Project Number: MQP CAB 0407

TRANSMITTING INJURIOUS TORQUES WITH A SNOWBLADE BINDING CAM DEVICE

A Major Qualifying Project Report

Submitted to the Faculty

of the

WORCESTER POLYTECHNIC INSTITUTE

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Degree of Bachelor of Science

by:

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ABSTRACT

There have been recent advances made at WPI within the past five years regarding the development of a mechanism that limits the amount of torque transmitted to the lower tibia from snowblades. Our project group analyzed previous works, evaluated manufacturing regulations, and completed a successful production run for a cam and follower housing unit that can be used interchangeably with various cam and follower designs to eliminate injurious torques with snowblade bindings.

Table of Contents

List of Figures

Introduction

Objective

The objective of this paper is to apply the principles of axiomatic design to the manufacturing process for the housing for a preexisting cam and follower mechanism. The device is then used in conjunction with non releasable snowblade bindings and calibrated to release when loaded with an injurious torque.

Rationale

In a previous project at WPI, a cam and follower device was designed to eliminate injurious torques to the lower legs of snowbladers. Unfortunately, the housing unit for this device was never properly manufactured, so it failed structurally.

State-of-the-Art

The company that provided the earlier project group with the plastic for their housing was called Hapco Inc. Hapco offers a full line of plastics with varying physicals (Technical Data, Appendix 8.1). In addition, they also offer meter/mixers and dispensing equipment to ensure proper mixing and rationing which are advertised for providing results. Hapco also has a lab on site, where they make all the samples that are sent out to their clients. The method they use to prepare the samples varies from that which is offered to the consumer as proper, but no study or data compilation has been done to compare/contrast the final product. (Derek, Head of Sample Production, Hapco Inc.)

Approach

We redesigned the old housing mechanism and reinforced with extra material where the earlier housing failed. We performed finite element analysis on the new design to determine the parts load bearing capabilities, and selected material based on those findings. We tested different plastic preparation and pouring methods, as well as curing conditions to achieve maximum material quality. Then under optimum conditions, we tested two different releasing agents, to determine which was most compatible with our design. We assembled the cam and follower mechanism with a system for adjusting the internal spring displacement. The device was then calibrated to release under a specified load, and compared with the ASTM standard for releasable bindings. Based on these results, we redesigned the cam to retract or continue to rotate based on load release. This cam can be used interchangeably with the old one, which means it will function properly within the confines of our newly designed housing unit.

Section 2: Background Information

Section 2.1: Previous Works

In 2002, a project was done at WPI by Robert Koch and William Leblanc under advisor Christopher Brown at that dealt with the design of a Torque-limiting Snowblade Binding. The risk of lower leg fracture among snowbladers is approximately 17 times greater than that of an alpine skier. This information suggests that the lack of release bindings on snowblades has contributed to an unacceptably high rate of injury (Johnson et al 2001). Current snowblade bindings have no release mechanism or any means of torsion control for injury reduction.

The device designed by Koch and Leblanc was a cam and follower mechanism that released under injurious torque set forth by ASTM specification. The cam and follower mechanism were designed using a method learned in a class taught by Professor Robert Norton at WPI. They found that because of size constraints, they were unable to produce a cam-follower system that could "release" within the first 20 degrees of rotation while still limiting the correct amount of torque. The overall height of the design ended up higher then what they would have liked because such a large spring rate and preload was necessary. The one inch diameter spring they designed the binding around proved to be an obstacle (Koch, Leblanc, 2002).

From bench testing, which is defined later in cam analysis, it became evident that the slope of the torque-theta curve is not as steep as that of current alpine ski bindings. The recommended procedure for addressing this issue of increasing torque-theta slope was to use a smaller diameter roller at the end of the follower. This would decrease the amount of degrees before release occurs, thus increasing the slope of the curve (Koch, Leblanc, 2002).

In 2006, Dan Landau and Michael Murphy developed a similar system using axiomatic design. They developed a list of functional requirements and design parameters for torsion release in snowblade bindings. These axioms can be found in Appendix ##. Landau and Murphy analyzed the design of Koch and Leblanc and made changes that were necessary to make a production quantity, (Landau, Murphy, 2006). While their design for production quantity was a success, the housing unit they designed for the cam and follower mechanism failed to meet the physical requirements of the entire mechanism. As a result, they had no system for conducting analysis on the improved cam and follower design. Thus, there is no evidence to suggest the adjustments made in cam design were beneficial.

Koch and Leblanc developed the cam and follower mechanism, but were unable to make it release as desired. Landau and Murphy developed a new production method for the housing, but the final result was inadequate structurally. They redesigned the cam and follower system in accordance with Koch and Leblanc's recommendations, but were never able to test it.

Our project group made suggested improvements to the structural design set forth by Murphy and Landau, and made a small production run. Failure analysis of Landau and Murphy's production results provided us with a new set of functional requirements that applied strictly to the manufacturing process. The result was successful production of an inexpensive housing that can be used in accordance with the testing criteria set forth by Koch and Leblanc to determine if it meets the ASTM standard for binding release.

Section 2.2: Background in Material Science

In our project we selected a plastic polymer known as polyurethane for our molding process. We used this plastic because it is a cheap, strong, and an easily reproduced way of creating our mold. A picture of the stress-strain curve of our particular polymer can be seen below in Figure 2a. In order for us to receive the best results we needed to be able and determine the best possible way to cure our particular plastic. In this section we have compiled a short introduction to the properties and chemical reactions undergone during the curing stage of our plastic.

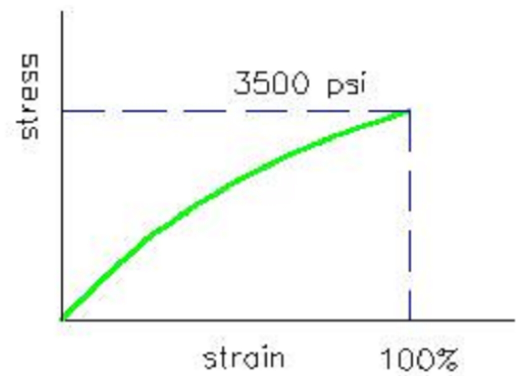

Figure 2a: Stress Strain Curve of Polyurethane

The process known as curing refers to the toughness or hardening of a polymer material by the cross-linking of polymer chains brought about by chemical additives, ultraviolet radiation, electron beam (EB) or heat. In order for our particular mold to cure hard enough to withstand forces during use, the polyurethane is mixed with an ultra alloy hardener epoxy resin. Other plastics polymers commonly use similar methods to strengthen their plastic composites with materials such as fibers, fillers, particulates, powders and other matrix reinforcements to provide improved strength and/or stiffness.

There are multiple techniques used in curing technology for polymer and plastic composites. Heat or heat and pressure is used to cure thermoplastics and hot melt adhesives, vulcanization is used with heat and pressure in conjunction with a vulcanizing agent to produce materials with greatly increased strength, stability, and elasticity., other plastics cure with radiation, electron beam irradiation, ultra violet light, or simply at room temperature. Different curing techniques create different results based on the chemical makeup of the plastic composite. Our particular plastic composite, polyurethane mixed in a 2:1 ration with ultra alloy resin, uses a two-component curing system that consists of a resin and a hardener that becomes a crosslinker or catalyst when mixed.

Common mechanical, thermal, and physical properties used to describe and distinguish plastics include viscosity, tensile strength, thermal conductivity, deflection temperature, melt flow index, electrical resistivity, coefficient of thermal expansion and water absorption. These properties help distinguish different plastics for there respected applications. For example plastics with an efficient level of electrical resistivity are used for electoral components, while plastics using thermal compounds are often used for heat-generating device such as heat sinks.

Section 3: Modeling Decomposition and Constraints

3.1: FR 1 –Withstands torque of cam follower system

Before we could begin the molding process we needed to first design our device and select a plastic strong enough to absorb the torques created when skiing. To create our design we utilized the computer aided software, Solid Works, to create our initial model.

Our major point for concern in the design was the shaft of the cam-follower system, and specifically where it comes into contact with the cam. Most of the forces caused when displacing the cam would be in this area between where the shaft meets the center of the mold and where the follower makes contact with the cam. When an injurious torque occurs and the boot begins to rotate displacing the cam, the follower is constantly being pressed up against the side of the corner of the mold where the shaft ends creating a dangerous amount of pressure that could possibly crack the plastic. We employed extra material in this area, making it the thickest area of the part in order to account for the torques. An image of our design can be seen below marking out the main area of concern in Fig 3.1a

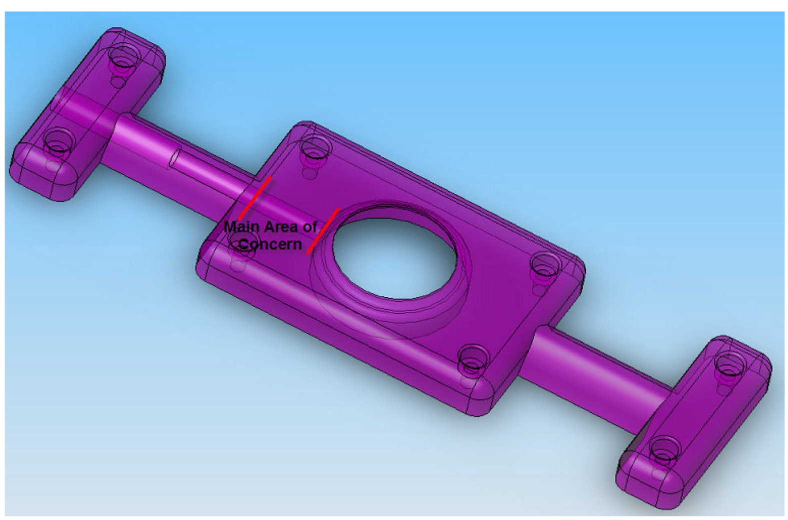

Figure 3.1a: Area of Concern in Mold Design

To compensate for the extra stress being received from the cam follower system we added as much material as we could to minimize the chances of the device failing. You can see a close up image of how bulky we mad this specific area. Figure 3.1b

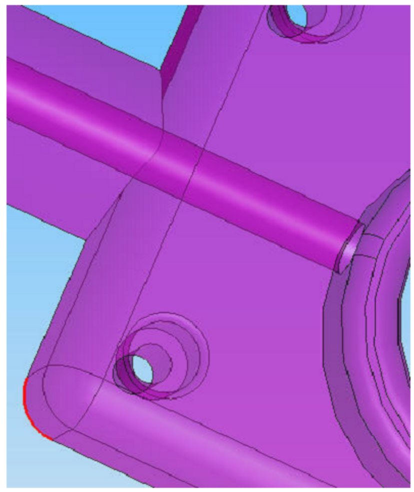

Figure 3.1b: Increased Material in Mold

After we came up with a preliminary design we wanted to determine how strong the structural and elastic properties of our mold would really be. In order to do this we used the Cosmos Express tool in Solid Works to give us a Finite Element Analysis on the CAD part. Using this mode we were able define the material, points of constraint, and place different loads on the base component to see how it reacts. Using a modulus of Elasticity of 400 MPa and a coefficient of thermal expansion being 150 (10^-6/ degrees Celsius) it was determined that the plastic began to deform when the deviatoric stress reaches a critical value of 3.644e+005 Von Mises (N/m^2) and the shaft would deform to 1.639e-004 inches. This gave us a Factor of Safety (FOS) of 567.54. Figures 3.1c and 3.1d of these tests can be seen on the next page.

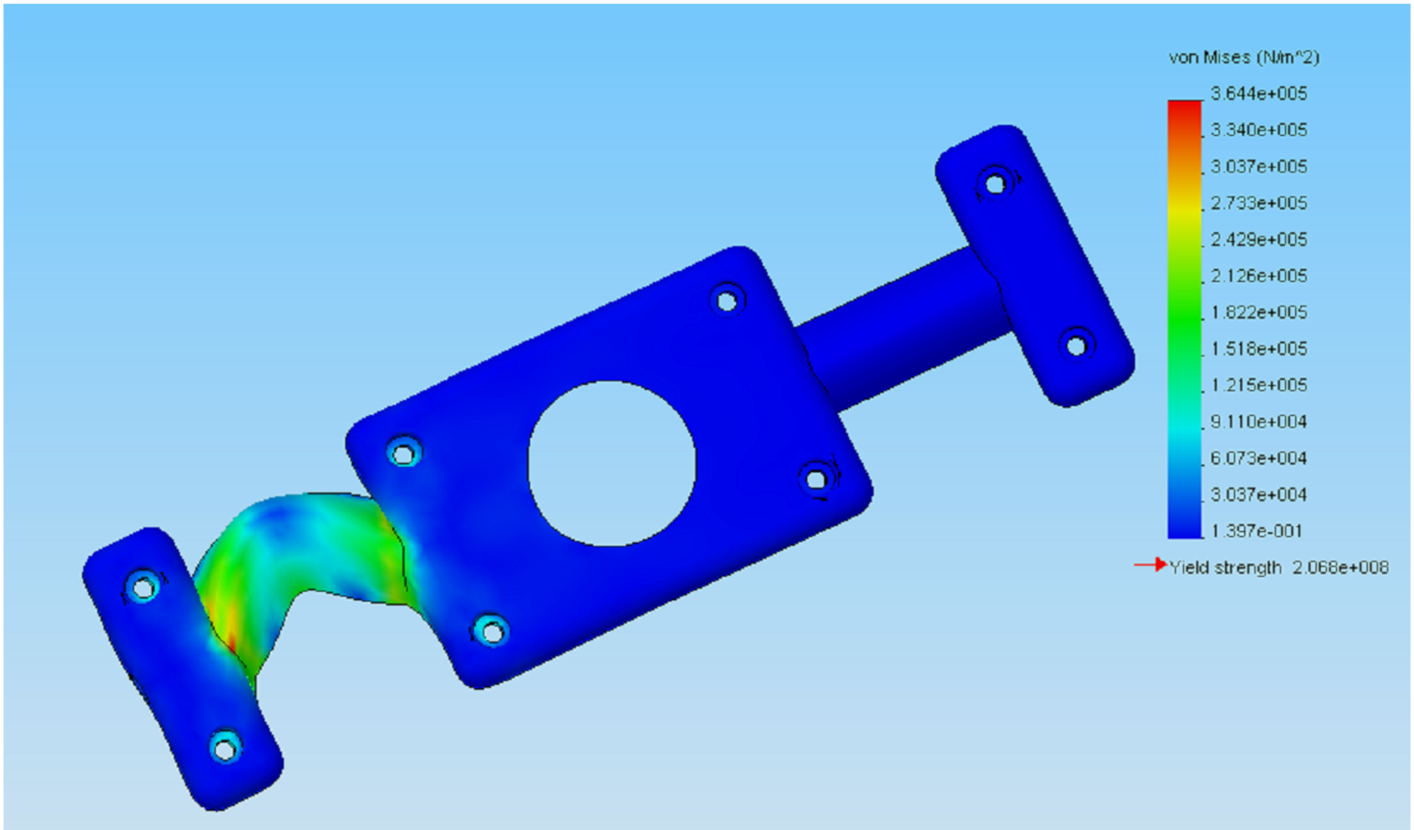

Figure 3.1c: Stress Deformation of Follower Shaft

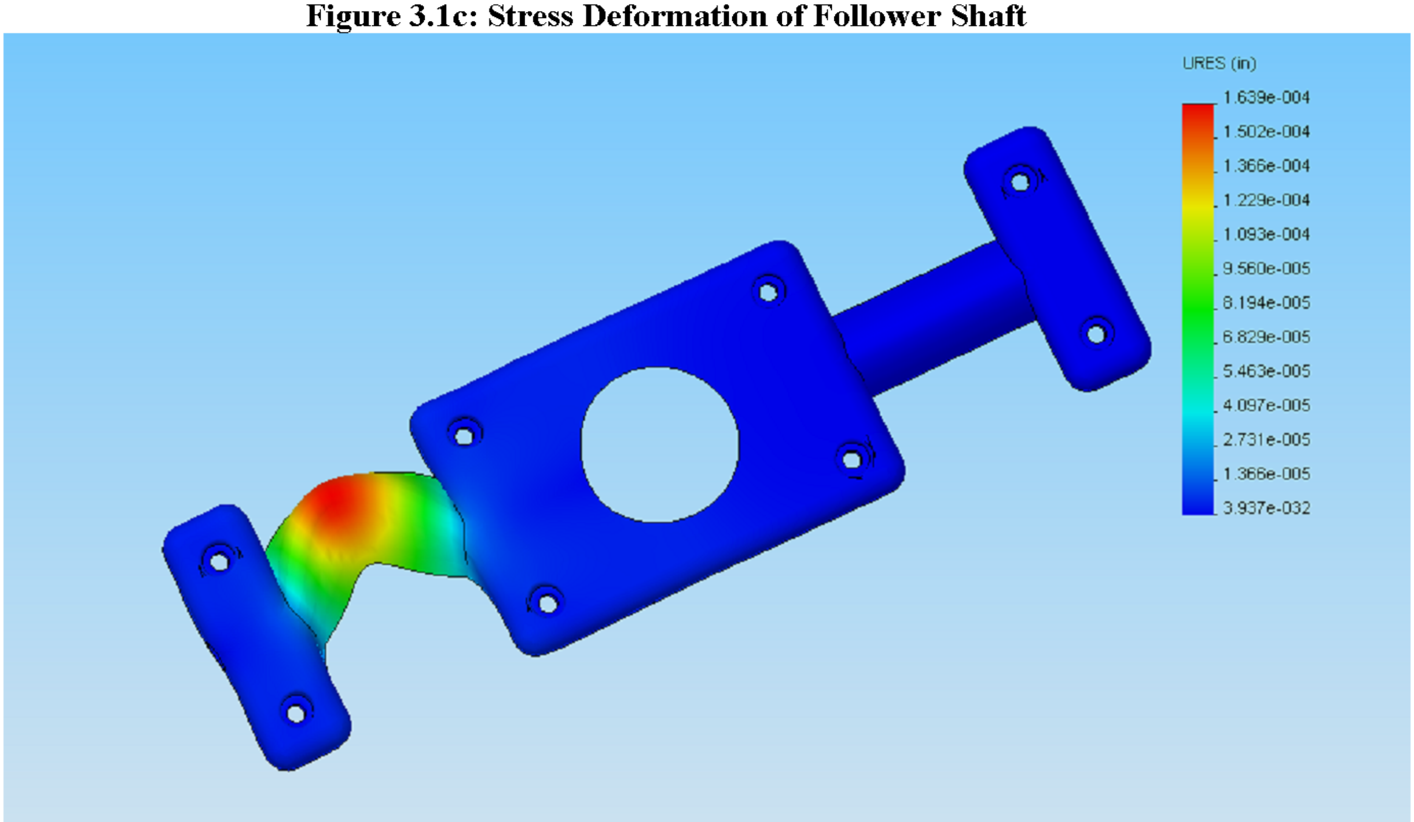

Figure 3.1d: Displacement of Follower Shaft

3.2: FR 2 – Houses cam

Another functional requirement we need to take into consideration in our molding process, was some way to allow the base mold to house the cam. The cam being utilized in our project had a radius of approximately 1.12 inches and was 0.65 inches thick. The base mold was designed to be 0.63 inches thick in order to allow 0.02 inches to extrude from the base to attach to the binding plate without interfering with the mold itself.

The housing piece had to be designed separately from the casting block in order to be able to take the mold out of the cast. To accomplish this we designed an attachment to the casting bock that would sit in the center of the mold and take up the right amount of space to fit the cam. The piece designed would be detachable so that we could take it out when the mold had cured long enough.

In order to make sure the piece aligned just right in the mold to where the cam need to be situated, we created a three holes to line it up. We punched a small divot in the center of the Aluminum casting block to first position the piece and then drilled two holes on the top of the Aluminum casting block for the flanges of the piece to screw into to make sure the piece would not move. Once the plastic had cure hard enough to keep its form we could remove the piece so it would not interfere with the overall removal of the mold from the casting block. Figure 3.2a can be seen below detailing this description further.

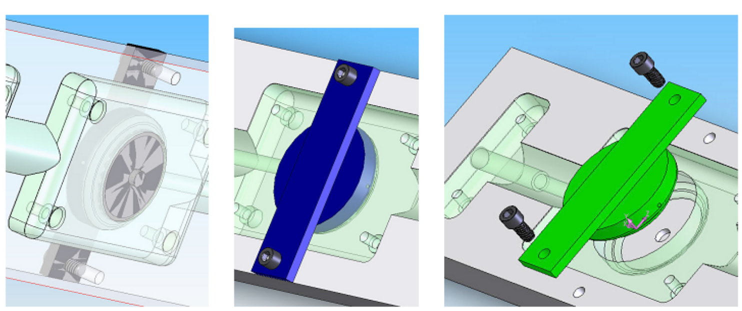

Figure 3.2a: Bottom View and Top View of Housing Cam, and Cam Removal View

3.3: FR-3 Houses spring and follower

Along with being able to house the cam we also needed some type of way to create a shaft to house the spring and follower being pushed up against the cam. Not only did we need a way to create the shaft we needed to able an remove this extension before the plastic completely molded or we would be unable to remove the mold from the Aluminum casting block. Another issue we had to take into consideration was that we needed to create two different shaft diameter sizes for the follower of 0.37 inches and another one for the spring of 0.29 inches. Images of the two shaft sizes can be seen below in Figure 3.3a.

