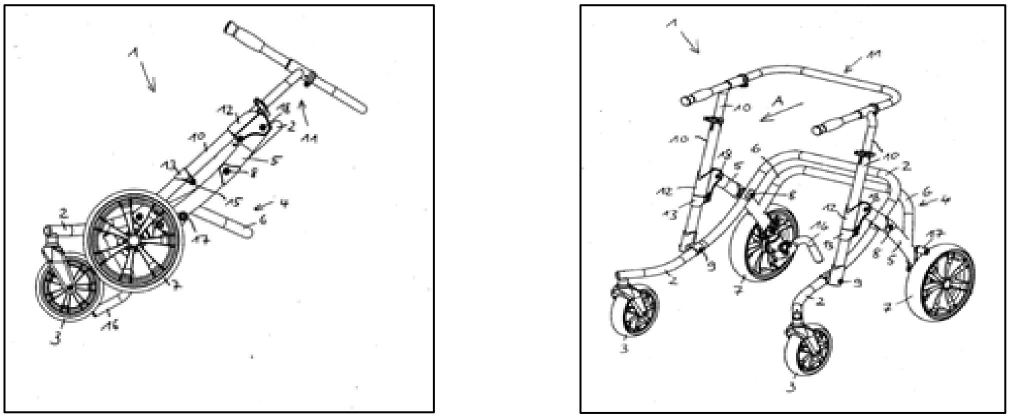


Figure 2-F and 2-G. Collapsible Walking Aid.

2.3 Literature

There were a few pieces of literature that we have referenced in continuing to design the beach walker for Sean. The first was the final report from a previous senior project, the Beach Wheelchair Project for Bridge II Sports. This report is a great resource for our project, especially the extensive testing they performed in selecting the proper tires. They also performed detailed analysis on the frame to ensure strength and corrosion resistance. In addition we have completed a basic search for materials that are corrosion resistant in a saltwater environment. For this we looked at resources such as the Engineering Toolbox website and a paper on material selection for seawater pumps written by the Chief Metallurgist and Global Manager of Materials Technology at ITT Corporation, Stephen J. Morrow. We learned that interaction between different types of metals in an important consideration when evaluating corrosion. With that said, the biggest thing that we can take away from this report is that aluminum on aluminum is one of the most corrosive-resistant metal combinations available, ideal for our design. In addition to these reports, an extensive search of existing walkers was done on Google Patents. Some of the patented designs have been previously mentioned and can be seen above in Figures 2-E and 2-F.

2.4 Applicable Standards

For this project there was only one standard that applied. The standard comes from Americans with Disabilities Act [ADA]. The requirement taken from this standard was that the walker must be 32” wide or less, so that it may fit through standard doorways and walkways.

Chapter 3: Design Development

3.1 Concept Generation and Selection Process

The top concept was determined through many weeks of ideation, discussion and testing of existing products. The design process began with several weeks of background research on mobility walkers for both youth and adults. This allowed us to gather a better understanding of what materials, features, and design shapes are currently used. Most of what we found was very basic, constructed from a simple aluminum tube frame, with fixed wheels, and some sort of collapsible feature for better storage capability. Using these existing products as a baseline we individually began to develop many concept sketches. The sketching phase was done over several weeks following our Project Proposal, along with testing of existing mobility walkers that were collected from Craigslist ad postings. Our ideation was kicked-off by a model-building day at which our group was able to creatively design as many models as possible using basic craft supplies. The models, found in Figure 3-A below, produced a wide spectrum of creative methods for flotation, turning methods, frame concepts, and sand traversability.

Figure 3-A. Simple models developed during first ideation session

At the beginning of October 2013, we started to collect free walkers and mobility aids found from postings on the internet. This enabled us to test different wheel configurations and analyze the existing frame designs. We found that all the walkers were constructed from aluminum tube frames with simple plastic wheels. These basic wheels were not conducive to easy mobility when used across sand; they quickly sank and prohibited further motion. Professor James Widmann provided us with a wheel used on a Beach Wheelchair developed for a previous senior project. This wheel, developed by Wheeleez, was significantly more effective at traversing sand and was ultimately used in our final design. Despite the lack of sand traversability, we continued to test different configurations using the free walkers. We mixed and matched parts from the various walkers and developed some possible prototype models. These models helped us learn a lot about maximizing and reducing mobility and significantly helped with our concept creation.

The top three physical models constructed from the donated supplies are shown below in Figure 3-B through Figure 3-D. The design in Figure 3-B, allowed us to experiment with different handle locations and angles and how they affect the overall mobility of the user. The design in Figure 3-C, was made to determine how a walker operated with three wheels instead of the conventional four wheel designs. The caster wheel was placed at the rear of the walker and actually provided a small turn radius and easy maneuverability. This design required a lot of additional framework to support the single rear wheel. The third prototype shown in Figure 3-D, was much more conventional in that it had two fixed wheels in the rear, and caster wheels in the front. This model demonstrated the benefit of having caster wheels and their ability to provide a much better turning radius. We tested both rear and front locations for the caster wheels which heavily influenced our concept design.

Figure 3-B. Prototype model 1, constructed by attaching canes to the frame of a basic mobility walker.

Figure 3-C. Prototype model 2, consisting of two large wheels in front and one rear caster wheel.

Figure 3-D. Prototype model 3, with two fixed wheels and two free-rotating caster wheels

In order to select our final concept design, we held several meetings, as well as individually and collectively assessing the various concept sketches. The first assessment of concepts was done individually using a Pugh Matrix on each team member's designs. This is a decision-making method where all concepts are compared to a single Datum based on a list of set design criteria. The Datum was selected to be each teammate's "top concept"; the one they felt best met the needs of the customer. The remaining concepts are ranked as better than, worse, or the same at meeting each of the design criteria. The rankings are totaled at the end of the evaluation, making it clear which of the concepts were more effective at meeting the design requirements.

Using the results from the individual assessments, we narrowed our list down three concepts each. For each concept we required a list of reasons why it was suitable for meeting the needs of the customer. These individual top three concepts were brought to another meeting where a final Pugh Matrix was developed. This can be found attached in the Appendix.

The final Pugh Matrix used Sean's current beach walker as the Datum and also used a new set of well-defined design criteria. After each of the twelve concepts were ranked, we were left with 6 possible solutions. These all had unique features and frame designs but all met the needs of the customer. Using these top 6 concepts, we generated a few final concept sketches. These final concept sketches utilized various features such as frame design, wave-riding aid, and wheel layout from each of the top concepts. The concept proposed in this report was a product of all these different features with a minor touch of originality. The following images are the top 6 concept sketches found after several sessions of ideation, sketching, testing and discussion.

The design shown below in Figure 3-E was selected to the top six due to its utilization of posterior caster wheels, visually appealing curved design and adjustable hand grips. Its aluminum frame would make for an overall lightweight walker. This shape of this concept had a major influence on the final design.

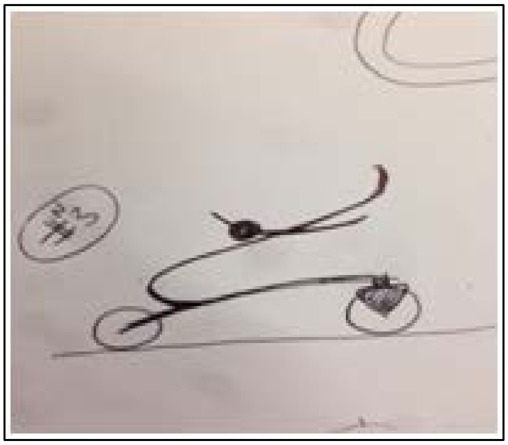


Figure 3-E. *Concept 1*. Design created by Nick,
labeled N3 in overall design Pugh matrix.

The design shown below in Figure 3-F, was selected for its open, non-restrictive design, adjustable foot rests and easy-grip handles. The U-shaped back is visually appealing, and the walker would be designed to be adjustable to Sean’s potential growth over time. This particular walker is also similar to the design of Sean’s current hockey-walker, so he would likely be very comfortable with the familiar design.

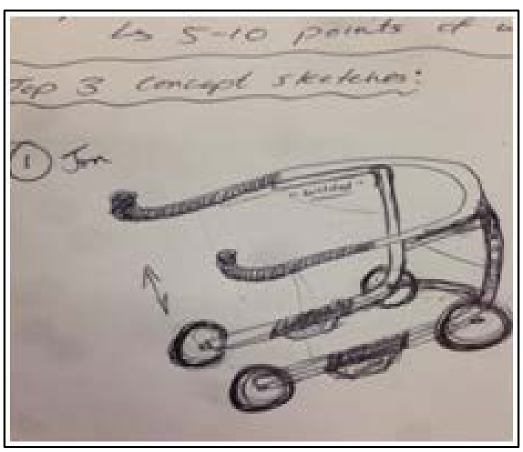


Figure 3-F. *Concept 2*. Design created by Jon,
labeled Jon 1 in Pugh matrix.

The design shown below in Figure 3-G, was selected for its minimalistic material use and U-shaped design that contained a seat. The walker is unique from the other designs due to its ability to collapse. This specific feature was ultimately rejected in the creation of the final design, due to safety concerns from the sponsor. However, the wide, open aluminum frame would not restrict Sean’s mobility and contribute to stability on uneven sandy terrain.

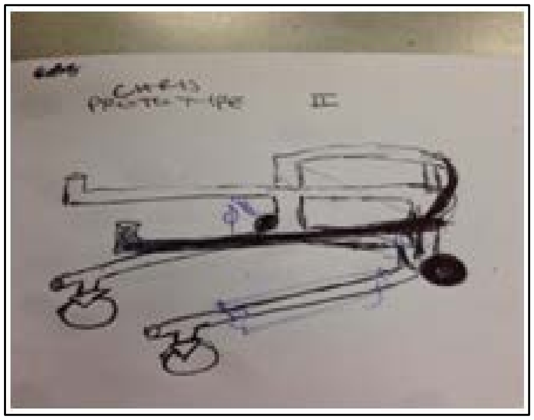


Figure 3-G. *Concept 3.* Design created by Chris, labeled as C2 in overall design Pugh matrix.

The design shown below in Figure 3-H, was selected for its unique incorporation of a “boogie board” back that would contribute to its overall buoyancy and force distribution. The simple design would be easy to manufacture, and its free-rotating wheels would provide for easier manipulation of the walker; with adjustable footrests for comfort. The frame would be wrapped in a foam material, which is durable against salt-water corrosion, non-abrasive and lightweight

Figure 3-H. *Concept 4.* Design created by Jessica, labeled as Jess 2 in the overall design Pugh matrix

The design shown below in Figure 3-I, was selected for adjustable handle location, which would allow adjustability of the walker for overall comfort. The design also contains collapsible rear handles for Gabby to interface the walker when necessary. The minimal open fiberglass frame would ideally provide the necessary buoyancy and meet the required weight.

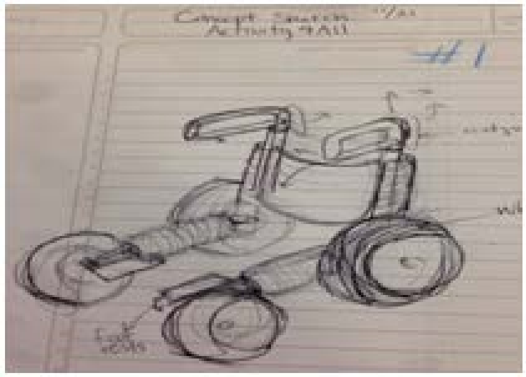


Figure 3-I. *Concept 5*. Design created by Jessica, labeled as Jess2 on the overall Pugh matrix

The design shown below in Figure 3-J, utilizes a U-shaped design to accommodate a mesh resting net for Sean's comfort while wave-riding. He would be able to recline into this mesh for stability and safety while in the water. Fenders would provide additional surface area that would help catch water and propel the walker forward. The free rotating caster wheels provide a much better turning radius than a standard fixed-wheel design.

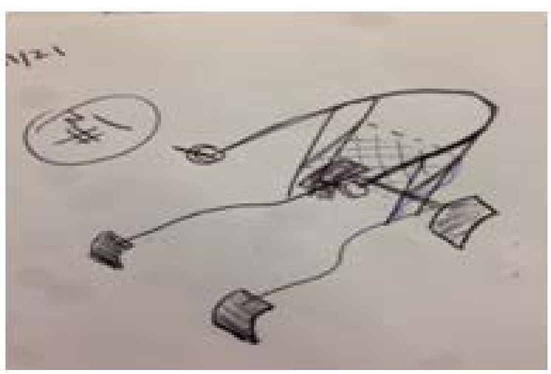


Figure 3-J. *Concept 6.* Design created by Nick, labeled N1 in the design Pugh matrix.

3.2 Preliminary Concept Design:

At the end of Fall Quarter 2013, the top features from each of concept sketches and prototype models were combined into the preliminary design shown below in Figure 3-K. The main features are shown by the arrows on the figure. A design review with our professor and peers brought several design considerations to our attention and significantly helped improve the design. The overall shape of the walker was kept relatively the same as the initial SolidWorks model shown below. One of the biggest modifications from our initial concept model to the final model was location of the caster wheels. In the top concept model, the caster wheels were placed at the rear of the walker due to the preliminary testing done with the prototype walkers. This was later discovered to ultimately be ineffective for the goals we were trying to achieve in terms of turning capabilities. The caster wheels were moved to the front in our final design.

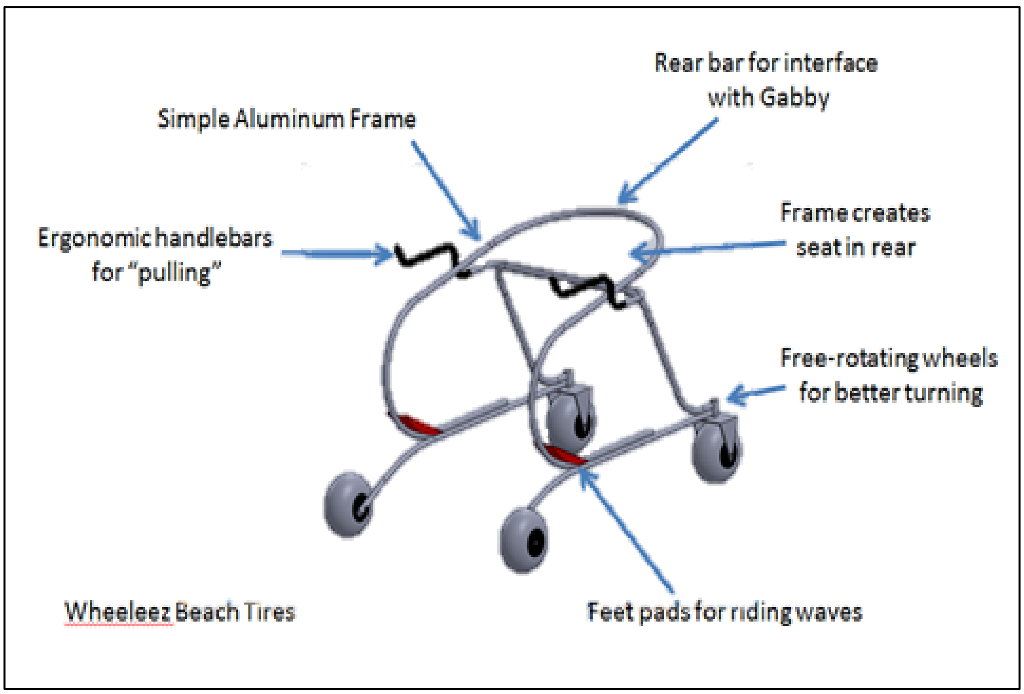


Figure 3-K. Top concept model from Fall Quarter 2013.

3.3 PVC Prototype

Once our concept design was approved by both our professor and client, we constructed a simple prototype out of PVC pipe and hardware collected from the donated walkers. This model enabled us to learn a lot about the overall walker dimensions and geometry. We built the walker initially oversized so that we could bring it to Sean and trim the PVC down to the appropriate dimensions, providing him with the best fit. The PVC prototype included small caster wheels in the front as opposed the rear, as shown in the concept model from Fall Quarter 2013. The rear supports that join the two halves of the frame were set at the appropriate height for two primary functions. The top bar is at a height where Sean's mother can easily interact with the walker and reach down to assist Sean through tough terrain and in the water. The lower horizontal bar is set a height for Sean to sit while he is riding waves into the shore. The handlebars were significantly oversized in order to allow Sean to try different hand positions and stand at different locations in the walker during use. This enabled us to see how comfortable he was using the device and if there were any locations that caused discomfort or restriction to his mobility.

The testing of the PVC prototype produced several important results and aided in the overall final design. The base rails of PVC model are low to the ground and repeatedly collided with Sean's feet and legs during use. This demonstrated the need for the base rail to be set higher off the ground and the use of protective padding on the frame components that may contact Sean's body. In addition to functional testing, the prototype was equipped with the Wheeleez beach tires used in our final design, for a buoyancy test. This preliminary test, conducted at the Cal Poly Rec Center pool, demonstrated that the wheels we selected were more than capable of floating and supporting additional loads.

Figure 3-L. PVC prototype model prior to resizing

Figure 3-M. Preliminary buoyancy testing of PVC prototype (Jessica)

3.4 Final Concept Model

The SolidWorks model underwent a lot of improvements in the overall design between our first Design Review in the Fall and the final Review held mid-Winter Quarter 2014. The model shown in Figure 3-N. below was our proposed Final model going into manufacturing.

final design features the use off-the-shelf aluminum pipe-fittings and clamps in order to hold a majority of the frame components together. This was done in order to allow for easy assembly and ensure proper alignment of all the frame components. One of the primary concerns regarding our initial concept from Fall Quarter was the method for joining the various members of the frame. There was no clear method for fastening the different members, other than welding, which we wrongly assumed would be easy to accomplish. The proposed final design only required welding along the base rail, to join the lower portion of the frame to the top. The final concept eliminates more than half of the proposed welding, from our initial concept, through the use of the pipe fittings and clamps.

The overall shape of the initial design featured large radius curves that we found to be very hard to fabricate. We brought our design to a local pipe-bending shop and were told that it would be almost impossible to produce two identical pieces for each side of the walker. This forced us to redesign the geometry of the curves into a more rectangular shape with multiple smaller radius curves. This redesign improved the ease of manufacturing and eliminated a majority of the welding as required by the final concept design developed winter quarter, shown in the Figure below. Despite the setbacks encountered early on the manufacturing process, the final concept design was modified in order to meet the manufacturing capabilities and was eventually produced with great success.

Figure 3-N. Final concept model from the end Winter Quarter 2014.

Chapter 4: Final Design

The final design was successfully completed with all of the proposed features and requirements met. Our group delivered the walker to Sean after the Senior Expo and was featured on a local news station. Pictures of the final design can be found below. Notice that the physical model includes the protection foam on the frame and the foam footrests. The walker was powder coated with satin black, to appeal to Sean's preferences. A detailed description of the various features is also included.

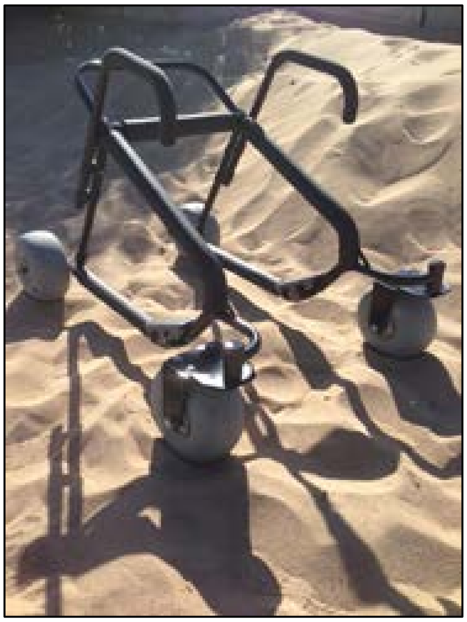


Figure 4-A and **4-B.** Final beach walker shown with (left) and without (right) protective padding.

4.1 Detailed Design Description

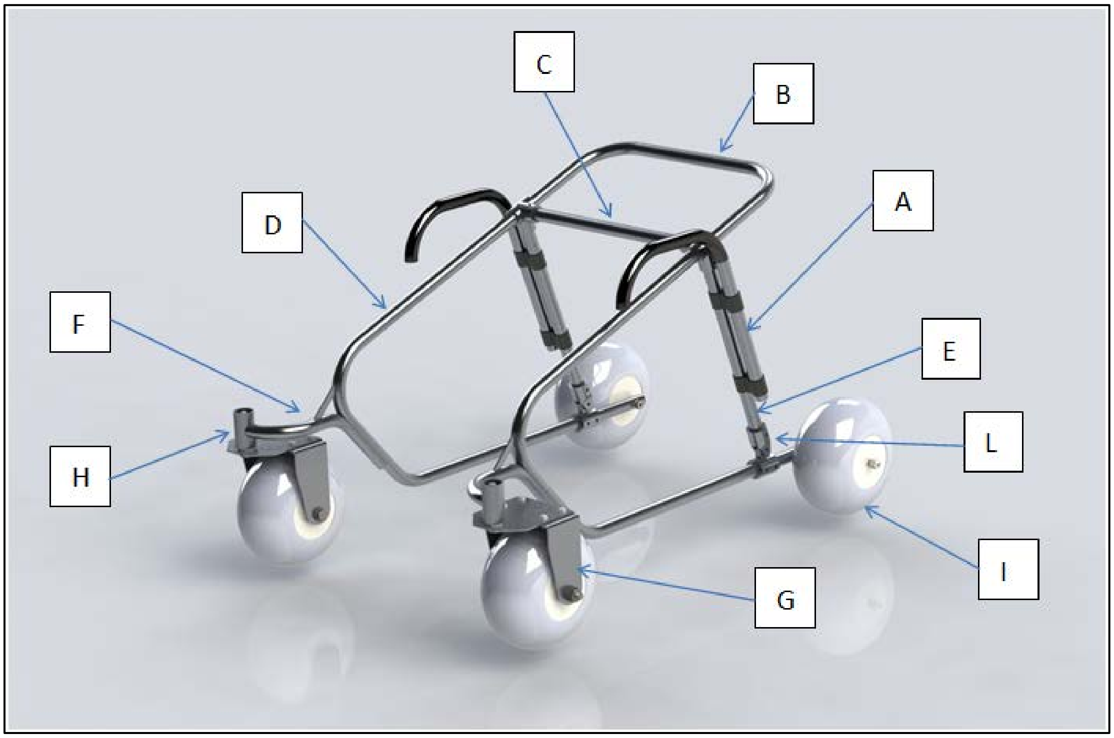


Figure 4-C. Final beach walker model with labeled features.

<u>A. Adjustable Handlebars</u>

One of the requirements for our beach walker was a life-span of five years, which meant we needed to design for Sean's future growth. To accommodate this need, we incorporated adjustable handlebars that provide a range of 26 +/- 3 inches of vertical height from the ground. This gives our handlebars the same range of height adjustability as the walker Sean currently uses every day. The final handlebar design, shown below in Figure 4-D, utilizes multiple parallel pipe clamps as the main feature to provide the required adjustability. To ensure the clamps do not slide or rotate during use, rivets were inserted permanently fastening the clamps to the handle bar and rear support. This ensured that the handle bars remained in the same orientation throughout its lifetime, and only was able to move vertically, when adjustment is necessary. To adjust the handlebars, the user needs to loosen two set screws per side, with an Allen key which will be provided upon delivery. The end of the handlebar has been curved down to give Sean a large range of hand locations maximizing comfort. To provide adequate grip for Sean, rubber hand grips were placed on entire gripping surface of the handle bars. This grip is made out of heavy-duty closed cell vinyl foam.

Figure 4-D. Adjustable handlebars
with parallel pipe clamps

B. Rear Curve

The large curve extending from the rear is designed as a way for Sean's mother to make contact with the walker when necessary. There are times where he may need assistance traversing difficult portions of the beach. While in the water, Sean usually requires some assistance with turning the walker around to "ride the waves" into the shore. This rear curve will provide Gabby the means to provide help whenever it is needed. It also significantly adds to the structural integrity of the walker, by providing a secondary connection between the left and right halves. The bent aluminum tube will be attached to the frame in the Tee pipe fittings and secured using a set-screw. This bar can also be directly welded into the fitting if more a more permanent joint is required. For the final design we solely used the set-screws of the clamp, to allow the frame to be disassembled into two halves. Sean also likes to hang a backpack from rear end of his current beach walker, which can be done on the new design using this curvature. See Figure 4-E. below for a close up of the Rear Curve.

Figure 4-E. Rear curve and Center Link

C. Center Link

The two halves of the frame will be joined using the rear curve and the primary center link. This is simply a straight aluminum tube that will be secured in the Tee pipe fitting. This bar is part of the design requirement to provide Sean with a place to rest the back of his body when riding waves. It is set at a height that will allow for this action. The center link is a main structural feature in the design and has been analyzed for both deflection and yielding. Along with the rear curve, we are able to achieve an axle-less rear end. This effectively eliminates any locations that Sean may "kick" or bump into while moving his feet forward and back. In the final design, the set-screws were used as the main fastening method for the center link due to ease of disassembly. It is convenient to have the ability to remove the rear curve and center link, effectively producing two individual halves of frame. This would significantly decrease the overall storage volume of the walker and also allow for repairs if necessary. See Figure 4-E. above for a close up of the center link.

D. Side Curve

The side curve in the final design has evolved from a multiple piece design into a single bent tube made with two smaller curves. The final design incorporates two three-inch radius bends with three straight sections. The front of the rail is bent at an angle that allows for the foam foot rests to be attached, providing Sean with a place to stand while riding waves. The front section also allows for the front arms to be securely welded to the rest of the frame. For this member, 1/8 inch wall aluminum tube was used to significantly improve the overall strength of the walker. At the rear of the side curve a ½ inch hole was drilled to allow for the attachment of the rear wheels using a shoulder screw. To improve the overall strength of the walker, a rivet was used to permanently attach the top end of the curve into the Hollaender Tee fitting.

E. Rear Supports

The rear supports at the rear end of the walker provide the majority of the strength and structural integrity. A straight section of aluminum tube is fastened between the open ends of the side curves using the Hollaender Tee and adjustable pipe fittings. The adjustable fitting at the bottom end eliminated the need to weld the rear supports. The rear tube is placed in the fitting and then the fitting is adjusted along the base rail to ensure proper alignment with the rest of the frame. In addition to the structural fittings, the clamps used for the handlebars are fixed to these supports with rivets. The rivets ensure that the clamps do not rotate about the rear support during use. A detailed view of the rear support with clamps can be seen below in Figure 4-F.

Figure 4-F. Close up view of the rear
support with pipe clamps and handle bar

F. Front Wheel Arm and Gusset

The front wheels are held by a welded sub assembly consisting of multiple components. Due to the more rectangular shape of the side curves, where a straight section connects the two smaller radius bends, we designed an arm that could be welded on the curve. This arm was bent to match the angle of the side curve and cut to half of the diameter, to ensure proper alignment. The arm is bent in two dimensions in order to allow the front wheels to be in line with those in the rear. A small gusset was added to improve the strength of the arm and prevent any bending associated with maximum load conditions. The end of the arm was cut to the proper diameter using a tube-notcher in order to connect the bushing housing. The gusset, bushing housing, front arm, and side curve were welded as a single assembly, and can be seen in Figure 4-G below.

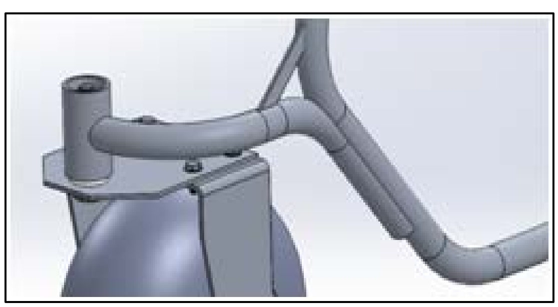


Figure 4-G. Close up view of the front arm assembly.

G. Caster

For our walker we were forced to fabricate our own caster due to the lack of availability of off the shelf parts that can fit the width of the Wheeleez beach tire. Since the design was completely custom, the caster quickly became one of the most difficult components of our project. We quickly learned that bending 6061-T6 aluminum was not possible and were forced to rethink how to manufacture the caster. Instead of bending the material into the desired shape, three separate pieces were welded together, providing the desired shape. In addition to a material problem, we had not fully considered the required offset angle between the vertical and horizontal points of rotation. The first full testing of our walker immediately proved that our design was flawed due to the lack of turning that occurred. To fix this offset issue, we placed an additional plate on the top of the caster, providing the necessary offset. This plate is attached using zinc plated steel hardware for corrosion resistance. The two-piece caster design, shown below in Figure 4-H, is fully-functional and allows the walker to turn with ease.

