Adaptive Kayak Seating: The Tide Rider 360

June 12, 2014

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2013-2014

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Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant No. 0756210, "Access by Design: Capstone Projects to Promote Adapted Physical Activity." Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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List of Nomenclature

AEL – Adaptive Engineering Lab

APP – Adaptive Paddling Program

HDPE – High Density Polyethylene

PFD – Personal Floatation Device

NSF – National Science Foundation

RAPD – Research to Aid People with Disabilities

RK – Rose Krieger (Joint Manufacturer)

Terms used in analysis:

θ – Seat back angle measured from the horizontal

α – Angle of member AB with respect to the seat back

β – Angle of member AB with respect to the horizontal

F_{AB} – Compression in member AB

$\sigma_{s\text{-}b}$ – Bending stress on seat back

d_{AB} – Compression in member AB

$\delta_{s\text{-}b}$ – Deflection in seat back

W – Applied weight of user on frame

W_{tot} – Total weight of person

Executive Summary

The Adaptive Paddling Program at California Polytechnic State University has sponsored the construction of an adaptive kayak seat, the Tide Rider 360, to provide paddlers with disabilities sufficient trunk support while out on the water. In particular, this design focused on providing the least restrictive environment for all users while still providing sufficient lateral, neck, back, and hip support. This seat is intended for use in the quarterly Adaptive Paddling Program to allow people with disabilities to experience the joys of kayaking in the most comfortable and supportive environment possible.

The following report details the background research, design development, manufacturing, and testing processes that went into designing this seat. It provides in-depth breakdowns on aspects such as the concept generation and material selection methods in order to prove that this kayak seat meets the requirements of the Adaptive Paddling Program. In particular, this seat was designed for use in marine environments with maximum levels of adjustability, support, and comfort. It was designed to fit to all different types of people in terms of weight, disability, and paddling ability.

This kayak seat was manufactured out of aluminum tubing and joints, high density polyethylene sheets, and polyethylene foam. In addition to these materials, we added pre-manufactured wheelchair support components for the lateral supports, headrest, hip supports, and seat base. The total cost for the manufacturing of this prototype came out to be approximately $2100 and the final weight was just around 30 pounds.

We conducted multiple levels of testing on the kayak seat, including a load test and in-pool assessment. Our load testing proved that the aluminum seat frame experiences minimal deflection and bending when subjected to a constant weight for an extended period of time. The in-pool testing verified that the seat is able to support a paddler while still allowing them a wide range of motion, if so desired. The prototype as is does have a few shortcomings, such as some hard to reach adjustment bolts, but the Adaptive Paddling Program still feels confident in the ability of this seat and the fulfillment of the preset requirements. We believe that with a few slight modifications to the seat back angle and some additional reach of the supports, this product would be able to change the lives of the participants in the Adaptive Paddling Program.

Chapter 1: Introduction

The Adaptive Kayak Seating project was a joint effort among senior project students at California Polytechnic State University, San Luis Obispo (Cal Poly) to develop a supportive, adjustable, and easy to use kayak seating system, the Tide Rider 360. It provides provide trunk support and comfort for paddlers with various disabilities. The project was funded through a grant from that National Science Foundation (NSF) and the NSF's Research to Aid People with Disabilities (RAPD) program. The design team consisted of mechanical engineering students Irvin Camacho, Grant Petersen, and Audrey Riddle along with kinesiology student Andrea Voigt.

This project consisted of a nine month long design process. Through this design process, our team combined knowledge gained through background research and analyzing existing solutions in order to design, manufacture, and test a system that met the appropriate customer requirements and corresponding engineering requirements. Together, we collaborated to help the Cal Poly Adaptive Paddling Program (APP) by providing the program organizers and participants with a fully functional adaptive kayak seat. Our goal was to develop an effective design to establish lateral, back, and neck support while allowing the paddler to safely experience his or her own least restrictive environment in a kayak. We strove to ensure that this new kayak seat could act as a means to fit the boat to each individual so that everyone could comfortably experience the pleasure of kayaking.

Explanation of Name: Tide Rider 360

The name of "Tide Rider 360" was selected to serve as a motivator and help drive the project to a successful final product. The name was founded in the peaceful ebb and flow of the tide as it rises and falls in a predictable pattern. Morro Bay, California, where the APP takes place, is known for its tidal currents that make the bay an ever changing and dynamic place to paddle. The consistency of the tides represents the security and consistency of performance of the Tide Rider 360. The term 'rider' gives a sense of activity and movement to the seat while still focusing on the function of support and being seated. The sense of activity given by the Tide Rider 360 is rooted in the drive to make the activity of kayaking available to everyone, including people with disabilities. The "360" term is used to show the all-around support of the seat. Although the support will not go a full 360 degrees around the user, the number gives a sense of all around quality and a sense of security.

Adaptive Paddling Program Background

The Cal Poly Adaptive Paddling Program is a 13 year-old paddling clinic that is run through the Cal Poly Kinesiology Department. It is organized and run by Tom Reilly, John Lee, and Dr. Kevin Taylor with the goal of providing the best possible paddling experience to participants with a wide range of disabilities. The paddling clinics are held once per quarter, and each clinic consists of two weekend-long sessions. The first weekend is a training session designated to teach Cal Poly kinesiology students who will be working with the participants about all of the safety procedures that go into making the program a success. The second weekend is spent with participants. The first day of the participant weekend is spent at the pool where the kinesiology students meet with the participants and apply their knowledge to help the paddlers get comfortable in a safe, controlled environment. This initial exposure is a prelude to the event that takes place the following day out at Morro Bay. The Morro Bay kayaking day is what the paddling program is built around and includes a safe and fun paddle in the Morro Bay estuary area along with a discussion about natural history of the area. Figure 1 below shows a participant from a past paddling program training weekend in a kayak with a volunteer kinesiology student at the Cal Poly pool.

Figure 1: Participant at APP Training Weekend

Currently, the paddling program uses three different kayaks that need improved seating for participants: the Malibu II from Ocean Kayak, the Sky 2 by Necky, and the Gannet II by Necky. These can be seen below in Figures 2, 3, and 4, respectively and are all shown with their standard seats and mounting straps. The Malibu II is a sit-on-top kayak that is used in the program. Due to its shape, it offers the easiest entrance, and is the most stable platform. The surface texture and foot supports, however, are not conducive to preventing skin breakdown or pressure points and it is also the most difficult to stably attach a seat to. The Sky 2 has a short, open-cockpit design which allows moderate entry access. It has limited leg room in the bow for the participant and has uncomfortable existing seats, but it is very stable and easy to maneuver on the water. The Gannet II is a longer and heavier, open-cockpit tandem kayak than the Sky 2. It offers similar benefits along with more leg room for the participant. The two open-cockpit kayaks limit access to the legs and can feel intrusive when situating a participant in the kayak. In order to make a successful design, the different widths, depths, and attachment restrictions of each unique kayak were accounted for.

Figure 2: Malibu II Sit-on-Top Tandem Kayak

Figure 3: Sky 2 Open-Cockpit Tandem Kayak

Figure 4: Gannet II Open-Cockpit Tandem Kayak

The adaptations currently used by the APP involve different types of foam, duct tape, and previously designed seat supports. The foam used differs by each specific application. Hard, closed-cell ethafoam is used to produce a bulkhead for the participants to push their feet against. Soft, dense ensolite foam is used to create soft cushioning on the seat and around the participant. Pipe insulation is used for padding the edge (combing) of the cockpit in the Sky 2 and Gannet II. A variety of other foams are used for supporting the participant by creating different shapes and fitting them around the participant. For example, if participants require under-knee support, the kinesiology students will use a small roll of foam that will help to support the legs. Figure 5 below shows some kinesiology students working to fit a kayak to a particular paddler who needed additional foam support.

Figure 5: Kinesiology Students Fitting Kayak to Participant

Fitting the kayaks to the paddlers involves understanding the functional challenges for each individual rather than looking only at their medical diagnosis. The kinesiology students work with the participants to tailor the program and the boats to the paddlers' specific needs in order to provide an enjoyable experience. This methodology aims to provide each paddler with his or her own least restrictive requirement. The training weekend helps the kinesiology student assistants learn about the importance of developing safe adaptations that avoid creating situations where pressure sores, abrasion, or skin deterioration are possible. These problems can be compounded by moisture and the marine environment. By combining this knowledge with a drive to create the least restrictive environment, the APP can provide the most enjoyable, safe and comfortable experience for participants.

By attending the APP's fall 2013 orientation and participant weekends, we were able to gain valuable insight into the program. Getting to see and sit in the kayaks, watch the approach to creating supportive seating, and learn about the health and safety issues involved with the program and the participants was all very informative. It was also helpful talking to and working with participants that attended the program because it gave us a better perspective on how to best fulfill their needs. We are all grateful to have been included in the clinic as it was an invaluable experience that ended up being critical in the overall design process.

Formal Problem Definition

The currently used kayak seats are very small, flimsy, and do not provide enough support to paddlers with or without disabilities. These seats are especially lacking in areas of trunk or hip support. Without sufficient support, the paddlers cannot experience the least restrictive environment. As we saw from attending the fall program, the APP and its kinesiology students currently have to use a good deal of foam and duct tape in order to provide any level of comfort and support to the participants. That fact makes for a very time-consuming setup process that is undesirable for everyone involved and can result in tiring participants before they get out on the water.

The addition of all of the support foam also tends to constrain a paddler's range of motion. This can make a paddling motion very difficult and prevent participants from having an enjoyable experience out on the water. When an exceptional amount of trunk support is needed, foam pieces have to be stacked up fairly high along the back and sides. This intrusive and bulky creation of support can be less than comfortable while also making the paddler stick out on the water.

Since the current kayak seats are not designed to minimize pressure points, paddlers will occasionally develop pressure sores. This is more of a problem with participants who have limited sensation in their lower bodies, making them unable to adjust their position to relieve pressure. The minimal amount of padding on kayak seats combined with the effects of wet plastic and fabrics can cause painful skin abrasions

One of the logistical challenges involved in adaptive padding is simply trying to get the paddler into the boat. The tight cockpit designs, limited legroom, and current seat back design are not conducive to easily lowering someone into the kayak. Although uncommon, there are also various challenges surrounding the problem of capsizing. If a boat with an adaptive paddling participant capsizes, the structure of the support is quickly lost in the water and all of the foam has to be resituated around the kayaker once they are back in the boat. This can be especially difficult to resolve without creating new problems such as wet foam rubbing on the participant.

Objective and Specification Development

In order to avoid the aforementioned problems and help the clinic run more smoothly, the APP was in search of a fully adaptive kayak seat that could replace current seating options by adding support and comfort for people with disabilities. The program's main goal is to make kayaking a fun and freeing activity for people who are mobility impaired. The water acts as a great equalizer and providing better seating can make kayaking an all-inclusive activity. It is important to find a way to make entry into the kayak simpler and to design a seat so that participants will not need to worry about potential pressure sores or skin abrasions. An optimal seat design would provide adjustable levels of back, neck, lateral, and hip support while still allowing the paddler to experience his or her own least restrictive environment in a safe manner. Creating a durable seat that develops the ability to add support where it is needed without developing restriction where support is not required was at the foundation of our goals.

Customer Requirements

The full list of customer requirements can be seen in Table 8 in Appendix A. These were taken directly from the project sponsors after discussing what the APP specifically needs in a strong design. The background research that we completed further contributed to determining our customer requirements. We classified each of these requirements as either a high, medium, or low priority in order to clarify which needs were the most important ones to focus on for our idea generation and conceptual design development. For example, ensuring that there is sufficient back support is much more crucial to the design's overall success than adding a cup holder.

Engineering Requirements

Table 1 below outlines the engineering requirements that we have developed from our analysis of background research and our understanding of the problem. Some of these were based directly off of customer requirements while others were developed by the team based on expected engineering challenges. Some estimates regarding the quantifiable requirements were developed so that we had more objective goals to work towards.

We specified the tolerance on each requirement (as being a maximum, minimum, or absolute requirement) in order to focus the project design to meet requirements appropriately. We then assessed the risk of meeting each of our targets; a goal is high risk if there is any doubt of meeting it while low risk goals are those which we believe we can absolutely satisfy. Through risk analysis, we did not find any goals to be high risk. The highest risk level of component goals was only medium risk, indicating that we should be able to meet our listed goals without significant difficulty, which we were successful in doing.

We also determined how to formally evaluate whether or not our design meets our goals by creating a compliance method. This method states that we will judge the success of our product via either one or a combination of the following means: engineering analysis, product testing, comparison to similar existing designs, and visual inspection. These compliance methods along with the risk levels can be seen in Table 1 below.

Table 1: Table of Engineering Requirements

Formal Engineering Requirements for Adaptive Kayak Seat					
Specification No.	**Parameter Description**	**Requirement or Target**	**Tolerance**	**Risk of Meeting Targets**	**Compliance Method**
1	Weight Supported by Lateral Arms	150 Pounds (on each support pad)	Min	M	S, T
2	Weight Supported by Back Rest	Support 200 Pounds	Min	M	S, T
3	Weight Supported by Head/Neck Support	30 Pounds	Min	M	S, T
4	Seat Back Angle	$65°<\theta<85°$	±5 Degrees	L	I
5	Force on Pad Eyes	100 Pounds	Max	L	T
6	Force for Sliding Adjustments	15 Pounds	Max	L	T
7	Force for Side Adjustments	15 Pounds	Max	L	T
8	Force for Seatback Removal	15 Pounds	Max	L	T
9	Surface Roughness of Padding	Non-abrasive	Absolute	L	S, I
10	Seat Pan Width	17-20 Inches	±1 Inch	L	I
11	Seat Pan Length	17-20 Inches	±1 Inch	L	I
12	Seat Back Height	20 Inches	Min	L	I
13	Modular/Removable	2 Separate Pieces	Min	L	I
14	Material Selection	Corrosion Resistant	Absolute	L	S
15	Remain in Working Condition with Weekly Use	5 Years	Min	M	A, S
16	Product Weight	40 Pounds	Max	M	T
17	Production Cost	$1500	Negotiable	M	I

Legend	**Risk**	**Compliance**
	High (H)	Analysis (A)
	Medium (M)	Test (T)
	Low (L)	Similarity to Existing Designs (S)
		Inspection (I)

Quality Function Deployment

In order to better understand the problem at hand and focus on what needed to be designed rather than how it should be designed, we filled out a Quality Function Deployment (QFD) table that can be seen in Table 9 in Appendix A. This QFD method is often used in industry to help quantify customer requirements and compare those to the project's engineering requirements as well as any existing products.

We began this process by first identifying the customer's specific needs. We listed all of the customer's requirements and compared each one of them against one another in order to determine the importance of each requirement. This analysis of what we was most important can be seen in the weighting section of the QFD, and it showed which features we needed to spend the most time and money on in order to create an effective product design.

We then took these customer requirements and measured them against a benchmark. The benchmark we used in our comparison was the seat from Creating Ability because we feel that it is the best idea currently on the market and the biggest competition we face. This process showed us how their product measures up against our specific customer requirements. We were able to see where it succeeded and fell short, and from that, we got a better idea of what concepts would and would not work.

The QFD also helped us to analyze the engineering requirements that we set for the project. We took the time to compare our engineering requirements to the customer requirements to see how strongly they correlated. On our QFD diagram, we marked requirements that were strongly correlated with a solid circle, ones that had a medium correlation with an open circle, and ones that were only slightly correlated with a triangle. We wanted to make sure that our engineering requirements did not stray too far from what the customers had asked for and we also wanted to double check that we had truly identified the critical specifications and how to address them. When there were customer requirements without any strongly correlated engineering requirements, we could see that we needed to put more thought into that need.

The QFD table, although disjointed in overall view, offered a valuable view of the relationships among the different engineering and customer requirements. It showed that the Creating Ability seat is a good product, but it does have limitations. The different symbols offered an instantaneous view of what requirements corresponded strongly and which did not correlate. This was helpful in creating a design that focused on relating components to functions.

Project Management Plan

All successful projects start out with a strong management plan to keep the team on track. This section serves to outline the management plan that we set up for ourselves to help us get this product done within the time limit. We understood that time is money, so our goal was to be efficient, yet still as thorough as possible, in completing this design.

Method of Approach

To ensure that we kept on track throughout this process, our team developed a method of approach to our design development. Although our outline changed slightly as we progressed with the design, this skeleton plan served as an overview for the process we followed. We also developed a more structured time management plan with specific tasks that is explained in the Management Plan section of this report and included a Gantt chart in Figure 50 in Appendix A. The basic progression of the design process that we followed throughout this course was as follows (partially taken from "The Mechanical Design Process" by D. Ullman):

1. Specification Development and Planning
    - Form the design team
    - Background research/existing products
    - Hone in on the specific need of the customer
    - Generate customer and engineering requirements
    - Begin forming design records
2. Conceptual Design
    - Generate and evaluate concepts
    - Update design records and turn them into plans
    - Perform necessary testing on concepts
3. Product Design
    - Search for sources to order materials from
    - Reevaluate the design in case new issues surface
    - Pre-order all necessary materials before next stage
4. Production
    - Manufacture the prototype
    - Perform quality control, analysis, and tests
    - Mass production if desirable and plausible

Each of these four main components of our method of approach was crucial in helping us come up with a quality design that we could send into service and fulfill the customer's needs. The design process was highly iterative and many parts of this general process needed to be completed several times in order to create the best possible solution. We had to loop back to different points in the design process several times to re-analyze different parts of the design and to reevaluate our process.

Team Member Roles

One of the most important aspects of having a successful team was in knowing how to delegate responsibilities among each of the team members. These roles ensured that our team completed work efficiently and looked out for each other while still holding others accountable when necessary. It also made sure that no part of the project was overlooked by compelling everyone to always be actively participating in the process and checking up on one another. Our team member's main roles throughout this design process were as follows:

Irvin Camacho

Treasurer

- Maintain the team's overall budget
- Record any expenses such as travel or product materials
- Fill out any travel forms, if necessary

Materials Manager

- Order any materials necessary for manufacturing purposes
- Ensure that any long-lead items are ordered well in advance
- Put together the bill of materials (BOM) from the SolidWorks assembly

Grant Petersen

Engineering Communications Officer

- Be the main point of communication with the sponsors and vendors
- Facilitate meetings with the sponsors
- Make sure to keep an open line of communication with the customer and inform them of any future changes to the project

Manufacturing Lead

- Heads all of the manufacturing processes
- Draws up designs before heading into the shops

SolidWorks Master

- In charge of the master SolidWorks copy of the product
- Verifies that any desired changes are within tolerances

Audrey Riddle

Secretary/Recorder

- Update information repository for the team including electronic copies of any notes or formal documents
- Maintain the team binder and keep it up to date
- Take notes during meetings with sponsors and team status meetings
- Update each report as necessary
- Put together detailed part drawings from SolidWorks

Lead Analyst

- Determine which calculations must be done before and after manufacturing to ensure that the product is safe
- Double check all calculations

Andrea Voigt

Liaison to Sponsors

- Maintain contact and interaction among the design team, sponsors, and kinesiology department
- Lead interdisciplinary communication
- Provide a kinesiology background for the team to design effectively

Quality Enforcement

- Verify that manufactured product meets all safety requirements
- Ensure that the product meets all visual inspection tests

Even though each team member did have specific individual roles that he or she had to fulfill, a strong team effort was also required in order for the project to progress smoothly. Each member was also expected to take on any additional responsibilities that arose and had to be willing to help teammates when needed. All of the idea generation, data analysis, and product manufacturing and testing were primarily a collaborative team effort. Individual assignments and roles evolved as different parts of the design process required different roles and jobs to support a successful design.

Project Milestones

The major deadlines that were enforced by our senior project class are as follows:

October 24, 2013	Project Proposal
November 4	Conceptual Model
December 5	Conceptual Design Report
December 10	Conceptual Design Review with Sponsor

January 14, 2014	Test Plan Development
February 6	Critical Design Report
February 9	Critical Design Review with Sponsor
March 4	Manufacturing and Test Review
March 11	Project Update Memo
May 31	Senior Project Expo
June 6	Final Report

In addition to these dates set by the course, the APP was held once per quarter. We aimed to make our prototyping and manufacturing completion points throughout the design development coincide with APP clinic dates so that we could complete field testing and generate feedback generated for improving our design. The training days and the actual event dates are listed below:

October 19-20, 2013	Fall Quarter Training Weekend
November 2-3, 2013	Fall Quarter Participant Event
February 15-16, 2014	Winter Quarter Training Weekend
March 1-2, 2014	Winter Quarter Participant Event
April 26-27, 2014	Spring Quarter Training Weekend
May 10-11, 2014	Spring Quarter Participant Event

We developed a more detailed time management plan that goes through specific tasks. Our scheduling plan aimed to keep the project on track for an on time product deployment while allowing ample time on each phase of the design process to ensure that we could create the best product possible. We also developed dependency criteria to relate the different tasks to one another. This plan was outlined in a Gantt chart which is attached in Figure 50 in Appendix A.

In order to maintain trust and agreement with our sponsors, we continued to uphold an open line of communication by holding design reviews and consistently reporting our progress along the way. We also hoped to be able to test our design at the APP's various events so that we could get direct feedback from our sponsors and customers. Although we were not able to bring our prototype to any of the APP events, our sponsors were always ready and eager to answer any questions we came across throughout the process.

Chapter 2: Background

All of our background research into the problems and solutions surrounding adaptive paddling has helped us gain an appropriate understanding of the problem. Having this strong foundation has helped to guide us in developing a useful product. This chapter summarizes the results of our background search into patents and existing products to understand what advances toward adaptive kayaking are already being considered.

Existing Products

Adjustable Seat Design

In our research of existing solutions, we found that the adaptive seating options available for kayaking or similar applications were very limited. We were only able to find one mass-produced seating system for kayakers with limited mobility. Thus, this design was the focus of most of our research regarding existing solutions. Most other seating options are similar to those already in use by the APP and involve foam and duct tape solutions tailored to individuals.

The seat that we focused our research on is produced by a company called Creating Ability, based out of Minnesota. The kayak seat, which they sell for approximately $550, was designed in conjunction with a company called Beneficial Designs. The design was originally specific to a canoe, but has since been modified to work in kayaks as well. The seating system is designed specifically to be compatible with kayaks from a company called Current Designs which makes a variety of recreational and touring kayaks with varying cockpit sizes. The company, however, does not make any sit-on-top kayaks so the seat is not designed for attachment to sit-on-top vessels. Creating Ability does offer mounts that support some kayak seat systems used in Necky brand kayaks, as used in the APP. More discussion about the Creating Ability seat can be found in the Current State of the Art section of this report.

Padded Cushion Design

In researching existing solutions for comfortable kayak seating, we found an existing product that offers comfortable and adjustable seating for kayaks. The Sweet Cheeks seat pad is made by Jackson Kayaks in Tennessee. The unique seat pad is able to conform to the shape of different users and eliminate uncomfortable pressure points for each individual. The Sweet Cheeks system uses small Styrofoam beads in an airtight fabric pocket; when air is blown into the seat cushion, the beads are freed up and can move about. In order to customize the seat to a person's figure, the user sits on the unmolded pouch with loose beads and air. A valve is then opened, allowing the air to escape. Once the air is pulled out of the cushion, the remaining shape of the foam beads is custom-fit to the user's shape. When a different user needs to use the seat, they simply start the process over and remold it to their own figure. Figure 6 below shows the overall shape of the Sweet Cheeks seat cushion and also illustrates the mounting straps and valve hose.

The seat was developed for whitewater kayaks, but is simple in its attachment mode of Velcro or simple straps, allowing it to be fit to other kayak or seating systems. The seat comes in two options of differing volume. The bigger, more expensive seat sells for approximately $75. This seat is the most adjustable one that we could find in our research. There do not seem to be many other options for fitting seat cushions comfortably to different individuals. The seat does not have any considerable drawbacks and may be a useful component to incorporate into design.

Figure 6: Jackson Kayaks Sweet Cheeks Cushion

Current State of the Art

As stated above, we have found that the state of the art kayak seat is the Creating Ability seat. Figure 7 shows a front view of the seat to give a clear illustration of the seat pad shapes along with the general layout of the pelvic and upper lateral support system. Figure 8 shows a view of the seat as situated inside the cockpit of a Current Designs kayak. Figure 9 gives a back view of the seat in order to show the general support structure as well as some of the adjustability of the design.

Figure 7: Creating Ability Seat Front View

Figure 8: Creating Ability Seat in a Kayak


Figure 9: Creating Ability Seat Back View

This seat is by far the best adjustable kayak seat currently on the market and has many positive attributes. The seat back angle is adjustable to give any individual the necessary support and position that fits their needs. The seat has a telescoping back support piece with two tapered pads that allow for support at adjustable heights. These pads allow for shoulder movement once they are adjusted appropriately. If desired, the upper pad can be removed and flipped upside down so that it tapers downwards and can provide support to the shoulder blades. Additionally, the product uses highly adjustable lateral support pieces that attach to "ribs" which branch off of the main vertical support piece. These lateral support pieces allow for adjustable width and provide lateral support at varying heights. They are also removable for easier side entry into the kayak.

However, the Creating Ability design is not perfect and does have several drawbacks. The seat back does not seem to remove from the seat pan, and having this option would allow for the easiest entry into the kayak. Also, the design neglects to include options for neck and head support that may be needed by some paddlers. Although the lateral supports are removable for kayak entry, the support removal system exposes protrusions that could pose a threat to participants as they enter the kayak. Padding on the seat pan and back support also seems to be insufficient for persons with minimal sensation who need to avoid pressure points. Not being able to use the seat on a sit-on-top kayak is another drawback as sit-on-tops offer the simplest entry and excellent stability on the water.

Patent Search Results

Our patent research using Google Patent was largely unproductive. Although there are many patented kayak seating systems in the database, we were unable to find a single adaptive kayaking seat after digging through the archives. There are many different attachment and strapping systems for kayak seating but nothing specifically adjustable or designed with focus on use by people with varying disabilities.

We were, however, able to find a few patents related to kayak seats with adjustability, but the designs are not targeted at helping people with disabilities. All three designs that were found incorporated the importance of adapting the entire component to any kayak or watercraft.

One design somewhat focused on providing comfort for the user, but more specifically focused on adjusting the height of the seat. The purpose of the height adjustment was to raise the user above the water level relative to the kayak for better control of the elevation and submersion over the ends of the kayak (Kayak Seat; Patent # 6112693; September 5, 2000). Another patented design was intended to provide the user with a better seating surface and a backrest coupled to the seat pan (Adjustable Seating System; Patent # 6990920; January 31, 2006). The third design that was found focused more on the adjustability of the subcomponents in order to accommodate the seat to the users' preferences and the rigidity of the seat was tailored so that it could be firmly secure in all watercrafts (Adjustable Kayak Chair; Patent # 20130238973; September 19, 2013).

Of the three designs, the last two adjustable seats are more related to our project's objectives. Even though the main ideas behind each design are to fulfill the needs of the users and adapt the kayak or watercraft to the riders, each of the solutions, including ours, is different in structure. This gave us some room to work with when developing our final design.

Existing Programs

Our research showed that there is a quickly growing community of adaptive paddling programs throughout the United States. Adaptive paddling programs can be found from coast to coast and many places in between. The Midwest and Southeast seem to have large concentrations of paddling programs. In researching the solutions used for trunk support by other programs, we found that trunk support is mostly created with foam and duct tape. There are several programs that have begun using the Creating Ability seat. It appears to be a useful tool for many of them, but most programs do not need to create substantial support for a large percentage of their kayakers. Most programs have a majority of participants with sufficient trunk support to require minimal additional seating adaptation.

Chapter 3: Design Development

Spending extensive amounts of time on the design development phase was crucial to coming up with a functional design that met all of the previously listed needs. This chapter covers the process of how our team came up with initial concepts and how we managed to narrow them down to a final design.

Discussion of Conceptual Designs

In order to get to choose a top concept, we first went through several rounds of idea generation. The philosophy behind our idea generation was to fail early and often in order to get a good feeling for what would and would not work in the final design. By failing early in the design process, we were able to catch any problems that would be unsolvable had we been too far invested into a design. By failing often, we learned more lessons which helped to ensure an excellent final design.

Idea Generation

The idea generation process began with simple brainstorming. Our individual brainstorming sessions provided us with valuable time to think to ourselves about all of the ways that we imagined this design and its subcomponents working out to make an elegant and effective design. By starting with individual brainstorming, our creativity was unrestrained by the mental restrictions we inherently place on ourselves in a group environment, regardless of how positive the group dynamics are. We were able to come up with an enormous variety of ideas as a result of the lack of mental barriers. Some ideas were better than others, but no matter how bad an initial idea might have been, each one was still valuable. Even bad overall designs contained some positive attributes in that they led us to consider new solutions and look at the problem in a whole new light.

The next phase of idea generation was to make a morphological matrix using post-it notes. A photo of our morphological matrix can be seen in Figure 51 in Appendix B. We generated this matrix by concentrating on specific subsystems of the overall design and individually writing out all of the ideas for what we thought would satisfy both the customer and engineering requirements for that subsystem. This was all done in a timed environment to help give a sense of haste for purging all thoughts quickly without worrying about viability or what the group would think. The timer idea also acted to try to minimize the problems of anyone holding back on more outside-the-box ideas. When we put all of our ideas together into one big matrix, we were able to see all the various ways that the components could fit together. It gave an endless range of possibilities for us to choose from and we made sure to consider as many of the possibilities as we could no matter how radical. This method effectively allowed us to get together as a team and share all of the ideas that we had previously come up with.

Conceptual Modeling

In order to attempt to narrow down the huge list of options, we spent a few weeks doing conceptual modeling with pieces of foam board and any other materials we could find, including Popsicle sticks, wooden dowels, and rubber bands. This conceptual modeling phase gave us a chance to express our individual ideas in a visual manner in order to better explain what we were thinking. In addition, it helped to further show which designs were and were not plausible. For example, we were able to see that some types of back support would be more rigid and less prone to rotation than others just by creating a couple of basic mock-ups and applying some force. It even showed us that some components could not be fitted together due to physical limitations of the models we created. Conceptual modeling led us to generate more ideas as we started to physically work with our ideas and found that some new ideas might work better to solve some of the problems that were revealed in the models. Figures 10 and 11 below show a couple of the ideas that were explored in our foam models. They demonstrate potential hip support shape and possible lateral support shape, respectively.

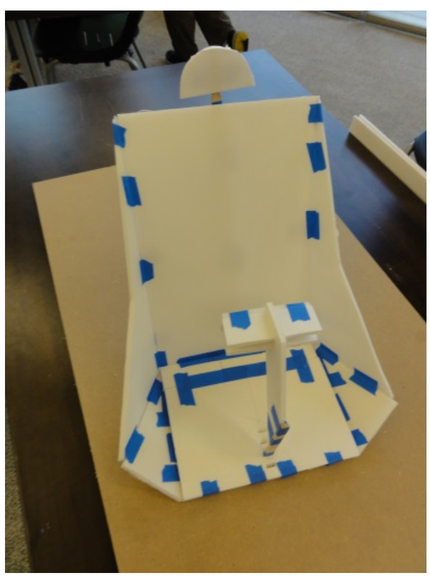


Figure 10: Foam Concept Model for Hip Support

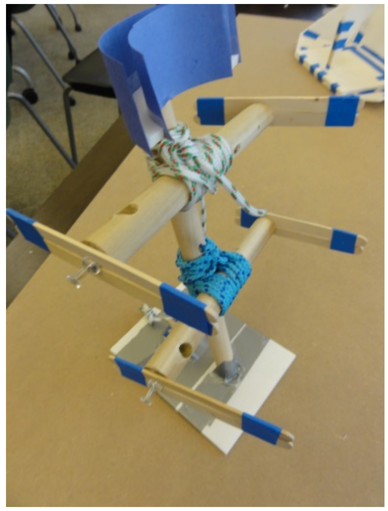


Figure 11: Foam Concept Model for Lateral Support

Concept Selection

After making conceptual models, we were able to narrow down our ideas once again. In order to do this, we utilized concept evaluation Pugh matrices to further analyze each specific subsystem. We each created an individual Pugh matrix in which we compared different ideas for a single subsystem against that respective system in the Creating Ability seat. Our comparison strategy was to list each of the concepts as better than, worse than, or basically similar to the Creating Ability seat datum. We then used these ratings to determine which solution(s) we believed would be most beneficial for each subsystem. The Pugh matrices did not tell us exactly which concept we should choose, but they did show us the positive and negative aspects of each one. From that, we tried to determine how to maximize the utility of the subsystem by combining positive attributes from the different ideas in the Pugh matrix. This helped us generate new ideas for putting good attributes from subsystem ideas with limited overall utility into the concepts with the best overall results. The concept evaluation Pugh matrices for the lateral support, back support, and seat back angle subsystems are shown in Tables 10-12 in Appendix B.

Finally, we used a method known as controlled convergence in order to narrow down our ideas down one last time. We all got together as a group and managed to eliminate some concepts based on their unsolvable negative aspects. If a concept did not meet one or more of our high priority requirements and we could not find any way to get around it, we were forced to eliminate it. Next, we listed any newly generated ideas based on any positives from those eliminated concepts, and then repeated that elimination/generation process until we got down to the best ideas. Although this method was very time consuming, it ultimately resulted in us being able to decide upon our top three concepts.

Description of Top Three Concepts

Each of the top three concepts that we chose shared some similar aspects. A basic breakdown of the subsystems of each can be seen in Table 13 in Appendix B. Each one employed the use of a double spine for back support due to its rigidity and lack of rotation under uneven or large loading forces. The top three concepts also used a configuration of an industrial strength suction cup system to attach the bottom of the seat pan to the kayaks. This suction cup method would only work on the smooth plastic boats. Thus, the sit-on-top kayak would make use of straps connected to the pad-eyes that are already installed on the boat and a padding system for allowing the seat to sit stably in the Malibu II. The seat pad in all three concepts used the Sweet Cheeks seat from Jackson Kayaks due to its high level of adjustability and comfort. The seat back design incorporated an open shoulder section in order to offer the participant full range of paddling motion if so desired. In addition, each top concept included options for both a head and neck support and foot support bulkhead add-ons. These would be used for participants who needed that extra level of support in either direction to keep them comfortable and secure in the kayak while out on the water.

Concept #1

The first of our top three concepts focused on the use of a single set of straps to adjust the lower lateral and hip supports as well as the seat angle. Those straps would allow for fine tuning of the lower lateral and hip support for the participant. There could be as many or as few straps as desired in order to keep the participant supported. In addition, they could be adjusted to serve as the method for altering the seat back angle. In terms of component separation, this concept relied on the idea that the seat back would have an attachment that would allow it to slide into a slot in the back of the seat pan similar to how the Sky II and Gannett II factory seatbacks fit into the seat pans.

A downfall to this concept was that the straps could potentially create unwanted pressure points for the participant. This is due to the fact that it relied on the person's weight being distributed over a series of narrow straps. This method could easily be the cause of minor injuries to the participants, especially ones who have less sensation in their legs and lower torso leading to inability to feel pressure points. Another negative aspect of this design was that the component separation method did not make it easy enough to adjust the seat back angle with a participant in the kayak. The slide-in method restricted the seat back from being able to achieve the full range of angles we had specified in our engineering requirements due to its restriction in the slot in the seat pan.

Concept #2

The second of our top three concepts explored a different option to alter the seatback angle. It utilized a small hydraulic jack behind the seat back to allow for very fine adjustment tuning that would be non-invasive to the paddler. This design also incorporated a type of slide-in seatback attachment/separation design. However, this slide-in attachment would include a hinge on it to make it simpler to lean the seat back if desired. The lateral support of this design also differed from that of the first. It employed a bent arm design, similar to that of the Creating Ability seat. These bent arms allowed for a more even pressure distribution than the straps and had the ability to be adjusted up and down as well as out to the sides. The lateral supports held onto the main frame using push buttons similar to those used in feathering a kayak paddle. Instead of using straps for hip support, this concept included sliding side trays that slid out from a slot in the seat pan to allow width adjustment of hip support.

This second design, however, also had its downfalls. The hydraulic jack was difficult to incorporate into the design of the kayak seat so it ended up becoming more of a hassle than a solution. There were also concerns with using hydraulic cylinders in a marine environment since it would greatly reduce durability of the system. Although it would have been nice to have, there are much simpler options for reclining that still meet the customer and engineering requirements. In addition, the push buttons for the lateral support attachment could potentially become problematic due to any corrosion or salt and sand build up on the button itself or the main frame.

Concept #3 – Chosen Concept

Our third top concept was the one that we ultimately decided was the best and a basic sketch of it can be seen in Figure 12 below. It kept the same idea for the lateral support arms as the second concept, but instead of using buttons, it used pins to hold the arms in place on the track. It also utilized the same sliding trays idea for hip support and width adjustment. Instead of using a slide-in method for attaching the pan to the back, it used a pin-in-hinge method to maintain security while allowing for easier angle adjustment than before. While the pins would hopefully be less affected by material rust than the buttons would, one now runs the risk of misplacing the pins when they are not in use. However, we felt that the positive aspects of this design outweighed this negative point and were confident in the success of this design. This design is described in more detail in the following section.

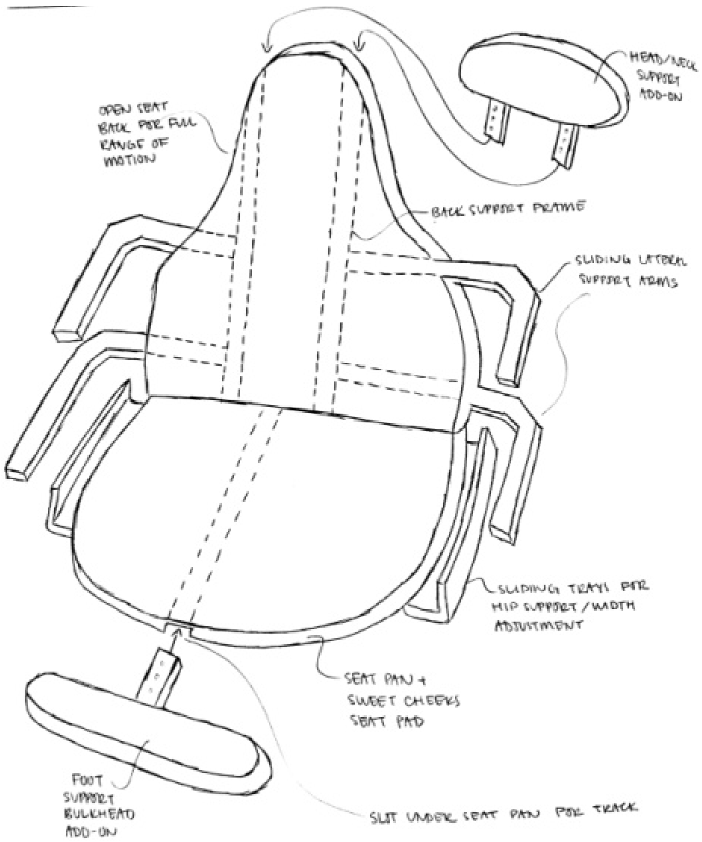


Figure 12: Basic Sketch of Chosen Design Concept

Detailed Description of Top Conceptual Design

We believed that our top conceptual idea satisfied, at the least, the higher priority requirements of the Tide Rider 360. This conceptual model was a big step in making our way toward our final product design. An isometric view of the fully assembled conceptual design is shown below in Figure 13 to demonstrate what it would look like with all the potential attachments in place. This section describes the conceptual model in order to show how we eventually progressed from this design to our final design which will be described in the next chapter.

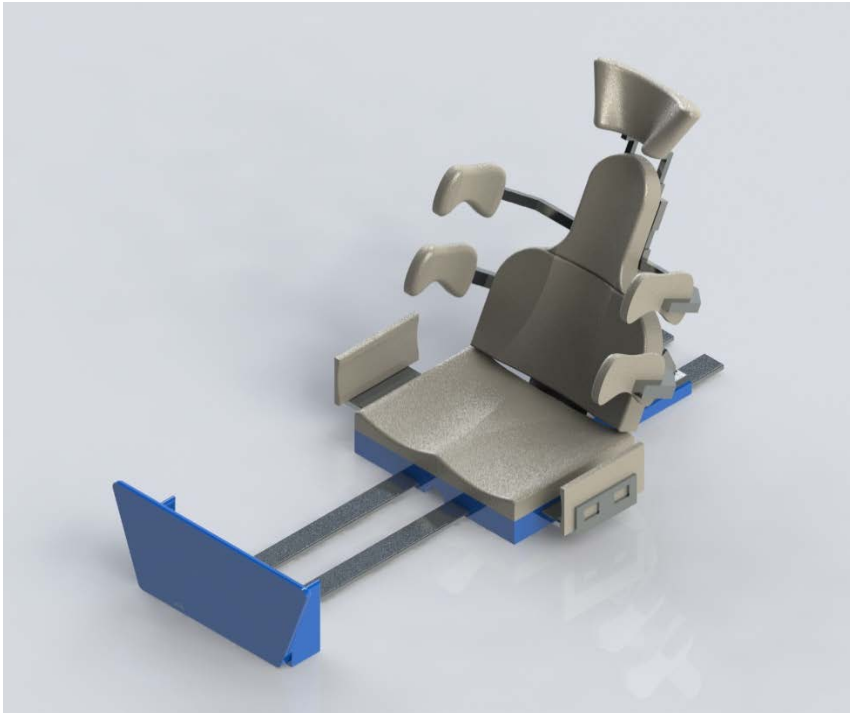


Figure 13: SolidWorks Conceptual Design Model

Our kayak seat design provided the least restrictive environment for the paddler due to reduced side padding (which can be restrictive) as well as a sleek seat back shape. These features allowed for a full range of shoulder movement so that the paddler could participate as much or as little as they would like or are capable. If they did not need the extra level of high back support, the top half of the seat could be completely removed to allow for even more freedom out on the water. Modularity in our design was a huge requirement. It allowed for easy entry and exit into or out of the kayak because the upper seat back and lateral support arms could both easily be removed off of the rails on which they slide. The seat pan could also be separated from the seatback to break up the overall weight and make it easier to get the seat out of the kayak for storage until its next use. The seatback could also be laid flat behind the seat pan for when a participant entered the kayak, allowing for the seat back to already be attached to the hinge point for quicker adjustment.

The Tide Rider 360 conceptual kayak seat offered full lateral support by utilizing two, padded aluminum arms on each side of the seat. These arms comfortably supported the participant from leaning without being too encroaching or restrictive. Since the arms did not wrap around the front of the paddler at all, they were not in any danger of being trapped in the seat in the event of capsize. The lateral arms were attached to sleeves that rested on the back support frame and could be secured in vertical adjustment with pins. The sleeves could slide the arms up and down behind the seat back to adjust to the necessary height. In addition, they could slide side-to-side in order to better fit a person's width.

The seat also offered full back support due to a high seat back with just the right combination of stiffness and comfort. The two aluminum tracks in the back added strength to the seat back. Having an H-shaped back support also ensured that the seat back would not rotate in the event that the paddler leaned to one side more than the other. In addition, the seat back angle could be easily adjusted between the range of 70 to 90 degrees from horizontal using the sliding track attached to extensions coming off of the back of the seat pan. There were two rods coming off from the back of the H-frame that slid along this track for angle adjustment. The rods were secured in place using the Yak Attack set screw system. This system held the rod in place by screwing it tight to the track and holding it in a fixed position with sufficient pressure.

For those paddlers who required additional head and neck support while out on the water, we also included an airplane-style headrest that could simply slide and lock via a pin in the seat back H-frame. The headrest could be adjusted to form comfortably to each individual's head shape by pulling the sides of the headrest forward to form a slight curve around the sides of the head. However, this curve would not be so extreme that the paddler's head would be completely restricted from movement.

Another add-on we included with the conceptual Tide Rider 360 model was a foot support bulkhead in the front end of the kayak that the participants could rest their feet against. The current method of providing foot support is very invasive to the participant because a kinesiology student is forced to reach in between their legs to be able to move foam around. We developed a way to be able to adjust the distance from the seat pad to the bulkhead via a set screw in a track behind the seat back.

The seat was made out of durable, non-corrosive materials that would hopefully be able to withstand the windy, salty, sandy environment of Morro Bay. Our design also eliminated the use of any duct tape or excess foam that was previously needed. This way, the support set up would take considerably less time than it currently does; a benefit to both the participant as well as the kinesiology students. We designed this seat so that we could easily fit the boat to the person and make their kayaking experience the best one possible.

Improvements for Final Design

This conceptual design was a crucial step for our team in figuring out what modifications needed to be made in order to make the final design even better. We had the opportunity to discuss this concept with our advisor and sponsors, and from that discussion, we realized that our conceptual design still did have a few flaws. Thankfully, there were not any issues that would have forced us to change our whole design, so we were able to keep the majority of it the same.