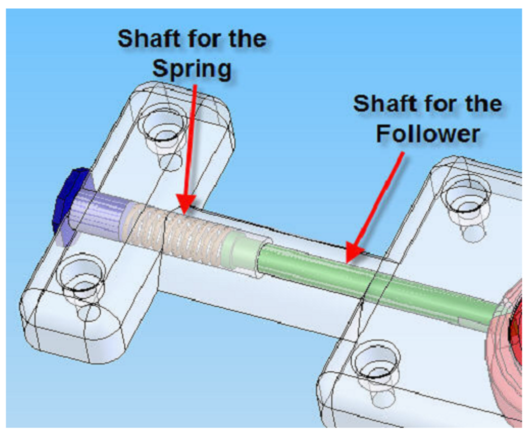

Figure 3.3a: Spring and Follower Inside the Mold.

Taking all of these design parameters into consideration, we designed a removal shaft for the mold that would accommodate our mold design. The shaft was designed with the two needed diameters in order for the mold to house the spring and follower comfortably. To insert the pin into the casting block we drilled a hole in the front face of the block. To successfully position the pin relative to the shaft so it would align with the cam, we punched a small hole in the cam housing piece and added a small extrusion on the shaft to insert into the cam housing piece. An image of this can be seen below in Figure 3.3b.

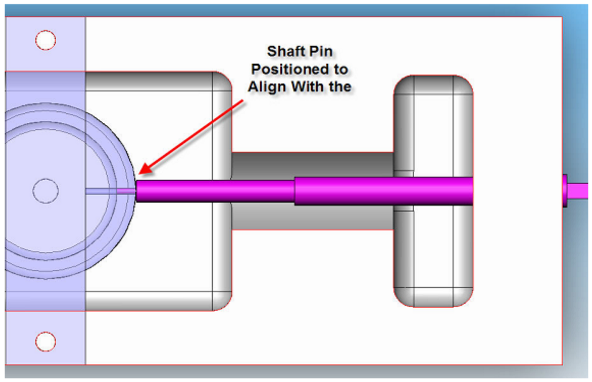

Figure 3.3b: Pin Positioned and aligned in Casting block

3.4 FR-4: Cures Air Free

To allow are design to have the most success for preparation and testing, an important functionality requirement for our injection process was creating a way for the plastic to cure air free. A major issue in molding with plastic is air bubbles created in the mixing process. Our plastic utilized in this project is 420 Ultra Clear, which is a two part epoxy that needed to be mixed as a 2:1 ratio. If the plastic cures with air sockets that form little bubbles, it would compromise and weaken the design of the mold. This could possibly cause the mold to crack during use or even be so weak that it prevents us from being able to remove it from the casting block. This pushed us to look for an efficient way to inject the plastic air free into the casting block for the best possible results during the curing process.

Initially we thought of different ways to effectively mix by hand. One Possibility was trying to vibrate the plastic as we mixed it and injected it into the casting block to help prevent bubbles. In the end we determined mixing by hand would be very tedious and produce inconsistent results. We looked for another alternative to mixing the plastic manually that would produce more consistent results. After doing some preliminary research we found a cheap alternative that we would be able to afford on our budget that could meet our requirements, Hapco RapidShot Dispensing System.

The Hapco RapidShot Dispensing System is a low cost meter/mix injection that allowed us to mix plastic in 1:1 ratios and 2:1 ratios. Some other benefits the RapidShot provided was its low cost, portable use allowing us to move from lab to lab, easy to use, and created consistent results. The RapidShot gun became an integral part to our injection process which, after a few tries, gave us some very usable molds. An image of the Hapco RapidShot Dispensing System can be seen in Figure 3.4a on the next page.

Figure 3.4a: Hapco RapidShot Dispensing System

3.5 FR 5 – Cures hard enough to withstand removal from cast

A major concern with our mold would be the removal process. Releasing the mold from the cast without cracking, or distorting the plastic would prove to be a difficult task. To avoid any serious problems we looked to us e a plastic that would harden relatively quickly in the curing process to allow us to remove the mold before completely cured. If we had waited till the plastic had totally cured inside the Aluminum casting block, it would be very difficult to remove the mold, especially without cracking or distorting it.

To avoid this problem we chose a plastic that would harden anywhere between first third or first sixth of the curing process. This would allow us an adequate time window in which we could remove the mold from the cast. The plastic we utilized was a liquid molding compound called 420 Ultra Clear, purchased from Hapco Inc. located in Hanover, Massachusetts. This plastic is a two part epoxy of one part ultra urethane and one part ultra alloy resin mixed in a two to one ratio. For best properties the plastic cured at room temperature (21-23ºC) for two hours or until hardened and than an additional post curing period of 4-12 hours at 60-80ºC with the higher posture yielding a higher HDT. A more detailed description of our plastic properties can be seen in Appendices A. (http://www.hapcoweb.com, retrieved on 1/25/07)

To prepare the surface of the casting block we used sand paper to first smoothen the Aluminum casting block so the surface would be as smooth as possible. To prevent adhesion of the plastic to the metal we used a release agent known as Grease-It II also purchased and recommended from Hapco Inc. We applied the Grease-It I agent across the entire surface using a fine 2-inch bristle brush.

Once our casting block was prepared we injected the plastic using our Hapco Inc. Rapid Shot Dispensing gun, which is described earlier in Section: 3.4 of the report. We allowed a general time period of one and a half hours to two hours when trying to remove the mold. We were able to release the mold with the greatest rate of success within this time period. When attempting to remove the mold earlier, we found that the plastic had not cured completely and removing it from the block could cause unwanted deformation. When trying to remove the mold after two hours we found to be very difficult due to the increasing hardening of the mold making it a very tight fit with the Aluminum casting block. A time table is shown below in Figure 3.5a to better describe our plastics curing process.

420 Ultra Clear Liquid Plastic Molding Compound			
	Time Period	Temperature	Plastic Properties During Stage
Initial Curing Stage	0-1.5 hours	room temperature (21-23ºC)	uncured
Curing Stage	1.5-2 hours	room temperature (21-23ºC)	not totally cured but hardening for final form is complete
Post Curing Stage	2-10 hours	60-80ºC	completely cured

Figure 3.5a: Table of 420 Ultra Clear Liquid Plastic Molding Compound Curing Process

3.6 FR 6 Releases follower from inside mold

An important requirement in our molding process is our ability to remove the shaft pin from the casting block when we needed to. The weakest part of the device would be the material covering the shaft, more or less because it has a hole placed through the center of it. This area of the design brought concern for a few reasons. Reason number one being because this hole houses the spring follower and would be an area of high stress. Our second concern was the plastic curing to hard to be able to remove the follower with out cracking the plastic.

To allow us the ability to remove the follower when we wanted to we punched a hole in the front face of the casting block allowing for easy insertion and removal. Being able to remove the pin from the mold allowed us to take the shaft out before the plastic had completely hardened. When trying to remove the pin when the plastic had mostly cured, we found out that the plastic would begin to crack because of the stress caused by the force needed to remove the pin. After several different removals we found that 40 minutes into the curing process would be the best time to remove the shaft from the mold. This amount of time allowed the plastic long enough to maintain it's shape while still being able removing the pin without any cracking of the plastic. An image of the removal process can be seen below in Figure 3.6a.

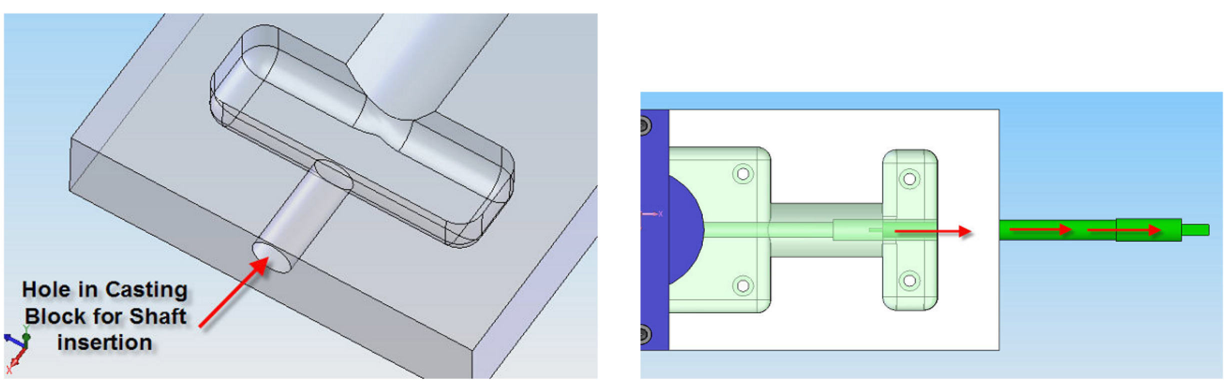

Figure 3.6a: Shaft Removal Process

3.7 FR 7 Mold must be produced cheaper than other releasable bindings.

For our molding process to have any relative success in the world of skiing, a functional requirement for the process was that it must be able to be produced cheaper than other products on the market. Although the majority of snow blades in the past have not been fitted for releasable bindings we still felt it necessary to create our process around the idea that in the near future they will be. The previous thought process of the smaller skis, snow blades, being too small to create enough torque to cause lower leg injuries has been seen time and time again to be wrong. After some initial research we found data showing that lower leg injuries were actually more common in snowblading than skiing. A picture of a releasable snow blade binding can be seen in Figure 3.7a as well as a graph illustrating snow blade injuries more clearly can be seen below in Figure 3.7b. (http://www.ski-injury.com/skiboard.htm, retrieved 2/15/07)

Figure 3.7a: Picture of Current Releasable Binding for Snowblades

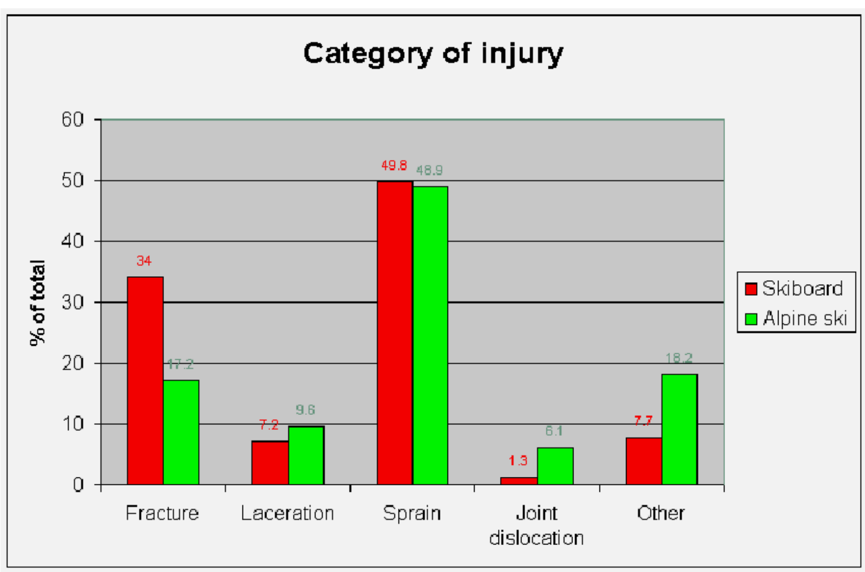

Figure 3.7b: Graph of Common Snowblading Injuries

Current releasable bindings on the market can range anywhere from $250.00 to $400.00 depending on brand and how new they are on the market. This is pretty expensive considering sometimes skis do not even cost this much. To combat the high expense of current releasable bindings, we opted to go with a plastic mold casting system which would be easy to simulate and able to be reproduced without needing to spend a lot of money on materials. This prompted us to use a plastic where a casting block could be constantly reused. (www.EasternMountainSports.com, retrieved 2/15/07)

When doing our cost analysis we looked to purchase our material in bulk quantity. To order a gallon of 420 Ultra Clear Liquid Molding Plastic, enough plastic to produce 16 molds, it would cost us $ 40.24 which includes tax. This would make each mold cost around $ 2.50. To determine the costs it would take to bulk manufacture the rest of the pieces needed for the device to successfully operate I asked a former WPI student, Michael Murphy who is currently working in a machine shop as a CAD drafter at Carbone Metal Fabricator, Inc. Although the mold can be constantly reproduced with the one casting block, the 8-12 hour curing process would make it difficult to produce a large amount of molds within a reasonable time. Our final cost estimate to create our device would cost around $ 10.90. Figure 3.7c shows a Table of the information behind this analysis can be see below.

Price Analysis		
Material	Quantity	Cost
Molding Plastic (8 Oz)	1	$2.50
Cam Block (Acetal Copolymer Delrin 3"X3")	1	$3.50
Follower Rod (Aluminum .5" X 4")	1	$0.75
Mounting Screws	4	$0.10
Base Plate (Aluminum 3"X12")	1	$3.50
Spring	1	$0.55
	total cost	$10.90

Figure 3.7c: Table of Cost Analysis per Mold

Section 4: Description of Molding Process

4.1: Material Selection

The mold for the housing was CNC machined by members of the WPI Washburn Shop staff. The shop machines a great deal of aluminum, so making the mold of that was the most cost effective solution.

Based on the findings of finite element analysis, it was determined that the material used to produce the previous mold would not suffice. The plastic we used was a urethane from the Ultraclear line provided by Hapco Inc. of Hanover, MA. Ultraclear is a new line that Hapco is currently trying to market. It is a young product, so the distributor offers it at a low price. The Ultraclear's physical attributes are listed in the appendix. What was particularly important, given the mechanism's applications, were the physical properties under cold and wet conditions.

Once the mold was made and the plastic was chosen, we needed to find a successful release agent. The two that were chosen were recommended by the Hapco staff. One was a liquid based release agent which had a consistency similar to that of Vaseline, but when stirred, turned into a liquid. You brush it on and then buff it with a rag. You repeat this process twice before you pour the mold. This release agent acts almost like a lubricant, and is designed to prevent bonding between the mold and casting. It was found that this method slightly impeded the curing process.

The second release agent came in an aerosol can. It sprayed on the cast as a liquid, but then solidified to become a barrier between the cast and mold. The barrier is similar to that of wax paper, and the design is to create easily breakable bonds between it and both mold and casting. This method was found to be the most effective, and provided a higher quality finish on our final part.

4.2 Casting Block Design

When designing the casting block several parameters were taking into consideration. First we needed to design the mold itself and than make sure it could be reversed engineered into a casting block, second the block needed to be able and be machined using the CNC machines provided in the WPI manufacturing shops, and finally the block needed to able and create the initial mold we designed. After taking all of this into consideration we began designing the casting block.

We first designed the mold using the computer aided design software, Solid Works, so we would be able and see the image were cutting out of the molding block. Once the initial design of the mold was completed we would now know how we needed to design the casting block. An image of our mold can be seen in Figure 4.2c. Using reverse engineering and Solid Works we created the casting block out of a 13 by 4.5 inch block of 1 inch thickness. We began making cuts into our block in the same manner in which we mad extrusions to design our mold. Using this process we were able to create a casting block that perfectly reflected our mold design. Images of the casting block can be seen in Figure 4.2a.

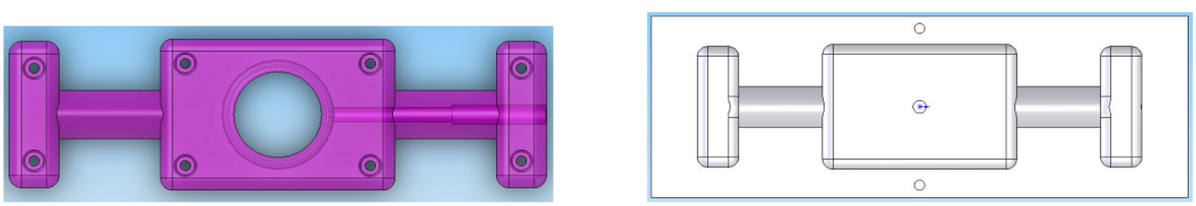

Figure 4.2a: Initial Design of Mold and Casting Block

To ensure that our casting block could be machined in the WPI Manufacturing Labs we designed the block to not have any sharp geometry that could cause complications in the machine. The curves and fillets of the design were large with very common radius and low tolerances, example being 0.25 inches or 0.1 inches. Using common values on our curves and areas that did not need high tolerances also allowed the block to machined quicker with less problems.

To complete the casting block so that it would be able and forge the mold into our initial design we needed to create a few extensions. First, for the mold to house the cam we designed a top piece that would have the same shape and geometry with just larger dimensions buy about.04 inches for a comfortable fit. To position this piece within the casting block three holes were tapped into the block, two threaded for screw insertion and one unthreaded. The middle hole would be the unthreaded hole that would be simply used to position the piece in the middle. The other two threaded holes on the top sides of the block would be used to secure and tighten the piece on the way in. An image of the cam housing piece can be seen below in Figure 4.2b.

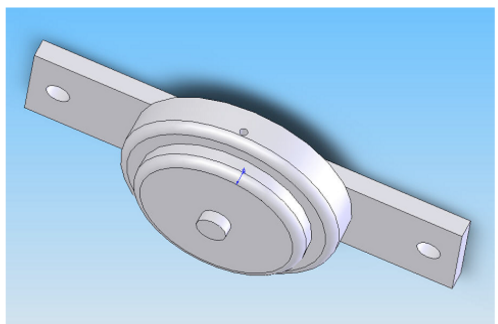

Figure 4.2b: Cam Housing Piece

To create the shaft inside the mold a shaft pin was designed to be inserted in the block. This piece was designed with two radiuses to accommodate both the follower and spring that would be needed to sit inside the mold. A hole was punched onto the top cam housing piece to align the shaft with cam. An image of the shaft can be seen below in Figure 4.2c.

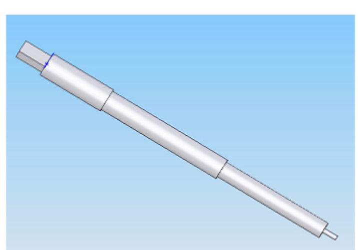

Figure 4.2c: Shaft Pin

After these extensions were designed we could see how our casting block would be able and create and forge a mold that would mirror our initial design. Using GibbsCam to model the instructions being inputted into the CNC machines we were now able to complete our casting block by using the CNC machines in WPI's Washburn manufacturing shop. We created the casting block out of the standard 6061 Aluminum provided in the shop. Images of our completed model and actual Aluminum casting block can be seen below in Figure 4.2d.

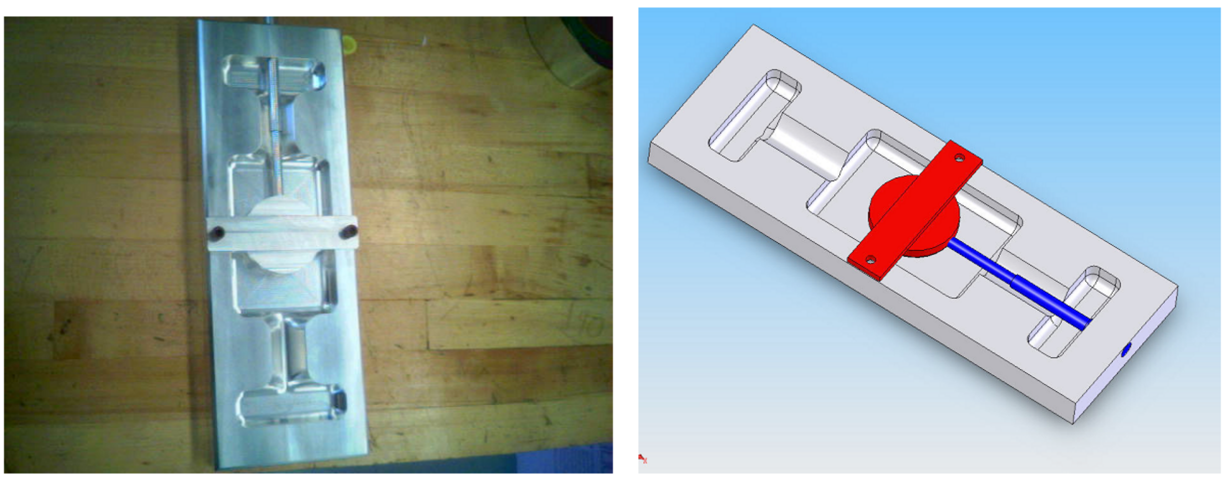

Figure 4.2d: Actual Aluminum Casting Block and Solid Works Model

4.3: Injection Process

The previous project group had trouble with the formation of air bubbles in their mold. In our early experimentation, we mixed the two plastic components by hand and in the process, our skin became exposed. The result was a contact dermatitis on our arms, face, and ears. Treatment required eighteen days of prednosone.