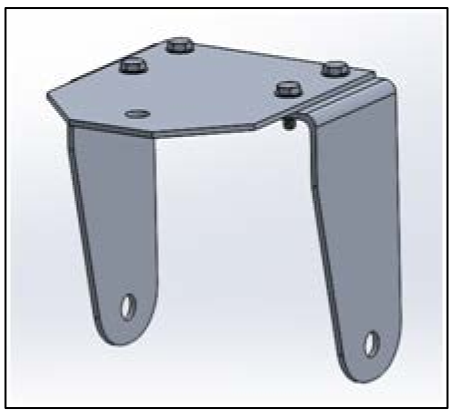


Figure 4-H. Caster sub-assembly

H. Nylon Bushings

In order to provide Sean with a walker that was capable of turning, a custom bushing assembly was designed. The bushings are made with Nylon 6/6 and are cut in a stepped manner in order to prevent the entire assembly from falling out of the bushing housing. The bushing housing was cut using a boring bar in order to provide the mating steps for the nylon bushings to rest on. The nylon bushings were drilled in the center in order to press-fit a spacer between them. The bushing-spacer assembly is inserted into the housing prior to attaching the caster assembly. The spacer provides a hole for a bolt to be inserted through, attaching the caster housing to the frame. During operation, the entire bushing assembly, with spacer, and caster assembly rotates in the bushing housing. An exploded view of the sub assembly is shown below in Figure 4-I. To ensure that the bushings do not bind up in the housing, all-purpose lube was applied in the housing.

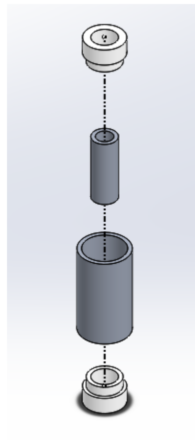


Figure 4-I. Bushing sub-assembly

I. Wheeleez Beach Tires

The new walker utilizes “Wheeleez” Beach Tires, which are highly buoyant balloon-inflatable tires. These wheels were selected above others based on the research of buoyant, sand-traversing, wheels from a past senior project team that had focused on the creation of a beach wheelchair. The wheels that we have deemed appropriate for Sean’s walker are the 24cm PU Beach Wheels, which weigh 1.5 lbs. apiece. The tires low pressure allows easy traversing over uneven surfaces, and the balloon tires high surface area will help prevent sinking into the soft sand. They also provide a significant amount of buoyancy to the entire walker, allowing it to float in the seawater without tipping.

Figure 4-J. Wheeleez PU beach wheel

J. Foam Foot Rests and Safety Foam

In our final design, we have included two foot rests that will provide Sean with a place to stand on the frame while riding waves. This can be seen in Figure 4-K. below. These were shaped out a block of medium-density Polyurethane foam. This foam is easily formable and was coated in fiberglass, effectively sealing and protecting the foam from water-absorption and damage. These feet rests slide over the base rails at an angle and are secured in place using Nylon Velcro straps. This makes them removable if Sean decides they are unnecessary to the overall function of the walker. In addition to the foam foot rests, the walker frame is encased in mold-resistant PE foam. This foam is essentially outdoor pipe insulation but provides a soft cushion for Sean in case he falls into the frame. The foam was wrapped on the frame locations that Sean could possibly make contact with the frame during use.

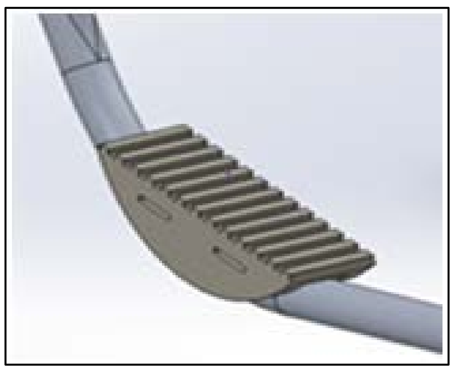


Figure 4-K. Foam foot rests attached to base rail

K. Hardware

All hardware used in the fabrication of our walker was either galvanized steel, zinc-plated steel, stainless steel, or nylon. These various materials provide the best corrosion resistance for the marine environment. We noticed that the hardware on the Beach Wheelchair from a previous senior project was already showing signs of rust after one year. This demonstrated the urgent need to select hardware that has a high level of corrosion resistance. We considered using Stainless Steel for the entire walker due to its high resistance to corrosion in salt water, but galvanic reaction potential with the Aluminum base metal made it an unacceptable material choice. However, in the final design, stainless steel shoulder screws are used to attach the rear wheels. This was considered to be acceptable in terms of corrosion due to the fact the holes for the bolts would already be powder-coated, eliminating direct contact with the aluminum. The shoulder screws were slightly longer than what was required so nylon washers were placed on the shaft to try and prevent any “sliding” of the screw in its respective hole. All of the hardware is easily obtainable from many different sources locally and online.

L. Hollaender Pipe Fittings and Amico Parallel Pipe Clamps

In order to attach the different members of the body together, we have utilized pipe clamps and fittings that provide a significant amount of clamping force. The handle bar is attached using several Amico parallel pipe clamps that have a clamping force of 600 lbs., which is more than sufficient. The main junction in the frame is achieved using structural hand-rail fittings produced by Hollaender. These aluminum-alloy fittings contain set-screws that have a very high push-out force limit of 1000 lbs. Using these set-screw clamps, we were able to construct the frame with minimal welding. They also allow for the frame to be disassembled if necessary. Separating the two halves of the walker would be great feature for the storage of the walker at home and in the car. Data sheets for the pipe fittings can be found in the Appendix for reference.

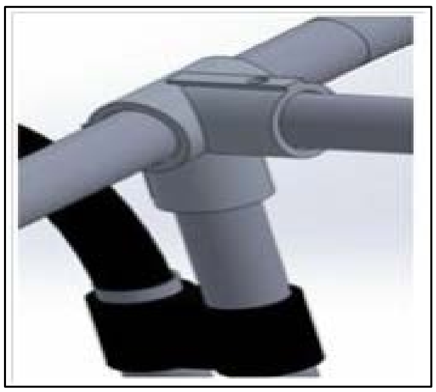


Figure 4-L. View of the Hollaender Pipe Tee fittings

4.2 Detailed Analysis

Simple beam theory was used throughout the analysis of this project. The use of simple geometries along with standard shaped tubes or plates allowed for this simplification to be valid. All parts of this project were modeled as either a cantilever beam or a simply supported beam. The properties used from these beam modeling can be seen in Figure 4-M through Figure 4-O. A condensed view of the critical analysis for the project can be seen in Table 4-A, [Please see Appendix E for the detailed calculations]. Shigley's Mechanical Design text was used for the simple beam theory and concentration factors, such as those found in the base bar analysis. Von Mises stress was used for one portion of the structure in order to account for both bending and torsion on a bent tube. The properties of the stock aluminum was also assumed to be the value displayed on the supplier website (onlinemetals.com), no testing was conducted to confirm a more appropriate value of the stock material.

$$\text{Deflection Max}: \quad \delta_{max} = \frac{FL^3}{48EI}$$

$$\text{Max Bending Stress}: \quad \sigma_{max} = \frac{yFL}{4I}$$

$$\text{Max Angle of Twist}: \quad \theta_{max} = \frac{FL^2}{16EI}$$

Figure 4-M. Simply supported beam properties

$$\text{Defelction Max}: \quad \delta_{max} = -\frac{FL^3}{3EI}$$

$$\text{Max Bending Stress}: \quad \sigma_{max} = \frac{yFL}{I}$$

Figure 4-N. Cantilever beam properties

$$\sigma = \sqrt{0.5\left[\left(\sigma_x - \sigma_y\right)^2 + \left(\sigma_y - \sigma_z\right)^2 + (\sigma_z - \sigma_x)^2\right]} + \sqrt{3({\tau_{xy}}^2 + {\tau_{yz}}^2 + {\tau_{zx}}^2)}$$

Figure 4-O. Von Mises stress equation.

Table 4-A. Condensed view of final predicted analysis results.

Design Feature/ Analysis Done	Calculated Value	Factor of Safety
Handle Bars		
Max Deflection (in)	0.182	n/a
Max Bending Stress (psi)	18300	2.18
Center Link		
Max Deflection (in)	0.048	n/a
Max Bending Stress (psi)	10135	3.95
Max bowing (degrees)	0.008	n/a
Base Bar		
Deflection (in)	0.322	n/a
Max Bending Stress (psi)	6984	5.72
Max Shear Stress (psi)	11300	2.03
Angle of Twist (degrees)	0.078	n/a
Caster		
Max Deflection (in)	0.045	n/a
Max Bending Stress (psi)	4800	8.33
Max bowing (degrees)	0.023	n/a
Max Normal Stress (psi)	509	78.5
Top Plate Max Deflection (in)	0.042	n/a
Top Plate Max Bending Stress (psi)	10560	3.78
Front Arm		
Max Shear Stress (psi)	1452	15.8
Max Bending Stress (psi)	3628	11.0
Max Von Mises Stress (psi)	4415	n/a
Max Deflection due to Bending (in)	0.00565	n/a

4.3 Cost Estimation

The total cost for our prototype walker can be found below in Table 4-B. The cost associated with the fabrication of the walker was significantly reduced through generous donations by Wheeleez and Central Coast Powder Coating. The prototype walker cost is relatively high due to the excess material purchased for manufacturing practice. The cost associated with a mass produced walker is estimated in Table 4-C. This table is a refined cost analysis using the materials from the prototype walker. The mass production cost also includes the cost for the items that were donated, such as the powder coating and Wheeleez Beach tires. The mass production cost could significantly be reduced with higher volume purchases of the hardware and aluminum tubing.

Table 4-B. Detailed cost estimation for the entire project (Prototype, Testing, Production)

Description	Where used	Source/ Part #	Unit Cost ($)	Quantity	Total Cost ($)
Raw Materials and Hardware					
6061-T6 Aluminum Tube (1" OD, .870" ID, .065" Wall, 7 ft. long)	Frame	Onlinemetals.com	25.87	2	51.74
6061-T6 Aluminum Tube (1" OD, .870" ID, .065" Wall, 8 ft. long)	Frame	Onlinemetals.com	28.74	2	57.48
6061-T6 Aluminum Tube (1" OD, .750" ID, .125" Wall, 5 ft long)	Frame	Onlinemetals.com	28.93	1	28.93
6061-T6 Aluminum Tube (1" OD, .750" ID, .125" Wall, 6 ft long)	Frame	Onlinemetals.com	33.79	1	33.79
6061-T6 Aluminum Tube (1" OD, .750" ID, .125" Wall, 8 ft long)	Frame	Onlinemetals.com	45.62	2	85.24
6061-T6 Aluminum Tube (1" OD, .500" ID, .250" Wall, 6 ft long)	Bushing Spacer/Prototype	Onlinemetals.com	81.86	1	81.86
6061-T6 Aluminum Bar (1.75" diameter)	Bushing Housing	Onlinemetals.com	12.70	1	12.70
6061-T6 Aluminum Plate (.125" thick, 12 in X 48 in)	Caster Housing, Gusset	Onlinemetals.com	42.63	1	42.63
Nylon 6/6 White Bar (1.25" Diameter, 1 ft long)	Bushings	Onlinemetals.com	13.18	1	13.18
Polyurethane foam and Fiberglass materials	Footrests	Donated (Cal Poly)	0.00	1	0.00
Rivet, 3/16" Diam., Zinc-Plated Steel, 25 pieces	Handlebar clamps, Frame	McMaster-Carr	9.44	1	9.44
Shoulder Screw, 1/2" X 6.5' long', 18-8 Stainless Steel	Rear axles for wheels	McMaster-Carr	30.33	2	60.66
Nylon locknut, 3/8"-16, 18-8 Stainless Steel, 5 pieces	Rear axles for wheels	McMaster-Carr	7.71	1	7.71
Edge Trim, Standard-4, Rubber, per ft	Caster Housing	McMaster-Carr	0.94	10	9.40
Cushioned Grips, 0.9375-1.1875 in. Diam. X 21 IN, 2 pieces	Handlebars	McMaster-Carr	8.54	1	8.54
1/2-13X6.5" long Hex Bolt, 5 pieces	Front axels for wheels	McMaster-Carr	8.73	1	8.73
1/2-13X3" Hex Bolt, 10 pieces	Bushing/Caster attachment	McMaster-Carr	11.46	1	11.46
1/2-13 Hex Nut, 25 pieces	Front axels bolts	McMaster-Carr	10.56	1	10.56
17/32 inch Washer, 50 pieces	Front Caster Assembly	McMaster-Carr	10.88	1	10.88
0.25 inch Spring button, 10 pieces	Handle Bars (Not used in Final Design)	McMaster-Carr	5.10	1	5.10
Amico Parallel Pipe Clamp	Handlebars	McMaster-Carr	6.08	5	30.40
1 inch X 12 inch Long Velcro Strap, 5 pieces	Footrests	McMaster-Carr	6.85	1	6.85
Hollaender #11 Side Outlet Tee Fitting (3/4 IN IPS)	Frame	Hollaender	11.52	2	23.04
Hollaender #17 Adjustable Elbow Fitting (3/4 IN IPS)	Frame	Hollaender	11.52	2	23.04
24 CM PU Beach Wheel	Front and Rear Wheels	Donated (Wheeleez)	0.00	4	0.00
Pipe Insulation (protection padding) 6 ft.	Frame	Home Depot	6.54	2	13.08
Services					
Welding	Frame (Front arm, gusset) and Caster Housing	Hank Van Gaale Custom Welding and Fabrication	200.00	1	200.00
Powder Coat	Entire frame	Donated (Central Coast Powder Coating)	0.00	1	0.00
				Total ($)	**846.44**

Table 4-C. Cost estimation for mass production (no donations)

Description	Where used	Source/ Part #	Unit Cost ($)	Quantity	Total Cost ($)
Raw Materials and Hardware					
6061-T6 Aluminum Tube (1" OD, .870" ID, .065" Wall, 8 ft. long)	Frame	Onlinemetals.com	28.74	3	86.22
6061-T6 Aluminum Tube (.75" OD, 0.5" ID, .125" Wall, 1 ft. long)	Bushing Spacers	Onlinemetals.com	8.70	1	8.70
6061-T6 Aluminum Plate (.125" thick, 12 in X 48 in)	Caster Housing, Gusset	Onlinemetals.com	42.63	1	42.63
Nylon 6/6 White Bar (1.25" Diameter, 1 ft long)	Bushings	Onlinemetals.com	13.18	1	13.18
Rivet, 3/16" Diam., Zinc-Plated Steel, 25 pieces	Handlebar clamps, Frame	McMaster-Carr	9.44	1	9.44
Shoulder Screw, 1/2" X 6.5' long', 18-8 Stainless Steel	Rear axles for wheels	McMaster-Carr	30.33	2	60.66
Nylon locknut, 3/8"-16, 18-8 Stainless Steel, 5 pieces	Rear axles for wheels	McMaster-Carr	7.71	1	7.71
Edge Trim, Standard-4, Rubber, per ft	Caster Housing	McMaster-Carr	0.94	10	9.40
Cushioned Grips, 0.9375-1.1875 in. Diam. X 21 IN, 2 pieces	Handlebars	McMaster-Carr	8.54	1	8.54
1/2-13X6.5" long Hex Bolt, 5 pieces	Front axels for wheels	McMaster-Carr	8.73	1	8.73
1/2-13X3" Hex Bolt, 10 pieces	Bushing/Caster attachment	McMaster-Carr	11.46	1	11.46
1/2-13 Hex Nut, 25 pieces	Front axels bolts	McMaster-Carr	10.56	1	10.56
17/32 inch Washer, 50 pieces	Front Caster Assembly	McMaster-Carr	10.88	1	10.88
Amico Parallel Pipe Clamp	Handlebars	McMaster-Carr	6.08	5	30.40
1 inch X 12 inch Long Velcro Strap, 5 pieces	Footrests	McMaster-Carr	6.85	1	6.85
Hollaender #11 Side Outlet Tee Fitting (3/4 IN IPS)	Frame	Hollaender	11.52	2	23.04
Hollaender #17 Adjustable Elbow Fitting (3/4 IN IPS)	Frame	Hollaender	11.52	2	23.04
24 CM PU Beach Wheel	Front and Rear Wheels	Wheeleez	53.00	4	212.00
Pipe Insulation (protection padding) 6 ft.	Frame	Home Depot	6.54	2	13.08
Polyurethane foam and Fiberglass materials	Footrests	Home Depot	25.00	1	25.00
Services					
Welding	Frame (Front arm, gusset) and Caster Housing	Hank Van Gaale Custom Welding and Fabrication	150.00	1	150.00
Powder Coat	Entire frame	Central Coast Powder Coating	50.00	1	50.00
			Mass Production Total ($)		**796.52**

4.4 Maintenance and Repair:

The final design has a few minor maintenance and repair procedures to ensure a long life. The primary source of failure in our design is corrosion due to the marine environment. In order to reduce the negative effects of corrosion on the walker the following steps should be taken by the user:

<u>1. Rinsing and Drying the Entire Walker After Use</u>

One of the best ways to prevent corrosion from the marine environment is to rinse the walker with fresh water after every use. This will remove most of the salt water and sand that may have accumulated in crevices of the frame. The most important location to rinse with fresh water is the Bushing Housing, since it is the most susceptible to failure from saltwater and sand build up. Drying with a towel after rinsing will help ensure that the metal does not rust during storage.

2. Lube Rotating Parts

After the walker has been rinsed and has had sufficient time to dry, all-purpose lube should be applied at the front and rear wheel locations. In the front caster assemblies, the bushing housing needs to be lubed after every rinse. This will help ensure that they remain functional and do not bind up due to mineral build-up. The inner bushing on each of the Wheeleez beach wheels should have lube applied after every other use at the beach.

3. Hardware Tightening/Replacement

To ensure that the walker stays rigid and complete for many years of use, all of the hardware should be tightened every year. The Hollaender pipe fittings are held in place with set-screws that have the potential to vibrate and lose a secure grasp of the frame components. Using the Allen wrenches provided, the user will be able to ensure that these remain tight. The various bolts and nuts used for the wheels can be tightened with standard box wrenches and socket sets. Extra hardware was provided to the customer in case significant corrosion occurs and replacement is necessary. Replacement is relatively straightforward and requires the use of the same tools used for annual tightening.

4. Protective Foam Replacement

The foam used to encase the frame and ensure that the walker is safe for use is not designed for a beach walker application. Therefore, it has the potential to degrade from the marine environment. It also is a soft material that can rip and tear. To ensure that the walker stays protected in foam, replacement may be necessary eventually. In order to replace the foam, the user simply needs to cut the existing foam off with a razor blade or small knife. Replacement foam can be purchased at any local hardware store. For the final design foam insulation for outdoor pipes was used and was relatively low in cost.

5. Wheeleez Beach Tire Flat Repair

The Wheeleez Beach tires are designed to withstand puncture, however there is always a chance for a flat. The manufacture provides a repair kit with detailed instructions on how to patch any holes and the required pressure for inflation, once fixed. If additional support is needed, there are helpful video tutorials available online.

Chapter 5: Product Realization

5.1 Manufacturing

The beach walker designed for Sean required extensive manufacturing time throughout Spring Quarter 2014. Each member of the team spent approximately 60-70 hours each over an 8 week time period. Our final design allowed us to learn a wide variety of manufacturing process on most of the machines in the Cal Poly machine shops. The primary processes are detailed below with images.

<u>1. Tube Bending</u>

Most of the frame geometry was achieved by bending the aluminum tube into the desired dimensions. The bending was done by the TubeShark, shown below in Figure 5-A, in Cal Poly's hangar. Although this apparatus may sound very straightforward and simple to use, and in a way it was, however it was difficult to get symmetrical results with this pneumatic tube bender. Results may vary due to tube thickness, tube diameter, the size of the die being used, the amount of lubrication applied and the rate at which the bending load was applied and also spring back. Many online sources gave their own version of how they went about getting accurate dimensions with a tube bender but we decided to go with our own technique. We utilized a 3" die for the tube to bend around. It took a few weeks of practicing with scrap metal tube and extra material before our team was able to formulate a process and once we did, we became the masters of the TubeShark. All of our components were within design specifications so we were satisfied with our learning and performance with respect to tube bending.

Figure 5-A. Chris (left) and Nick (right) bending aluminum tube using the TubeShark at the Cal Poly Hanger.

2. TIG welding

A major concern for our design beginning from the conceptualization stage was attaching the front caster wheel assembly to the rest of the frame. It was a concern because that connection needed to hold up against Sean's weight. In addition, the strength of the connections needs to be strong enough to support lateral forces caused by turning of the caster wheel assembly. In short, extensive attention was placed in addressing this issue because we wanted to design a strong but at the same time aesthetically pleasing method to fasten the arms to the frame. We brainstormed through several alternatives before deciding on TIG welding:

a. Clamps - similar to the clamps used to attach the handlebars to the frame, we considered using two clamps for each arm to attach it to the frame. Although these clamps have would have been able to clamp with a force up to 600 lbs., we decided not to go with this alternative because of the awkward spacing that the clamp would create.

b. Flatten and Fasten - with this approach, we wanted to take the arm and work the tube until it was completely caved in and when held against the frame of the walker, the arm would hug the frame like a puzzle piece. Once held against the frame, it would be fastened using rivets or other hardware. We also considered welding it to frame, which led us to our final decision in attaching the arms.

c. Notch and Weld - selected method. Instead of caving (smashing) in the arm so that it fits over the frame tube like a sleeve, we utilized a cut-off wheel to custom notch the arm so that it rests seamlessly over the frame tubing. Since none of the group members had much experience with the very difficult to master TIG welding, not to mention that thin walled aluminum is a challenge in itself to weld, so we made the decision of resourcing the services of a local welding shop, Hank's Welding and Fabrication. We had this connection welded along with the caster walls and the bushing housing, and were extremely content with the results. As you can see from the picture below, the weld beads looks impeccable; they have a large, uniform, surface area and there was no trace of any burn marks or other weld errors. Granted we had to spend a little money ($200) but it was money well spent, especially if the weld job addressed the largest design concern for our project.

Figure 5-B. Welded frame sub-assembly

3. Milling

The mill was used to perfect the dimensions of the caster walls, drill the holes into the casters and drill the rear wheel pin holes into the frame. Prior to welding the caster walls together, holes were pre-drilled into them for assembly feasibility. A ½” end mill was used to face all the walls to exact symmetrical dimensions; holes were the carefully placed to achieve a concentric assembly that would provide the best axle functionality. When milling the ½” rear wheel pin hole, we had to use v-blocks to keep the tube in place. We began with a tap drill and increased the diameter increment of the drill by 1/16” - ⅛ until we finally drilled with the ½”. This was done to prevent the drill from fracturing or causing thermal deformation in the tubing.

Figure 5-C. Shaping the caster housing pieces on the mill

4. Fiberglass

The process to manufacturing the footrests began by shaping medium density polyurethane foam to a geometry that would accommodate the size of Sean's feet and also the curve on the tubing where it would be placed. This process was done completely by hand, utilizing sandpaper and a curved file. In addition, the slots where the Velcro straps feed through were made using a straight file. After the desired shape was accomplished, a layer of fiberglass sheet is applied to the surface of the foam and then cured using an ultraviolet (UV) hardener. The slots were masked before this process to prevent the any permanent obstructions near the rim of the slots, making it difficult to feed the Velcro into. Once hardened, Bondo was applied to the entire surface to give it a smoother finish and cleaner definition. The footrests were then painted with a shade of gray similar the color of the Wheeleez beach tires. Lastly, the footrests were covered with a UV hot coat to give it a hardened, water-resistant, glossy finish.

Figure 5-D. Fiberglass coated foam footrests, prior to final paint and hot coat.

5. Lathe

The bushing assembly components were all manufactured using the lathe. The bushing housing was made from 1.75" round aluminum stock that was machined down to a 1.5" outer diameter and a 1.2" inner diameter. The nylon bushings were made machined from stock as well. For the bushing spacer, we used a 1" outer diameter, 0.25" thick aluminum tube that was originally purchased to manufacture the handlebars. It wasn't used for the handlebars because we found out we could use a lesser thickness and still achieve our design load requirements. The material ended up being useful in creating the bushing spacers because we needed a 0.5" hole, which is exactly the size hole in the 0.25” tubing. The 1” diameter on the .25” tubing was machined down to the inner diameter of the nylon bushing so that a tight interference was achieved.

Figure 5-E. Cutting inner diameters of bushing housing using boring tool.

Figure 5-F. Jon manufacturing the nylon bushings.

5.2 Design Changes

Our final prototype is extremely accurate to the design specification from our SolidWorks model. It is expected that the dimensions won’t be exactly as specified in our drawings but all components are moderately within tolerance. The one quality outside of tolerance was the mating between the Hollaender fittings and the tube. The holes in the fitting were slightly bigger than the outer diameter of the tubing, so there was clearance as opposed to an interference fit. This is because the fittings are made for 1” pipe, not 1” tube. Although the difference is minimal, it was significant in our design because once the set screw in the fitting was tightened, the clearance allowed the two sides of the walker to pivot on the set screw. When testing the walker, the bowing movements allowed by the clearance made the user feel insecure. We thought that powder coating the material would fix the problem but there was still a clearance present even after a small layer of thickness was added to both the fittings and tube. This problem was solved by wedging a very then aluminum shim between the tube and the hold of the fitting. Once the shim was fixed between the two components, a rivet was fastened to the outside wall of the T-fitting which would further prevent the sides of the walker from pivoting about the set screw. Which the shim and rivet in place, the bowing was significantly minimized or essentially eliminated.

Another problem that we encountered with our early design was the caster. In order for a caster to function properly, there needs to be a sufficient lever arm between the axis of rotation of the caster and the axis of the wheel. We did not include this lever arm initially, instead we had the axis of the wheel directly below the axis of the caster. Once we discovered our problem, we brainstormed a few alternatives before arriving to a solution. We were initially going to redesign the entire caster, manufacture the parts, pay to get it welded again and then send to get it powder coated again. Although this probably would have been the most professional and aesthetically pleasing route, it was not ideal because this problem occurred one week before the senior expo. We needed a quick fix that would provide functionality and could be presentable. With the help of Jon’s dad, we were able to come up with a solution that did not include purchasing any new material or professional welding; the fix consisted of fastening a ⅛” plate to the top of the caster that would provide the lever arm we needed to make the wheels rotate. We were able to get the plates to the powder coater in time so that the walker would be ready for presentation at the senior expo. This was probably the biggest design flaw that we experienced throughout our project; we were happy with our performance in addressing the issue and also finding a quick, inexpensive and presentable solution.

The design, manufacture and assembly of this project has been a wonderful learning experience however there a few changes that we would make if we were to manufacture and assemble another walker.

a. Thinner Aluminum - Most of the tubing in the walker has a ⅛” thickness. When compared to other walkers and mobility devices on the market, whose aluminum thickness usually maxes at 0.065”, our walker is oversized. We decided to go with a thicker aluminum for several reasons: welding feasibility, adviser/faculty recommendation and large factor of safety. Using a smaller thickness tube would make the walker roughly 5 pounds lighter, which doesn’t seem like much but it makes a significant difference for Sean and Gabby.

b. Secure Foam, Add Grip Tape - When Sean was using the walker in the water and attempted to ride waves like with his previous walker, we observed that we hasn’t able to prop his feet onto the walker because either the foam on the base tube would rotate, making it difficult to secure his feet onto the walker or his feet would slide off the footrest. These problems could be easily fixed by securing the foam to the tubing using an adhesive or zip ties and adding grip tape or surf wax to the footrests.

c. Tube Fitting - A tight interference fit between the tube and fittings is desired. Since we could not locate any fittings that were made for tube, one alternative is to use pipe for the frame. However pipe may not be manufactured with thin walls so there is still the problem of weight. Another alternative would be to CAD model the fittings with proper dimensions that would provide a tight interference fit with the selected tube size. The CAD model would then be machined from a stock of aluminum using CNC. Although this process may sound more appealing, the process is extensive and would require a strong background with CAD/CAM software. Another solution would be to utilize the present components and attach a mandrel on the end of the tube; the mandrel would expand once in the fitting and hopefully eliminate any clearance present.