One of the big issues with our conceptual design was the lack of an anti-thrust seat. There was not enough confidence in the ability of the Sweet Cheeks seat to be able to hold the paddler back in their seat and prevent them from slipping off of the front. In addition, it did not seem like the shape of the seat back padding would be supportive enough. The shape of the seat seemed to lack lumbar support. The aluminum track supporting the foot bulkhead casing went too far out the back and most likely would have been disruptive to the student assistant sitting behind the participant. The box to hold the feet in was also very large and bulky and might have had some issues with squeezing into the tight cockpit areas at the front of the kayaks. Finally, the use of pins was not ideal since the pins were not attached in any way to the seat itself. If one was to lose the pin, the design would not be able to lock in place, therefore making it unsafe.

These modifications were incorporated into our final design that will be described in the following chapter. This conceptual design review stage was critical to improving our product and solving problems before manufacturing. Had we waited until manufacturing to figure out these issues, we would have produced an inferior seat.

Chapter 4: Description of the Final Design

After all of our idea generation and conceptual design analysis, we managed to come to a single final design. We feel as though this final design sufficiently meets the customer's requirements and will help to make the APP even more successful. This chapter discusses all of the details that make up our final design including the overall layout, supporting analysis, material selection, and more.

Overall Description/Layout

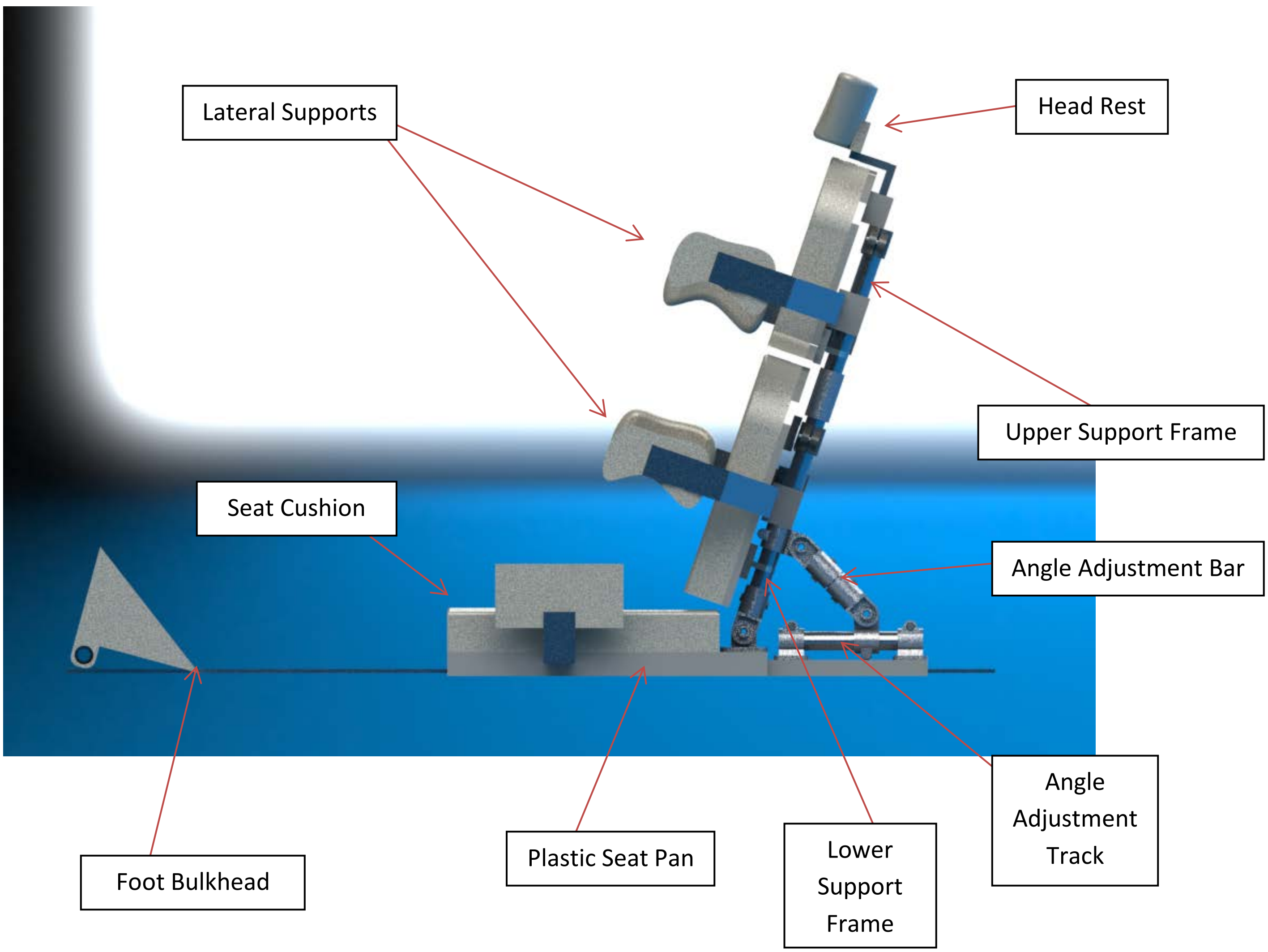


Figure 14: Final Design Labeled Side View


Figure 15: Final Design Isometric View

Our final design with all of the attachments in place is shown in the figures above. Figure 14 shows a side view while Figure 15 illustrates an isometric view. We were able to find ways to incorporate all of the higher priority add-ons such as the foot bulkhead and headrest into this design. As shown in the picture, each one of these components was ultimately connected back to the main frame on the seat back.

At the base of our design was a seat pan with an anti-thrust cushion located on top of it. The rails for the foot bulkhead slid out the front end of the seat back and supported two foot boxes for the paddler to rest their feet in. Hip support pads would slide in and out at the sides of the seat pan base. The seat back attached to the back of the seat pan and its angle could be adjusted. The main support frame was attached to the back of the seat back. Stemming from that main frame were two lateral support arms per side to hold the paddler upright. Also coming off of the frame was the headrest on its bracket that could be adjusted up and down as well as front to back.

This design was very modular. The foot bulkhead, hip supports, headrest, and any of the lateral supports could be individually removed if they were deemed unnecessary by the user. The top half of the seat back could also be removed if the participant did not need that additional level of back support. A more detailed description of this final design can be found in the following section.

Detailed Design Description

*It may be helpful to review Appendix E which includes drawings of the assemblies involved in the design in order to best understand the full concept.

Figure 16: Final Design Front Corner View

We needed to design a seat pad base that was strong and sturdy but also allowed for the tracks of the foot bulkhead and the hip support brackets to slide in and out. We had originally thought of using a single solid piece of high density polyethylene (HDPE) to provide that necessary strength and stiffness, but we found that it would have been difficult to manufacture internal features within a solid piece. Therefore, we decided to go with a "sandwich style" construction method for the seat pan base. This meant that we would use three layers of half inch HDPE sheets instead of one solid chunk. We would machine the slots across the top of the plastic sheets; a much easier process than trying to machine a hole through the middle. The bottom plastic sheet would then have the slots for the foot bulkhead to slide back and forth in. The middle plastic sheet would contain slots on the sides for the hip support brackets to slide in. Finally, the top sheet would remain solid to provide a sturdy top platform. The locations of these slots can be seen in Figure 16 above where the hip supports and bulkhead rails enter the seat pan.

The hip supports shown above are stand-in models for the actual products from AEL. We chose to incorporate the AEL components described in the material section including the hip pad and mounting system. The hip support brackets only needed to be able to slide out a short distance due to the limited room inside the cockpit of the kayak. The slots in the HDPE still went all the way through the plastic in order for easy cleaning. The bracket would lock inside the attachment slot using screws in the bottom level of the plastic in the seat pan base. The bracket had a 90° bend (as seen in Figure 26) which allowed for the vertical section with the pad attached to it to come up right next to the base of the seat, eliminating areas for pinch points. If desired, the hip support pad and top part of the bracket could be easily removed from the lower half via a simple quick-release, spring-loaded handle.

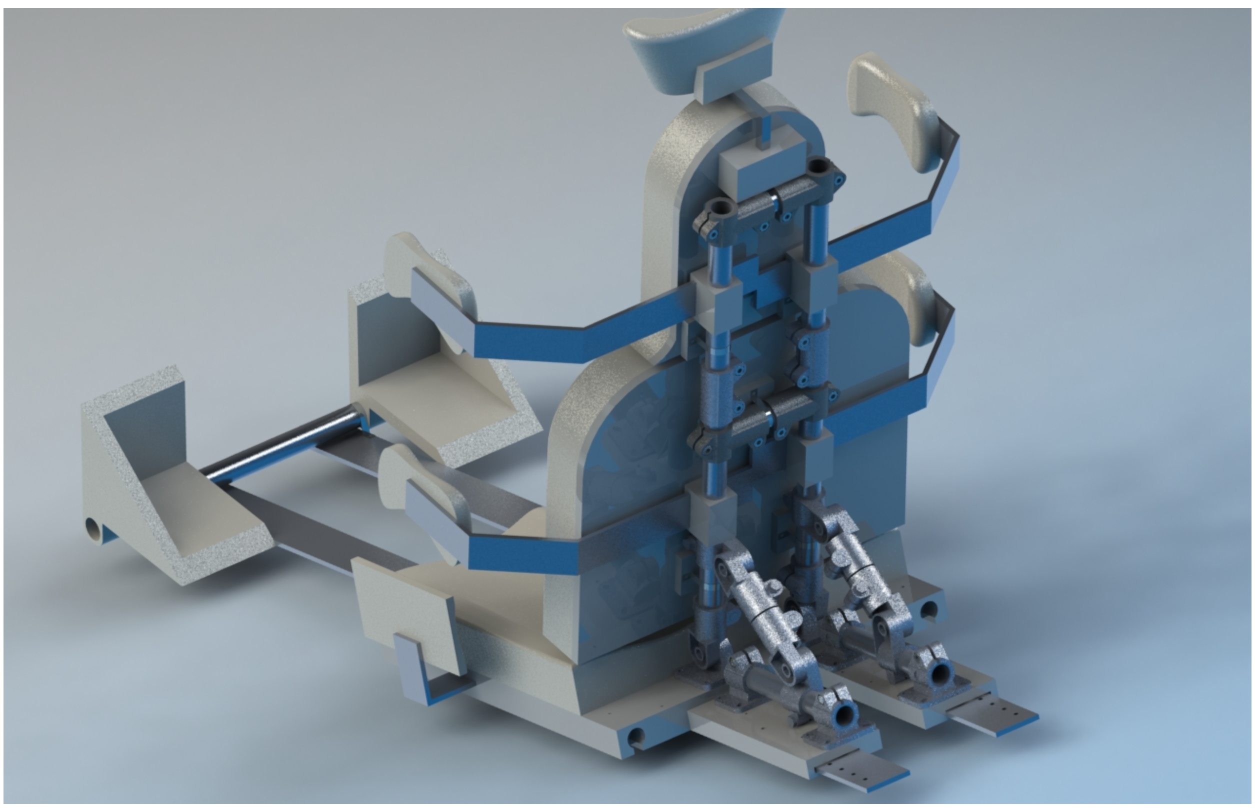


Figure 17: Final Design Rear Corner View

The foot support bulkhead also slid back and forth via a slot in the seat pan base, as seen in Figure 17 above. The foot boxes were mounted to the two ends of an aluminum rod that spanned the width of the boat. There was a spring located in the middle of that rod that allowed for the foot boxes to slide in toward each other as the foot bulkhead was pushed down into the narrow nose of the kayak. That rod was attached via a joint to two perpendicular, rectangular aluminum bars that spanned back behind the seat. These bars were used in order to slide the foot boxes forward or backward, depending on the leg length of the paddler. They could be locked in place using a pin located behind the seat back. The pin would drop down into a hole in the rod to secure it in the desired position. In order to keep the pin attached to the seat and eliminate the possibility of misplacing it, we threaded a bungee cord through the head of the pin and attached that cord to either side of the seat pan rear protrusions. The pin was held in place by the bungee, and in addition, the bungee would also ensure that the pin would not be separated from the seat. This method of adjustability was nice due to the fact that it was simple and non-invasive to the participant by providing access from the back.

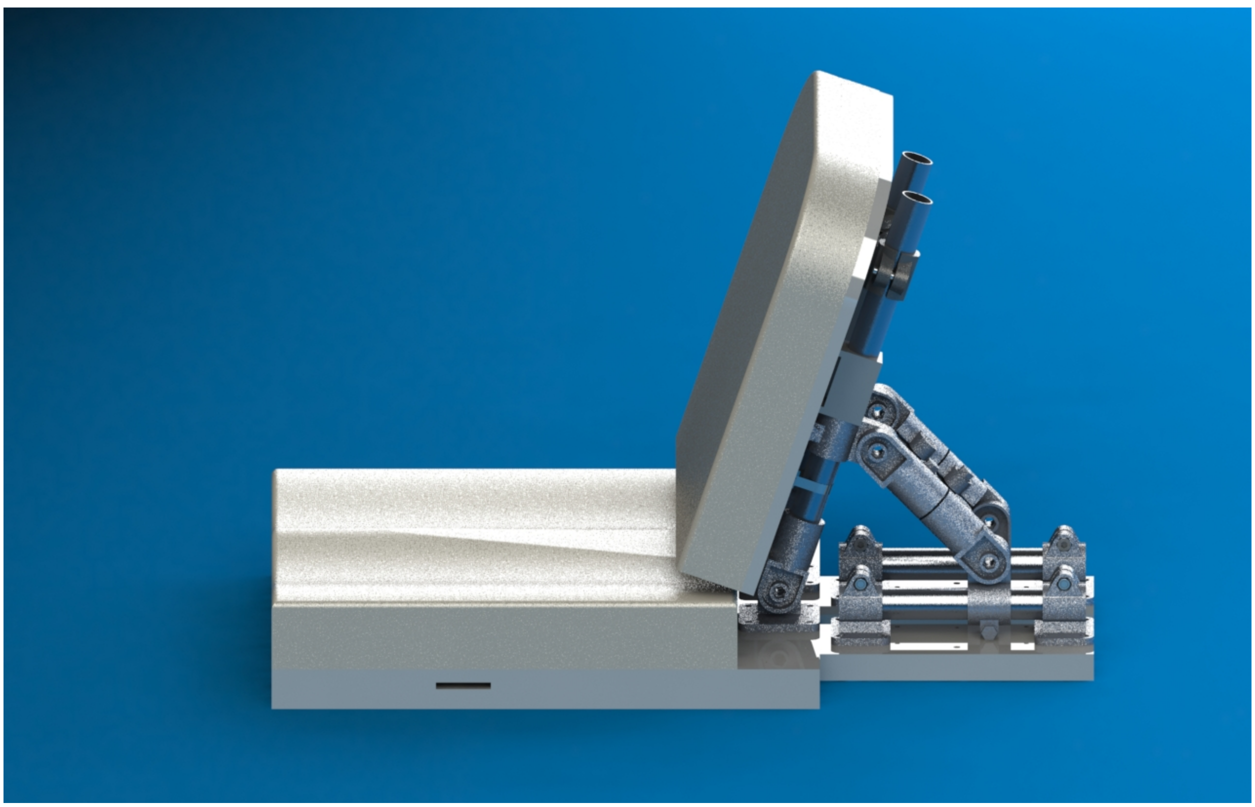


Figure 18: Final Design Basic Side View

In order to secure this seat pan base to the kayak, we decided to use four suction cups attached at the four corners. We decided to go with the Ram Mount suction cups that have a ball joint on the top. We planned on drilling slots in the corners of the bottom HDPE sheet for the ball joint to slide into. A plate would be screwed to the slot opening so that the seat could slide off of the suction cups. We have already tested these suction cups on the bottom of the kayaks and they stick very well with negligible slipping. The holes for the ball joints can be seen in the bottom of the seat pan in Figure 18 above.

We also decided to utilize a "sandwich style" construction for the seat back. We planned on having a HDPE sheet at the back that we could screw the main frame to. This plastic backing would also add sufficient strength to our seat back and allow it to hold up the weight of an average paddler. The next layer on top of the HDPE was a sheet of Styrofoam. This foam was lightweight and would not affect the overall weight very much, but it was still rigid enough to handle the weight of the paddler and reduce bending of the seat pad. The final layer that came in contact with the participant was a slightly contoured piece of cross-linked polyethylene closed-cell foam. This foam was soft enough to be comfortable, with just enough stiffness to ensure that the seat back could provide enough support to the paddler. In addition, the seat back was comprised of two sections, as shown in the difference between Figures 18 and 19. Figure 18 shows a very basic kayak seat with the top half of the seat back removed, while Figure 19 demonstrates what the seat would look like with the full seat back.

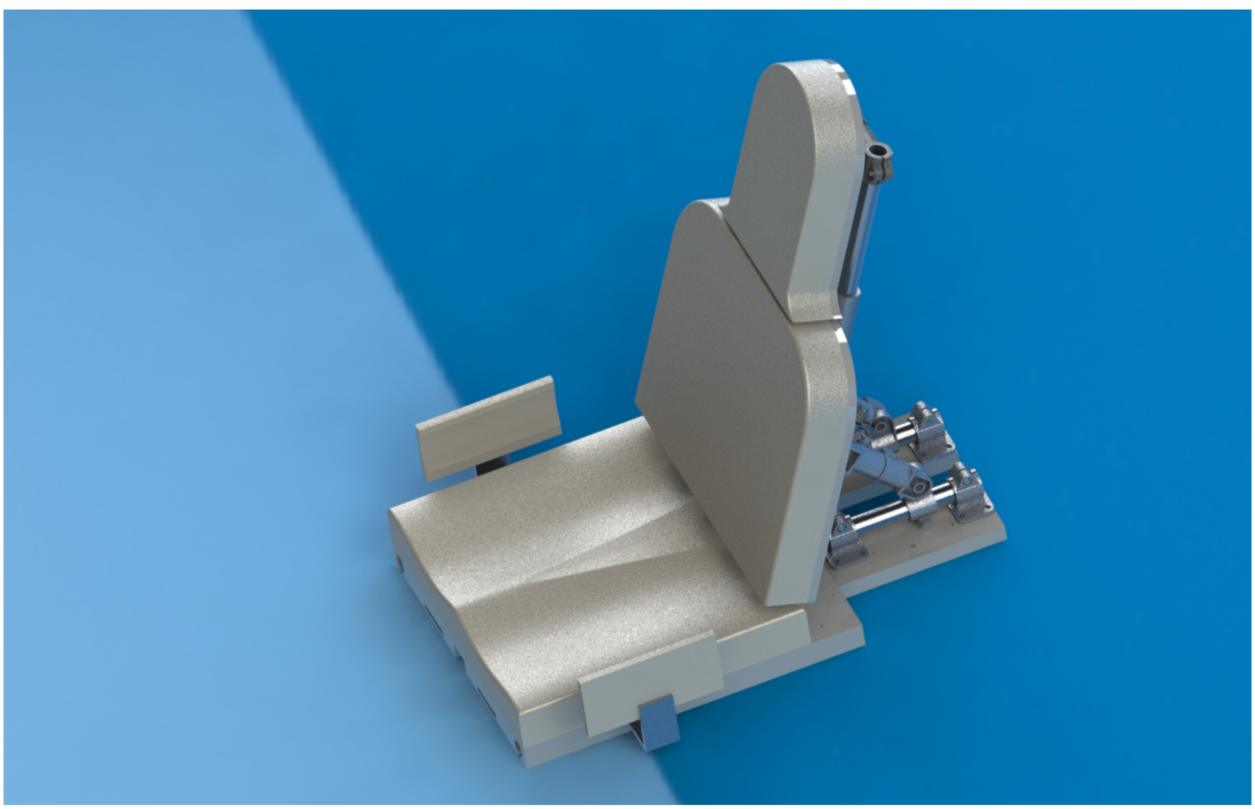


Figure 19: Final Design Upper Corner View

The main frame that attached to the HDPE backing of the seat back was made up of round aluminum tubing joined together via the use of a combination of plastic and aluminum joints from Rose-Krieger. Conduit clamps would be used to attach the aluminum tubing to the back pads. The final sizing of the conduit clamps depended on the depth of the AEL lateral support components. The AEL lateral support system allowed supports to slide along the aluminum tubing. The hinging joints would be able to rotate when loosened for angle adjustment. The rear track bars would have a hinge joint sleeve mounted to them and would be able to slide and then lock in place at the desired angle.

Analysis

Prior to beginning any analysis, several assumptions had to be formulated to simplify the system and achieve accurate results. The first assumption we made was to only consider the weight of the paddler's upper body when analyzing the back frame. We felt that this was a reasonable assumption since the majority of the person's weight was being supported by the seat pan assembly and the upper portion of their body was the only part in contact with the seat back. We also decided to model the system with the weight load distributed evenly across the seat back. This even weight distribution further simplified the calculations by allowing us take advantage of symmetry and only having to analyze the force from one side. Figure 20 below illustrates how a person's weight is applied and distributed along the seat back.

In addition, we assumed that the seat pad cushions did not absorb any of the person's weight, meaning that all of the loading was focused directly on the aluminum frame. We based this assumption on the fact that we did not know the spring constant of the cushioning foam. Even if that value was known, it would be very minor and insignificant to the overall analysis.

The next assumption we made prior to analysis was to neglect the weight of the aluminum members that made up the frame. This assumption was reasonable due to the fact that the weight of the aluminum was significantly small in comparison to any paddler's weight.

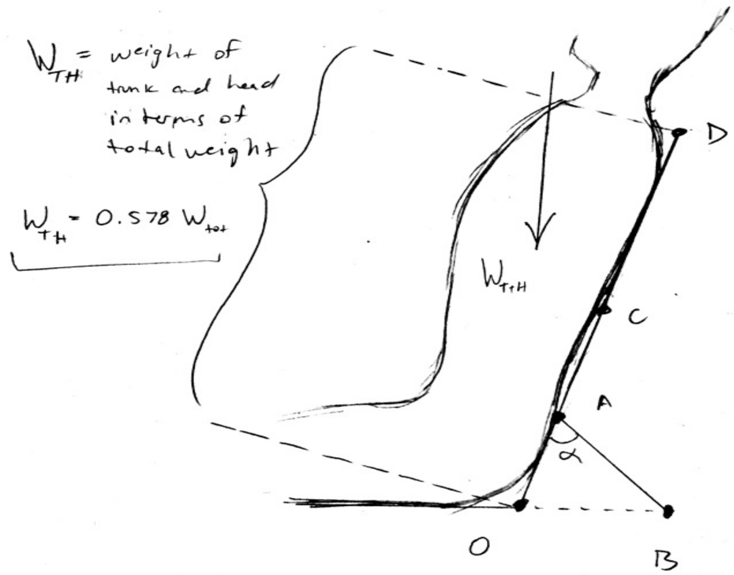


Figure 20: Weight Distribution on Seat Frame

Figure 21 below shows a free body diagram of the loads acting on the seat frame. All of the calculations were performed symbolically in terms of the weight and angles because those parameters were subject to change depending on the particular individual and his or her desired seat back angle. However, in order to obtain some sample values, we decided to analyze the conditions with a 200 pound load across the frame. We had also previously specified that the seat back angle could range from 65 to 90 degrees from horizontal, so our calculations focused on seeing how the bending and deflection of the frame varied across that angle range.

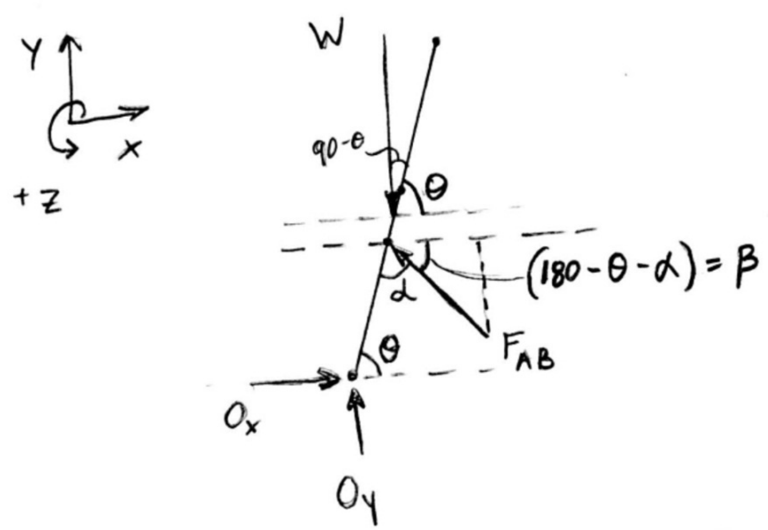


Figure 21: Free Body Diagram of Seat Frame

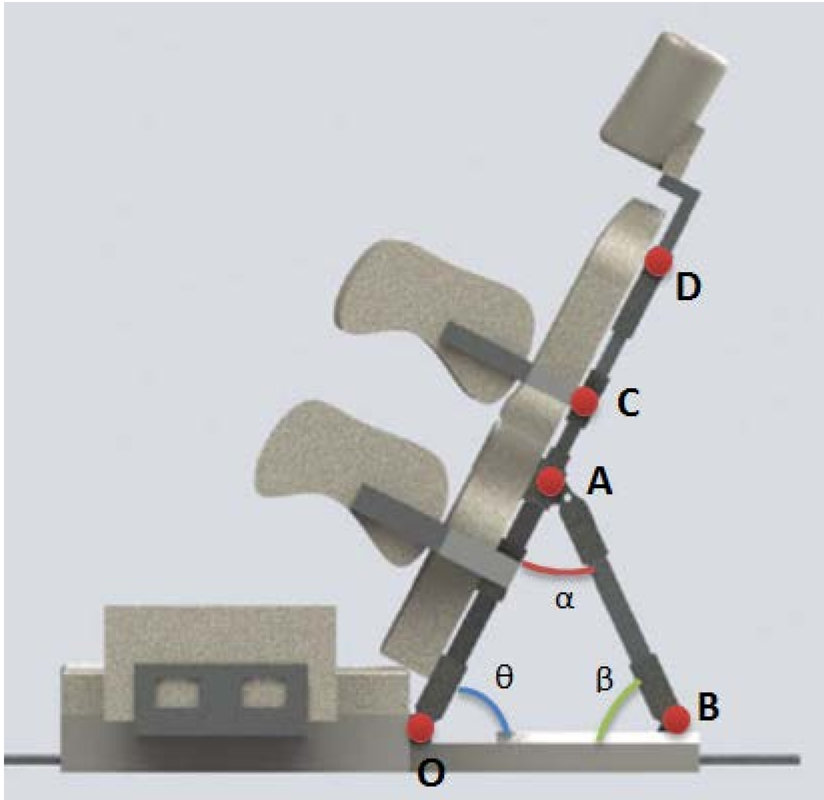


Figure 22: Points of Interest for Analysis

Figure 22 shows a left side view of how the frame was labeled to identify points of interest for the analysis. The frame was made up of three main members: the lower seat back (OC), the upper seat back (CD), and the sliding angle adjustment bar (AB). The angle theta, θ, describes the seat back angle and ranges from 65 to 90 degrees. Angles alpha, α, and beta, β, were used in the hand calculations to solve for the force in the sliding angle adjustment bar as shown in Appendix C.

We first performed a static analysis on the frame to discover the force in the member, AB as well as the reaction force at pin O. These forces were then used to find the maximum bending stress, $\sigma_{s\text{-}b}$, in the fully-extended seat back member OD along with the maximum compression, F_{AB}, in member AB. We focused the calculation on the case with both the upper and lower section of the frame in place because that resulted in the largest moment arm. The calculation results with respect to varying values of θ can be seen in Table 2 below. As we expected, the most reclined case where θ is 65^{o} resulted in the largest frame deflection. This analysis informed us that we needed to look into this specific case during testing in order to simulate the worst case loading scenario.

Table 2: Data from the Calculations with Respect to Seat Back Angle

θ (degrees)	F_{AB} (lb)	O (lb)	d_{AB} (in.)	$\sigma_{s\text{-}b}$ (psi)	$\delta_{s\text{-}b}$ (in.)
65	40.56	37.07	0.00015	4417.81	0.425
70	35.36	36.42	0.00013	3575.28	0.343
75	29.37	37.63	0.00011	2705.55	0.257
80	22.01	41.18	8.10E-05	1815.22	0.169
85	12.52	47.67	4.60E-05	911.08	0.083
90	0.00	57.80	3.70E-20	0.00	2.00E-17

As observed in Figures 52-56 in Appendix C, an increase in value of the seat back angle from horizontal (decreasing θ due to how the system was defined) leads to higher load, stress, and deflection seen by the frame. The only exception to this was the reaction force at joint O. That join experiences more compression when the load is smaller in the other sections of the frame. This result makes sense because as the seat back approaches vertical, more of the weight is distributed downward to joint O while less is distributed across the rest of the frame.

Cost Analysis

The cost analysis estimates, without shipping and handling fees, are presented in Tables 3-5 below. A complete table of all the vendors and their contact information can be seen in Appendix D. The components we ordered from the Adaptive Engineering Lab came out to cost just a little over $1000. The joints from Rose Krieger will cost us somewhere around $660. Finally, the other parts such as the plastic backing, foam sheets, and the off-the-shelf supplies are estimated to cost close to $450. Our budget was specified as $1,500, so we did end up going slightly over this budget with an exact total of $2,119.94. However, this was not a problem as there was extra money available from the RAPD grant. The APP wanted us to be able to buy the best parts available so that we could come up with a quality product and not have to settle for inferior, cheaper options.

Table 3: Cost Analysis for Adaptive Engineering Lab

Item	Size	Description	Quantity	Cost per Item	Total Cost
Seat Cushion	19"x19"2"	Anti-thrust, instead of Sweet Cheeks	1	174.00	174.00
Lateral Support Pad (Upper)	3"x5"	Plastic based Dartex pads	2	33.00	66.00
Lateral Support Pad (Lower)	4"x5"	Plastic based Dartex pads	2	33.00	66.00
Lateral Support Bracket	6"	Bracket to attach to clamp	4	25.50	102.00
Clamp Slide Release Bracket	8", 1" offset	Attach lateral to frame	4	69.00	276.00
Hip Support Pad	4"x8"x1"	Wood based, Dartex covered	2	33.00	66.00
Hip Pad Bracket	6"	Removable bracket	2	53.00	106.00
Headrest	5"x11"	Soft Dartex headrest	1	62.50	62.50
Headrest Bracket	8.5"	Bracket to attach to back	1	99.50	99.50
				TOTAL:	**1018.00**

Table 4: Cost Analysis for Rose Krieger

Item	Size	Description	Quantity	Cost per Item	Total Cost
FK30-4 Joint	30 mm	RD IND FLANGE CLAMP	4	34.80	139.20
GW30 Joint	30 mm	RD IND HINGE CLAMP	4	53.11	212.44
GF30 Joint	30 mm	RD IND HINGE CLAMP	2	52.46	104.92
W-KU Joint	30 mm	RD RK LIGHT ANGLE CLAMP (5-pack)	1	54.94	54.94
M30 Joint	30 mm	RD IND SLEEVE CLAMP	2	41.19	82.38
Clamping Levers	TBD	Eliminate wrench for sliding joints	2	35.64	71.28
				TOTAL:	**665.16**

Table 5: Cost Analysis of Additional Components

Item	Size	Description	Quantity	Cost per Item	Total Cost
Soft Foam	82"x24"x1"	Additional layer for seat cushion comfort	1	8.99	8.99
Polyethylene Foam	2'x4'x0.25"	Seat pad top layer	1	11.99	11.99
Polyethylene Foam	2'x4'x2"	Seat back comfort and strength	1	54.99	54.99
Seat Cover Skin	6'x4'x0.0625"	Polyethylene cover for the chair	1	7.99	7.99
HDPE Sheet	2'x4'x1"	Seat pad base plastic	1	99.25	99.25
HDPE Sheet	2'x2'x0.5"	Seat pad top and seat back plastic	3	24.81	74.43
Round Tubing	30mmx2mmx10'	Aluminum for the frame	1	92.46	92.46
Aluminum Block	2"x2"x12"	Cut out sliding clamps	1	20.52	20.52
Suction Cups	3.3"	Twist lock, connect seat pad to kayak	4	16.54	66.16
				TOTAL:	**436.78**

Material, Geometry, and Component Selection

Our material selection decisions were based largely on three factors: durability in a marine environment, strength for support and stability, and safety and comfort for users. In general, we chose to use the following materials for manufacturing: aluminum, stainless steel, HDPE plastic sheets, cross-linked polyethylene foam and skins, Styrofoam, and suction cups.

We chose aluminum for use in components that supported significant loads and that were large enough to contribute to the overall weight of the system. Aluminum is fairly durable in the corrosive marine environment and also has strength to weight ratio sufficient for our needs. We chose aluminum over stainless steel because of cost and weight considerations while maintaining similar or better durability. This selection was a slight tradeoff in strength of material, but the reduced strength of aluminum relative to stainless steel was counteracted by the geometry of structural components. Essentially, aluminum maximized the utility of the system. The following components were manufactured out of aluminum:

- Main frame supports
- Seat frame connectors

- Bulkhead and angle adjustment slide rails
- Sliding lateral support connectors

We chose stainless steel for use in small fasteners such as the screws used to hold the plastic sheets together. The strength and hardness of stainless steel would help in having fasteners that are reliable for our seat. The corrosion resistance of stainless steel will be adequate for our marine application. We were able to purchase our fasteners off-the-shelf from retailers like Home Depot or Lowes.

We used plastic in components with large surface areas that needed to be rigid. This mainly included the seat pan and seat back support structures. We used a high density polyethylene (HDPE) in order to maintain rigidity and durability of the components. These plastic sheets also added additional layers of strength to each of these components.

We decided to use cross-linked polyethylene foam for the padding components that would be in contact with the participants. It is closed-cell foam, meaning that it has low moisture permeability and will not rot away over time. This foam was covered with a smooth polyethylene skin that would not abrade the paddler's skin. The skin also provided a tough, extra waterproofing layer to ensure that the components inside did not get damaged by the environmental conditions.

We chose to go with Ram Mount suction cups, seen in Figure 23 below, due to their strength and ability to grab on easily to the surface of the kayak. These suction cups have a ball joint on the top to allow for easy attachment to the base of our seat. In addition, this suction cup was very simple to attach and remove due to its quick release lever that rotated about a vertical axis. The kinesiology students would simply need to attach the cup to a clean surface and turn the lever clockwise in order for the cup to grab on the surface. To remove this suction cup, the lever would be turned the opposite way.

Figure 23: Ram Mount Suction Cup

As previously stated in the cost analysis section, we tried to find as many premade parts as we could when looking to buy our materials for this product. We found several component manufacturing companies that sell various products that we incorporated into our design. By buying so many of our components from these retailers, we significantly cut back on our manufacturing time.

The first of these online retailers was the Adaptive Engineering Lab (AEL). AEL specializes in making parts that go on the seating systems of wheelchairs. They focus on being able to customize every component to the user's needs. The company is also known for providing safe, comfortable and easy to use products. After looking at all the components they had to offer, we selected several to attach to our main frame. We decided to incorporate the following parts from AEL:

- Lateral support pads, bracket, and connection piece
- Headrest pad and bracket
- Hip support pads and bracket
- Foot bulkhead boxes
- Anti-thrust seat cushion

The lateral support pads, shown below in Figure 24, are flat, plastic-based, Dartex-coated foam pads. We decided on the flat pads rather than the curved option to be sure to avoid any potential trapping of the passenger. Dartex is a smooth, polyurethane transfer coated fabric that is anti-bacterial, waterproof, anti-fungal, latex-free, stretchy, easy to clean, and breathable. For those reasons, we believed Dartex would be a very appropriate and safe covering for our parts. In order to more easily attach these pads to the main frame, we decided to go with the sliding clamp brackets as shown in the figure below. These brackets also allowed for adjustability up and down as well as side to side.

Figure 24: AEL's Lateral Support Pads and Sliding Clamps

The headrest and its respective bracket are shown below in Figure 25. The headrest pad is a made of soft, comfortable poly foam that is sealed by a removable Dartex covering. Since the headrest was not curved around the head, it did not run the risk of trapping the passenger in the rare event of capsize. This headrest attached to the bracket shown which was then secured to the main frame on the seat back. This bracket allowed for the headrest to slide up and down on the vertical axis to easily fit to different heights.

Figure 25: AEL's Headrest Pad and Bracket

Figure 26 below shows a picture of the hip support mounted on its quick-release bracket. It is a flat, wood-based, Dartex-coated foam pad. We were not worried about the fact that is a wood-based support because of its waterproof coating. We did not have any reason to believe that the properties of the wood would become compromised as long as it was protected by the layers of foam and polyurethane. The hip support pads were attached to brackets that came with an easy, one-hand, spring-loaded release and locking mechanism. This made it very simple to remove the hip support if the participant did not feel that they needed it.

Figure 26: AEL's Hip Support Pad

The foot support boxes that we planned on using are shown below in Figure 27. They have a plastic outer shell with fairly stiff padding on the interior. The shape of these foot boxes is very simple, yet efficient. The triangle on the side prevented the foot from sliding off to the outside which was helpful for people who have limited control of their legs. These boxes were mounted on an aluminum track that was able to slide back and forth through a slot in the seat pan's plastic base. The track was locked in place using a pin located behind the seat. The pin would drop into a hole in the track when it reached the appropriate location and would be secured by a bungee cord.

Figure 27: AEL's Foot Support Boxes

Figure 28 below shows the anti-thrust seat that we planned to use in our final design. The benefit of an anti-thrust seat is that it provides an increased step in the front that helps to hold a person's pelvis back on the seat. Without this angle of around 10°, some paddlers might unintentionally slide forward while out on the water and could potentially even fall off of the seat. Due to this newly discovered requirement, we chose to not use the Sweet Cheeks seat as originally intended. The Sweet Cheeks did not provide enough of an anti-thrust angle and it would be unnecessary if it was added to the top of the anti-thrust seat as an additional cushion.

Figure 28: AEL's Anti-Thrust Seat Cushion

The second online retailer is called Rose Krieger (RK). They focus on designing plastic, aluminum, and stainless steel joints for use in tube connecting systems. We planned on using their plastic and aluminum joints in our main frame design due to their simplicity and convenience. These joints saved us from having to weld the frame together which was nice because welding aluminum is no easy task. In addition, these joints made it much easier to slide components along the main frame and also made it easier to disassemble if necessary.

We decided to order flange clamps, hinge clamps, light angle clamps, and sleeve clamps. We also ordered a combination of plastic and aluminum joints and clamps. Aluminum was for the places with higher stress concentrations, while plastic was used in other areas to save some money. The joints can be seen in all of the back views of the design presented in the figures in the previous sections. These joints offered an elegant simplicity in creating a rugged and sturdy frame system that aligned effectively and allowed for simple adjustments to the seating system.

More information on our prospective vendors can be seen in Appendix D. Catalogs for the parts we wish to order are included at the end of this report. However, this is not an extensive list because some of our vendors did not provide catalogs.

Manufacturing Drawings

Our team has generated detail drawings for each one of the parts that we plan on using in manufacturing purposes. All of the parts that we will cut into or work with that were not ordered from online retailers can be seen in Appendix E. These detail drawings will tell us the necessary dimensions and allowable tolerances that we must stick to when we go to start manufacturing this kayak seat.

Safety Considerations

In order to evaluate the safety of our design, we first looked over a generic safety checklist to make sure there was nothing we were overlooking. We were able to determine that our design would be safe for the users since it does not have any rotating parts, sharp edges, large moving masses, flammable liquids, electrical components, or the like. It also had no risk of launching any projectiles or generating high levels of noise. There was no pressure stored in the system that the user or kinesiology students would have to worry about. We designed our product to be easier to use safely than unsafely.

The one safety consideration that was the biggest concern to us was the environmental conditions that the kayak seat would have to endure. The Morro Bay environment has high winds and cold temperatures due to its location by the ocean. The kayak seat components also run the risk of becoming worn down and corroded by the saltwater in the bay. Although the APP would only use this product a couple times per quarter, we still made it our goal to design the seat to be as resistant to the environmental conditions as possible. We managed to account for these risks to the best of our ability by using aluminum as the majority of the frame due to its resistance to corrosion. We also made the decision to cover the seat back with cross-linked polyethylene in order to protect the foam and plastic components that make up the seat. These decisions should help make safe upkeep a simple task.

Maintenance and Repair Considerations

Although we do not anticipate that this design will require maintenance often, it is simple to clean or repair due to its modularity. If the aluminum is rinsed with fresh water after each use it will help to further prevent any potential corrosion from the salty environment. The Dartex and polyethylene skin can also be easily wiped clean after each use. As long as this product is stored in a safe, dry environment, it should not run into degradation issues in the near future.

Any of the parts that we are ordering from AEL can easily be replaced by simply ordering a new part and screwing it into the bracket. If new suction cups are needed at the base of the seat, they can be removed via the slot in the seat pan and a new one can be slid into its place. If desired, one could also screw a cover plate over the slot in order to keep the seat pan from sliding away from the suction cup. Since the frame is made up of many different joints, it is fairly easy to replace a single piece of aluminum tubing if needed. You would simply need to unfasten the joint, remove the attached piece of aluminum tubing, and place the new one in its spot.

Chapter 5: Product Realization

After designing what the final prototype would look like in SolidWorks, we moved on to the manufacturing phase of the process. During this phase, we learned much more about our design and how various pieces of it had to change based on manufacturing limitations. This chapter details all of our manufacturing processes, discusses how the physical prototype differs from our computer model, and summarizes recommendations we have for future manufacturing.

Description of Manufacturing Processes

Frame

The most critical component of the Tide Rider 360 was the aluminum frame since that was what held everything together. The frame consisted of aluminum tubing of a 30 mm diameter and 2 mm thickness. We began by using a chop saw to cut the aluminum tubing down from its initial length of 10 feet to the sizes we had previously specified to fit the average person's torso height. The dimensions of each of the pieces of aluminum tubing can be seen in the SolidWorks detailed drawings in Appendix E.

The reason we purchased the aluminum tubing in metric units was so that it could fit in the 30 mm diameter Rose Krieger joints we planned on using to allow for a high level of adjustability. In order to get the joints to fit smoothly on the tubing, we used a lathe to remove 0.020 inches of the thickness of the aluminum, a process known as turning. Once the joints were able to slide easily onto the tubing, we were able to assemble the main structure of the frame. The layout of the various joints can be seen in Appendix E. The design of these joints dictated that they must be loosened or tightened via use of either crescent or Allen wrenches, so we had to make sure to leave enough room in between parts for these tools to be easily used.

To add another level of adjustability to the frame, we manufactured four sliding clamps that we used with the four lateral support arms. These clamps allowed for the lateral supports to slide in and out as well as up and down. In order to make these clamps, we first purchased a block of 6061 aluminum to cut down to size. Next, we used a drill press to drill a 1-1/8 inch diameter hole in each block to allow enough interference for a tight fit between the clamps and the tubing. A picture of this process can be seen in Figure 29. Once the hole was drilled, we cut the block across the hole with a vertical band saw to create the two sides of the clamp. Since we wanted to make the clamps as easy as possible to adjust, we drilled and threaded 1/4 inch holes in the blocks in order to add handle clamps. The handle clamps held the lateral support brackets by the use of pressure that was adjusted by handles. The handles loosened or tightened the contact between a flat plate and the lateral support brackets to control the adjustment of the lateral support pads from side to side. We also drilled and tapped 5/16 inch holes through the aluminum block through which bolts were used to control the adjustability of the sliding movement up and down the tubing. Once the clamps were finished they were cleaned up and detailed with a metal belt sander and pneumatic sander. A picture of one of the sliding clamps in its separated state can be seen below in Figure 30. A view of a fully assembled sliding clamp with the handle attachment is shown in Figure 31.

Figure 29: Drill Press for Sliding Clamps

Figure 30: Aluminum Sliding Clamp

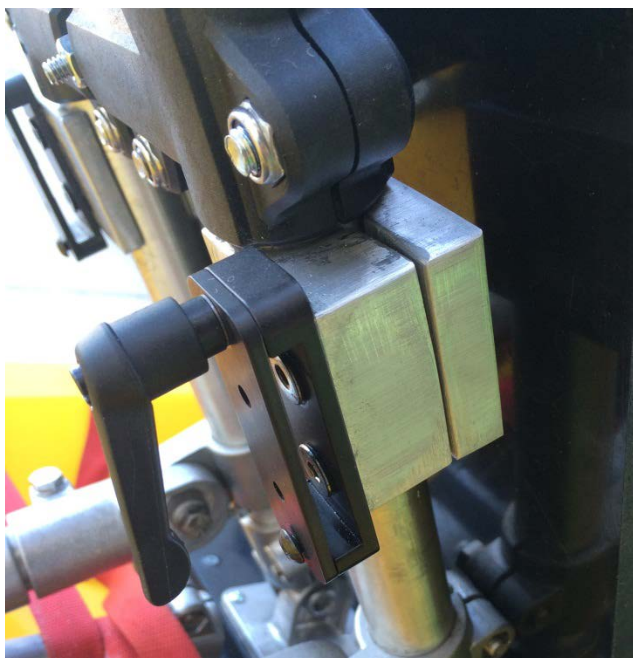


Figure 31: Aluminum Sliding Clamp on Frame

Seat Base

The seat base needed to be durable and stiff in order to help the kayak seat maintain its overall strength. Therefore, we manufactured that component out of HDPE. The seat base served as a mount for the frame as well as the anti-thrust seat cushion, so it needed to be as long and as wide as the combination of those parts. The seat base was designed in the shape shown below in Figure 32 to cover this total area while removing any unnecessary regions to help minimize the weight.