The RapidShot Dispensing System is designed for consumers who do not use these components on a regular basis. They may not have the proper facilities for vacuum mixing, and pressure curing, and they may only use a small volume of product per production run. In essence, it makes plastic injection molding possible for ametures.

The Rapidshot Dispensing System stores the two components in separate containers that are sealed with plungers to eliminate all presence of air. Once the two have been filled, a nozzle is put on the oposite end of the plungers. An air compressor is attached, and pressure is controled by the knob on the handle. Pressure is directly related to the rate of dispense.

The first thing done is to eliminate the presence of air in the nozzle, so at low pressure, a small amount of material is discarded into a waste container. At this time, the system has eliminated all presence of air. The material is then dispensed into the mold by pulling on a trigger which pushes two pistons against the plungers. The two components are dispersed at the proper ratio and at the same time thoroughly mixed. The result is an air free mixture, which did not require mixing by hand. It minimized chemical exposure and at the same time, met two functional requirements.

When the injection has been completed, the nozzle is discarded and a cap is put on the remaining material. The system used keeps the two components separate, and able to be stored for future use.

Not using this system would require mixing by hand which increases the risk of exposure to the components. Carcinogenic information is available in appendix ##. Also, if the components are mixed by hand, they must be done so thoroughly. Derek from Hapco recomends mixing the components for a minimum of twenty minutes, which means you need to use a product with a long gel time, which means a longer cure time, which means a longer production time. Also, all unused product must be discarded, so if you have a quart of plastic mixed, and a mold that holds 0.25 quarts, you end up discarding 75% of your product. It would require three more molds to make the process efficient.

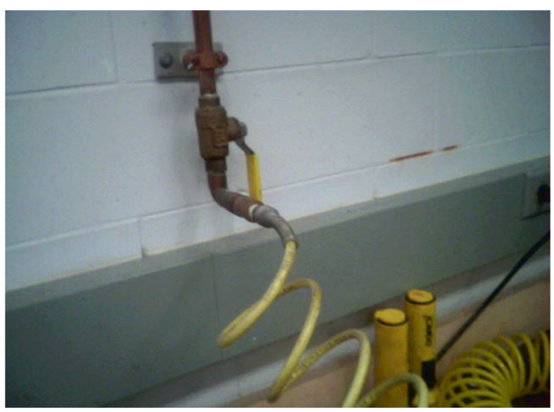

Figure 4.3: Injection Process

4.4 Curing Process

Once we were able to inject the plastic relatively air free, or as air free as possible without a pressure cooker, we needed to now cure the plastic. Utilizing the 420 Ultra Clear liquid molding compound, we used a few different time periods with mixed results.

We found that the plastic would begin to harden about five to ten minutes once the plastic had been injected into the cast. This made it very important to locate an area for the casting block that would not be moved or disturbed before the plastic began to really take shape. Our first initial try the casting block was moved allowing the plastic to flow out of the casting block and in the end deform the mold to where it would be unable to be used.

Once the plastic was injected into the casting block in a secure in a stationary position, we began to watch the plastic dry to determine the best time to remove the different pieces of our casting block set up. Our plastic selected was able to cure at room temperature (21-23ºC) which allowed us stand over the casting block and watch the plastic cure. Any air bubbles formed in the plastic happened with in the first 45 minutes of harden. The edges of the mold, specifically where the two bridges meet the end of the mold, were the areas that seemed consistently forming bubbles. Although bubbles did form there were never enough to really affect the mold. A figure of air bubbles forming during the initial curing process can be seen on the next page in Figure 4.4a.

Figure 4.4a: Air Bubbles Forming During Curing Process

Now that we began to learn when the plastic would begin to harden, we set off to determine the best time to remove the follower. As stated earlier in the report in Section 3.6, we needed to take the follower out of the mold, before the plastic hardened to a state that would crack the mold upon removal. We also needed to be careful to not pull the follower out before the plastic would be unable to maintain it's shape, creating deformation within the mold. After trying to remove the follower within the first 30 minutes it was determined that this was just to early in the curing process for removal. When we did try removing the shaft before 30 minutes, the plastic would begin to deform closing the shaft it had created. When trying to wait 2 hours into the process when the plastic had completely hardened and was ready to remove from the casting block, we would create cracks in the bridge of the mold from the forces needed to remove the shaft. We determined that the shaft removal for optimal results should occur between 45 minutes to an hour during the initial curing process.

Once the shaft had been removed we could let the casting block rest while the plastic could cure for the time needed. Our plastic selected, 420 Ultra Clear liquid molding compound, finishing an initial curing process around 2 hours. At this time the mold had taken it's final shape and was hard enough to be ready for removal. Figure 4.4b is an image that can be seen below of the plastic sitting in the casting block curing at room temperature, while Figure 4.4c displays a graph of our time vs percentage of plastic cured.

Figure 4.4b: Plastic Curing Inside of Casting Block

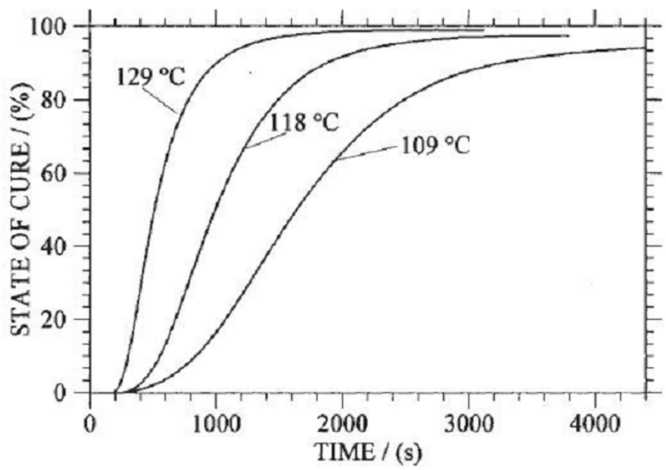

Figure 4.4c: Curing Status vs. Time

4.5: Removal Methods

After allowing the mold to cure at room temperature for two hours we could begin removing the mold from the casting block. Removing the mold proved to be a more difficult task than initially realized. The mold was a very tight fit inside the casting block and the edges were also flush with casting block making it difficult to get any sort of leverage underneath it. Since the plastic had not totally completed its 8-12 hour curing process, it had not fully hardened making it easy to crack the mold especially around the shaft.

Our first few attempts we tried to just simply pry the mold out of the casting block. This resulted in the plastic cracking during the removal causing us to revaluate our process. Using more caution we used very flat screw drivers to get in between the mold and the casting block. We slowly worked the mold out of the block inching our way around the outline of the mold. Once we could release an area of the mold the pressure keeping the mold tight in the casting block began to lessen making it gradually easier to get the mold out until we could finally fully remove the mold.

To try and improve on our results we tried using a different release agent, still from Hapco Inc., called Grease-It FDG. Our previous release agent, Grease-It I, was simply liquid grease that was applied to the casting block before the injection. Although it definitely prevented the plastic from adhering to the casting block it didn't help much with the removal. Grease-It FDG is a spray able polymeric release system that rapidly dries to form an excellent release. It is applied onto the casting block before you inject the plastic creating a very thin layer in between the mold and the casting block making it easier to release the mold from the casting block. Once the mold could be removed the thin layer was than peeled off of the mold. (http://www.hapcoweb.com, retrieved on 1/25/07)

Another technique we utilized that gave us much success was heating the mold up for a few minutes and than begin trying to release it. After the initial 2 hour curing process we would put the mold in an oven heated to a 175 degrees Fahrenheit. For the first few minutes the mold adjusts to the heat by softening against the rapidly heating Aluminum, before beginning to fully harden. By monitoring the mold in the oven we were able to determine the right time to remove it from the oven. Once out of the oven it became very easy to remove the mold from the casting block. The high temperatures of the Aluminum casting block sitting in the oven relieved the pressure of the mold eventually beginning to very slowly push the mold out.

After releasing the mold from the casting block we placed it back inside an oven heated to 175 degrees Fahrenheit for 6 hours to complete the post curing process. The additional time in the oven hardened and cured the plastic completely in all areas. A chronological order of our progress and success can be seen below in Figure 4.5a.

Figure 4.5a: Different Molds Presented in Chronological order

After having difficulty removing the mold from the casting block we made a few recommendations and changes in our design. To help the mold release easier we changed the geometry of our casting block. The original 90 degree angle of the middle section created a tight fit that made it difficult to slide the mold out. By increasing this angle to around 120 degrees it would help push the mold out during removal. Also by punching holes in the bottom of the piece, we would be able to have more control popping the mold out of the casting block. Images of these recommendations can be seen below in Figures 4.5b and 4.5c.

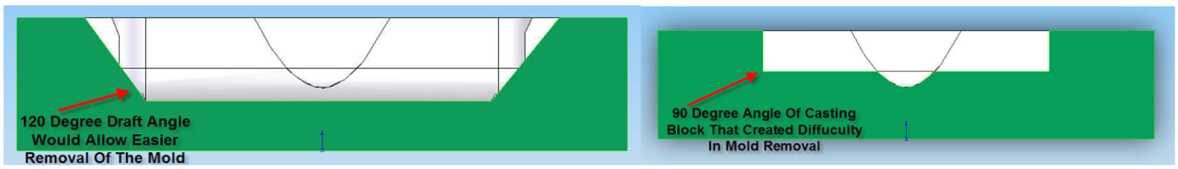

Figure 4.5b: Casting Block with Easier Release Angle Compared to Original Casting Block Design

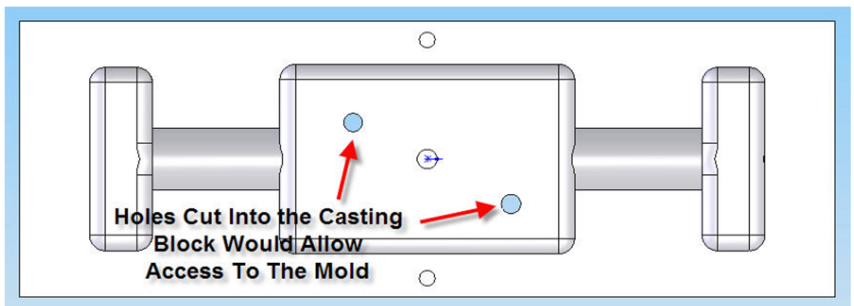

Figure 4.5c: Casting Block with Holes Punch through for Easier Removal

4.6 Device Preparation

Now that the mold had fully completed the 8-12 hour curing process, additional preparations had to be performed before the mold could house the cam follower system and attach to the snowblade. Using different machines in the Washburn machine shop at WPI we performed a few different tasks that would allow the mold to be screwed into the snowblade and ready for use.

For our design to function properly we had to find away to attach the bindings of the snowblade to the cam. To do this we create an intermediary binding plate which would mimic the same hole geometry the snowblade had to initially used attach to the bindings. To prepare our mold to attach to the snowblade we utilized that same hole geometry, minus the inside holes where the cam attached to the binding plate. To prepare the mold for this we tapped holes though it that would align with the holes of the snowblade where the bindings normally attach. We used the binding plate to mark the holes on the mold, and than used a drill press to tap the holes through the mold. After the initial holes had been tapped we than needed to countersink them in order to make the screws flush with the top of the mold so they would not interfere with the twisting motion of the cam-binding plate. A picture of us tapping holes in the mold can be seen in Figure 4.6a.

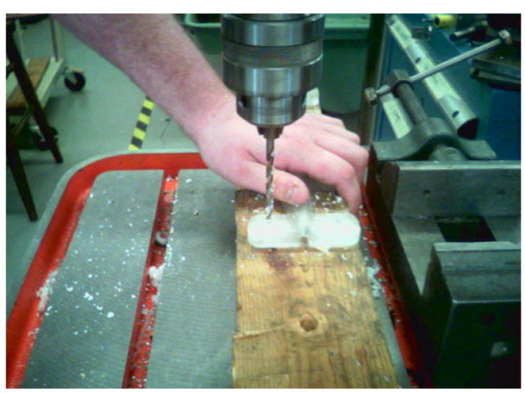

Figure 4.6a: Tapping Holes into the Mold Using the Drill Press

After the holes had been drilled we next needed to fit in the spring and follower into the mold. Some additional drilling had to be done due to the tight squeeze of the initial holes created by the pin shaft of the casting block. Once we were able to clear enough space to comfortably fit the cam, follower, and spring inside the mold we than needed to install a securing system for the spring and follower. To create this we temporarily removed the spring and follower from the mold to do some additional drilling. We cut out a very thin aluminum plate to cover the hole of the spring follower and than tapped holes in it to drill into the side of the mold. We than punched a hole in the middle of it to insert a placement screw threw it to enable us the ability to adjust the spring tension. Once we drilled these holes we could now return the spring and follower into the shaft of the mold and secure with our newly drilled plate. Using the securing nut inside of the shaft of the mold we tightened a screw to push up flush against the spring and than used an additional securing nut on the outside to keep it in place. This screw would allow us to adjust the spring tension. A picture of our configuration can be seen below in Figure 4.6b.

Figure 4.6b: Cam, Follower, Spring Configuration

Once our mold was completely configured we could than begin to attach the mold to the snowblade. To do this, we first attached the cam to the binding plate before the mold could screw into the snow blade or else it would prevent us from having access to the cam. After the binding plate was attached we than we could screw the mold onto the snowblade. The final step would be securing the binding plate to the bindings and than inserting the boot. Our design is now ready for use. A picture of the completed design can be seen below in Figure 4.6c. Another picture of our assembly of the working model can be seen on the next page in Figure 4.6d.

Figure 4.6c: Completed Design

Once the mold was complete, it was time to prepare the aluminum cast for another production run. Failed molding attempts from early on left residue which would prove detrimental for multiple mold production. The manufacturer solution for clean up was muriatic acid. While this was an optimum solution for residue removal, it ate away a layer of the aluminum mold in the process. The result was an increased static coefficient of friction between the housing and binding plate. While this was not our intention, it removed some of the constraints that currently plague cam design for this application.

For future applications, we suggest using acetone for cast clean-up, and design for a rougher surface finish.

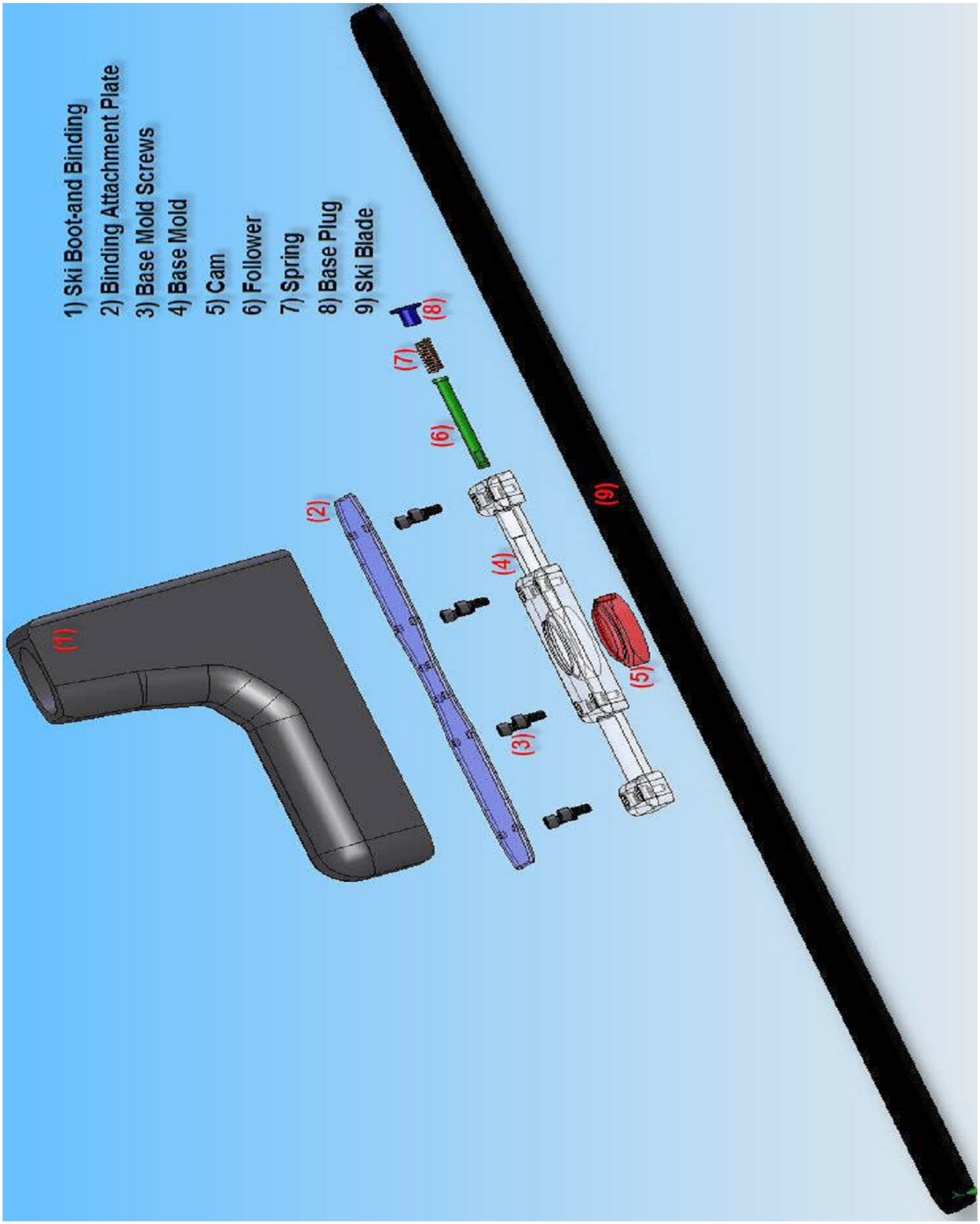

Figure 4.6d: Complete Assembly of Working Model

Section 5: Analysis and Testing

5.1 Hardness Testing

Plastic quality can be defined by hardness. The hardness of plastics is most commonly measured by the Shore® (Durometer) test. The Durometer is used to measure the resistance of plastics toward indentation and provide an empirical hardness value. Shore Hardness, using the Shore D scale, is the preferred method for rubbers/elastomers and is also commonly used for 'harder' plastics such as polyolefins, fluoropolymers, and vinyls. The Shore A scale is used for 'softer' rubbers while the Shore D scale is used for 'harder' ones. Many other Shore hardness scales, such as Shore O and Shore H hardness, exist but are only rarely encountered by most plastics engineers. (John, @ Durometer Contact)

The results obtained from this test are a useful measure of relative resistance to indentation of various grades of polymers. However, the Shore Durometer hardness test does not serve well as a predictor of other properties such as strength or resistance to scratches, abrasion, or wear, and should not be used alone for product design specifications.

Shore hardness is often used as a proxy for flexibility (flexural modulus) is specifying elastomers. The correlation between Shore hardness and flexibility holds for similar materials, especially within a series of grades from the same product line, but this is an empirical and not a fundamental relationship. (Callister)

Given problems during the initial curing process, it became necessary to examine, and determine optimum curing conditions. Using Shore hardness to define quality, we tested Hapco's Ultraclear line of urethane under different curing conditions; time and temperature. The results were in accordance with Hapco's recommended curing procedure.

We made thirty small molds out of one inch diameter pvc piping and we filled them with about half an inch of urethane using the Rapidshot dispensing method. Curing five at a time, we tested hardness using a type D durometer every hour in the recommended 4-12 hour post curing time window. We repeated this process at six different temperatures using box made of pink insulation board lined with aluminum foil insulation to induce reflection and increase radiation. The heat sources used were an ordinary kitchen oven for the highest, four light bulbs of different wattage in conjunction with the insulation box, and room temperature. The average hardness for each hour at each temperature are shown below in figure 4.7, and the data compilation is included in Appendix 8.6Our finding; that for best results one must cure at 80°C for 12 hours.