Chapter 6: Design Verification

6.1 Testing

1. Static and Kinetic Load Test

The fully assembled walker was tested on sand in order to determine the force required to break away from static equilibrium and force required to move the walker at constant velocity. To determine the force required for both Static and Kinetic cases, a digital fish scale was hooked onto a thread wrapped around both handlebars. By pulling on the handle of the fish scale, we were able to determine an average force of 7.55 lbs., required to cause the wheels to begin rotation. Once the walker was in motion, the force required to maintain a slow constant velocity was determined to be an average of 3.5 lbs.

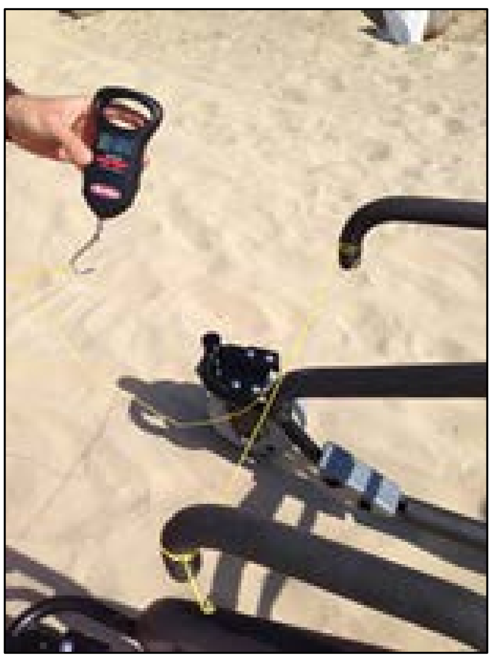


Figure 6-A. Device used to measure forces needed to loads needed to move walker

Figure 6-B. Kinetic load testing on sand with digital scale

2. Overall weight

The weight of the walker was tested using two different methods. The initial preliminary tested was done by holding the walker while standing on a basic bathroom scale. By subtracting off the weight of the person who stood on the scale, we were able to estimate the walker's weight. The second method was done using the fish scale. The walker was hung from the fish scale using the same string used in the static and kinetic load test. The weight was averaged to be 22.5 lbs. from the fish scale measurements.

3. ADA Ramp/Doorways

To test the walker for ADA compliance several measurements were taken in addition to physical testing. ADA requires that assistive devices fit through standard door openings with a minimum width of 32 inches. The final assembled walker was measured to be just less than 32 inches wide at its maximum width. Compliance to the ADA requirement was verified by taking the walker through several doors on campus at Cal Poly. In addition to fitting through standard door openings, the walker was also tested to ensure that it was capable of maneuvering on accessibility ramps. Testing for this requirement was done on the ramp in front of the Bonderson Engineering Building. The walker worked great going around the turns and had plenty of ample space on both sides for easy maneuverability on the ramp.

Figure 6-C. Testing the final product on an access ramp in front of the Bonderson Bldg.

4. Gabby’s Trunk

The overall volume of the walker was specifically controlled to ensure that it would easily fit within the trunk of Gabby’s SUV. The goal was to have the walker fit without having to put down any of the seats or adjusting the handlebars to make it shorter. On the day we gave Sean his walker, the last thing we did before leaving was test if it fit in Gabby’s trunk and it did! As seen in Figure 6-C below, the walker was capable of fitting with only a slight incline on the front end of the walker. Without any seats down, the walker fits in the trunk of Gabby’s Saturn Vue without any interference from the rear door. This was especially pleasing to Gabby’s because loading Sean’s old walker in and out of her car was a hassle.

Figure 6-D. Fully-assembled walker in trunk of Saturn Vue

5. Submergibility

One of the design requirements for the walker was that it should be able to float in water without tipping. To quantify this, we decided that the wheels should submerge no more than 75% into the water while floating. If the wheels were to submerge any more than that, water could flow above the top surface of the caster and sink the front end. When tested, the walker floated individually in seawater with about 25%-50% of the wheels submerged. When Sean used the walker in the water, the force he needs in order to maintain his balance submerged the wheels about 60%-70%. This was an exciting result because we had many doubts about the walker potentially being too heavy to load. The padding, foot rests, and sealing the tube aided in providing buoyancy to the walker.

Figure 6-E and **6-F.** Walker being submerged in the ocean.

6. Handlebar Adjustment

The handlebars will need to be adjusted in the future to accommodate Sean’s growth. Or they may just need be adjusted to a temporary comfort level. Either way, Gabby or another adult will need to help Sean in adjusting the handlebars. This is done by first loosening the bolts on the handlebar clamps, adjusting the height, then tightening the bolts again. When Sean first got his walker, the handlebars were too high for him. In less than 2 minutes, both handlebars were adjusted accordingly using the procedure previously described. It’s simple, straightforward and effective.

Figure 6-G and **6-H.** Chris (left) and Nick (right)
adjusting the handle bars for Sean.

A summary of our tests and their respective results were documented on a DVP&R table, which can be found in Appendix F. A Design Verification Procedure and Report lays out the testing required verifying our projects design and also documents test results. The test parameters were established early on in the design phase as a way to ensure that the requirements are met. The details of the testing have evolved with the project development in order to verify the primary areas of concern with the final design.

Chapter 7: Conclusion/Closing Remarks

Team Sean's Beach Walker utilizes balloon inflatable tires and an ergonomically developed light-weight frame to maximize the walker's effectiveness both on sand and in water. The final design was developed through multiple design iterations over the course of the Academic Year 2013-2014. Despite many design changes throughout the entire project, Team Sean remained focused on meeting the required customer specifications. The final product is aesthetically pleasing as well as functional, created to be stable in shallow water and traverse the sand with ease. The new walker utilizes "Wheeleez" tires, which are highly buoyant inflatable balloon wheels, designed specifically for the beach environment. The custom designed casters and bushings for these wheels are easily removable for ease of maintenance. The walker features an aluminum frame that utilizes pipe clamps and fittings that allow for ease of assembly and provide a significant level structural integrity to the walker. The two most important applications of this walker are to allow Sean to have more independence at the beach and provide him a means to continue to develop strength through continued use of the walker.

Our project was blessed with teammates and advisers that were equally motivated and energetic about meeting project goal. The different skills and aspects of every team member combined with the mentality of producing the highest quality walker for our customer were the keys to our success. Although our team only endured a few major obstacles with respect to the project development, we would like to credit our combined determination in realizing our individual potential and especially our project's potential to significantly impact someone's life.

The entire process, from day one where we met our group for the first time, to the day we delivered the final product to Sean, has been nothing less than rewarding. Having the ability to influence the overall well-being of a local youth has left our group with a tremendous amount of pride and joy. The frustration, setbacks, and obstacles were quickly forgotten the moment we saw the reaction on Sean's face, when he used his new beach walker for the first time.

As a team, we would like to extend a special thanks to the numerous people who helped made this project possible. Our concept ideation phase was significantly improved through the use of mobility walkers that were donated by the Garden View Inn-Assisted Living Community in Paso Robles, Ca. Special thanks is in order for the helpful design advice and extremely fast turnaround on the welding services provided by Hank J Van Gaale Custom Welding & Fabrication in San Luis Obispo, Ca. The exceptional powder coating of the final design and last minute design "fixes" was generously donated by Central Coast Powder Coating in San Luis Obispo, Ca. The manufacturing of our walker would not have been possible without the help of the numerous Shop Technicians at the Cal Poly Machine Shops. Finally, we would like to thank our advisors, Dr. Widmann and Dr. Taylor, for their patience, advice, and support throughout the entire process.

Appendices

Appendix A:

Table 1. Pugh Matrix of each team member’s top 3 concepts with Sean’s current walker as the Datum for comparison. The design criteria assessed is shown in the far left column. The top ranked concepts are highlighted in yellow.

Categories	Sean’s Walker	Jon 1	Jon 2	Jon3	N1	N2	N3	C1	C2	C3	Jess1	Jess2	Jess 3
Fabrication Feasibility	D	s	-	-	-	-	+	+	s	+	s	+	-
Overall Operational Volume	D	+	+	+	+	+	+	-	+	+	s	+	s
Adjustability of Height	D	+	+	s	+	s	s	+	s	+	+	s	s
Safety/Hazard Prone	D	S	-	-	s	+	-	-	-	-	s	-	s
Strength/ Durability	D	+	-	+	+	s	s	s	s	s	s	s	-
Interchangeability/ Replaceability	D	+	+	s	+	s	s	+	s	s	s	+	s
Turning Ability	D	s	+	+	+	+	+	+	+	+	s	+	s
External Interface with Gabby	D	s	-	s	s	s	s	s	-	-	s	-	s
Weight	D	s	+	+	-	+	s	s	s	s	+	+	+
Wave-riding Comfort	D	s	-	s	+	+	+	s	+	+	+	+	+
S+	D	4	5	4	6	5	4	4	3	5	3	6	2
S-	D	0	5	2	2	1	1	2	1	2	0	2	2
S	D	6	0	4	2	4	5	4	6	3	7	2	6

The QFD table below contains customer requirements found on the left column, along with a corresponding weighted value of importance in our design. To quantify these customer requirements we developed a list of engineering requirements with units, which can be found along the bottom. We then were able to assess the correlation between each customer requirement and the engineering specifications with a number of 1, 3 or 9 based on relevance. Cells that were left blank represent zero correlation. We are to able assess the ability of the benchmarks in meeting the customer requirements, with a 5 being complete compliance and a 1 being minimal. At the bottom of the table, we developed a target value for each of the engineering specifications. The reported values for each of the researched products were also included as a way to compare the differences in engineering compliance.

Table 2. QFD table quantifying engineering requirements

TEAM SEAN		Engineering Requirements													Benchmarks		
Customer Requirements	Weighting (Total 100)	Dry/Wet Sand	Overall Width (in)	Overall Height (in)	Overall Depth (in)	Submersibility	Adjustable Grip range (in)	Weight (lbs)	Factof Safety	Corrosion Resistance	Number of Attachments	Operational Volume (ft^3)	% Customer Comfort Satisfaction	Fabrication Costs	Homemade PVC	Elderly Beach Walker	Job Walker
Functional Performance																	
1. Traverse Sand	13	9				9	3	9	3	3					5	5	5
2. Floats/Stable in Water	12					9		9	3		9	3			2	2	2
3. Least Restrictive Enviroment	11	9	9	3	9	1		3			1	9			2	2	3
4. Interchangable Wheels	4	1	1	1		9		1	3	3				1	2	3	3
5. Corrosion Resistant	10	9				3				9				9	4	2	2
6. Durable Materials	9	3				1	1	9	9	9	3			9	3	3	3
7. Adjustable Grip Angle	4		1	1	1		3		3	3				1	1	2	2
8. Adjustable Grip Height	7			3		1	9		1	3				1	1	1	3
9. Small and Compact	5		9	9				9			3	9		3	1	4	4
Human Factors/Interface																	
1. Modular	4									1	9			3	1	2	1
2. Harness/Seat	3								1				3		1	1	1
3. Comfort	5									3			9		1	3	4
4. Lightweight	10	1						9				1	9		5	4	4
5. Color	1									3			9		1	4	2
6. Decals/Décor	1										3				1	1	1
Cost	1													9	x	x	x
Total	100																
Units		%	in	in	in	in	in	lbs	#	CR	#	ft^3	%	$			
Sean's Walker		100	30	36	50	5.5	5	15	1.2	tbd	4	50	100	999			
Homemade PVC		100	16	18	12	0	0	5	1	tbd	1	36	90	60			
Elderly Beach Walker		100	24	39.6	20	2	2	18	1	WP	0	13	na	1			
Job Walker		100	32.4	36	28	3	2	17.5	1	WP	3	21	na	2.2			

● = 9	Srong Correlation
○ = 3	Medium Correlation
Δ = 1	Small Correlation
Blank	No Correlation

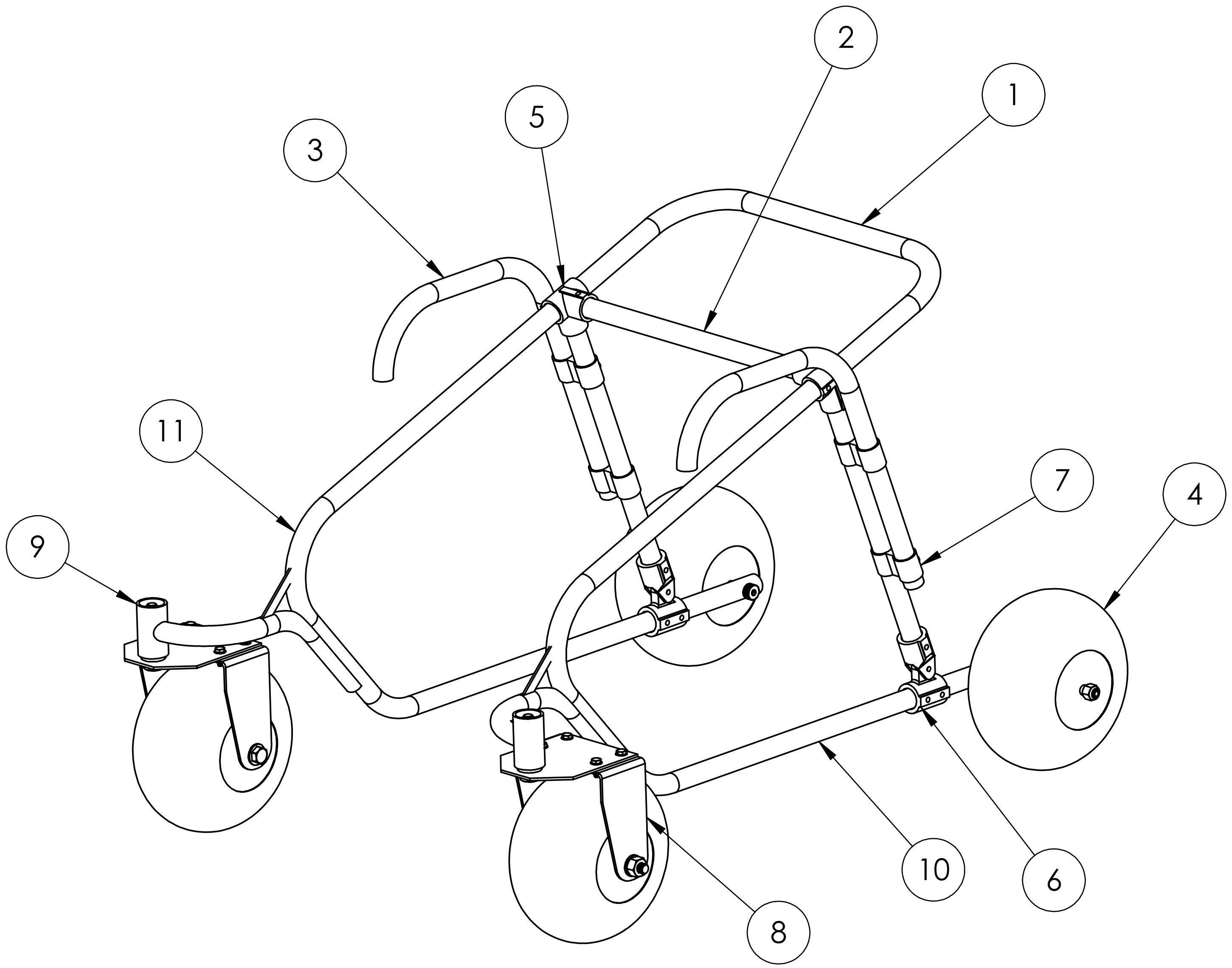
SENIOR PROJECT CONCEPTUAL DESIGN REVIEW HAZARD IDENTIFICATION CHECKLIST

Y	N	
■	□	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?
□	■	Can any part of the design undergo high accelerations/decelerations?
■	□	Will the system have any large moving masses or large forces?
□	■	Will the system produce a projectile?
□	■	Would it be possible for the system to fall under gravity creating injury?
□	■	Will a user be exposed to overhanging weights as part of the design?
□	■	Will the system have any sharp edges?
□	■	Are there electrical systems? If so, are they properly grounded?
□	■	Will there be any large batteries or electrical voltage in the system above 40 V either AC or DC?
□	■	Will there be any stored energy in the system such as batteries, flywheels, hanging weights or pressurized fluids?
□	■	Will there be any explosive or flammable liquids, gases, dust fuel part of the system?
□	■	Will the user of the design be required to exert any abnormal effort or physical posture during the use of the design?
■	□	Will there be any materials known to be hazardous to humans involved in either the design or the manufacturing of the design?
□	■	Can the system generate high levels of noise?
■	□	Will the device/system be exposed to extreme environmental conditions such as fog, humidity, cold, high temperatures, etc…?
■	□	Will the system be easier to use safely than unsafely?
□	■	Will there be any other potential hazards not listed above? If yes, please explain below?

Appendix B:

Final Drawings of Manufactured Parts

ITEM NO.	PART/ASSEM. NO.	DESCRIPTION	QTY.
1	60-0010	REAR CURVE	1
2	60-0011	CENTER LINK	1
3	60-0021	HANDLE BAR	2
4	60-0022	WHEELEEZ 24CM PU BEACH WHEEL	4
5	40-0016	HOLLAENDER NO. 11 CLAMP 3/4 IN PIPE	2
6	40-0017	HOLLAENDER NO. 17 CLAMP 3/4 IN PIPE	2
7	40-0018	1.0 IN PARALLEL PIPE CLAMP	4
8	30-0011	CASTER SUB-ASSEMBLY	2
9	30-0012	BUSHING SUB-ASSEMBLY	2
10	30-0013	WELDED FRAME SUB-ASSEMBLY (LEFT)	1
11	30-0013	WELDED FRAME SUB-ASSEMBLY (RIGHT)	1



NOTE: NOT ALL ITEMS ARE IDENTIFIED WITH BALLOONS IN VIEW
ONLY THE PRIMARY MEMBERS ARE IDENTIFIED

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ARE:
FRACTIONS ± 1/32 DECIMALS .X ±.1 .XX ±.03 .XXX±.005 ANGLES ± 1/2

MATERIAL:

FINISH:

DRAWN BY: JONATHAN LARSEN

DO NOT SCALE DRAWING

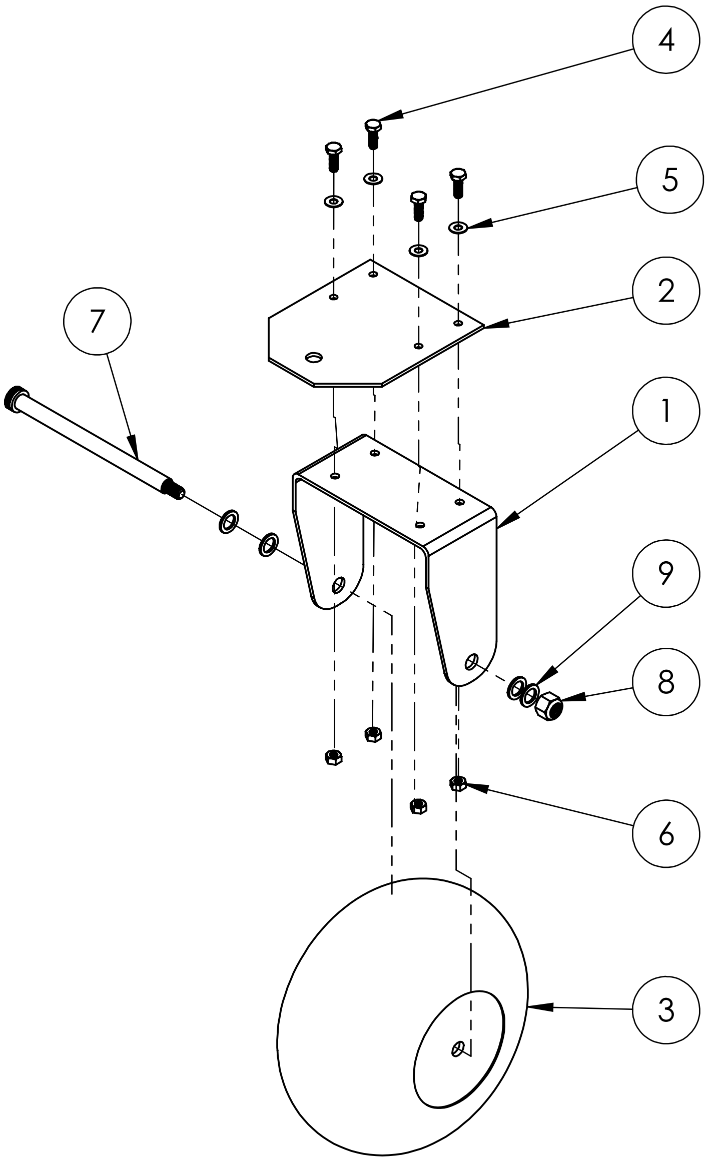
CALIFORNIA POLYTECHNIC
STATE UNIVERSITY
TEAM SEAN

TITLE: BEACH WALKER ASSEMBLY

SIZE: B | DWG. NO.: 30-0010 | REV: 1.0

SCALE: 1:8 | WEIGHT: 20.8 LBS | SHEET 1 OF 1

ITEM NO.	PART NO.	DESCRIPTION	QTY.
1	60-0017	CASTER HOUSING	1
2	60-0016	CASTER TOP PLATE	1
3	60-0022	WHEELEEZ 24CM PU BEACH WHEEL	1
4	40-0010	1/4X20 X .75 IN ZINC STEEL BOLT	4
5	40-0011	1/4 IN ID ZINC STEEL FLAT WASHER	4
6	40-0012	1/4X20 HEX NUT	4
7	40-0013	1/2X6.5 IN STAINLESS STEEL SHOULDER SCREW	1
8	40-0014	3/8X16 STAINLESS STEEL LOCK NUT	1
9	40-0015	1/2 IN ID NYLON FLAT WASHER	4



NOTE: CASTER HOUSING AND TOP PLATE ARE TO BE POWDER COATED PRIOR TO ASSEMBLY.

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ARE:

FRACTIONS ± 1/32
DECIMALS .X ±.1 .XX ±.03 .XXX ±.005
ANGLES ± 1/2

MATERIAL: 3.

FINISH: 2.

DRAWN BY: JONATHAN LARSEN

DO NOT SCALE DRAWING

CALIFORNIA POLYTECHNIC
STATE UNIVERSITY
TEAM SEAN

TITLE:

CASTER SUB-ASSEMBLY

SIZE A

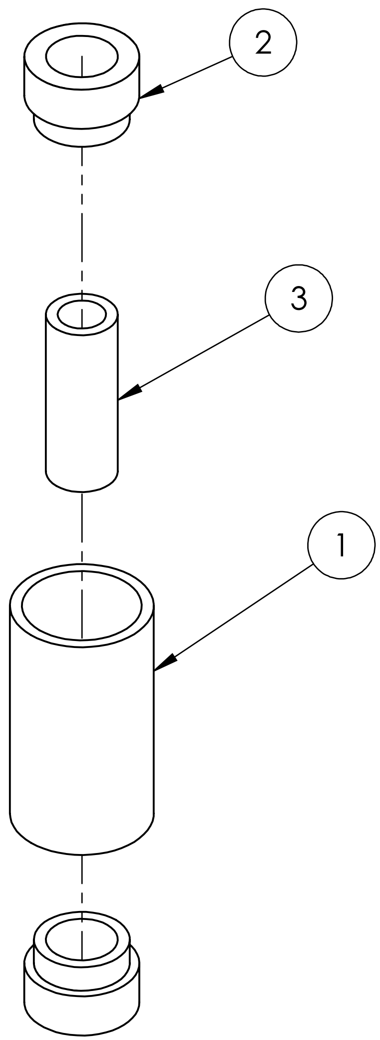
DWG. NO. 30-0011

REV 1.0

SCALE: 1:6 WEIGHT: 2.90 LBS SHEET 1 OF 1

5 4 3 2 1

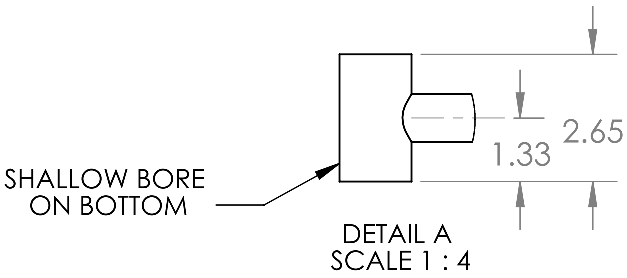
ITEM NO.	PART NO.	DESCRIPTION	QTY.
1	60-0018	BUSHING HOUSING	1
2	60-0019	NYLON BUSHING	2
3	60-0020	BUSHING SPACER	1

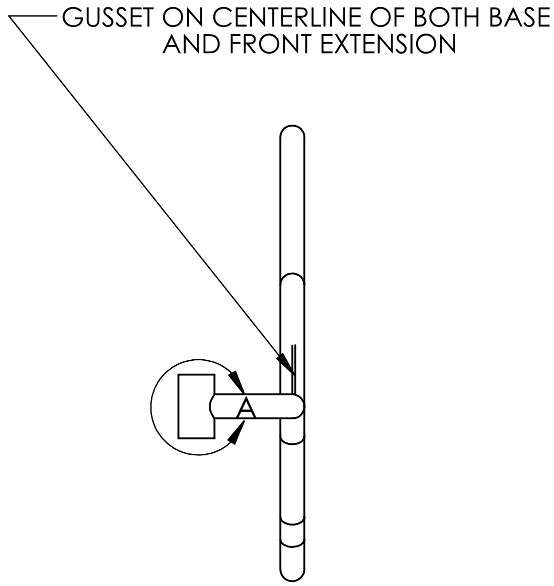


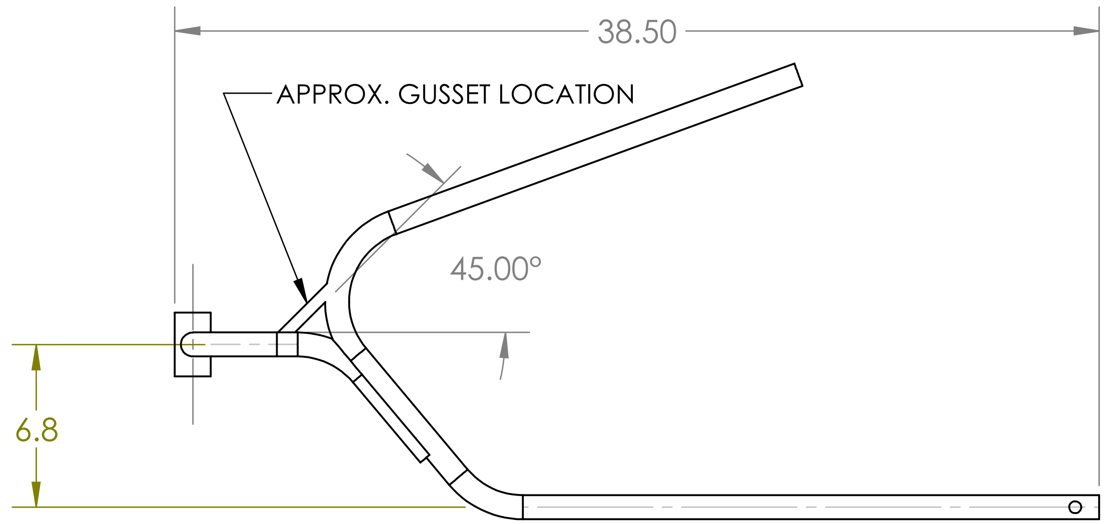
NOTES:
1. BUSHINGS ARE PRESS FIT ONTO SPACER WHILE PLACED IN BUSHING HOUSING. BUSHING ASSEMBLY TO OCCUR AFTER FRAME HAS BEEN WELDED.