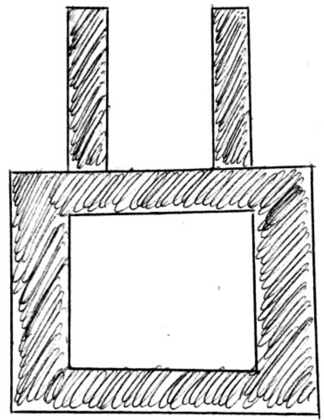


Figure 32: General Shape of Seat Base

In order to cut out this particular shape, we first used a table saw to get the overall rectangle cut out. We used a band saw to cut out the edges to begin forming the two back legs that would hold the frame. We used a jig saw to cut out the middle rectangle between the two legs and a rotary sander to smooth out any rough bits that were left by the saw blade. To cut out the middle rectangle under the seat cushion, we used an end mill in order to get a straight, smooth finish. Although this process was time consuming, it was critical to remove any excess weight to make the final product as light as possible. Figure 33 shows a view of the seat base HPDE clamped to the mill that was used to cut out this internal rectangle.


Figure 33: Milling of Seat Base

Once this final seat base shape was machined, we were able to secure the frame to the HDPE. The joints we chose fit flush against the plastic and we were able to secure them by simply drilling corresponding holes through which to place nuts and bolts. This joint mounting can be seen in Figure 34 below. The anti-thrust seat cushion was attached to the base by use of industrial strength Velcro strips. We attached one side of the Velcro to the seat cushion bottom and screwed the other side to the seat base to reduce the risk of it peeling off.

Figure 34: Joints Bolted to Seat Frame

In addition to being the attachment piece for the frame and the seat cushion, we also used the seat base to attach the suction cups. Since the suction cups came with a ball joint attachment, we took advantage of that and milled out a hole and slot for each ball joint to slide into. We milled the slots to be slightly larger than the diameter of the joint so that the suction cup would have some play in it to better adjust to the bottom contours of the kayak. A view of a suction cup in the milled out slot can be seen in Figure 35 below.

Figure 35: Suction Cup in Seat Base Slot

Seat Back and Cushions

The seat back plates were also made out of HDPE to give them strength and rigidity. We manufactured two pieces; one for the lower section of the seat back and a smaller portion for the upper section. To attach these plastic segments to the aluminum frame, we drilled holes through the HDPE and the tubing through which to stick bolts. We also used additional nuts as spacers to add some distance between the plastic and the frame to create the aforementioned additional room needed for tightening and loosening of the frame joints.

In addition to adding strength to the seat backing, these two HDPE segments also served as the mounting surfaces for the seat cushions. The upper and lower seat cushions were mounted with Velcro strips, just like the anti-thrust seat cushion. The Velcro strip placement can be seen in Figure 36 below. The seat cushions themselves were made out of a layer of super soft cushioning foam on top of a sheet of stiffer polyethylene foam. We sewed a smooth, water resistant, polyethylene skin cover over these two foams. We also sewed the Velcro strips to the polyethylene skin so that they would not peel off when removing the seat cushions from the HDPE backing. Figure 37 shows a close up of some of the stitching used on the seat cushions.

Figure 36: Placement of Velcro on Seat Cushion

Figure 37: Stitching on Seat Cushion

Support Pieces

Although all of the support attachments (lateral arms, hip supports, and headrest) were purchased from AEL, we still needed to determine the most effective ways to attach them to our particular seat. As previously stated, the lateral arms were attached via the use of sliding clamps that grabbed onto the arm extender pieces. The hip supports were attached directly to the HDPE seat base. In order to make the hip support placement adjustable, we drilled multiple sets of holes that could be used to bolt the hip support frame in place. The headrest cushion was screwed to a set of parallel bars which were then secured in a clamp that could slide up and down a long vertical bar. This vertical bar was bolted onto a small piece of HDPE that was in turn bolted onto the aluminum tubing on the backside of the seat frame.

Final Product

The final manufactured product is shown in Figures 38 through 40 below. These images display the front and back sides as well as a view of the seat positioned in a kayak. Although it is similar to what we had initially modeled, there are some minor differences that are discussed in the following section.

Figure 38: Final Product Front View

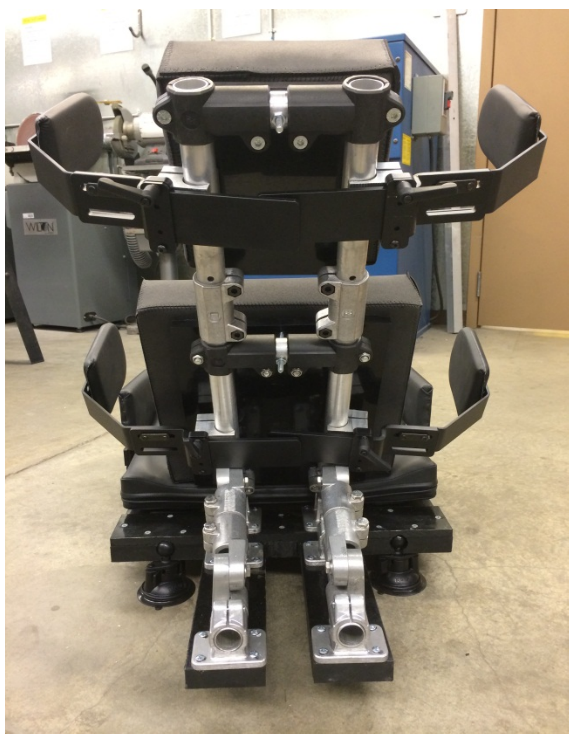


Figure 39: Final Product Back View

Figure 40: Final Product in Kayak

Differences between Prototype and Planned Design

During our manufacturing phase of this project, we ran into some problems with our original design plan and had to make some minor changes. None of these alterations changed the overall functionality of the seat. They were just small modifications that we did not quite account for in our initial design due to some lack of knowledge in the area of manufacturing.

One main difference between the final prototype and the initial design is that we cut out some portions in order to reduce the weight. Since the HDPE was the heaviest component of the seat, we tried to cut out as much of that as we could. This meant that we cut out the entire middle section of the base and only left enough plastic for the mounting of the frame and seat cushion. We also slightly modified the seat back to lessen the weight of the product. Instead of our initial idea of a full seat back "sandwich," we cut out the Styrofoam completely and made the HDPE backing sheets as small as possible without being too slight. The HDPE sheets were stiff enough to provide sufficient strength and rigidity without needed the additional Styrofoam layer and the smaller sheet sizes were more manageable to work with. One final change with regards to the seat back was the shape of the seat back cushions. It would not have been easy for us to have made the cushions into the more streamlined shapes we had previously planned on using. We instead spent less time by making the seat cushions square, but still small enough to allow for range of motion.

Another difference was that we did not end up having the time to manufacture a foot bulkhead apparatus for the kayak seat. This also diminished the need for conduit clamps, set pins, and bungee cords. However, even if we had time for this element, we would have modified the design from the initial idea to make it easier to manufacture and more lightweight.

Although we did machine the slots for the suction cups to fit into, we discovered that they did not provide the adjustability range we had anticipated. The suction cups were not quite able to all grab on to the inside of each kayak so we ended up having to make a late change in the mounting of the seat. We decided to use ratchet straps that could loop through the seat base and tie onto the pad eyes on the side of the kayak. The red attachment straps can be seen below the seat cushion in Figure 41.

Figure 41: Modified Seat Attachment to Malibu II

A final difference between the prototype and the planned design was that our design had us plan on using sliding clamps from AEL. We were forced to make our own clamps when these clamps did not fit our aluminum tubing well enough to get a strong grip. This is not a very significant difference though, due to the fact that the functionality is exactly the same as we had planned it to be.

Recommendations for Future Manufacturing

Manufacturing was a long and arduous part of this project and there were aspects that could have been planned out better. If this project were to be redone, the following are recommendations we have to make it easier to manufacture.

First of all, none of us had ever done any machining with HDPE before and we only really knew it because of its strength and its ease of access. HDPE, like any material, heats up very quickly when being machined. Unlike metals or wood, however, the plastic has a strong tendency to actually melt when it is cut or drilled. This property of the material made it difficult to manufacture quickly and cleanly. Cuts with a jig saw and the end mill had to be stopped often to allow the material to cool down and in the end, left rough edges that had to be filed down. Holes that we drilled often had some plastic residue left over at the other end of the hole. The only perfectly clean HDPE cuts came from using the table saw because it was able to cut quickly enough to separate the material before melting it.

Another recommendation we have for manufacturing would be to find a way to make a tool-less system. During manufacturing and testing, we spent a good amount of time on simply tightening and loosening bolts on the joints; time that could have been saved if we had determined a way to eliminate the use of tools. In addition, the bolts were sometimes difficult to get to due to components being too close to one another. It did not help that the joints purchased from RK did not seem to be of the highest quality. The joints took much longer to work with than we had expected, so a slightly modified seat frame design would most likely be easier to adjust on the go.

Chapter 6: Design Verification Plan

In order to ensure that we developed a fully functioning and safe design, we had to go through various testing procedures. If our design was not properly tested before its use out on the water, we would have been putting the participant's personal health and safety at risk. This chapter details the various tests we performed in order to verify that this design met our specified engineering requirements.

Test Descriptions and Results

After we constructed our product, we needed to test it to make sure that it met all of our previously listed engineering and customer criteria. There were various methods of testing available to us such as data collection and analysis, physical testing, comparison to existing designs, and visual inspection. We tried to use visual inspection and similarity to existing designs as much as possible because they were very effective for testing our product against the specified requirements without the arduous time demands of analysis and physical testing.

Visual inspection was sufficient on parameters such as the seat pan width, seat pan length, seat back height, and modularity of the design. The seat pan only needed to be able to fit within the allotted space in each of the kayaks so that was simple to test via inspection. The seat back height needed to be tall enough to provide sufficient room for two levels of lateral support along with a properly placed headrest for the average person. The target dimensions for each of these parameters can be found in the table of engineering requirements (Table 1). As for modularity of the design, we specified that we needed the seat back to be at least two separate pieces which was also easily verified by visual inspection.

Other parameters such as surface roughness, overall material selection, and life expectancy required more than just visual inspection. The surface roughness of the padding that came in contact with the participants could have either been tested by physically testing it via skin contact or by using similarity to existing designs. We chose to test this by similarity to existing designs and determined that it would not abrade the participant's skin. The rest of the materials were also tested in the same way. For example, since aluminum has proven to be more resistant to corrosion in other applications, we had confidence in using aluminum in our design. The lifetime of our design was estimated based on similar models. Our seat's overall structure was fairly similar to that of the Creating Ability kayak seat so its lifetime should be comparable to that of theirs.

Additionally, specifications such as the amount of weight that could be supported by the lateral supports, hip supports, and headrest was evaluated based on the success that AEL has had using them. We know that these products have worked in wheelchair designs and we were not planning on attaching them any differently than they would be attached to a wheelchair. The components would experience the same amount of force on them in either case. Therefore, we were able to confidently say that these parts would not fail and could provide sufficient support to a paddler when attached to our kayak.

We also performed technical analysis on some components such as the seat frame and the support rods behind the seat that acted in the seat back angle adjustment process. This analysis helped to verify that these components were safe and have a reasonable factor of safety. For our tests, we decided to use a strong floor which is essentially a large clamping area. We built a simple test stand out of HPDE that could be bolted to this strong floor as shown in Figure 42 below. The kayak seat frame was bolted onto the testing frame exactly how it would be attached to the actual seat base.

Figure 42: Test Stand Mounted to Strong Floor

We had initially wanted to test the seat frame by using a combination of a load cell and actuator as shown in Figure 43 below. The actuator would provide a constant force that would pull on the frame while the load cell would be able to measure that force. However, the digital readout required for this test was not functional at the time of our testing.

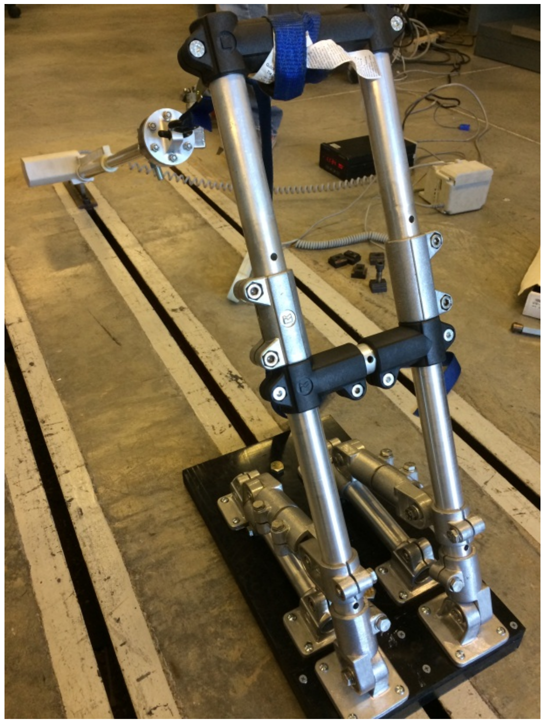


Figure 43: Test Setup with Actuator and Load Cell

Therefore, in order to perform some type of loading test, we decided to make use of a pulley system to hang weights off of the seat frame. We tested the worst case loading scenario by hanging weights off of the upper back member of the frame where we expected the highest moment. We suspended weights up to 100 pounds off the back by using a pulley system. The seat back experienced minimal deflection and bending even when the weight was applied for an extended period of time. We were limited to applying only 100 pounds since that was all that was available at the time of the testing. However, we found that this amount was just what we needed to simulate the applied weight of a 200 pound person since the weight applied on the frame by the user is about half of their total weight. Thus, the frame proved to withstand the load if a 200 pound person were to sit in the seat. Figure 44 shows a view of the frame mounted on its test stand to the strong floor with the weights hanging off of the upper back member.

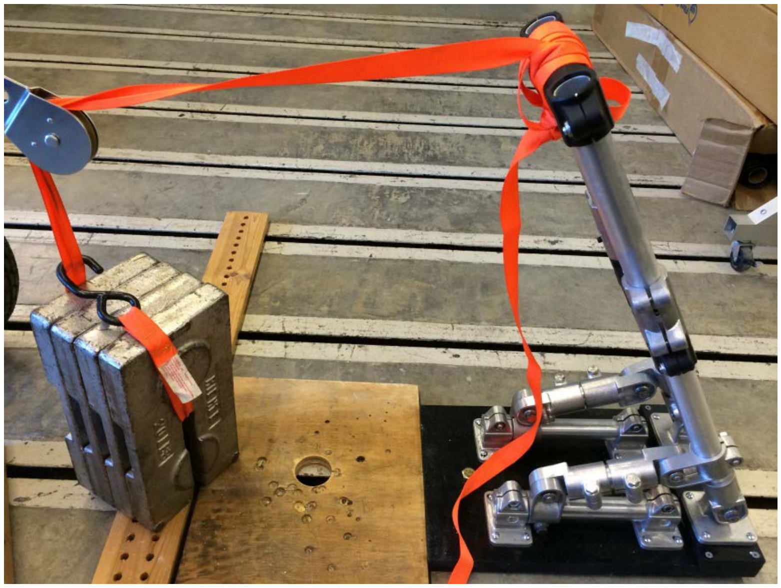


Figure 44: Hanging Weights Test

APP Testing

In addition to formal testing, we were planning on taking our product to the spring APP training and participant weekends for customer testing. We wanted to get feedback from the participants by putting the product in its true environment with its intended users. Feedback from the customers would have been the most beneficial to us because it would have enabled us to see the design from their point of view and understand which features they find most or least useful. However, since we were not able to meet this deadline, we instead had to test the kayak seat in the Cal Poly pool with our sponsor and APP coordinator, Tom Reilly. He is somewhat of an expert in the field of kayaking so even though we were unable to get a paddler with disabilities to test our seat, we could rely on Tom's feedback to be of high quality.

As expected, Tom was able to give us useful criticism on the performance of our prototype as well as recommendations for future changes. One of his main comments was that it would be better if the hip and lateral supports were more prominent. The seat cushions and anti-thrust seat were a little thicker than we had initially planned, so the supports did not stick out as far as Tom would have liked. As shown in Figure 45 below, it can be seen that the lateral support and hip support pads would need to be lengthened a bit in order to truly be effective. They do not quite reach far enough as is, especially since the lifejacket, or personal flotation device (PFD), adds some thickness to the paddler. For the hip supports, Tom suggested that we attach them to the sides of the kayak instead of at the HDPE seat base. That way, the hip supports could accommodate wider paddlers and one would simply need to add some foam blocks to fit it to smaller paddlers. The hip supports could be attached to the kayak side by using metal tracks bolted onto the sides.

Figure 45: Tom Testing AEL Supports

However, Tom was pleased with the fact that the AEL lateral supports could be slightly angled to provide a closer fit to one's body. Figure 46 shows the lower lateral supports angled more toward Tom's body to better hold him in place while kayaking. The image also shows that the amount of room between the upper and lower supports provides an appropriate range of motion. He commented that it felt more supportive when the lateral supports were higher up on the aluminum tubing.

Figure 46: Tom Testing Angled AEL Supports

Another suggestion Tom supplied was that the angle adjustment bar could be simply locked in at one of two locations by use of pins. During his time in the seat, he felt that he would either like to be using it in fully reclined mode for comfort, or in a more upright mode for paddling purposes. He did not believe that the level of fine tuning we had provided was fully necessary and suggested that a drop-in-pin system would make it easier on the assistant kinesiology students. Figure 47 below demonstrates the difference in seat back angle between a more vertical paddling mode (left) and a leisurely, comfort mode (right).


Figure 47: Suggested Levels of Seat Back Angle

Tom also proposed that we find some way to fill out the space between the upper support cushion and the headrest. In fully reclined position, there is a slight gap there that could be filled in with small foam pieces if necessary. Alternatively, Tom mentioned that if we could have the upper portion at a slightly different angle than the lower section, that offset would solve the problem of the gap. Through comfort testing, we determined that having an angle of about 135 to 145 degrees from lower to upper portions would be ideal. This could be achieved by either buying an angled joint to replace the current one or by bending an aluminum tube to that angle. A view of this idea is shown in Figure 48.

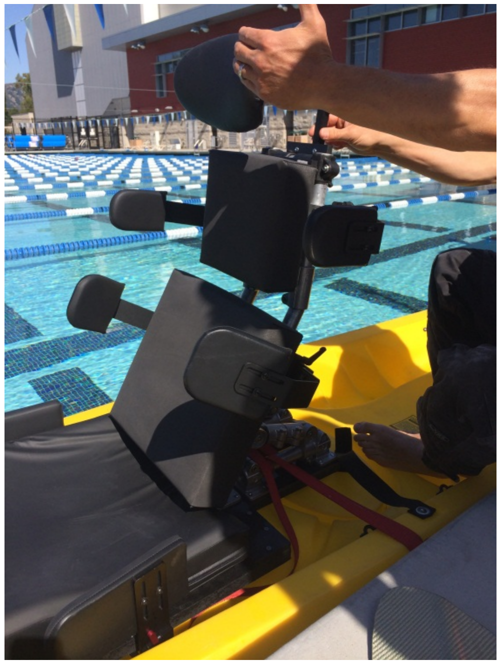


Figure 48: Proposed Angle between Upper and Lower

Despite these concerns, Tom did speak highly of the seat, saying that it was much more comfortable and supportive than what they are currently using. He believed that the weight distribution worked out well and would not cause any additional tip over problems. He was pleased with the modularity of the design and specified that even just the lower half of the seat (upper portion and headrest removed) would be highly beneficial to the participants and easy to use.

Design Verification Plan and Report

Our group outlined a design verification plan and report (DVP&R) on the following page in Tables 6 and 7. The purpose of this plan was to list out all of the requirements that we needed to test in some way, whether it be by inspection, similarity, analysis, or physical testing. This table also gives a brief description of the testing method that was used to check whether or not each requirement met its listed specifications within tolerance. The DVP&R provides a breakdown on who will perform which test, during what stage of design process each stage will be performed (DV being the design verification phase when the product is being manufactured), and the predicted start and finish dates of the test. The samples that are type B refer to the test being able to be completed during the design verification phase while the samples that are type C need to wait to be verified until the product is complete. This plan helped to keep our group on track with our testing procedures. The report shown in Table 7 shows the results of our testing.

Table 6: Design Verification Plan

Item No	Specification	Test Description	Acceptance Criteria	Test Responsibility	Test Stage	SAMPLES TESTED		TIMING	
						Quantity	Type	Start date	Finish date
1	Seat Pan Width	Visual inspection of how it fits in kayak	17-20 in	Audrey	DV	1	B	Feb	April
2	Seat Pan Length	Visual inspection of how it fits in kayak	17-20 in	Audrey	DV	1	B	Feb	April
3	Seat Back Height	Visual inspection of the amount of room that the two sets of lateral supports need to fit properly	20 in MIN	Audrey	DV	1	B	Feb	April
4	Modularity	Visual inspection of how many parts this design can be separated into	2 parts MIN	Andrea	DV	1	B	Feb	April
5	Seat Back Angle	Visual inspection of how much it can move	65<theta<90	Audrey	DV	1	B	Feb	April
6	Surface Roughness	Physical and/or visual test of its abrasive properties	Non-abrasive	Andrea	DV	1	C	Feb	April
7	Product Weight	Test weight using a scale	40 lbs MAX	Andrea	DV	1	C	Feb	April
8	Force for Seat Pan Removal	Physically test this against some object with a known removal force	15 lbs MAX	Irvin	DV	1	C	Feb	April
9	Force for Seat Back Removal	Physically test this against some object with a known removal force	15 lbs MAX	Irvin	DV	1	C	Feb	April
10	Force for Sliding Adjustments	Physically test this against some object with a known sliding force	15 lbs MAX	Irvin	DV	6	C	Feb	April
11	Weight Supported by Seat Back	Perform a force analysis on this component	200 lbs MIN	Grant	DV	1	B	Feb	April
12	Weight Supported by Head Rest	Use test data from AEL	30 lbs MIN	Grant	DV	1	B	Feb	April
15	Weight Supported by Lateral Supports	Use test data from AEL	150 lbs MIN (each)	Grant	DV	4	B	Feb	April
16	Product Life	Comparison to how long Creating Ability seat can last	5 years MIN	Irvin	DV	1	B	Feb	April

Table 7: Design Verification Results

Item No	Specification	TEST RESULTS			NOTES
		Test Result	Quantity Pass	Quantity Fail	
1	Seat Pan Width	Pass	1	0	19 inches
2	Seat Pan Length	Pass	1	0	19 inches
3	Seat Back Height	Pass	1	0	23.5 inches
4	Modularity	Pass	1	0	Upper and Lower
5	Seat Back Angle	Pass	1	0	
6	Surface Roughness	Pass	1	0	Similarity
7	Product Weight	Pass	1	0	35 pounds
8	Force for Seat Pan Removal	Pass	1	0	
9	Force for Seat Back Removal	Pass	1	0	
10	Force for Sliding Adjustments	Pass	6	0	
11	Weight Supported by Seat Back	Pass	1	0	Hanging Weights
12	Weight Supported by Head Rest	Pass	1	0	Similarity
15	Weight Supported by Lateral Supports	Pass	4	0	Similarity
16	Product Life	Pass	1	0	Similarity

Chapter 7: Conclusion

We are very excited to have completed this kayak seat for the Adaptive Paddling Program. We hope that it can help them run their program more smoothly in the future and give the participants an even more enjoyable time out on the water. We greatly appreciate the chance we were given to work with the coordinators of the APP on this inspirational project. In addition, it was a pleasure to meet some of the participants that would potentially use this seat and to see their faces light up when they were out on the water. Even though we did not get the chance to complete some components such as the foot bulkhead and the cup holder add-on, we still personally believe that this project was successful and are proud of what we have managed to put together in a year's time. This senior project has taught us so much and we are grateful to have been given this opportunity.

Figure 49: Team Photos at Senior Project Expo

References

This section is a compilation of all of our team's work throughout this design process. The following appendices contain documents from specification tables to idea generation charts to detailed drawings of our final design. We have also listed vendor information and catalogs in these reference pages.

Appendix A: Objectives and Requirements

Table 8: Table of Customer Requirements

Formal Customer Requirements for Adaptive Kayak Seat		
Specification No.	**Requirement Description**	**Priority**
1	Provide the Least Restrictive Environment for the Customer	High
2	Make Seating more Durable by Cutting Back on Duct Tape Usage	High
3	Provide a Fully Padded Seat for Comfort	Medium
4	Offer Full Lateral Support	High
5	Offer Full Neck Support	High
6	Offer Full Back Support	High
7	Must not Trap Passengers in Case of Tip-Over	High
8	Adapt to the Needs of Different Paddlers	High
9	Avoid Pressure Points on the Body to Prevent Tremors or Spasticity	High
10	Be Durable Enough to Withstand a Windy, Saltwater Environment for Extended Time Periods	High
11	Be able to Attach to a Wide Variety of Kayaks	Medium
12	$1500 Overall Budget	Medium
13	Allow for Full Range of Shoulder Movement if Paddler Desires	High
14	Make it Wide Enough to Fit Larger Customers	Medium
15	Have Detachable Neck Support	Medium
16	Fit the Boat to the Person so that the Person Wears the Boat	High
17	Keep Small Parts in Check	Medium
18	Make the Seat Easily Adjustable	High
19	Remove the Old Factory Seat	High
20	Have the Seat Modular in Design so that at Least the Upper Half is Removable	High
21	Prevent Paddler from Leaning from Side to Side	High
22	Add a Cup or Bottle Holder to the Seat	Low
23	Add a Canopy to Shield from Environment	Low
24	Make a DIY Kit for Self-Assembly	Low

Table 9: Quality Function Deployment

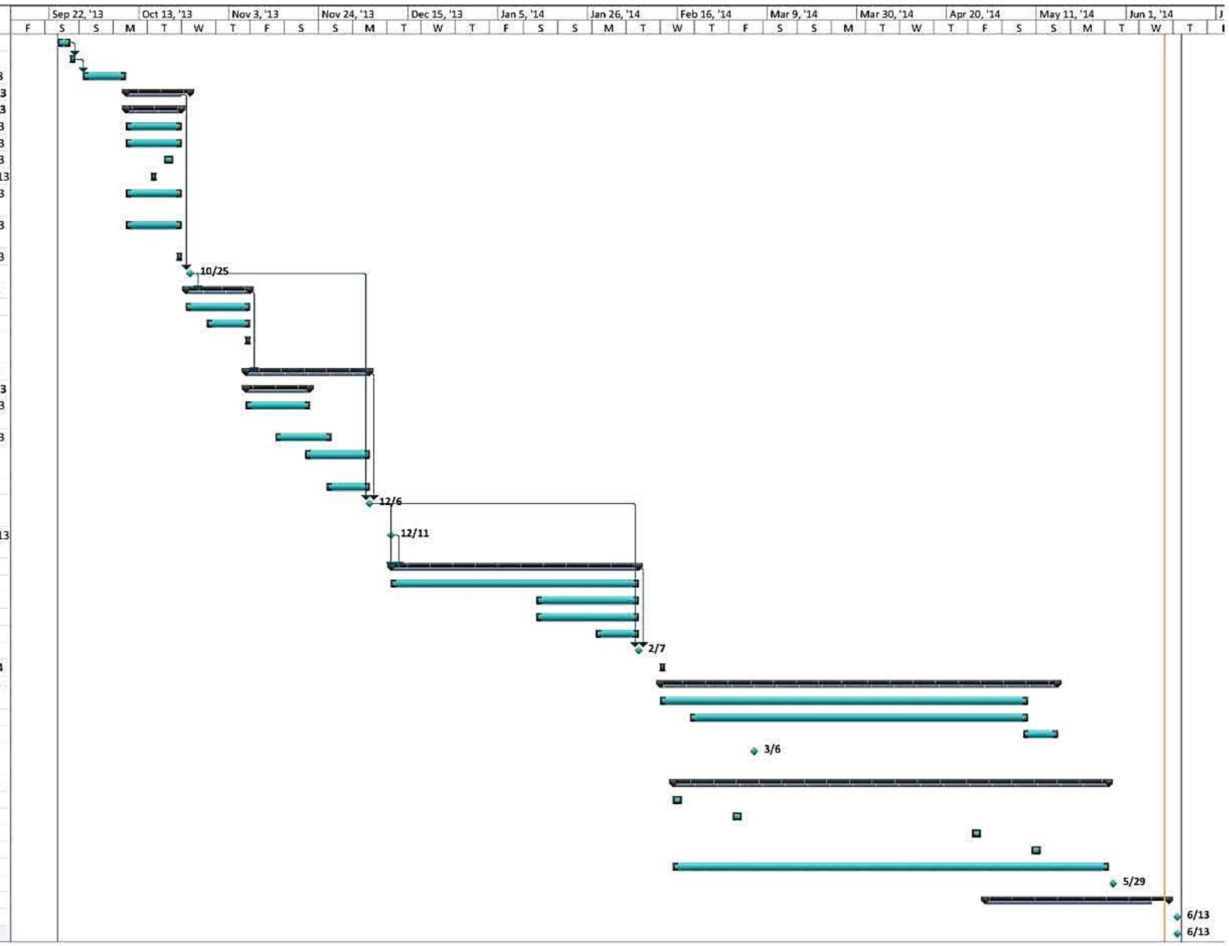
Team: Adaptive Kayak Systems
Product: Tide Rider 360

Engineering Requirements (HOWS)

Customer (Step #1) Requirements (Whats) / Customer Requirements (Step #2)	Weighting (Total 100)	Trunk Support (Pelvic and Upper Rib Cage Region)	Back Support (Full Thoracic Region)	Neck Support (Full Cervical Spine and Weight of Head	Weight Supported by Back Rest	Seat Recline Angle	Force/Pad Eye	Force on Side Adjustments	Force for Seat Back Removal	Surface Roughness (Non abrasive)	Seat Pan Width	Seat Pan Length	Seat Pan Height	Modular/Removable	Material Selection (Corrosion Resistant)	Lifetime	Product Weight	Productio Cost			Benchmarks: Creating Abilities		
Provide LRE	4.04	•	•	•		○															○		
Durable Seating (Use and Abuse)	3.68	Δ	Δ	Δ	Δ									Δ	•	•					•		
Fully Padded Seating	5.51	•	•	•						•	•	•	•		•	•	•				•		
Full Neck/Back Support	6.99	•	•	•	•	•	Δ	○	○	•			•	•	•	•	•				•		
Doesn't Trap Participant	8.09	•	•	•		○					•	○	Δ								•		
Adapt to All Users (Fit Boat to Person)	4.78	•	•	•	•	•	○	○		•	•	•	•	Δ			○	○			•		
Avoid Pressure Points	6.25	•	•	•		Δ	Δ	Δ		•	•	•	•	○	Δ						•		
Fit to a Variety of Kayaks (3 main types)	2.21	○	○	○	○	•	•	Δ			•	•	•	•			•	○			Δ		
Durable In Marine Environment	3.68	•	•	•						Δ				Δ	•	•		○			•		
Easy Attachment	3.31	•	•	•					•		○	○	○	•		○	○	○			○		
Easy Entry/Exit	6.25	•	•	•		○	Δ			Δ	○	○	○								•		
Lateral Support	6.25	•	•	•		○	○	•		Δ	•	○	•	•	•	•	•				•		
Modular (removable in parts or in full)	2.57	•	•	•		Δ	○	○	•		•	•	•	•	•	•	•	•			•		
Fit Range of Mobilities - Allow for User's Full Range of Motion	3.68	•	•	•	•	•	○	○		•	•	•	•	•									
Wide Enough for larger customers	4.04	•	•	•				•			•	•	•	•		•	○	Δ			○		
$1500 Budget	1.1									Δ					•	•	•	•					
Detachable Neck Support	4.04			•	○					•			•	•			•	•					
Keep Small Parts In Check	1.47	Δ	Δ	Δ		Δ								•		○		○			○		
Easy Adjustable	6.99	•	•	•		•		•						•		Δ		○			•		
Remove Old Factory Seat	8.46										○	○	○				Δ						
Prevent Paddler from Leaning to the Sides	6.02	•	•	•	○	•	•	•		Δ	•	•	•										
Add Cup/Bottle Holder	0									Δ							○	•					
Canopy To Shield User from Environment	0									Δ					•	○	•	•					
DIY Kit for Self-Assembly	0													•		○		•			•		
Units					lbs	deg	lbs	lbs			in	in	in	pieces		yrs	lbs	$					
Targets					200	80-100	100	5			15-20	16-19	20	2		5	20	500					
Benchmark #1			•	Δ	•	○	Δ	Δ		○	Δ	Δ	Δ	•	•	•	○						
Benchmark #2																							

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

ID	WBS	Task Mode	Task Name	Duration	Start	Finish
1	1		Project Presentations	3 days	Tue 9/24/13	Thu 9/26/13
2	2		Team Selection	1 day	Fri 9/27/13	Fri 9/27/13
3	3		Team Development	8 days	Mon 9/30/13	Wed 10/9/13
4	**4**		**Project Definition**	**11 days**	**Thu 10/10/13**	**Thu 10/24/13**
5	**4.1**		**Background Research**	**9 days**	**Thu 10/10/13**	**Tue 10/22/13**
6	4.1.1		Patent Search	9 days	Thu 10/10/13	Tue 10/22/13
7	4.1.2		Internet Research	9 days	Thu 10/10/13	Tue 10/22/13
8	4.1.3		APP Training	2 days	Sat 10/19/13	Sun 10/20/13
9	4.2		Sponsor Meeting	1 day	Wed 10/16/13	Wed 10/16/13
10	4.3		Customer Requirements	9 days	Thu 10/10/13	Tue 10/22/13
11	4.4		Engineering Requirements	9 days	Thu 10/10/13	Tue 10/22/13
12	4.5		QFD	1 day	Tue 10/22/13	Tue 10/22/13
13	5		Project Proposal	0 days	Fri 10/25/13	Fri 10/25/13
14	**6**		**Conceptual Generation**	**11 days**	**Thu 10/24/13**	**Thu 11/7/13**
15	6.1		Idea Generation	11 days	Thu 10/24/13	Thu 11/7/13
16	6.2		Foam Modeling	8 days	Tue 10/29/13	Thu 11/7/13
17	6.3		Conceptual Design Presentations	1 day	Thu 11/7/13	Thu 11/7/13
18	**7**		**Concept Selection**	**21 days**	**Thu 11/7/13**	**Thu 12/5/13**
19	**7.1**		**Conceptual Analysis**	**11 days**	**Thu 11/7/13**	**Thu 11/21/13**
20	7.1.1		Controlled Convergence	11 days	Thu 11/7/13	Thu 11/21/13
21	7.2		Component Selection	9 days	Thu 11/14/13	Tue 11/26/13
22	7.3		Concept Sketches/Models	11 days	Thu 11/21/13	Thu 12/5/13
23	7.4		Testing Plan	8 days	Tue 11/26/13	Thu 12/5/13
24	8		Conceptual Design Report	0 days	Fri 12/6/13	Fri 12/6/13
25	9		Conceptual Design Review	0 days	Wed 12/11/13	Wed 12/11/13
26	**10**		**Detailed Design**	**42 days**	**Wed 12/11/13**	**Thu 2/6/14**
27	10.1		Detailed Drawings	42 days	Wed 12/11/13	Thu 2/6/14
28	10.2		Engineering Analysis	18 days	Tue 1/14/14	Thu 2/6/14
29	10.3		Bill of Materials	18 days	Tue 1/14/14	Thu 2/6/14
30	10.4		Defined Test Plan	8 days	Tue 1/28/14	Thu 2/6/14
31	11		Design Report	0 days	Fri 2/7/14	Fri 2/7/14
32	12		Critical Design Review	1 day	Wed 2/12/14	Wed 2/12/14
33	**13**		**Manufacturing**	**67 days**	**Wed 2/12/14**	**Thu 5/15/14**
34	13.1		Purchase of Materials	62 days	Wed 2/12/14	Thu 5/8/14
35	13.2		Construction	57 days	Wed 2/19/14	Thu 5/8/14
36	13.3		Safety Checklist	6 days	Thu 5/8/14	Thu 5/15/14
37	14		Manufacturing and Test Review	0 days	Thu 3/6/14	Thu 3/6/14
38	**15**		**Testing**	**73 days**	**Sat 2/15/14**	**Tue 5/27/14**
39	15.1		APP Testing	2 days	Sat 2/15/14	Sun 2/16/14
40	15.2		APP Testing	2 days	Sat 3/1/14	Sun 3/2/14
41	15.3		APP Testing	2 days	Sat 4/26/14	Sun 4/27/14
42	15.4		APP Testing	2 days	Sat 5/10/14	Sun 5/11/14
43	15.5		Independent Testing	73 days	Sat 2/15/14	Tue 5/27/14
44	16		Design Expo	0 days	Thu 5/29/14	Thu 5/29/14
45	**17**		**Final Report**	**31 days**	**Tue 4/29/14**	**Tue 6/10/14**
47	18		Final Report	0 days	Fri 6/13/14	Fri 6/13/14
48	19		Library Submission	0 days	Fri 6/13/14	Fri 6/13/14



Project: AKS Gantt Chart
Date: Tue 6/10/14

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

Page 1

Figure 50: Gantt Chart

Appendix B: Design Development

Figure 51: Morphological Matrix

Table 10: Lateral Support Pugh Matrix

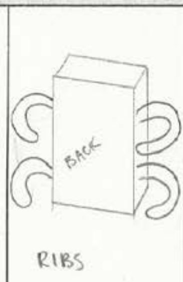
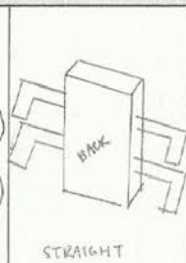
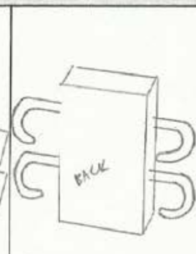
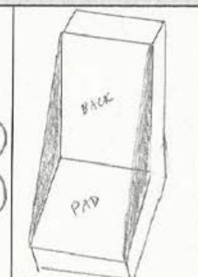
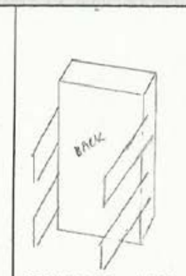
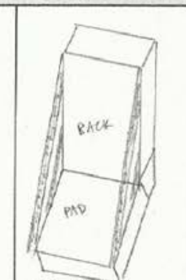
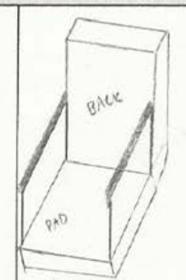
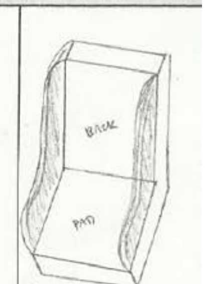
	Concepts								
	See Pictures From Previous Page	 RIBS	 STRAIGHT BENDS	 1+2 COMBO	 FULL SIDE PADS	 STRAIGHT ARMS	 SIDE STRAPS	 ARMRESTS	 SIDE CUSHIONS
	Datum	1	2	3	4	5	6	7	8
Criteria									
A		S	S	S	+	-	+	-	+
B		S	S	S	S	S	S	-	-
C		+	S	+	-	S	+	-	-
D		S	S	S	S	S	S	S	S
E		S	+	+	-	S	+	+	-
F		S	S	S	S	S	S	S	S
G		-	S	-	+	S	-	-	+
Σ+		**1**	**1**	**2**	**2**	**0**	**3**	**1**	**2**
Σ-		**1**	**0**	**1**	**2**	**1**	**1**	**4**	**3**
ΣS		**5**	**6**	**4**	**3**	**6**	**3**	**2**	**2**

Table 11: Back Support Pugh Matrix

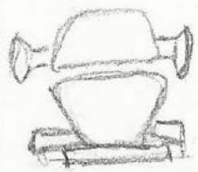
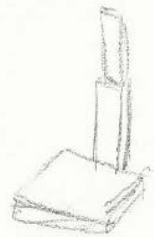
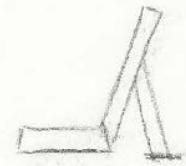
Design Criteria/Back Support Style	 C. A. Seat (Datum)	 Single Bar	 Double Bar	 Skeletal Frame	 Kick-Stand	 Straps
A	+	+	+	+	+	-
B	+	-	+	+	-	+
C	-	+	+	-	-	-
D	+	-	-	S	-	+
E	+	+	+	+	+	-
F	+	+	+	+	+	+
G	+	+	+	+	+	+
H	-	-	-	-	-	+
I	+	+	+	+	+	+
J	+	+	+	+	+	-
$\Sigma+$	8	7	8	7	6	6
$\Sigma-$	2	3	2	2	4	4
ΣS	0	0	0	1	0	0

Table 12: Seat Back Angle Pugh Matrix

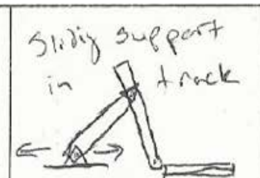
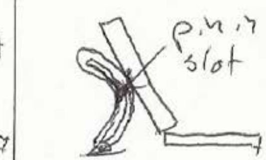
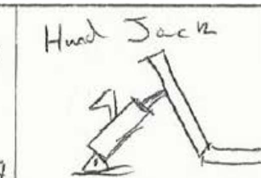
	 **Bar on Rails Behind Seat**	 **Sliding Track Behind Seat**	 **Notched Seatback**	 **Sliding Pin in Slot**	 **Hydraulic Jack Behind Seat**	 **Straps between Back and Seat**
A	0	+	-	-	+	+
B	+	0	+	0	-	+
C	0	0	0	0	0	0
D	+	+	0	0	+	0
E	+	+	0	0	+	-
F	-	+	-	+	+	-
Positive	3	4	1	1	4	2
Negative	1	0	2	1	1	2
Same	2	2	3	4	1	2

Table 13: Top Three Conceptual Design Descriptions

		Concepts		
		1	2	3
Components/Subsystems	Lateral Attachment	Straps	Sleeves with Button	Sleeves with Pin
	Hip Support	Straps	Sliding Trays	Sliding Trays
	Bottom Attachment	Suction Cups with Foam and Sweet Cheeks	Suction Cups with Springs	Suction Cups with Springs
	Head/Neck Support	Airplane Style (Circular)	Airplane Style (Rectangular)	Airplane Style (Circular)
	Lateral Support	Straps	Bent Arm	Bent Arm
	Back Support	Double Spine	Double Spine	Double Spine
	Seat Angle	Straps	Hydraulic Jack	Track
	Component Separation	Slide in with Buckle	Slide in with Hinge	Pin in Hinge
	Material	Aluminum, Stainless Fasteners, Carbon Fiber, Memory Foam, Plastic, Sweet Cheeks	Aluminum, Stainless Fasteners, Carbon Fiber, Memory Foam, Plastic, Sweet Cheeks	Aluminum, Stainless Fasteners, Carbon Fiber, Memory Foam, Plastic, Sweet Cheeks
	Seat Pan	Sweet Cheeks	Sweet Cheeks	Sweet Cheeks
	Seat Back	Open Shoulder Section	Open Shoulder Section	Open Shoulder Section
	Foot Support Bulkhead	Slide out from Under Seat Pan	Slide out from Under Seat Pan	Slide out from Under Seat Pan