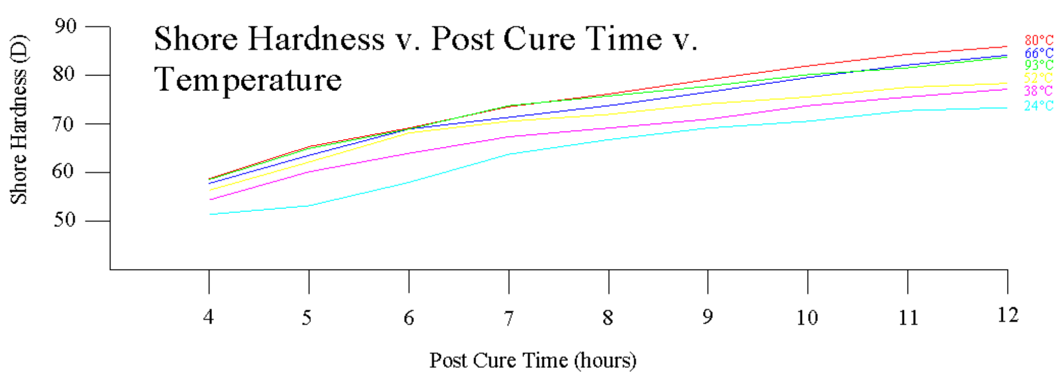

Figure 5.1: Shore Hardness Testing Results

5.2 Cam Analysis and Testing

Torque Testing Procedure

The standards state to release the binding three times at room temperature before measuring the result. Equations based on the skiers weight and height are used to determine the release settings on alpine ski bindings. A DIN chart, located in Appendix ## has the corresponding release settings marked in accordance with the ASTM standards for simplicity when setting release values on skis.

For precision, all the bindings tested were set to the DIN chart specifications similar to the characteristics of a level two 5’10” 185lb skier. This skier should have an approximate twist of 58 N-m.

In Koch and Leblanc’s testing, after clamping the skis down and releasing the binding three times, they then measured the perpendicular displacement of the toe of the boot from the center of the ski in 5 N-m intervals. Then using simple trigonometry they were able to find the angle of displacement of the boot from the ski about the center of the tibia, (Koch, Leblanc, 2002). When we did our testing, we measured torque v. rotation using a dial with one degree increments. This dial is available in the appendix.

Unfortunately when torque testing our ski, the tibia is not stationary since our ski rotates about the center of the boot rather than at the tibia. Although this is not a truly accurate representation, the curve of angular displacement caused from tibia rotation can still be analyzed to determine where our binding stands in relation to the current alpine ski bindings (Koch, Leblanc, 2002).

Theoretical Design of Cam

The cam and follower mechanism from Murphy and Landau's design was analyzed to determine under which conditions it should theoretically release, a schematic of these results is available in Figure5.2a.

Position	Spring Displacement (in)	Radius (in)	Cam Angle (°)
0	0	0.935	0
1	0.008	0.943	1.9
2	0.034	0.969	3.6
3	0.073	1.008	4.97
4	0.109	1.044	6.09
5	0.152	1.087	7.32
6	0.176	1.111	7.99
7	0.185	1.046	8.21

Figure 5.2a: Data for Theoretical Use

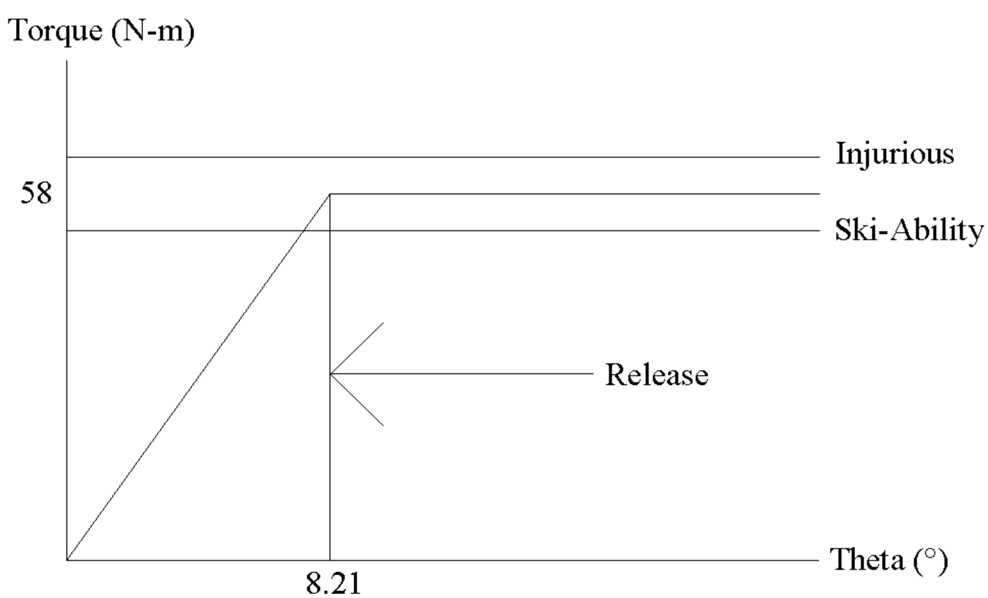

Figure 5.2b: Graph of Angular Cam Release vs. Torque

Theoretical Design of Cam to Promote Retraction

One part of Koch and Leblanc's design that did not make the transition into Murphy and Landau's design was for retraction after load removal. Once the specified load has been exceeded, the system releases, and must be reset manually. The desired effect is that it pop out within the first 10° of angular rotation, but retract to its original position if the load is removed. It was found that the Murphy-Landau cam met the specifications for release set forth by Koch and Leblanc. Posted in Figure 5.2c, is an adaptation of the Murphy-Landau cam that meets the functional requirement for retraction.

Position	Spring Displacement (in)	Radius (in)	Cam Angle (°)
0	0	0.861	0
1	0.008	0.869	1.9
2	0.034	0.895	3.6
3	0.073	0.934	4.97
4	0.109	0.97	6.09
5	0.152	1.013	7.32
6	0.176	1.037	7.99
7	0.185	1.046	8.21
8	0.204	1.065	28.66
9	0.222	1.083	49.11
10	0.241	1.102	69.56
11	0.259	1.12	90

Figure 5.2c: Theoretical Data Promoting Retractable Release

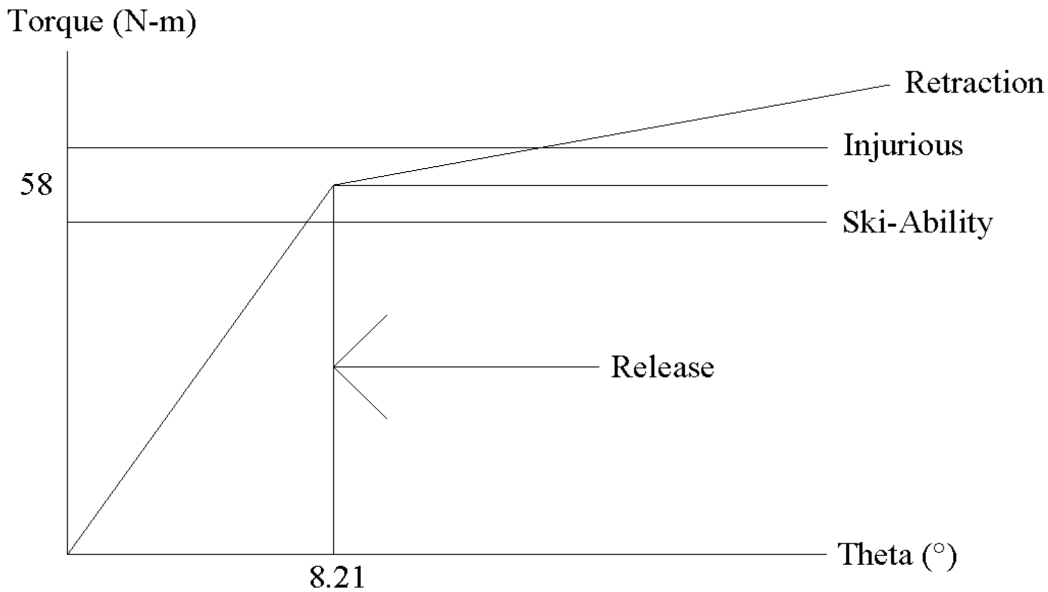

Figure5.2d: Graph of Angular Displacement of Cam vs. Torque

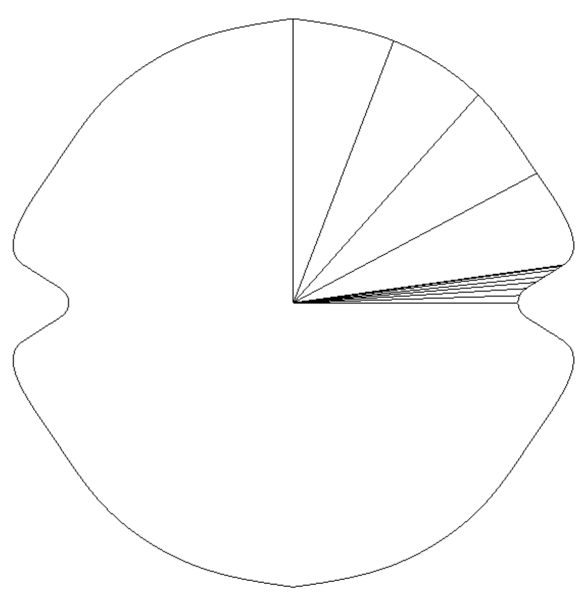

Figure 5.2e - Theoretical Cam Profile - Promote Retraction

Theta (°)	Torque (N-m)
0	0
1	5
2	5
3	5
4	5
5	5
6	10
7	15
8	25
9	33
10	40
11	50
12	55
13	60
14	Release

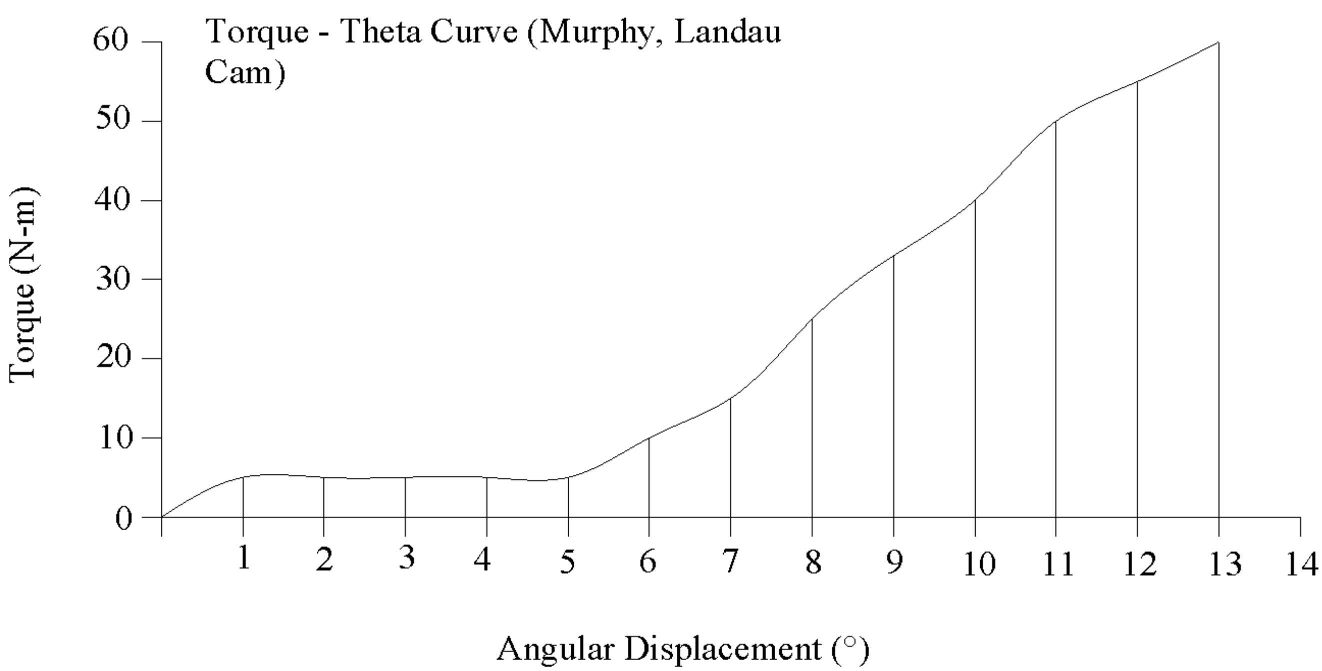

Figure 5.2f: Results from Bench Testing

The cam designed by Murphy and Landau released at 14°, at this point, the torque had reached its maximum limit of 60 N-m. The graph shown in figure ## demonstrates a four degree period of rotation where torque does not increase as displacement does. This can be corrected by adjustment of the cam dimple and or the follower tip.

Section 6: Conclusions and Recommendations

The overall goal of our project was to produce a molding process that would be able to efficiently mold a housing unit able to support the functionality of our cam follower system. After having some initial problems we were able to successfully create and thoroughly describe a process in which we could obtain efficient and consistent molds. We were able to use the molds to function on a snowblade, allowing us to test functionality of the cam follower system.

Our molds we received were relatively strong for the purpose needed and had no problems housing the cam follower system. Our mold design had no problem absorbing the torque caused by the displacement of the cam during use and showed much resiliency in further harness testing and FEA analysis. The mold created is able to be universally used on all snow blades and allows the user to adjust the spring load being applied allowing a wide variety of users.

When attempting to perfect our process we found out quickly that practice makes perfect. It took us several attempts and different processes to find the best results. The entire molding process takes anywhere from 8-12 hours with additional device preparation needed before use. Using the HapcoShot Dispensing Gun we inject the plastic into the casting block for initial curing. We than let the plastic settle and take form for 45 minutes to an hour before we completed the next step of removing the shaft pin from the mold. After two hours of the initial curing process at room temperature (20 to25° C) we removed the mold from the casting block. We than placed the mold inside an oven for an additional 4-12 hours for post curing. After the post curing stage the mold was ready for device preparation. For device preparation, we drilled holes through the mold and for insertion to the snowblade and than configured the cam follower system.

When attempting to do this project we came across a few recommendations we would make for future progress. One issue we experienced that gave us a large portion of our problems was trying to remove the mold from the casting block with out damaging it. We determined that the angle of the sides for the casting block could be machined on an angle as opposed to 90 degrees which would encourage the mold to release easier from the casting block. Also, we had much trouble getting underneath the mold to gain leverage for removal. By punching holes through the bottom of the casting block, you would be able to gain easy access underneath the mold.

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Section 8: Appendices

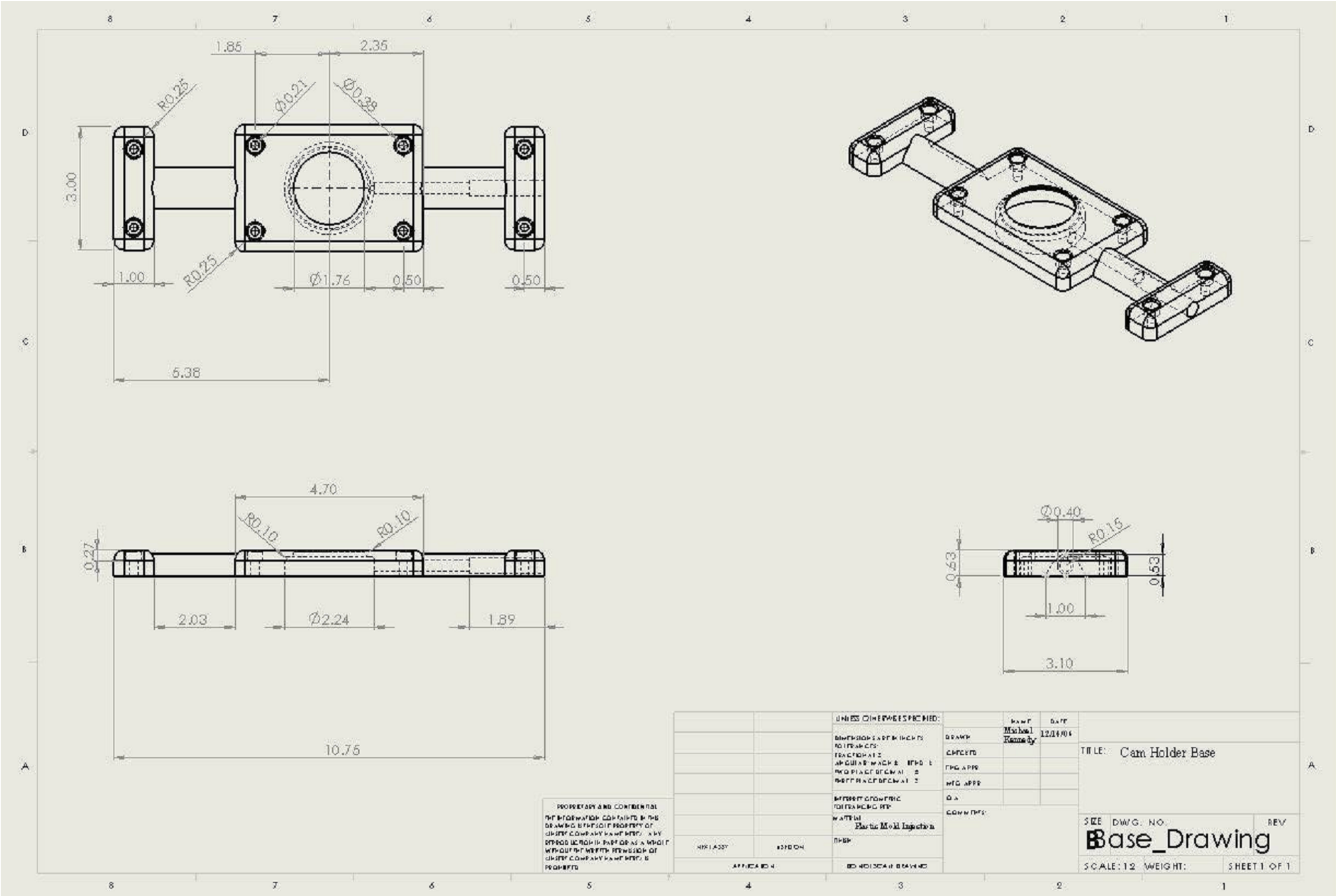
Appendix A: Plastic Properties

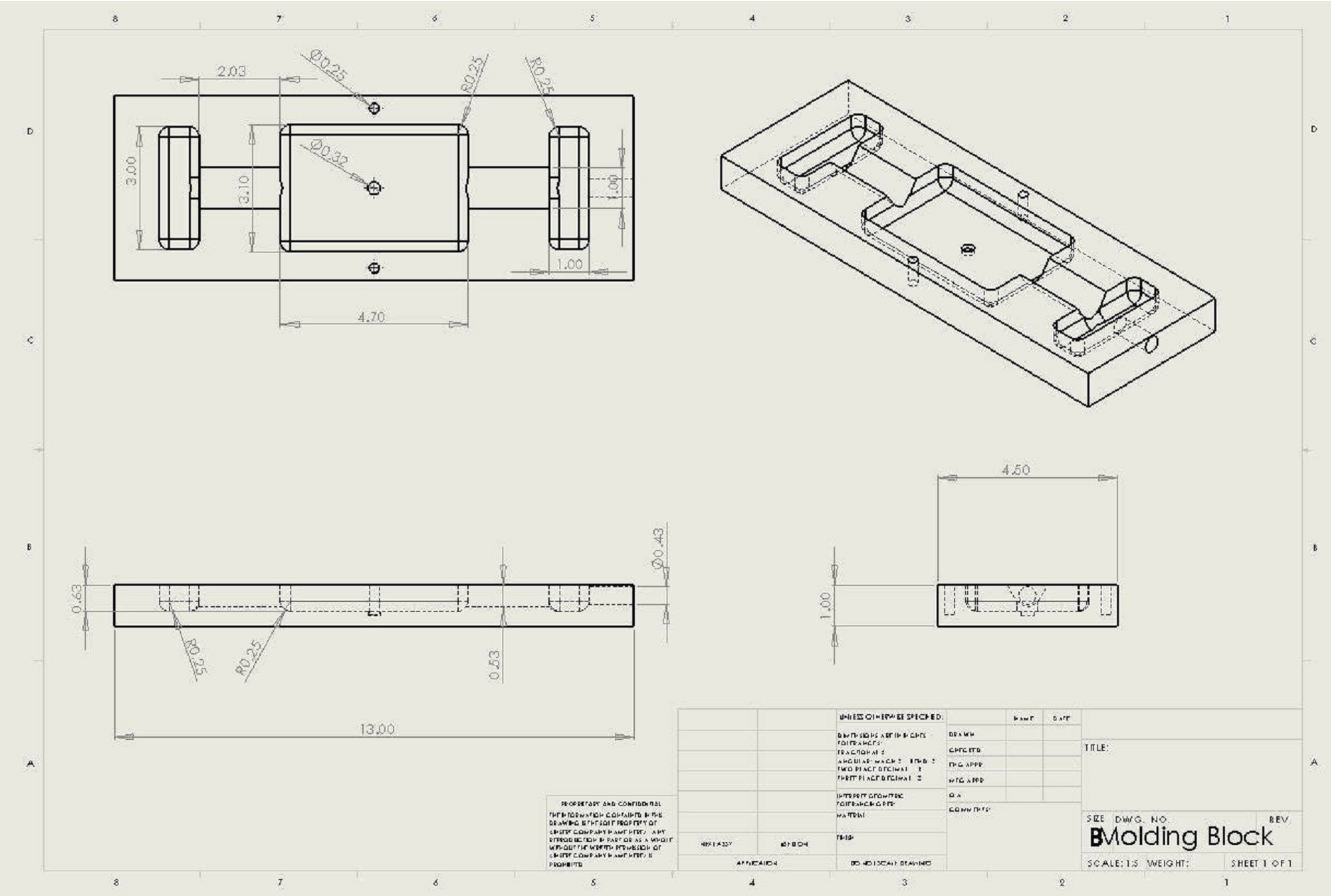
ULTRACLEAR 400 SERIES

A series of **crystal clear Liquid Molding Compounds** with exceptional clarity and outstanding physicals.