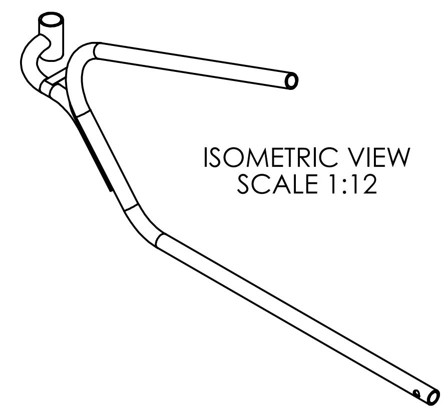
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS ± 1/32; DECIMALS .X ±.1 .XX ±.03 .XXX ±.005; ANGLES ± 1/2	CALIFORNIA POLYTECHNIC STATE UNIVERSITY TEAM SEAN		
MATERIAL: SEE PART DRAWINGS	TITLE: BUSHING SUB-ASSEMBLY		
FINISH: SEE PART DRAWINGS	SIZE A	DWG. NO. 30-0012	REV 1.0
DRAWN BY: JONATHAN LARSEN			
DO NOT SCALE DRAWING	SCALE: 1:2	WEIGHT: 0.27 LBS	SHEET 1 OF 1

5 4 3 2 1









SolidWorks Student Edition.
For Academic Use Only.

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ARE:

FRACTIONS	DECIMALS	ANGLES
± 1/32	.X ±.1 .XX ±.03 .XXX ±.005	± 1/2

MATERIAL: SEE PART DRAWINGS

FINISH: SEE PART DRAWINGS

DRAWN BY: JONATHAN LARSEN

DO NOT SCALE DRAWING

CALIFORNIA POLYTECHNIC
STATE UNIVERSITY
TEAM SEAN

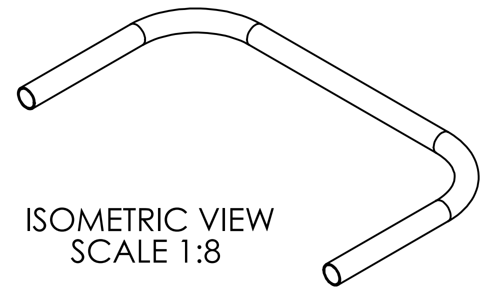
TITLE: WELDED SUB-ASSEMBLY

SIZE	DWG. NO.	REV
A	30-0013	1.0

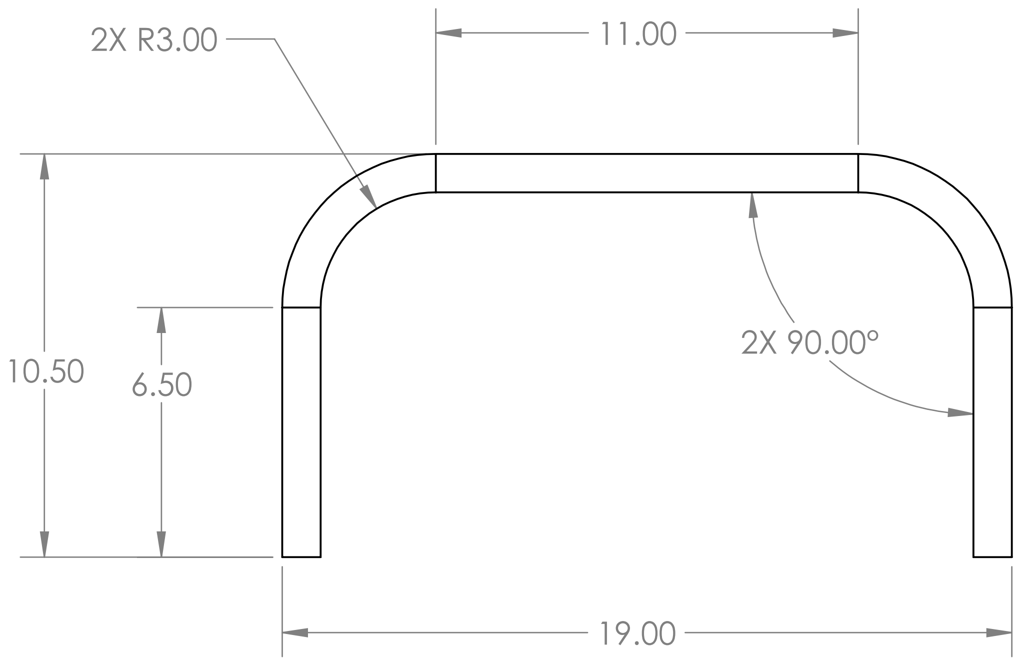
SCALE: 1:8 | WEIGHT: 2.63 LBS | SHEET 1 OF 1

5 4 3 2 1

NOTES: UNLESS OTHERWISE SPECIFIED
1. BREAK ALL SHARP EDGES AND CORNERS.
2. FINSH: BLACK POWDER COAT
3. ALUMINUM 6061-T6 (1.0" OD X 0.65" WALL)



ISOMETRIC VIEW
SCALE 1:8

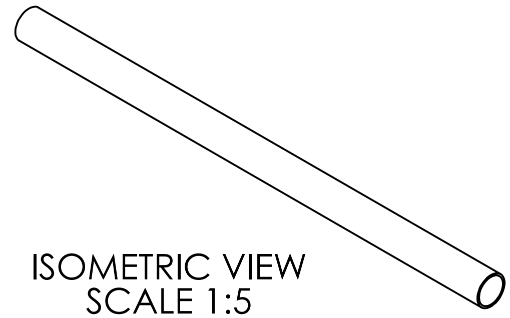


UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS ± 1/32; DECIMALS .X ±.1 .XX ±.05 .XXX ±.005; ANGLES ± 1/2	CALIFORNIA POLYTECHNIC STATE UNIVERSITY TEAM SEAN
MATERIAL: 3.	TITLE: REAR CURVE
FINISH: 2.	SIZE A; DWG. NO. 60-0010; REV 2.0
DRAWN BY: JONATHAN LARSEN	
DO NOT SCALE DRAWING	SCALE: 1:5; WEIGHT: 0.65 LBS; SHEET 1 OF 1

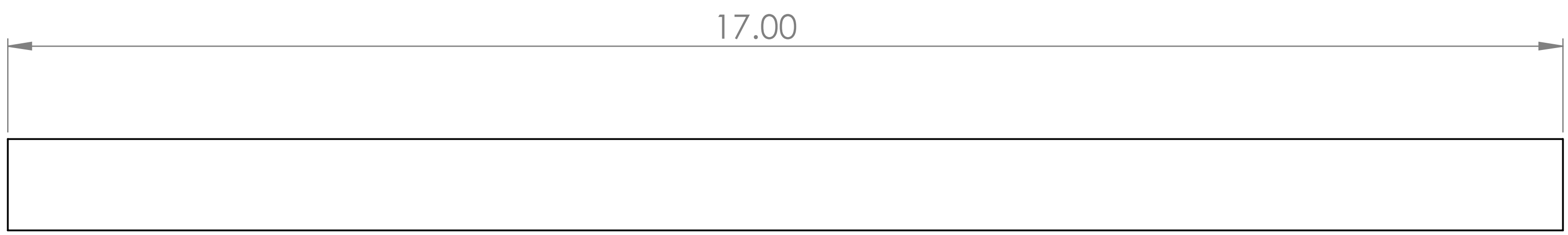
5 4 3 2 1

NOTES: UNLESS OTHERWISE SPECIFIED

1. BREAK ALL SHARP EDGES AND CORNERS.
2. FINSH: BLACK POWDER COAT AFTER HEAT TREAT
3. 6061-T6 ALUM TUBE (1" OD, .870" ID, .065" WALL THICKNESS)



ISOMETRIC VIEW
SCALE 1:5

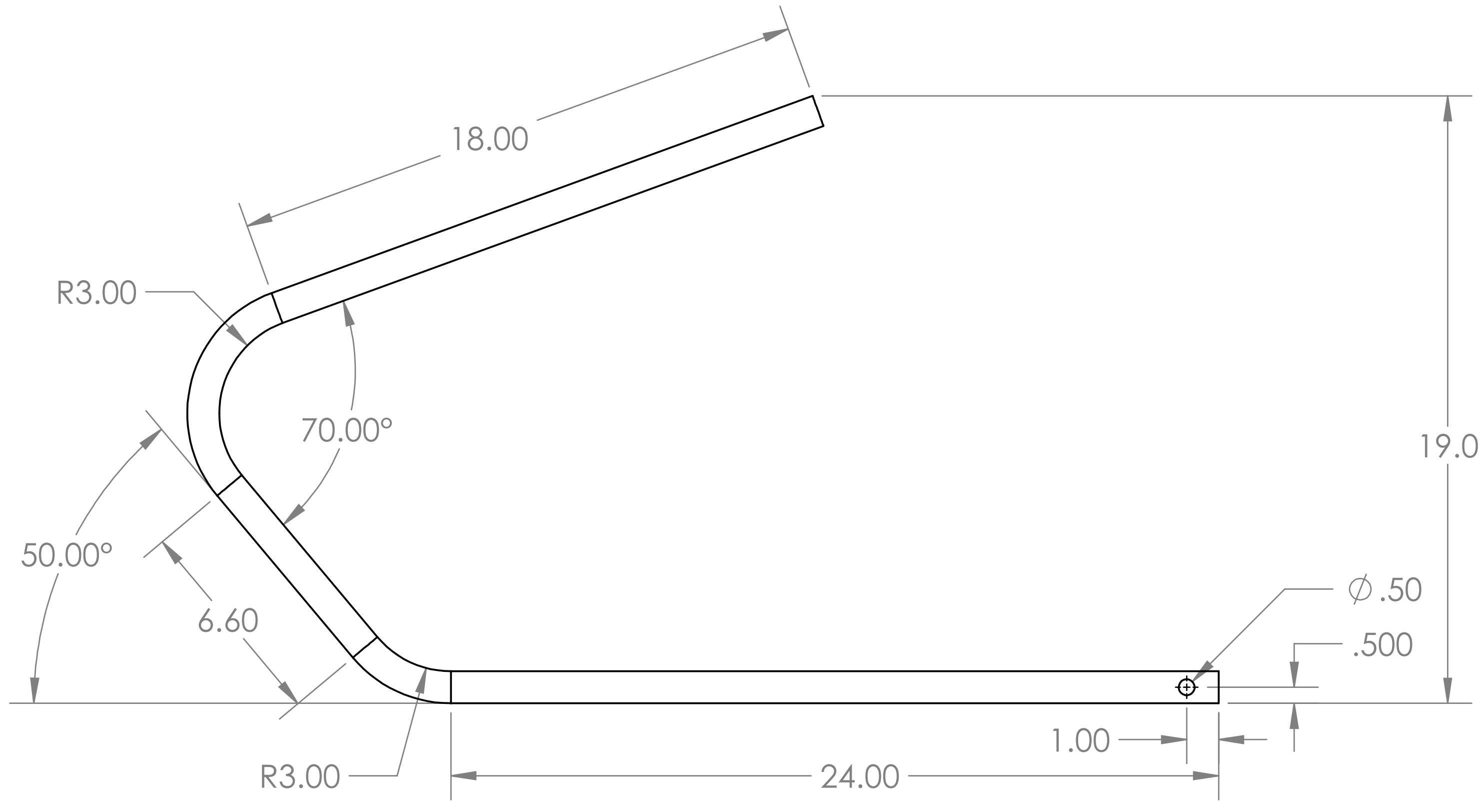


UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS ± 1/32 DECIMALS .X ±.1 .XX ±.03 .XXX ±.005 ANGLES ± 1/2	CALIFORNIA POLYTECHNIC STATE UNIVERSITY TEAM SEAN
MATERIAL: 3.	TITLE: CENTER LINK
FINISH: 2.	SIZE: A — DWG. NO. 50-0013 — REV 1.0
DRAWN BY: JONATHAN LARSEN	
DO NOT SCALE DRAWING	SCALE: 1:2 — WEIGHT: 0.29 LBS — SHEET 1 OF 1

5 4 3 2 1

NOTES: UNLESS OTHERWISE SPECIFIED

1. BREAK ALL SHARP EDGES AND CORNERS.
2. FINSH: BLACK POWDER COAT
3. 6061-T6 ALUM TUBE (1" OD, .750" ID, .125" WALL THICKNESS)



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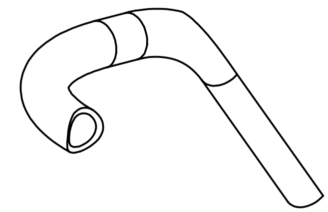
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS ± 1/32; DECIMALS .X ±.1, .XX ±.03, .XXX ±.005; ANGLES ± 1/2	CALIFORNIA POLYTECHNIC STATE UNIVERSITY TEAM SEAN
MATERIAL: 3.	TITLE: SIDE CURVE (ONE PIECE)
FINISH: 2.	SIZE A — DWG. NO. 60-0012 — REV 1.0
DRAWN BY: JONATHAN LARSEN	
DO NOT SCALE DRAWING	SCALE: 1:6 — WEIGHT: 1.95 LBS — SHEET 1 OF 1

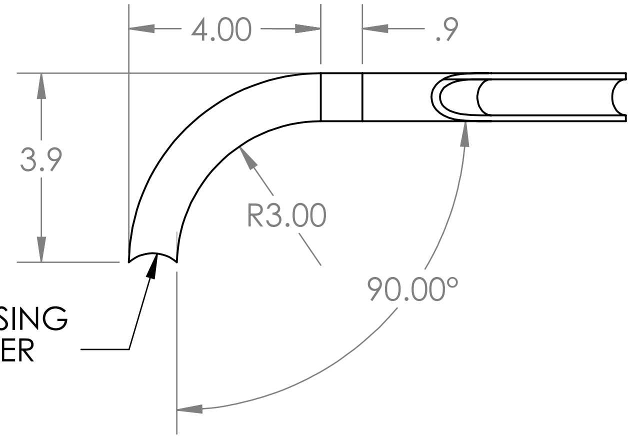
5 4 3 2 1

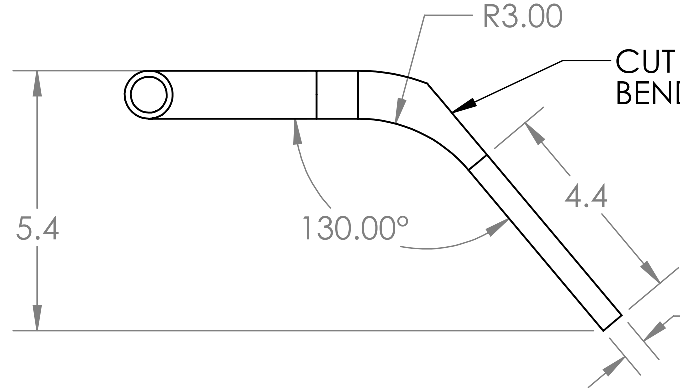
NOTES: UNLESS OTHERWISE SPECIFIED

1. BREAK ALL SHARP EDGES AND CORNERS.
2. FINSH: BLACK POWDER COAT
3. 6061-T6 ALUM TUBE (1" OD, .750" ID, .125" WALL THICKNESS)



ISOMETRIC VIEW
SCALE 1:4





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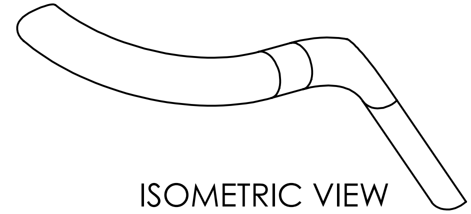
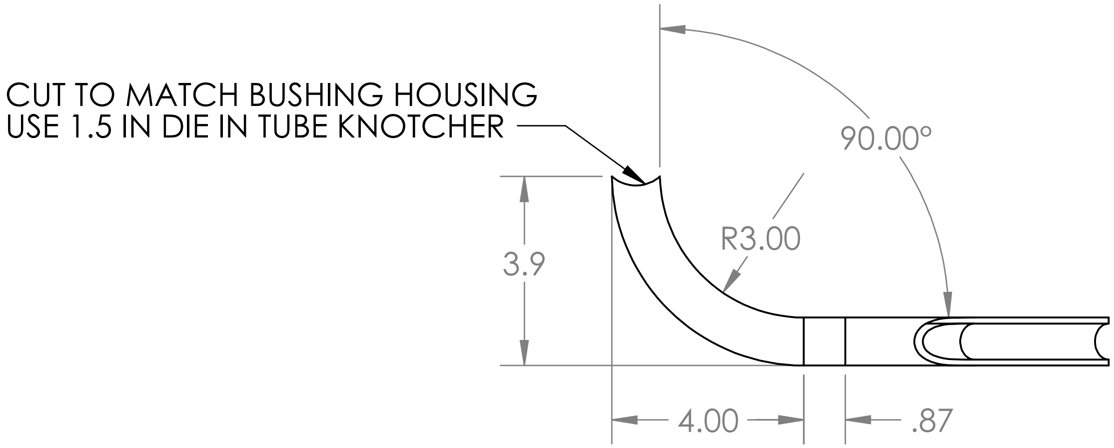
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS ± 1/32 DECIMALS .X ±.1 .XX ±.03 .XXX ±.005 ANGLES ± 1/2	CALIFORNIA POLYTECHNIC STATE UNIVERSITY TEAM SEAN
MATERIAL: 3.	TITLE: FRONT ARM LEFT
FINISH: 2.	SIZE: A — DWG. NO.: 60-0013 — REV: 1.0
DRAWN BY: JONATHAN LARSEN	
DO NOT SCALE DRAWING	SCALE: 1:4 — WEIGHT: 0.36 LBS — SHEET 1 OF 1

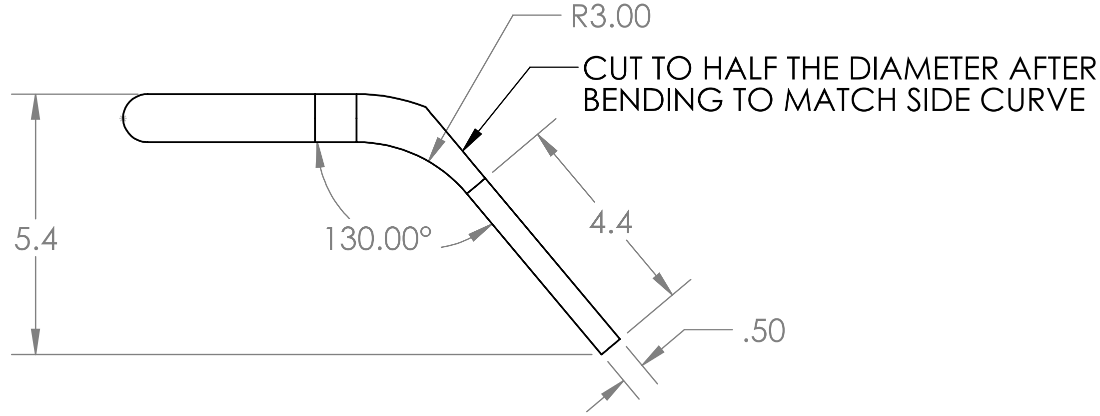
5 4 3 2 1

NOTES: UNLESS OTHERWISE SPECIFIED

1. BREAK ALL SHARP EDGES AND CORNERS.
2. FINSH: BLACK POWDER COAT
3. 6061-T6 ALUM TUBE (1" OD, .750" ID, .125" WALL THICKNESS)







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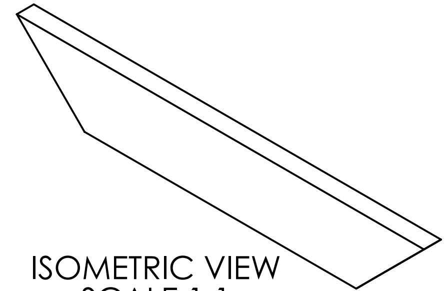
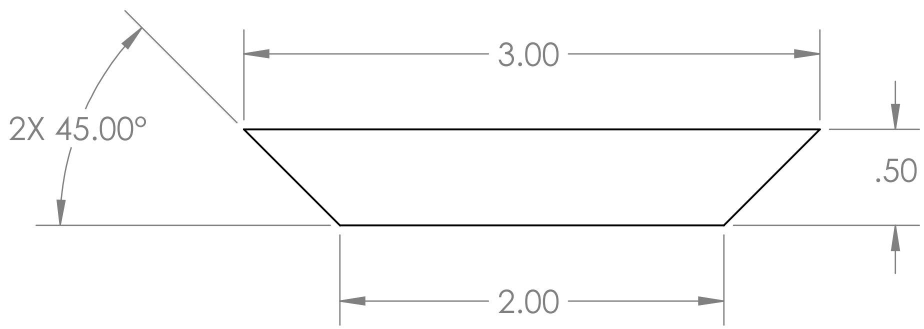
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS ± 1/32 DECIMALS .X ±.1 .XX ±.03 .XXX ±.005 ANGLES ± 1/2	CALIFORNIA POLYTECHNIC STATE UNIVERSITY TEAM SEAN
MATERIAL: 3.	TITLE: FRONT ARM RIGHT
FINISH: 2.	SIZE A DWG. NO. 60-0014 REV 1.0
DRAWN BY: JONATHAN LARSEN	SCALE: 1:4 WEIGHT: 0.36 LBS SHEET 1 OF 1
DO NOT SCALE DRAWING	

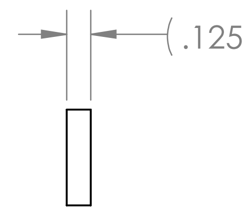
5 4 3 2 1

NOTES: UNLESS OTHERWISE SPECIFIED
1. BREAK ALL SHARP EDGES AND CORNERS.
2. FINSH: BLACK POWDER COAT
3. 6061-T6 ALUM SHEET (0.125" THICK)



ISOMETRIC VIEW
SCALE 1:1





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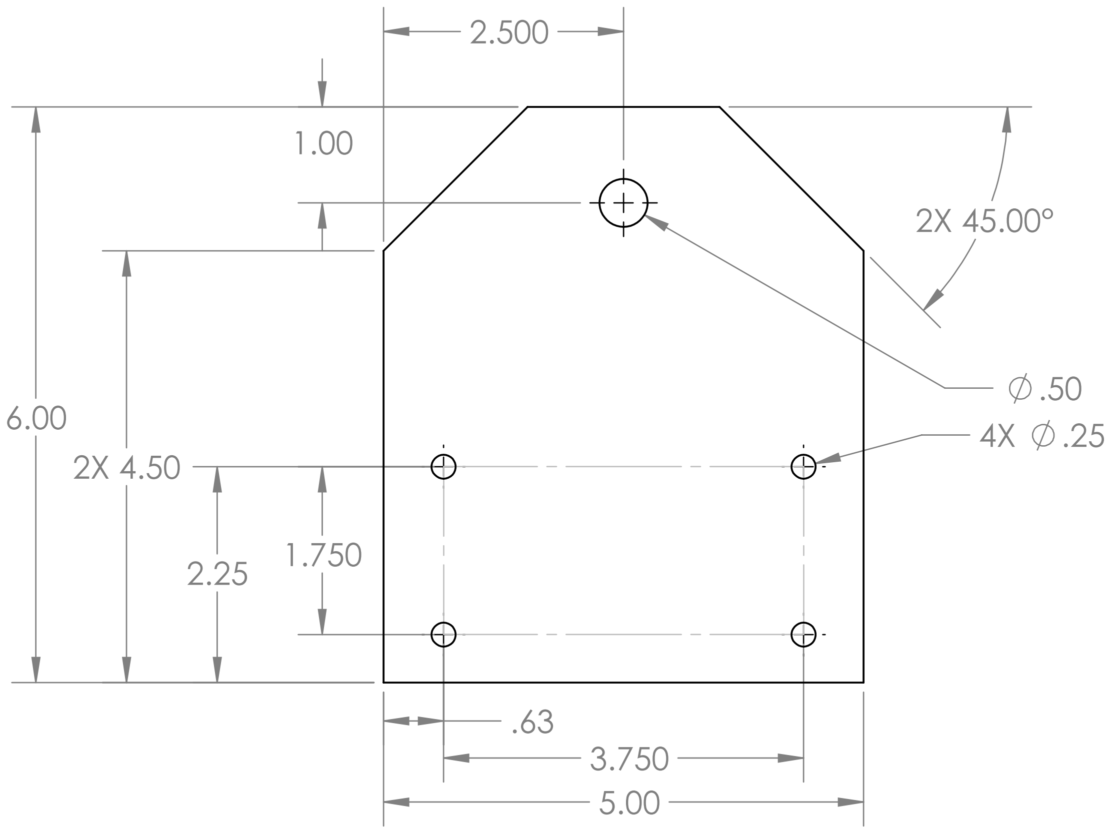
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS ± 1/32 DECIMALS .X ±.1 .XX ±.03 .XXX ±.005 ANGLES ± 1/2	CALIFORNIA POLYTECHNIC STATE UNIVERSITY TEAM SEAN		
MATERIAL: 3.	TITLE: GUSSET		
FINISH: 2.			
DRAWN BY: JONATHAN LARSEN	SIZE A	DWG. NO. 60-0015	REV 1.0
DO NOT SCALE DRAWING	SCALE: 1:1	WEIGHT: 0.02 LBS	SHEET 1 OF 1

5 4 3 2 1

NOTES: UNLESS OTHERWISE SPECIFIED

1. BREAK ALL SHARP EDGES AND CORNERS.
2. FINSH: BLACK POWDER COAT
3. 6061-T6 ALUM SHEET (0.125" THICK)



UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ARE:

FRACTIONS	DECIMALS	ANGLES
± 1/32	.X ±.1 .XX ±.03 .XXX ±.005	± 1/2

MATERIAL: 3.

FINISH: 2.

DRAWN BY: JONATHAN LARSEN

DO NOT SCALE DRAWING

CALIFORNIA POLYTECHNIC
STATE UNIVERSITY
TEAM SEAN

TITLE:

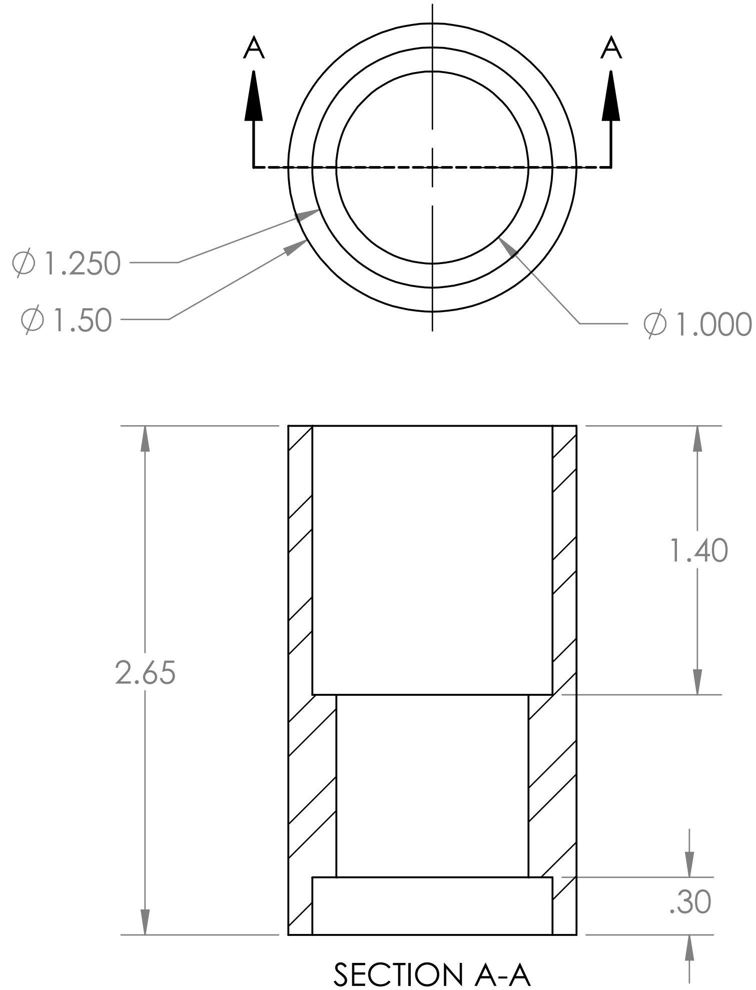
CASTER TOP PLATE

SIZE	DWG. NO.	REV
A	60-0016	1.0

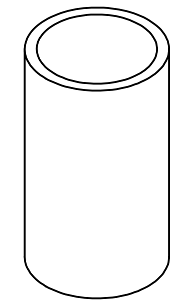
SCALE: 1:2 | WEIGHT: 0.33 LBS | SHEET 1 OF 1

5 4 3 2 1

NOTES: UNLESS OTHERWISE SPECIFIED
1. BREAK ALL SHARP EDGES AND CORNERS.
2. FINSH: BLACK POWDER COAT. MASK OFF INNER BORE.
3. 6061-T6 ALUM ROD



SECTION A-A

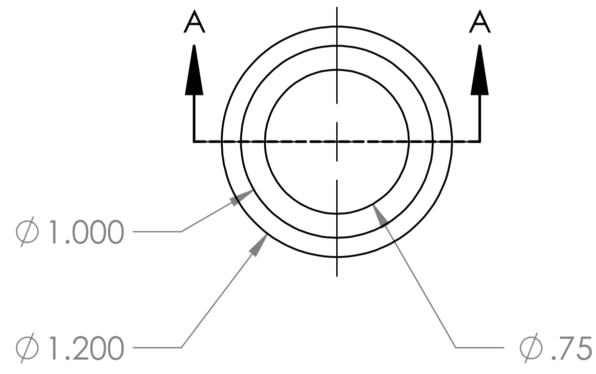


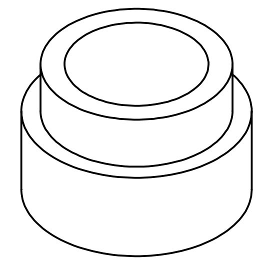
ISOMETRIC VIEW
SCALE 1:2

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS ± 1/32; DECIMALS .X ±.1, .XX ±.01, .XXX ±.005; ANGLES ± 1/2	CALIFORNIA POLYTECHNIC STATE UNIVERSITY TEAM SEAN
MATERIAL: 3.	TITLE: BUSHING HOUSING
FINISH: 2.	SIZE: A; DWG. NO. 60-0018; REV 1.0
DRAWN BY: JONATHAN LARSEN	
DO NOT SCALE DRAWING	SCALE: 1:1; WEIGHT: 0.18 LBS; SHEET 1 OF 1

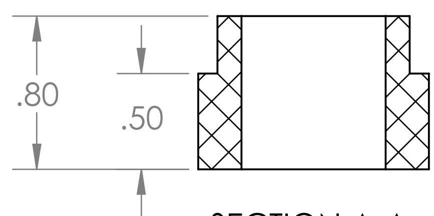
5 4 3 2 1

NOTES: UNLESS OTHERWISE SPECIFIED
1. BREAK ALL SHARP EDGES AND CORNERS.
2. FINSH: N/A
3. NYLON 6/6 WHITE





ISOMETRIC VIEW
SCALE 1 : 1



SECTION A-A
SCALE 1 : 1

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ARE:

FRACTIONS	DECIMALS	ANGLES
± 1/32	.X ±.1 .XX ±.01 .XXX ±.005	± 1/2

MATERIAL: 3.