Appendix C: Detailed Supporting Analysis

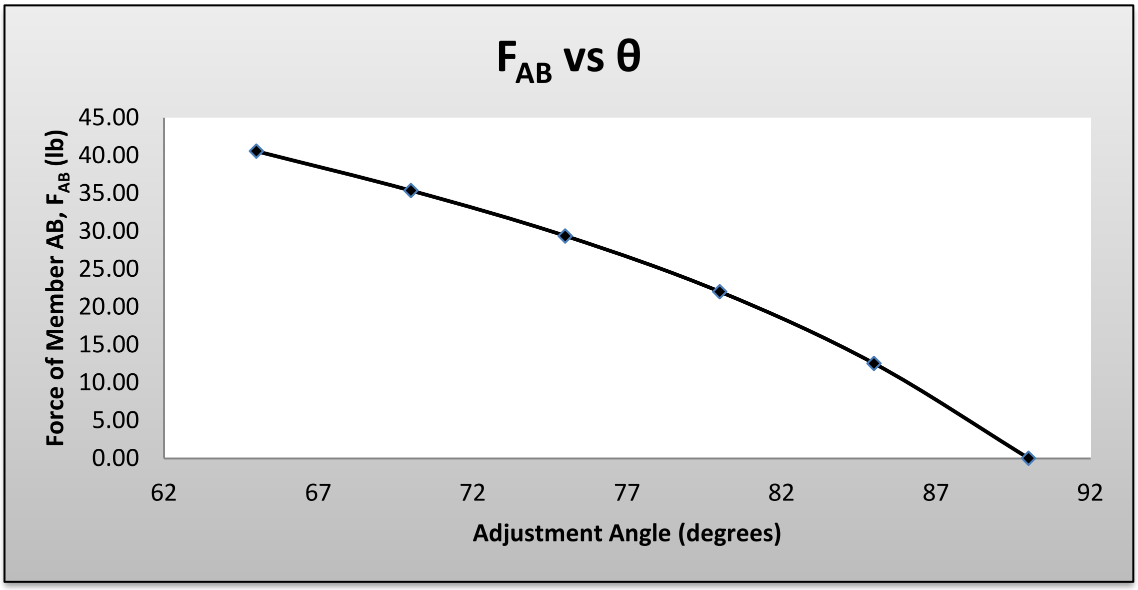


Figure 52: Force in AB vs. Seat Back Angle

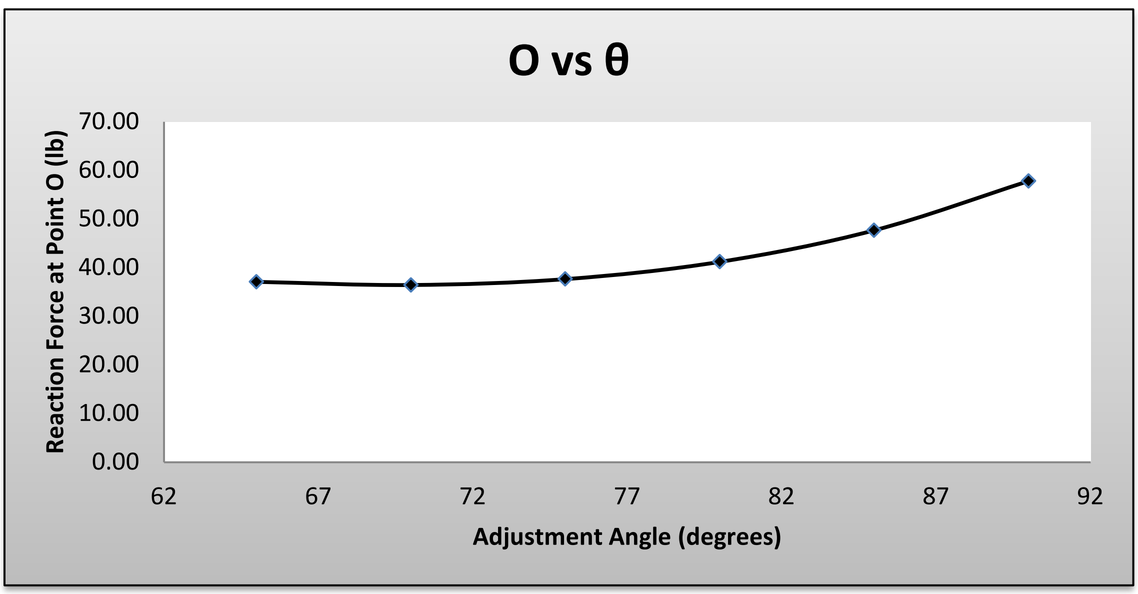


Figure 53: Force at Pin O vs. Seat Back Angle

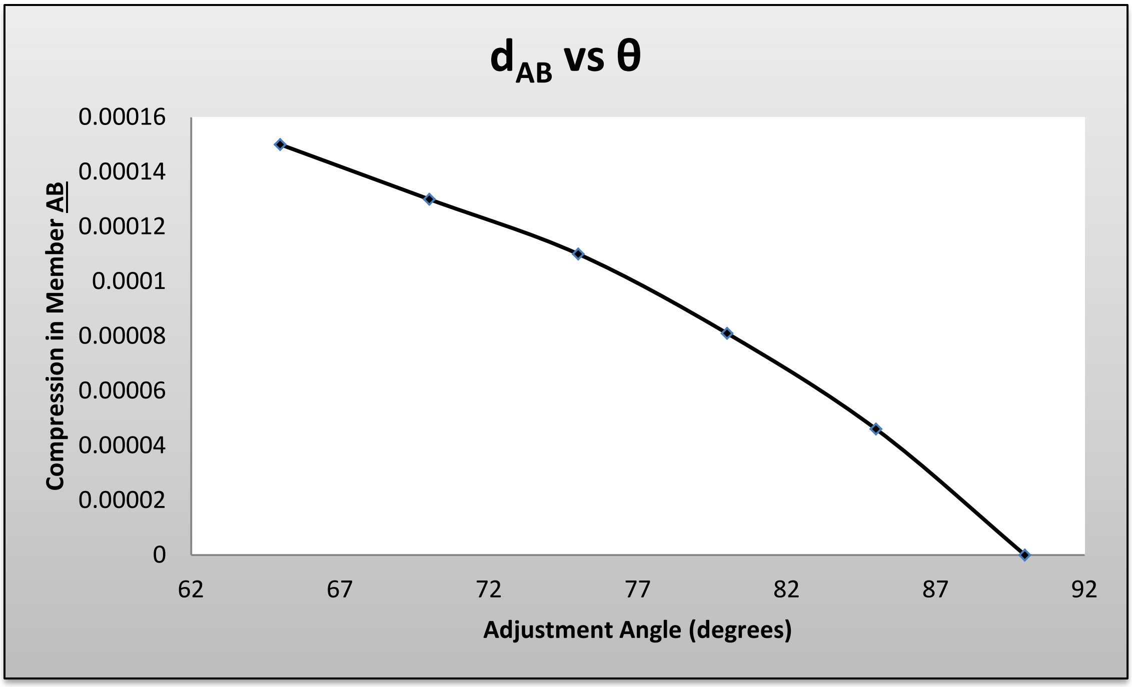


Figure 54: Compression in AB vs. Seat Back Angle

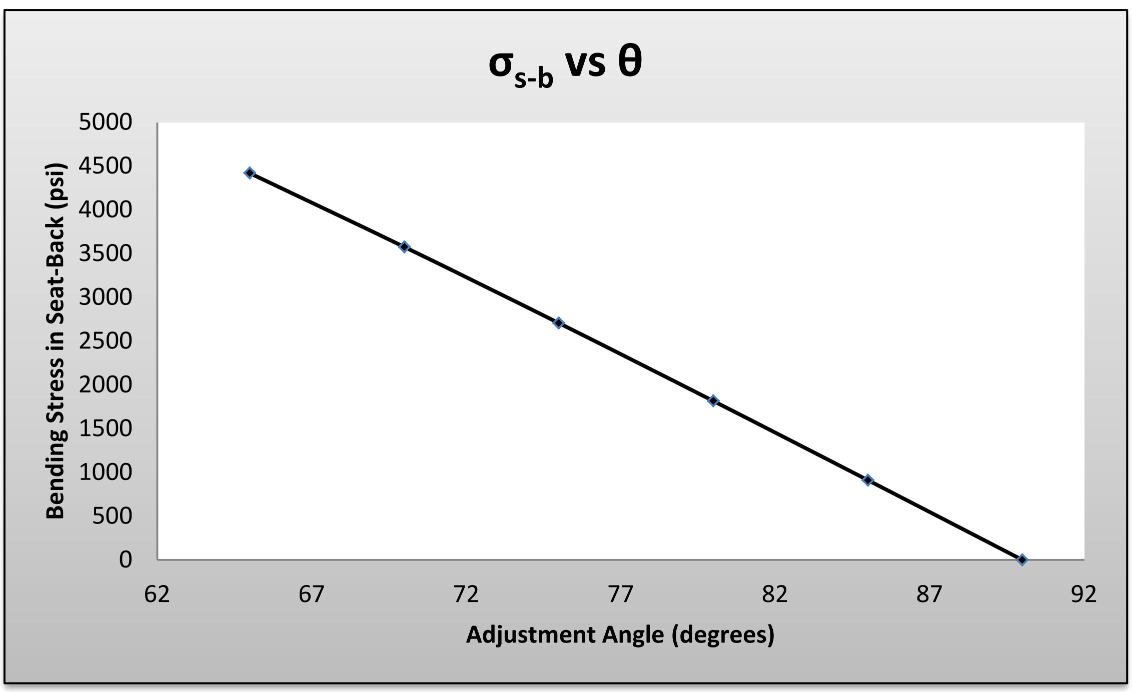


Figure 55: Bending Stress in Seat Back vs. Seat Back Angle

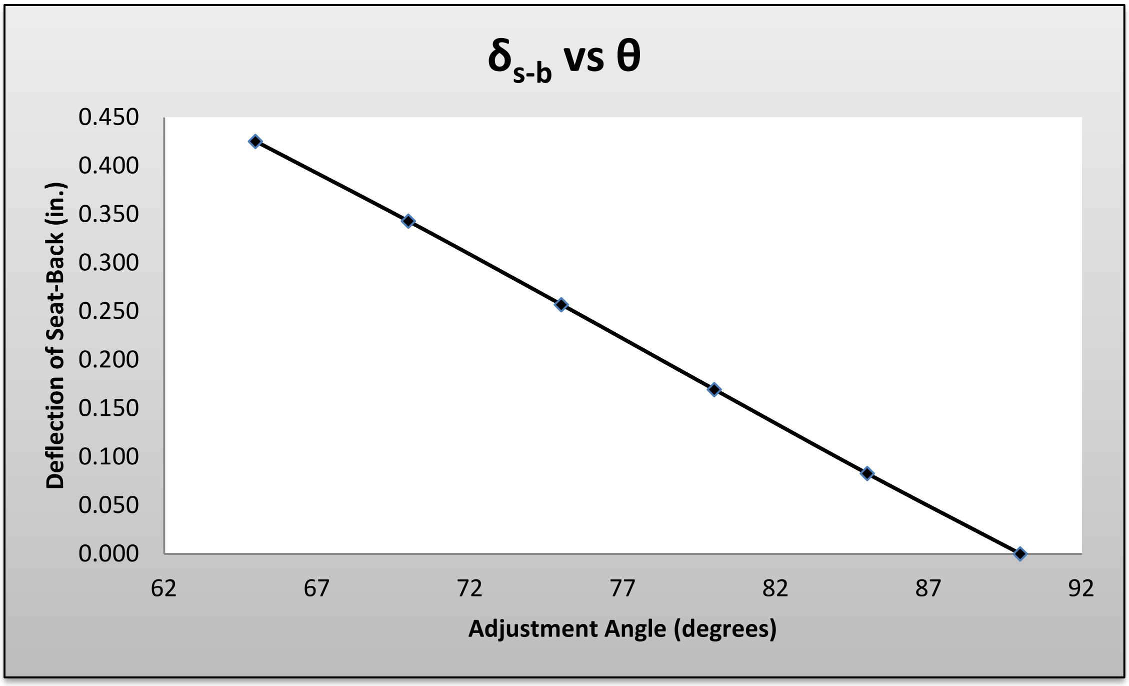


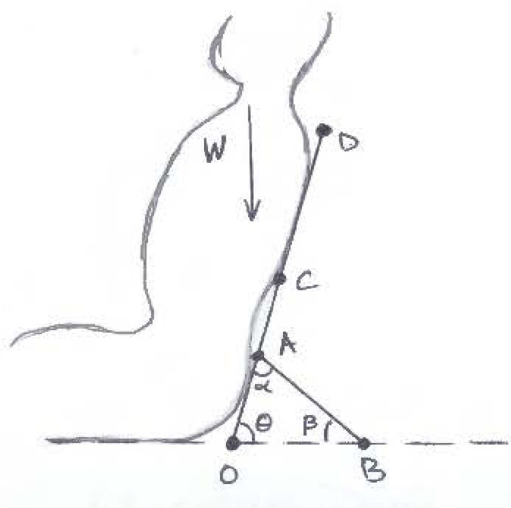
Figure 56: Deflection of Seat Back vs. Seat Back Angle

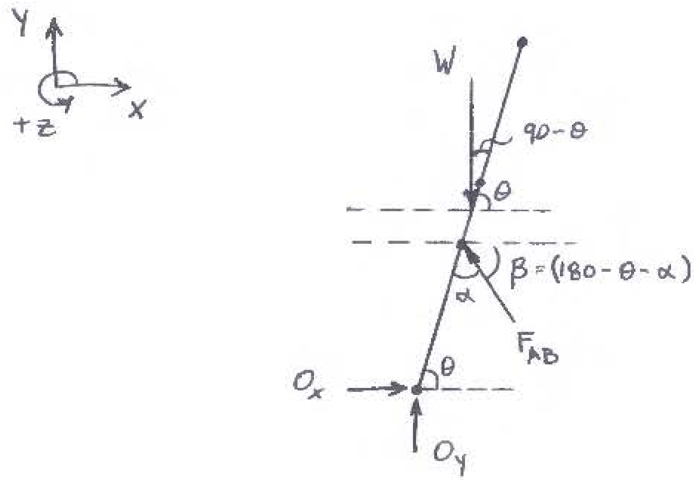
These graphs are supported by the hand calculation analysis which can be found below on the next seven pages.

Fully Extended Seat-Back

Assumptions:

- Weight of user equally distributed on frame
  - Acts halfway down $\overline{OD}$ (full seat back)
- W = weight of person's trunk + head (portion of weight acting on the frame)
  - $W = 0.578\ W_{TOTAL}$
    - ↳ Equation from Orthopedic Biomechanics book: Mechanics and Design in Musculoskeletal Systems; Bartel, Davy, Keavenly
  - W_{TOTAL} given by user's weight
- Geometry known for a given θ





ΣF_x: $O_x - F_{AB}\cos(180-\theta-\alpha) = 0$

$\Rightarrow$ $O_x = F_{AB}\cos(180-\theta-\alpha)$

ΣF_y: $O_y + F_{AB}\sin(180-\theta-\alpha) - W = 0$

$\Rightarrow$ $O_y = W - F_{AB}\sin(180-\theta-\alpha)$

$$\Sigma M_o: \left(F_{AB}\cos(180-\theta-\alpha)\cdot\overline{OA}\sin\theta\right) + \left(F_{AB}\sin(180-\theta-\alpha)\cdot\overline{OA}\cos\theta\right) - W\left(\frac{\overline{OD}}{2}\right)\cos\theta = 0$$

$$\Rightarrow F_{AB}\cdot\overline{OA}\cdot\cos(180-\theta-\alpha)\cdot\sin\theta + F_{AB}\cdot\overline{OA}\cdot\sin(180-\theta-\alpha)\cdot\cos\theta = W\cdot\frac{\overline{OD}}{2}\cdot\cos\theta$$

$$\Rightarrow F_{AB}\cdot\overline{OA}\underbrace{\left[\cos(180-\theta-\alpha)\cdot\sin\theta + \sin(180-\theta-\alpha)\cdot\cos\theta\right]}_{\text{Trig Identity}} = W\cdot\frac{\overline{OD}}{2}\cos\theta$$

cont'd →

cont'd →

Identity: $\sin u \cos v \pm \cos u \sin v = \sin(u \pm v)$

↳ $u = \theta$

$v = 180 - \theta - \alpha$

$$\Rightarrow F_{AB} \cdot \overline{OA} \cdot \sin(\theta + 180 - \theta - \alpha) = W \cdot \frac{\overline{OD}}{2} \cdot \cos\theta$$

$$\Rightarrow \boxed{F_{AB} = \frac{W \cdot \overline{OD} \cdot \cos\theta}{2 \cdot \overline{OA} \cdot \sin(180 - \alpha)}}$$

Force in member $\overline{AB}$ in terms of $W, \theta, \&\ \alpha$

$$\Rightarrow O_x = F_{AB} \cos(180 - \theta - \alpha) = \left[\frac{W \cdot \overline{OD} \cdot \cos\theta}{2 \cdot \overline{OA} \cdot \sin(180 - \alpha)}\right] \cos(180 - \theta - \alpha)$$

$$\Rightarrow \boxed{O_x = \frac{W \cdot \overline{OD}}{2 \cdot \overline{OA}} \cdot \frac{\cos\theta \cdot \cos(180 - \theta - \alpha)}{\sin(180 - \alpha)}}$$

Horizontal reaction force at O in terms of $W, \theta, \&\ \alpha$

$$\Rightarrow O_y = W - F_{AB} \sin(180 - \theta - \alpha)$$

$$\Rightarrow O_y = W - \left[\frac{W \cdot \overline{OD} \cdot \cos\theta}{2 \cdot \overline{OA} \cdot \sin(180 - \alpha)}\right] \cdot \sin(180 - \theta - \alpha)$$

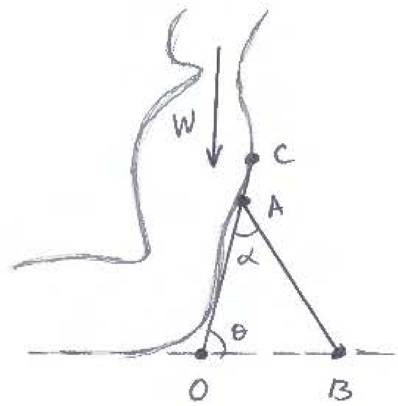
$$\Rightarrow \boxed{O_y = W\left[1 - \frac{\overline{OD} \cdot \cos\theta \cdot \sin(180 - \theta - \alpha)}{2 \cdot \overline{OA} \cdot \sin(180 - \alpha)}\right]}$$

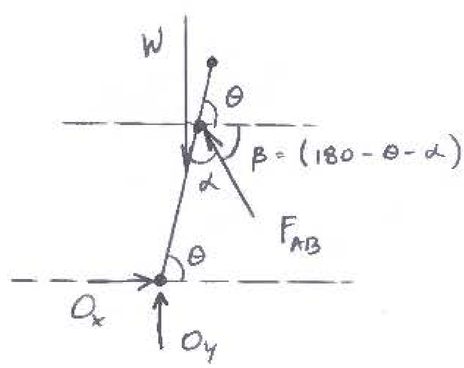
↳ Vertical reaction force at O in terms of $W, \theta, \&\ \alpha$

Short Seat Back

Assumptions:

- W acting half way between $\overline{OC}$ since equally distributed



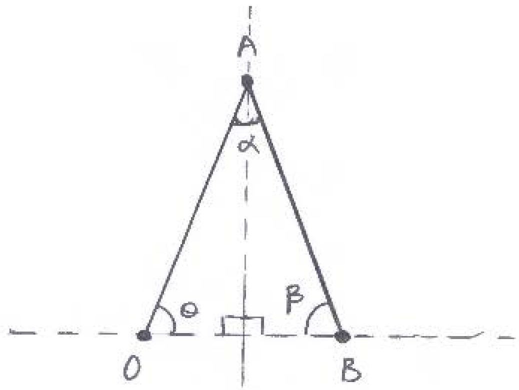


Note: • Force/Moment equations stay the same since the only thing that changes is location of W

∴ (in ΣM_o equation) instead of $\frac{\overline{OD}}{2} \Rightarrow \frac{\overline{OC}}{2}$

Rechecking Geometry of Members $\overline{OA}$ and $\overline{AB}$

Knowns: θ, $\overline{AB}$, $\overline{OA}$



Law of Sines

$$\frac{\sin\beta}{\overline{OA}} = \frac{\sin\theta}{\overline{AB}}$$

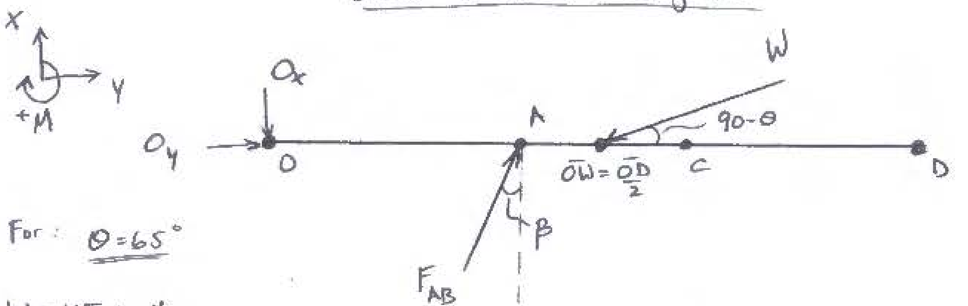
$$\Rightarrow \boxed{\beta = \sin^{-1}\left[\frac{\overline{OA}}{\overline{AB}}\sin\theta\right]}$$

$$180 = \theta + \alpha + \beta$$

$$\Rightarrow \alpha = 180 - \theta - \beta$$

$$\Rightarrow \boxed{\alpha = 180 - \theta - \sin^{-1}\left[\frac{\overline{OA}}{\overline{AB}}\sin\theta\right]}$$

Shear - Moment Diagrams



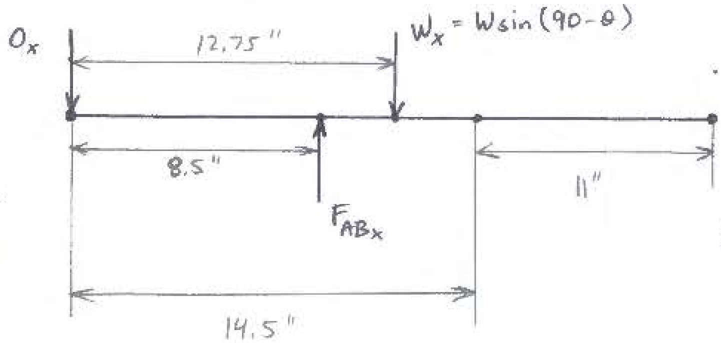
For: $\theta = 65°$

$W = 115.6$ lb

↳ Person of 200 lb

↳ Only applied to one side/set of members (symmetry)

↳ $W = 57.8$ lb (effective)



ΣM_O: $W_x(12.75") - F_{ABx}(8.5") = 0$

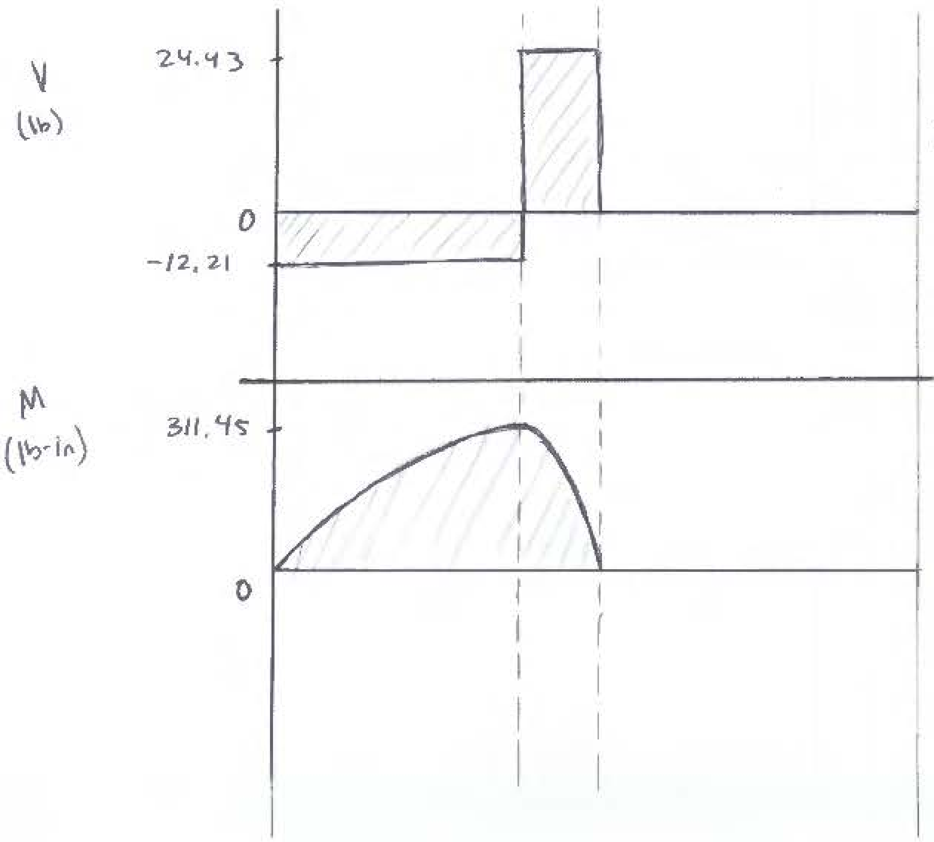
$\Rightarrow F_{ABx} = \frac{12.75}{8.5} W_x$

$\Rightarrow F_{ABx} = 36.64$ lb

ΣF_x: $F_{ABx} - O_x - W_x = 0$

$\Rightarrow O_x = F_{ABx} - W_x$

$\Rightarrow O_x = 12.21$ lb



$M_1 = F_{ABx}(8.5")$

$M_1 = 311.45$ lb-in

$M_2 = W_x(12.75")$

$M_2 = -311.45$ lb-in

Deflection Analysis

$$M = -O_x \langle y \rangle^1 + F_{AB_x} \langle y - 8.5 \rangle^1 - W_x \langle y - 12.75 \rangle^1$$

↑ Singularity Function

$$\frac{M}{EI} = \frac{d^2x}{dy^2}$$

I.C.'s: $\frac{dx}{dy} = 0$ @ $y = 8.5''$

$x = 0$ @ $y = 0$

$$\Rightarrow \frac{dx}{dy} = \frac{1}{EI} \int -O_x \langle y \rangle^1 + F_{AB_x} \langle y - 8.5 \rangle^1 - W_x \langle y - 12.75 \rangle^1 \, dy$$

$$\Rightarrow \frac{dx}{dy} = \frac{1}{EI} \left[\frac{-O_x}{2} \langle y \rangle^2 + \frac{F_{AB_x}}{2} \langle y - 8.5 \rangle^2 - \frac{W_x}{2} \langle y - 12.75 \rangle^2 + C_1 \right]$$

$$\Rightarrow x = \frac{1}{EI} \int \left[\frac{-O_x}{2} \langle y \rangle^2 + \frac{F_{AB_x}}{2} \langle y - 8.5 \rangle^2 - \frac{W_x}{2} \langle y - 12.75 \rangle^2 + C_1 \right] dy$$

$$\Rightarrow x = \frac{1}{EI} \left[-\frac{O_x}{6} \langle y \rangle^3 + \frac{F_{AB_x}}{6} \langle y - 8.5 \rangle^3 - \frac{W_x}{6} \langle y - 12.75 \rangle^3 + C_1 y + C_2 \right.$$

At $y = 0$, $x = 0$:

$$\Rightarrow 0 = \frac{1}{EI} \left[0 + \frac{F_{AB_x}}{6} \langle -8.5 \rangle^3 - \frac{W_x}{6} \langle -12.75 \rangle^3 + 0 + C_2 \right]$$

$$\Rightarrow C_2 = F_{AB_x} (102.354) - W_x (345.445)$$

At $y = 8.5''$, $\frac{dx}{dy} = 0$

$$\Rightarrow 0 = \frac{1}{EI} \left\{ \frac{-O_x}{2} \langle 8.5 \rangle^2 + 0 - \frac{W_x}{2} \langle 8.5 - 12.75 \rangle^2 + C_1 \right\}$$

$$\Rightarrow C_1 = O_x (36.125) + W_x (9.03125)$$

$$x = \frac{1}{EI} \left[\frac{-O_x}{6} \langle y \rangle^3 + \frac{F_{AB_x}}{6} \langle y - 8.5 \rangle^3 - \frac{W_x}{6} \langle y - 12.75 \rangle^3 + \left(O_x (36.13) + W_x (9.03) \right) y + \left(F_{AB_x} (102.35) - W_x (345.45) \right) \right]$$

→ deflection of seat back

$$\sigma_{Max} = \frac{Mc}{I} \quad , \quad I = \frac{\pi(d_o^4 - d_i^4)}{64} \quad , \quad c = r_o = \frac{d_o}{2}$$

↳ Maximum Bending Stress

↳ Moment of Inertia of Tubing

$$\Rightarrow \quad \sigma_{max} = \frac{M\left(\frac{d_o}{2}\right)}{\frac{\pi}{64}\left(d_o^4 - d_i^4\right)}$$

$$\Rightarrow \quad \boxed{\sigma_{max} = \frac{M \cdot d_o \cdot 32}{\pi\left(d_o^4 - d_i^4\right)}}$$

Maximum Bending stress in tubing of frame

$$\delta = \frac{FL}{AE}$$

– Compression of member w/axial Load

$$\delta_{AB} = \frac{F_{AB} L_{AB}}{A_{AB} E} \quad , \quad A_{AB} = \pi r_o^2 - \pi r_i^2$$

$$\hookrightarrow A_{AB} = \pi\left(r_o^2 - r_i^2\right)$$

$$\Rightarrow \quad \delta_{AB} = \frac{F_{AB} L_{AB}}{\pi\left(r_o^2 - r_i^2\right) E} \quad , \quad L_{AB} = \overline{AB}$$

$$\Rightarrow \quad \boxed{\delta_{AB} = \frac{F_{AB} \cdot \overline{AB}}{\pi\left(r_o^2 - r_i^2\right) E}}$$

compression in member $\overline{AB}$

Appendix D: Vendor Information

Table 14: Vendor Contact Information and Overall Pricing

Vendor	Contact Info	Pricing
Adaptive Engineering Lab	Loren Groeschl	1018.00
	lgroeschl@aelseating.com	
	866-656-1486	
	www.aelseating.com	
Rose Krieger	Brett Dooley	665.16
	brettd@iptech1.com	
	877-478-3241	
	www.rk-rose-krieger.com/english/	
Speedy Metals	sales@speedymetals.com	20.52
	866-938-6061	
	www.speedymetals.com	
Foam Factory	info@foambymail.com	83.96
	586-627-3626	
	www.foambymail.com	
Interstate Plastics	crm@interstateplastics.net	173.68
	888-768-5759	
	www.interstateplastics.com	
Metric Express	sales@metricexpress.com	92.46
	877-405-0787	
	www.metricexpress.com	
Ram Mounts	websales@rammount.com	66.16
	206-763-8361	
	www.rammount.com	

***Catalog cutouts for Adaptive Engineering Lab and Rose Krieger can be found at the very end of this report.

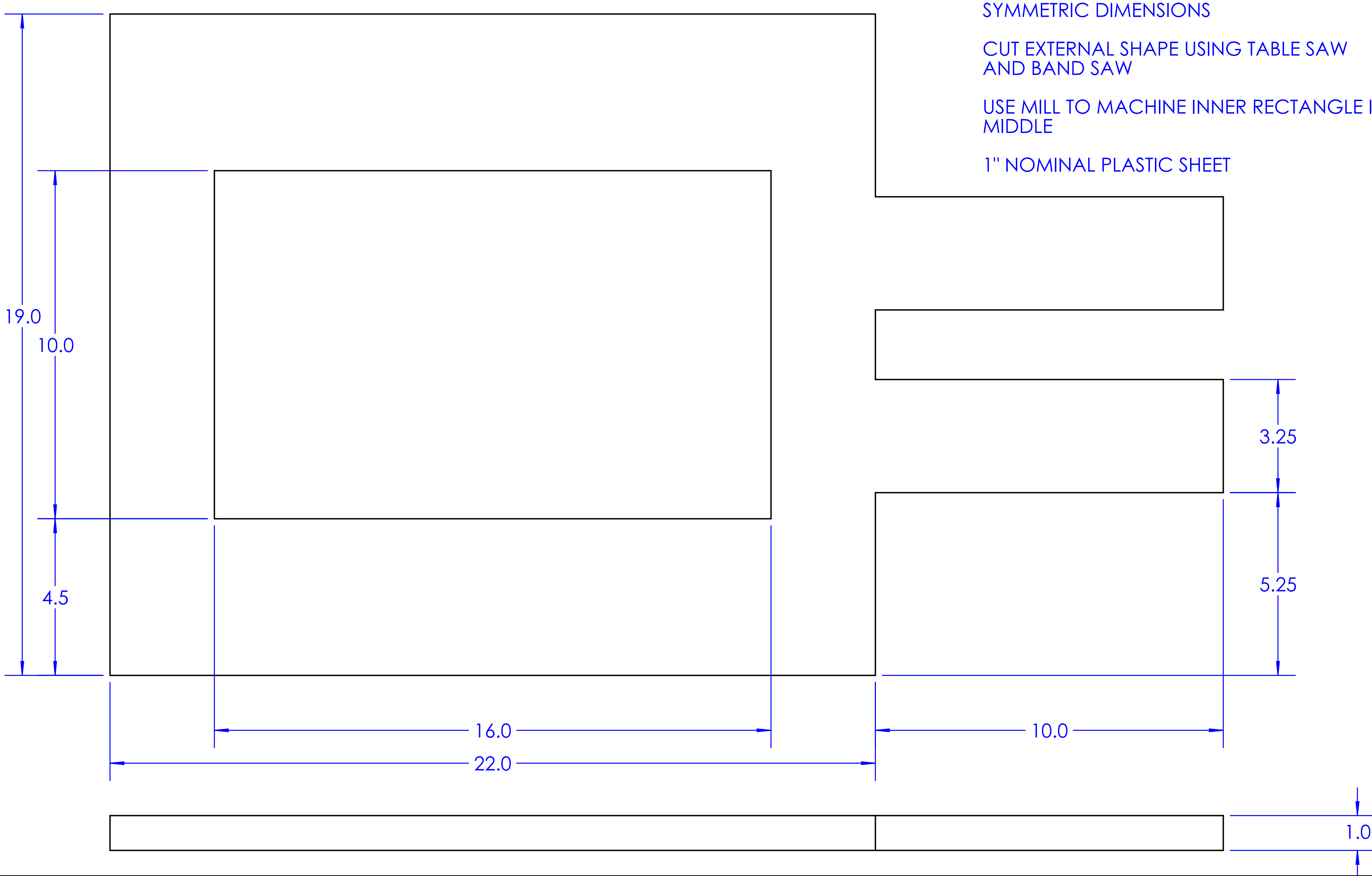
Appendix E: Final Design Drawings

NOTE:
SYMMETRIC DIMENSIONS

CUT EXTERNAL SHAPE USING TABLE SAW AND BAND SAW

USE MILL TO MACHINE INNER RECTANGLE IN MIDDLE

1" NOMINAL PLASTIC SHEET



TIDE RIDER 360

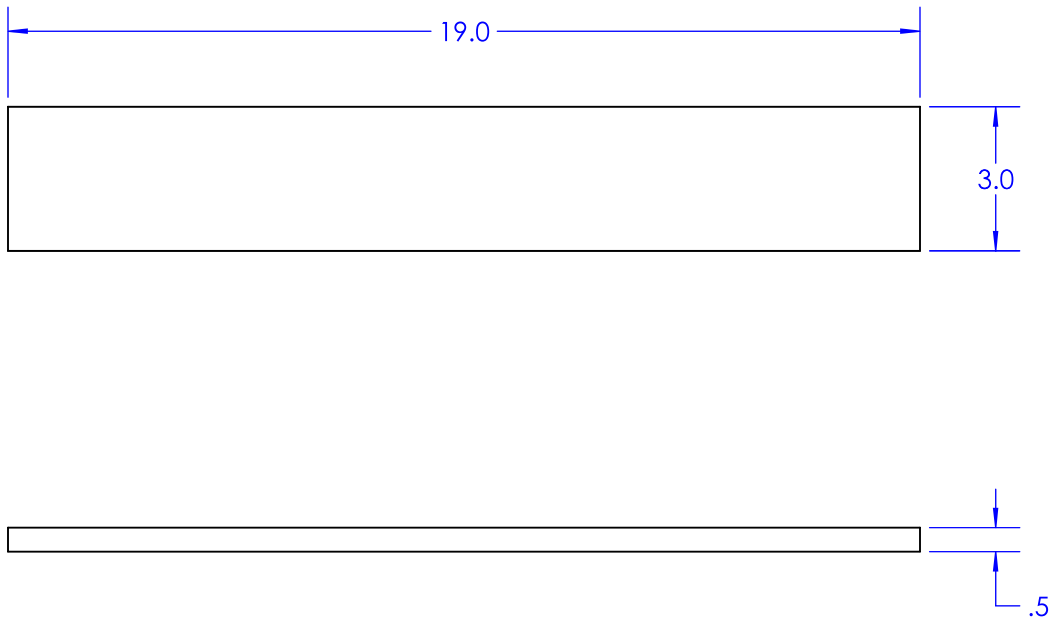
Mechanical Engineering
CAL POLY

TITLE: PLASTIC SEAT BASE		
UNITS: INCHES	DWG #: TR 360 B1	MATERIAL: HDPE
TOLERANCE:1/4"	NEXT ASSY: TR 360 BA	NAME: GRANT PETERSEN
SCALE: 1:4	DATE: 6/7/14	CHECKED BY:

5 4 3 2 1

NOTE:
CUT EXTERNAL SHAPE USING TABLE SAW

1/2" NOMINAL PLASTIC SHEET

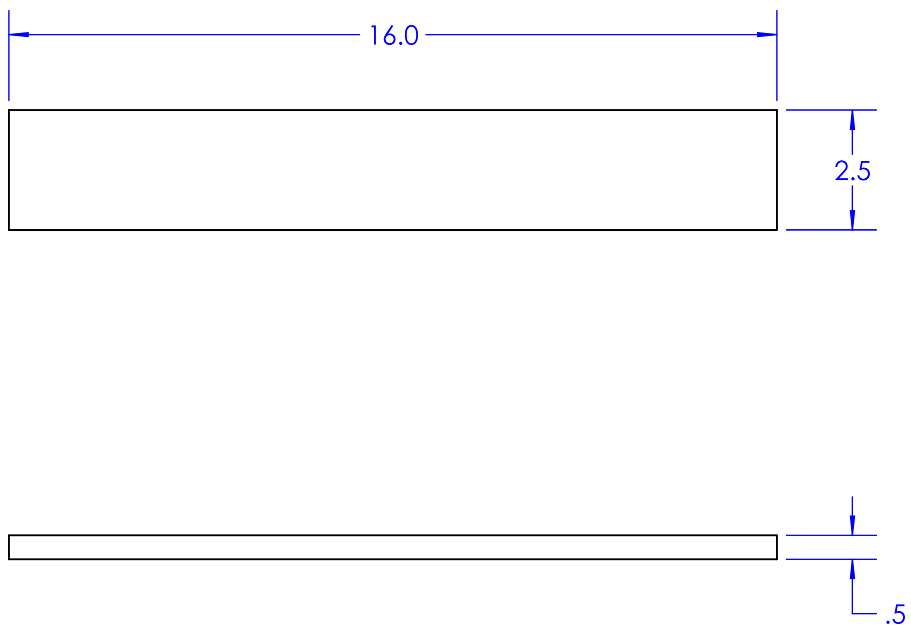


TIDE RIDER 360	TITLE: PLASTIC SEAT FRONT AND BACK PLASTIC		
	UNITS: INCHES	DWG #: TR 360 B2	MATERIAL: HDPE
	TOLERANCE:1/4"	NEXT ASSY: TR 360 BA	NAME: GRANT PETERSEN
Mechanical Engineering CAL POLY	SCALE: 1:4	DATE: 6/7/14	CHECKED BY:

5 4 3 2 1

NOTE:
CUT EXTERNAL SHAPE USING TABLE SAW

1/2" NOMINAL PLASTIC SHEET



TIDE RIDER 360

Mechanical Engineering
CAL POLY

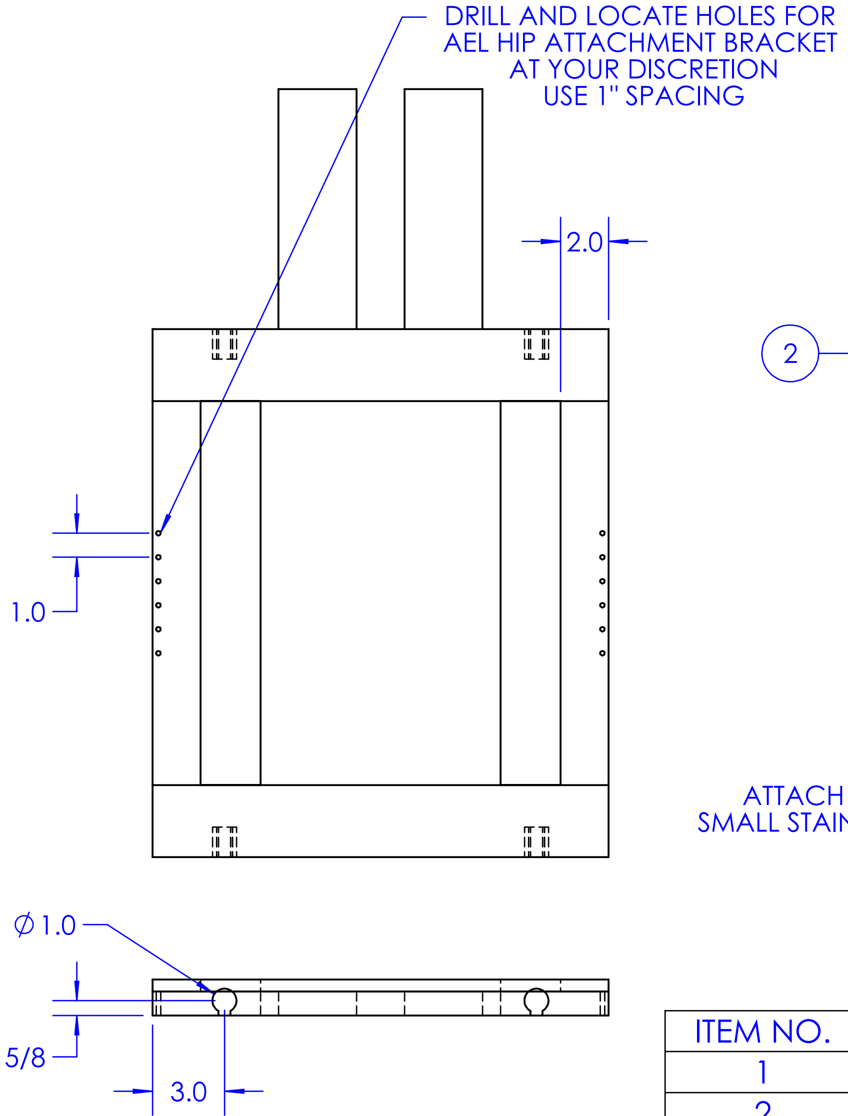
TITLE: PLASTIC SEAT VELCRO ATTACHMENT PIECES		
UNITS: INCHES	DWG #: TR 360 B3	MATERIAL: HDPE
TOLERANCE:1/4"	NEXT ASSY: TR 360 BA	NAME: GRANT PETERSEN
SCALE: 1:4	DATE: 6/7/14	CHECKED BY:

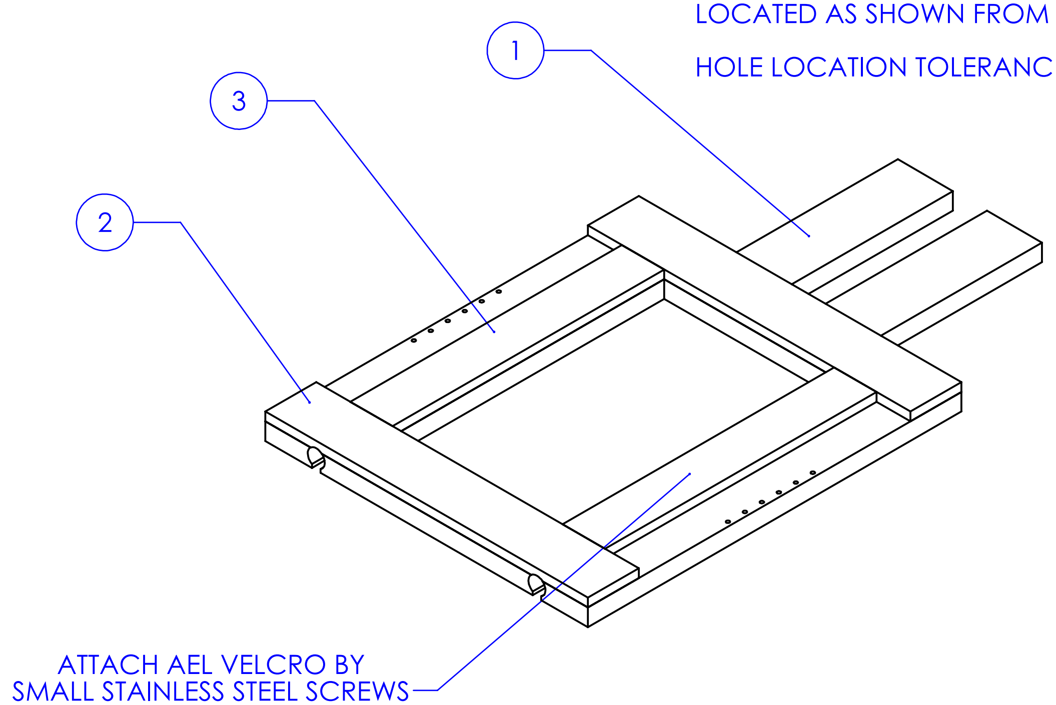
5 4 3 2 1

NOTE:
ASSEMBLE PLASTIC WITH EXTERIOR SCREWS

FOUR SUCTION CUP HOLES SHOULD BE DRILLED AFTER ASSEMBLY OF PLASTIC COMPONENTS
1 - 1/4" DEPTH
1" DIAMETER
LOCATED AS SHOWN FROM CORNER