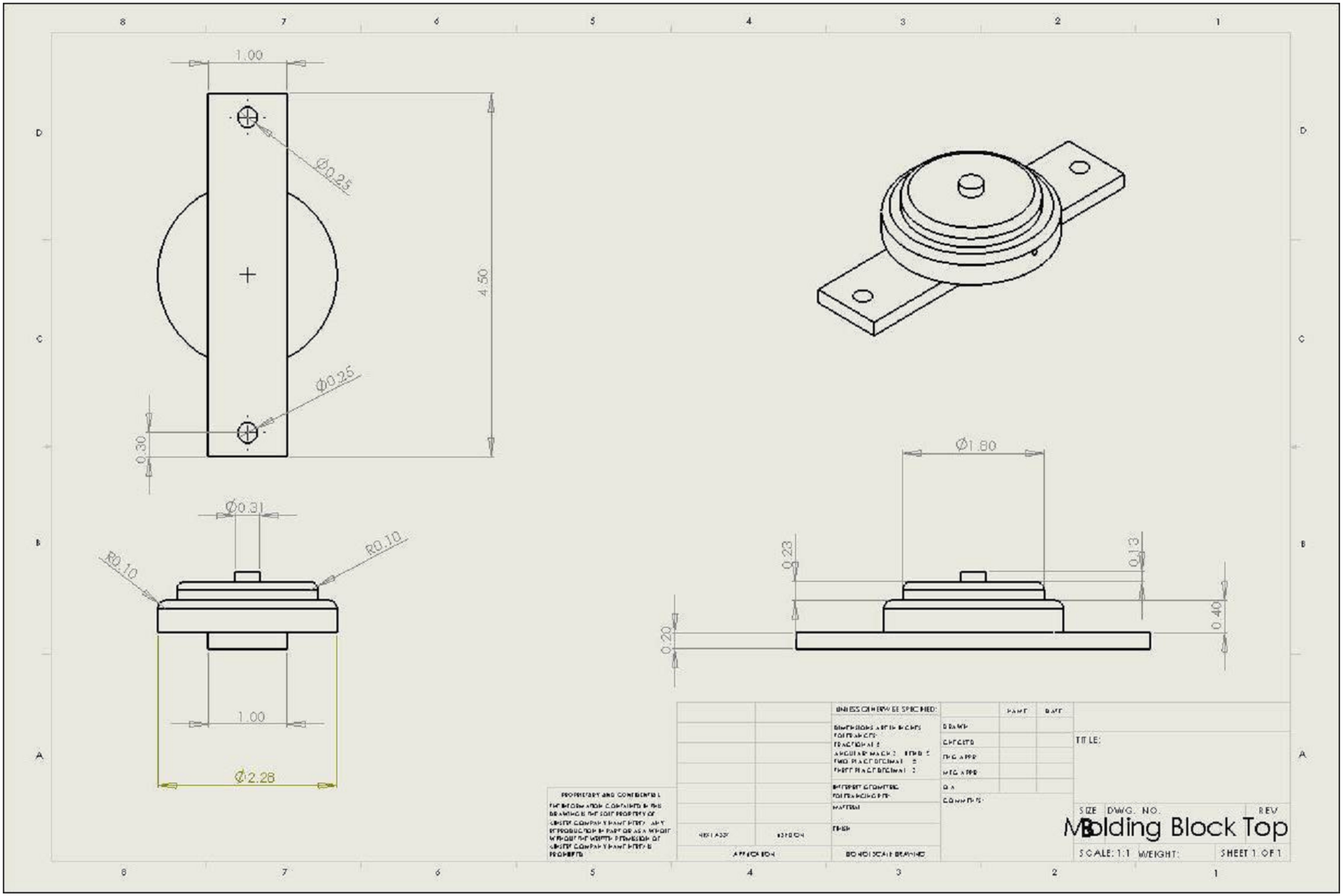
PROPERTIES	TEST METHOD	420	421	425	426	*427	440	441	445	446	447
Mix Ratio by volume A:B by weight A:B	Calculation	100:50 100:50	100:50 100:50	100:50 100:50	100:50 100:50	100:50 100:50	100:43 100:40	100:43 100:40	100:40 100:40	100:40 100:40	100:40 100:40
Gel time 100 grams @ 25°C	ASTM D-2971	5 min.	15 min.	20 min.	30 min.	50 min.	5 min.	15 min.	20 min.	30 min.	50 min.
Color (cured)	Visual	crystal clear	crystal clear	crystal clear	crystal clear	crystal clear	crystal clear	crystal clear	crystal clear	crystal clear	crystal clear
Hardness Shore	ASTM D-2240	85 D	85 D	82 D	82 D	82 D	80-85 D	80-85 D	85 D	85 D	85 D
Viscosity mixed @ 25°C cps	ASTM D-4878	940	940	650	650	650	650	650	700	700	700
Specific Gravity Mixed @ 25°C	ASTM D-4669	1.05	1.05	1.05	1.05	1.05	1.06	1.06	1.06	1.06	1.06
Shrinkage inch/inch **See shrinkage paragraph**	ASTM D-2566	0.002-0.006	0.002-0.006	0.002-0.006	0.002-0.006	0.002-0.006	0.002-0.006	0.002-0.006	0.002-0.006	0.002-0.006	0.002-0.006
Demold time @ 70°F 1/8" thick	HAPCO TEST	1-3 hrs.	6-10 hrs.	4-6 hrs.	5-7 hrs.	18-24 hrs.	1-3 hrs.	6-10 hrs.	3-5 hrs.	5-8 hrs.	10-12 hrs.
Weight per cubic inch (lbs.)	Calculation	0.0379	0.0379	0.0379	0.0379	0.0379	0.0383	0.0383	0.0383	0.0383	0.0383
Tensile Strength (psi)	ASTM D-638	10,200	10,200	9,500	9,500	9,500	9,500	9,500	10,200	10,200	10,200
Elongation %	ASTM D-638	13%	13%	13%	13%	13%	12±2%	12±2%	10%	10%	10%
Modulus of Elasticity psi (000)	ASTM D-638	440	440	440	440	440	305	305	448	448	448
Izod Impact (ft.lbs/in.) notched unnotched	ASTM D-256	0.30 1.40	0.30 1.40	0.30 1.40	0.30 1.40	0.30 1.40	0.23 2.10	0.23 2.10	0.23 2.10	0.23 2.10	0.23 2.10
Heat Distortion Temperature (°C) 66 psi 264 psi	ASTM D-648	96°C 92°C	96°C 92°C	96°C 92°C	96°C 92°C	96°C 92°C	100°C 98°C	100°C 98°C	100°C 98°C	100°C 98°C	100°C 98°C
Flexural Strength (psi)	ASTM D-790	11,000	11,000	11,000	11,000	11,000	11,800	11,800	11,800	11,800	11,800
Flexural Modulus psi (000)	ASTM D-790	197	197	197	197	197	208	208	208	208	208
Dielectric Constant 1 KHz 100 KHz	ASTM D-150						3.25	3.25	3.25	3.25	3.25
Dielectric Strength (volts/mil.)	ASTM D-149						>=350	>=350	>=350	>=350	>=350
Volume Resistivity (ohm-cm)	ASTM D-270						6×10^{14}	6×10^{14}	6×10^{14}	6×10^{14}	6×10^{14}
Dissipation Factor 100 KHz @ 25°C	ASTM D-150						0.011	0.011	0.011	0.011	0.011

Appendix 8.2: Final Drawings


1.85
2.35
R0.25
Ø0.21
Ø0.38
3.00
R0.25
1.00
Ø1.76
0.50
0.50
5.38
4.70
R0.10
R0.10
0.27
2.03
Ø2.24
1.89
10.76
Ø0.40
R0.15
0.63
0.53
1.00
3.10
UNLESS OTHERWISE SPECIFIED:
DRAWN
Michael Kennedy
12/14/06
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
MATERIAL
Plastic Mold Injection
TITLE: Cam Holder Base
SIZE DWG. NO.
B Base_Drawing
REV
SCALE: 1:2 WEIGHT:
SHEET 1 OF 1



2.03
Ø0.25
R0.25
R0.25
3.00
Ø0.32
3.10
1.00
1.00
4.70
4.50
0.63
Ø0.43
R0.25
R0.25
0.53
1.00
13.00
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NAME
DATE
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.
TITLE:
SIZE DWG. NO. REV
B Molding Block
SCALE: 1:5 WEIGHT: SHEET 1 OF 1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Ø0.25
4.50
Ø0.25
0.30
Ø0.31
R0.10
R0.10
1.00
Ø2.28
Ø1.80
0.23
0.13
0.20
0.40
UNLESS OTHERWISE SPECIFIED:
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NAME
DATE
TITLE:
PROPRIETARY AND CONFIDENTIAL
NEXT ASSY
USED ON
APPLICATION
MATERIAL
FINISH
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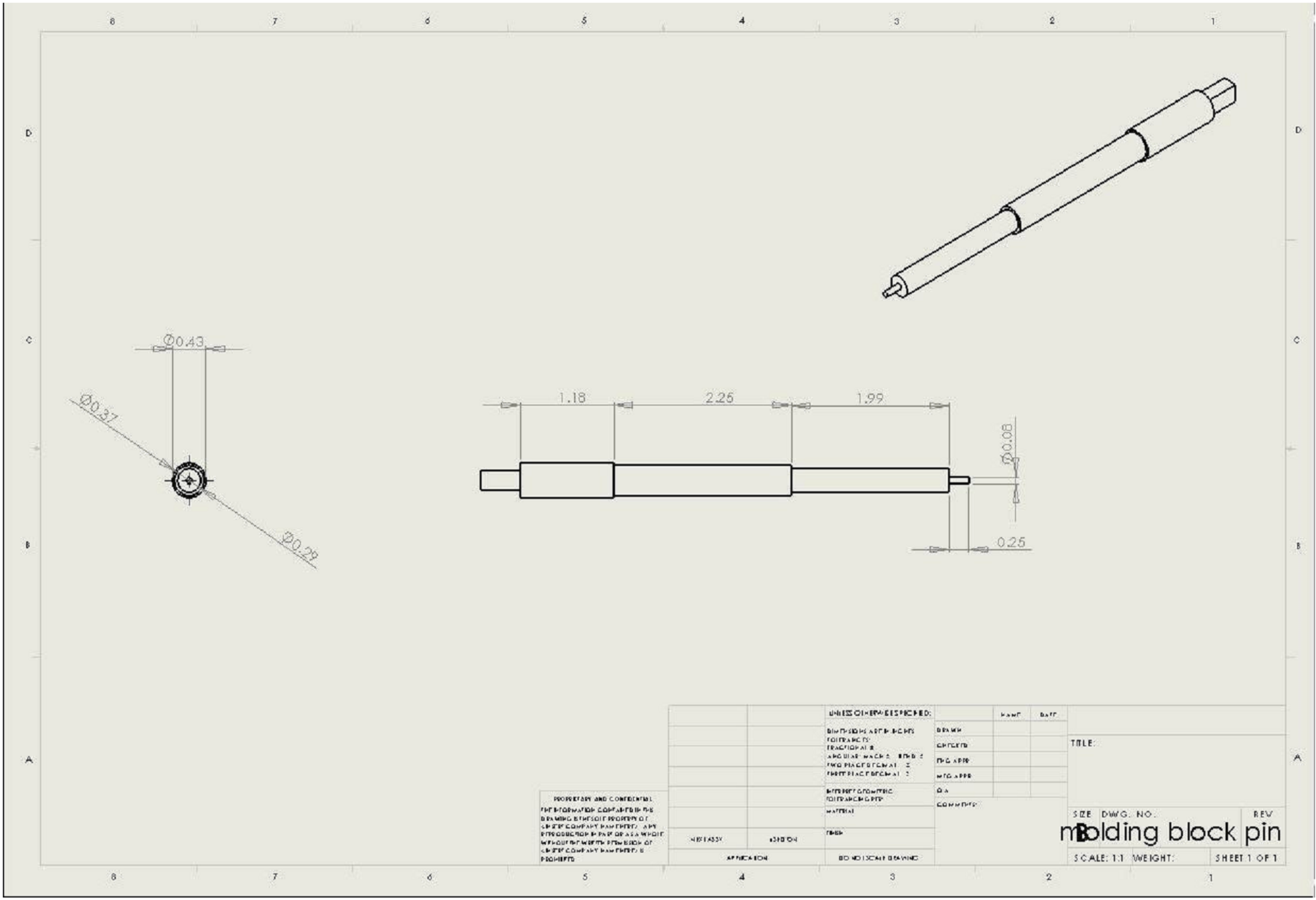
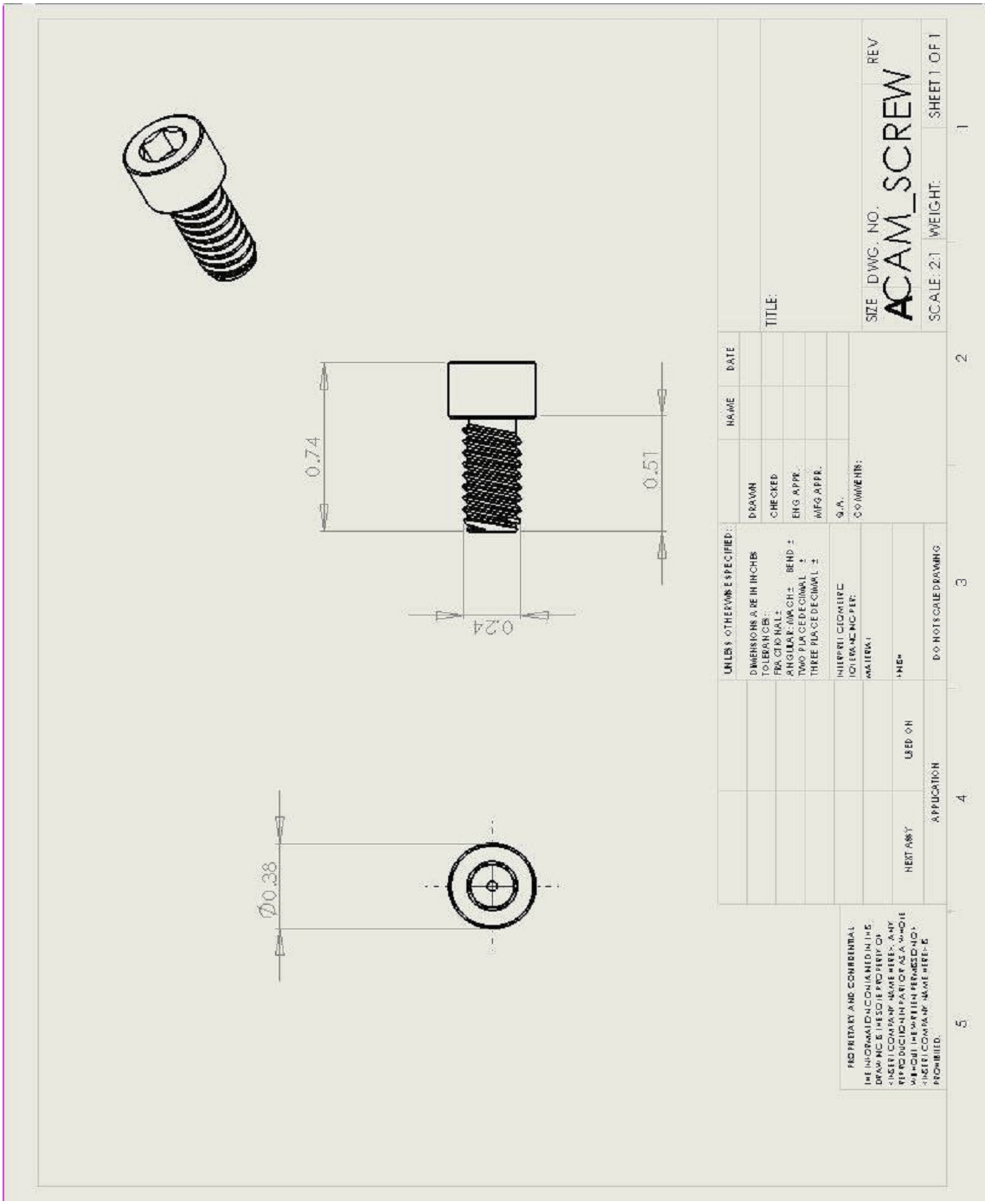
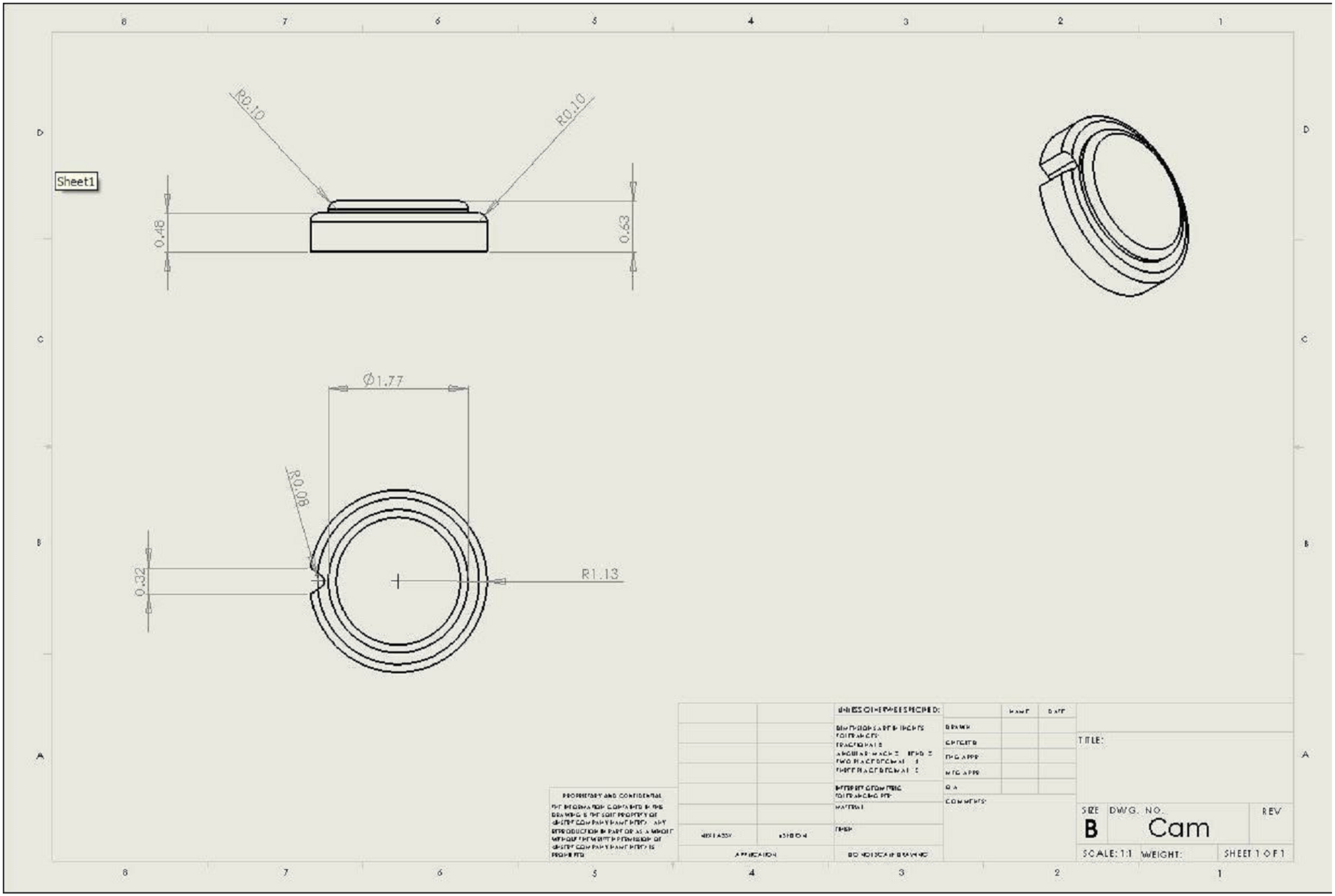
SIZE
DWG. NO.
REV
Molding Block Top
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1