FINISH: 2.

DRAWN BY: JONATHAN LARSEN

DO NOT SCALE DRAWING

CALIFORNIA POLYTECHNIC
STATE UNIVERSITY
TEAM SEAN

TITLE: UNIVERSAL BUSHING

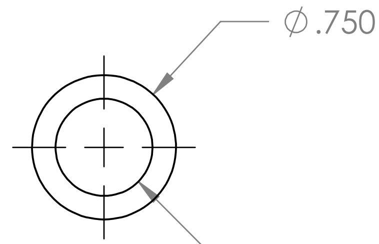
SIZE	DWG. NO.	REV
A	60-0019	1.0

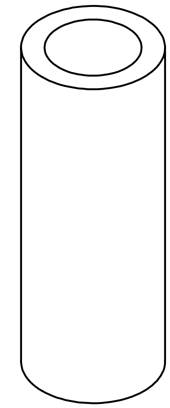
SCALE: 1:1 | WEIGHT: 0.02 LBS | SHEET 1 OF 1

5 4 3 2 1

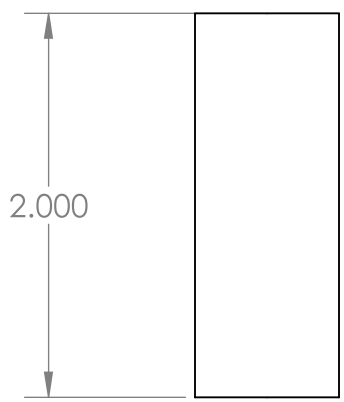
NOTES: UNLESS OTHERWISE SPECIFIED

1. BREAK ALL SHARP EDGES AND CORNERS.
2. FINSH: N/A
3. ALUM 6061-T6 TUBE





ISOMETRIC VIEW
SCALE 1:1



NOTE: OUTER DIAMETER MAY NEED TO BE ADJUSTED SLIGHTLY TO ENSURE PRESS FIT INTO BUSHING. INNER DIAMETER TO FIT LOOSE ON BOLT.

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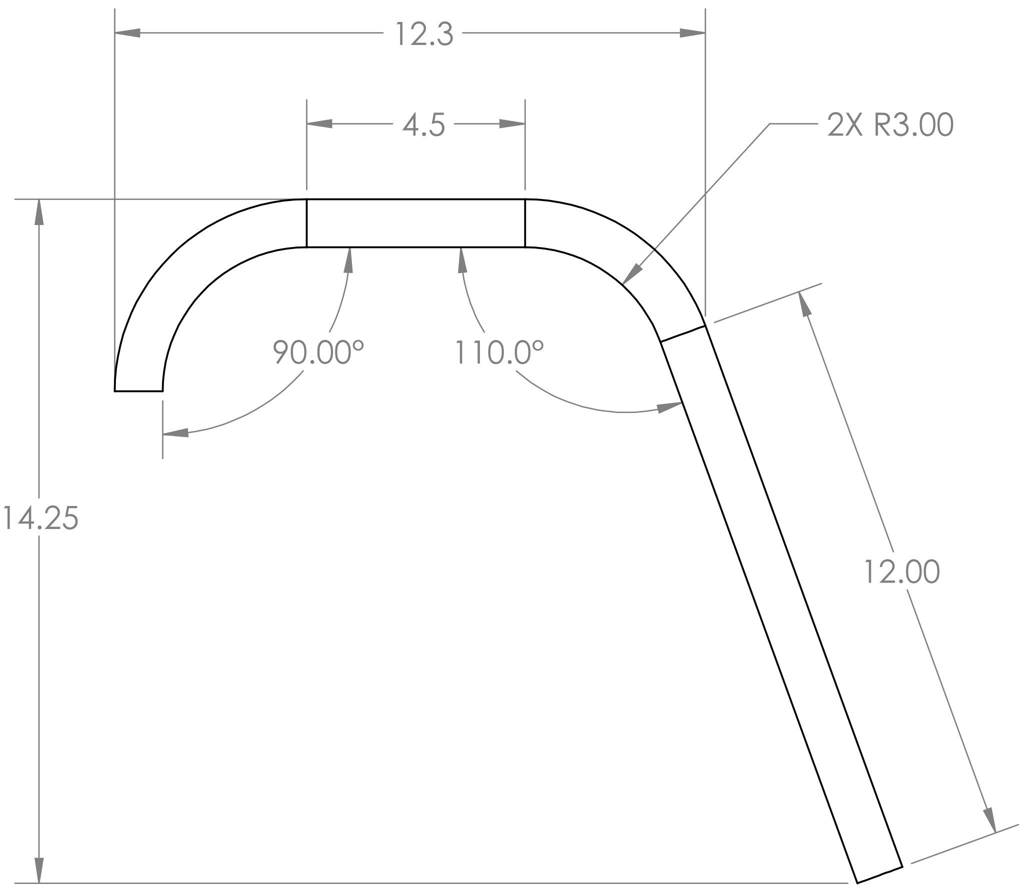
MATERIAL: 3.	TITLE: BUSHING SPACER		
FINISH: 2.	SIZE A	DWG. NO. 60-0020	REV 1.0
DRAWN BY: JONATHAN LARSEN			
DO NOT SCALE DRAWING	SCALE: 1:1	WEIGHT: 0.05 LBS	SHEET 1 OF 1

5 4 3 2 1

NOTES: UNLESS OTHERWISE SPECIFIED

1. BREAK ALL SHARP EDGES AND CORNERS.
2. BLACK POWDER COAT
3. 1.00 x 0.125 IN WALL ALUM. 6061-T6 TUBE



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS ± 1/32; DECIMALS .X ±.1 .XX ±.03 .XXX±.005; ANGLES ± 1/2	CALIFORNIA POLYTECHNIC STATE UNIVERSITY TEAM SEAN		
MATERIAL: 3.	TITLE: HANDLE BAR		
FINISH: 2.	SIZE A	DWG. NO. 60-0021	REV 1.0
DRAWN BY: JONATHAN LARSEN			
DO NOT SCALE DRAWING	SCALE: 1:4	WEIGHT: 0.88 LBS	SHEET 1 OF 1

5 4 3 2 1

Appendix C:

List of Vendors:

1. McMaster-Carr
2. Onlinemetals.com
3. Wheeleez, Inc.
4. Hank J Van Gaale Custom Welding & Fabrication- San Luis Obispo, Ca.
5. Central Coast Powder Coating- San Luis Obispo, Ca.
6. Home Depot- San Luis Obispo, Ca.
7. Miner’s Ace Hardware- San Luis Obispo, Ca.

Appendix D:

Vendor Supplied Component
Specifications and Data Sheets

Beach Wheels--
Heavy Duty Beach Wheels
- 24cm Beach Cart Wheels
- 30cm Beach Cart Wheels
- 42cm Beach Cart Wheels
- 49cm Beach Cart Wheels
- Replacement Tires

Recreational Beach Wheels
- 22cm Beach Cart Wheels
- 30cm Beach Cart Wheels
- Replacement Tires

Utility Wheels
- 25cm Plastic Spoke Utility Wheels
- 26cm Foam "Tuff Tire" Wheels
- 26cm Pneumatic Rubber Wheels
- 38cm Foam "Tuff Tire" Wheels

Beach Carts
- Beach Cart
- Umbrella for Beach Cart
- Beach Cart-Folding
- Beach Cart Folding-Mini
- Wonder Wheeler® Beach Conversion Kit
- Beach Wagon
- The Monster Beach Furniture Cart
- **Compare all Beach Carts**

Kayak Carts / Canoe Carts
- Kayak/Canoe Cart w/ *Tuff-Tires*
- Kayak Cart-Beach
- Kayak Cart-Mini
- Boat Wheeler
- **Compare all Boat Carts**

Small Boat Dollies
- Boat Dolly

Jet Ski / PWC Dollies
- Jet Ski Dolly/ PWC Dolly 12
- Jet Ski Dolly/ PWC Dolly 24
- Jet Ski Dolly/ PWC Dolly 36

Utility Carts
- Beach Cart
- Beach Cart Folding
- Wonder Wheeler® Beach Conversion Kit

Mobility
- Beach Wheelchair Dolly

Axles & Wheel Accessories
- Stainless Steel Axles (1/2" dia.)
- Aluminum Axles (1" dia.)
- RoboCup Cup Holder
- Axle Quick Clip Pins
- Hub Twist Lock Knobs
- Tire Pump & Gauge
- Need parts?

Applications

Polyurethane Beach Wheels	 zoom	 zoom	 zoom	 zoom
Product Name & Number	24cm PU Beach Wheel WZ1-24U	30cm PU Beach Wheel WZ1-30U	42cm PU Beach Wheel WZ1-42U	49cm PU Beach Wheel WZ1-49U
Dimensions*	9.4 x 4.8" (24 x 12.3 cm)	11.8 x 7" (30 x 18 cm)	16.5 x 7.9" (42 x 20 cm)	19.3 x 9" (49 x 23 cm)
Width at Bushing/Bearing	5" (12.8 cm)	7.3" (18.5 cm)	7.8" (19.8 cm)	7.8" (19.8 cm)
Max. Payload per Wheel	88 lbs (40 kg)	121 lbs (55 kg)	176 lbs (80 kg)	264 lbs (120 kg)
Weight	1.5 lbs (0.7 kg)	2.91 lbs (1.32 kg)	5.5 lbs (2.5 kg)	6.1 lbs (2.78 kg)
Materials	Tire: Polyurethane **Hub:** Polypropylene	**Tire:** Polyurethane **Hub:** Polypropylene	**Tire:** Polyurethane **Hub:** Polypropylene	**Tire:** Polyurethane **Hub:** Polypropylene
Ideal & Ship Pressure	2.5 psi (0.17 bar)	2.5 psi (0.17 bar)	2.5 psi (0.17 bar)	2.5 psi (0.17 bar)
Pressure Range	Low Pressure 2–4 psi (0.14-0.28 bar)	Low Pressure 2–4 psi (0.14-0.28 bar)	Low Pressure 2–4 psi (0.14-0.28 bar)	Low Pressure 2–4 psi (0.14-0.28 bar)
Temperature Range	5 to 167 F (-15 to 75 C)	5 to 167 F (-15 to 75 C)	5 to 167 F (-15 to 75 C)	5 to 167 F (-15 to 75 C)
Works on	• Kayak Cart-Mini • Hobie Trax Cart' (Important note!!) 'With Twist Lock Knob	• Kayak Cart, Beach • Platform Dolly	• Beach Cart	• Jet Ski Dollies • Platform Dolly
Price	**$53.00**/wheel	**$74.00**/wheel	**$120.00**/wheel	**$147.00**/wheel
Add to Cart **Add to Cart by selecting Bushing or Bearing Option to the right.** **Sold individually, not as pairs.**	• 1/2" Bushing • 1/2" Bushing w/Twist Lock Knob <<more info>> • 5/8" Bushing • 3/4" Bushing	• 1/2" Bushing • 1/2" Bushing w/Twist Lock Knob <<more info>> • 3/4" Bearing • 1" Bearing	• 1" Bearing	• 1" Bearing

* With tire pressure 2.5 psi at sea level and at a temp range of 75-80° F (24-26.5° C). Wheel dimensions may vary temporarily by up to +/- 1" (2.5 cm) in diameter and/or width, depending on temperature and elevation.

Read a great review of the Wheel EEZ™ 24cm wheels on Hobie Forums.

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Share Pin it

Armacell 1 in. x 6 ft. Tubolit Self-Seal Foam Pipe Insulation

Model # OES11838 Store SKU # 420048

★★★½☆ (5) | Write a Review +

$1.98 / each

42 in Stock at San Luis Obispo #1052
(change pick up store)

PRODUCT SOLD : In Store Only

Quantity: 1

Item must be picked up in store

Pick Up Today
Free
42 in stock
at San Luis Obis...
(change pick up store)

+ ADD TO CART

ADD TO LIST

SUGGESTIONS BASED ON YOUR RECENTLY VIEWED ITEMS

Product Overview | Specifications | Customer Reviews | Shipping Options

PRODUCT OVERVIEW

The Armacell 1 in. x 72 in. Foam Pipe Insulation is designed for use with copper and iron pipes. It helps protect a pipe from freezing while saving energy. The self-sealing insulation is also mold resistant.

- Self-seal foam pipe insulation
- Compatible with copper and iron pipes
- Helps protect pipes from freezing
- Saves energy
- Mold resistant

Return To Top

SPECIFICATIONS

Accessory Type	Insulation	Assembled Depth (in.)	72 in
Assembled Height (in.)	1.98 in	Assembled Width (in.)	1.98 in
Compatible pipe material	Copper	ENERGY STAR Certified	No
Fire rated	Yes	Manufacturer Warranty	None
Maximum compatible pipe size (in.)	1	Minimum compatible pipe size (in.)	1
Pipe or Fitting Product Type	Accessory	Product Height (in.)	1.875 in
Product Length (in.)	72 in	Product Weight (lb.)	.25 lb
Product Width (in.)	1.875 in	R Value	2.4
Self-sealing	Yes		

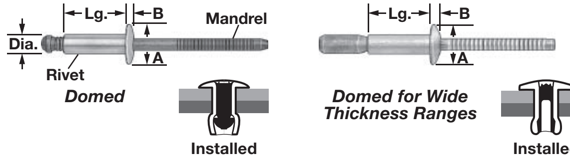
High-Strength Blind Rivets

Also known as structural rivets, they have higher shear and tensile strengths than standard blind rivets of the same size and material.

Domed—Also known as Q-rivets, they're resistant to vibration.

Domed for Wide Thickness Ranges—Also known as ultra-grip rivets, they can handle a wide range of thicknesses.

18-8 stainless steel rivets and mandrels have excellent corrosion resistance and may be mildly magnetic. ***Zinc-plated steel*** rivets and mandrels have good corrosion resistance. ***Aluminum*** rivets and mandrels are corrosion resistant and nonmagnetic.



	Head Dimensions			
	Domed		Domed for Wide Thickness Ranges	
Dia.	(A)	(B)	(A)	(B)
1/8″	0.25″	0.04″	—	—
3/16″	0.375″	0.06″	0.385″	0.085″
1/4″	0.5″	0.08″	0.525″	0.117″

	SHEAR AND TENSILE STRENGTHS							
	Domed				Domed for Wide Thickness Ranges			
	18-8 SS		Zinc-Plated Steel		18-8 SS and Zinc-Plated Steel		Aluminum	
Dia.	Shear, lbs.	Tensile, lbs.	Shear, lbs.	Tensile, lbs.	Shear, lbs.	Tensile, lbs.	Shear, lbs.	Tensile, lbs.
1/8″	700	600	500	400	—	—	—	—
3/16″	1,650	1,300	1,050	825	1,400	1,000	700	500
1/4″	2,450	2,250	1,750	1,450	2,750	2,200	1,300	890

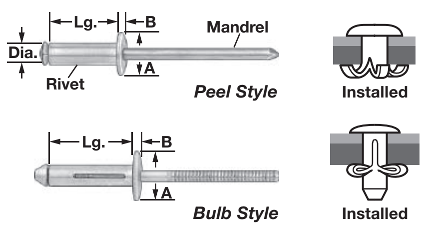
Material Thick. Range	Lg.	Pkg. Qty.		Pkg.
Domed				
18-8 Stainless Steel				
1/8″ Dia.—*For Hole Size: 0.129″-0.133″ (Drill Size #30)*				
0.126″-0.25″	0.4″	10	98780A111	$7.24
0.188″-0.312″	0.462″	10	98780A112	8.24
0.251″-0.375″	0.535″	10	98780A113	8.24
3/16″ Dia.—*For Hole Size: 0.192″-0.196″ (Drill Size #11)*				
0.126″-0.25″	0.45″	10	98780A212	14.12
0.251″-0.375″	0.575″	5	98780A213	8.06
0.376″-0.5″	0.7″	5	98780A214	8.16
1/4″ Dia.—*For Hole Size: 0.257″-0.261″ (Drill Size F)*				
0.126″-0.25″	0.5″	5	98780A412	12.58
0.251″-0.375″	0.625″	1	98780A413	2.87
0.376″-0.5″	0.75″	1	98780A414	3.18
0.501″-0.625″	0.9″	1	98780A415	3.31
Zinc-Plated Steel				
1/8″ Dia.—*For Hole Size: 0.129″-0.133″ (Drill Size #30)*				
0.126″-0.25″	0.4″	25	98777A111	8.00
0.188″-0.312″	0.462″	25	98777A112	8.05
0.251″-0.375″	0.535″	25	98777A113	8.19
3/16″ Dia.—*For Hole Size: 0.192″-0.196″ (Drill Size #11)*				
0.062″-0.125″	0.325″	25	98777A211	8.46
0.126″-0.25″	0.45″	25	98777A212	9.44
0.251″-0.375″	0.575″	25	98777A213	9.82
0.376″-0.5″	0.7″	25	98777A214	10.29
0.501″-0.625″	0.85″	25	98777A215	10.63
1/4″ Dia.—*For Hole Size: 0.257″-0.261″ (Drill Size F)*				
0.062″-0.125″	0.375″	25	98777A311	10.23
0.126″-0.25″	0.5″	25	98777A312	10.36
Domed (Cont.)				
Zinc-Plated Steel (Cont.)				
1/4″ Dia.—*For Hole Size: 0.257″-0.261″ (Drill Size F) (Cont.)*				
0.251″-0.375″	0.625″	25	98777A313	$12.21
0.376″-0.5″	0.75″	10	98777A314	5.69
0.501″-0.625″	0.9″	10	98777A315	6.68
Domed for Wide Thickness Ranges				
18-8 Stainless Steel				
3/16″ Dia.—*For Hole Size: 0.191″-0.201″ (Drill Size #11)*				
0.062″-0.27″	0.415″	10	98778A525	9.76
1/4″ Dia.—*For Hole Size: 0.261″-0.272″ (Drill Size F)*				
0.08″-0.375″	0.56″	10	98778A531	12.17
0.35″-0.625″	0.81″	10	98778A528	9.04
Aluminum				
3/16″ Dia.—*For Hole Size: 0.191″-0.201″ (Drill Size #11)*				
0.062″-0.27″	0.415″	50	98778A501	10.06
0.062″-0.437″	0.572″	50	98778A502	12.95
1/4″ Dia.—*For Hole Size: 0.261″-0.272″ (Drill Size F)*				
0.08″-0.375″	0.56″	25	98778A503	9.25
0.08″-0.625″	0.81″	25	98778A504	11.15
Zinc-Plated Steel				
3/16″ Dia.—*For Hole Size: 0.191″-0.201″ (Drill Size #11)*				
0.062″-0.27″	0.415″	50	98778A511	11.73
0.062″-0.437″	0.572″	50	98778A512	12.68
1/4″ Dia.—*For Hole Size: 0.261″-0.272″ (Drill Size F)*				
0.08″-0.375″	0.56″	25	98778A513	8.94
0.08″-0.625″	0.81″	25	98778A514	11.33

Blind Rivets for Soft and Brittle Materials

When installed, rivet bodies fan out to provide a uniform grip. They're good for oversized holes. Heads are domed.

Peel Style—Fasten soft materials such as plastic and fiberglass to thin materials such as sheet metal. When installed, the body splits into "petals" that draw materials together without pulling through them. Rivets are aluminum, which is corrosion resistant and nonmagnetic. Mandrels are steel.

Bulb Style—Part of the mandrel is retained, which increases shear strength. They're designed to fasten brittle materials such as plastic and laminates without damaging them. Rivets and mandrels are aluminum, which is corrosion resistant and nonmagnetic.



Material Thick. Range	Lg.	Pkg. Qty.		Pkg.
Peel Style				
1/8″ Dia.—*For Hole Size: 0.142″ (Drill Size #27)*				
0.039″-0.138″	0.354″	100	93372A310	$10.49
0.098″-0.197″	0.433″	100	93372A315	10.81
0.177″-0.276″	0.512″	100	93372A320	11.13
0.256″-0.354″	0.59″	100	93372A325	13.73
0.335″-0.433″	0.669″	100	93372A330	14.21
5/32″ Dia.—*For Hole Size: 0.173″ (Drill Size #17)*				
0.039″-0.118″	0.354″	100	93372A340	11.71
0.098″-0.197″	0.433″	100	93372A345	11.94
0.177″-0.256″	0.512″	100	93372A350	13.38
0.236″-0.315″	0.59″	100	93372A355	14.24
0.295″-0.394″	0.669″	50	93372A360	9.76
0.354″-0.422″	0.748″	50	93372A365	8.60
0.452″-0.551″	0.827″	50	93372A370	10.88
3/16″ Dia.—*For Hole Size: 0.204″ (Drill Size #6)*				
0.039″-0.118″	0.354″	100	93372A072	13.68
0.098″-0.197″	0.433″	100	93372A375	14.71
0.177″-0.276″	0.512″	50	93372A377	9.85
0.256″-0.354″	0.59″	50	93372A379	9.26
0.335″-0.394″	0.669″	50	93372A380	9.41
0.375″-0.472″	0.748″	50	93372A382	11.37
0.453″-0.551″	0.827″	50	93372A385	12.17
0.531″-0.748″	1.024″	50	93372A387	13.37

		Head Dimensions		Shear Strength, lbs.	Tensile Strength, lbs.
	Dia.	(A)	(B)		
Peel Style	1/8″	0.256″	0.048″	180	210
	5/32″	0.315″	0.059″	310	450
	3/16″	0.374″	0.063″	450	600
Bulb Style	5/32″	0.375″	0.057″	160	220
	3/16″	0.455″	0.062″	400	450

Material Thick. Range	Lg.	Pkg. Qty.		Pkg.
Bulb Style				
5/32″ Dia.—*For Hole Size: 0.162″-0.167″ (Drill Size #20)*				
0.125″-0.25″	0.79″	50	97545A010	$14.18
0.187″-0.375″	0.852″	50	97545A020	14.37
0.25″-0.5″	0.977″	25	97545A030	8.54
3/16″ Dia.—*For Hole Size: 0.209″-0.221″ (Drill Size #4)*				
0.125″-0.25″	0.77″	25	97545A050	8.54
0.187″-0.375″	0.895″	25	97545A060	8.59
0.25″-0.5″	1.02″	25	97545A070	8.80
0.375″-0.625″	1.145″	25	97545A080	8.96
0.5″-0.75″	1.27″	25	97545A090	10.30

Roll over image to zoom in

Amico 1.1" Hole Dia Double Port Pipe Clamp Clip Lean Tube Connector

by Amico
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Price: $6.08 & **FREE Shipping** on orders over $35. Details

Only 1 left in stock.
Sold by uxcell and Fulfilled by Amazon. Gift-wrap available.

Want it Tuesday, Feb. 11? Order within **38 hrs 12 mins** and choose **One-Day Shipping** at checkout. Details

- Product Name : Pipe Clamp;Material : Metal
- Main Color : Black;Hole Dia : 2.8cm/1.1"
- Size(each) : 6.8 x 3.3cm / 2.6" x 1.3" (L*W);Bear Weight : 300kg / 661.4 pound
- Weight : 115g
- Package Content : 1 x Pipe Clamp

› See more product details

2 new from $5.23

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Square Nuts

Square nuts have a large bearing surface and plenty of surface area for your wrench to grip. Choose from flat top and round top styles. Nuts with a flat top are also known as machine screw square nuts. Inch size nuts have a Class 2B thread fit; metric size nuts have a Class 7H thread fit and meet DIN 557.

Flat-top nuts (except those made from fiberglass) and ***round-top*** nuts made from 18-8 stainless steel have dimensions that meet ANSI/ASME B18.6.3. All other ***round-top*** nuts have dimensions that meet ANSI/ASME B18.2.2.

Fiberglass nuts are gray.