HOLE LOCATION TOLERANCE = 1/16"





ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	TR 360 B1	BASE PLASTIC	1
2	TR 360 B2	FRONT AND BACK PLASTIC	2
3	TR 360 B3	VELCRO ATTACHMENT PLASTIC	2

TIDE RIDER 360

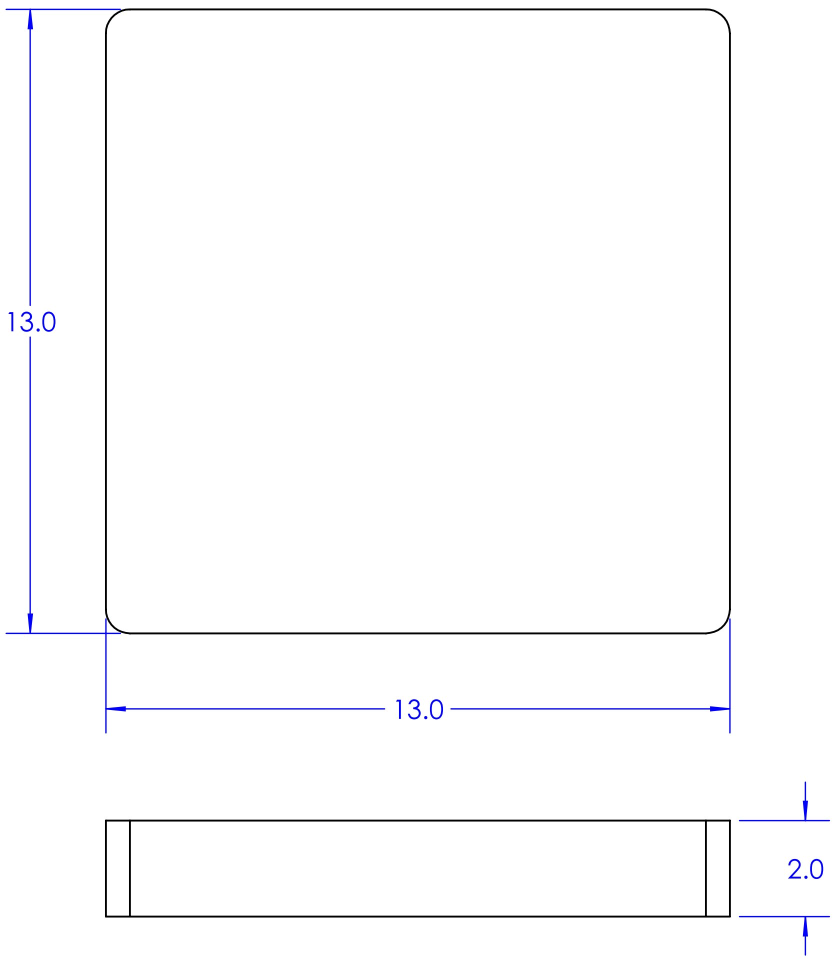
Mechanical Engineering
CAL POLY

TITLE: PLASTIC SEAT BASE ASSEMBLY		
UNITS: INCHES	DWG #: TR 360 BA	MATERIAL: HDPE
TOLERANCE:1/4"	NEXT ASSY: TR 360 CP	NAME: GRANT PETERSEN
SCALE: 1:8	DATE: 6/7/14	CHECKED BY:

NOTE:
NOMINAL 2" CLOSED CELL FOAM

CUT SQUARE USING TABLE SAW

ROUND EDGES BY TABLE BELT SANDER TO TAKE OFF EDGE



TIDE RIDER 360

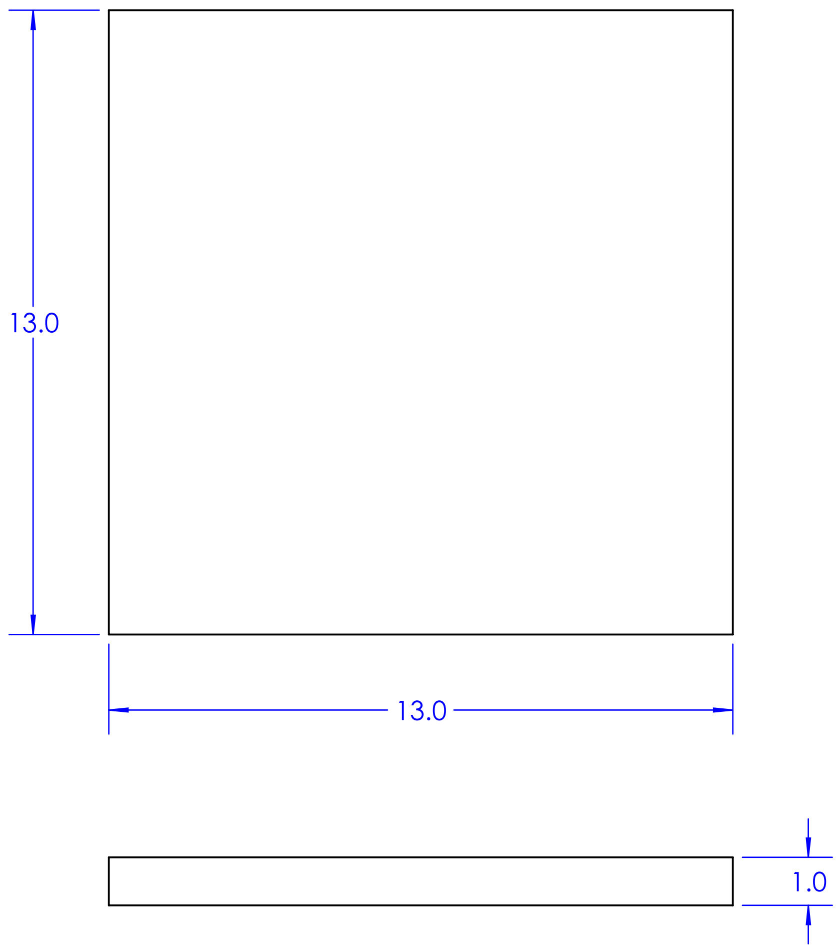
Mechanical Engineering
CAL POLY

TITLE: LOWER SEAT CUSHION - FIRM		
UNITS: INCHES	DWG #: TR 360 C1A	MATERIAL: CROSS LINKED PE FOAM
TOLERANCE:1/4"	NEXT ASSY: TR 360 C1	NAME: GRANT PETERSEN
SCALE: 1:4	DATE: 6/7/14	CHECKED BY:

5 4 3 2 1

NOTE:
NOMINAL 1" SOFT FOAM

CUT SQUARE USING SCISSORS



TIDE RIDER 360

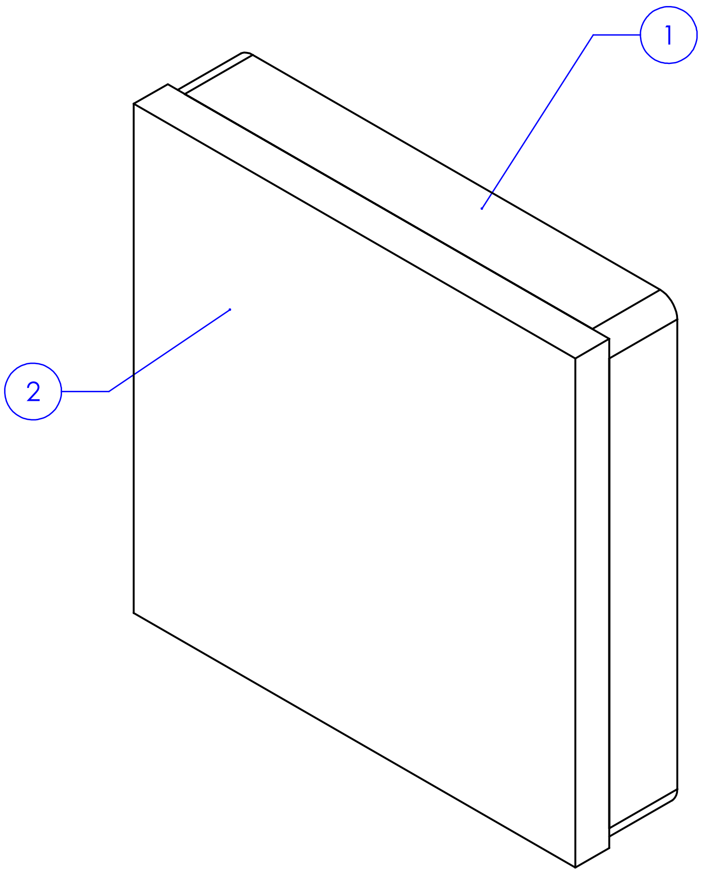
Mechanical Engineering
CAL POLY

TITLE: LOWER SEAT CUSHION - SOFT		
UNITS: INCHES	DWG #: TR 360 C1B	MATERIAL: SOFT FOAM
TOLERANCE:1/4"	NEXT ASSY: TR 360 C1	NAME: GRANT PETERSEN
SCALE: 1:4	DATE: 6/7/14	CHECKED BY:

5 4 3 2 1

NOTE:

ASSEMBLY METHOD
1. WRAP FOAMS TOGETHER WITH PLATIC WRAP
2. WRAP FOAMS WITH 1/8" CROSS-LINKE PE SKIN AND STITCH TOGETHER



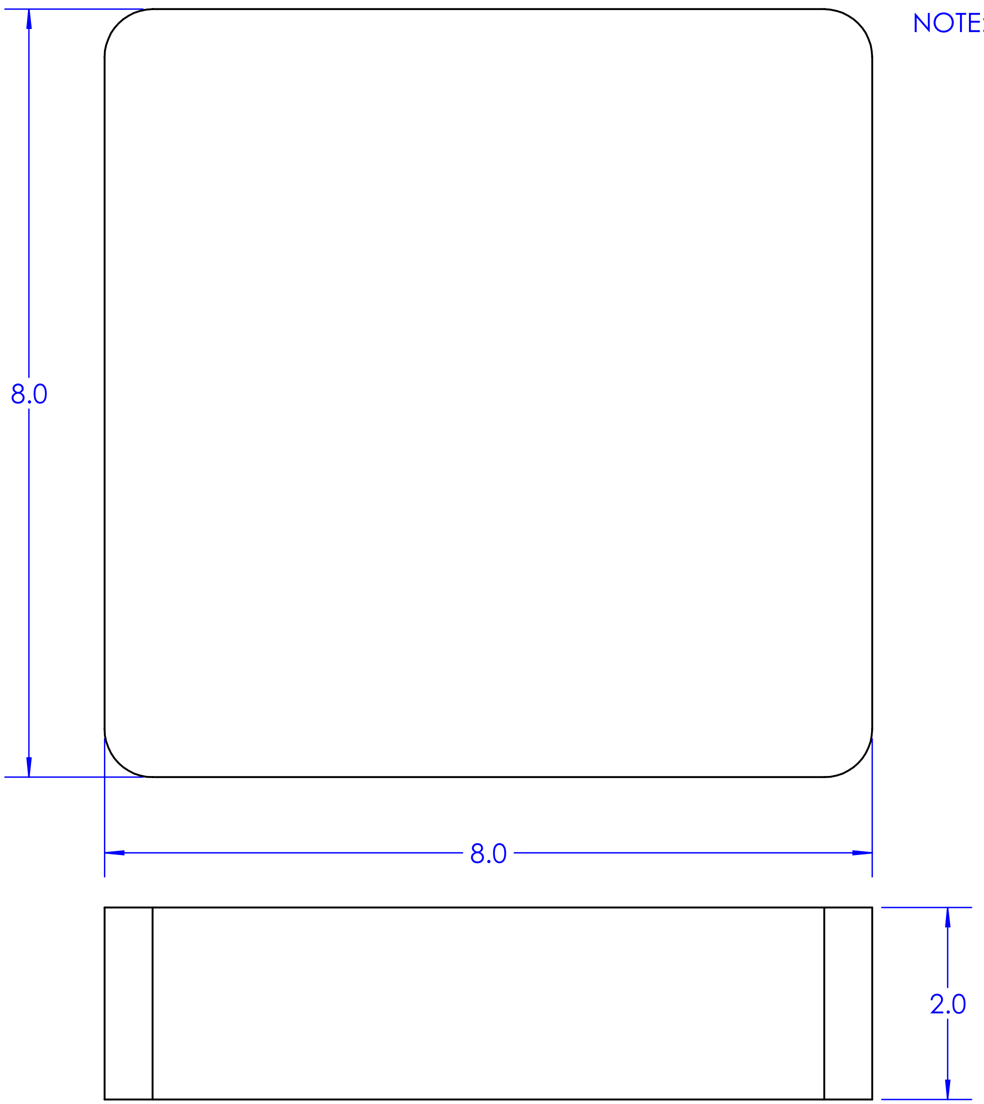
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	TR 360 C1A	LOWER BACK CUSHION - FIRM	1
2	TR 360 C1B	LOWER BACK CUSHION - SOFT	1

TIDE RIDER 360

Mechanical Engineering
CAL POLY

TITLE: LOWER SEAT CUSHION ASSEMBLY		
UNITS: INCHES	DWG #: TR 360 C1	MATERIAL:FOAM
TOLERANCE:1/4"	NEXT ASSY: TR 360 CP	NAME: GRANT PETERSEN
SCALE: 1:4	DATE: 6/7/14	CHECKED BY:

5 4 3 2 1

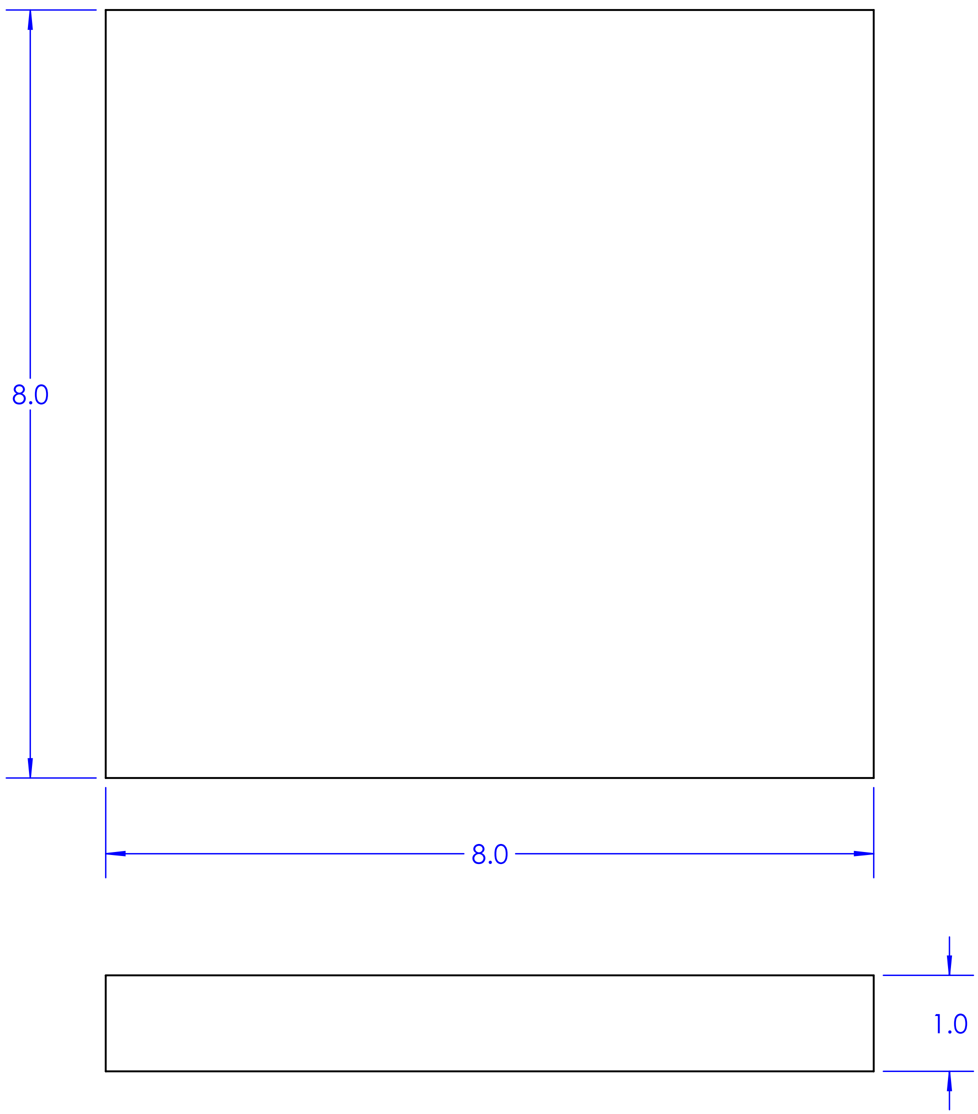


NOTE:
NOMINAL 2" CLOSED CELL FOAM

CUT SQUARE USING TABLE SAW
ROUND EDGES BY TABLE BELT SANDER TO RADIUS OF OWN DISCRETION

TIDE RIDER 360 Mechanical Engineering CAL POLY	TITLE: UPPER SEAT CUSHION - FIRM		
	UNITS: INCHES	DWG #: TR 360 C2A	MATERIAL: CROSS LINKED PE FOAM
	TOLERANCE:1/4"	NEXT ASSY: TR 360 C2	NAME: GRANT PETERSEN
	SCALE: 1:2	DATE: 6/7/14	CHECKED BY:

5 4 3 2 1

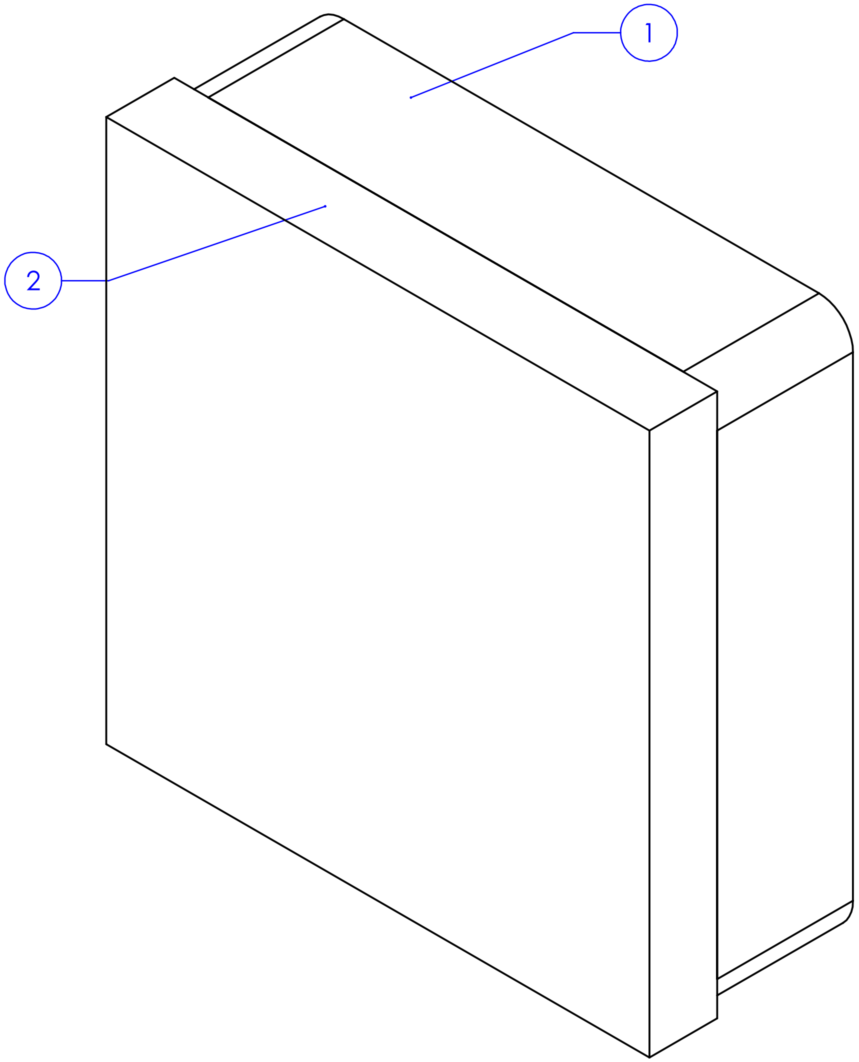


NOTE:
NOMINAL 1" SOFT FOAM

CUT SQUARE USING SCISSORS

TIDE RIDER 360	TITLE: UPPER SEAT CUSHION - SOFT		
Mechanical Engineering CAL POLY	UNITS: INCHES	DWG #: TR 360 C2B	MATERIAL: SOFT FOAM
	TOLERANCE:1/4"	NEXT ASSY: TR 360 C2	NAME: GRANT PETERSEN
	SCALE: 1:2	DATE: 6/7/14	CHECKED BY:

5 4 3 2 1



NOTE:

ASSEMBLY METHOD
1. WRAP FOAMS TOGETHER WITH PLATIC WRAP
2. WRAP FOAMS WITH 1/8" CROSS-LINKE PE SKIN AND STITCH TOGETHER

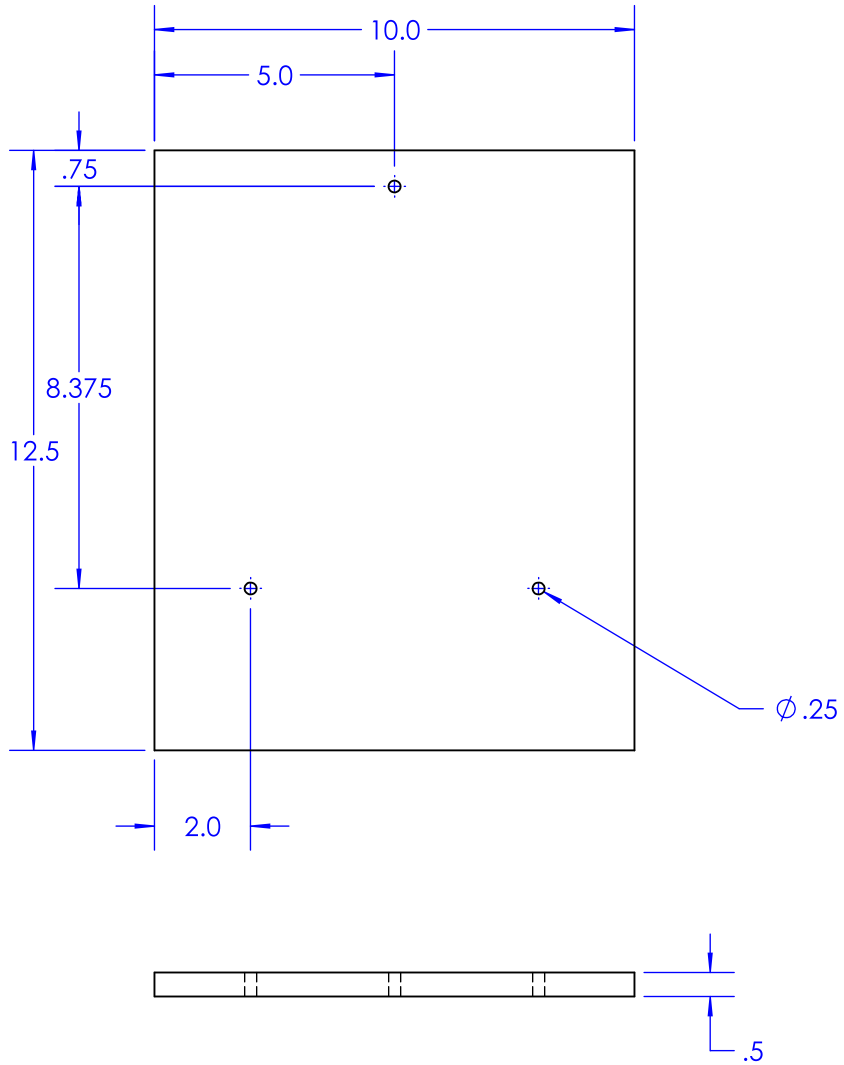
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	TR 360 C2A	UPPER BACK CUSHION - FIRM	1
2	TR 360 C2B	UPPER BACK CUSHION - SOFT	1

TIDE RIDER 360

Mechanical Engineering
CAL POLY

TITLE: UPPER SEAT CUSHION ASSEMBLY		
UNITS: INCHES	DWG #: TR 360 C2	MATERIAL:FOAM
TOLERANCE:1/4"	NEXT ASSY: TR 360 CP	NAME: GRANT PETERSEN
SCALE: 1:2	DATE: 6/7/14	CHECKED BY:

5 4 3 2 1



NOTE:
NOMINAL 1/2" HDPE

CUT USING TABLE SAW

THROUGH HOLES CAN BE DRILLED BEFORE OR AFTER FINAL ASESMBLY

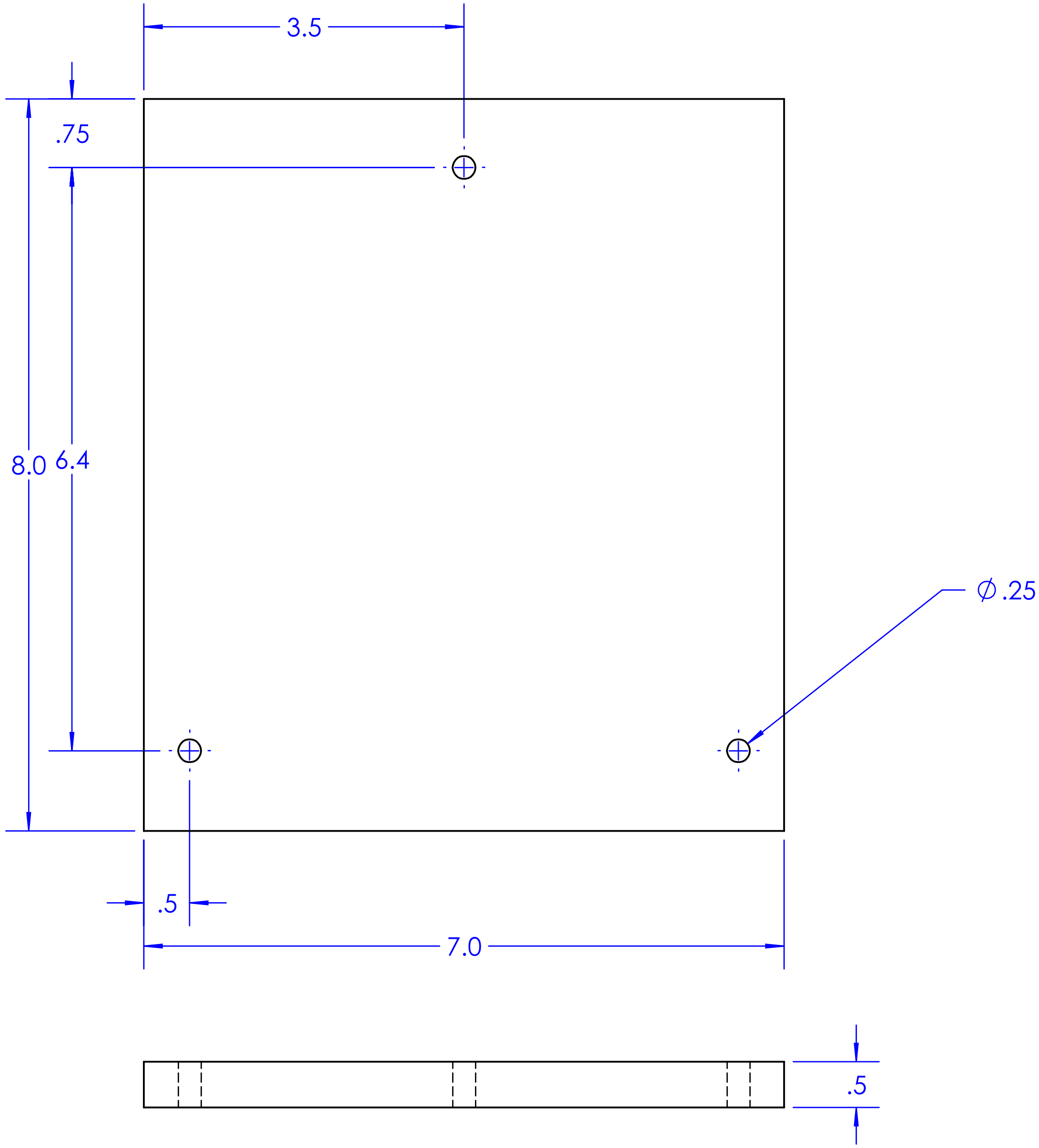
HOLE LOCATION TOLERANCE = 1/8"

TIDE RIDER 360

Mechanical Engineering
CAL POLY

TITLE: LOWER CUSHION SUPPORT		
UNITS: INCHES	DWG #: TR 360 S1	MATERIAL: HDPE
TOLERANCE:1/4"	NEXT ASSY: TR 360 CP	NAME: GRANT PETERSEN
SCALE: 1:4	DATE: 6/7/14	CHECKED BY:

5 4 3 2 1



NOTE:
NOMINAL 1/2" HDPE

CUT USING TABLE SAW

THROUGH HOLES CAN BE DRILLED BEFORE OR AFTER FINAL ASESMBLY

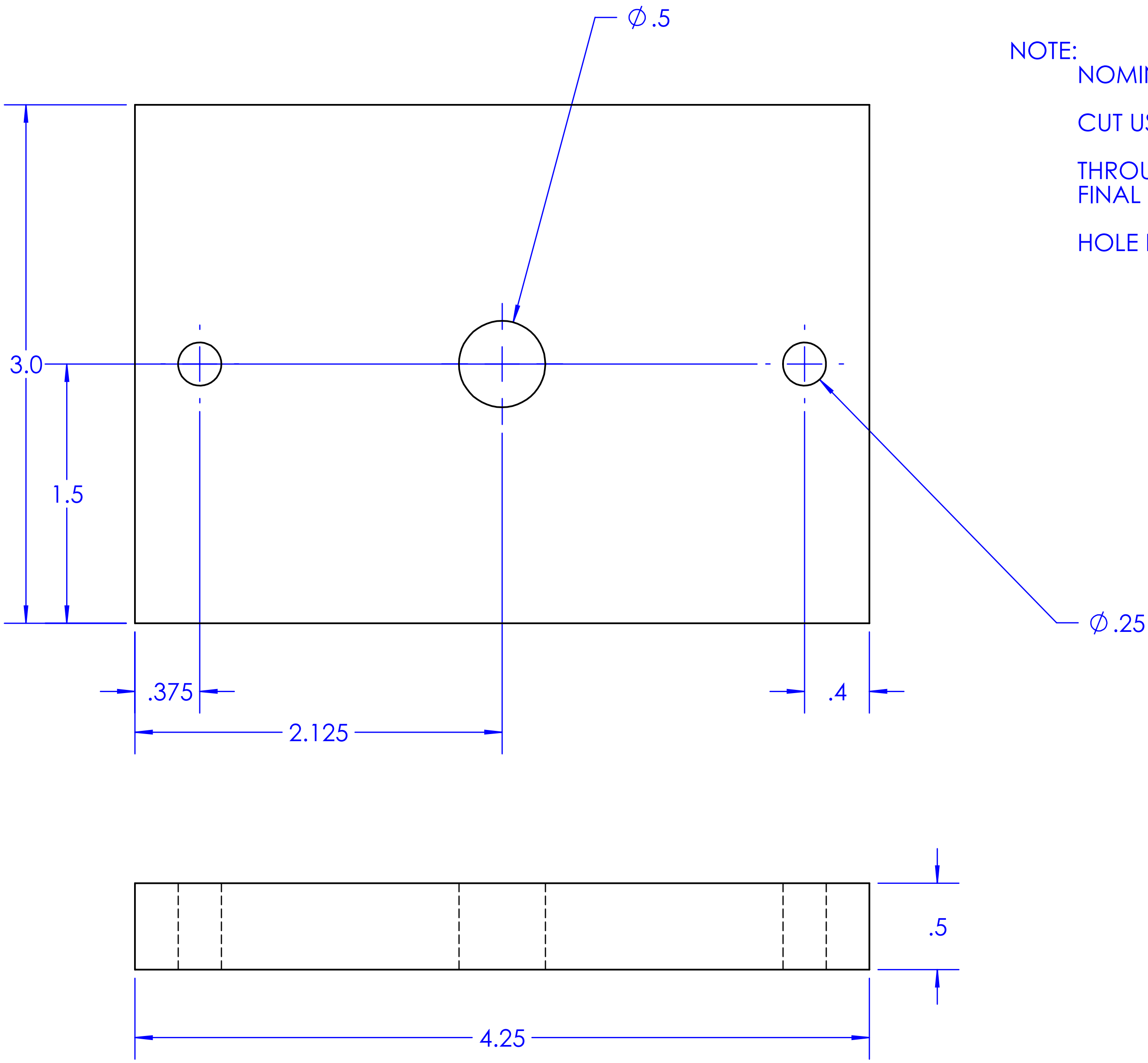
HOLE LOCATION TOLERANCE = 1/8"

TIDE RIDER 360

Mechanical Engineering
CAL POLY

TITLE: UPPER CUSHION SUPPORT		
UNITS: INCHES	DWG #: TR 360 S2	MATERIAL: HDPE
TOLERANCE:1/4"	NEXT ASSY: TR 360 CP	NAME: GRANT PETERSEN
SCALE: 1:2	DATE: 6/7/14	CHECKED BY:

5 4 3 2 1



NOTE:
NOMINAL 1/2" HDPE

CUT USING TABLE SAW AND COMPOUND MITER SAW

THROUGH HOLES CAN BE DRILLED BEFORE OR AFTER FINAL ASESMBLY

HOLE LOCATION TOLERANCE = 1/8"

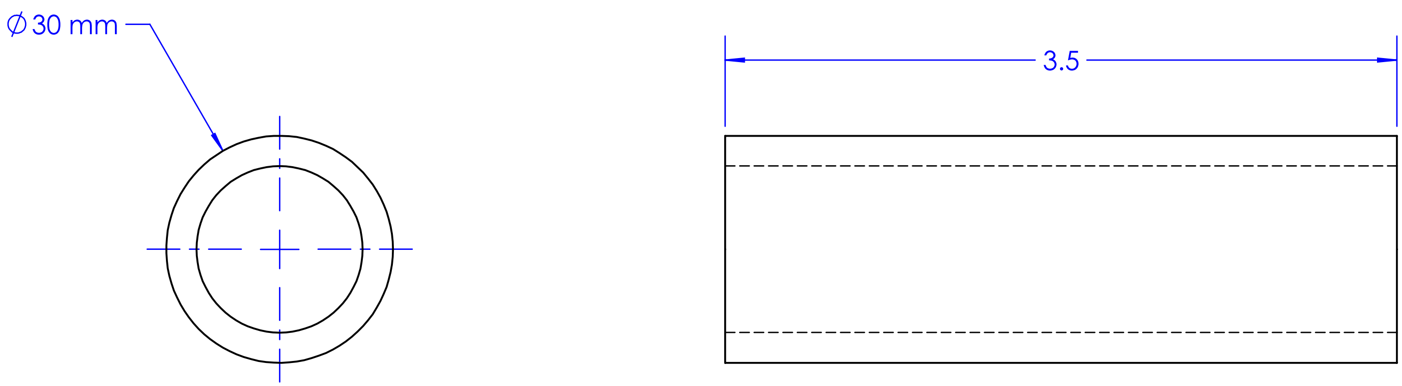
TIDE RIDER 360 Mechanical Engineering CAL POLY	TITLE: HEAD REST SUPPORT		
	UNITS: INCHES	DWG #: TR 360 S3	MATERIAL: HDPE
	TOLERANCE:1/4"	NEXT ASSY: TR 360 CP	NAME: GRANT PETERSEN
	SCALE: 1:1	DATE: 6/7/14	CHECKED BY:

5 4 3 2 1

NOTE:
CUT TO LENGTH WITH METAL CHOP SAW
FILE OFF SHARP EDGES

30 MM NOMINAL ALUMINUM TUBING

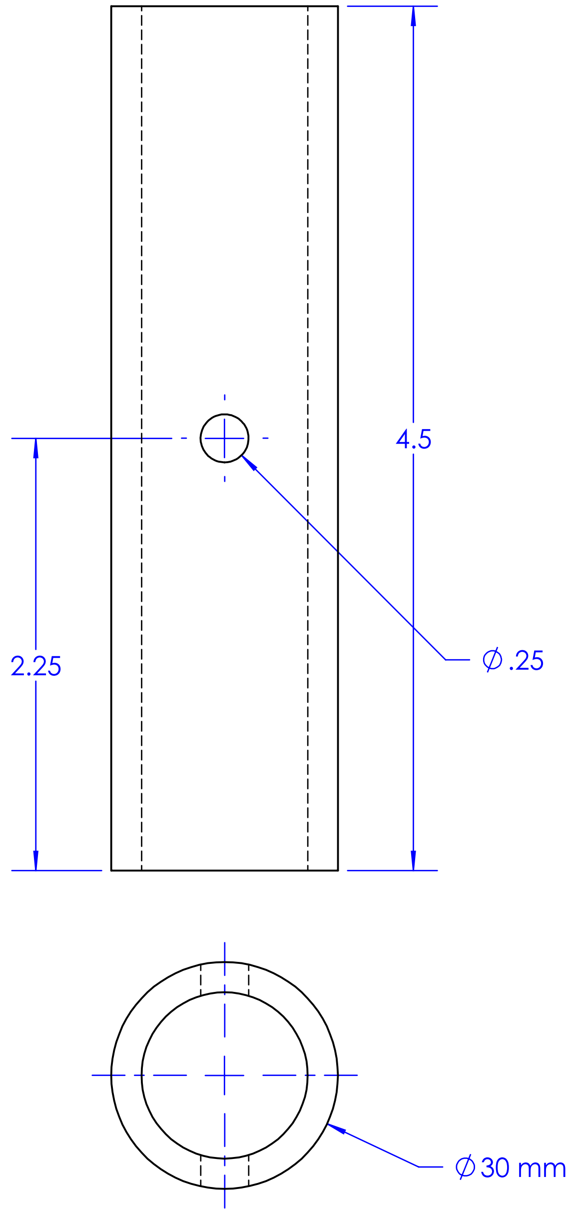
LENGTH IN INCHES



TIDE RIDER 360	TITLE: ANGLE TUBE	
UNITS: INCHES	DWG #: TR 360 T1	MATERIAL: ALUMINUM 6061
TOLERANCE:1/8"	NEXT ASSY: TR 360 TA	NAME: GRANT PETERSEN
SCALE: 1:1	DATE: 6/7/14	CHECKED BY:

Mechanical Engineering CAL POLY

5 4 3 2 1



NOTE:
CUT TO LENGTH WITH METAL CHOP SAW
FILE OFF SHARP EDGES

30 MM NOMINAL ALUMINUM TUBING

LENGTH IN INCHES

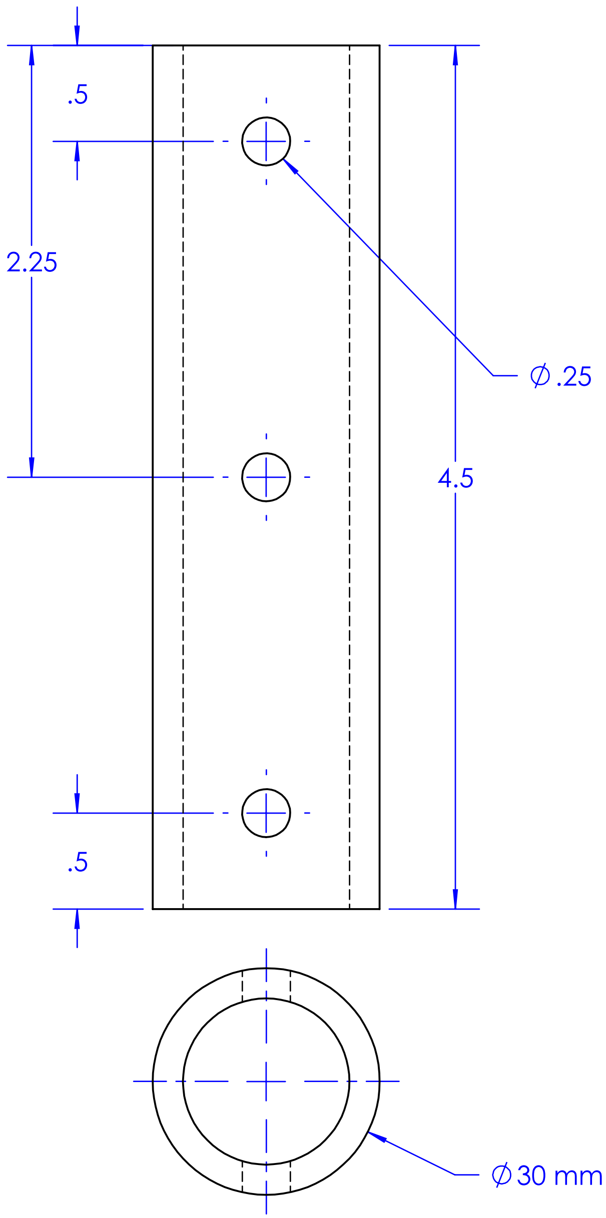
THROUGH HOLE CAN BE DRILLED BEFORE
OR AFTER TUBING ASSEMBLY

TIDE RIDER 360

Mechanical Engineering
CAL POLY

TITLE: LOWER HORIZONTAL TUBE		
UNITS: INCHES	DWG #: TR 360 T2A	MATERIAL: ALUMINUM 6061
TOLERANCE:1/8"	NEXT ASSY: TR 360 TA	NAME: GRANT PETERSEN
SCALE: 1:1	DATE: 6/7/14	CHECKED BY:

5 4 3 2 1



NOTE:
CUT TO LENGTH WITH METAL CHOP SAW
FILE OFF SHARP EDGES

30 MM NOMINAL ALUMINUM TUBING

LENGTH IN INCHES

THROUGH HOLES CAN BE DRILLED BEFORE OR AFTER TUBING ASSEMBLY

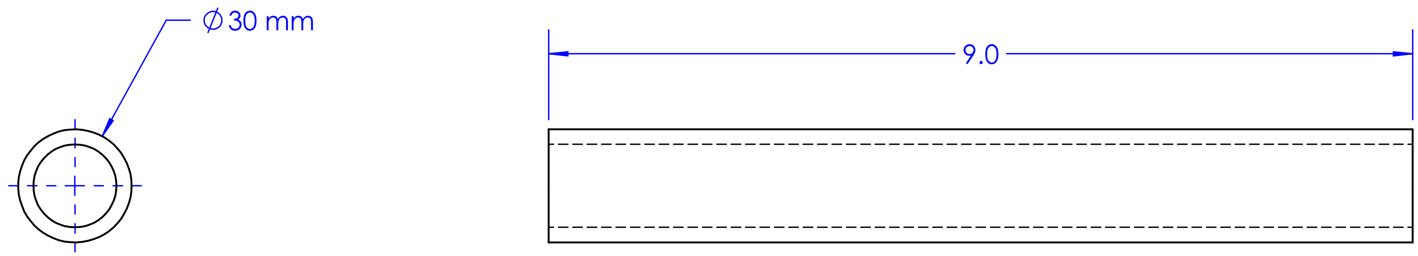
TIDE RIDER 360	TITLE: UPPER HORIZONTAL TUBE	
UNITS: INCHES	DWG #: TR 360 T2B	MATERIAL: ALUMINUM 6061
TOLERANCE:1/8"	NEXT ASSY: TR 360 TA	NAME: GRANT PETERSEN
SCALE: 1:1	DATE: 6/7/14	CHECKED BY:

5 4 3 2 1

NOTE:
CUT TO LENGTH WITH METAL CHOP SAW
FILE OFF SHARP EDGES

30 MM NOMINAL ALUMINUM TUBING

LENGTH IN INCHES

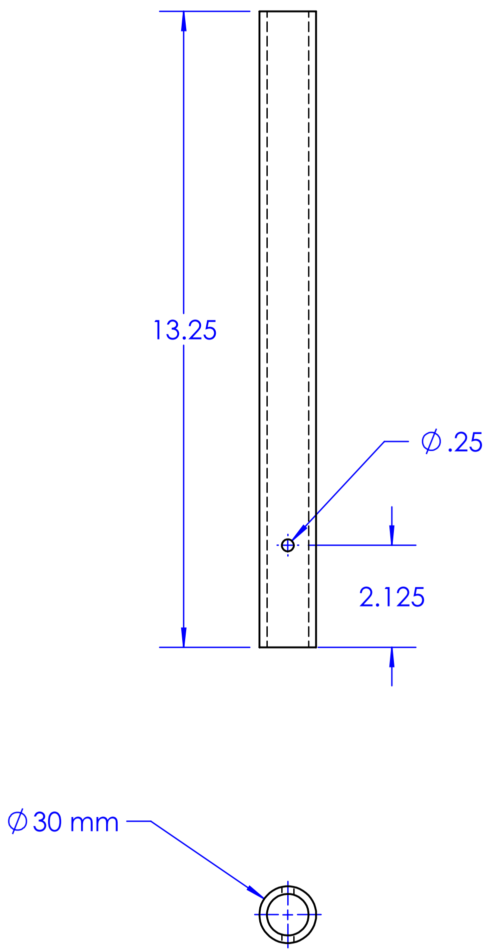


TIDE RIDER 360

Mechanical Engineering
CAL POLY

TITLE: TRACK TUBE		
UNITS: INCHES	DWG #: TR 360 T3	MATERIAL: ALUMINUM 6061
TOLERANCE:1/8"	NEXT ASSY: TR 360 TA	NAME: GRANT PETERSEN
SCALE: 1:2	DATE: 6/7/14	CHECKED BY:

5 4 3 2 1



NOTE:
CUT TO LENGTH WITH METAL CHOP SAW
FILE OFF SHARP EDGES

30 MM NOMINAL ALUMINUM TUBING

LENGTH IN INCHES

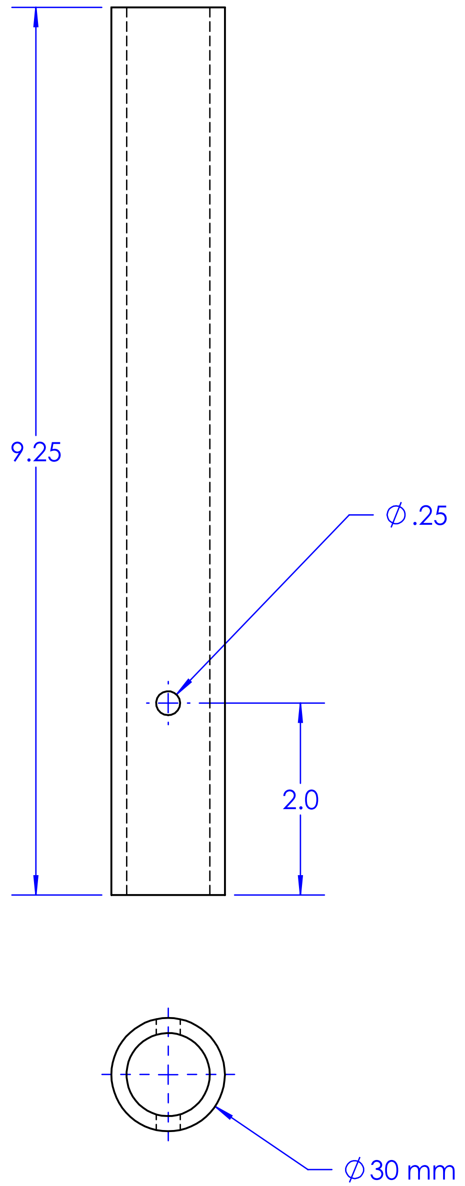
THROUGH HOLE CAN BE DRILLED BEFORE OR AFTER TUBING ASSEMBLY

TIDE RIDER 360

Mechanical Engineering
CAL POLY

TITLE: LOWER VERTICAL TUBE		
UNITS: INCHES	DWG #: TR 360 T4	MATERIAL: ALUMINUM 6061
TOLERANCE:1/8"	NEXT ASSY: TR 360 TA	NAME: GRANT PETERSEN
SCALE: 1:4	DATE: 6/7/14	CHECKED BY:

5 4 3 2 1



NOTE:
CUT TO LENGTH WITH METAL CHOP SAW
FILE OFF SHARP EDGES

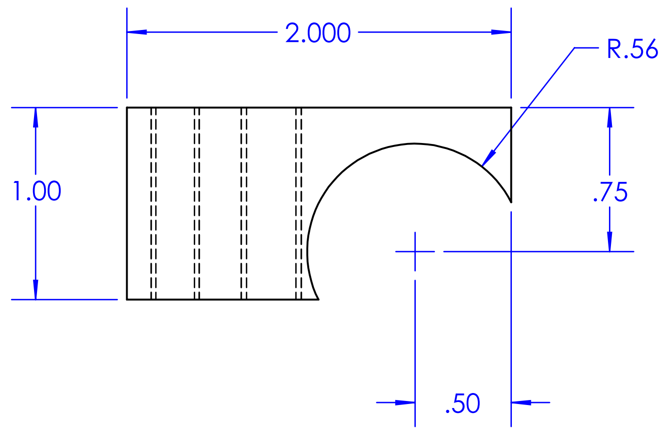
30 MM NOMINAL ALUMINUM TUBING

LENGTH IN INCHES

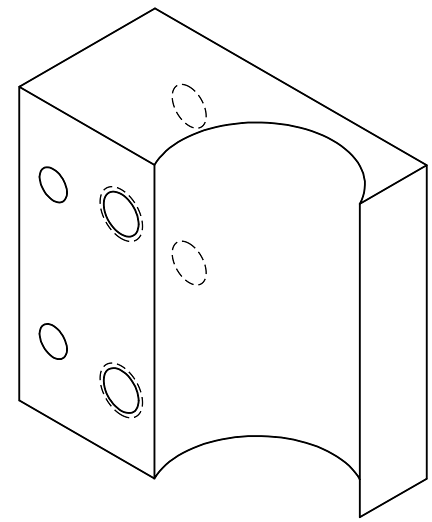
THROUGH HOLE CAN BE DRILLED BEFORE
OR AFTER TUBING ASSEMBLY

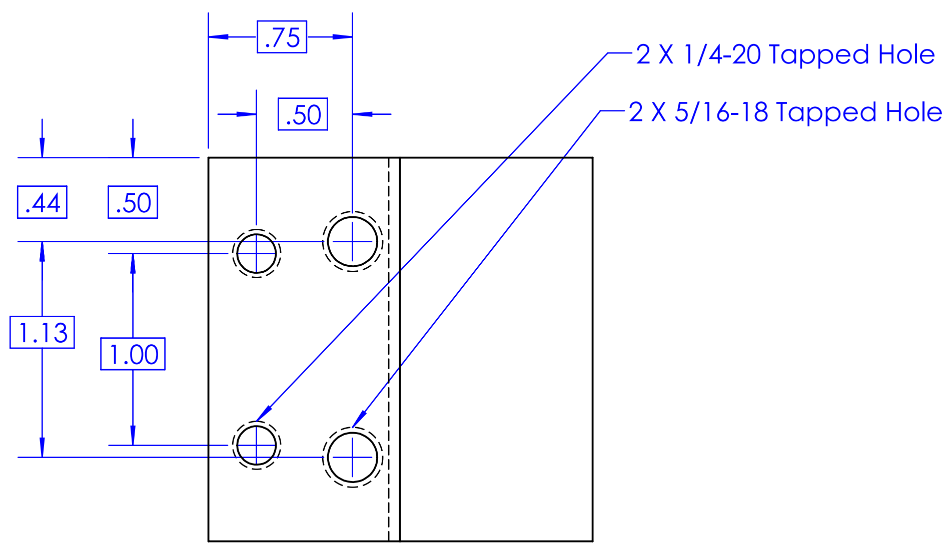
TIDE RIDER 360	TITLE: UPPER VERTICAL TUBE		
Mechanical Engineering CAL POLY	UNITS: INCHES	DWG #: TR 360 T5	MATERIAL: ALUMINUM 6061
	TOLERANCE:1/8"	NEXT ASSY: TR 360 TA	NAME: GRANT PETERSEN
	SCALE: 1:2	DATE: 6/7/14	CHECKED BY:

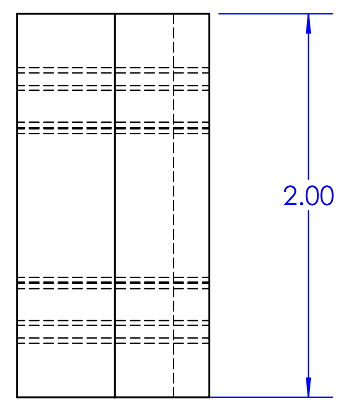
5 4 3 2 1



NOTES:
- UNITS:
  - ALL DIMENSIONS IN INCHES
- TOLERANCES
  - ±0.01 INCHES

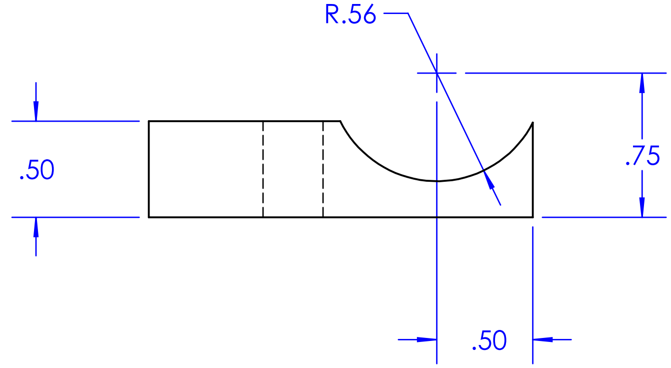




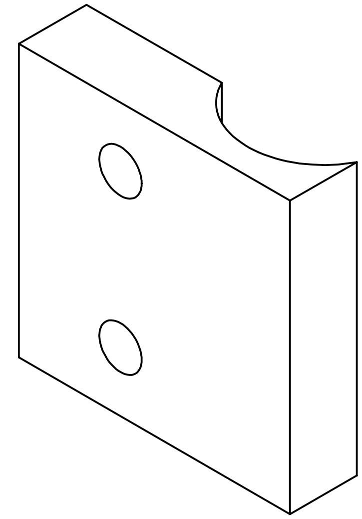


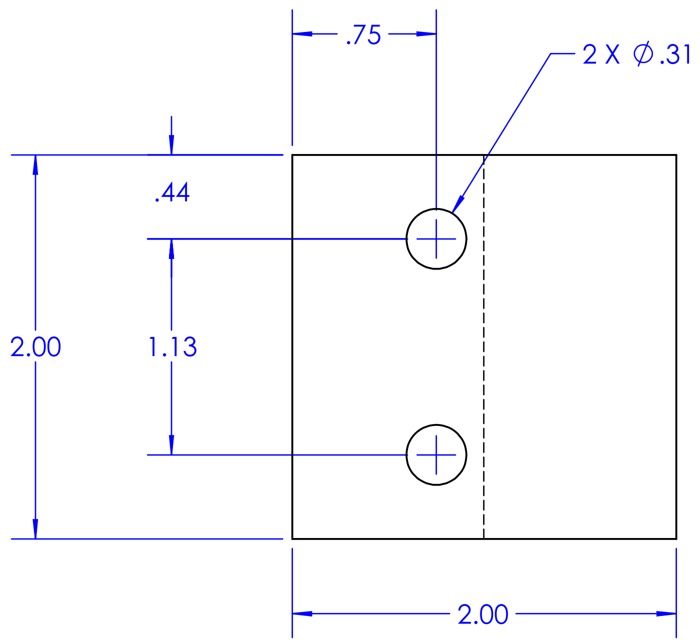
TIDE RIDER 360 Mechanical Engineering CAL POLY	TITLE: LATERAL SUPPORT CLAMP - LARGE		
	UNITS: INCHES	DWG #: TR 360 T6A	MATERIAL: ALUMINUM 6061
	TOLERANCE: 0.01	NEXT ASSY: TR 360 T6	NAME: IRVIN CAMACHO
	SCALE: 1:1	DATE: 5/17/14	CHECKED BY:

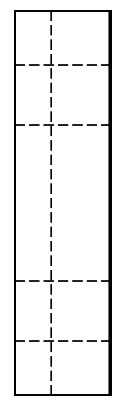
5 4 3 2 1



NOTES:
- UNITS:
  - ALL DIMENSIONS IN INCHES
- TOLERANCES
  - ±0.01 INCHES

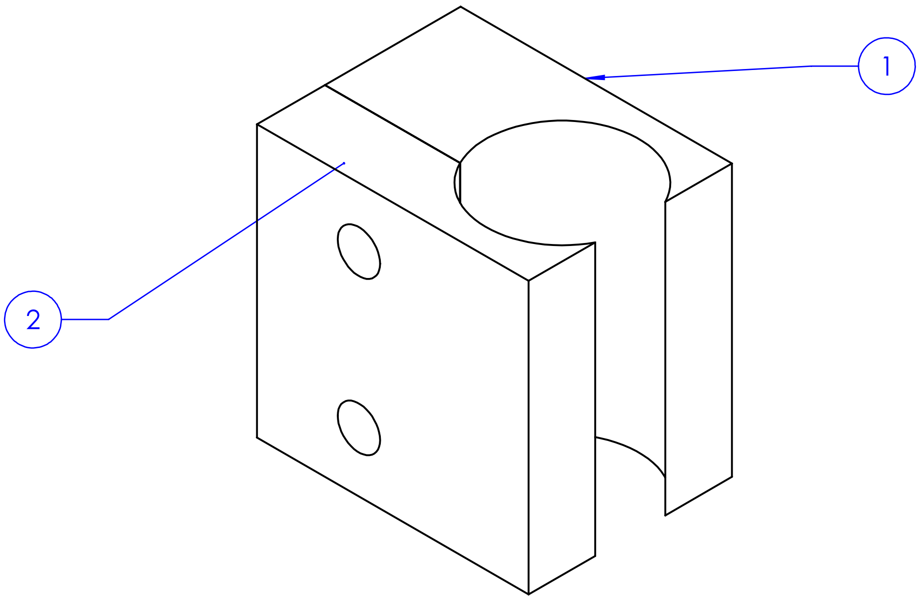






TIDE RIDER 360	TITLE: LATERAL SUPPORT CLAMP - SMALL	
UNITS: INCHES	DWG #: TR 360 T6B	MATERIAL: ALUMINUM 6061
TOLERANCE: 0.01	NEXT ASSY: TR 360 T6	NAME: IRVIN CAMACHO
SCALE: 1:1	DATE: 5/17/14	CHECKED BY:

5 4 3 2 1



NOTE:

ASSEMBLE TWO PIECES USING 5/16 - 18 BOLT

ATTACH AEL MOUNT WITH 1/4-20TAPERED MACHINE SCREWS

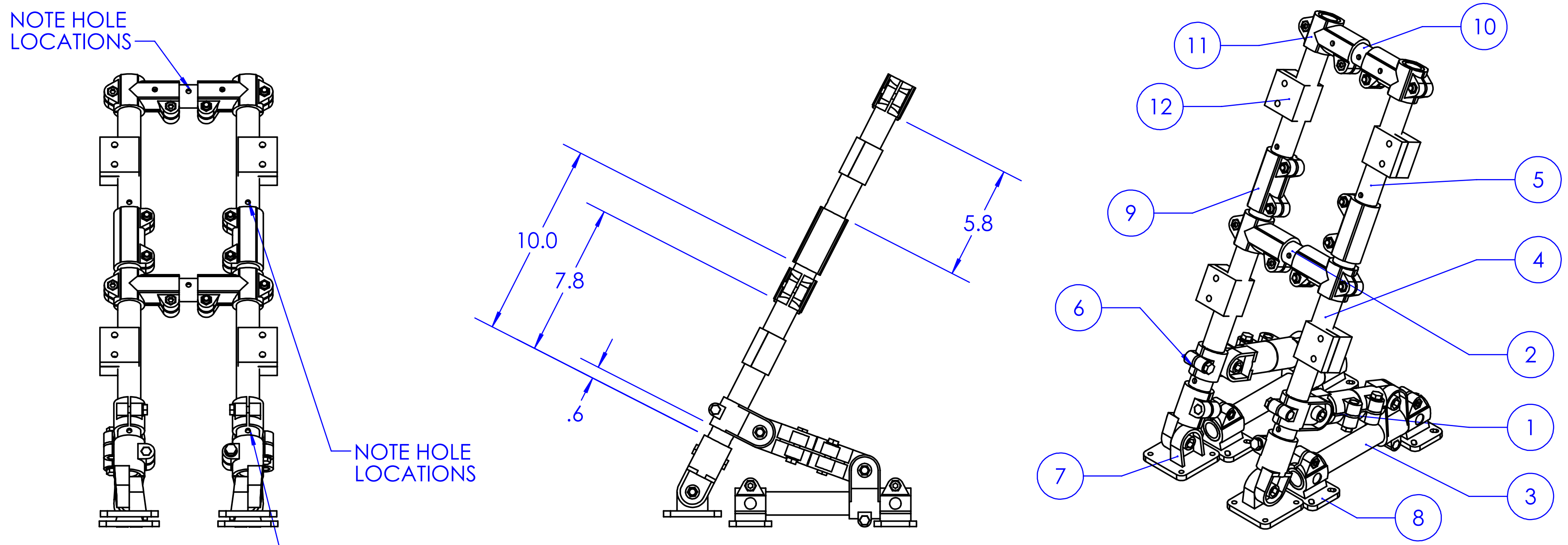
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	TR 360 T6A	LATERAL SUPPORT CLAMP - LARGE	1
2	TR 360 T6B	LATERAL SUPPORT CLAMP - SMALL	1

TIDE RIDER 360

Mechanical Engineering CAL POLY

TITLE: LATERAL SUPPORT CLAMP ASSEMBLY		
UNITS: INCHES	DWG #: TR 360 T6	MATERIAL: ALUMINUM 6061
TOLERANCE:	NEXT ASSY: TR 360 TA	NAME: GRANT PETERSEN
SCALE: 1:1	DATE: 6/7/14	CHECKED BY:

5 4 3 2 1



NOTE:
PLACE TUBING FULLY INTO JOINTS

LOWER AND UPPER VERTICAL TUBES SHOULD MEET AT CENTER OF JOINT 8

IF JOINTS ARE VERY TIGHT USE WD-40 LUBRICANT
IF STILL DIFFICULT: GRIND OR TURN DOWN TUBING DIAMETER SLIGHTLY

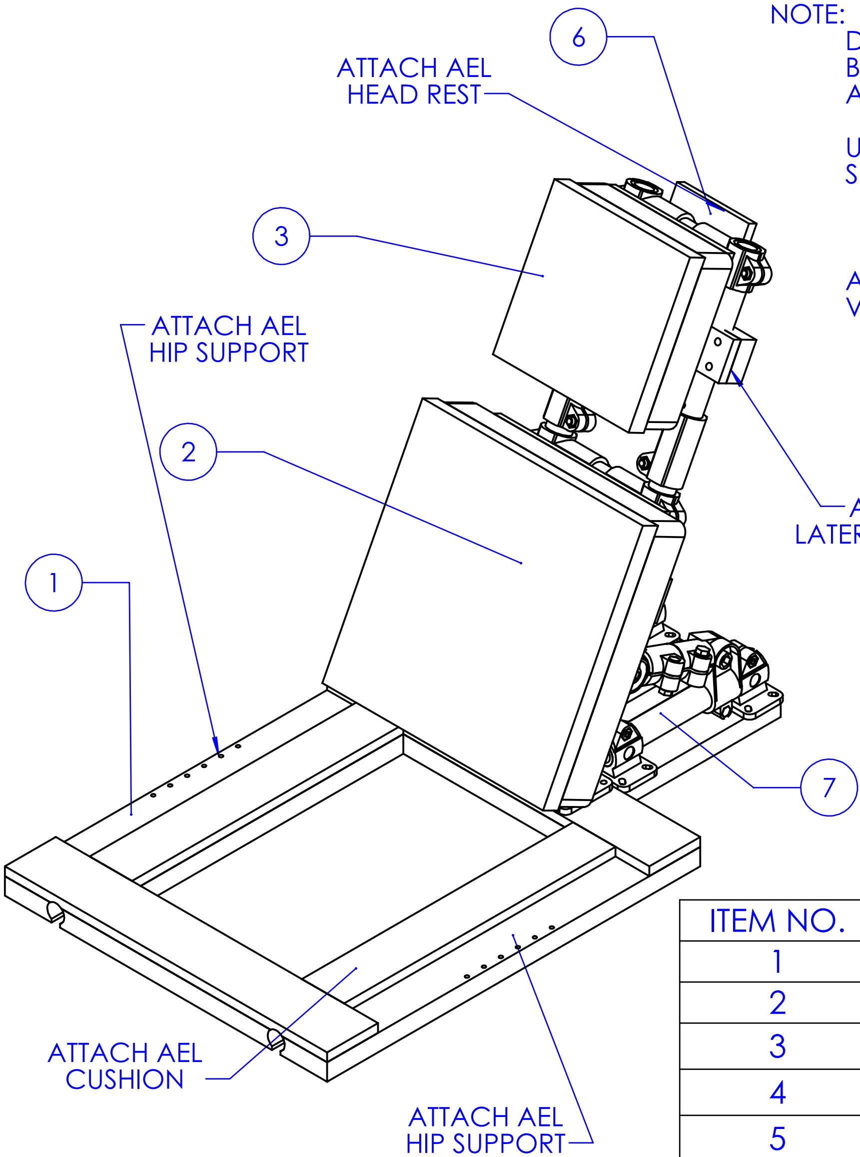
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	TR 360 T1	ANGLE TUBE	2
2	TR 360 T2A	LOWER HORIZONTAL TUBE	1
3	TR 360 T3	TRACK TUBE	2
4	TR 360 T4	LOWER VERTICAL TUBE	2
5	TR 360 T5	UPPER VERTICAL TUBE	2
6	RK 17300000020	SLIDING HINGE	4
7	RK 1730000202	BASE HINGE	2
8	RK FK30-4 12300100020	FLANGE JOINT	4
9	RK K40030BCSV20V20	SLEEVE JOINT	2
10	TR 360 T2B	UPPER HORIZONTAL TUBE	1
11	RK K10030BCSV20V20	T-JOINT	4
12	TR 360 T6	LATERAL SUPPORT CLAMP	4

TIDE RIDER 360

Mechanical Engineering
CAL POLY

TITLE: TUBING ASSEMBLY		
UNITS: INCHES	DWG #: TR 360 TA	MATERIAL: ALUMINUM 6061
TOLERANCE:1/4"	NEXT ASSY: TR 360 CP	NAME: GRANT PETERSEN
SCALE: 1:8	DATE: 6/7/14	CHECKED BY:

5 4 3 2 1



NOTE:

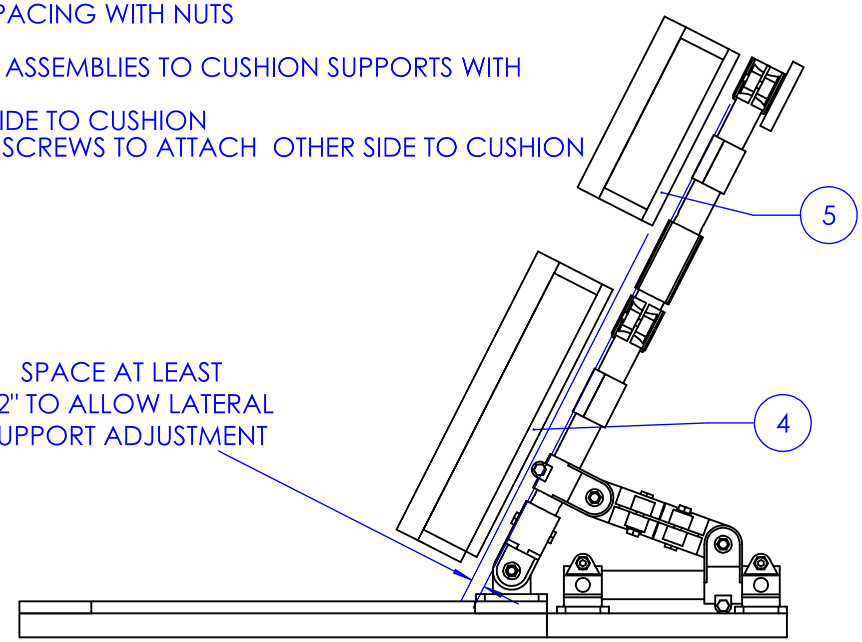
DRILL HOLES FOR ATTACHING TUBING ASSEMBLY TO SEAT BASE BY LINING UP ACTUAL HARDWARE AND MARKING APPROPRIATELY

USE 1/4 - 20 MACHINE SCREWS AND NUTS TO ATTACH CUSHION SUPPORTS AND HEAD REST SUPPORT TO TUBING ASSEMBLY

- LEAVE A GAP BETWEEN SUPPORT PLASTIC AND TUBING FRAME BY SPACING WITH NUTS

ATTACH CUSHION ASSEMBLIES TO CUSHION SUPPORTS WITH VELCRO

- SEW ONE SIDE TO CUSHION
- USE SMALL SCREWS TO ATTACH OTHER SIDE TO CUSHION SUPPORT



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	TR 360 BA	SEAT BASE ASSEMBLY	1
2	TR 360 C1	LOWER CUSHION ASSEMBLY	1
3	TR 360 C2	UPPER CUSHION ASSEMBLY	1
4	TR 360 S1	LOWER CUSHION SUPPORT	1
5	TR 360 S2	UPPER CUSHION SUPPORT	1
6	TR 360 S3	HEAD REST SUPPORT	1
7	TR 360 TA	TUBING ASSEMBLY	1

TIDE RIDER 360

Mechanical Engineering CAL POLY

TITLE: COMPLETE ASSEMBLY		
UNITS: INCHES	DWG #: TR 360 CP	MATERIAL:
TOLERANCE:1/4"	NEXT ASSY:	NAME: GRANT PETERSEN
SCALE: 1:8	DATE: 6/7/14	CHECKED BY:

5 4 3 2 1

Product List
v2013.3

Adaptive Engineering Lab
102 E Keefe Ave
Milwaukee, WI 53212

P: 866.656.1486
F: 866.656.1487
E: sales@AELseating.com
W: AELseating.com

Published November 15, 2013

Product List

Product List

Planar Seats & Backs | Seats

Easy-to-Order Process for Custom Seats

This part number example would be for a Full-Width Seat, 15 3/4" W x 18" D, with 1" Soft SunMate in black Vinyl.

332	-	6	18	-	20	+	01
Seat Type		**Frame Width**	**Seat Depth**		**Foam**		**Upholstery**

Seats

STEP 1: Choose SEAT TYPE

Part No.	Style	Base	Width	Description
331	Drop-In Seat	Plywood	Frame Width Less 2 3/4"	Enables the Seat to drop between the rails of the chair
332	Full-Width Seat	Plywood	Frame Width Less 1/4"	Provides broader seating surface
334	Full-Width Cushion	EVA Foam	Frame Width Less 1/4"	Includes Loop Velcro on bottom to attach to a Seat Base

STEP 2: Provide FRAME WIDTH

Part No.	Frame Width
2	12"
3	13"
4	14"
5	15"
6	16"
7	17"
8	18"
9	19"
0	20"

STEP 3: Provide SEAT DEPTH

Part No.	Seat Depth
12	12"
13	13"
14	14"
15	15"
16	16"
17	17"
18	18"
19	19"
20	20"

Drop-In Seat

Full-Width Seat

Full-Width Cushion

STEP 4: Choose FOAM

Part No.	Foam
00	No Foam (1/4" Landau)
10	Poly - 1" Soft
11	Poly - 1 1/2" Soft
12	Poly - 2" Soft
13	Poly - 1" Medium
14	Poly - 1 1/2" Medium
15	Poly - 2" Medium
20	SunMate - 1" Soft
21	SunMate - 1 1/2" Soft
22	SunMate - 2" Soft

Part No.	Foam
23	SunMate - 1" Medium
24	SunMate - 1 1/2" Medium
25	SunMate - 2" Medium
50	SunMate - 1/2" Soft over 1/2" Medium
51	SunMate - 1/2" Soft over 1" Medium
53	SunMate - 1" Soft over 1" Medium
54	1/2" Pudgee over 1/2" Medium SunMate
55	1/2" Pudgee over 1" Medium SunMate
57	1" Pudgee over 1" Medium SunMate
70	Contour-One
71	Contour-One without Adductors
72	Contour-One without Abductor

STEP 5: Choose UPHOLSTERY

Part No.
See *Upholstery Guide* on pages 1.14-1.15

Contour-One

AEL's Contour-One Seat has layered SunMate foam (1/2" soft over 1/2" medium) over a contoured EVA base. Base includes:

- 1" High Anti-Thrust
- 1" High Abductor
- 1 1/2" High Adductors

Modifications for Pressure Relief

SynerGel™

Part No.	Description	Seat Size
32083	1/2” Gel Overlay	Seat Less than 20” x 20”
32084	1/2” Gel Overlay	Seat 20” x 20” or Greater
32081	1/2” Gel Under Pelvic Area	All
32082	1” Gel Under Pelvic Area	All

Former part number 32080 is no longer available
Use part number 32083 or 32084

NEW! SynerGel ™

Soft Foam Overlay

Part No.	Description
32050	1/2” Soft SunMate
32052	1” Soft SunMate
32060	1/2” Soft Poly
32062	1” Soft Poly
32070	1/2” Soft T-Foam
32072	1” Soft T-Foam

Waterfall Foam

Part No.	Description
36200	Waterfall top 1/2” layer of foam over the front of the seat

Pudgee

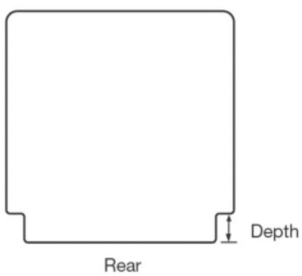
Part No.	Description
32090	1/2” Overlay

Modifications for Cut-Outs

Growth Notches (Full-Width Seats Only)

Allow the seat to be moved forward as the client needs more seat depth

- Cutouts at the rear corners of Full-Width Seat allow the rear of the seat to be positioned back between the uprights of the wheelchair



Part No.	Depth
35001	1”
35002	2”
35003	3”

Leg Length Differential Modification

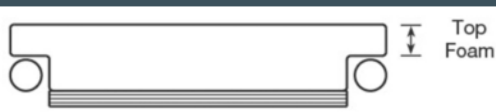
Shortens the right or left side to accommodate for a discrepancy in leg length

Depth	Right Side	Left Side	Right Side with Abductor T-Nuts	Left Side with Abductor T-Nuts
1/2” Shorter	31022	31012	31042	31032
1” Shorter	31024	31014	31044	31034
1 1/2” Shorter	31026	31016	31046	31036
2” Shorter	31028	31018	31048	31038

Note: Right and Left are viewed as if sitting in the chair.

Full-Width Top Foam (Drop-In Flat Seats Only)

Top width of seat is Full-Width, while bottom width of seat is Drop-In
Use this mod on Drop-In Flat Seats only



Part No.	Top Foam Thickness
36001	1/2”
36002	1”
36003	1 1/2”

Rail Cuts (Full-Width Contour Seats Only)

Top width of seat is Full-Width, while bottom width of seat is Drop-In
Use this mod on Full-Width Contour Seats only

Part No.	Height of Seat Between the Rails
36012	1”
36013	1 1/2”

Bevel

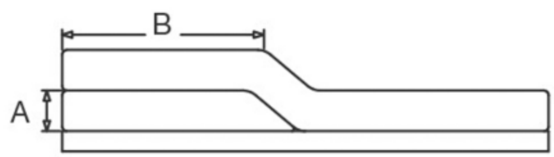
Bevels the front of the seat 1” or 2”. The top of the seat will be the total seat depth, while the bottom will be 1” or 2” less than the total seat depth.

Part No.	Description
31502	1” Bevel
31504	2” Bevel

Modifications for Contoured Positioning

Anti-Thrust

Provides an increased step to help hold the pelvis back on the seat



A = height of step, B = depth of step

Step Depth	1/2" Step Height Part No	1" Step Height Part No	1 1/2" Step Height Part No
4"	30204	30404	30604
5"	30205	30405	30605
6"	30206	30406	30606
7"	30207	30407	30607
8"	30208	30408	30608
9"	30209	30409	30609
10"	30210	30410	30610
11"	30211	30411	30611
12"	30212	30412	30612

Adductors

Part No.	Description
30702	1/2" High Adductors
30704	1" High Adductors
30706	1 1/2" High Adductors
30708	2" High Adductors

Abductor

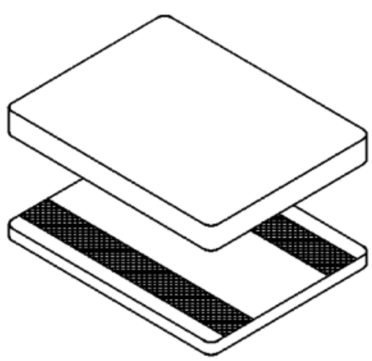
Part No.	Description
30802	1/2" High Abductor
30804	1" High Abductor
30806	1 1/2" High Abductor
30808	2" High Abductor

Modifications to Keep the Seat Clean

Seat Base with Removable Cushion

Modifies the seat to be a separate upholstered base and upholstered cushion with an easily removable cover. Base and cushion attach with Velcro

Part No.
39000



Extra Cover Modification

The Elastic Cover slips over the standard Zippered Cover.
Easily slip off the Elastic Cover as needed to clean

Part No.	Description
37200	Extra Cover with Zipper
37400	Extra Cover – Elastic "Shower-Cap" Style

Incontinence Liner

Plastic liner is wrapped over the foam under the upholstery

Part No.
39100

Product List

Headrests | Headrest Pads

Soft Headrest

Designed for both comfort and support, the low profile allows the person rather than the headrest to be seen.

- Removable, washable cover with zipper across the rear
- 1” Super Soft Poly over 1” Soft Poly foam under Black Dartex or Lycra cover

Headrest bracket sold separately

Part No.	Height	Width	Fabric
18001+51	5”	11”	Black Lycra
18001+61	5”	11”	Black Dartex Smooth
18001+62	5”	11”	Black Dartex Fabric
18003+51	5 1/2”	14”	Black Lycra
18003+61	5 1/2”	14”	Black Dartex Smooth
18003+62	5 1/2”	14”	Black Dartex Fabric

Curved Headrest

Comfortable, contoured pad that is low profile

- 1/2” Medium SunMate foam under a black Dartex or Vinyl cover

Headrest bracket sold separately

Part No.	Height	Width	Fabric
18007+01	3”	7”	Black Vinyl
18007+61	3”	7”	Black Dartex Smooth
18007+62	3”	7”	Black Dartex Fabric
18012+01	4”	9”	Black Vinyl
18012+61	4”	9”	Black Dartex Smooth
18012+62	4”	9”	Black Dartex Fabric

Tri-Pad Headrest

Provides more aggressive head support without interfering with sensory perception. Pads are curved with a occipital contour at the bottom of the middle pad.

- 1/2” Medium SunMate foam under a black Dartex or Vinyl cover

Headrest bracket sold separately

		Center Pad		Side Pad		
Part No	Size	Height	Width	Height	Width	Fabric
18087+01	Regular	4”	4 1/2”	1 1/2” - 3”	5”	Black Vinyl
18087+61	Regular	4”	4 1/2”	1 1/2” - 3”	5”	Black Dartex Smooth
18087+62	Regular	4”	4 1/2”	1 1/2” - 3”	5”	Black Dartex Fabric
18092+01	Large	6”	5 1/2”	1 3/4” - 3 1/2”	6”	Black Vinyl
18092+61	Large	6”	5 1/2”	1 3/4” - 3 1/2”	6”	Black Dartex Smooth
18092+62	Large	6”	5 1/2”	1 3/4” - 3 1/2”	6”	Black Dartex Fabric

Forehead Strap

Attaches to Tri-Pad Headrest.
Includes a small Lycra pad slipped over a webbing strap

Part No.	Size
18075	Regular

Headrests | Headrest Modifications

Curved Headrest SynerGel™ Modification

Replaces foam with 1/2" SynerGel. Suggested with Dartex Smooth

NEW! SynerGel™

Part No.	Compatible with
18081	Curved Headrest Style (Stock Sizes Only)

Headrests | Headrest Brackets

POSAlinc® Adjustable Headrest Brackets

Provides a full range of adjustment to position the headrest pad in precise location

- 2 Pad mounting plate options available
- The Flip-Down style swings the headrest away while staying attached to the chair.
- The Removable style allows the headrest pad to be removed from the system with a twist of the knob.

Order Part No. 83306 to attach to a Pro-tech® back shell

Part No.	Style	Mounting Plate
18171	Flip-Down	S-Plate (AEL)
18191	Removable	S-Plate (AEL)
18172	Flip-Down	Otto Bock
18192	Removable	Otto Bock

Note: The S-Plate is compatible with AEL headrests pads

POSAlinc® Removable Bracket

POSAlinc® Flip-Down Bracket

Standard Removable Headrest Bracket

Provides vertical adjustment or removes by loosening the knob and sliding the post into position. Horizontal and angle adjustment achieved by loosening the clamp and sliding the bars forward, backward or at an angle.

Order Part No. 83306 to attach to a Pro-tech® back shell

Part No	Bar
18053	5"
18051	8 1/2"

Headrests | Headrest Pad & Bracket Combo

Soft Headrest & Headrest Bracket

Receive an additional discount when you purchase the pad and bracket together

Height	Width	Fabric	Soft Headrest + Standard Removable Bracket Part No.	Soft Headrest + POSAlinc® Removable Bracket Part No.	Soft Headrest + POSAlinc® Flip-Down Bracket Part No.
5"	11"	Black Lycra		**18022+51**	**18023+51**
5"	11"	Black Dartex Smooth	**18021+61**	**18022+61**	**18023+61**
5"	11"	Black Dartex Fabric	**18021+62**	**18022+62**	**18023+62**
5 1/2"	14"	Black Lycra		**18025+51**	**18026+51**
5 1/2"	14"	Black Dartex Smooth	**18024+61**	**18025+61**	**18026+61**
5 1/2"	14"	Black Dartex Fabric	**18024+62**	**18025+62**	**18026+62**

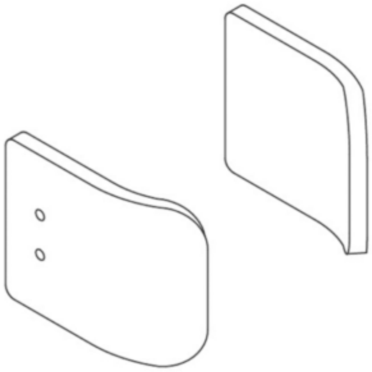
Product List

Laterals | Lateral Pads

Laterals

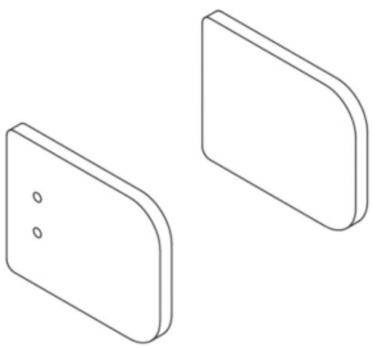
Plastic-Based Pads

- 3/16” Plastic Base with 1/2” medium SunMate foam
- Covered with your choice of black Vinyl or Dartex



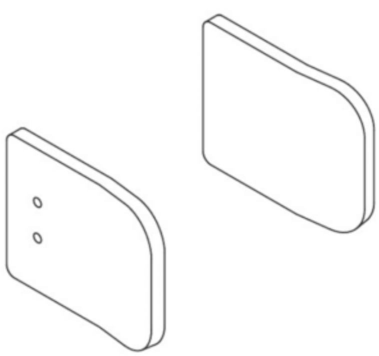
Plastic-Based Curved Trunk Pad

Height	Depth	Hole Spacing	Black Vinyl Part No.	Black Dartex Smooth Part No.	Black Dartex Fabric Part No.	Unit of Measure
3”	4”	1”	**25134+01**	**25134+61**	**25134+62**	1 ea
3”	5”	1”	**25135+01**	**25135+61**	**25135+62**	1 ea
4”	4”	1”	**25144+01**	**25144+61**	**25144+62**	1 ea
4”	5”	1”	**25145+01**	**25145+61**	**25145+62**	1 ea
4”	6”	1”	**25146+01**	**25146+61**	**25146+62**	1 ea
4”	7”	1”	**25147+01**	**25147+61**	**25147+62**	1 ea
5”	6”	1” & 2”	**25156+01**	**25156+61**	**25156+62**	1 ea



Plastic-Based Flat Trunk Pad

Height	Depth	Hole Spacing	Black Vinyl Part No.	Black Dartex Smooth Part No.	Black Dartex Fabric Part No.	Unit of Measure
3”	4”	1”	**25234+01**	**25234+61**	**25234+62**	1 ea
3”	5”	1”	**25235+01**	**25235+61**	**25235+62**	1 ea
4”	5”	1”	**25245+01**	**25245+61**	**25245+62**	1 ea
4”	6”	1”	**25246+01**	**25246+61**	**25246+62**	1 ea



Plastic-Based Flared Trunk Pad

Height	Depth	Hole Spacing	Black Vinyl Part No.	Black Dartex Smooth Part No.	Black Dartex Fabric Part No.	Unit of Measure
4”	5”	1”	**25345+01**	**25345+61**	**25345+62**	1 ea

Pro-tech® Pads

Pro-tech® Lateral Pad

Height	Depth	Hole Spacing	Pro-tech Back Size	Black Dartex Fabric Part No.	Unit of Measure
4 3/4”	3 3/4”	1”	12 – 14	**P25000+62**	1 ea
6”	5”	1”	16 – 24	**P25002+62**	1 ea

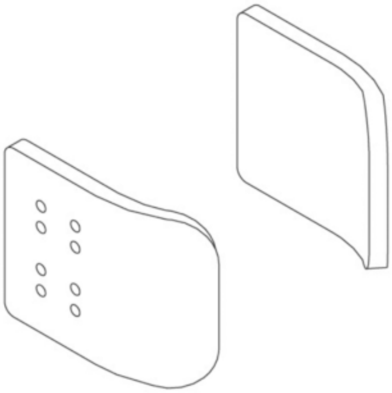
Suggested For Physical Conditions:

Used to control unwanted weight shifts and decrease the risk of orthopedic deformity. Laterals will help stabilize and align the trunk and pelvis, adding to comfort while enabling the legs, arms and hands the freedom to function effectively.

Metal-Based Pads

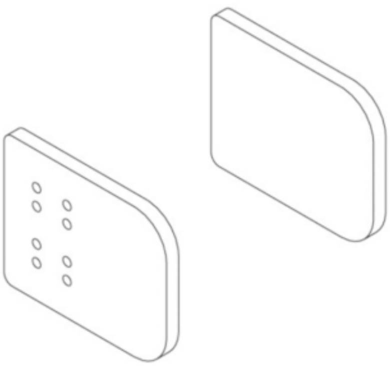
Extra strength custom formable pad option

- Steel base with 1/2” Evazote foam on the contact side and 1/8” Evazote foam on the non-contact side
- Covered with your choice of black Vinyl, Lycra or Dartex upholstery



Metal-Based Curved Trunk Pad

Height	Depth	Hole Spacing	Black Vinyl Part No.	Black Lycra Part No.	Black Dartex Smooth Part No.	Black Dartex Fabric Part No.	Unit of Measure
3”	4”	1”	**27134+01**		**27134+61**	**27134+62**	1 ea
3”	5”	1”	**27135+01**		**27135+61**	**27135+62**	1 ea
4”	5”	1” & 2”	**27145+01**		**27145+61**	**27145+62**	1 ea
4”	6”	1” & 2”	**27146+01**	**27146+51**	**27146+61**	**27146+62**	1 ea
5”	6”	1” & 2”	**27156+01**	**27156+51**	**27156+61**	**27156+62**	1 ea



Metal-Based Flat Trunk Pad

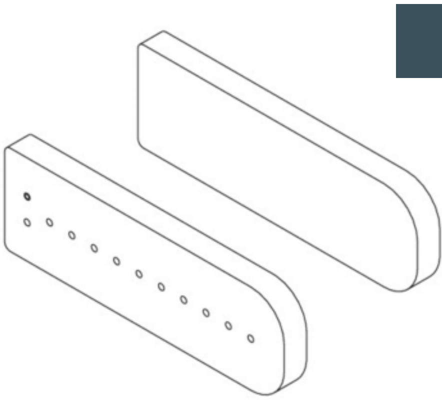
Height	Depth	Hole Spacing	Black Vinyl Part No.	Black Lycra Part No.	Black Dartex Smooth Part No.	Black Dartex Fabric Part No.	Unit of Measure
4”	5”	1” & 2”	**27245+01**		**27245+61**	**27245+62**	1 ea
4”	6”	1” & 2”	**27246+01**	**27246+51**	**27246+61**	**27246+62**	1 ea
5”	6”	1” & 2”	**27256+01**	**27256+51**	**27256+61**	**27256+62**	1 ea

Wood-Based Pads

Wood-Based Pads are suggested for use along the hip

- 1/2” Plywood base with 1/2” medium SunMate foam under a black Vinyl or Dartex cover
- Assortment of T-nuts for mounting off the bottom of solid seats or backs
- Choose from short pads for lateral support of the trunk or hip, or long pads which travel the length of the sitting surface to support the hip, thigh and knee.