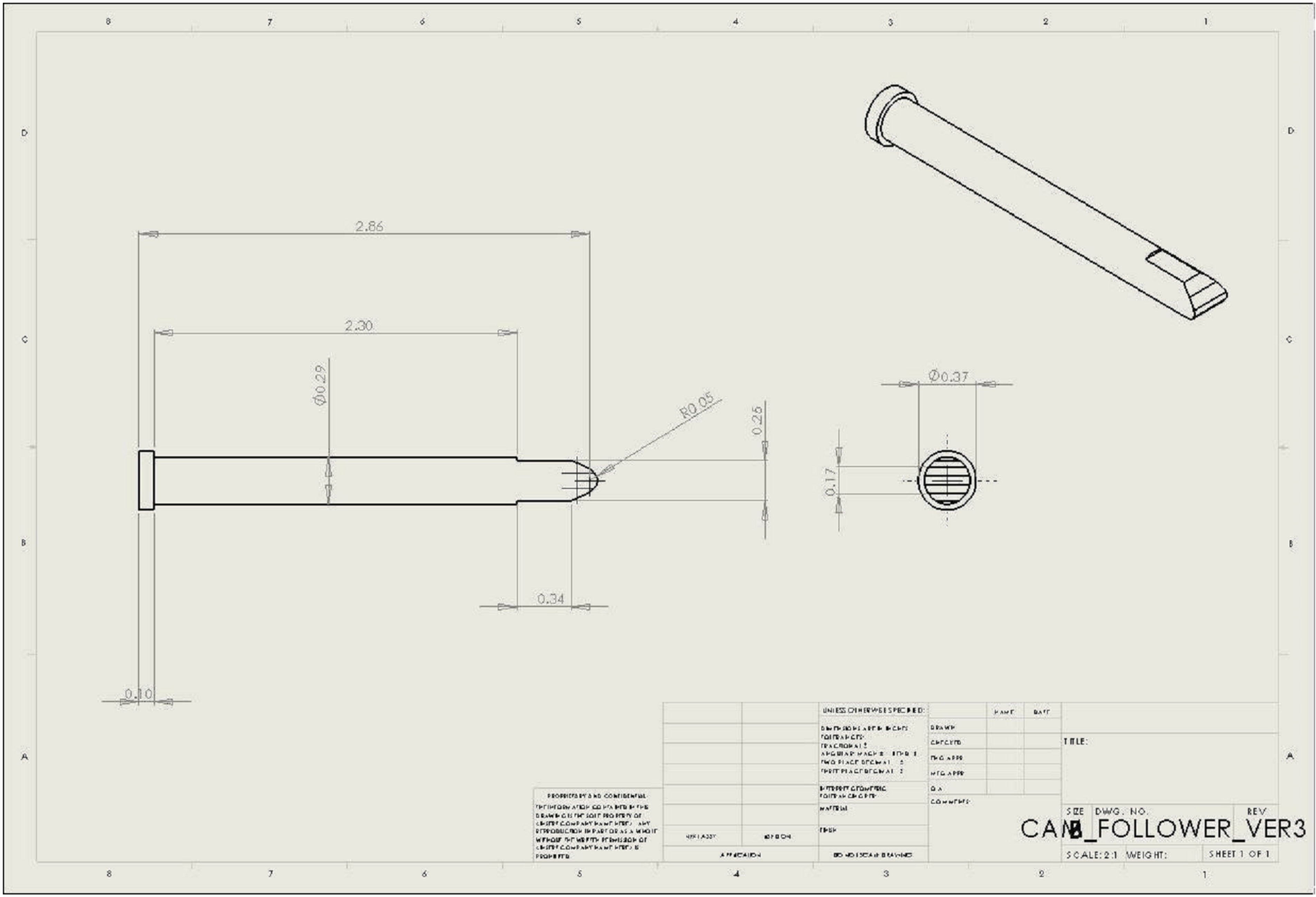


Ø0.43
Ø0.37
Ø0.29
1.18
2.25
1.99
Ø0.08
0.25
UNLESS OTHERWISE SPECIFIED:
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
PROPRIETARY AND CONFIDENTIAL
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
TITLE:
SIZE
B
DWG. NO.
REV
molding block pin
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1



Ø0.38
0.74
0.51
0.24
TITLE:
SIZE
DWG. NO.
ACAM_SCREW
REV
SCALE: 2:1
WEIGHT:
SHEET 1 OF 1
DO NOT SCALE DRAWING


Sheet1
R0.10
R0.10
0.48
0.63
Ø1.77
R0.08
0.32
R1.13
PROPRIETARY AND CONFIDENTIAL
UNLESS OTHERWISE SPECIFIED:
NAME
DATE
TITLE:
SIZE
DWG. NO.
B
Cam
REV
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1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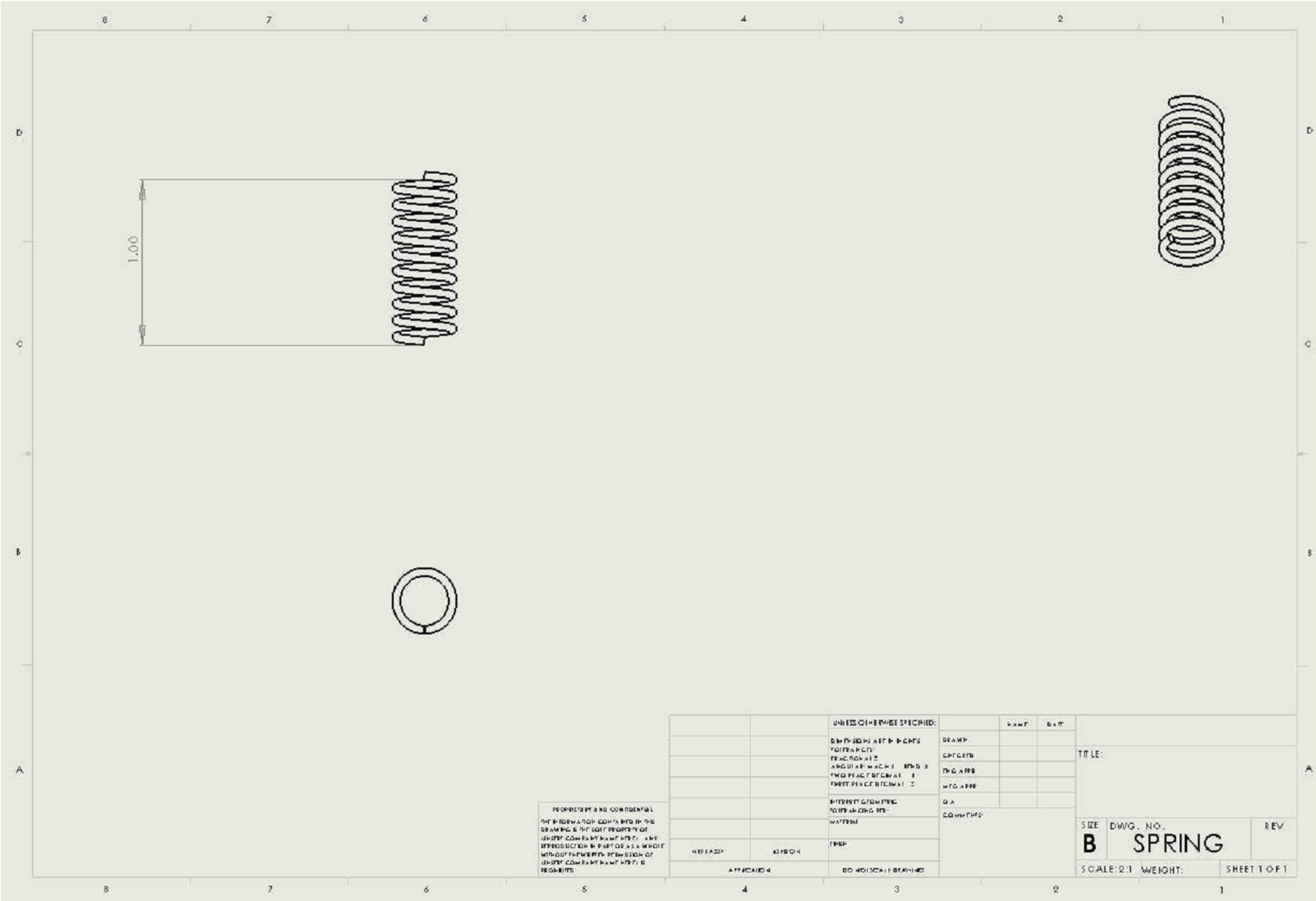
2.30
Ø0.29
R0.05
0.25
0.34
0.10
Ø0.37
0.17
UNLESS OTHERWISE SPECIFIED:
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
SIZE
DWG. NO.
REV
CAM_FOLLOWER_VER3
SCALE: 2:1
WEIGHT:
SHEET 1 OF 1
APPLICATION
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL


1.00
UNLESS OTHERWISE SPECIFIED:
TITLE:
SIZE
B
DWG. NO.
SPRING
REV
SCALE: 2:1
WEIGHT:
SHEET 1 OF 1

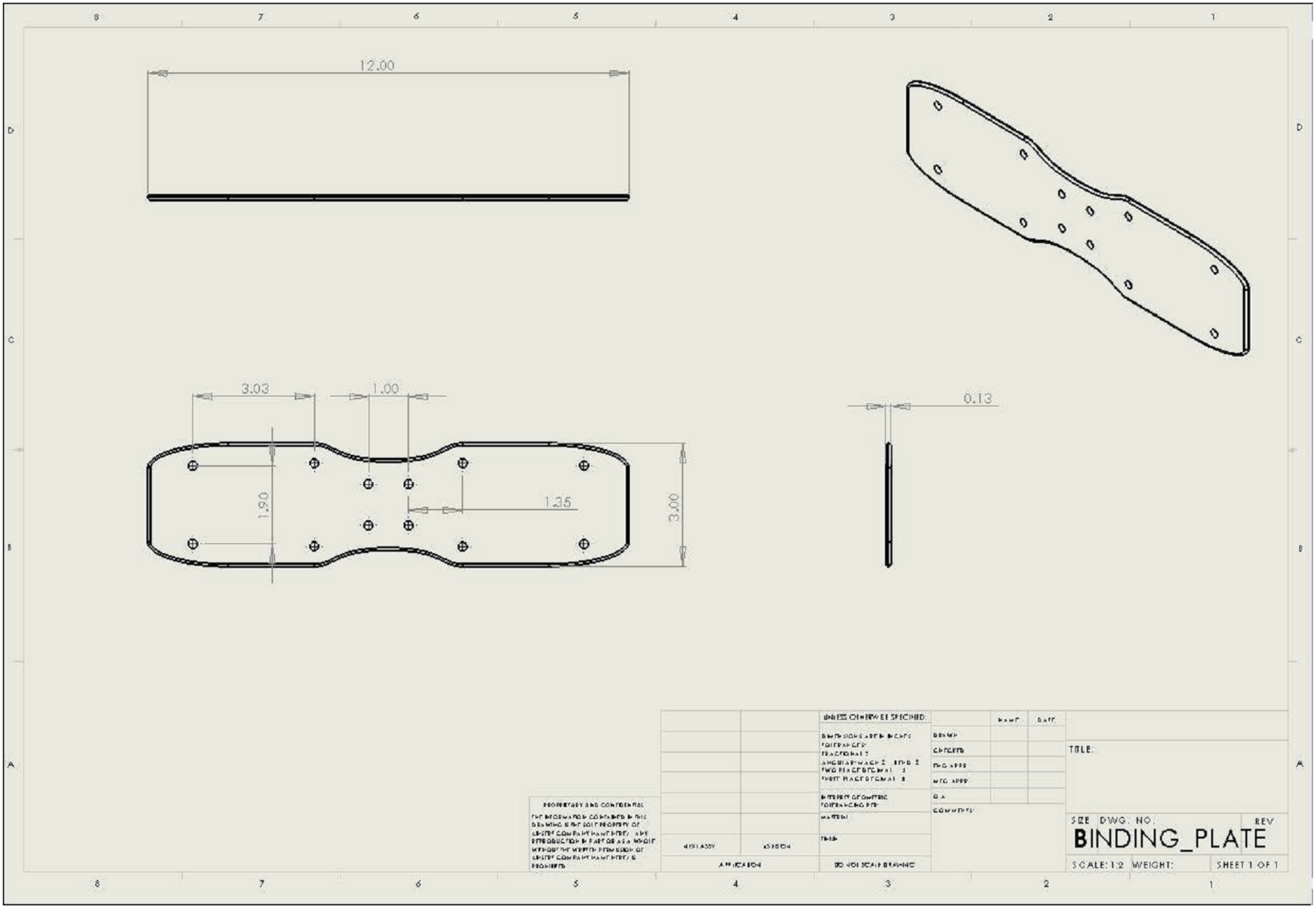
UNLESS OTHERWISE SPECIFIED:		NAME	DATE
	DRAWN		
	CHECKED		
	ENG APPR.		
	MFG APPR.		
MATERIAL	Q.A.		
FINISH	COMMENTS:		
DO NOT SCALE DRAWING			

NEXT ASSY	USED ON
APPLICATION	

PROPRIETARY AND CONFIDENTIAL

TITLE:

SIZE	DWG. NO.	REV
B	base_plug	
SCALE: 2:1	WEIGHT:	SHEET 1 OF 1


12.00
3.03
1.00
1.90
1.35
3.00
0.13
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
PROPRIETARY AND CONFIDENTIAL
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NEXT ASSY
USED ON
APPLICATION
SIZE
DWG. NO.
REV
BINDING_PLATE
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1

Appendix 8.3: DIN Chart

Skier Weight: Pounds (kilos)	Skier Height: Ft. In. (cm)	Skier Code	Toe and Heel Setting Indicator Value — Boot Sole Length 1: ≤ 250 mm	2: 251 - 270 mm	3: 271 - 290 mm	4: 291 - 310 mm	5: 311 - 330 mm	6: ≥ 331 mm	Release Torque Range (Nm) — Twist min.	Twist Ref.	Twist max	Forward Lean min	Forward Lean Ref	Forward Lean max
										5			18	
22 - 29 lbs. 10 - 13 kg		A	0,75	0,75					5	8	11	19	29	39
30 - 38 lbs 14 - 17 kg		B	1	1	0,75				8	11	14	30	40	50
39 - 47 lbs 18 - 21 kg		C	1,25	1,25	1				11	14	17	42	52	57
48 - 56 lbs. 22 - 25 kg		D	1,75	1,5	1,5				14	17	20	54	64	74
57 - 66 lbs. 26 - 30 kg		E	2	2	1,75				17	20	23	65	75	85
67 - 78 lbs. 31 - 35 kg		F	2,5	2,5	2,25	2	1,75	1,75	20	23	26	77	87	97
79 - 91 lbs. 36 - 41 kg		G		3	2,5	2,5	2,25	2	24	27	30	92	102	112
92 - 107 lbs. 42 - 48 kg	4'10" or 148	H		3,5	3	3	2,5	2,5	28	31	34	109	120	132
108 - 125 lbs. 49 - 57 kg	4'11" - 5'1" 149 - 157	I		4,25	4	3,5	3,25	3,25	33	37	41	127	141	155
126 - 147 lbs 58 - 66 kg	5'2" - 5'5" 158 - 166	J		5	4,75	4,5	4	4	39	43	47	148	165	182
148 - 174 lbs. 67 - 78 kg	5'6" - 5'10" 167 - 178	K		6	5,5	5,25	5	4,75	45	50	55	175	194	213
175 - 209 lbs. 79 - 94 kg	5'11" - 6'4" 179 - 194	L		7	6,75	6,25	6	5,75	52	58	64	206	229	252
210 + lbs. 95 - kg	6'5" + 195 -	M		8,5	8	7,5	7	6,75	60	67	74	244	271	298
		N		10	9,5	9,0	8,5	8,25	70	78	86	283	320	352
		O		12	11,25	10,75	10,25	10	82	91	100	342	380	418
										105			452	

Designation: F 1061 – 97

Specification for Ski Binding Test Devices[1]

This standard is issued under the fixed designation F 1061; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

The purpose of this specification is to aid in the selection of ski binding test devices appropriate for the needs of ski equipment sales and rental facilities. Devices which meet this specification exceed the requirements of ASTM Practices F 1063, F 1064, and F 1065. Therefore, a device that does not meet this specification may still satisfy the requirements of ASTM Practices F 1063, F 1064, and F 1065.

1. Scope

1.1 This specification covers requirements for devices used to determine the release moments of ski equipment in retail sales and rental facilities.

1.2 This specification is applicable to the manufacture, repair, and calibration of such devices.

1.3 This specification is to be used with Test Method F 1062.

1.4 The values expressed in deka-Newton metres, deka-Newtons, and centimetres are to be regarded as the standard.

1.5 The values expressed in units of torque may be converted to the appropriate force values when devices which indicate force are used.

2. Referenced Documents

2.1 *ASTM Standards:*

E 456 Terminology Relating to Quality and Statistics[2]

F 504 Test Method for Measuring the Quasi-Static Release Moments of Alpine Ski Bindings[3]

F 939 Practice for Selection of Release Torque Values for Alpine Ski Bindings[3]

F 1062 Test Method for Verification of Ski Binding Test Devices[3]

F 1063 Practice for Functional Inspections and Adjustments of Alpine Ski/Boot/Binding Systems[3]

F 1064 Practice for Sampling and Inspection of Complete Alpine Ski/Boot/Binding Systems in Rental Applications[3]

F 1065 Practice for Inspection of Incomplete Alpine Ski/Boot/Binding Systems in Rental Applications[3]

2.2 *ISO Standard:*

8061 Method for the Selection of Release Torqu

3. Terminology

3.1 The terms and abbreviations used in this doc defined in Practice E 456, Method F 504, and Te F 1062.

3.2 Terms and abbreviations used in this doc repeated here for convenience. Refer to Test Meth for equations.

3.2.1 *a*—the difference between the calibration o cific device tested for agreement with an instrument described in Method F 504, and the calibration of an device of the same design.

3.2.2 *d*—the agreement between the test devic standard apparatus described in Method F 504.

3.2.3 *r*—the imprecision of the device tested.

3.2.4 *Recommended Operating Range (ROR)*—t of the full range of the test device which is in compl this specification.

3.2.5 *Operating Range (OR)*—the portion of the of the test device which may be employed in compl Practices F 1063, F 1064, and F 1065. OR shall be the user in accordance with the section on Inspectio A1 of Practice 1063, or in the section on Inspection 2 of Practice F 1064.

3.2.6 *M1*—a moment in a horizontal plane as defi 1b of Method F 504.

3.2.7 *M3*—a moment in a vertical plane with defined in Fig. 1b of Method F 504.

3.2.8 *reference binding*—a binding (or group of used in the verification of a test device.

3.2.9 *standard apparatus*—laboratory equipment

[1] This specification is under the jurisdiction of ASTM Committee F-27 on Snow Skiing and is the direct responsibility of Subcommittee F27.10 on Binding Test Procedures.

Current edition approved March 10, 1997. Published June 1997. Originally published as F 1061 – 90.

[2] *Annual Book of ASTM Standards*, Vol 14.02.

[3] *Annual Book of ASTM Standards*, Vol 15.07.

[4] Available from American National Standards Institute, 11 W. Floor, New York, NY 10036.

a test frame and instrumentation (see Method F 504) used as the basis of comparison with the test device.

3.2.10 *test device*—a machine for determining the release moments of ski/boot/binding systems.

4. Classification

4.1 *Type I*—a device capable of indicating both positive and negative release moments (M_z).

4.1.1 *Type IA*—a Type I device with specified limits of linear displacement or angular deflection.

4.1.2 *Type IB*—a Type I device limited in use to a specified binding or group of bindings.

4.2 *Type II*—a device capable of indicating both positive and negative release moments (M_y).

4.2.1 *Type IIA*—a Type II device with specified limits of linear displacement or angular deflection.

4.2.2 *Type IIB*—a Type II device limited in use to a specified binding or group of bindings.

4.3 *Type III*—a device other than Type I or Type II with specified capability.

5. Selection of Reference Bindings

5.1 A binding (designation B, 4.1.2, 4.2.2) or group of bindings shall be selected by the test device manufacturer which are appropriate for the type of equipment defined by the test device classification. For designations other than B (4.1.2, 4.2.2), six bindings from at least three binding manufacturers will be used.

NOTE 1—Method F 504 may be used to select reference bindings which are typical of bindings in common usage.