Flat Top

Round Top

Thread Size	Wd.	Ht.	Pkg. Qty.		Per Pkg.
Flat Top					
Zinc-Plated Grade 2 Steel					
6-32	5/16"	7/64"	100	94855A201	$2.03
8-32	11/32"	1/8"	100	94855A216	2.75
10-24	3/8"	1/8"	100	94855A232	2.87
1/4"-20	7/16"	3/16"	100	94855A247	4.71
5/16"-18	9/16"	7/32"	100	94855A263	8.80
3/8"-16	5/8"	1/4"	50	94855A278	8.47
Plain Grade 2 Steel					
6-32	5/16"	7/64"	100	94855A115	1.63
8-32	11/32"	1/8"	100	94855A119	2.08
10-24	3/8"	1/8"	100	94855A123	3.10
1/4"-20	7/16"	3/16"	100	94855A127	3.72
5/16"-18	9/16"	7/32"	100	94855A131	7.86
3/8"-16	5/8"	1/4"	100	94855A135	10.66
Black Zinc-Plated Steel ■					
1/4"-20	7/16"	3/16"	100	94859A111	6.56
5/16"-18	9/16"	7/32"	50	94859A122	9.57
3/8"-16	5/8"	1/4"	50	94859A133	7.92
Fiberglass ■					
3/8"-16	11/16"	7/16"	1	91332A031	2.80
1/2"-13	7/8"	9/16"	1	91332A033	4.00
5/8"-11	1 1/16"	11/16"	1	91332A035	5.40
3/4"-10	1 1/4"	13/16"	1	91332A036	7.00
1"-8	1 5/8"	1 1/16"	1	91332A038	11.00
Round Top					
Zinc-Plated Grade 5 Steel					
1/4"-20	7/16"	7/32"	100	98694A110	6.76
5/16"-18	9/16"	17/64"	100	98694A115	11.41

Thread Size	Wd.	Ht.	Pkg. Qty.		Per Pkg.
Round Top					
Zinc-Plated Grade 5 Steel (Cont.)					
3/8"-16	5/8"	21/64"	50	98694A120	$9.05
7/16"-14	3/4"	3/8"	25	98694A125	9.91
1/2"-13	13/16"	7/16"	25	98694A130	12.53
5/8"-11	1"	35/64"	10	98694A135	8.28
3/4"-10	1 1/8"	21/32"	10	98694A140	11.28
7/8"-9	1 5/16"	49/64"	5	98694A145	12.65
1"-8	1 1/2"	7/8"	1	98694A150	3.26
1 1/8"-7	1 11/16"	1"	1	98694A155	8.28
1 1/4"-7	1 7/8"	1 3/32"	1	98694A160	8.28
1 1/2"-6	2 1/4"	1 5/16"	1	98694A165	11.58
Hot-Dipped Galvanized Grade 2 Steel					
5/16"-18	9/16"	17/64"	100	93430A410	10.40
3/8"-16	5/8"	21/64"	100	93430A415	11.96
1/2"-13	13/16"	7/16"	50	93430A421	12.88
5/8"-11	1"	35/64"	25	93430A425	10.81
3/4"-10	1 1/8"	21/32"	10	93430A430	6.78
7/8"-9	1 5/16"	49/64"	10	93430A435	14.30
1"-8	1 1/2"	7/8"	5	93430A440	10.67
Plain Grade 2 Steel					
1/4"-20	7/16"	7/32"	100	90043A029	4.73
5/16"-18	9/16"	17/64"	100	90043A030	8.11
3/8"-16	5/8"	21/64"	100	90043A031	11.79
7/16"-14	3/4"	3/8"	50	90043A034	18.07
1/2"-13	13/16"	7/16"	50	90043A055	13.05
5/8"-11	1"	35/64"	25	90043A065	11.15
3/4"-10	1 1/8"	21/32"	10	90043A075	6.62
7/8"-9	1 5/16"	49/64"	10	90043A085	21.14
1"-8	1 1/2"	7/8"	5	90043A095	8.71

Thread Size	Wd.	Ht.	Pkg. Qty.		Per Pkg.
Round Top					
Plain Grade 2 Steel (Cont.)					
1 1/8"-7	1 11/16"	1"	5	90043A105	$13.64
1 1/4"-7	1 7/8"	1 3/32"	1	90043A115	5.01
1 1/2"-6	2 1/4"	1 5/16"	1	90043A125	7.51
Type 316 Stainless Steel					
1/4"-20	7/16"	3/16"	25	92891A100	7.84
5/16"-18	9/16"	7/32"	10	92891A200	5.76
3/8"-16	5/8"	1/4"	10	92891A300	9.63
1/2"-13	13/16"	7/16"	1	92891A400	2.63
18-8 Stainless Steel ♣					
6-32	5/16"	7/64"	100	94785A007	8.58
8-32	11/32"	1/8"	100	94785A009	7.51
10-24	3/8"	1/8"	100	94785A013	8.73
10-32	3/8"	1/8"	100	94785A411	8.73
1/4"-20	7/16"	3/16"	50	94785A415	6.31
5/16"-18	9/16"	7/32"	25	94785A419	6.55
3/8"-16	5/8"	1/4"	25	94785A423	8.84
1/2"-13	13/16"	7/16"	5	94785A427	5.03
5/8"-11	1"	35/64"	1	94785A431	5.66
3/4"-10	1 1/8"	21/32"	1	94785A435	9.05
1"-8	1 1/2"	7/8"	1	94785A438	17.92

Thrd. Size	Pitch	Wd.	Ht.	Pkg. Qty.		Per Pkg.
Metric Round Top—*Dimensions in mm*						
Zinc-Plated Class 5 Steel						
M6	1	10	5	100	96887A319	$12.00
M8	1.25	13	6.5	25	96887A322	5.00
M10	1.5	17	8	25	96887A325	8.00
M12	1.75	19	10	10	96887A328	6.10

■ Not rated for hardness. ♣ May have flat or rounded top.

Concave Square Locknuts

Also known as utility-pole nuts, these hot-dipped galvanized steel nuts have a cupped shape with corners that bite into soft materials to hold securely. The cupped shape assures a flush fit against round-top square nuts and that they'll resist loosening when jammed against flat-top square nuts. Locknuts are not rated for thread fit or hardness.

Thread Size	Wd.	Ht.	Pkg. Qty.		Per Pkg.
3/8"-16	5/8"	15/64"	25	99453A100	$10.29
1/2"-13	13/16"	9/32"	10	99453A200	6.54
5/8"-11	15/16"	11/32"	10	99453A300	9.20
3/4"-10	1 1/8"	13/32"	5	99453A400	$6.81
7/8"-9	1 5/16"	27/64"	5	99453A500	9.15

Nylon-Insert Heavy Hex Locknuts

To provide extra strength and greater thread engagement, these reusable locknuts are thicker than standard nylon-insert locknuts. When fully tightened, the nylon insert provides vibration resistance and prevents loosening—without damaging mating threads. Each locknut has a Class 2B thread fit and is reliable at temperatures up to 250° F.

Thread Size	Wd.	Ht.	Pkg. Qty.		Per Pkg.
Zinc-Plated Grade 2 Steel					
1/4"-20	1/2"	3/8"	100	90648A029	$7.91
5/16"-18	9/16"	29/64"	100	90648A030	8.72
3/8"-16	11/16"	35/64"	50	90648A215	9.97
7/16"-14	3/4"	39/64"	25	90648A220	10.61
1/2"-13	7/8"	45/64"	25	90648A225	10.97
9/16"-12	15/16"	13/16"	5	90648A230	7.37
5/8"-11	1 1/16"	55/64"	10	90648A235	7.61
3/4"-10	1 1/4"	1 1/64"	5	90648A240	5.93
Zinc-Plated Grade 2 Steel (Cont.)					
7/8"-9	1 7/16"	1 9/64"	5	90648A245	$6.95
1"-8	1 5/8"	1 5/16"	1	90648A250	4.53
1 1/4"-7	2"	1 41/64"	1	90648A260	6.77
1 1/2"-6	2 3/8"	1 59/64"	1	90648A265	10.62
18-8 Stainless Steel					
1/4"-20	1/2"	3/8"	10	90099A029	6.64
5/16"-18	9/16"	29/64"	5	90099A030	3.94
3/8"-16	11/16"	35/64"	5	90099A031	7.71
18-8 Stainless Steel (Cont.)					
7/16"-14	3/4"	19/32"	1	90099A032	$4.91
1/2"-13	7/8"	45/64"	1	90099A033	2.80
5/8"-11	1 1/16"	55/64"	1	90099A035	4.48
3/4"-10	1 1/4"	1"	1	90099A036	14.69
7/8"-9	1 7/16"	1 9/64"	1	90099A037	18.95
1"-8	1 5/8"	1 5/16"	1	90099A038	28.56

Nylon-Insert Extra-Wide Thin Hex Locknuts

These reusable locknuts have an extra-wide bearing surface and a nylon insert that provides vibration resistance and prevents loosening—without damaging mating threads. They have a Class 2B thread fit and are reliable at temperatures up to 250° F.

Black-phosphate Grade C steel nuts have a minimum Rockwell hardness of C25. Grade C steel is equivalent to high-strength alloy steel (Grade 8).

Thread Size	Wd.	Ht.	Pkg. Qty.		Per Pkg.
Black-Phosphate Grade C Steel					
1 1/4"-12	2"	1 1/8"	1	93126A110	$6.96
1 1/2"-12	2 3/8"	1 11/32"	1	93126A120	9.12
1 3/4"-12	2 3/4"	1 17/32"	1	93126A130	12.80
2"-12	3 1/8"	1 47/64"	1	93126A140	15.44
2 1/4"-12	3 1/2"	2"	1	93126A150	24.62
2 1/2"-12	4"	2 1/4"	1	93126A160	34.23
2 3/4"-12	4"	2 1/4"	1	93126A170	35.38
Zinc-Plated Grade 2 Steel					
1/4"-20	1/2"	9/32"	100	90652A029	$7.95
5/16"-18	9/16"	5/16"	100	90652A030	11.11
3/8"-16	11/16"	13/32"	50	90652A040	11.15
1/2"-13	7/8"	17/32"	25	90652A050	9.28
5/8"-11	1 1/16"	39/64"	10	90652A055	8.40
3/4"-10	1 1/4"	45/64"	10	90652A060	13.38
1"-8	1 5/8"	57/64"	1	90652A065	3.71
1 1/4"-7	2"	1 7/64"	1	90652A070	9.06
18-8 Stainless Steel					
1/4"-20	1/2"	9/32"	25	90098A110	$13.22
5/16"-18	9/16"	5/16"	20	90098A115	12.10
3/8"-16	11/16"	13/32"	10	90098A120	13.52
7/16"-14	3/4"	7/16"	1	90098A125	3.98
1/2"-13	7/8"	17/32"	1	90098A130	4.03
5/8"-11	1 1/16"	39/64"	1	90098A035	8.87
3/4"-10	1 1/4"	45/64"	1	90098A036	11.40

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Nylon, 1" Wide, .095" Thick, 12" Overall Length

Strap Color

- Black
- Blue
- Green
- Orange
- Red
- Yellow

Packs of 5

ADD TO ORDER

$6.85 per pack of 5
3955T347

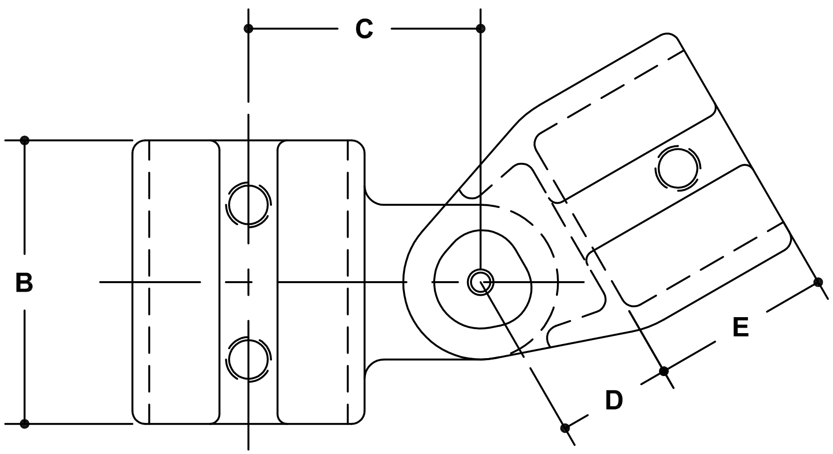
The hook and loop closure provides a quick way to secure your bundle. Use straps again and again without any loss in gripping strength. Straps have a nickel-plated steel ring unless otherwise stated.

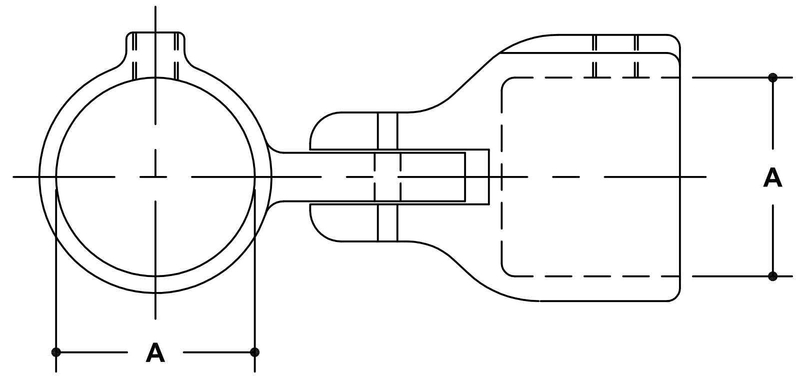
Choose-a-color nylon straps come in black, blue, green, orange, red, and yellow. Ring is plastic. **To Order:** Please specify color.

Warning! Never use for lifting applications.

Overall Length	12"
Additional Specifications	Straps
	1" Wide
	Choose-a-Color Nylon

NOTE: DIMENSIONS LOCATED IN BOXES ARE COMMON
SETBACK DIMENSIONS FOR EACH FITTING





#17 Adjustable Elbow or Tee Assembly

SCALE: HALF

ENGLISH UNITS (Inches)							
PIPE SIZE	A	B	C	D	E	F	G
2"	2.41	3.88	2.63	1.13	2.13		
1½"	1.93	2.75	2.25	1.11	1.73		
1¼"	1.68	2.38	2.06	1.13	1.44		
1"	1.33	2.00	1.63	0.86	1.14		
3/4"	1.07	2.00	1.38	0.97	0.97		

METRIC UNITS (mm)							
PIPE SIZE	A	B	C	D	E	F	G
2"	61	98	67	29	54		
1½"	49	70	57	28	44		
1¼"	43	60	52	29	37		
1"	34	51	41	22	29		
3/4"	27	51	35	25	25		

Slide-On Round Grips


1

2

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11

12

Need to get a grip? Simply slide these grips onto handles. All have one closed end.

Standard—Made of heavy duty PVC for strength and durability. Temperature range is –20° to +180° F. **To Order:** Please specify color from those listed below.

High Temperature—They're made of silicone rubber to withstand temperatures of –50° to +600° F.

Cushioned—Made of closed-cell vinyl foam with a wall thickness of 0.125″ to 0.15″ to insulate and cushion vibration. Temperature range is –40° to +225° F.

Fits OD	O'all Lg.	Available Colors	Pkg. Qty.		Per Pkg.
***(1) Standard—**Smooth Surface*					
5/8″	4 7/8″	Black, Red	6	97065K38	$5.58
3/4″	5 1/16″	Black, Red, White	6	97065K39	9.92
7/8″	5 1/16″	Black, Red, White	6	97065K41	9.50
1″	5 1/16″	Black, Red, White	6	97065K42	9.50
1 1/8″	5 1/4″	Black	6	97065K81	14.73
1 1/4″	5 1/4″	Black	6	97065K82	15.17
***(2) Standard—**Smooth Surface, Tapered*					
7/8″	4 1/2″	Black, Red, White	6	97065K43	12.61
1″	4 1/2″	Black, Red, White	6	97065K44	13.07
***(2) High Temperature—**Smooth Surface, Tapered*					
1″	4 1/2″	Orange	2	5271T11	9.37
***(3) Standard—**Hex Surface*					
7/8″	4 1/2″	Black	6	9729K21	7.55
1 1/4″	4 5/8″	Black	6	9729K76	15.32
***(4) Standard—**Dimpled Surface*					
5/8″	4 9/16″	Black, Red	6	9729K22	9.37
3/4″	4 9/16″	Black, Red	6	9729K23	6.46
***(5) Standard—**Ribbed Surface*					
1 1/4″	4 11/16″	Black	6	97065K83	15.83
***(6) Standard—**Ribbed Surface*					
3/4″	4 13/16″	Black, Red	6	97045K48	10.68
7/8″	4 3/4″	Black, Red	6	97045K49	7.94
1″	4 1/2″	Black, Red	6	97045K51	10.85
1 1/8″	4 11/16″	Black	6	97045K58	13.26
1 1/4″	4 11/16″	Black	6	97045K61	12.44
***(6) High Temperature—**Ribbed Surface*					
1″	4 1/2″	Orange	2	5271T12	5.63
***(7) Standard—**Ribbed Surface, Tapered*					
7/16″	3 1/8″	Black	6	97045K64	13.74
1/2″	3 1/8″	Black	6	97045K65	13.03
5/8″	3 1/8″	Black	6	97045K66	10.90
***(8) Standard—**Ribbed Surface, Contoured*					
7/8″	4 9/16″	Black, Red, White	6	97045K56	12.68
***(9) Standard—**Ribbed Surface with Flange*					
7/8″	4 9/16″	Black, Red, White	6	97045K57	13.95
***(10) Standard—**Ribbed Surface with Finger Grip*					
5/8″	3 3/8″	Black, Red	6	97045K52	10.50
3/4″	4 13/16″	Black, Red	6	97045K53	11.05
7/8″	3 3/4″	Black	6	97045K63	10.77
7/8″	4 5/8″	Black, Red	6	97045K54	11.02
1″	4 9/16″	Black, Red	6	97045K55	11.07
1 1/8″	4 3/4″	Black	6	97045K59	13.74
1 1/4″	4 13/16″	Black	6	97045K62	12.96
***(10) High Temperature—**Ribbed Surface with Finger Grip*					
1″	4 9/16″	Orange	2	5271T13	8.13

Fits OD	O'all Lg.	Available Colors	Pkg. Qty.		Per Pkg.
***(11) Standard—**Smooth Top/Ribbed Bottom Surface, Contoured*					
7/16″	3 13/16″	Black	6	97045K67	$15.75
1/2″	3 13/16″	Black	6	97045K68	14.55
5/8″	3 13/16″	Black	6	97045K69	12.87
***(12) Cushioned—**Smooth Surface*					
3/16″-1/4″	3″	Black	10	9282K11	6.11
1/4″-5/16″	4″	Black	10	9282K12	7.02
5/16″-3/8″	4″	Black	10	9282K13	7.02
5/16″-3/8″	7″	Black	10	9282K111	8.74
3/8″-27/64″	4″	Black	10	9282K14	7.81
3/8″-27/64″	6″	Black	10	9282K112	9.36
27/64″-5/8″	7 3/4″	Black	2	9282K36	7.53
31/64″-9/16″	5″	Black	6	9282K113	15.41
1/2″-5/8″	6″	Black	2	9282K114	5.40
1/2″-5/8″	12″	Black	2	9282K115	6.59
1/2″-5/8″	21″	Black	2	9282K116	7.67
9/16″-11/16″	6″	Black	2	9282K117	5.49
9/16″-11/16″	12″	Black	2	9282K118	6.73
9/16″-11/16″	15″	Black	2	9282K119	7.23
9/16″-11/16″	21″	Black	2	9282K121	7.81
5/8″-45/64″	4 1/2″	Black	6	9282K15	12.19
5/8″-45/64″	12″	Black	2	9282K122	6.71
45/64″-25/32″	4 1/2″	Black	6	9282K16	13.82
45/64″-25/32″	6″	Black	2	9282K123	5.37
45/64″-25/32″	12″	Black	2	9282K124	7.02
45/64″-25/32″	19″	Black	2	9282K125	7.81
27/32″-7/8″	4 3/4″	Black	6	9282K17	13.97
27/32″-7/8″	6″	Black	6	9282K25	13.97
27/32″-7/8″	8″	Black	6	9282K26	14.84
27/32″-7/8″	15″	Black	2	9282K27	6.04
27/32″-7/8″	21″	Black	2	9282K126	8.27
15/16″-13/64″	4 3/4″	Black	6	9282K19	14.64
15/16″-13/64″	12″	Black	2	9282K21	8.27
15/16″-13/64″	21″	Black	2	9282K127	8.54
15/16″-113/64″	6″	Black	6	9282K28	13.70
15/16″-113/64″	8″	Black	6	9282K29	14.83
15/16″-113/64″	15″	Black	2	9282K31	8.26
1 1/8″-13/16″	6″	Black	2	9282K128	7.16
1 1/8″-13/16″	12″	Black	2	9282K22	8.25
1 1/8″-13/16″	21″	Black	2	9282K129	8.69
1 7/32″-1 19/64″	4 3/4″	Black	6	9282K23	13.29
1 7/32″-1 19/64″	6″	Black	6	9282K32	14.32
1 7/32″-1 19/64″	8″	Black	2	9282K33	8.23
1 7/32″-1 19/64″	12″	Black	2	9282K24	9.33
1 7/32″-1 19/64″	15″	Black	2	9282K34	10.45
1 7/32″-1 19/64″	21″	Black	2	9282K131	11.38
1 7/16″-1 19/32″	6″	Black	2	9282K35	8.10
1 7/16″-1 19/32″	12″	Black	2	9282K132	8.86
1 7/16″-1 19/32″	21″	Black	2	9282K133	11.43
1 11/16″-1 7/8″	12″	Black	2	9282K134	9.94

Slide-On Rectangular and Square Grips

Grips fit flat, rectangular, and square handles and have one closed end.

Standard—Made of heavy duty vinyl for strength and durability. Temperature range is –20° to +180° F. Style 15 is a round grip with a rectangular slot. **To Order:** Please specify color from those listed.

Cushioned—The closed-cell vinyl foam has a wall thickness of 0.15″ to insulate and cushion vibration. Temperature range is –40° to +225° F.

Fits Size	O'all Lg.	Available Colors	Pkg. Qty.		Per Pkg.
***(13) Standard—**Smooth Surface with Finger Grip*					
1/8″ × 1″	4 11/16″	Black, Red	6	9692K35	$10.77
3/16″ × 1″	4 11/16″	Black, Red	6	9692K36	9.75
1/4″ × 1″	4 11/16″	Black, Red	6	9692K37	10.19
***(14) Cushioned—**Coarse Surface*					
3/4″ × 1/4″	4 3/4″	Black	6	9282K83	12.88
1″ × 1/8″	5″	Black	6	9282K81	10.08
1″ × 3/16″	5″	Black	6	9282K82	12.88
***(15) Standard—**Ribbed Surface, Tapered*					
3/8″ × 1/2″	3 1/4″	Black	6	9692K38	12.90
***(16) Cushioned—**Coarse Surface*					
1″ × 1″	5″	Black	6	9282K92	13.95

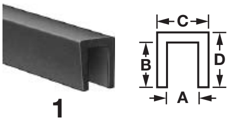

13

14

15

16

Rubber Edge Trim



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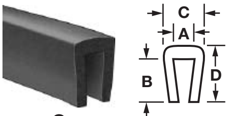

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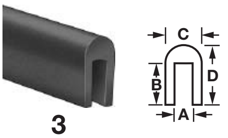

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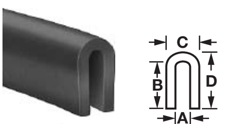

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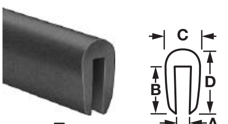

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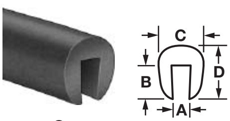

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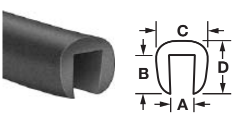

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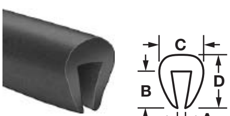

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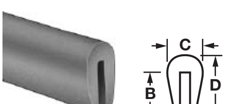


9

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.

Weather-resistant trim is EPDM rubber with excellent weather and ozone resistance. It can be used outdoors; temperature range is –50° to 300° F. Material is marking.

High-temperature trim is silicone rubber that withstands temperatures from –80° to 450° F. It can be used outdoors. Material is nonmarking.

Abrasion-resistant trim is made of SBR rubber. For indoor use only; temperature range is 0° to 225° F. *Styles 1-2* are marking and *Style 9* is nonmarking.

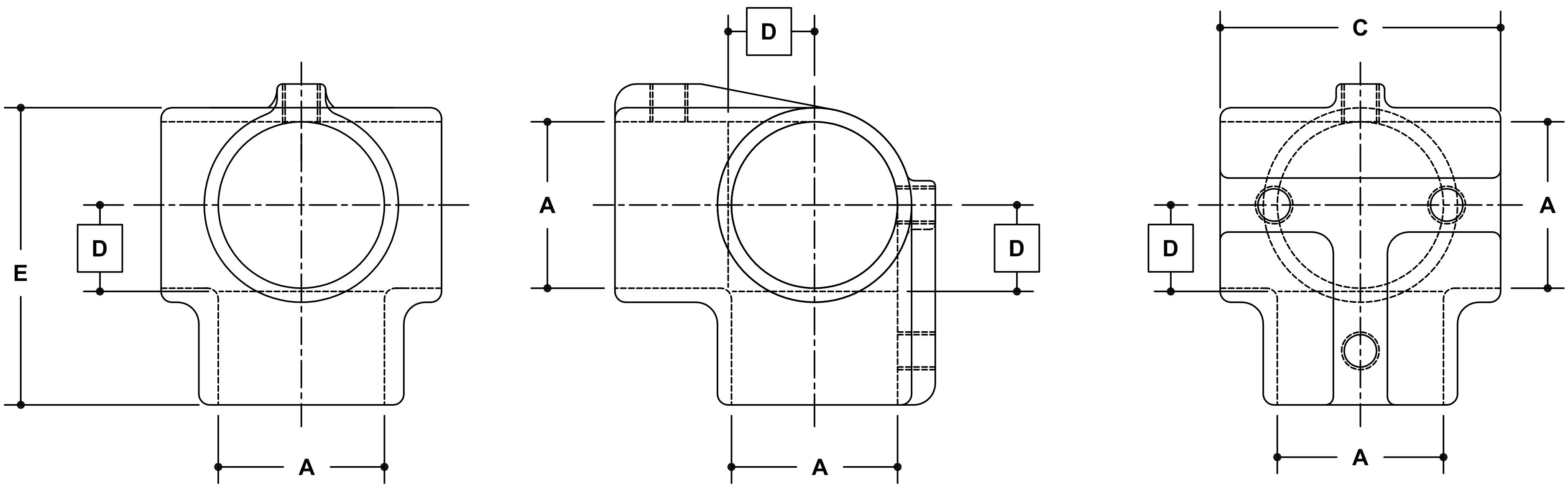
Conductive trim has a surface resistivity of 1.4 ohms and is made of EPDM rubber. It can be used outdoors; temperature range is –20° to 250° F. Material is nonmarking.

Also Available: High-temperature trim made of silicone foam rubber in sizes marked with a ★. Please ask for 4869A9 and specify the corresponding part number and color below.