Wood-Based Flat Hip Pad



Height	Depth	Black Vinyl Part No.	Black Dartex Smooth Part No.	Black Dartex Fabric Part No.	Unit of Measure
3”	4”	**26304+01**	**26304+61**	**26304+62**	1 ea
4”	5”	**26405+01**	**26405+61**	**26405+62**	1 ea
4”	6”	**26406+01**	**26406+61**	**26406+62**	1 ea
4”	8”	**26408+01**	**26408+61**	**26408+62**	1 ea
4”	10”	**26410+01**	**26410+61**	**26410+62**	1 ea
4”	12”	**26412+01**	**26412+61**	**26412+62**	1 ea
4	14”	**26414+01**	**26414+61**	**26414+62**	1 ea
4”	15”	**26415+01**	**26415+61**	**26415+62**	1 ea

SynerGel™ Lateral Pad Modifications

Replaces foam with 1/2" SynerGel. Suggested with Dartex Smooth
Not available for Metal-Based Pads

NEW! SynerGel ™

Part No.	Lateral Pad Base	Unit of Measure
22081	Plastic-Based Pad (Stock Sizes Only)	1 ea
22082	Wood-Based Pad (Stock Sizes Only)	1 ea

Custom Foam Modifications

Replaces the standard 1/2" medium SunMate on the pad

Choose part number by pad size
- Small Pads: Trunk Pads 5" x 6" or smaller or Hip Pads 4" x 7" or smaller
- Large Pads: Trunk Pads larger than 5" x 6" or Hip Pads larger than 4" x 8"

If larger than 4" x 15" or 60 square inches, contact Customer Service for pricing

Custom Foam Option	Small Pad Part No.	Large Pad Part No.	Unit of Measure
1/2" Medium Poly	**22060**	**22160**	1 ea
1/2" Medium T-Foam	**22070**	**22170**	1 ea
1/2" Pudgee	**22090**	**22190**	1 ea
1" Medium SunMate	**22052**	**22152**	1 ea

Waterfall Foam Modification

Modifies the foam so that it waterfalls over the top and front edge of the pad

Choose part number by pad size
- Small Pads: Trunk Pads 5" x 6" or smaller or Hip Pads 4" x 7" or smaller
- Large Pads: Trunk Pads larger than 5" x 6" or Hip Pads larger than 4" x 8"

If larger than 4" x 15" or 60 square inches, contact Customer Service for pricing

Small Pad Part No.	Large Pad Part No.	Unit of Measure
24000	**24100**	1 ea

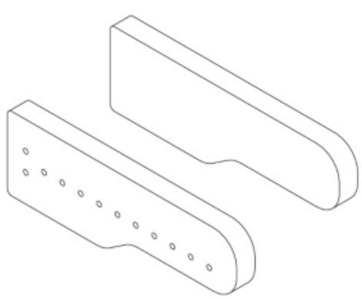
Contoured Hip Pad Modification

Contours the Hip Pad to the Anti-Thrust of the seat or cushion. Compatible with hip pads ordered with a Contour-One Seat or Anti-Thrust Seat

Choose part number by pad size
- Small Pads: Trunk Pads 5" x 6" or smaller or Hip Pads 4" x 7" or smaller
- Large Pads: Trunk Pads larger than 5" x 6" or Hip Pads larger than 4" x 8"

If larger than 4" x 15" or 60 square inches, contact Customer Service for pricing

Small Pad Part No.	Large Pad Part No.	Unit of Measure
23000	**23100**	1 ea



Zipper Closure Modification

Adds a zipper closure along the bottom of the pad to make the cover removable. Compatible with all Trunk and Hip Pads 5" x 15" or smaller
If larger than 5" x 15", contact Customer Service for pricing

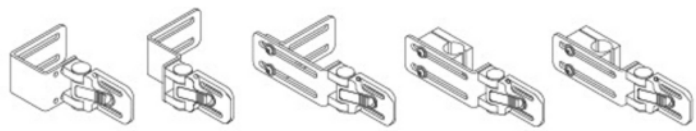
Part No.	Unit of Measure
21000	1 ea

Swing-Away Hardware

QuickPlus® Swing-Away Lateral Bracket

Designed to swing lateral pads out of the way with the touch of a button for quick and easy transfers

- Side-to-side lateral adjustment
- Angle adjustment to rotate the front of the pad in or out
- Brackets are made of 1/8" steel with black powder-coat finish



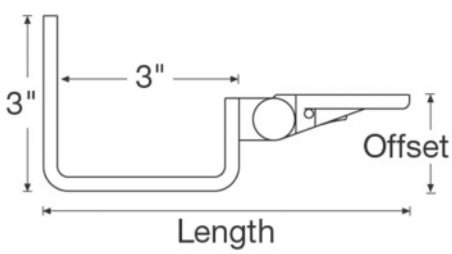
Slot Spacing	C-Style Part No.	Z-Style Part No.	L-Style Part No.	7/8" Clamp Part No.	1" Clamp Part No.	Unit of Measure
1"	**15711**	**15721**	**15731**	**15741**	**15751**	1 ea
1" & 2"	**15712**	**15722**	**15732**	**15742**	**15752**	1 ea

Heavy-Duty QuickPlus® Swing-Away Lateral Bracket

For added durability, choose one of our heavy-duty options

- Brackets are made of 1/4" aluminum with black powder-coat finish
- Optional wider width for 3" thick solid backs

Slot Spacing	Maximum Back Thickness	C-Style Part No.	Z-Style Part No.	Unit of Measure
1"	2 1/4"	**15713**	**15723**	1 ea
1" & 2"	2 1/4"	**15714**	**15724**	1 ea
1"	2 3/4"	**15717**	**15727**	1 ea
1" & 2"	2 3/4"	**15718**	**15728**	1 ea



Pro-tech® QuickPlus® Swing-Away Lateral Bracket

Designed to swing Pro-tech® Lateral Pads out of the way with the touch of a button for quick and easy transfers

Part No.	Slot Spacing	Height	Length	Pro-tech Back Size	Unit of Measure
P25250	1"	1 1/2"	6"	12 – 18	1 ea

Fixed Lateral Hardware

Standard Lateral Bracket

Designed to mount pads off solid backs or seats
- Available in a range of lengths to accommodate varieties of back and seat thicknesses
- Slots allow for both side-to-side and forward-to-back adjustment
- Choose 90º angle to mount to a flat back or 100º angle to mount to a curved back

Slot Spacing	Height	Length	90º Bracket Part No.	100º Bracket Part No.	Unit of Measure
1”	2”	4”	**15224**	**15324**	1 ea
1”	2”	5”	**15225**	**15325**	1 ea
1”	2”	6”	**15226**	**15326**	1 ea
1”	2”	8”	**15228**		1 ea
2”	3”	4”	**15234**	**15334**	1 ea
2”	3”	5”	**15235**	**15335**	1 ea
2”	3”	6”	**15236**	**15336**	1 ea
2”	3”	8”	**15238**		1 ea

Offset-In Lateral Bracket

Designed to mount lateral pads off solid backs or seats for clients who are narrower than the back or seat and need the lateral pads or hip pads positioned in from the edge
- Choose 90º angle to mount to a flat back or 100º angle to mount to a curved back

Seat or Back Thickness	Slot Spacing	Height	Length	Offset	90º Bracket Part No.	100º Bracket Part No.	Unit of Measure
2 1/4”	1”	2”	5”	1/2”	**15821**	**15921**	1 ea
2 1/4”	1”	2”	4”	1”	**15822**	**15922**	1 ea
2 1/4”	1”	2”	5”	1”	**15823**	**15923**	1 ea
2 1/4”	1”	2”	5”	1 1/2”	**15825**		1 ea
2 1/4”	1”	2”	4”	2”	**15826**		1 ea
2 1/4”	1”	2”	5”	2”	**15827**		1 ea
2 1/4”	2”	3”	5”	1”			1 ea
3”	1”	2”	6”	1”	**15843**		1 ea
3”	1”	2”	6”	1 1/2”	**15845**		1 ea

Offset-Out Lateral Bracket

Designed to mount lateral pads off solid backs or seats for clients who are wider than the back or seat and need the lateral pads positioned out from the edge

90º Bracket Part No.	Slot Spacing	Height	Length	Offset	Unit of Measure
15829	1”	2”	5”	1	1 ea

Pro-tech® Standard Lateral Bracket

Mounts a Pro-tech® Lateral Pad off a Pro-tech® Back

Part No.	Slot Spacing	Height	Length	Pro-tech Back Size	Unit of Measure
P25160	1”	1 3/4”	5”	12 – 14	1 ea
P25162	1”	1 3/4”	6”	16 – 24	1 ea

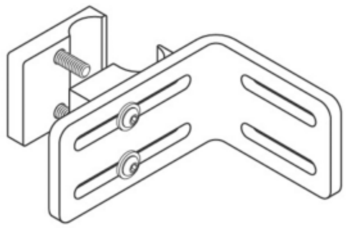
Laterals

Fixed Lateral Hardware (continued)

Clamp Bracket

- Designed to attach to tubing.
- Includes Clamp Bracket and Standard Lateral Bracket (Part No. 15224)
- Provides many adjustment options: (1) depth adjustment of 1 1/2" by sliding the pad on the slots of the L-bracket; (2) lateral adjustment of 3" per side by moving the L-bracket in or out on the clamp; and (3) vertical adjustment by moving the clamp up or down along the canes

Part No.	Tube Diameter	Unit of Measure
15071	7/8"	1 ea
15076	1"	1 ea

Slide Hardware

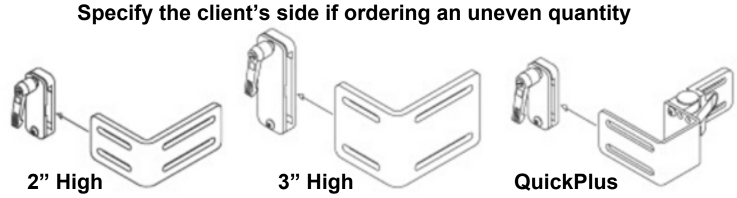
Slide Adjust Mount (Summer/Winter Bracket)

- Quick and easy side-to-side adjustment of lateral brackets without tools
- Allows for the bracket to be removable
- Includes index labels for easy and consistent adjustments

Lateral brackets sold separately

Mounting	Compatibility	Part No.	Unit of Measure
To Back	2" High Lateral Bracket	**15602**	1 ea
To Back	3" High Lateral Bracket	**15603**	1 ea
To Back	QuickPlus	**15705**	1 ea
To Back	Heavy-Duty QuickPlus	**15602**	1 ea
To Track Hardware	2" High Lateral Bracket	**15604**	1 ea
To Track Hardware	3" High Lateral Bracket	**15605**	1 ea
To Track Hardware	QuickPlus	**15707**	1 ea
To Track Hardware	Heavy-Duty QuickPlus	**15604**	1 ea

Specify the client's side if ordering an uneven quantity

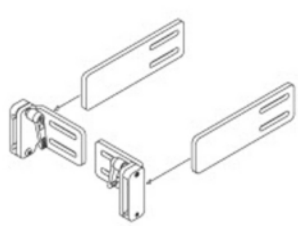
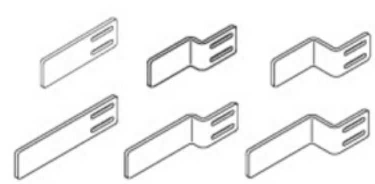


Lateral Slide Release with Pad Mounting Bracket

Quick and easy removal of laterals for transfers, as well as fore and aft adjustments

Height	Length	Flat Bracket Part No.	1" Offset Bracket Part No.	2" Offset Bracket Part No.	Unit of Measure
2"	6"	**15620**	**15621**	**15622**	1 ea
2"	8"	**15623**	**15624**	**15625**	1 ea

Specify the client's side if ordering an uneven quantity

Flat **1" Offset** **2" Offset**

Lateral Slide Release Bracket

Order replacement mounting bracket separately

Part No.	Unit of Measure
15612	1 ea

Specify the client's side if ordering an uneven quantity

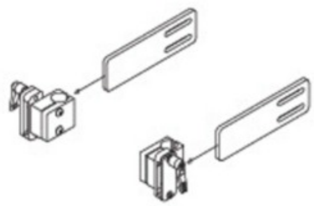
Slide Hardware (continued)

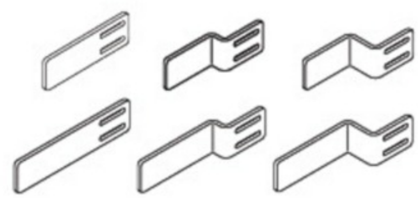
Clamp Slide Release Bracket with Pad Mounting Bracket

Quick and easy removal of laterals for transfers, as well as fore and aft adjustments. Mount lateral pads off frame tubing.

Tube Diameter	Height	Length	Flat Bracket Part No.	1" Offset Bracket Part No.	2" Offset Bracket Part No.	Unit of Measure
1"	2"	6"	**15641**	**15642**	**15643**	1 ea
1"	2"	8"	**15644**	**15645**	**15646**	1 ea

Specify the client's side if ordering an uneven quantity





Flat **1" Offset** **2" Offset**

Clamp Slide Release Bracket

Order replacement mounting bracket separately

Part No.	Tube Diameter	Unit of Measure
15630	7/8"	1 ea
15640	1"	1 ea

Specify the client's side if ordering an uneven quantity

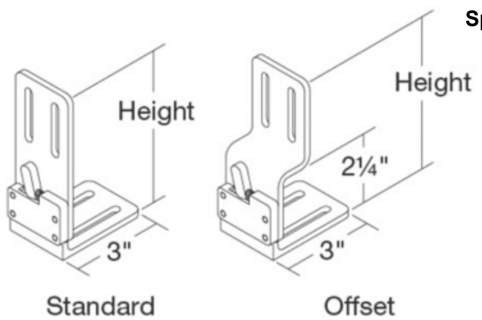
Hip Pad Hardware

Removable Hip Pad Bracket

- Slim-line design
- Easy one-hand release with spring-loaded locking mechanism

Part No.	Offset	Height	Slot Spacing	Unit of Measure
15114	Standard	6"	1"	1 ea
15117	1" Offset	5"	1"	1 ea

Specify the client's side if ordering an uneven quantity



Adjustable Angle Hip Pad Bracket

- Adjusts the angle of hip pads mounted off the bottom of solid seats
- Two-piece lateral brackets offer up to 50º of angle adjustment
- Can be used for mounting lateral trunk pads to solid backs for angle adjustment

Part No.	Height	Slot Spacing	Offset	Unit of Measure
15120	5"	1"	1"	1 set (2 ea)

Foot Accessories | Replacement Straps

Replacement Straps

Replacement Toe Straps for Dynaform Foot Positioners

Part No.	Size	Unit of Measure
13181	Small	1 set (2 ea)
13182	Medium	1 set (2 ea)
13183	Large	1 set (2 ea)

Replacement Shoe Holder Straps

Part No.	Size	Unit of Measure
13121	Small	1 set (2 ea)
13122	Medium	1 set (4 ea)
13123	Large	1 set (4 ea)

Foot Accessories | Foot Boxes

Foot Boxes

Comfortable containment for feet with some freedom of movement

- Padding on all inside surfaces attaches with Velcro for easy mounting and cleaning
- Protective one-piece outer plastic shell

Full Foot Box

		Outer Shell Dimensions			Inner Shell Dimensions		
Part No.	Size	Width	Depth	Height	Width	Depth	Height
13202+01	Small	11”	8”	6”	9 1/2”	7 1/4”	5 1/4”
13204+01	Medium	13”	10”	7”	11 1/2”	9 1/4”	6 1/4”
13206+01	Large	15”	12”	10”	13 1/2”	11 1/4”	9 1/4”

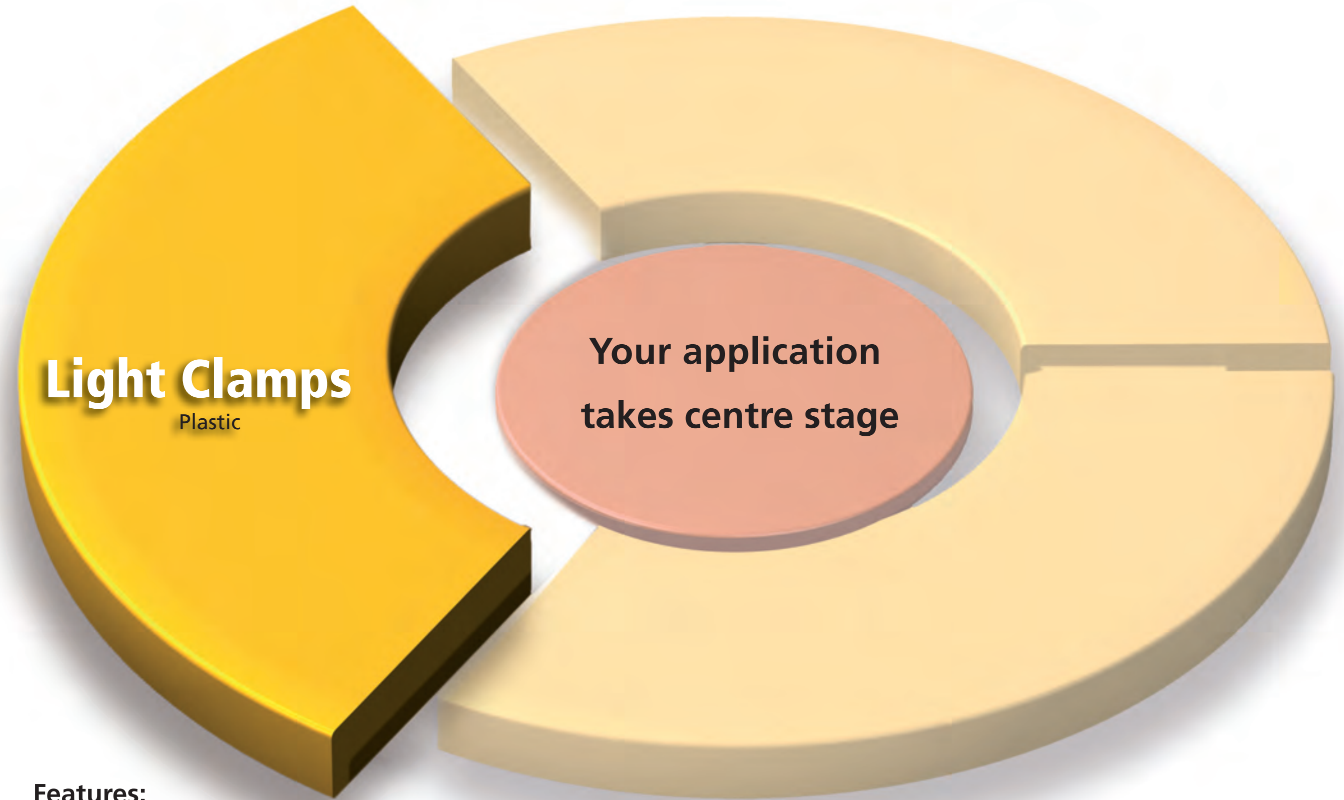
Split Foot Box

		Outer Shell Dimensions			Inner Shell Dimensions		
Part No.	Size	Width	Depth	Height	Width	Depth	Height
13212+01	Small	5 1/2”	8”	6”	4 3/4”	7 1/4”	5 1/4”
13214+01	Medium	6 1/2”	10”	7”	5 3/4”	9 1/4”	6 1/4”
13216+01	Large	7 1/2”	12”	10”	6 3/4”	11 1/4”	9 1/4”

Specify the client’s side if ordering an uneven quantity

Adaptive Engineering Lab
102 E Keefe Ave
Milwaukee, WI 53212

P: 866.656.1486
F: 866.656.1487
E: sales@AELseating.com
W: AELseating.com



Features:

- ✓ Easy
- ✓ Good value
- ✓ Variable

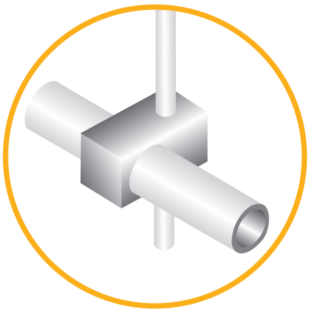
...the constructive plastic element connecting technology

Light load range

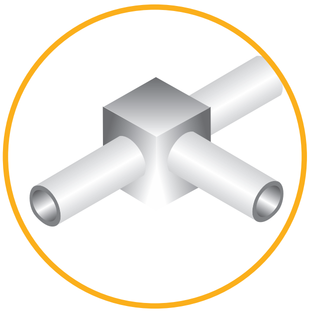
Light Clamps

...the constructive plastic element connecting technology

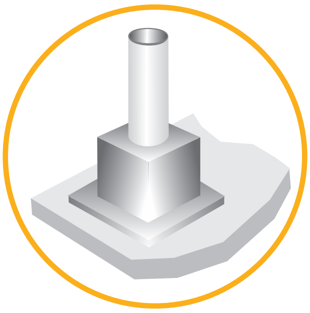
Right angle tube connector



Cross clamps

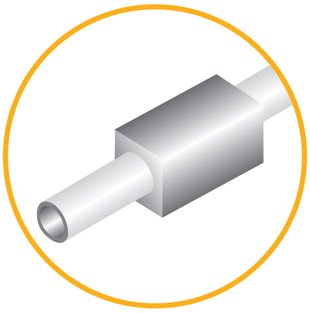


Angle clamps

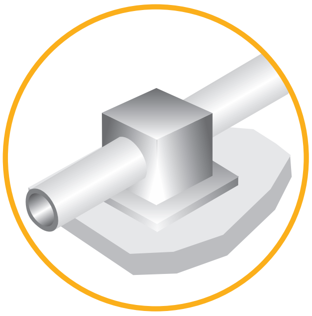


Base clamps

Axially parallel tube connector

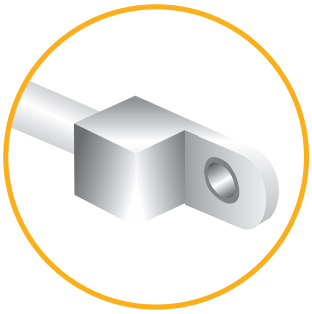


Sleeve clamps

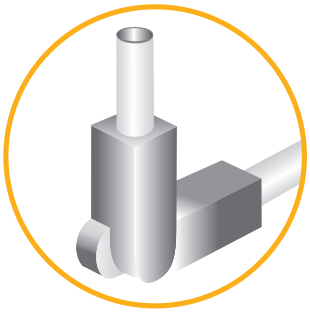


Flange clamps

Hinge tube connector



Strap clamps



Hinge clamps

Features:

- Only one element per type (Ø18 / Ø30 / ☐ 30)
- Elements made of reinforced polyamide
- Closed elements or half cups
- Tube clamping of different diameters or sections due to a special bush system
- Every bush form is worked with the needed tube diameter
- Anti turning device for the bush former due to a lokation pin in the bush
- Attractive design
- Zinc plated screws
- Compatibility to the BLOCAN® profile system

Options:

- Equipped with stainless steel screws for usage in the food industry and the wet areas in the beverage industry

Table of contents - *RK LightClamps*

Right angle tube connector
(Single-piece and multi-piece elements)

Axially parallel tube connector
(Single-piece and multi-piece elements)

Hinge tube connector
(Single-piece and multi-piece elements)

Properties

Accessories

Version: Light Clamps

Single-piece elements

✓ For faster and more economic assembly

Multi-piece elements

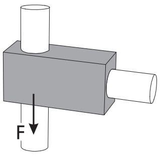
✓ For add-on assembly and upgrading

Features:

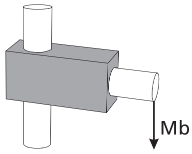
- Restistance against corrosion and agressive substances
- Low dead load
- Applicable e.g. in the food packaging industry
- Two basic diameters can be flexibly adapted with reducing bushes

delivery from stock

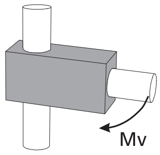
Loads *RK LightClamps*



Adhesion force F [KN]



Bending moment Mb [Nm]

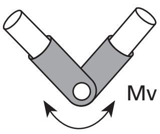


Twisting moment Mv [Nm]

Tightening torque max:
Sizes: 10 – 18: 2,5 Nm
Sizes: 20 – 30: 8,0 Nm

Material data sheet available upon request.

Sizes	□10			Ø12 - 18			□20			Ø20 - 30			□30			Ø30		
Type	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv
Cross clamps																		
K-KU	0,30	130	15	0,50	111	5	0,50	164	31	1,00	184	11,50						
KV-KU													1,30	122	23	1,60	120,50	19
KVR-KU Insert													1,40	136	23	1,60	142,50	19
KVR-KU Bushes													0,60	134,50	30,50	1,80	107,50	19
Angle clamps																		
W-KU	0,20	91	8	0,60	83	4,50	0,60	153,50	30	1,00	177	10,50						
WV-KU													1,00	136,50	23	1,40	109,50	15,50
Base clamps																		
FS-KU	0,20	36	11	0,40	40	2,50	0,60	158	31	1,10	181,50	13						
FV-KU													1,00	77	23	1,60	72	19,50
Sleeve clamps																		
M-KU	0,10	91	8	0,50	75,50	4	0,70	225,50	31	1,00	242,50	11,50						
Flange clamps																		
FK-KU	0,20	35	7,50	0,40	38,50	4	0,60	134,50	31	1,20	137,50	12,50						
FKV-KU													1,30	144,50	23	1,60	142,50	20,50
V-KU													0,90	-	23	1,20	-	15,50
Strap clamps																		
LP-KU	0,30	16	7,50	0,40	18,50	4,50	0,70	38,50	27	0,90	41,50	11,50						
LPZ-KU	0,40	16	7,50	0,50	18,50	2,50	0,70	43	28	0,90	45,50	12						
LW-KU	0,20	27,50	7,50	0,70	27,50	4	0,80	40,50	31	1,10	41	14						
LF-KU																		



Twisting moment Mv [Nm]

Sizes	□10			Ø12 - 18			□20			Ø20 - 30			□30			Ø30		
Type			Mv			Mv			Mv			Mv			Mv			Mv
Hinge clamps																		
GW-KU ohne Verzahnung			1,50			1,70			4,00			4,20						
GWZ-KU mit Verzahnung																		
GP-KU ohne Verzahnung			1,10			1,50			2,50			2,10						
GPZ-KU mit Verzahnung																		
GF-KU ohne Verzahnung																		
GFZ-KU mit Verzahnung			27			23			68			68						

Reducing bushes / -insert size

You can choose the size of the insert you want to introduce into the clamping element between 10 and 25 mm.

The basic size of the round tubular connections is either 18 or 30mm. For any other required diameter the corresponding reducing bush can be delivered.

Should you work with square tubes, which offer a choice between 10 and 20 mm, reducing bushes are a necessity.

Reducing bushes / -insert form

Not only can you choose the diameter of the reducing bush you require, you also have the possibility to choose its form. All you need to do is to choose the tube section you would like to work with.

The following forms are at your disposal:

For round tubes Ø
For square tubes □

Detailed information for the reducing bushes and inserts can be found in the chapter accessories page 48

Order information and accessories

The clamping elements are automatically provided with a zinc-plated fixation screw. Also, stainless steel screws and plastic levers can be optionally ordered for the fixation.

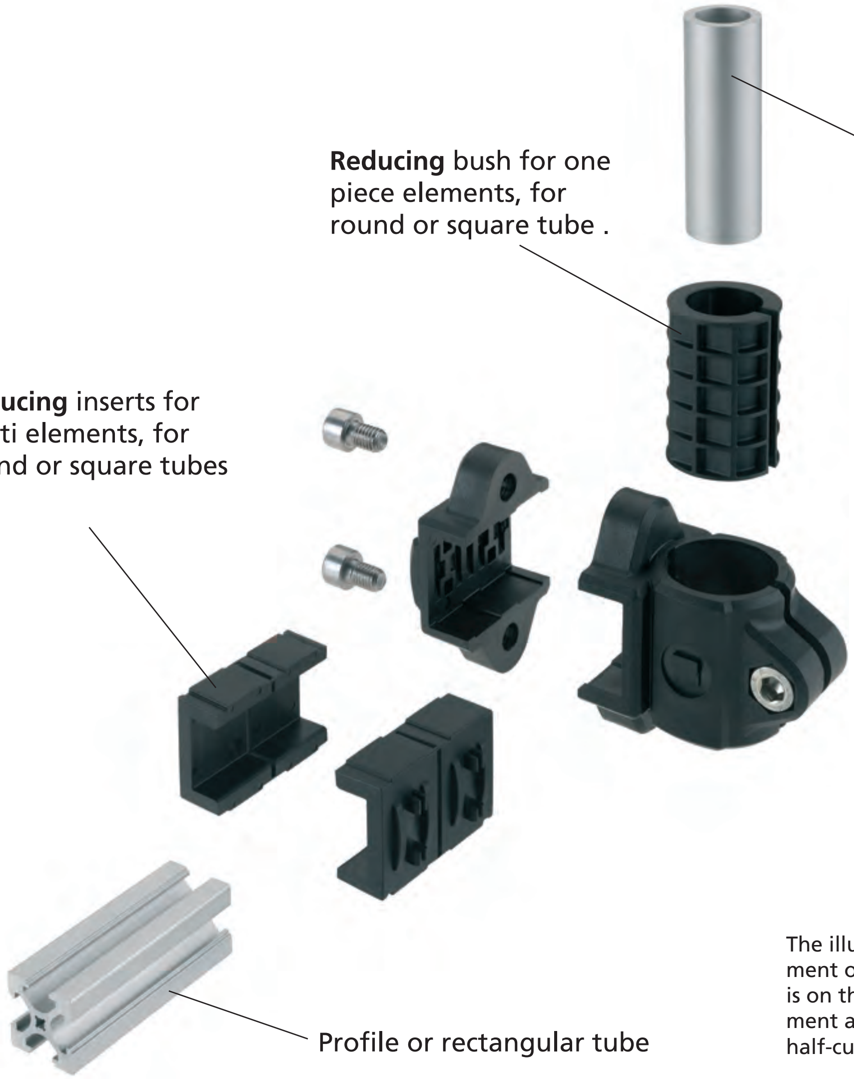
The reducing bushes and -inserts are not included in the standard delivery. They are separately listed in the accessory chapter.

Delivery set:
The code number contains one packaging unit.
Type 12-18 10 pieces in PET bags
Type 20-30 5 pieces in PET bags

Applications:

- ✓ Areas of the laboratory technology
- ✓ Food industry
- ✓ Wet area in the beverage industry
- ✓ Photo technical applications

The variable reduction sleeve concept :



The illustration shows an element of type KVR. This element is on the one side a closed element and on the other side a half-cup element.

RK LightClamps – Comprehensive view

Right angle tube connector


K-KU p. 34


KV-KU p. 34


FS-KU p. 37


FV-KU p. 39

Axially parallel tube connector


M-KU p. 38


V-KU p. 40

Hinge tube connector


LP-KU p. 41


LPZ-KU p. 41


LW-KU p. 42


LF-KU p. 42


KVR-KU p. 35


W-KU p. 36


WV-KU p. 36


FK-KU p. 39


FKV-KU p. 39


GW/GWZ-KU p. 43


GP/GPZ-KU p. 44


GF/GFZ-KU p. 45

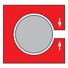
RK LightClamps – Angle-/Base clamps

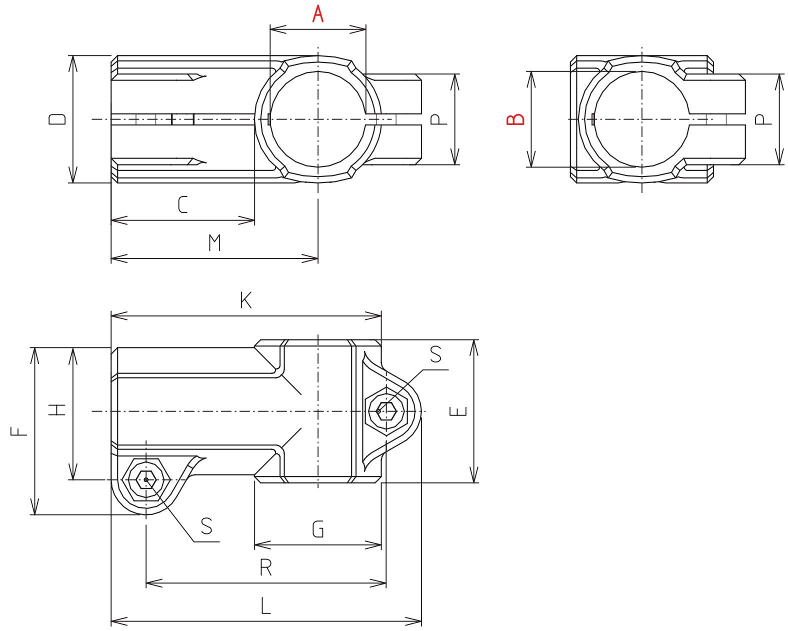
Order information:

- Inserts and bushes for diameter/cross-section changes see accessories page 48
- For clamping levers see accessories page 49

On request:

- Stainless screws

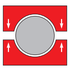


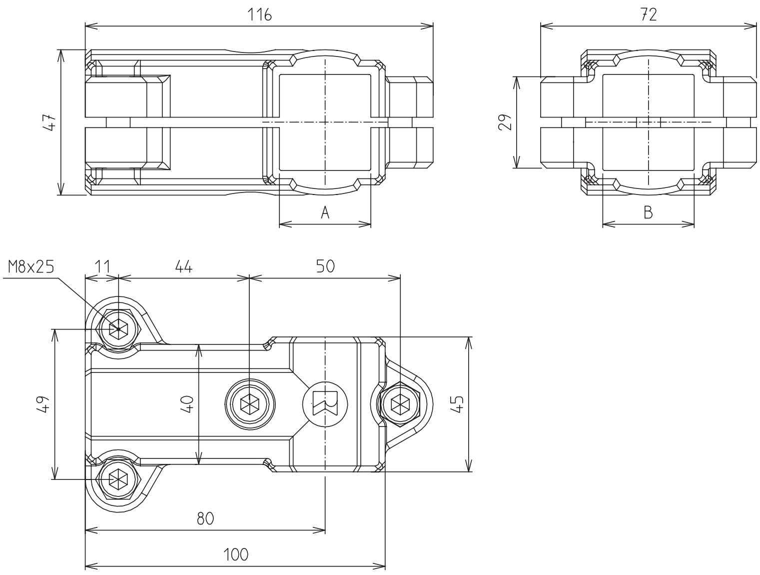


Angle clamps W-KU

[mm]

Code No.	Type	Packaging	Clamping* A	Clamping* B	C	D	E	F	G	H	K	L	M	P	R	S	Weight m [g]
K10018CCSR18R18	12-18	10 Pcp.	18		30,5	25	30	34	25	26,5	55,5	64,5	43	21	49,5	M6x18	44
K10030BCSR30R30	20-30	5 Pcp.	30		45	40	45	52,5	40	41,5	85	97,5	65	28,5	75,5	M8x25	115





Angle clamps WV-KU

[mm]

Code No.	Type	Packaging	Clamping * A	Weight m [g]
K10430BCSV30V30	20-30	5 Pcp.	30	194

Medium	resistant	conditionally resistant	not resistant
Acetic acid		◐	
Aqua regia			○
Benzene + Fuel	●		
Benzole	●		
Brake fluid	●		
Butane	●		
Butanol	●		
Butyl acetate	●		
Carbon Tetrachloride	●		
Caustic soda	●		
Chloroflourocarbon	●		
Chloroform		◐	
Cresol		◐	
Dekalin	●		
Dibutyl phthalate	●		
Diesel	●		
Dimethylformamide		◐	
Dioctyl phthalate	●		
Dioxan	●		
Engine oils	●		
Ethanol		◐	
Fats + Waxes	●		
Fatty acids	●		
Gear oil	●		
Glycol		◐	
Glysantin	●		
Glycerine	●		
Heating oil	●		
Heptane, Hexane	●		
Hydraulic oil	●		
Hydrochloric acid			○
Isopropanol	●		
Isooctane	●		
Methanol		◐	
Methylene chloride			○
Mineral oils		◐	
Naphthalene	●	◐	
Ozone			○
Phenol		◐	
Phosphoric acid		◐	

Medium	resistant	conditionally resistant	not resistant
Potassium hypochloride			○
Sulphuric acid			○
Silicone oil	●		
Styrolene	●		
Tetrahydrofurane	●		
Toluol	●		
Trichlorethylene		◐	
Water	●		
Xylene		◐	

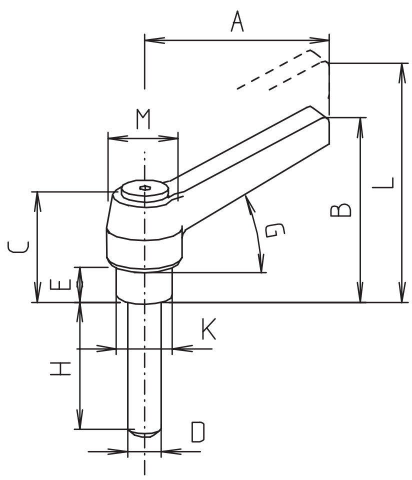
This table is valid for all the clamping elements of the RK Light-Clamps programme.
The indications in the table are provided without guarantee, being the materials behaviour under real application conditions affected by different factors i.e. temperature, substance concentration, short-term or permanent presence of chemicals.

Material	Reinforced polyamide
Working temperature	
0°C bis 80°C	always
-30°C bis 120°C	temporary

Clamping lever

- The clamping lever enables the re- adjustment of the clamping elements. This can be done by easy exchange of the cylinder screw.
- By lifting the grip, the free mo-vement of the serration toothing enables the clamping lever to swing into the desired position. The grip moves into its original position when released.