6. Performance Requirements

6.1 The test device shall be of a design such that when tested by Test Method F 1062 (Section 8 and 9.3) will meet the following requirements:

6.1.1 *Type I (d)*—not greater than ±5 %[5] or ±0.25 daNm,[5] whichever is greater, for the reference binding(s) as a group and not more than ±7½ %[5] or 0.38 daNm,[5] whichever is greater, for any one binding in a group of two or more reference bindings.

6.1.2 *Type II (d)*—not greater than ±5 %[5] or ±1 daNm,[5] whichever is greater, for the reference binding(s) as a group and not more than ±7½ %[5] or 1.5 daNm,[5] whichever is greater, for any one binding in a group of two or more reference bindings.

6.1.3 *Type III (d)*—not greater than ±5 %.[5]

6.2 The test device shall be of a design such that repeatability, when tested by Test Method F 1062 (Section 8 and 9.4) with a single operator is as follows:

6.2.1 *Type I (r)*—not greater than 3 %[5] or 0.15 daNm,[5] whichever is greater, for the reference bindings as a group.

6.2.2 *Type II (r)*—not greater than 3 %[5] or 0.6 daNm,[5] whichever is greater, for the reference bindings as a group.

Method F 1062 (Section 8.2.1) and meet the following tolerances:

6.3.1 *Type I (a)*—not greater than ±2.5 % or ±0.13 daNm, whichever is greater, over the ROR.

6.3.2 *Type II (a)*—not greater than ±2.5 % or ±0.5 daNm, whichever is greater, over the ROR.

6.3.3 *Type III (a)*—not greater than ±2.5 % over the ROR.

6.4 The magnitude of the smallest scale increment, which can normal'y be estimated, shall not exceed the following:

6.4.1 *Type I*—five percent of the smallest value in the ROR or 0.13 daNm, whichever is greater.

6.4.2 *Type II*—five percent of the smallest value in the ROR or 0.5 daNm, whichever is greater.

6.4.3 *Type III*—five percent of the smallest value in the ROR.

6.5 If the device is designed to indicate force, and a distance measurement is required to calculate the moment, the magnitude of the smallest increment of the distance measurement shall not be greater than 5 % of the shortest measurement anticipated.

6.6 Correction factors may be supplied with the test devices which do not meet the requirements of 6.1.

7. Other Requirements

7.1 If no letter designation is included in the classification, the device shall be suitable for releasable ski/boot/binding systems commonly in use at the time of manufacture.

7.1.1 Specific products or conditions which may limit the use of the device may be specified without adding a letter designation to the classification.

7.1.2 Devices classified with a letter designation shall be supplied with a description of all product types or conditions for which its use is appropriate.

7.1.3 Type III devices shall be supplied with specific references to the products and conditions for which its use is intended.

7.2 Instructions supplied with the device shall include the following:

7.2.1 All information necessary to determine the proper use and limitations of the device, including an explanation of all terminology and coded information used in the labeling device;

7.2.2 Procedures necessary for the proper operation of the device with the skin equipment commonly in use at the time of manufacture. All procedures shall be compatible with Practices F 939, F 1063, F 1064, and F 1065, or the equivalent ISO Standard 8061;

7.2.3 Precautions required to minimize operator error;

7.2.4 Procedures necessary to check reproducibility among operators (see Annex A1);

7.2.5 Routine maintenance and inspection procedures, and

7.2.6 Calibration requirements and procedures.

8. Product Labeling

Designation: F 1062 – 97

Standard Test Method for Verification of Ski Binding Test Devices[1]

This standard is issued under the fixed designation F 1062; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method defines procedures to determine agreement between a standard apparatus for measuring the release moments of ski bindings and a test device of unspecified design.

1.2 This test method also covers procedures for checking agreement between individual devices of identical but unspecified design, intended for determining the release moments of ski bindings.

1.3 Values expressed in newton meters, newtons, and centimeters are to be regarded as the standard.

1.4 Values expressed in units of torque may be converted to the appropriate force values when devices which indicate force are used.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

E 4 Practices for Load Verification of Testing Machines[2]
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance With Specification[3]
E 74 Practice for Calibration of Force Measuring Instruments for Verifying the Load Indication of Testing Machines[2]
E 456 Terminology Relating to Quality and Statistics[3]
F 504 Method for Measuring Release Moments of Adult Alpine Ski Bindings[4]
F 1061 Specification for Ski Binding Test Devices[5]
F 1063 Practice for Functional Inspections and Adjustments for Alpine Ski/Boot/Binding Systems[5]
F 1064 Practice for Sampling and Inspection of Complete Alpine Ski/Boot/Binding Systems in Rental Applications[5]

3. Terminology

3.1 *Definitions*—The terms and abbreviations used in this document are defined in accordance with Method F 504, Specification F 1061, Practice E 456, Methods E 4 and E 74.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *a*—difference between the calibration of the specific device tested for agreement with an instrument of the type described in Method F 504 and the calibration of an individual device of the same design.

3.2.2 *d*—agreement between the test device and the standard apparatus described in Method F 504 and Section 9 of this test method.

3.2.3 *r*—imprecision of the device tested.

3.2.4 *operating range (OR)*—the portion of the full range of the device which may be employed in accordance with Practices F 1063 and F 1064. OR shall be defined by the user in accordance with the Inspection section of Annex 2 of Practices F 1063 and F 1064.

3.2.5 *recommended operating range (ROR)*—the portion of the full range of the test device that is in accordance with Proposed Specification P 193.

3.2.6 *reference binding*—a binding or group of bindings used in the verification of a test device.

3.2.7 *standard apparatus*—laboratory equipment including a test frame and instrumentation used as the basis for comparison with the test device.

3.2.8 *test device*—a machine for determining the release moments of ski/boot/binding systems.

3.3 *Symbols:*

3.3.1 M_z—a moment in a horizontal plane as shown in the figure in Method F 504 which illustrates terminology relating to the boot/ski system.

3.3.2 M_y—a moment in a vertical plane with the ski as shown in the figure in Method F 504 which illustrates terminology relating to the boot/ski system.

4. Significance and Use

4.1 Results obtained by this test method can be used to determine the suitability of specific test device designs in measuring the release moments of ski/boot/binding systems.

4.2 This test method provides a means by which manufacturers of test devices and manufacturers of releasable ski [illegible]

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[1] This test method is under the jurisdiction of ASTM Committee F-27 on Snow Skiing and is the direct responsibility of Subcommittee F27.10 on Binding Test Procedures.

Current edition approved March 10, 1997. Published June 1997. Formerly under Committee F-27 Proposal P 194. Originally published as F 1062 – 88. Last previous edition F 1062 – [illegible]

4.3 This test method is not appropriate for determining precision between operators.

5. Apparatus

5.1 *Test Ski*—The test ski shall meet the stiff ski definition in the portion of the Apparatus Section of Method F 504 pertaining to skis and bindings.

5.2 *Test Sole*—The test sole shall meet the requirements in the portion of the Apparatus Section of Method F 504 pertaining to boots, and shall be of a design compatible with the reference binding. The test sole may be modified to establish necessary interfaces with the standard apparatus and test device providing such modifications do not influence the proper function of the reference binding.

5.3 *Test Frame and Instrumentation*:

5.3.1 All apparatus shall meet the portions of the Apparatus Section of Method F 504 pertaining to cable, instrumentation, and load application.

5.3.2 Devices shall be employed to monitor cable tension. Differences of more than 5 % in cable tension at the attachment points with the ski may significantly bias results.

5.4 *Reference Binding*—The reference binding shall be of the type specified by the manufacturer of the test device.

6. Preparation of Apparatus

6.1 Mount the reference binding on the test ski and fit to the test sole in accordance with the specification of the binding manufacturer.

6.2 Lubricate all interfaces within the reference binding and all areas of sliding contact between test sole and binding with a compatible grease.

6.3 Calibrate the binding in tests 1.1 and 2.1 (and 2.2 if appropriate) of Method F 504, using the standard apparatus.

6.3.1 The calibration of the reference binding shall be as specified by the test device manufacturer.

NOTE 1—Methods E 4 and E 74 may be used as general guides in developing calibration procedures.

6.4 Condition the binding prior to each test series by causing the mechanism to release three times in the appropriate direction.

7. Conditioning

7.1 Unless the test device is to be used at other than normal room temperatures, conduct all tests at a temperature of 23 ± 5°C and a relative humidity of 50 ± 5 %. Do not vary temperature over the course of the test by more than 2°C and humidity by more than 5 %.

8. Procedure

8.1 Perform five repetitions of the following procedure:

8.1.1 Using the standard apparatus, perform three repetitions of a test required for Type I, II, or III devices, and perform three repetitions of the analogous test on the test device.

8.1.1.1 Randomly select which series of three tests will be conducted first.

8.1.1.2 From the Table on Load Application of Method F 504, use tests 1.1 and 1.2 for Type I devices, tests 2.1 and 2.2 (if appropriate) for Type II devices and tests as specified by the test device manufacturer for Type III devices.

8.1.1.3 Follow the test device manufacturer's instructions for conducting analogous tests.

8.2 Perform the procedure in 8.1-8.1.1.3 at the beginning, middle, and end of the ROR. If the reference binding cannot be adjusted for release over the full ROR, perform the test(s) at 10 or 90 % of the limit(s) of the reference binding as appropriate.

8.2.1 Immediately before and after each cycle of 8.1-8.1.1.3, measure and record the calibration of the test device, in accordance with the method specified by the test device manufacturer. Use a dead weight or instrument which is accurate to within 1 %.

NOTE 2—Methods E 74 may be used as a general guide for selecting calibration devices.

8.2.1.1 Check the calibration of the test device at both extremes and the middle of the ROR and at 10 and 90 % of full scale unless such values fall within the ROR.

8.3 Repeat the steps given in 8.2 for all appropriate tests listed in 8.1.1.2.

8.4 Make and record all readings to a resolution of one half the smallest scale division of the test device unless otherwise specified in the operating instructions for the test device. Read the data recorded by the standard apparatus to a significance of 2 % of the lower limit of the ROR.

9. Calculation

9.1 Determine the middle quantitative value (median) of each test series (three repetitions of each test constitute a series) and use it for all calculations.

9.2 Calculate the mean and standard deviations for the test device and the standard apparatus in each cycle of 8.1.

9.2.1 Calculate the standard deviation, in percent, as follows:

$$s = \frac{0.43R}{\bar{X}} \times 100$$

where:
$\bar{X}$ = mean, and
R = range of observations.

9.3 Calculate d for each cycle of 8.1, in percent, as follows

$$d = \frac{\bar{X}_{td} - \bar{X}_{sa}}{\bar{X}_{sa}}$$

where:
sa = standard apparatus, and
td = test device.

9.4 Calculate r for each cycle of 8.1, in percent, as follow

$$r = \sqrt{S_{sa}^2 - S_{td}^2}$$

$$\text{if } S_{sa} > S_{td}, \quad \text{then } r = 0$$

9.5 Plot a calibration curve for each cycle of 8.3 in terms of the data recorded in 8.2.1. By the least squares method, fit second order polynomial equation to the data.

10. Report

10.1 Prepare a clear and complete report of each verification of a test device including:

10.1.1 Name of the calibrating agency,

10.1.2 Date of verification,

10.1.3 Test device description and serial number,

10.1.4 Reference binding,

10.1.5 Temperature at which tests were conducted,

10.1.6 ROR, *d*, and *r* for all test series listed by test method, and the point in the ROR, (lower, middle, or upper), and

10.1.7 All calibration curves and their equations.

11. Precision and Bias

11.1 Repeatability and reproducibility will be determined.

11.2 The bias of this test method has not been determined.

ANNEX

(Mandatory Information)

A1. CALIBRATION OF SKI BINDING TEST DEVICES

A1.1 Scope

A1.1.1 This test method covers procedures for checking agreement between individual devices of identical but unspecified design, intended for determining the release moments of ski bindings.

A1.2 Procedure

A1.2.1 From the calibration curves, determine the loads which correspond to the lower and upper limits and middle of the ROR.

NOTE A1.1—Averaging calibration curves derived for positive and negative moments may be appropriate.

A1.2.2 By the method employed in 8.2.1 and using the loads determined in A1.2.1, check the calibration of the test device and record the values indicated by the specific device at each test point in the ROR.

A1.3 Calculation

A1.3.1 For upper, middle, and lower test points, calculate the difference, in percent, of *a* between the moment derived from the calibration curve and the moment indicated by the test device, using the following equation:

$$a = \frac{M_d - M_t}{M_t} \times 100$$

where:

M_d = moment indicated by the test device, and

M_t = moment derived from the calibration curve.

A1.4 Report

A1.4.1 Prepare a clear and complete report of the calibration of each test device including:

A1.4.1.1 Name of calibrating agency,

A1.4.1.2 Date of calibration,

A1.4.1.3 Test device description, serial number, and location,

A1.4.1.4 Test loads, test points and calibration method, and

A1.4.1.5 ROR, and a_l, a_m, a_u for each classification,

where:

l = lower,

m = middle, and

u = upper.

APPENDIXES

(Nonmandatory Information)

X1. EXAMPLE OF A RELEASE VALUE SELECTION TABLE USING DISCRETE VALUES

X1.1 Using Table X1.1, determine the skier code that corresponds to the skier's weight and the skier code that corresponds to the skier's height.

X1.1.1 If these skier codes are different, select the code closest to the top of the table (lower torque values).

X1.2 To correct for skier type:

X1.2.1 *I*—No correction necessary.

X1.2.2 *II*—Move down the table one skier code.

X1.2.3 *III*—Move down the table two skier codes.

X1.2.4 *I(−)*—Move up the table one skier code.

X1.2.5 *III(+)*—Move down the table three skier codes.

X1.3 To correct for age move up the table one skier code for skiers 50 years and over.

TABLE X1.1 Release Value Selection

Skier Weight, lb	Skier Height, ft, in.	Skier Code	Reference Torque	
			Twist	Forward Lean
			5	19
22 to 29		A	8	29
30 to 38		B	11	40
39 to 47		C	14	52
48 to 56		D	17	64
57 to 66		E	20	75
67 to 78		F	23	87
79 to 91		G	27	102
92 to 107	4,10 or less	H	31	120
108 to 125	4,11 to 5,1	I	37	141
126 to 147	5,2 to 5,5	J	43	165
148 to 174	5,6 to 5,10	K	50	194
175 to 209	5,11 to 6,4	L	58	229
210 or greater	6,5 or greater	M	67	271
		N	78	320
		O	91	380
			105	452

X2. EXAMPLES OF OTHER DEFINITIONS OF SKIER TYPE

X2.1 *Type I*—Cautious skiing on smooth slopes of gentle to moderate pitch.

X2.2 *Type III*—Fast skiing on slopes of moderate to steep pitch.

ANNEXES

(Mandatory Information)

A1. TESTING DEVICE INSPECTION REQUIREMENTS

A1.1 Definition

A1.1.1 For the purposes of this practice, a testing device is defined as any piece of equipment capable of indicating the torque or force required to release the boot or plate.

A1.1.2 Testing equipment should be of a type that conforms to Specification F 1061.

A1.2 Inspection Schedule

A1.2.1 The test device is inspected prior to preseason testing and at least once during the skiing season or whenever it is apparent that the device is not performing as intended, or both.

A1.3 Inspection

A1.3.1 The test device is inspected in accordance with all procedures recommended by the manufacturer of the test device or by the manufacturer of the system to be tested (if appropriate).

A1.3.2 The calibration of the test device is checked by a procedure recommended by either the test device manufacturer or system manufacturer. A dead weight may be used as a loading method.

A1.3.3 The calibration is checked at three points over the range in which the test device is intended to be used or as specified by the test device manufacturer.

A1.3.4 The test device is corrected by means of an adjustment to the indicator, if necessary, to read within ±5 % or ±2.5 Nm, whichever is greater, of the desired value.

A1.3.5 If a dead weight is used, its weight should be known to be accurate within ±2 %.

A1.3.6 Calibration of the testing device may also be made with respect to a reference binding if recommended by the manufacturer.

A1.3.7 A reference boot or binding, if used, is as recommended by the manufacturer for that purpose and tested with all surfaces lubricated unless otherwise specified in the manufacturer's procedures.

A2. RELEASE TORQUE SELECTION PROCEDURES

A2.1 Skier Code Selection Instruction

A2.1.1 Using Table A2.1, determine the skier code that corresponds to the skier's weight and the skier code that corresponds to the skier's height (for more information consult Practice F 939).

A2.1.2 If these skier codes are different, select the code closest to the top of the table (lower torque values).

A2.1.3 To correct for skier type (see Table A2.2):

A2.1.3.1 *Type I*—No correction is necessary.

A2.1.3.2 *Type II*—Move down the table one skier code.

A2.1.3.3 *Type III*—Move down the table two skier codes.

TABLE A2.1 Release Torque Selection

Skier Weight, lb	Skier Height, ft, in.	Skier Code	Reference Torque	
			Twist	Forward Lean
			5	18
22 to 29		A	8	29
30 to 38		B	11	40
39 to 47		C	14	52
48 to 56		D	17	64
57 to 66		E	20	75
67 to 78		F	23	87
79 to 91		G	27	102
92 to 107	4, 10 or less	H	31	120
108 to 125	4, 11 to 5, 1	I	37	141
126 to 147	5, 2 to 5, 5	J	43	165
148 to 174	5, 6 to 5, 10	K	50	194
175 to 209	5, 11 to 6, 4	L	58	229
210 or greater	6, 5 or greater	M	67	271
		N	78	320
		O	91	380
			105	452

TABLE A2.2 Skier Type Selection[A, B, C]

NOTE—The use of these definitions in determining the release setting may be inappropriate for some types of competition skiing or competition training.

Type I	Type II	Type III
Cautious skiing on smooth slopes of gentle to moderate pitch		Fast and aggressive skiing on slopes of moderate to steep pitch
Applies to entry-level skiers uncertain of their classification	Skiers not classified as in Type I or Type III	Receive higher than average release/retention settings
Receive lower than average release/retention settings		Decreased releasability in a fall in order to gain a decreased risk of inadvertent binding release
Increased risk of inadvertent binding release		

[A] Skiers who desire release/retention settings lower than Type I may designate themselves (I-).

[B] Skiers who desire relelase/retention settings higher than Type III may designate themselves (III+).

[C] Skiers may select skier type designations that are different for twist and forward lean. In such cases, the selection shall be indicates by a slash separating twist and forward lean selections, in that order (for example, *T/H*).

A2.1.3.4 *Type I-* —Move up the table one skier code.

A2.1.3.5 *Type III+* —Move down the table three skier codes.

A2.1.4 To correct for age, move up the table one skier code for skiers 50 years of age and over.

A2.2 Release Torque Value Selection Instruction

A2.2.1 Reference torque values for twist and forward lean

Designation: F 779 – 93 (Reapproved 1998)

Standard Test Method for Torsion Characteristic of Alpine Skis[1]

This standard is issued under the fixed designation F 779; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the measurement of ski forebody torsion and ski afterbody torsion of adult Alpine skis.

1.2 No limitation to ski size is proposed. This test method is applicable to all Alpine skis.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Terminology

2.1 *Definitions of Terms Specific to This Standard:*

2.1.1 *afterbody torsion angle,* θ_A—that angle, in degrees, to which the running surface is rotated at Point A when a moment, M_t, is applied at Point A as shown in Fig. 1.

2.1.2 *afterbody torsional spring constant,* C_A—the moment per degree of rotation of the ski afterbody when the ski is clamped in accordance with Fig. 1 and the moment applied in accordance with Fig. 2.

$$C_A(\text{N}\cdot\text{m/deg}) = \frac{M_t}{\theta_A}$$

2.1.3 *forebody torsion angle,* θ_F—that angle, in degrees, to which the running surface is rotated at Point F when a moment, M_t, is applied at Point F as shown in Fig. 1.

2.1.4 *forebody torsional spring constant,* C_{TS}—the moment per degree of rotation of the ski forebody when the ski is clamped in accordance with Fig. 1 and the moment applied in accordance with Fig. 2.

$$C_F(\text{N}\cdot\text{m/deg}) = \frac{M_t}{\theta_F}$$

2.1.5 *moment of torsion,* M_t—the moment in newton-metres applied to rotate the ski about its longitudinal axis when the ski is clamped according to Fig. 1 and the moment is applied according to Fig. 2.

3. Significance and Use

3.1 This test method provides a means for determining the torsional stiffness of Alpine skis. It is not intended to evaluate the data with regard to the quality of the ski.

4. Apparatus

4.1 *Clamping Fixture,* to grip the ski as a vise with a flat, rigid jaw and three clamps with at least 150 +50, –0 mm spacing between them. One clamp is located at each end of the fixture and one in the center as illustrated in Fig. 1. The clamps should be at least 30 mm wide and cover the full width of the ski.