8-Piece Assortment—Includes a 6″ length of items marked with a ■ **8510K95** $4.17

Style	Inside Wd. (A)	Inside Ht. (B)	Outside Wd. (C)	Outside Ht. (D)	Available Colors	Available Lengths, ft.		Per Ft. 1-99	Per Ft. 100-Up
Standard									
1	1/32″	7/16″	3/16″	1/2″	Black	10, 25, 50, 100	**8507K41**	$1.03	$0.58
1	1/16″	1/8″	3/16″	1/4″	Black	10, 25, 50, 100	**8507K42**	1.11	.65
1	1/16″	5/32″	1/4″	1/4″	Black	10, 25, 50, 100	**8507K81**	1.72	1.14
1	1/8″	1/4″	1/4″	5/16″	Black	10, 25, 50, 100	**8507K43**	.87	.68
1	3/16″	5/16″	5/16″	3/8″	Black	10, 25, 50, 100	**8507K44**	1.22	.74
1	3/8″	3/4″	5/8″	1″	Black	10, 25, 50, 100	**8507K46**	2.58	1.90
1	3/4″	5/8″	1″	3/4″	Black	10, 25, 50, 100	**8507K47**	2.31	1.50
2	1/32″	9/32″	9/32″	3/8″	Black	10, 25, 50, 100	**8507K72**	1.16	.70
2	1/8″	23/32″	9/16″	1″	Black	10, 25, 50, 100	**8507K74**	3.01	2.17
2	1/4″	1/2″	1/2″	5/8″	Black	10, 25, 50, 100	**8507K45**	1.68	1.02
3	1/16″	1/4″	3/16″	5/16″	Black	10, 25, 50, 100	**8507K52**	.88	.65
3	3/16″	3/8″	3/8″	9/16″	Black	10, 25, 50, 100	**8507K54**	1.43	.85
4	1/32″	1/8″	5/32″	3/16″	Black	10, 25, 50, 100	**8507K61**	.72	.50
4	1/16″	5/16″	1/8″	3/8″	Black	10, 25, 50, 100	**8507K63**	.85	.49
4	1/8″	1/4″	1/4″	5/16″	Black	10, 25, 50, 100	**8507K65**	.94	.54
4	1/8″	7/16″	1/4″	1/2″	Black	10, 25, 50, 100	**8507K83**	2.36	1.55
4	3/16″	5/8″	7/16″	3/4″	Black	10, 25, 50, 100	**8507K67**	1.70	1.12
5	1/32″	1/4″	13/64″	3/8″	Black	10, 25, 50, 100	**8507K14**	.98	.51
5	1/16″	3/8″	1/4″	1/2″	Black	10, 25, 50, 100	**8507K15**	1.32	.76
5	1/8″	15/32″	23/64″	5/8″	Black	10, 25, 50, 100	**8507K16**	1.40	1.05
5	3/16″	9/16″	15/32″	3/4″	Black	10, 25, 50, 100	**8507K31**	2.21	1.60
5	1/4″	19/32″	37/64″	13/16″	Black	10, 25, 50, 100	**8507K32**	2.52	1.72
5	5/16″	23/32″	19/32″	15/16″	Black	10, 25, 50, 100	**8507K33**	2.76	1.85
5	3/8″	25/32″	43/64″	1″	Black	10, 25, 50, 100	**8507K34**	3.27	2.12
5	1/2″	31/32″	3/16″	1 1/4″	Black	10, 25, 50, 100	**8507K84**	11.12	7.30
6	1/32″	5/32″	11/64″	1/4″	Black	10, 25, 50, 100	**8507K11**	.88	.49
6	1/16″	7/32″	15/64″	5/16″	Black	10, 25, 50, 100	**8507K12**	1.10	.58
6	1/8″	9/32″	19/64″	3/8″	Black	10, 25, 50, 100	**8507K13**	1.22	.80
6	3/16″	5/16″	7/16″	15/32″	Black	10, 25, 50, 100	**8507K21**	1.41	.96
7	1/16″	5/32″	1/4″	1/4″	Black	10, 25, 50, 100	**8507K36**	1.51	.87
7	1/4″	11/32″	1/2″	1/2″	Black	10, 25, 50, 100	**8507K22**	1.61	.96
7	5/16″	7/16″	19/32″	5/8″	Black	10, 25, 50, 100	**8507K23**	2.48	1.69
7	3/8″	15/32″	11/16″	5/8″	Black	10, 25, 50, 100	**8507K24**	2.06	1.60
Weather Resistant									
1	1/2″	5/8″	11/16″	23/32″	Black	10, 25, 50, 100	**8693K16**	1.66	1.04
8	1/4″	5/8″	3/4″	15/16″	Black	10, 25, 50, 100	**8693K22**	2.25	1.41
8	3/8″	5/8″	3/4″	15/16″	Black	10, 25, 50, 100	**8693K24**	2.30	1.58
8	1/2″	5/8″	3/4″	15/16″	Black	10, 25, 50, 100	**8693K26**	2.73	1.87
High Temperature									
1	3/32″	21/64″	3/16″	3/8″	Black, Orange	10, 25, 50, 100	**4869A76** ★	1.40	.92
2	1/8″	1/4″	1/4″	5/16″	Orange	10, 25, 50, 100	**4869A4** ★	1.96	1.36
3	1/16″	1/4″	3/16″	5/16″	Black, Orange	10, 25, 50, 100	**4869A75** ★	1.44	.95
4	1/16″	5/16″	1/8″	3/8″	Black, Orange	10, 25, 50, 100	**4869A71** ★	1.03	.68
4	1/8″	1/4″	1/4″	5/16″	Black, Orange	10, 25, 50, 100	**4869A72** ★	1.36	.90
5	1/16″	3/8″	1/4″	1/2″	Orange	10, 25, 50, 100	**4869A1**	3.12	1.78
5	1/8″	15/32″	23/64″	5/8″	Orange	10, 25, 50, 100	**4869A2** ★	4.35	2.45
5	3/16″	9/16″	15/32″	3/4″	Black, Orange	10, 25, 50, 100	**4869A61** ★	4.29	2.82
5	1/4″	19/32″	37/64″	13/16″	Black, Orange	10, 25, 50, 100	**4869A79** ★	5.11	3.36
6	1/16″	7/32″	15/64″	5/16″	Black, Orange	10, 25, 50, 100	**4869A66** ★	1.60	1.06
6	1/8″	9/32″	19/64″	3/8″	Black, Orange	10, 25, 50, 100	**4869A67** ★	1.81	1.20
Abrasion Resistant									
1	1/32″	5/32″	7/64″	7/32″	Black	10, 25, 50, 100	**8510K11** ■	.39	.25
1	1/16″	11/32″	7/32″	7/16″	Black	10, 25, 50, 100	**8510K12** ■	.74	.45
1	3/32″	21/64″	3/16″	3/8″	Black	10, 25, 50, 100	**8510K14** ■	.42	.36
1	3/16″	7/16″	5/16″	1/2″	Black	10, 25, 50, 100	**8510K19** ■	.68	.52
1	1/4″	5/16″	3/8″	3/8″	Black	10, 25, 50, 100	**8510K22** ■	.65	.42
1	3/8″	13/32″	1/2″	1/2″	Black	10, 25, 50, 100	**8510K25** ■	.84	.56
1	1/2″	1/2″	5/8″	5/8″	Black	10, 25, 50, 100	**8510K29** ■	1.16	.87
2	1/8″	1/4″	1/4″	5/16″	Black	10, 25, 50, 100	**8510K16** ■	.48	.32
9	3/64″	5/32″	19/64″	9/16″	Gray	2 1/2	**9279K11**	Each	$13.48
9	1/16″	5/16″	5/16″	37/64″	Gray	2 1/2	**9279K12**	Each	$14.97
9	1/16″	7/16″	21/64″	19/32″	Gray	2 1/2	**9279K13**	Each	$16.47
Conductive									
9	1/16″	5/16″	5/16″	37/64″	Black	2 1/2	**9279K22**	Each	$16.62
9	1/16″	7/16″	21/64″	19/32″	Black	2 1/2	**9279K23**	Each	$18.71

NOTE: DIMENSIONS LOCATED IN BOXES ARE COMMON
SETBACK DIMENSIONS FOR EACH FITTING

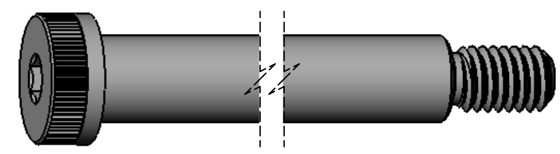


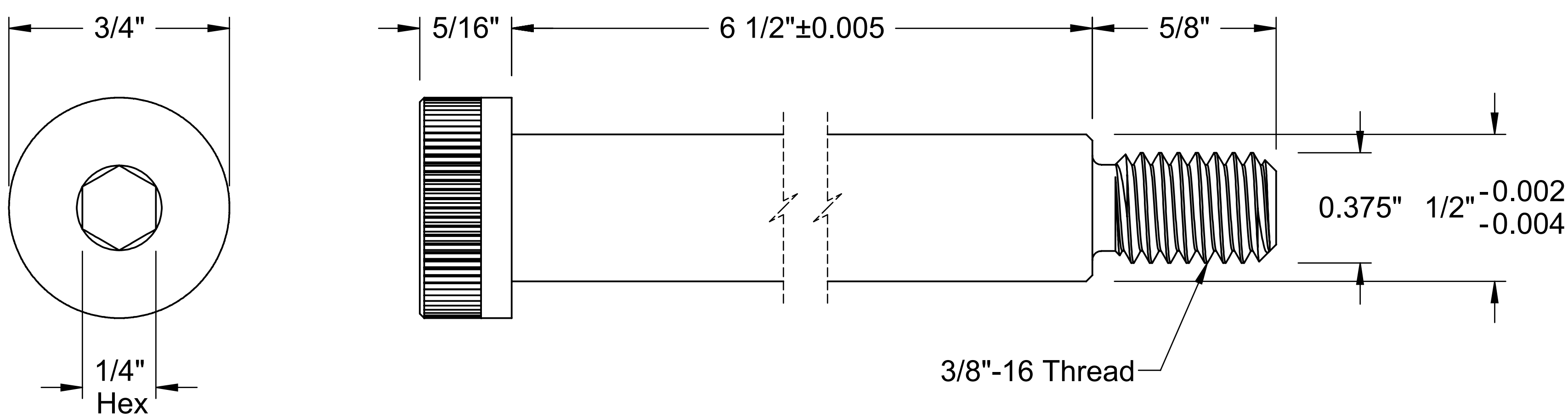
#11 Side Outlet Tee

SCALE: HALF

ENGLISH UNITS (Inches)							
PIPE SIZE	A	B	C	D	E	F	G
2"	2.40		3.88	1.25	4.68		
1½"	1.93		3.25	1.00	3.72		
1¼"	1.68		2.75	0.88	3.22		
1"	1.33		2.38	0.73	2.82		
3/4"	1.07		2.00	0.47	2.34		

METRIC UNITS (mm)							
PIPE SIZE	A	B	C	D	E	F	G
2"	61		99	32	119		
1½"	49		83	25	95		
1¼"	43		70	22	82		
1"	34		60	19	72		
3/4"	27		51	12	60		





McMASTER-CARR® CAD		PART NUMBER	90298A739
http://www.mcmaster.com © 2013 McMaster-Carr Supply Company Information in this drawing is provided for reference only.		Shoulder Screw	

- Dumbbells
- Olympic Plates
- Kettlebells
- Cable Attachments
- Bars
- Bar Collars
- Benches
- Racks
- Exercise Bikes
- Treadmills
- Elliptical Trainers
- Plate Load Machines
- Selectorized Machines
- Smith Machines
- Home Gyms
- Rehab Equipment
- Accessories
- Weight Lifting Belts
- Weight Lifting Gloves
- Body Armor
- Gym Chalk
- Plyometric Boxes
- Mini Step Hurdles
- Mini Trampolines
- Heavy Jump Ropes
- Resistance Bands
- Wearable Weights
- Power Sleds
- Body Bars
- Sand Bags
- Power Chains
- Power Ropes
- Medicine Balls
- Slam Balls
- Fitness Balls
- Exercise Mats

Home > End Caps & Plugs > 1" Diameter Internal Snap-in End Caps - Smooth Gloss

1" Diameter Internal Snap-in End Caps - Smooth Gloss

1" Diameter Internal Snap-in End Caps - Smooth Gloss

Item# CAP-1RA

Regular price: $2.99

Our price: $2.00, 2/$3.60, 10/$16.00, 100/$128.00

Availability: Usually ships the next business day

Add to Cart

Product Description

1" Diameter Internal Snap-in End Caps - Smooth Gloss Exposed Surface.

Fits securely into the open end(s) of 1" outside diameter round tubing with minimum wall thickness of .060" (16 gauge) and a maximum wall thickness of .120 (11 gauge).

Triple ribbed to maximize holding grip once installed.

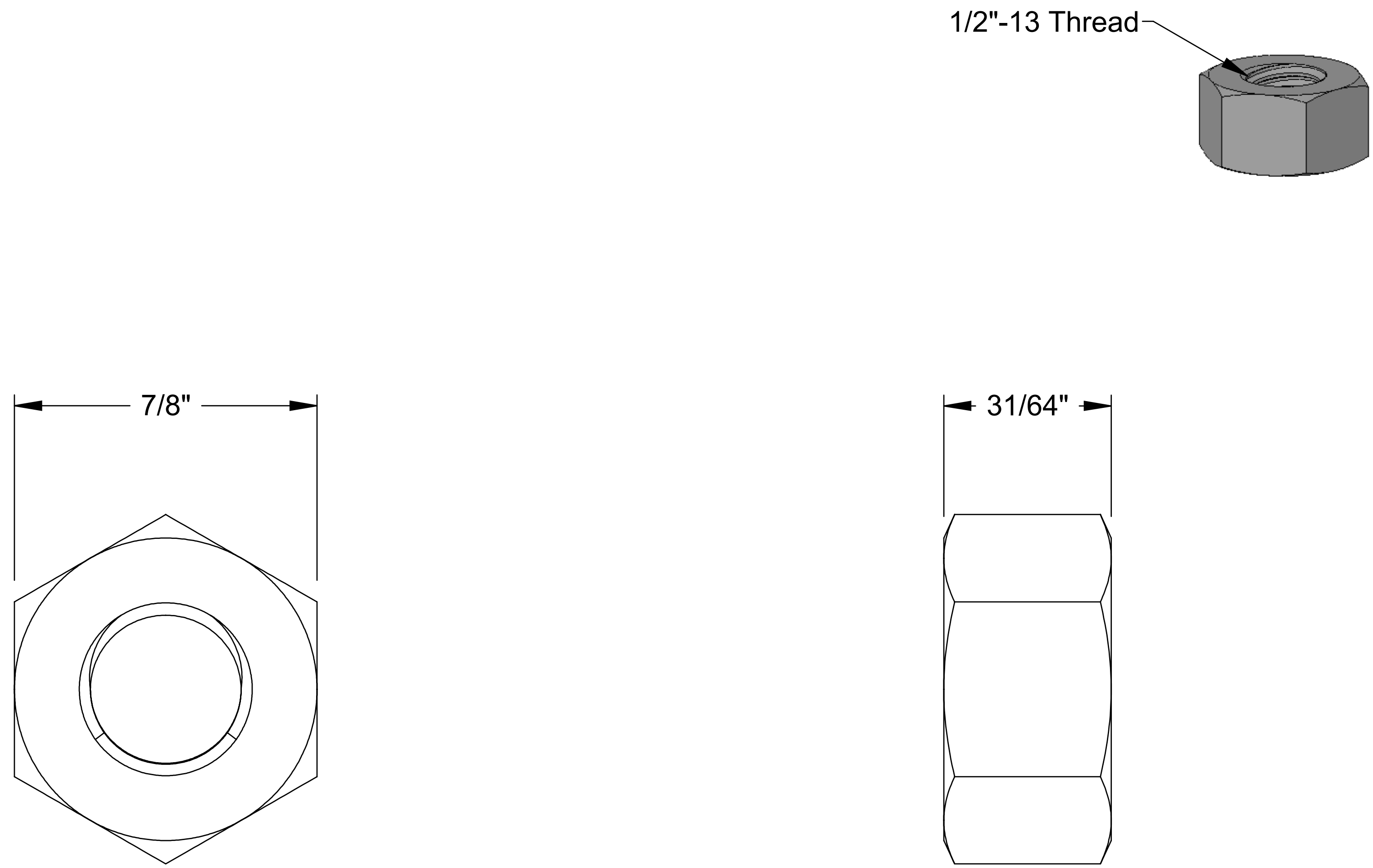
Ribs are deep to grip a wide range of inside diameters from 3/4" I.D. to 7/8" I.D.

Molded from ABS in one piece.

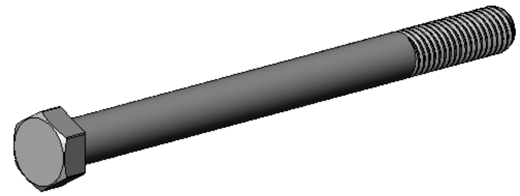
Simple installation, simply drive it in with a hammer.

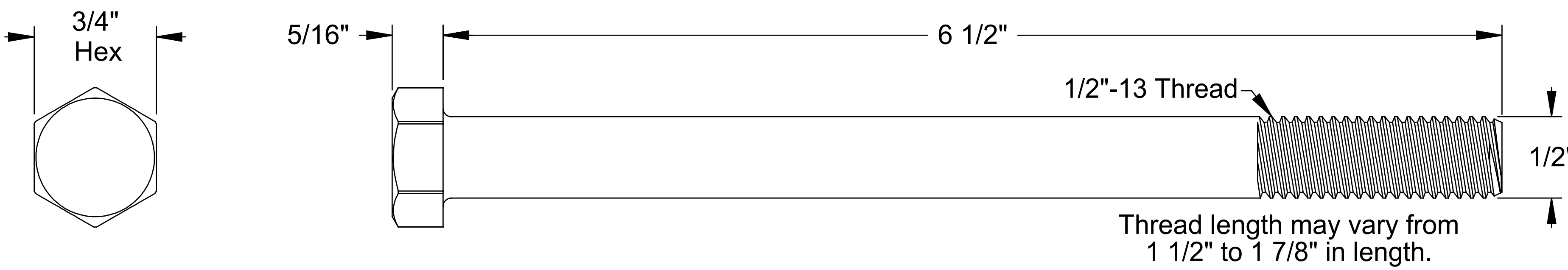
Once installed, plug penetrates 3/8" deep into tube end.

If you desire a plug that won't come out easily, this one is for you!

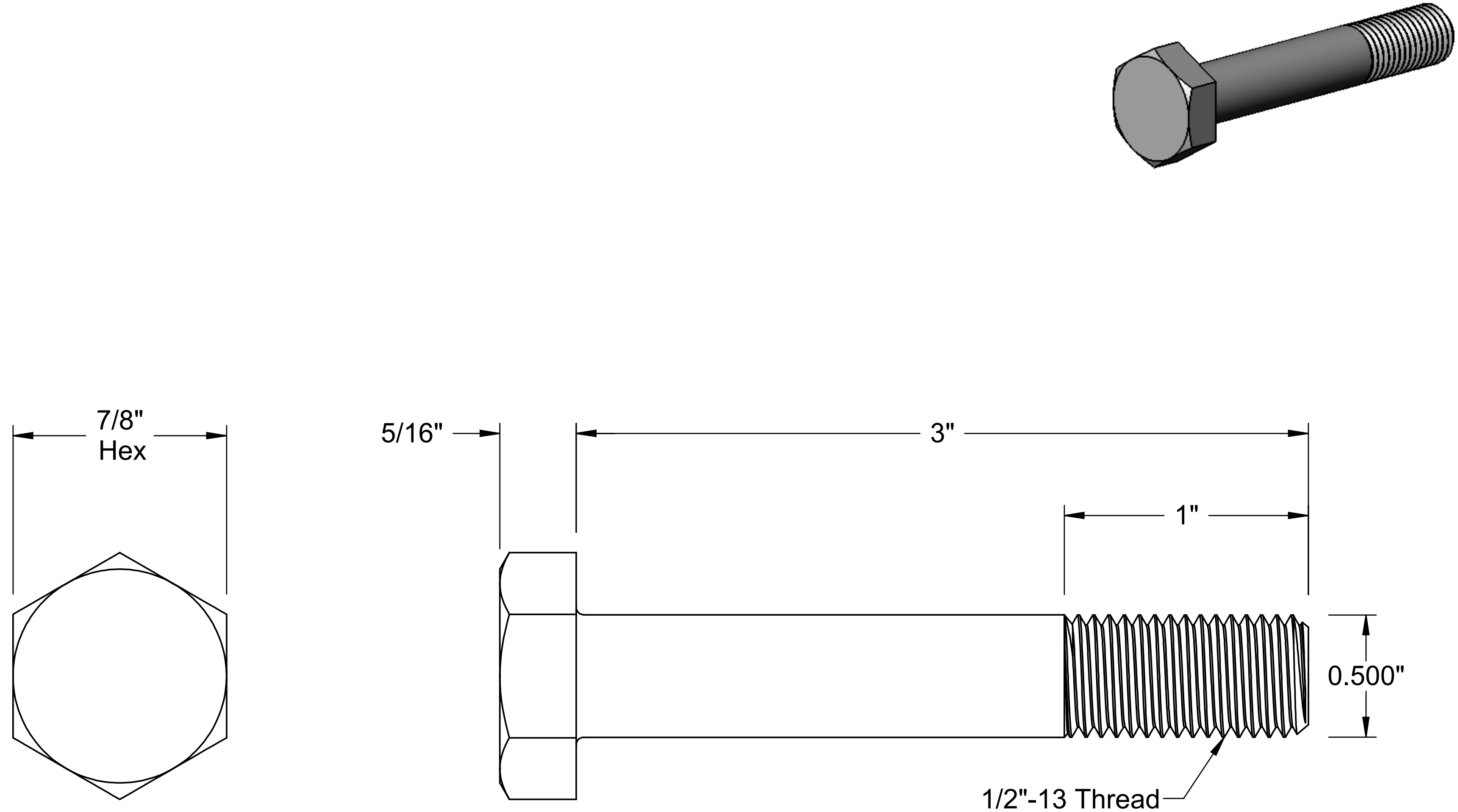


McMASTER-CARR® CAD	PART NUMBER	91694A315
http://www.mcmaster.com © 2009 McMaster-Carr Supply Company Information in this drawing is provided for reference only.	Hot-Dipped Galvanized Grade DH Steel Hex Nut	

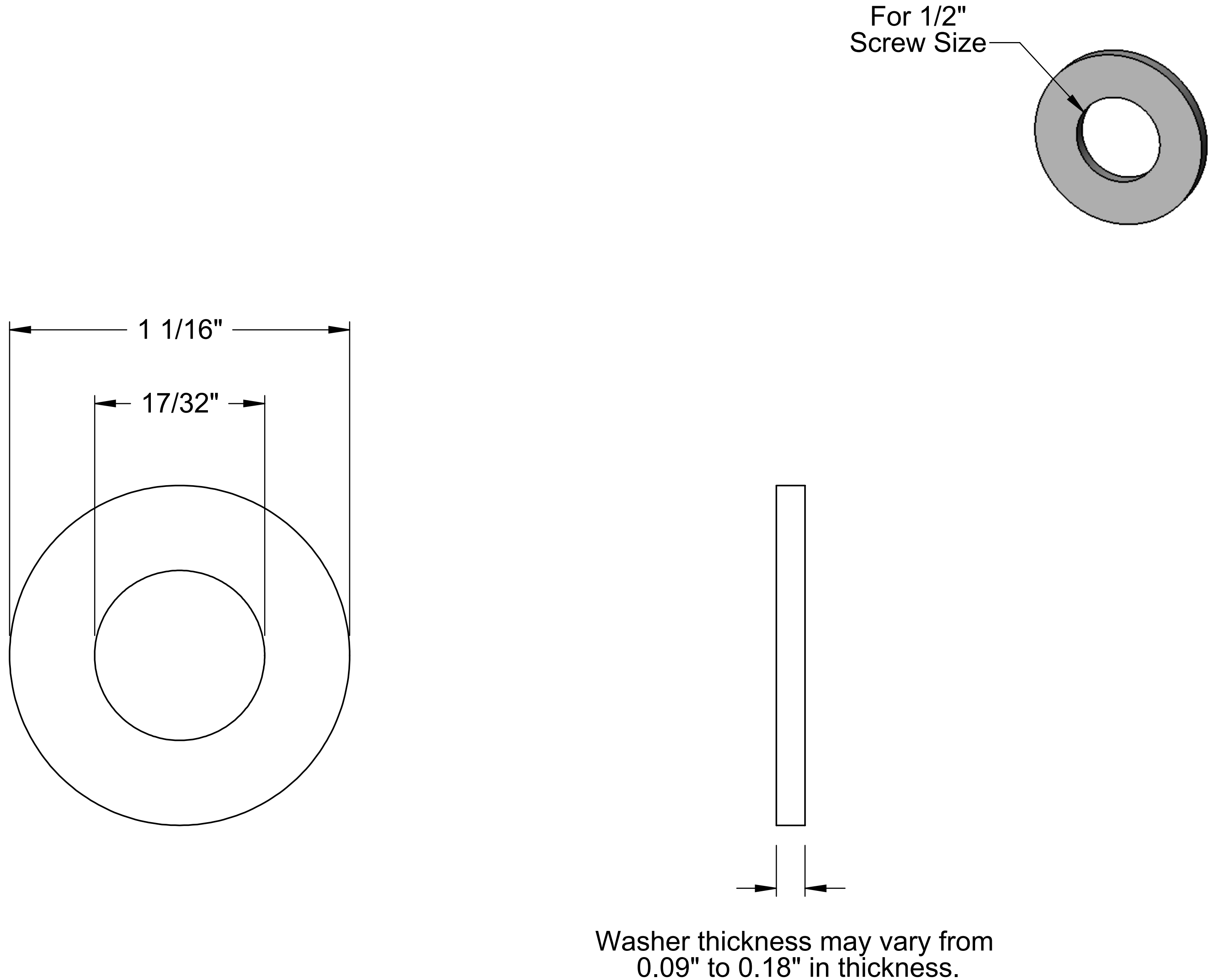




McMASTER-CARR® CAD	PART NUMBER 91247A737
http://www.mcmaster.com © 2013 McMaster-Carr Supply Company Information in this drawing is provided for reference only.	Grade 5 Zinc-Plated Steel Hex Head Cap Screw



McMASTER-CARR®	PART NUMBER	91583A127
http://www.mcmaster.com © 2012 McMaster-Carr Supply Company Information in this drawing is provided for reference only.	Hot-Dipped Galvanized Steel Hex Head Structural Bolt	

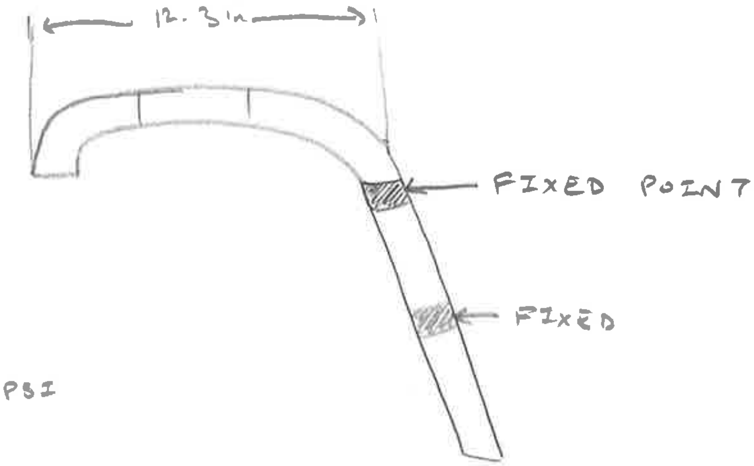


McMASTER-CARR® CAD	PART NUMBER	98119A033
http://www.mcmaster.com © 2009 McMaster-Carr Supply Company	Hot-Dipped Galvanized Steel Structural Washer for ASTM A325 Bolt	
Information in this drawing is provided for reference only.		