Material: Grip made of polyami-de, black, screws made of zinc-plated or stainless steel



Stainless steel (single-piece elements)

[mm]

Code No.	Type	A	B	C	D	E	G	H	K	L	M
93024	12-18	40	35,5	30	M6	10	20°	18	10	39,5	13
902381	20-30	65	48,5	36,5	M8	14		25	13	52,5	18

Screws – Steel, zinc-plated

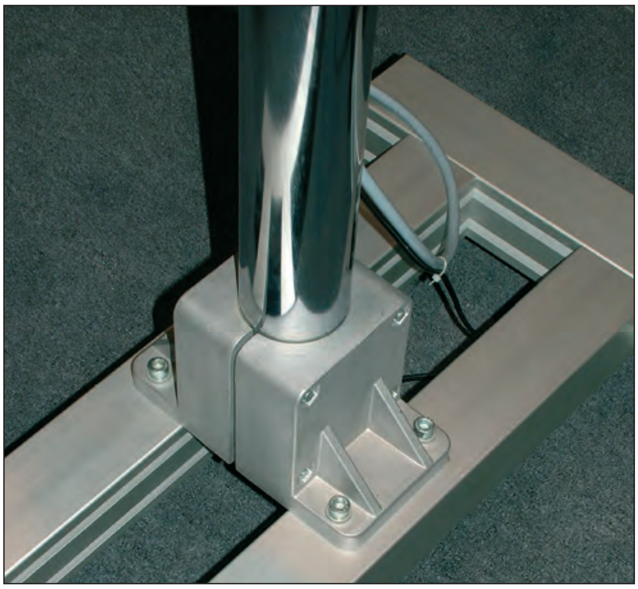
[mm]

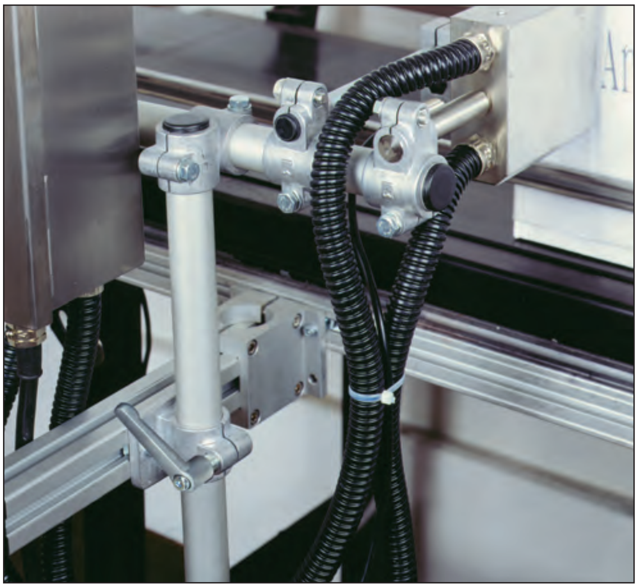
Code No.	Type	Size	Description	Packaging
4006160	12-18	M6x18 / DIN 7984	Socket head cap screw	100 Pcp. / bag
4006116		M6 / DIN 985	Hexagonal nut	
4006180	20-30	M8x16 / DIN 7984	Socket head cap screw	50 Pcp. / bag
4006185		M8x25 / DIN 7984	Socket head cap screw	
4006118		M8 / DIN 985	Hexagonal nut	

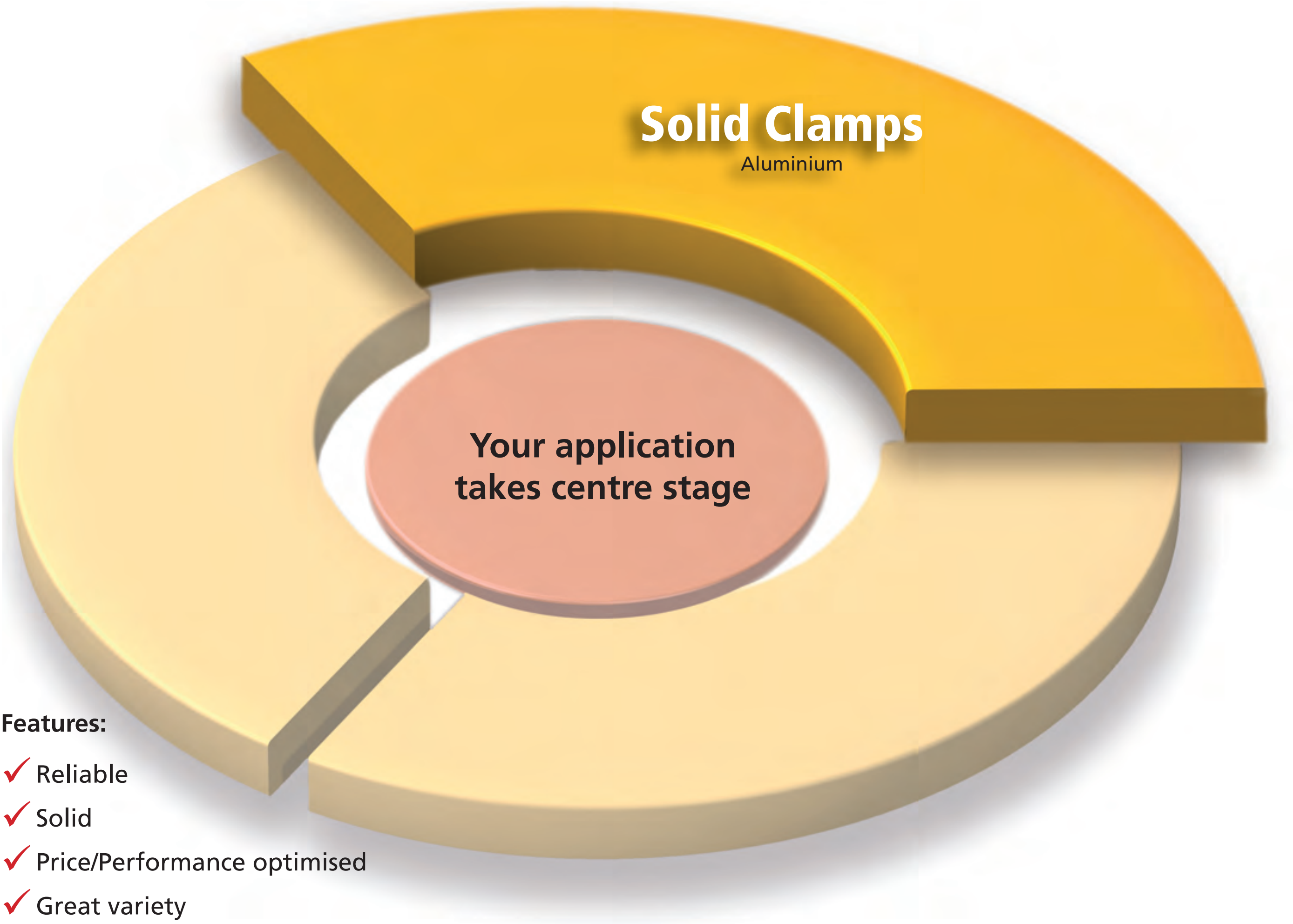
Screws – Stainless steel

[mm]

Code No.	Type	Size	Description	Packaging
4009160	12-18	M6x18 / DIN 7984	Socket head cap screw	100 Pcp. / bag
4009116		M6 / DIN 985	Hexagonal nut	
4009180	20-30	M8x16 / DIN 7984	Socket head cap screw	50 Pcp. / bag
4009185		M8x25 / DIN 7984	Socket head cap screw	
4009118		M8 / DIN 985	Hexagonal nut	







Features:

- ✓ Reliable
- ✓ Solid
- ✓ Price/Performance optimised
- ✓ Great variety

...the precise connecting technology made of aluminium

RK ROSE+KRIEGER

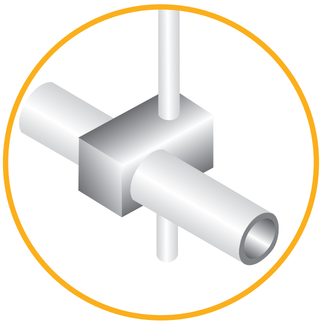
Medium to heavy load range

Solid Clamps

Solid Clamps Medium to heavy load range

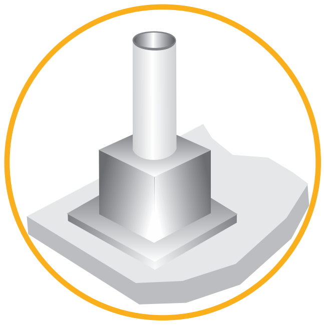
...the precise connecting technology made of aluminium

Right angle tube connector

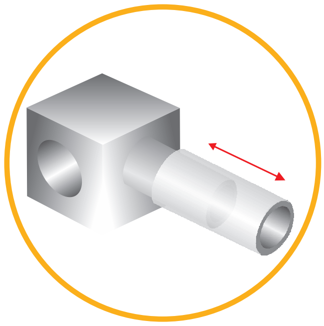


Cross clamps

Angle clamps

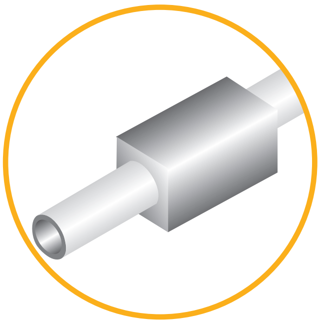


Base clamps

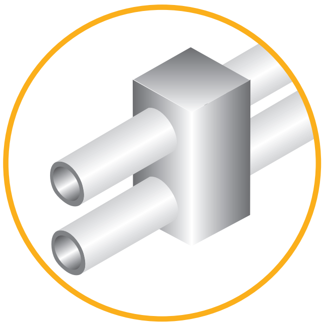


Insert clamps

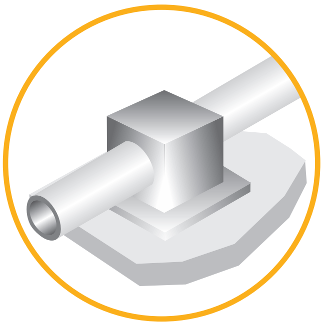
Axially parallel tube connector



Sleeve clamps

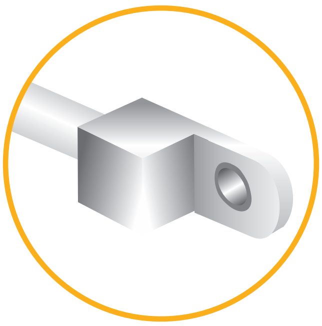


Parallel clamps

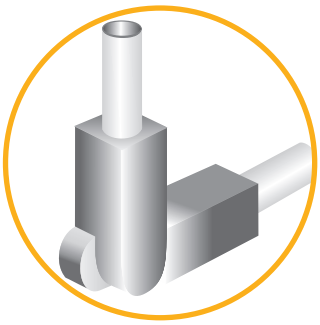


Flange clamps

Hinge tube connector



Strap clamps



Hinge clamps

Solid Clamps - table of contents

Right angle tube connector
(Single-piece and multi-piece elements)

Axially parallel tube connector
(Single-piece and multi-piece elements)

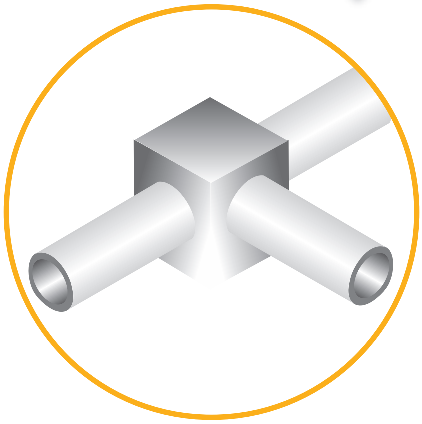
Hinge tube connector
(Single-piece and multi-piece elements)

Accessories

Solid Clamps – Angle clamps

Version: ■ Angle clamps

delivery
from stock



Single-piece elements

✓ For the quick and inexpensive installation

Industrial design
- Cast aluminium
- Great variety
- Single-piece elements

quad® elements
- Extruded aluminium
- Maximum torque loads
- High-quality anodized surface
- Single- and Multi-piece elements

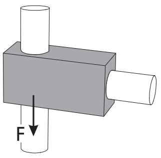
Multi-piece elements

✓ Also suitable for subsequent assembly and expansion

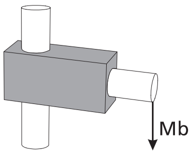
quad® elements
- Extruded aluminium
- Maximum torque loads
- High-quality anodized surface
- Single- and Multi-piece elements

Block form
- Cast aluminium
- Higher torque loads
- Plain surface
- Multi-piece elements

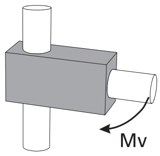
Loads angle clamps



Adhesion force F [KN]



Bending moment Mb [Nm]



Twisting moment Mv [Nm]

Tightening toryue of clamping screws:
M6: 10 Nm
M8: 25 Nm
M10: 50 Nm

Material data sheet available upon request.

Size	18			30			40			50			60			80		
Type	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv
Industrial design																		
W	1,1	189	20	6,6	447	104	4,3	1365	104	12,1	900	217	10,7	1388	299			
WV				3,3	413	345	4,3	464	546									
WR				5,1	870	59	5,1	1174	158									
WE	2,5	52	14	6,6	494	41	6,6	300	300	10,6	409	217						
WVT				3,3	144	345	2,6	765	546									
WRT				5,1	141	63	5,1	1174	120									

Size	18			30			40			50			60			80		
Type	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv
Block form																		
WV				3,6	383	283	3,3	528	847	3	600	425	7,8	1197	917	11	3038	2400
WR				5,1	809	66	6,2	1560	44	9,8	1200	262	12,3	1500	255	19	950	601
WVT				3,6	149	283	3,3	793	847									
WRT				5,1	136	66	6,2	1560	44									
WK				4,9	594	41	4,9	1388	139	10	750	179	11,4	650	315			
WEV							1,2	493	844	5,9		678						
WER							0,7	883	37	8,7	1280	131						
WKR							6,1	1361	93	8,7	1250	272						
WERT							0,7	883	37	8,7	1280	131						
WEVT							1,2	686	844	5,9		678						

Size	18			30			40			50			60			80		
Type	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv
quad® elements																		
W	4	634	61	7,8	960	68	5,8	1788	159									
WR	5	1650	168	7,6	960	128	11,8	2200	272									
WRT	5,7	1475	166	7,6	960	128	11,8	2200	272									
WKR	5,7	1365	172	7,5	1050	510	11,8	2200	272									
WVR	6,1	618	70	8,4	1050	128	7,5	1800	1800									
WRV	6,2	1000	325	7,5	1200	46	7,5	2200	272									
WER	6,1	1139	49	2,7	1020	450	11,8	2200	272									
WV	5	410	534	8,1	1212	450	7,5	2022	1800	20,1								
WVT	5,1	411	524	6,3	1229	450	7,5	2022	1800	20,1								
WKV	5,7	781	350	8,1	1256	459	7,5	2022	1800									
WEV	4,5	527	350	2,8	897		7,5	2022	1800									

Solid Clamps – Angle clamps

Right angle tube connector

Industrial design

W p. 74

WE p. 75

Block form

RRW p. 78

VVW p. 78

WR p. 79

WK p. 81

WKR p. 82

WKV p. 82

quad® elements

W p. 86

WR p. 86

WVT p. 89

WKR p. 89

RK ROSE+KRIEGER


WR p. 75


WV p. 76


WVR p. 76


WRT p. 77


WVT p. 77


WVR p. 79


WV p. 80


WRT p. 80


WVT p. 81


WER p. 83


WEV p. 83


WERT p. 84


WEVT p. 84


WRT p. 87


WVR p. 87


WRV p. 88


WV p. 88


WER p. 90


WKV p. 91

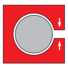

WEV p. 91

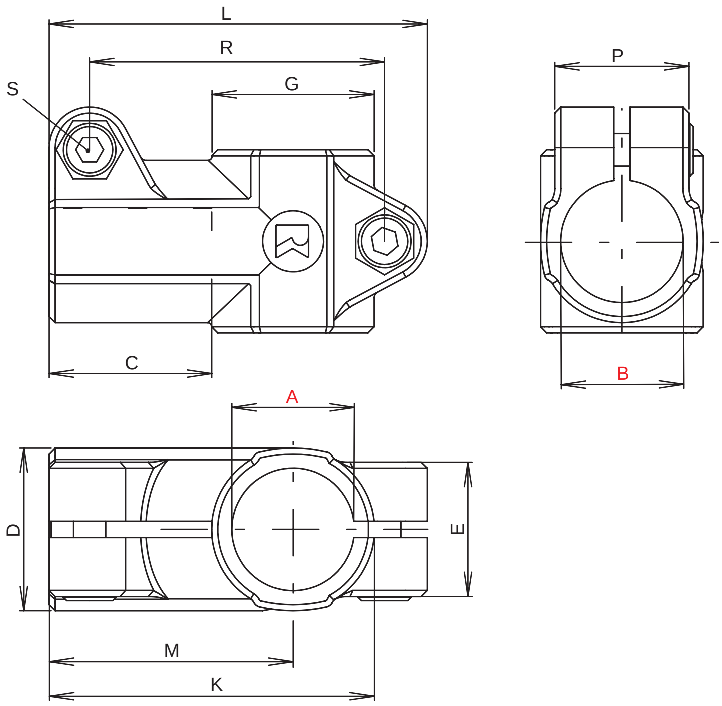
Order instruction:

- Standard equipment zinc plated screws
- Clamping lever see accessories page 222

On request:

- Stainless steel screws
- Ball-polished
- Colour





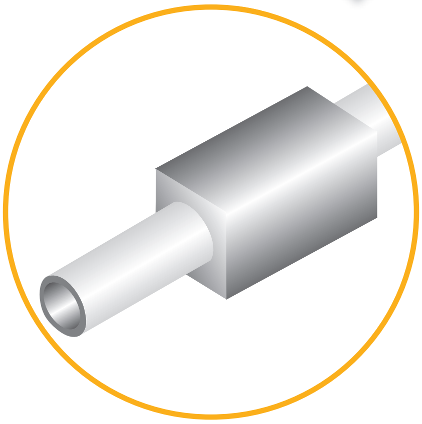
W - Industrial design

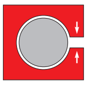
[mm]

Code No.	Type	A	B	C	D	E	G	K	L	M	P	R	S	m [g]
111200000200	W 12	12,1	12,1											97
111400000200	W 14	14,1	14,1											90
111500000200	W 15	15,1	15,1	28	26	32	26	56	66	43	23	49	M6x20	87
111600000200	W 16	16,1	16,1											83
111800000200	W 18	18,1	18,1											75
112000000200	W 20	20,1	20,1											278
112500000200	W 25	25,1	25,1	40	40	45	40	80	93	60	33	72,5	M8x25	240
113000000200	W 30	30,1	30,1											192
113200000200	W 32	32,2	32,2											680
113500000200	W 35	35,15	35,15	60	56	60	56	117	134	88	40	108	M10x30	623
114000000200	W 40	40,15	40,15											530
114800000200	W 48	48,22	48,22	65	66	70	66	136	149	98	45	123	M10x35	765
115000000200	W 50	50,22	50,22							98				710
116000000200	W 60	60,27	60,27	80	80	90	80	160	183	120	58	151	M12x45	1340
118000000200	W 80	80,35	80,35	121,7	110	123	110	231,7	259	176,8	82	214	M16x65	3750

Version: Sleeve clamps

delivery
from stock





Single-piece elements
✓ For the quick and inexpensive installation

Industrial design

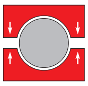
- Cast aluminium
- Great variety
- Single-piece elements

Block form

- Cast aluminium
- Higher torque loads
- Plain surface
- Multi-piece elements

quad® elements

- Extruded aluminium
- Maximum torque loads
- High-quality anodized surface
- Single- and Multi-piece elements

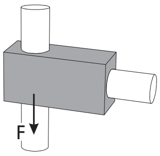


Multi-piece elements
✓ Also suitable for subsequent assembly and expansion

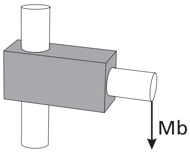
quad® elements

- Extruded aluminium
- Maximum torque loads
- High-quality anodized surface
- Single- and Multi-piece elements

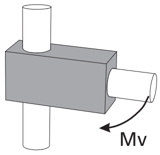
Loads sleeve clamps



Adhesion force F [KN]



Bending moment Mb [Nm]



Twisting moment Mv [Nm]

Tightening toryue of clamping screws:
M6: 10 Nm
M8: 25 Nm
M10: 50 Nm

Material data sheet available upon request.

Size	10			18			30			40			50			60		
Type	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv
Industrial design																		
M							1,9	435		4,7	698		2,8	1000		15	2400	
MD							2,7	440		5	994		2,7	1000				
MH							4,7			10			9,4					

Size	10			18			30			40			50			60		
Type	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv
Block form																		
M					141		5,3	351		9,2	519		6,5	875				
MD							1,8	451		8	713		4	1000		1,5	1125	

Size	30			40			50			80		
Type	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv
quad® elements												
M	11,2	352		8,0	619		11,8	1267				
MD	6,2	324		7,8	612		8	1267				
MH	2,6			3,4			7,8					
MR	9	810		4,5	1024		12,6	1596				
MV	7,8	433		2,5	1074		7,4	1568				
MVR	3,6	491		1,9	975		7,4	1568				

Solid Clamps – Sleeve clamps

Axially parallel tube connector

Industrial design

M p.128

MD p.128

Block form

M p.130

MD p.130

quad® elements

M p.131

MD p.131

MH p.129

MH p.132

MR p.132

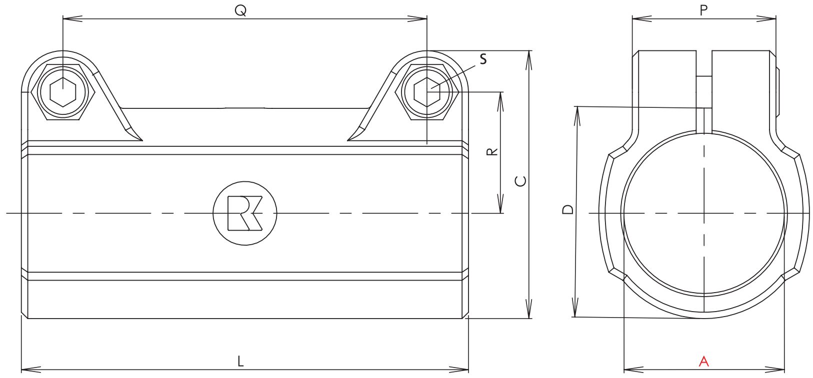
MV p.133

Order instruction:

- Standard equipment zinc plated screws
- Clamping lever see accessories page 222

On request:

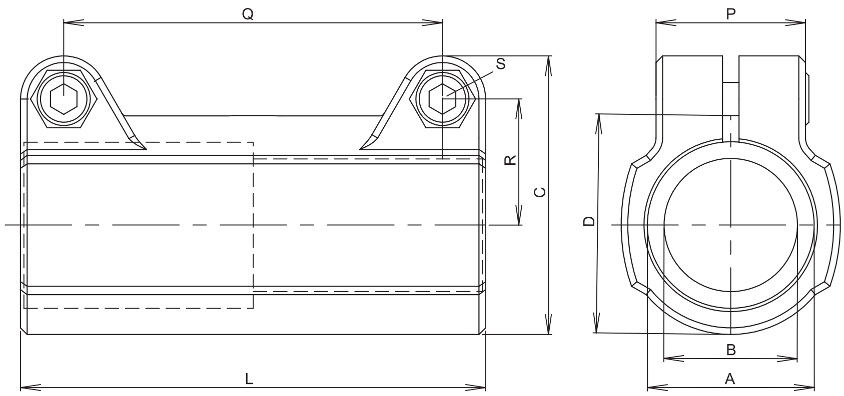
- Stainless steel screws
- Ball-polished
- Colour



M - Industrial design

[mm]

Code No.	Type	A	C	D	L	P	Q	R	S	m [g]
142000000200	M 20	20,1								256
142500000200	M 25	25,1	53	40	80	33	60	22,5	M8x25	220
143000000200	M 30	30,1								176
144000000200	M 40	40,17	73	56	120	40	94	32	M10x30	501
145000000200	M 50	50,22	84	66	140	45	114	38	M10x35	650
146000000200	M 60	60,27	103	80	150	58	118	47	M12x45	1092

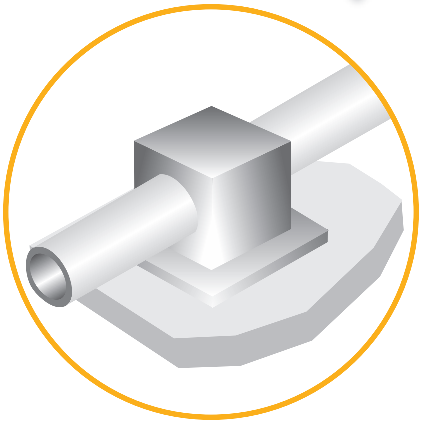


MD - Industrial design

[mm]

Code No.	Type	A	B	C	D	L	P	Q	R	S	m [g]
143025010200	MD 30x25	30,1	25,1	53	40	80	33	60	22,5	M8x25	176
144032010200	MD 40x32	40,17	32,15	73	56	120	40	94	32	M10x30	501
144840010200	MD 48x40	48,22	40,17	84	66	140	45	114	38	M10x35	853
145040010200	MD 50x40	50,22									822
146048010200	MD 60x48	60,27	48,27	103	80	150	58	118	47	M12x45	1288

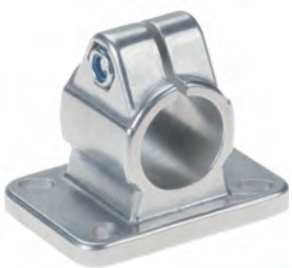
Version: Flange clamps



delivery
from stock

Single-piece elements

✓ For the quick and inexpensive installation



Industrial design
- Cast aluminium
- Great variety
- Single-piece elements

quad® elements
- Extruded aluminium
- Maximum torque loads
- High-quality anodized surface
- Single- and Multi-piece elements

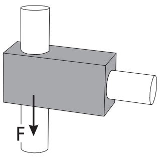
Multi-piece elements

✓ Also suitable for subsequent assembly and expansion

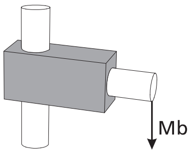
quad® elements
- Extruded aluminium
- Maximum torque loads
- High-quality anodized surface
- Single- and Multi-piece elements

Block form
- Cast aluminium
- Higher torque loads
- Plain surface
- Multi-piece elements

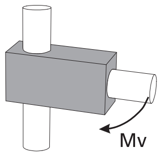
Loads flange clamps



Adhesion force F [KN]



Bending moment Mb [Nm]



Twisting moment Mv [Nm]

Tightening toryue of clamping screws:
M6: 10 Nm
M8: 25 Nm
M10: 50 Nm

Material data sheet available upon request.

Size	18			30			40			50			60			80		
Type	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv
Industrial design																		
FK	1,1	128	21	4,9	200	95	8,9	504	254	11,6	750	1025	9,9	1393	253			
FKR				6,8	429	117	6	1190	152									
FKV				5,2	270	381	3	1247	955									
R				6,8			6											
V				5,2			3											
RH				4,0			6,1			4,9			5,1			6,3		
VH				1,7			2,5			3			4			10		

Size	18			30			40			50			60			80		
Type	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv
Block form																		
FKR				4,3	438	96	2,5	450	700	8,2	1465	260	12,2	1456	255	10	2500	602
FKV				3,5	304	372	1,5	450	320	5,9	937	1250	7,8	1688	1203	20	2500	2250
R				4,3			5,7			9,4			12,2			10		
V				3,5			2,8			5,9			7,9			19		
RH				4,0			6,1			4,9			5,1			6,3		
VH				1,7			2,5			3			4			10		

Size	18			30			40			50			60			80		
Type				F	Mb	Mv	F	Mb	Mv	F	Mb	Mv				F	Mb	Mv
quad® elements																		
R				6,2			7,1			11,8						19,4		
RH				3,1			3,5			5,8						7,5		
V				5			7,4			7,5						20,1		
VH				1,9			4,2			2,6						7,7		
FK				2,5	484	59	4,9	750	89	6,3	1620	159						
FKH				2,7	96	48	3,2	102	62	5,6	230	86						
FKR				6,2	657	90	7,1	786	121	11,9	2146	272				19,4		950
FKRH				3,1	105	47	3,5	110	87	5,8	287	70				7,5		243
FKV				5	590	338	7,4	682	743	7,5	1904	1100				20,1		
FKVH				2,5	109	134	4,2	102	451	2,6	297	563				7,7		

Solid Clamps – Flange clamps

Axially parallel tube connector

Industrial design

FK p. 146

FKR p. 147

Block form

RRW p. 149

FFKR p. 149

FKV p. 151

R p. 152

quad® elements

FK p. 154

FKH p. 154

VH p. 156

FKR p. 157


FKV p. 147


R p. 148


V p. 148


VVW p. 150


FFKV p. 150


FKR p. 151


V p. 152


RH p. 153


VH p. 153


R p. 155


RH p. 155


V p. 156


FKRH p. 157


FKV p. 158


FKVH p. 158

Order instruction:

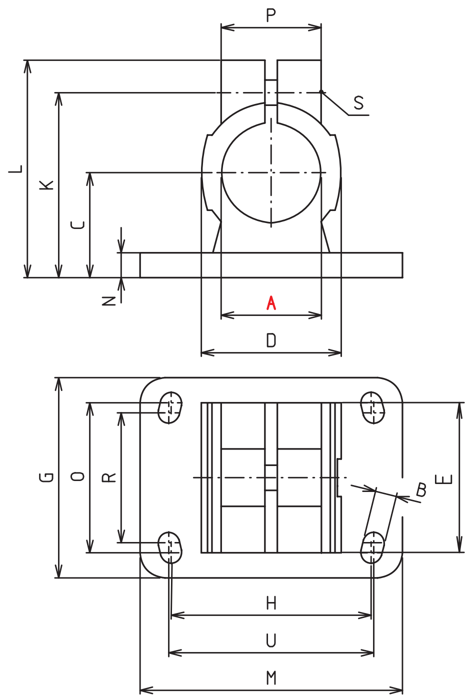
- Standard equipment zinc plated screws
- Clamping lever see accessories page 222

On request:

- Stainless steel screws
- Ball-polished
- Colour

FK 30-4 - 80
(4 drills, 20-60 with slotted hole)

FK 12-30
(2 central holes)



FK - Industrial design

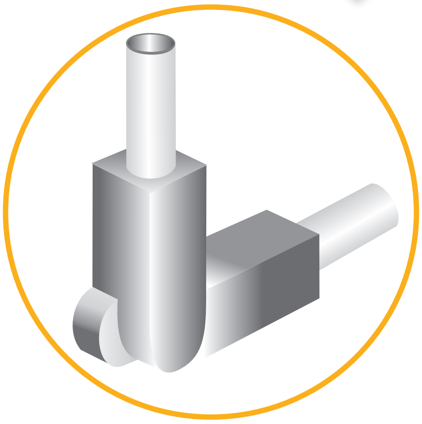
[mm]

Code No.	Type	A	B	C	D	E	G	H**	K	L	M	N	O*	P	R	S	U	m [g]
12120000020	FK 12	12,1	5,5	18	26	32	35	38	32,5	41	50	5	–	23	–	M6x20	40	67
12140000020	FK 14	14,1																64
12150000020	FK 15	15,1																62
12160000020	FK 16	16,1																60
12180000020	FK 18	18,1																56
12200000020	FK 20	20,1	6,5	30	40	40	55	53	53	63	78	7	–	33	–	M8x25	60	202
12200100020	FK 20-4	20,1											40		35			205
12250000020	FK 25	25,1											–		–			184
12250100020	FK 25-4	25,1											40		35			188
12300000020	FK 30	30,1											–		–			162
12300100020	FK 30-4	30,1											40		35			166
12300200020	FK30(32)	30,1	8,5	42	56	60	80	80	74	87	105	10	60	40	52	M10x30	82	489
12320000020	FK 32	32,17																473
12350000020	FK 35	35,15																449
12400000020	FK 40	40,17																404
12400200020	FK40(42)	40,17	10,5	50	66	65	90	98	85	98	128	14	62	45	60	M10x35	100	703
12420000020	FK 42	42,22																682
12480000020	FK 48	48,22																610
12500000020	FK 50	50,22																585
12600000020	FK 60	60,27	10,5	60	80	80	110	100	107	123	150	15	80	58	74	M12x45	118	1048
12800000020	FK 80	80,35	17,5	80	110	123	164,7	140	140	162,5	180	20	120	82	–	M16x65	–	2930

Solid Clamps – Hinge clamps

Version :

- Hinge clamps



delivery
from stock

Single-piece elements

✓ For the quick and inexpensive installation

Industrial design
- Cast aluminium
- Great variety
- Single-piece elements

quad® elements
- Extruded aluminium
- Maximum torque loads
- High-quality anodized surface
- Single- and Multi-piece elements

Multi-piece elements

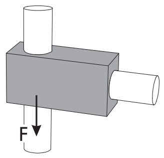
✓ Also suitable for subsequent assembly and expansion

quad® elements
- Extruded aluminium
- Maximum torque loads
- High-quality anodized surface
- Single- and Multi-piece elements

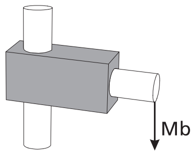
Block form
- Cast aluminium
- Higher torque loads
- Plain surface
- Multi-piece elements

RK ROSE+KRIEGER

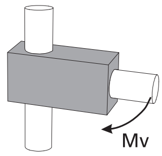
Loads hinge clamps



Adhesion force F [KN]



Bending moment Mb [Nm]



Twisting moment Mv [Nm]

Tightening toryue of clamping screws:
M6: 10 Nm
M8: 25 Nm
M10: 50 Nm

Material data sheet available upon request.

Size	10			18			30			40			50			60		
Type	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv
Industrial design																		
GW				2,2	25	7	5,8	85	15	6	233	38	11,9	244	143			
GP				1,1	25	7	4,8	85	15	6	233	38	12	244	143			
GQ				2,2	25	7	4,8	85	15	6	233	38	12	244	143			
GF				2,2	25	7	4,8	85	15	6	233	100	12	244	143			
GWZ				2,2	27	16	5,8	85	148	6	223	376	11,9	317	695			
GPZ				1,1	27	16	4,8	85	148	6	300	300	12	260	400			
GQZ				2,2	27	16	4,8	85	148	6	223	376	12	317	695			
GFZ				2,2	27	16	5,8	69	82	7,4	240	470	7,8	363	695			

Size	10			18			30			40			50			60		
Type	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv
Block form																		
GKR										5,7	253	43	9,3	563	60			
GKV										2,9	253	43	5,9	563	60			
GFKR										5,7	253	43	9,3	563	60			
GFKV										2,9	410	43	5,9	563	60			
GKRZ										5,7	343	619	9,3	444	548			
GKVZ										2,9	343	619	5,9	444	548			
GFKRZ										5,7	343	619	9,3	444	548			
GFKVZ										1,6	343	619	5,9	444	548			
GWR										5,7	306	75						
GPR										5,7	306	75						
GQR										5,7	375	75						
GFR										5,7	308	75						
GWV										2,9	306	75						
GPV										2,9	306	75						
GQV										2,9	306	75						
GFV										2,9	306	75						

Size	30			40			50			80		
Type	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv	F	Mb	Mv
quad® elements												
G												
GFM	3,2	268	14	4,1	404	17	6,4	1092	19			
GFW	3,1	268	14	4,3	404	17	6,4	1092	19			
GFF	3,1	268	14	4,3	404	17	6,4	1092	19			
GPR	3,1	268	14	4,2	404	17	6,4	1092	19			
GFR	3,1	268	14	4,2	404	17	6,4	1092	19			
GPV	3,1	268	14	4,2	404	17	6,4	1092	19			
GFV	3,2	268	14	4,2	404	17	6,4	1092	19			

Solid Clamps – Hinge clamps

Hinge tube connector

Industrial design

GW p. 176

GP p. 177

Block form

GKPR / GKPV p. 184

GKR / GKRZ p. 185

GFV p. 189

GWR p. 190

quad® elements

G p. 194

GFM p. 194


GQ p. 178


GF p. 179

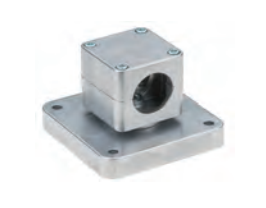

GWZ p. 180


GPZ p. 181


GFZ p. 182


GQZ p. 183


GKV / GKVZ p. 186


GFKR / GFKRZ p. 187


GFKV / GFKVZ p. 188


GFR p. 189


GPR p. 190


GQR p. 191


GWV p. 191


GPV / GQV p. 192


GFW p. 195


GFF p. 195


GPR p. 196


GFR p. 196


GPV p. 197


GFV p. 197

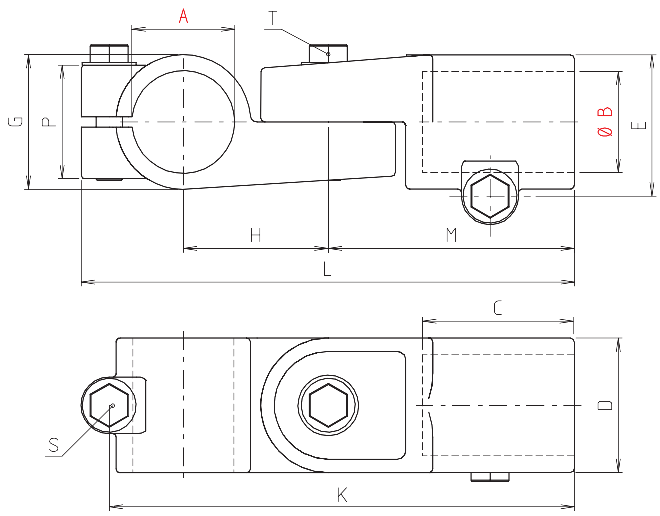
Solid Clamps – Hinge clamps

Order instruction:

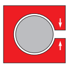
- Standard equipment zinc plated screws
- Clamping lever see accessories page 222

On request:

- Stainless steel screws
- Ball-polished
- Colour



Without toothing– 180° infinitely



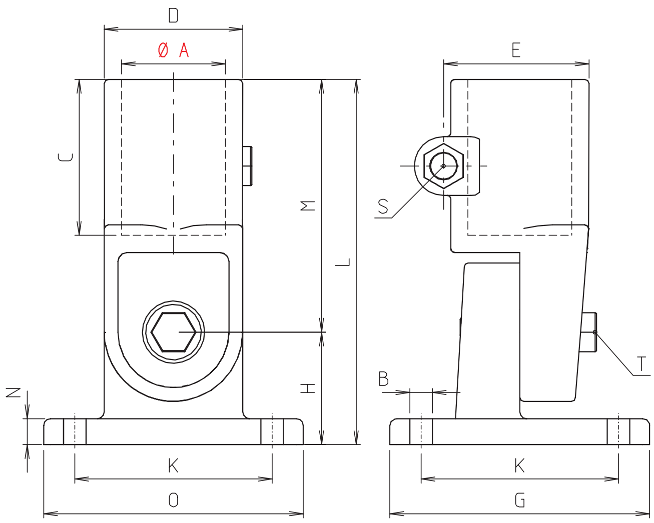
Type GW 12–18

Type GW 20–60

GW - Industrial design

[mm]

Code No.	Type	A	B	C	D	E	G	H	K	L	M	P	S	T	m [g]
181200010200	GW 12	12,1	12,1	25	26	29,4	26	27	84	95,5	44	21	M6x16	M6x16	135
181400010200	GW 14	14,1	14,1												129
181600010200	GW 16	16,1	16,1												123
181800010200	GW 18	18,1	18,1												115
182000010200	GW 20	20,1	20,1	45	40	40	40	43	136	146	73	33	M8x35	M8x35	387
182500010200	GW 25	25,1	25,1												346
183000010200	GW 30	30,1	30,1												300
183200010200	GW 32	32,2	32,2	60	56	56	56	60	188	200	100	48	M10x50	M10x50	961
183500010200	GW 35	35,2	35,2												900
184000010200	GW 40	40,2	40,2												810
184200010200	GW 42	42,2	42,2	70	66	66	66	70	218	230	115	58	M10x60	M10x60	1335
184500010200	GW 45	45,2	45,2												1253
184800010200	GW 48	48,2	48,2												1177
185000010200	GW 50	50,2	50,2												1121
186000010200	GW 60	60,3	60,3	80	80	80	85	85	260	273	135	68	M10x60	M12x50	2050



Without toothing180° infinitely

Type GF 12–18

Type GF 20–50

GF - Industrial design

[mm]

Code No.	Type	A	B	C	D	E	G	H	K	L	M	N	O	S	T	m [g]
18120002020	GF 12	12,1	5,3	25	26	29,4	50	20	40	64	44	5	35	M6x16	M6x16	106
18140002020	GF 14	14,1														103
18160002020	GF 16	16,1														100
18180002020	GF 18	18,1														96
18200002020	GF 20	20,1	6,5	45	40	40	75	33	57	106	73	7	75	M8x35	M8x35	371
18250002020	GF 25	25,1														374
18300002020	GF 30	30,1														325
18320002020	GF 32	32,2	8,5	60	56	56	100	44	76	144	100	10	100	M10x50	M10x50	963
18350002020	GF 35	35,2														880
18400002020	GF 40	40,2														827
18420002020	GF 42	42,2	8,5	70	66	66	125	52	98	167	115	12	125	M10x60	M10x60	1378
18450002020	GF 45	45,2														1287
18480002020	GF 48	48,2														1233
18500002020	GF 50	50,2														1213

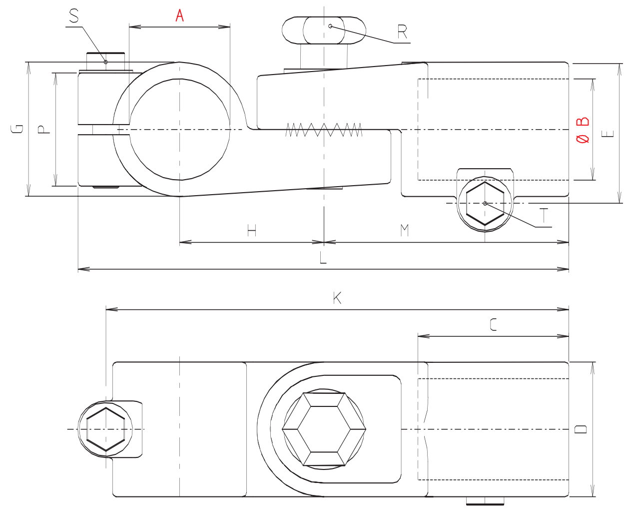
Solid Clamps – Hinge clamps

Order instruction:

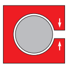
- Standard equipment zinc plated screws
- Clamping lever see accessories page 222

On request:

- Stainless steel screws
- Ball-polished
- Colour



With toothing - rotation of 180°, engaging at 15° intervals



Type GWZ 12–18

Type GWZ 20–60

GWZ - Industrial design

[mm]

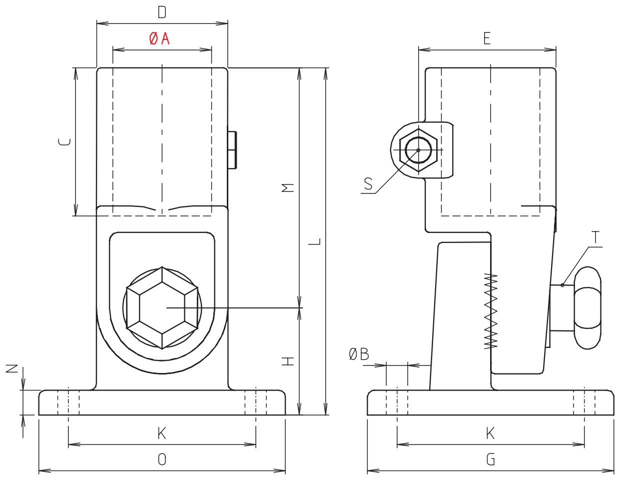
Code No.	Type	A	B	C	D	E	G	H	K	L	M	P	R	S	T	m [g]
181200040200	GWZ 12	12,1	12,1	25	26	29,4	26	27	84	95,5	44	21	M6x26	M6x16	M6x16	135
181400040200	GWZ 14	14,1	14,1													129
181600040200	GWZ 16	16,1	16,1													123
181800040200	GWZ 18	18,1	18,1													115
182000040200	GWZ 20	20,1	20,1	45	40	40	40	43	136	146	73	33	M8x40	M8x35	M8x35	428
182500040200	GWZ 25	25,1	25,1													391
183000040200	GWZ 30	30,1	30,1													344
183200040200	GWZ 32	32,2	32,2	60	56	56	56	60	188	200	100	48	M10x50	M10x50	M10x50	999
183500040200	GWZ 35	35,2	35,2													943
184000040200	GWZ 40	40,2	40,2													861
184200040200	GWZ 42	42,2	42,2	70	66	66	66	70	218	230	115	58	M10x50	M10x60	M10x60	1361
184500040200	GWZ 45	45,2	45,2													1287
184800040200	GWZ 48	48,2	48,2													1211
185000040200	GWZ 50	50,2	50,2													1166
186000040200	GWZ 60	60,3	60,3	80	80	80	85	85	260	273	135	68	M12x50	M10x60	M10x60	2050

Order instruction:

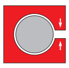
- Standard equipment zinc plated screws
- Clamping lever see accessories page 222

On request:

- Stainless steel screws
- Ball-polished
- Colour



With toothing - rotation of 180°, engaging at 15° intervals



Type GFZ 12–18

Type GFZ 20–50

GFZ - Industrial design

[mm]

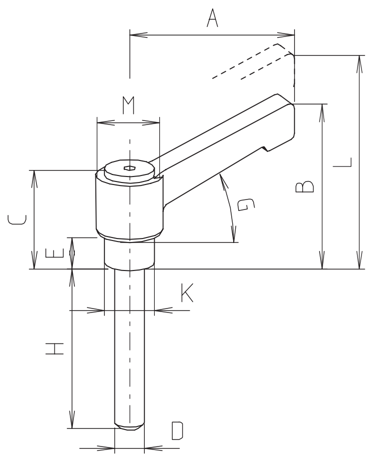
Code No.	Type	A	B	C	D	E	G	H	K	L	M	N	O	S	T	m [g]
18120007020	GFZ 12	12,1	5,3	25	26	29,4	50	27	40	64	44	5	35	M6x16	M6x26	106
18140007020	GFZ 14	14,1														103
18160007020	GFZ 16	16,1														100
18180007020	GFZ 18	18,1														96
18200007020	GFZ 20	20,1	6,5	45	40	40	75	32,5	57	105,5	73	7	75	M8x35	M8x40	409
18250007020	GFZ 25	25,1														398
18300007020	GFZ 30	30,1														368
18320007020	GFZ 32	32,2	8,5	60	56	56	100	44	76	144	100	10	100	M10x50	M10x52	949
18350007020	GFZ 35	35,2														923
18400007020	GFZ 40	40,2														866
18420007020	GFZ 42	42,2	8,5	70	66	66	125	52	98	167	115	12	125	M10x60	M10x60	1365
18450007020	GFZ 45	45,2														1318
18480007020	GFZ 48	48,2														1279
18500007020	GFZ 50	50,2														1287

■ **Instructions:**

Regarding its dimensions and adjustability the lever is perfectly adapted to the RK clamp system.
The handle must be lifted high enough to disengage allowing "confined space" tightening or loosening as desired. It relocks by means of spring pressure.

■ **Materials:**

Handle made of zinc pressure casting according to DIN 1743, steel parts quality class 5.8, galvanized.



Clamping lever

[mm]

Code No.	Type	A	B	C	D	E	G	H	K	L	M	m [g]
90201	HV 5x20	40	33,5	25,5	M5	5,5	20°	20	7,5	37,5	13,5	32
90211	HV 6x10	40	33,5	26,5	M6	6,5	20°	10	10	37,5	13,5	30
90249	HV 6x20							20				–
90210	HV 6x16	40	33,5	26,5	M6	6,5	20°	16	10	37,5	13,5	–
90209	HV 6x18							18				
90212	HV 6x25	40	33,5	26,5	M6	6,5	20°	25	10	37,5	13,5	34
90247	HV 6x30							30				–
90213	HV 6x35	40	33,5	26,5	M6	6,5	20°	35	10	37,5	13,5	38
90214	HV 6x40							40				40
90215	HV 6x45	65	43,2	29,2	M6	6,5	20°	45	10	47	18	65
90216	HV 6x55							55				75
90217	HV 6x60							60				80
90221	HV 8x15	65	45	31	M8	8,5	20°	15	13	49	18	68
90222	HV 8x25							25				72
90223	HV 8x30	65	45	31	M8	8,5	20°	30	13	49	18	75
90224	HV 8x35							35				80
90225	HV 8x45	65	45	31	M8	8,5	20°	45	13	49	18	86
90226	HV 8x50							50				91
90227	HV 8x55	80	53,5	36	M8	8,5	20°	55	13	57,5	22	100
90228	HV 8x60	65	45	31				60		49	18	
90229	HV 8x70	80	53,5	36	M8	8,5	20°	70	13	57,5	22	120
90230	HV 8x80							80				130
90231	HV 8x90							90				140
90241	HV 10x20	80	55	37,5	M10	10	20°	20	16	59	26	125
90250	HV 10x30							30				–
90251	HV 10x35	80	55	37,5	M10	10	20°	35	16	59	26	–
90242	HV 10x45							45				140
90243	HV 10x50	80	55	37,5	M10	10	20°	50	16	59	26	145
90244	HV 10x60	95	64	42,5	M10	10	20°	60	16	68	26	200
90246	HV 10x110							110				250
90255	HV 12x40	95	64	42,5	M12	13,5	20°	40	18	68	26	–
90253	HV 12x45							45				
90256	HV 12x80							45				
90271	HV 16x72	100	72	65	M16	19	20°	65	23	72	33	–

Upon request:

- ■ Hand levers with plastic handles
- ■ Hand levers with stainless steel threaded fitting