4.2 *Torsion Head,* shown in Fig. 2, with low-friction moment (≤0.2 N·m) and quasistatic loading system having a clamping fixture described in 4.1. Common devices for this loading system are a weight on a cable wrapped around the head, or a weight on a lever arm rigidly attached to the head. The torsion head clamping fixture should have a width of 10 ± 1 mm and a length equal to or greater than the width of the ski. The base surface of the torsion head fixture to the ski base should be in the same plane as the clamping fixture (that is, camber forced out of ski in clamped position).

4.3 *Scale,* to measure the torsion angle with an accuracy of 0.5°.

5. Procedure

5.1 Test skis at room temperature (23 ± 5°C) without specific preconditioning. Torsion head and clamping fixture are adjusted such that the distance between them is $C/2$ ± 2 mm shown in Fig. 1. Mount the ski to the clamping fixture so that the ski forebody or ski afterbody can rotate freely about Point M. The torsion head is attached to the ski at Point A or F ± 2 mm such that the longitudinal axis of the ski is in the center of the torsion head. Apply a moment, M_t, of 20 ± 0.2 N·m. (The moment should be applied quasistatically.) The torsion angle must be read within 2 to 5 s after the torsion moment, M_t, is initially applied.

6. Calculation

6.1 Calculate the afterbody torsional spring constant, C_A, in newton-metres per degree, in accordance with the following equation:

$$C_A = \frac{M_t}{\theta_A} \quad (1)$$

6.2 Calculate the forebody torsional spring constant, C_F, in newton-metres per degree, in accordance with the following equation:

$$C_F = \frac{M_t}{\theta_B} \quad (2)$$

---

[1] This test method is under the jurisdiction of ASTM Committee F-27 on Snow Skiing and is the direct responsibility of F27.30 on Alpine and Nordic Skis.

Current edition aproved Nov. 15, 1993. Published January 1994. Originally published as F 779 – 82. Last previous edition F 779 – 82 (1993)$^{\epsilon 1}$.

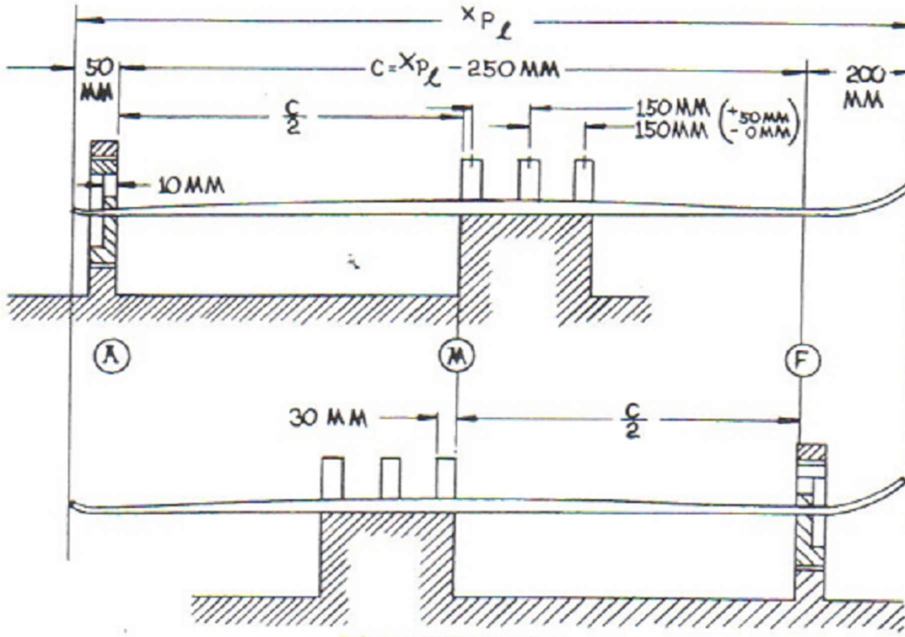


FIG. 1 Clamping Fixture

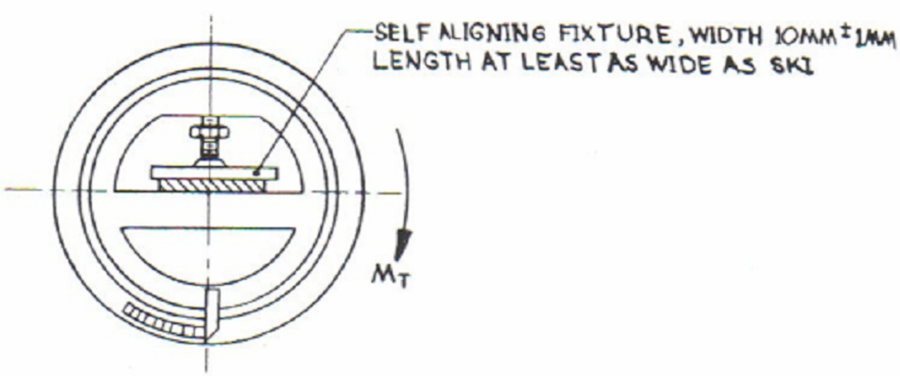


FIG. 2 Torsion Head Fixture

7. Report

7.1 Report the following information:

7.1.1 Brand, model designation, manufacturer's serial number of ski, and size of ski,

7.1.2 Afterbody torsional spring constant, forebody torsional spring constant,

7.1.3 Any deviations from this standard with explanations, and

7.1.4 ASTM F 779.

8. Precision and Bias

8.1 *Precision*—The precision of this test method is currently being determined.

8.2 *Bias*—The procedure in this test method has no bias because the values for torsion characteristics of alpine skis are defined only in terms of the test method.

9. Keywords

9.1 alpine skis; alpine skis; torsion characteristics

Appendix 8.4: Poster

Eliminating Injurious Torques with Releasable Snowblade Bindings

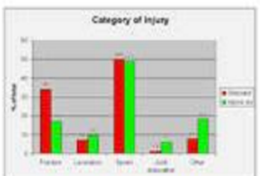
Michael Kennedy and Michael Shea
Advisor: Professor Christopher Brown
Mechanical Engineering Department

Objective

The objective for this project was to develop a device capable of limiting lower legs injuries created by dangerous torques encountered when skiing and than devise a feasible production method for testing.

Introduction

As skiing and snowboarding gain popularity other alternatives for enjoying the slopes have been developed. Ski blades have generated a lot of excitement in recent years due to a few reasons, primarily because they are half the size of normal skis making them also half the price, also the smaller size makes them much easier to use for the beginner because of the ability for the user to turn with more ease and have more control when carving. As more and more people delve into this extreme sport the rate of injuries has increased dramatically, especially with ski blades due to their encouraging nature to push beginners. The most common injuries seen with ski blades are spiral fractures to the tibia, mainly caused by high torques. Spiral fractures in the tibia occur when an individual is caught off balance with all their weight on one leg, and the individual tries to compensate or regain their balance by twisting his leg bearing the weight. This motion breaks the tibia in the lower third and sometimes the fibula in the upper third creating a line of fracture being spiral. It's easy to see how ski blades, which encourage faster movement with less control of balance, can cause this injury frequently.



Ski Blade Injury Statistics

X-ray of a Typical Spiral Fracture of the Tibia

State of the Art

A few manufacturers such as Head and Salomon have recently put out fully releasable bindings similar to their full size ski counterparts. Although these bindings are far more expensive than the standard non-releasable binding, they are much safer and prevent many lower leg injuries. They are not popular to the snowblading community though because the bindings often cost over $300 and are not standard with most snowblades.

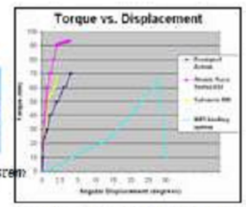
Past MQPs' in this area failed to reach their initial objectives do to the size of their design and the inability to successfully manufacture their device. The original prototype proved to be too thick and cumbersome to be used for at a comfortable level for average skiers. The more recent MQP worked to trim down the overall thickness but was unable to account for the stress caused when transmitting the injurious torques through the cam. Their plastic mold injection had many imperfections created in the molding process.

Our goal in developing this design was to create a cheaper and more marketable design for both the beginner to expert level skier. By utilizing the same proven cam mechanism to transmit the injurious torques, we set out to create a simpler more universal design to be able to be manufactured successfully with no weakness or imperfections in the molding process. By learning from past MQPs' mistakes we were able to create a more feasible design and method for producing our part.

Design Functionality

Utilizing a cam follower system, our design was able to take applied torque caused when skiing and transmit the forces through the cam instead for the skier's knee ligaments. The design uses a screw plug positioned inside the shaft of the base piece to hold in the spring pressing up against the follower. By adjusting this screw the user is able to create more or less pressure onto the follower giving the user the ability to adjust the torque needed to displace the cam. A picture of the cam follower system inside the base mold can be seen below as well as a graph of the efficiency of our design to similar ones on the market.

Internal view of the cam follower system inside the base mold

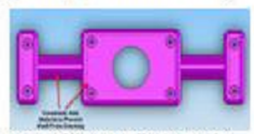


Efficiency of our design compared to other conventional bindings

Design Goals

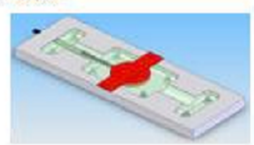
After reviewing the past MQPs' completed at WPI we created an initial list of improvements, along with the overall goal of creating a more feasible production process; that would help the functionality and manufacturability of our design.

1)Strengthen the mold where the shaft meets the center of the piece
~Added material to create a more stable rectangular design, better suited for taking the applied load of the spring follower



2) Simplify the part for easier machining
~Simpler aluminum block that allowed the least amount of time and effort to machine

3) Eliminate unneeded material
~Aluminum Cam profile without the unnecessary top plate



Manufacturing Methods

One of the major issues encountered in the previous MQP was the inability to successfully produce their plastic mold. These problems emerged during the injecting and curing stage of the plastic. Unable to fit all of the plastic needed to create the mold into a single syringe, the previous group used two different injections to unload the plastic. This created air bubbles that in the end weakened the mold making it unable to handle larger torques. By utilizing the Hapco Rapid Shot Dispensing System we were able to avoid this problem. Using a two part epoxy, a 2:1 combination of ultra alloy urethane and an ultra alloy hardener, the Hapco Rapid Shot gun mixed this plastic for us and than allowed us to inject the plastic onto our aluminum casting block air free with no discontinuities. In order to heat the plastic at the temperature needed for hardening, 128 degrees Fahrenheit, we constructed a heat insulating box using two inch thick housing insulation and reflective aluminum in siding.

Hapco Rapid Shot Gun

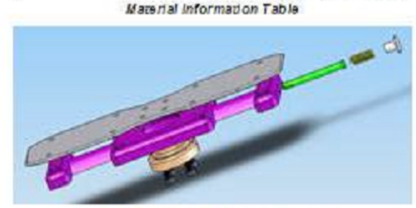
Heat Insulation Chamber

Results

After all of the purchasing was completed to construct the part, we completed a price analysis to determine the success and effectiveness of our design. We determined one part would cost around $ 30.00 in materials, making the part relatively cheap compared to the other products on the market that cost over $300.

Price Analysis		
Material	Quantity	Cost
Molding Plastic (8 fl Oz)	1	$11.00
Cam Block (Acetal Copolymer Delrin 3"X3")	1	$3.50
Follower Rod (Aluminum .5" X 4")	1	$1.20
Mounting Screws	4	$0.64
Base Plate (Aluminum 3"X12")	1	$9.00
Spring	1	$1.70
	total cost	$28.96

Material Information Table

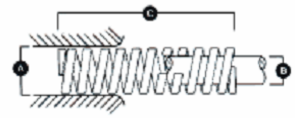


Completed Assembly of a Working Model

Appendix 8.5: Die spring data table

GREEN: Extra Heavy Duty Die Springs

(To print this page, be sure to set your print properties to landscape mode.)



Hole Dia. (in.)	Rod Dia. (in.)	Free Length (in.)	Catalog Number	Load at 1/10 in Def. (lb.)	LOAD DEFLECTION TABLE							
					For Optimum Life (15% of free length)		For Long Life (17% of free length)		Maximum Operating Def. (20% of free length)		*Maximum Deflection (25% of free length)	
A	B	C			Load (lb.)	Deflection (in.)	Load (lb.)	Deflection (in.)	Load (lb.)	Deflection (in.)	Load (lb.)	Deflection (in.)
3/8	3/16	1	HX-100	22.0	33.0	0.15	37.4	0.17	44.0	0.20	55.0	0.25
		1 1/4	HX-100A	16.0	30.0	0.19	34.0	0.21	40.0	0.25	50.0	0.31
		1 1/2	HX-101	12.5	28.1	0.23	31.9	0.26	37.5	0.30	46.9	0.38
		1 3/4	HX-101A	11.5	30.2	0.26	34.2	0.30	40.3	0.35	50.3	0.44
		2	HX-102	9.0	27.0	0.30	30.6	0.34	36.0	0.40	45.0	0.50
		2 1/2	HX-103	7.0	26.3	0.38	29.8	0.43	35.0	0.50	43.8	0.63
		3	HX-104	6.5	29.3	0.45	33.2	0.51	39.0	0.60	48.8	0.75
		12	HX-105	1.5	27.0	1.80	30.6	2.04	36.0	2.40	45.0	3.00
1/2	9/32	1	HX-110	32.0	48.0	0.15	54.4	0.17	64.0	0.20	80.0	0.25
		1 1/4	HX-110A	24.0	45.0	0.19	51.0	0.21	60.0	0.25	75.0	0.31
		1 1/2	HX-111	20.0	45.0	0.23	51.0	0.26	60.0	0.30	75.0	0.38
		1 3/4	HX-111A	17.0	44.6	0.26	50.6	0.30	59.5	0.35	74.4	0.44
		2	HX-112	14.0	42.0	0.30	47.6	0.34	56.0	0.40	70.0	0.50
		2 1/2	HX-113	11.5	43.1	0.38	48.9	0.43	57.5	0.50	71.9	0.63
		3	HX-114	9.0	40.5	0.45	45.9	0.51	54.0	0.60	67.5	0.75
		3 1/2	HX-115	8.0	42.0	0.53	47.6	0.60	56.0	0.70	70.0	0.88
		12	HX-116	2.5	45.0	1.80	51.0	2.04	60.0	2.40	75.0	3.00
		1	HX-120	63.0	94.5	0.15	107.1	0.17	126.0	0.20	157.5	0.25

Appendix 8.6: Axiomatic Design for Releasable Snowblade Binding

- FR-0 Provide safe attachment of boots to snowblades
  - FR-1 Restrain the boot to the snowblade
    - FR-1.1 Restrain the boot toe to the snowblade
      - FR-1.1.1 Restrain the boot toe in the longitudinal direction
      - FR-1.1.2 Restrain the boot toe in the lateral direction
      - FR-1.1.3 Restrain the boot toe in the vertical direction
    - FR-1.2 Restrain the boot heel to the snowblade
      - FR-1.2.1 Restrain the boot heel in the longitudinal direction
      - FR-1.2.2 Restrain the boot heel in the lateral direction
      - FR-1.2.3 Restrain the boot heel in the vertical direction
  - FR-2 Transmit control forces from the boots to the snowblade
    - FR-2.1 Transmit moments about the longitudinal axis (edging)
    - FR-2.2 Transmit moments about the lateral axis (pitch)
    - FR-2.3 Transmit moments about the vertical axis (yaw - low)
  - FR-3 Reduce risk of injuries
    - FR-3.1 Filter injurious torques about the tibial shaft from being transmitted from the snowblade to the
    - FR-3.2 Limit torques in backward and forward roll
    - FR-3.3 Provide tortional rotational release about vertical axis
    - FR-3.4 Return binding and boot to normal orientation following filtering displacements
    - FR-3.5 Prevent the snowblade from being separated from the boots from running away down the hill
  - FR-4 Provide universal adjustability for the boots of different users
    - FR-4.1 Adjust to screw hole patterns of different bindings
    - FR-4.2 Adjust to different levels based on skier traits
  - FR-5 Provide for manual removal and setup
  - FR-6 Provide for lock in postion of front foot
  - FR-7 Limit injuries due to unit design
    - FR-7.1 Prevent slicing action
    - FR-7.2 Prevent injury from falling on sharp surfaces
  - FR-8 Interface skier's boot to the snowblade
    - FR-8.1 Attach boot to snowblade
    - FR-8.2 Attach binding to flat rotational plate
    - FR-8.3 Attach rotation plate to cam
    - FR-8.4 Interface cam with housing unit
    - FR-8.5 Attach housing unit to snowblade

DP-0 Device for safe snowblade attachment

- DP-1 Boot restraint system
  - DP-1.1 Mechanism for restraining the boot toe
    - DP-1.1.1 Longitudinal restraint structure at the toe
    - DP-1.1.2 Lateral restraint structure at the toe
    - DP-1.1.3 Vertical restraint structure at the toe
  - DP-1.2 Mechanism for restraining the boot heel
    - DP-1.2.1 Longitudinal restraint structure for the boot heel
    - DP-1.2.2 Lateral restraint structure for the boot heel
    - DP-1.2.3 Vertical restraint structure for the boot heel
- DP-2 Devices for control force transmission
  - DP-2.1 Longitudinal surfaces to interface with the coresponding boot interface surface
  - DP-2.2 Lateral surfaces to interface with the coresponding boot interface surface
  - DP-2.3 Vertical surfaces to interface with the coresponding boot interface surface
- DP-3 Injury reduction systems
  - DP-3.1 Cam or detent device for filtering injurious loads
  - DP-3.2 Torque limitation system
  - DP-3.3 Shear release system
  - DP-3.4 Energy storing device for returning
  - DP-3.5 Device for keeping snowblades fixed to boots
- DP-4 Devices for adjustability
  - DP-4.1 Binding to detent interface plate
  - DP-4.2 Device for torque adjustment on detent
- DP-5 System of common screws and fuxturing devices
- DP-6 Cam and cam follower system
- DP-7 Injury limiting specifcations
  - DP-7.1 Slicing reducing specifications - rounding and chamfers
  - DP-7.2 Elimination of sharp corners, preplaced by rounds and fillets
- DP-8 Unit interface attachment device
  - DP-8.1 Binding attachment device
  - DP-8.2 Rotation attachment device - screws
  - DP-8.3 Cam attachment device
  - DP-8.4 Housing unit interface device - chamfer
  - DP-8.5 Snowblade attachment device

Appendix 8.7 Hardness Test Data

Temperature (°C)	Cure Time (h)	Shore Hardness (D-avg)	H1	H2	H3	H4	H5
24	4	51.4	49	52	51	52	53
24	5	53.2	51	54	52	53	56
24	6	58	58	57	58	59	58
24	7	63.8	61	65	64	64	67
24	8	66.8	68	69	65	64	68
24	9	69.2	70	73	68	65	70
24	10	70.6	72	73	71	66	71
24	11	72.8	74	74	72	68	74
24	12	73.4	75	76	72	69	75
38	4	54.4	54	53	56	54	55
38	5	60.2	57	61	60	62	61
38	6	64	62	64	65	66	64
38	7	67.4	66	69	71	66	65
38	8	69.2	68	70	71	69	68
38	9	71	69	72	72	71	71
38	10	73.8	73	74	75	73	74
38	11	75.6	75	76	76	74	77
38	12	77.2	77	78	77	75	79
52	4	56.4	56	58	56	55	57
52	5	62.2	62	61	63	62	63
52	6	68.2	68	67	69	68	69
52	7	70.6	71	69	71	72	70
52	8	72	71	71	72	74	72
52	9	74.2	74	73	74	76	74
52	10	75.6	76	75	75	77	75
52	11	77.6	79	78	76	78	77
52	12	78.4	80	78	77	78	79
66	4	57.8	57	59	60	56	57
66	5	63.6	63	64	66	63	62
66	6	69	68	69	67	70	71
66	7	71.4	70	71	70	72	74
66	8	73.8	73	74	72	75	75
66	9	76.6	76	77	75	77	78
66	10	79.6	79	80	78	80	81
66	11	82.2	82	82	81	82	84
66	12	84.2	83	84	83	84	87
80	4	58.8	59	60	58	59	58
80	5	65.4	65	66	65	67	64
80	6	69.2	69	67	70	71	69
80	7	73.6	73	72	74	75	74
80	8	76.2	75	77	76	77	76

80	9	79.2	79	81	78	80	78
80	10	82	82	84	82	82	80
80	11	84.4	84	86	85	85	82
80	12	86	85	87	88	86	84

93	4	58.6	58	59	59	60	57
93	5	65	64	66	65	66	64
93	6	69	68	69	69	70	69
93	7	73.8	73	73	74	75	74
93	8	75.8	76	75	75	77	76
93	9	77.8	78	76	77	80	78
93	10	80.2	81	78	79	82	81
93	11	81.6	83	79	80	83	83
93	12	83.8	85	81	82	85	86

Appendix 8.8: Angular Displacement Dial