Appendix E:

Detailed Supporting Analysis

HANDLE BAR



GIVEN:

MAX LOAD: 100 lbs

OD = 1.00 in

ID = 0.75 in

ALUM 6061-T6 PROPERTIES

$E = 10152642$ PSI $S_y = 40000$ PSI

FIND:

MAX DEFLECTION

MAX BENDING STRESS

FACTOR OF SAFETY

CANTILEVER BEAM ANALYSIS

$$\delta = \frac{FL^3}{3EI_x} \quad ; \quad \sigma_b = \frac{My}{I}$$

$$I_x = \frac{\pi(d_o^4 - d_i^4)}{64} = \frac{\pi(1^4 - .75^4)}{64}$$

$$I_x = .03355 \text{ in}^4$$

$$\delta_{max} = \frac{(100 \text{ lb})(12.3 \text{ in})^3}{3(10152642 \frac{\text{lb}}{\text{in}^2})(.03355 \text{ in}^4)}$$

$$\delta_{max} = \frac{186086.7 \text{ lb in}^3}{1021863 \text{ lb in}^2}$$

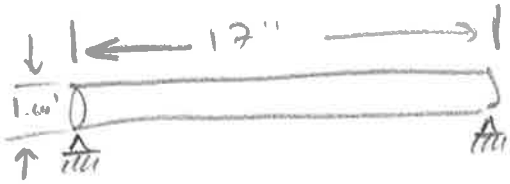
$$\boxed{\delta_{max} = .182 \text{ in}}$$

$$\sigma_{b,max} = \frac{(100 \text{ lb})(12.3 \text{ in})(1/2 \text{ in})}{(.03355 \text{ in}^4)}$$

$$\boxed{\sigma_{b,max} = 18{,}330 \text{ lb/in}}$$

$$F.o.S = \frac{\text{ALLOWED}}{\text{APPLIED}} = \frac{40{,}000}{18{,}330} = \underline{2.18}$$

CENTER LINK



GIVEN

MAX LOAD = 100 lb

OD = 1.00 in

ID = .87 in

ALUM 6061-T6 PROPERTIES

E = 10,150,000 psi S_y = 40,000 psi

FIND:

- MAX DEFLECTION
- MAX BENDING STRESS
- MAX BOWING ANGLE

SIMPLY SUPPORTED BEAM ANALYSIS

$$\delta = \frac{Fl^3}{48EI_x}, \quad \sigma_b = \frac{My}{4I}, \quad \Theta = \frac{Fl^2}{16EI}$$

$$I_x = \frac{\pi(d_o^4 - d_i^4)}{64} = \frac{\pi(1^4 - .87^4)}{64}$$

$$I_x = .0209 \text{ in}^4$$

$$\delta = \frac{(100 \text{ lb})(17 \text{ in})^3}{(48)(10\times10^6 \frac{\text{lb}}{\text{in}^2})(.0209 \text{ in}^4)}$$

$$\boxed{\delta_{max} = .048 \text{ in}}$$

$$\sigma_{max} = \frac{(100 \text{ lb})(8.5 \text{ in})(1/2 \text{ in})}{4(.0209 \text{ in}^4)}$$

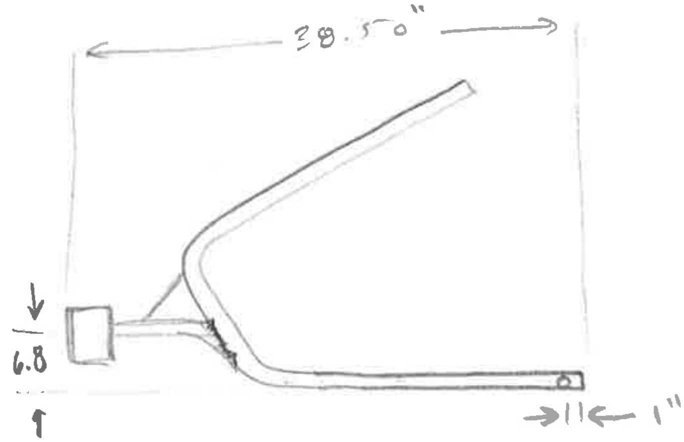
$$\boxed{\sigma_{max,b} = 5083 \text{ psi}}$$

→ $F.O.S = \frac{\text{ALLOWED}}{\text{APPLIED}} = \frac{40,000 \text{ psi}}{5083 \text{ psi}} = 7.87$

$$\Theta = \frac{(100 \text{ lb})(17 \text{ in})^2}{16(10\times10^6 \frac{\text{lb}}{\text{in}^2})(.0209 \text{ in}^4)}$$

$$\boxed{\Theta = .00851^\circ}$$

BASE BAR



GIVEN:

MAX LOAD: 100 lb

OD = 1.00 in

ID = 0.75 in

ALUM 6061-T6

$E = 10150000$ PSI, $S_y = 40000$ PSI

OFFSET: 3.25 in

FIND:

MAX DEFLECTION

MAX BENDING STRESS

MAX SHEAR STRESS

ANGLE OF TWIST

$$I_x = \frac{\pi(d_o^4 - d_i^4)}{64} = .03355 \text{ in}^4$$

ASSUME: BOTTOM HALF OF BAR CAN BE ACCURATELY MODELED AS A SIMPLY SUPPORTED BEAM.

$$\delta = \frac{FL^3}{48EI}, \quad \sigma_b = \frac{My}{4I}, \quad \theta = \frac{FL^2}{16EI}$$

ASSUME: FOR TORSION OF BASE BAR ASSUME THE BASE ACTS AS A CANTILEVER TYPE BEAM TO SIMULATE WORST CASE

$$\tau = \frac{K_{ts} Tr}{J_{net}}, \quad \theta = \frac{TL}{G J_{net}}$$

$$\delta_{max} = \frac{FL^3}{48EI_x} = \frac{(100 \text{ lb})(38.50 \text{ in})^3}{48(10{,}150{,}000 \text{ lb/in}^2)(.03355 \text{ in}^4)} = \boxed{.349 \text{ in} = \delta_{max}}$$

$$\sigma_{b,max} = \frac{(100 \text{ lb})(38.5 \text{ in}/2)(1/2 \text{ in})}{4(.03355 \text{ in}^4)} = \boxed{7172 \text{ psi} = \sigma_{b,max}}$$

$$S.F. = \frac{40{,}000 \text{ psi}}{7172 \text{ psi}} = 5.57$$

$$\theta_{max} = \frac{(100 \text{ lb})(38.5 \text{ in})^2}{16(10{,}150{,}000 \text{ lb/in}^2)(.03355 \text{ in}^4)} = \boxed{.027^\circ = \theta_{max}}$$

BASE BAR (CONT)

$$\tau = \frac{K_{ts} T r}{J_{net}}$$

$K_{ts} = 2.8$
$A = .6$

K_{ts} & A VALUES OBTAINED FROM TABLE A-16 IN SHIGLEYS. THROUGH HOLE IN A CIRCULAR TUBE

$$\tau_{max} = \frac{(2.8)(100\ lb)(3.25\ in)(1\ in/2)}{(.6)\ \frac{\pi\ ((1\ in)^4 - (.75\ in)^4)}{32}}$$

$$\boxed{\tau_{max} = 11{,}305\ psi}$$

$$F.O.S = \frac{23000}{11305} = \underline{\underline{2.03}}$$

$$\theta = \frac{TL}{G J_{net}} = \frac{(100\ lb)(3.25\ in)(37.50)}{(3900000\ psi)(.6)\left(\frac{\pi\ (1.00\ in^4 - .75\ in^4)}{32}\right)}$$

$$\boxed{\theta = .077°}$$

CASTER HOUSING

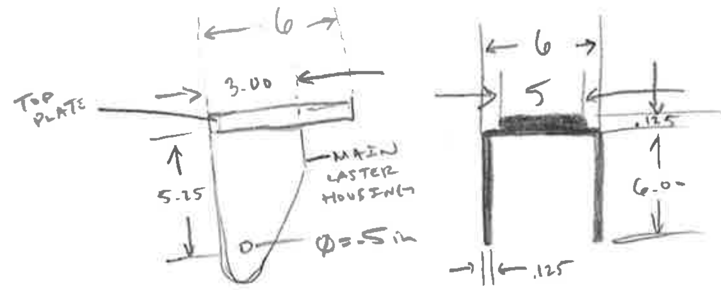
GIVEN:

MAX LOAD = 50 lb

W = .125 in

ALUM 6061-T6 PROPERTIES

$E = 10{,}150{,}000$ PSI $S_y = 40{,}000$ PSI



FIND:

MAX DEFLECTION

MAX BENDING STRESS

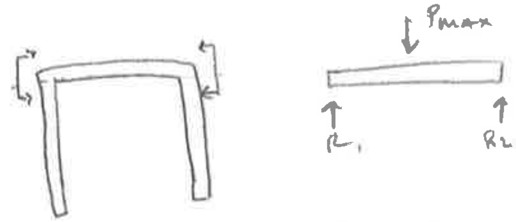
MAX BOWING ANGLE

MAX NORMAL STRESS IN PIN HOLE

MAX TOP PLATE DEFLECTION

MAX TOP PLATE BENDING STRESS

ASSUME MAIN CASTER HOUSING ACTS AS A SIMPLY SUPPORTED BEAM.



$$I_x = \frac{bh^3}{12} = \frac{(3)(.125)^3}{12} = .000488 \text{ in}^4$$

$$\delta_{max} = \frac{FL^3}{48EI_x} = \frac{(50 \text{ lb})(6 \text{ in})^3}{48(10{,}150{,}000 \frac{lb}{in^2})(.000488 \text{ in}^4)}$$

$$\boxed{\delta_{max} = .045 \text{ in}}$$

$$\sigma_{max,b} = \frac{My}{4I} = \frac{(50 \text{ lb})(6 \text{ in}/2)(.125 \text{ in}/2)}{4(.000488 \text{ in}^4)} = \boxed{4802 \text{ psi} = \sigma_{max,b}}$$

$$F.O.S = \frac{40{,}000}{4802} = 8.33$$

$$\theta = \frac{FL^2}{16EI} = \frac{(50 \text{ lb})(6 \text{ in})^2}{16(10{,}150{,}000 \frac{lb}{in^2})(.000488 \text{ in}^4)} = \boxed{\theta = .0227°}$$

$$\sigma_N = \frac{P}{A} = \frac{50 \text{ lb}}{2\pi(.5 \text{ in}/2)(.125)(.5)} = \boxed{\sigma_N = 509 \text{ psi}}$$

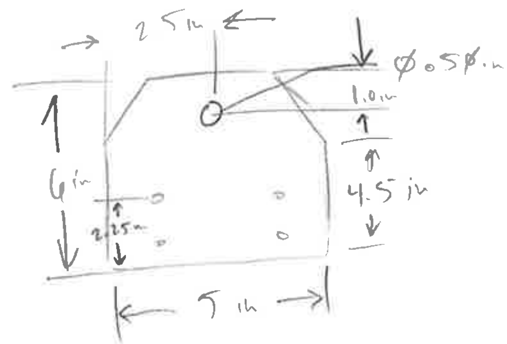
$$F.O.S = \frac{40{,}000}{509} = 78.5$$

CASTER HOUSING (CON'T)

$$I_x = \frac{bh^3}{12} = \frac{(5\,in)(.125)^3}{12} =$$

$$I_x = .000813\ in^4$$

ASSUME:
TOP PLATE CAN BE MODELED AS A CANTILEVER BEAM.



$$\delta_{max} = \frac{FL^3}{3EI}$$

$$\delta_{max} = \frac{(50\ lb)(6-1-2.25)^3}{3(10{,}150{,}000\ lb/in^2)(.000813\ in^4)} =$$

$$\boxed{\delta_{max} = .042\ in}$$

$$\sigma_{b,max} = \frac{My}{I}$$

$$\sigma_{b,max} = \frac{(50\ lb)(6-1-2.25\ in)(.125\ in/2)}{.000813\ in^4}$$

$$\sigma_{b,max} = 10{,}570\ psi$$

$$F.S. = \frac{40{,}000}{10{,}570} = 3.78$$

FRONT-ARM

LOAD @ A = 50 lb

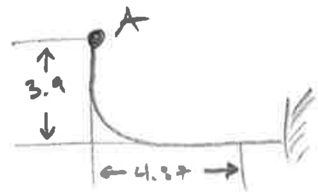
OD = 1.00 in

ID = .75 in

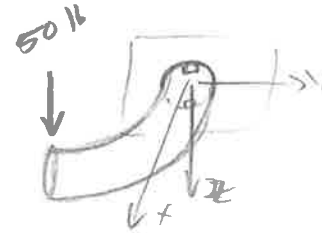
ALUM 6061-T6 PROP

$E = 10{,}150{,}000$ PSI $S_y = 40{,}000$ PSI

TOP VIEW



FRONT VIEW



FIND:

- MAX BENDING STRESS
- MAX SHEAR STRESS DUE TO TORSION
- MAX VON MISES STRESS
- MAX DEFLECTION DUE TO BENDING

ASSUME:

FRONT ARM CAN BE APPROX BY A CANTILEVER BEAM.

$$I_x = \frac{\pi(d_o^4 - d_i^4)}{64} = .03355 \text{ in}^4$$

$$\sigma_{b,max} = \frac{My}{I} = \frac{(50 \text{ lb})(4.87 \text{ in})(1 \text{ in}/2)}{.03355 \text{ in}^4} = 3629 \text{ psi} = \sigma_{b,max}$$

$$F.O.S = \frac{40000}{3629} = 11.02$$

$$\tau_{max} = \frac{16 T D_o}{\pi(d_o^4 - d_i^4)} = \frac{16(50 \text{ lb})(3.9 \text{ in})(1 \text{ in})}{\pi(1^4 - .75^4)} = 1453 \text{ psi} = \tau_{max}$$

$$F.O.S = \frac{23000}{1453} = 15.83$$

$$\sigma_{V.M.,max} = \sqrt{0.5\left[(\sigma_x - \sigma_y)^2 + (\sigma_y - \sigma_z)^2 + (\sigma_z - \sigma_x)^2\right] + 3(\tau_{xy}^2 + \tau_{yz}^2 + \tau_{zx}^2)}$$

$$= \sqrt{0.5\left[\sigma_x^2 + \sigma_x^2\right] + 3\tau_{xy}^2}$$

$$= \sqrt{\sigma_x^2 + 3\tau_{xy}^2} = \sqrt{(3629)^2 + 3(1453)^2}$$

$$\sigma_{V.M.,max} = 4416 \text{ psi}$$

$$\delta_{max} = \frac{FL^3}{3EI} = \frac{(50 \text{ lb})(4.87 \text{ in})^3}{3(10{,}150{,}000 \frac{\text{lb}}{\text{in}^2})(.03355 \text{ in}^4)} = .0056 \text{ in} = \delta_{max}$$

Appendix F:

DVP&R

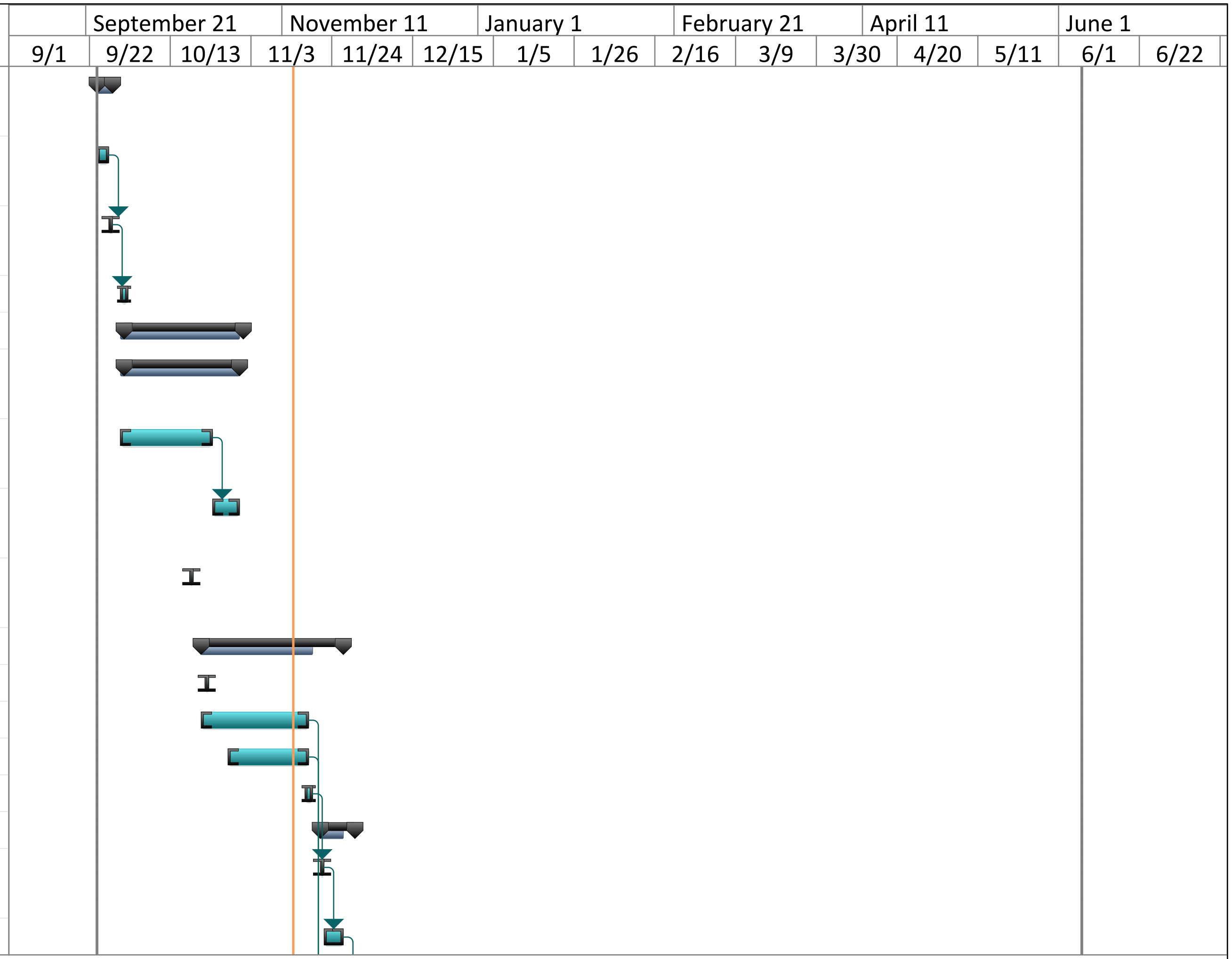
TEAM SEAN-DVP&R

Report Date		6/9/2014	Sponsor	RAPD & NSF					Component/Assembly	Entire Design		REPORTING ENGINEER:	Christian Nunez
TEST PLAN										**TEST REPORT**			
Item No	Specification	Test Description	Acceptance Criteria	Test Responsibility	Test Stage	SAMPLES TESTED		TIMING		TEST RESULTS			NOTES
						Quantity	Type	Start date	Finish date	Test Result	Quantity Pass	Quantity Fail	
1	ADA Compliant	Operate walker through ramps and door ways	32 in	ALL	Complete	4	length (in)	5/24/2014	6/7/2014	PASS	ALL	N/A	N/A
2	Static and Kinetic Load	Operate in sand with minimal horizontal force	4-8 lbf	ALL	Complete	10	force (lbs)	6/7/2014	6/7/2014	PASS	ALL	N/A	The wetter the sand, the smaller required force to overcome friction
3	Water Stability	Floats in water	Wheels 50% submerged	ALL	Complete	3	time (min)	6/7/2014	6/7/2014	PASS	ALL	N/A	When waves crash onto caster housing, it pulls front end of walker down
4	Handlebar Adjustment	Handle bars can be adjusted to desired heigth using Allen key to loosen and tighten bolt	Adjusts up to 6 in	ALL	Complete	1	length (in)	5/24/2014	6/7/2014	PASS	ALL	N/A	N/A
5	Fits in Cargo	Fit walker inside cargo of Gabby's Saturn Vue	Fits without putting seats down or interference from rear door	ALL	Complete	1	Pass/Fail	6/7/2014	6/7/2014	PASS	ALL	N/A	N/A
6	Overall Weight	Weigh using bathroom scale and fish scale	20 ± 3 lbs	ALL	Complete	4		5/24/2014	6/7/2014	PASS	ALL	N/A	N/A

Appendix G:

Gantt Chart

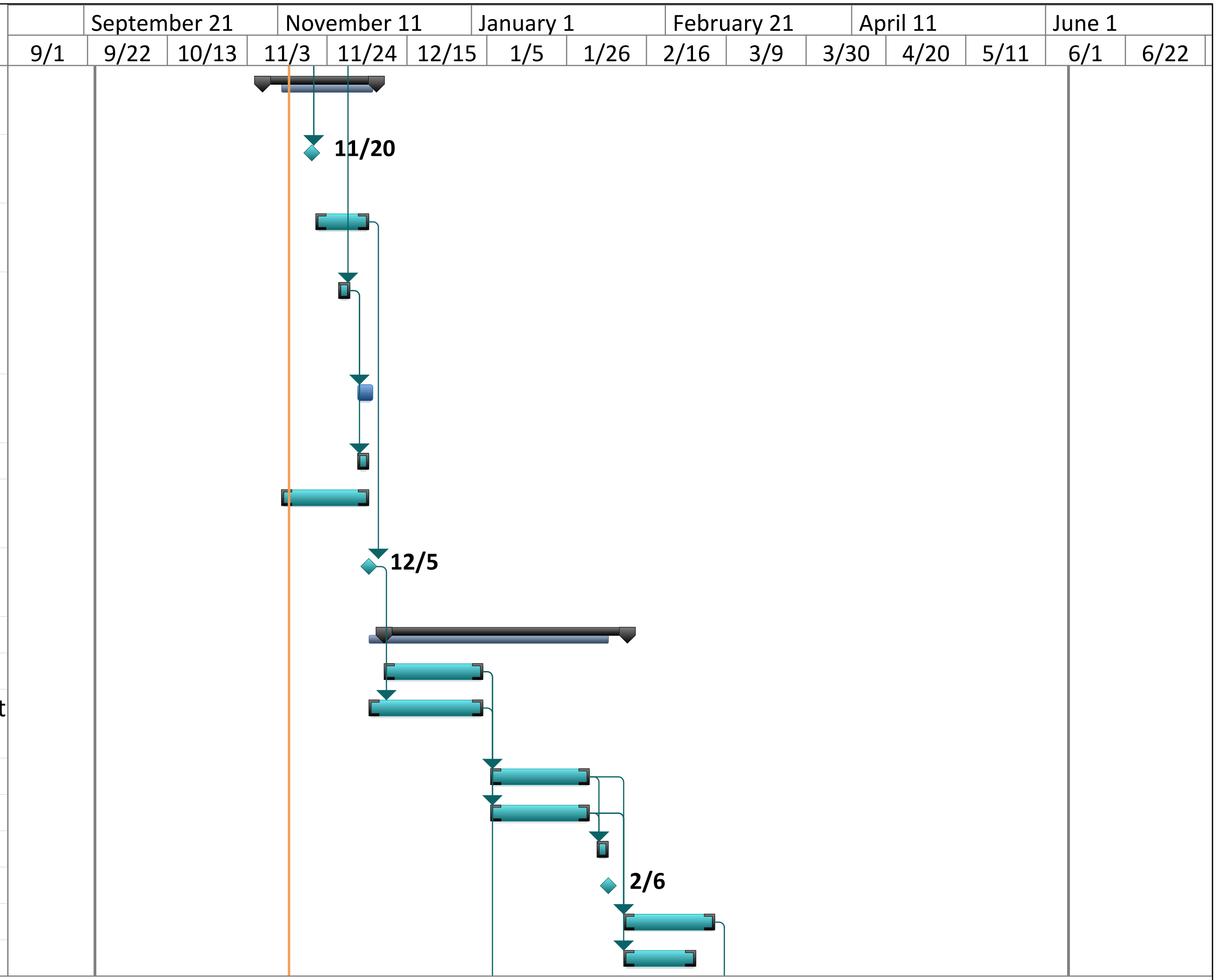
ID	Task Mode	WBS	Task Name
1		**1**	**Fill Out Project Preference Form**
2		1.1	Watch Project Presentations
3		1.2	Fill Out Project Preference Form
4		2	Create Team Contract
5		**3**	**Define Project**
6		**3.1**	**Complete Project Proposal Document**
7		3.1.1	Start Background Research
8		3.1.2	QFD/ Compliance Assesment
9		3.2	Meet with Sponsor (Gabby)
10		**4**	**Conceptualize Solutions**
11		4.1	Morphological Matrix
12		4.2	Concept Sketches
13		4.3	Conceptual Modeling
14		4.4	Pugh Matrix
15		**5**	**Pick a Solution**
16		5.1	Team Meeting to Discuss Solutions
17		5.2	Create Decision Matrix



Project: Gantt Chart_Team Sean
Date: Thu 11/14/13

Task		External Milestone		Manual Summary Rollup	
Split		Inactive Task		Manual Summary	
Milestone		Inactive Milestone		Start-only	
Summary		Inactive Summary		Finish-only	
Project Summary		Manual Task		Deadline	
External Tasks		Duration-only		Progress	

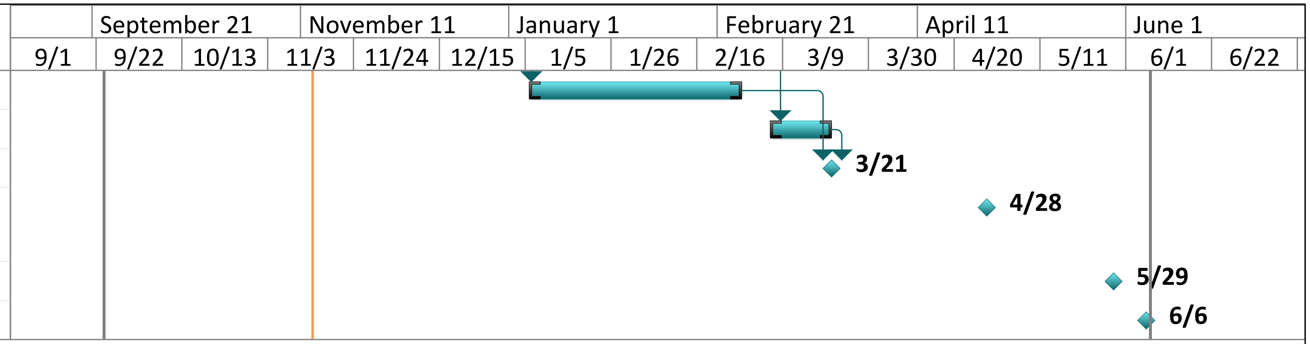
ID	Task Mode	WBS	Task Name
18		**6**	**Prepare Conceptual Design Report**
19		6.1	Conceptual Model Presentation
20		6.2	Improve Project Proposal Document
21		6.3	Complete Layout Drawings of Top Concepts
22		6.4	Concept Selection Description/Analysis
23		6.5	Solid Model Layout
24		6.6	Create/Update Gantt Chart
25		7	Conceptual Design Review with Sponsor
26		**8**	**Detail Design**
27		8.1	Create Detail Drawings
28		6.6	Create Design Development Plan
29		8.3	Complete Analysis
30		8.4	Material Selection
31		8.5	Cost Assesment
32		8.6	Critical Design Review
33		9	Create Test Plan (DVP&R)
34		10	Order Supplies



Project: Gantt Chart_Team Sean
Date: Thu 11/14/13

Task	External Milestone	Manual Summary Rollup
Split	Inactive Task	Manual Summary
Milestone	Inactive Milestone	Start-only
Summary	Inactive Summary	Finish-only
Project Summary	Manual Task	Deadline
External Tasks	Duration-only	Progress

ID	Task Mode	WBS	Task Name
35		11	Manufacturing/ Assembly
36		12	Test
37		13	Manufacturing & Test Review
38		14	Project Hardware & Assembly Demo
39		15	Senior Design Expo
40		16	Final Report Due



Project: Gantt Chart_Team Sean
Date: Thu 11/14/13

Task	External Milestone	Manual Summary Rollup
Split	Inactive Task	Manual Summary
Milestone	Inactive Milestone	Start-only
Summary	Inactive Summary	Finish-only
Project Summary	Manual Task	Deadline
External Tasks	Duration-only	Progress

Appendix H:

Team Contract

Contract for Team Sean

Mission:

The mission of the _Team Sean_ is to provide a device for our customer, Sean, to be able to traverse the beach and maintain comfortable stability at a desired water level, with consideration to the Least Restrictive Environment.

Section 1—Name

A. This organization shall be known as ______Team Sean_______ .

Section 2—Membership

A. Members of the team include: Jonathan Larsen, Christian Nunez, Nicholas Simon, Jessica Smith
B. No member shall purport to represent the team unless so authorized by the team.
C. Each member shall be provided a copy of the team contract.
D. Officers of the team shall include those listed below with their designated responsibilities. (spell out specific responsibilities of each officer position, some suggestions below).

1. Communications Officer - Jessica Smith
    a. Be main point of communication with sponsor and customer
    b. Facilitate meetings with sponsor and customer
2. Team Treasurer - Christian Nunez
    a. Maintain team's travel budget
    b. Maintain team's materials budget
    c. Relay purchase order information to ME dept office
3. Secretary/Recorder - Jonathan Larsen
    a. Maintain information repository for team (e.g. team binder, google docs site, etc..)
    b. Master note taker
4. Coordinator/Facilitator - Nicholas Simon
    a. Arrange team meetings and travel details
    b. Task and schedule manager

Section 3—Decision Making

A. The majority of decisions will be done by a group discussion
B. Major design changes will need to be presented in a panel-style discussion
C. Decisions will be made in group meetings with entire group in attendance
D. Communication outside of class will be done on KaKao-messaging service.
E. No single person can make a decision on behalf of the team

Section 4—Team Interactions

A. All affairs of the team shall be governed by Robert's Rules of Order, unless otherwise specified.
B. Meetings shall be held during lab Tuesday/Thursday 12-3 pm.
C. Unless otherwise noticed, all meetings will be held at Building 192-132 at Cal Poly.

D. Special meetings of the team may be called by any group member and proposed on Kakao at a minimum of 24 hours notice.
E. Attendance is mandatory unless an approved excuse work, special events, emergencies, or other urgent school work .
F. Meeting discussions will be conducted in a conversational format with special regard for a dialogue that is respectful and considerate of all members in attendance.
G. A meeting agenda, distributed at least one day in advance, will guide meeting topics and timing.
H. The length of meetings shall be stated in advance.
I. All team members are expected to be punctual.
J. Violation of team meetings will be publicized to members using: phone calls, Kakao, e-mail, and texting.
J. Notices of non-attendance shall be distributed not less than 48 hours before the meeting date.
K. Violation of team rules will result in providing food for the next meeting and possible discussion with advisor if violation is considered severe.

Section 5—Conflict Resolution

A. The team decides when it is necessary to form a special work group.
B. Work groups shall report to the team and these reports shall be entered into the minutes.
C. Committees can be standing or ad-hoc in nature.
D. Communication of the problem must occur immediately and taken seriously to move forward and prevent any future issues.
E. Meeting with Advisor is the last resort in conflict resolution.

Section 6—Amendments

A. Amendments can be proposed at any time by any team member
B. At the following group meeting the group member who proposed the amendment will come prepared with reasons for the change
C. The remaining team members will discuss the amendment and implement if considered beneficial

Section 7—Effective Date

A. This contract for __Team Sean__ shall become effective on October 10, 2013.
B. Dates of amendment must be recorded in minutes of meetings at which amendments were approved, together with a revised set of bylaws.

Signatures

Jonathan Larsen Nicholas Simon Christian Nunez Jessica Smith